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HANFORD ISOTOPE PRODUCTION CAPABILITIES
FOR SINGLE PASS REACTORS

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HANFORD ISOTOPE PRODUCTION CAPABILITIES

FOR SINGLE PASS REACTORS

R. L. Miller

December 12, 1968

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HANFORD ISOTOPE PRODUCTION CAPABILITIES
FOR SINGLE PASS REACTORS

I. INTRODUCTION

This report is a summary of several studies made by the author during 1967, and early 1968, while providing technical assistance to the Advanced Concepts and Planning Section. An attempt has been made to reduce the data to a usable form which will enable the reader to estimate the production of a particular isotope and the production of weapons grade plutonium that accompanies the co-product loading for different Uranium-235 concentrations of the driver fuels.

It should be emphasized that the production data shown in this document do not constitute an engineering study of the loading. As the safety analysis has not been performed and only minimal hydrokinetics have been studied, it is imperative that the use of the data contained in this report be used only for planning and estimating work. If any particular loading were to become a reality, a detailed engineering study would be required for that loading.

Although the B Reactor has been deactivated it is included in the report along with the C and K Reactors. Hence, it is possible to make estimates of the capabilities of the entire Hanford single pass reactor complex.

Although Orallo fuel for the Hanford reactors for isotope production has not been fully developed, there are several cases included for each isotope. If the state of the art is advanced in the future these preliminary calculations could possibly serve as a base point.

II. BASIS AND ASSUMPTIONS

Several broad assumptions were made concerning the utilization of the reactor: (1) all reactors are on a year-round bulk outlet temperature limit of 95C, (2) for flux dependent isotopes such as Cobalt-60 and Thulium-170, the entire flat zone of the reactor is considered available for E-target loading (note that this assumption is not valid at the C Reactor due to the overbore block), and (3) target element cladding dimensions are constant for each reactor type. It is further assumed that fuel elements could be designed to operate up to 200 percent of the present tube power level.

For the K Reactors an input production of 1400 KMWD per year per reactor is used. The input productions for the B and C Reactors of 566 KMWD per year and 640 per year respectively is used. In all cases, power splits between the central zone, enrichment ring, and fringe are considered unchanged by the co-product loadings.

Assumptions that are relevant to each particular isotope case are mentioned in the subsequent section for that isotope. In general, errors in the production data shown in this report are not expected to exceed 20 percent and probably do not exceed 10 percent except in cases where the enrichment of the driver elements is higher than about 3 w/o.

III. CALCULATIONAL TECHNIQUE

The general procedure used to find the production values was to determine the U-235 enrichment required in the driver elements to support any given target to driver ratio supercell with the same reactivity as is currently required by the particular reactor (as determined by MOFDA⁽¹⁾). The reactivities (or equivalently the material bucklings) of the supercells used for the study were 21.6 μb , 48.4 μb , and 44.8 μb respectively, for K, C, and B Reactors. The target to driver ratios of 0.3, 0.5, 0.8 and 1.0 were used which correspond to 130, 150, 180 and 200% tube power for the drivers. In each case the driver fuel was designed to meet the specific power and corrosion rates.

The buildup-burnout calculations for TM-170, CO-60, and Pu-238 were performed with the computer code ISOGEN⁽²⁾, using a one group "Westcott" flux from MOFDA.

Plutonium - equivalent grams per MWD for Tritium* and Uranium-233 are computed directly by MOFDA. For the Polonium-210 an empirical approach that best fits observed production is used: 90 days of irradiation gives A grams of Po-210 per ton of bismuth where A = average flux in the bismuth target times 10^{-13} .

IV. PRESENTATION OF DATA

At the expense of being repetitious a general format is used for each particular isotope. Included with each isotope section is a short description of calculational technique and basic assumptions. Although this format becomes quite burdensome for the reader that "reads straight through", it should be of some value to the reader that is interested in any particular isotope.

Studies using Oralloys as the driver fuel are presented at the end of the document.

V. PRODUCTION CAPABILITIES

Cobalt-60

Basic Assumptions:

- Input productions of 1400 KMWD, 640 KMWD, and 566 KMWD were used respectively for the K, C, and B Reactors.
- Entire central zone is available for E-target loading; 1800 tubes, 1130 tubes, and 940 tubes respectively for K, C, and B Reactors.
- The Cobalt-59 is charged in separate tubes and is uniformly distributed along the same charge lengths as the driver columns.

* Decay of Tritium ($T_{1/2} = 12.5$ yrs) was not taken into account during the irradiation time.

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- The enrichment ring is of the same enrichment as the driver element.
- The fringe is natural uranium of the current design (K5N-K4N, C2N or O3N).

Data:

Figures 1 through 6 show the mega-curies of Cobalt-60 and kilograms of weapons grade plutonium produced per year for each reactor type for 50, 100, or 150 curies/gram at discharge.

Required enrichment versus target to driver ratio is shown on Figure 7 for each cobalt weight (and reactor). To convert Mega-curies of Co-60 to plutonium equivalent kilograms of Co-60 multiply by 3.52.

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Figure 1
X Reactors, 65 grams/yr, 50-59
Production vs. w/o U-235

100-100
100-100
100-100

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Figure 2
X Reactors 128 grams of Co-60
Production vs. w/o U-235

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Figure 2
C Reactor, 70 grams of Co-59
Production vs. w/o U-235

Figure 4
C Reactor, 105 grams of CO_2
Production vs. w/o U-235

Figure 3
 B Reactor - 100 grams
 Production vs. w/o U-235

megacuries of U-235 per year

Figure 7

Cobalt-60
Target to Driver Ratio vs. w/o U-235 in Driver

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Polonium-210

Basic Assumptions:

- Input production of 1400 KMWD, 640 KMWD, and 566 KMWD respectively for K, C, and B Reactors were used for the calculation.
- The entire central zone is available for E-target loading: 1800 tubes at the K Reactors, 940 at the B Reactor, and 1130 tubes at the C Reactor.
- The bismuth is charged in separate tubes and the column length is the same as the uranium drivers.
- The enrichment ring is the same enrichment as the driver elements.
- The fringe is natural uranium of current design (K5N-K4N, C2N or O3N).
- Production of Po-210 is calculated to fit empirical data: 90 days of irradiation given A grams of Po-210 per ton of bismuth irradiated where flux = A times 10^{13} .

Data:

Figures 8-10 show the kilograms of Polonium-210 and weapons grade plutonium produced per year at the three reactors versus the w/o U-235 in the slightly enriched uranium drivers.

Required enrichment versus target to driver ratio is shown on Figure 11 for each reactor.

To convert kilograms of Po-210 to plutonium equivalent kilograms of Po-210 multiply by 1.138.

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Figure 8

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K Reactors, Polonium-210 and Neopentyl Grade Uranium
Production vs. w/o U-235 in driver

Kilograms of Polonium-210 per year

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1979

Production was 1.1 million

1979

Kilograms of Polonium-210 per year

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Figure 10
S Reactor, Polonium-210 and Weapons Grade U-235
Production vs. w/o U-235 in driver

Kilograms of Polonium-210 per year

Figure 11

Po-210 Production
Target to Driver Ratio vs. w/o U-235 in Driver

Target to Driver Ratio

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Plutonium-238

Plutonium-238 production is considered only for the irradiation of neptunium-237. The (n,2n) reaction with Uranium-238 is not included in the production calculations.

Basis Assumptions:

- Input production of 1400 KMWD, 640 KMWD, and 566 KMWD were used for the K, C, and B Reactors respectively.
- The entire reactor is considered available for E-target loading: 3220 tubes at the K Reactors, 2004 tubes at the B and C Reactors.
- The Neptunium-237 is charged in separate tubes from the drivers and column length are equal for the targets and drivers.
- The enrichment ring is the same enrichment as the driver elements.
- The buildup-burnout of Np-237 was calculated by ISOGEN⁽²⁾ using corrected MOFDA fluxes and cross-sections.

Data:

Figures 12 through 20 show the yearly productions of Pu-238 and the accompanying weapons grade plutonium for several target weights and qualities. The quality is defined as the amount of Pu-238 produced in the target elements divided by the total plutonium produced in the target elements.

Required enrichment versus target to driver ratio is shown on Figures 21-23.

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Figure 12

K Reactors, Pu-238 Production
51 Grams Np-237/ft.

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Figure 13

K Reactors, Pu-238 Production
76 grams kg-237/ft.

Figure 14
K Reactors, Pu-238 Production
102 grams Wp-237/ft.

Figure 15

C Reactor, Pu-238 Production
42 grams Np-237/ft.

w/o U-235 in Driver

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Figure 16

C Reactor, Pu-238 Production
63 grams Np-237/ft.

Kilograms of Pu-238 per year

Kilograms of Weapons Plutonium per year

w/o U-235 in driver

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Figure 17

C Reactor, Pu-238 Production
8+ grams Mo-237/ft.

w/o U-235 in Driver

Figure 18

B Reactor, Pu-238 Production
66 grams Np-237/ft.

Kilograms of Pu-238 per year

Kilograms of Weapons Plutonium per year

w/o U-235 in Driver

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Figure 19

B Reactor, Pu-238 Production
99 grams Np-237/ft.

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Figure 20
B Reactor, Pu-238 Production
152 grams Np-237/yr.

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Kilograms of Pu-238 per year

400
300
200
100

Kilograms of Weapons Plutonium per year

w/o U-235 in Driver

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Figure 21

K Reactors, Pu-238 Production
Target to Driver Ratio vs. w/o U-235 in Driver

- A. 102 g Np/ft.
- B. 76 g Np/ft.
- C. 51 g Np/ft.

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Figure 22

C Reactor, Pu-238 Production
Target to Driver Ratio vs. w/o U-235 in Driver

Target to Driver Ratio

- A. 84 g Hp/ft.
- B. 63 g Hp/ft.
- C. 42 g Hp/ft.

Figure 23

B Reactor, Pu-238 Production
Target to Drive Ratio vs. w/o U-235
in Driver

132 g No/ft.

199 g No/ft.

166 g No/ft.

w/o U-235 in Driver

Target to Driver Ratio

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Thulium-170

Basic Assumptions:

- Input productions of 1400 KMWD, 640 KMWD, and 566 KMWD were used respectively for the K, C, and B Reactors.
- The entire central zone is available for E-target loading: 1800 tubes at the K Reactors, 1130 tubes at the C Reactor, and 940 tubes at the B Reactor.
- The Thulium-169 is charged into separate tubes.
- The column length of the targets is the same as the driver column. However, in some cases the desired specific heat of the Tm-170 could not be obtained with the average flux along the column of the Hanford type reactor. In these cases, the length of charge was determined that when centered in a cosine flux (axial) would yield the correct activity. No attempt has been made to calculate the activity of the "ends" of the target charge. This effect is quite apparent with the B Reactor.
- A value of 440 curies/watt was used to calculate the specific power of the Tm-170. A search of the literature (and measured value obtained from Irradiation Testing Subsection) gave values of 385-500 curies/watt).
- The enrichment ring has the same enrichment as the drivers.
- The fringe is natural uranium of the current design (K5N-K4N, C2N or O3N).

Data:

Figure 24 shows the kilograms of Thulium-170 that can be produced with 1.0 watt/gram activity at discharge. Also shown on the figure is the accompanying weapons grade plutonium produced in the driver element.

Figure 25 shows the production of 1.5 watts/gram Thulium-170 for light weight, short charged targets at the K Reactors. As it is necessary to irradiate the thulium at fairly high flux levels, the target density is quite low, further, for a reasonable target density the column must be short charged. No attempt has been made to optimize these parameters; instead the data is presented as an isolated case study.

Figure 26 shows the required enrichment versus target to driver ratio.

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Figure 24

Tm-170 Production at 1.0 Watt/gram

w/o U-235 in Driver

- A. K Reactor Core Loading 91.0 grams Tm-169/ft
- B. B Reactor Core Loading 94.0 grams Tm-169/ft.
- C. C Reactor Core Loading 59.5 grams Tm-169/ft.

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Figure 25

K Reactors
Tm-170 Production at 1.5 watts/gram
10 g/ft. Tm-169

Figure 26
Th-170 Production

Target to Driver Ratio vs. w/o U-235 in Driver

K Reactor, 91 grams Th-169/ft.
C Reactor, 59.5 grams Th-169/ft.
B Reactor, 94 grams Th-169/ft.

Tritium, H-3

Basic Assumptions:

- Input productions of 1400 KMWD, 640 KMWD, and 566 KMWD were used respectively for K, C, and B Reactors.
- Entire reactor is considered available for E-target loading: 3220 tubes at the K Reactors, 2004 tubes at the B and C Reactors.
- The lithium-aluminum targets are charged into tubes separate from the drivers.
- The enrichment ring is of the same enrichment as the driver elements.
- Target material is of the standard LiAl alloy used at Hanford: 3.18 w/o lithium alloyed in aluminum. The lithium is enriched to 44% Li-6.

Data:

Figure 27 shows the tritium production capabilities along with the accompanying weapons grade plutonium production. The required enrichment versus target to driver ratio is shown on Figure 28.

To convert kilograms of tritium to plutonium equivalent kilograms of tritium multiply by 79.1.

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Figure 27
Tritium Production

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Figure 28

Plutonium Production
Target to Driver Ratio vs. w/o U-235 in Driver

Target to Driver Ratio

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Uranium-233

Basic Assumptions:

- Input production of 1400 KMWD, 640 KMWD, and 566 KMWD for K, C, and B Reactors respectively were used.
- Entire reactor is considered available for E-target loading: 3220 tubes at the K Reactors and 2004 tubes at the B and C Reactors.
- Thorium oxide target elements are charged into separate tubes from the driver fuel.
- The enrichment ring is of the same enrichment as the driver fuel.
- Target material is thorium oxide with an effective density of 7.5 grams per cubic centimeter.
- No burnout of target material (or its products) was considered during the irradiation period.
- The contamination of U-233 with U-232 is not considered as all cases are "continuous discharge". The total production shown are not affected by U-232 contamination; only the cycle time of the target material involved.

Data:

Figure 29 shows the U-233 production and the accompanying weapons grade plutonium production for each reactor type as a function of the driver fuel enrichment.

The required versus target to driver ratio is shown on Figure 30.

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Figure 29
U-233 Production

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w/o U-235 in D. 1971

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Figure 30

U-233 Production

Target to Driver Ratio vs. w/o U-235 in Driver

Oralloy Fuel

The use of oralloy type fuels for isotope production, even though the potential is known, has not been developed at Hanford. Some recent work⁽³⁾ has been done that considers a three component reactor loading of slightly enriched uranium or natural uranium, oralloy-aluminum alloy, and lithium-aluminum. As pointed out in the referenced work, very little technology has been developed to determine the operating and handling characteristics of highly enriched alloys. Some preliminary safety analysis studies have been made⁽⁴⁾ that indicate a non fail-safe condition exists upon fuel meltdown. For a full reactor loading of oralloy and lithium-aluminum the effect apparently exceeds 6% $\Delta k/k$ as the melt disperses into the moderator. This reactivity gain is, of course, far greater than can be terminated by the present single-pass reactor safety systems.

Another problem associated with full reactor oralloy loadings is the overheating of the graphite moderator due to the removal of heavy nuclei from the system which provide gamma ray attenuation. The magnitude and damage of this overheating is still not completely understood at the present state of the art.

For the purpose of this document the nuclear safety and the reactor damage aspects of oralloy are ignored and the isotope production capabilities presented as if all operational problems were solved.

In order to maintain consistency with the slightly enriched uranium several constraints are needed for the oralloy-target loadings. First, it is taken on faith that a metallurgical limit of about 20 w/o uranium (oralloy) can be alloyed with aluminum. Next, it is realized that a fully loaded reactor would expect to operate several days before it would be necessary to shutdown due to lack of reactivity; hence, a lower limit of 3 w/o oralloy in aluminum is imposed (except as noted with bismuth irradiation). Finally, the same physical dimensions were used for the oralloy as used with the slightly enriched uranium fuel of the preceding sections (see appendix).

Basic Assumptions:

- It has been assumed in all cases that a 30 mk change in the operating reactivity due to U-235 burnout could be tolerated at all the reactors.
- For the core load only case the entire central zone of the reactor is considered available for oralloy-target loading: 1800 tubes at the K Reactors, 1130 tubes at the C Reactor, 940 tubes at the B Reactor. Fringe tubes are considered natural (K5N-K4N, C2N or O3N).
- For the full reactor loadings 3220 tubes were assumed available at the K Reactors and 2004 tubes at the B and C Reactors.
- Target elements are located in tubes separate from the driver fuel.
- The target column length is the same as the driver fuel.
- The enrichment ring is of oralloy of the same concentration as the driver elements.

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- Input productions of 1400 KMWD, 640 KMWD, and 566 KMWD were used for the K, C, and B Reactors respectively.
- For the tritium and uranium-233 production no burnout or decay of the target material was considered during the irradiation period.
- The same target materials as used in the preceding slightly enriched uranium cases was used for these or alloy cases.
- In the core load only cases the miss-match in power between the enrichment ring and the fringe is ignored.

Data:

The production values for the various isotopes and the accompanying weapons grade plutonium is shown in the table. It should be noted that some plutonium is produced in the or alloy itself due to the small amount of U-238* present in the fuel.

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* The or alloy used in this study is considered to be of 93% quality; the remaining 7% of the uranium is U-238.

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K REACTOR (full reactor loadings)

Neptunium-Aluminum Targets

<u>Target</u>	<u>Target to driver ratio</u>	<u>w/o Oralloy in drivers</u>	<u>Kg Pu-238 per year</u>		
			<u>Q = 0.80</u>	<u>0.85</u>	<u>0.90</u>
51 g/ft. Np-237	0.5 1.0	3.72 10.5	419 532	512 651	419 769
76 g/ft. Np-237	0.5 1.0	4.61 14.8	501 606	623 757	735 909
102 g/ft. Np-237	0.5	5.55	546	689	819

Lithium-Aluminum Targets

<u>Target</u>	<u>Target to driver ratio</u>	<u>w/o Oralloy in drivers</u>	<u>Kg Tritium/year</u>
LiAl	0.3	6.65	15.3
	0.5	14.55	17.4

Thoria Targets

<u>Target</u>	<u>Target to driver ratio</u>	<u>w/o Oralloy in drivers</u>	<u>Kg Uranium-233/year</u>
Thoria (7.5 g/cc)	0.5	4.53	895
	1.0	14.05	1090

K REACTOR (core loaded with E-target,
fringe with natural uranium)
Cobalt Targets

<u>Target</u>	<u>Target to driver ratio</u>	<u>w/o Oralloy in drivers</u>	<u>Kg Weapons grade Pu/yr</u>	<u>Mci Co-60/yr.</u>	
				<u>50 ci/g</u>	<u>100 ci/g</u>
85 g/ft. Co-59	0.5	3.72	395	163	153
	1.0	10.5	396	201	188
128 g/ft. Co-59	0.5	4.61	396	186	172
	1.0	14.8	397	216	198

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Thulium Targets

<u>Target</u>	<u>Target to driver ratio</u>	<u>w/o Oralloy in drivers</u>	<u>Kg Weapons grade Pu/year</u>	<u>Kg Tm-170/yr. @ 1 watt/gram</u>
91 g/ft.	0.5	3.72	395	353
Tm-169	1.0	10.5	396	403

Neptunium -Aluminum Targets

<u>Target</u>	<u>Target to driver ratio</u>	<u>w/o Oralloy in drivers</u>	<u>Kg Weapons grade Pu/yr.</u>	<u>Kg Pu-238/yr.</u>		
				Q = .8	.85	.90
76 g/ft.	0.5	4.61	396	348	433	511
Np-237	1.0	14.8	397	421	526	632

Lithium-Aluminum Targets

<u>Target</u>	<u>Target to driver ratio</u>	<u>w/o Oralloy in drivers</u>	<u>Kg Weapons grade Pu/yr.</u>	<u>Kg Tritium per year</u>
Lial	0.3	6.65	397	10.6
	0.5	14.55	400	12.1

C REACTOR (full reactor loadings)

Neptunium-Aluminum Targets

<u>Target</u>	<u>Target to driver ratio</u>	<u>w/o Oralloy in drivers</u>	<u>Kg Pu-238/yr.</u>	
			Q = .85	.90
42 g/ft.	0.5	4.9	196	227
Np-237	1.0	12.0	256	300
63 g/ft.	0.5	5.9	243	285
Np-237	1.0	16.7	307	365
84 g/ft.	0.5	6.95	275	322
Np-237				

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Lithium-Aluminum Targets

<u>Target</u>	<u>Target to driver ratio</u>	<u>w/o Oralloy in drivers</u>	<u>Kg Tritium/year</u>
LiAl	0.5	20.6	7.47

Thoria Targets

<u>Target</u>	<u>Target to driver ratio</u>	<u>w/o Oralloy in drivers</u>	<u>Kg U-233 per year</u>
Thoria	0.5	6.0	347
(7.5 g/cc)	1.0	17.0	438

C REACTOR (core loading of E-target, fringe with C2N)

Cobalt Targets

<u>Target</u>	<u>Target to driver ratio</u>	<u>w/o Oralloy in drivers</u>	<u>Kg Weapons Plutonium/yr.</u>	<u>Mcuries of Co-60 at 100 ci/g</u>
70 g/ft.	0.5	4.9	202	60
Co-59	1.0	12.0	203	77
105 g/ft.	0.5	5.9	202	70
Co-59	1.0	16.7	203	86

Bismuth Targets

<u>Target</u>	<u>Target to driver ratio</u>	<u>w/o Oralloy in drivers</u>	<u>Kg Weapons Plutonium/yr.</u>	<u>Kg Po-210 per year</u>
Bismuth	1.0	0.814	201	1.46

Thulium Targets

<u>Target</u>	<u>Target to driver ratio</u>	<u>w/o Oralloy in drivers</u>	<u>Kg Weapons Plutonium/yr.</u>	<u>Kg Tm-170/yr. @ 1 watt/gram</u>
Tm-169	0.5	4.9	202	124
60 g/ft.	1.0	12.0	203	150

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B REACTOR (full reactor loadings)

Neptunium-Aluminum Targets

<u>Target</u>	<u>Target to driver ratio</u>	<u>w/o Oralloy in drivers</u>	<u>Kg Pu-238/yr.</u> Q = <u>.85</u> <u>.90</u>	
66 g/ft. Np-237	0.5 1.0	5.52 15.3	236 281	278 331
99 g/ft. Np-237	0.5 1.0	6.9 23.5	236 331	278 391

Lithium-Aluminum Targets

<u>Target</u>	<u>Target to driver ratio</u>	<u>w/o Oralloy in drivers</u>	<u>Kg Tritium per year</u>
LiAl	0.5	17.8	6.7

Thoria Targets

<u>Target</u>	<u>Target to driver ratio</u>	<u>w/o Oralloy in drivers</u>	<u>Kg U-233 per year</u>
Thoria (7.5 g/cc)	0.5 1.0	5.3 13.9	310 388

B REACTOR (core loading of E-target, fringe loaded with O3N)

Cobalt Targets

<u>Target</u>	<u>Target to driver ratio</u>	<u>w/o Oralloy in drivers</u>	<u>Kg Weapons Plutonium/yr.</u>	<u>Mci Co-60/yr.</u> <u>50 ci/g</u> <u>100 ci/g</u>	
Cobalt-59 111 g/ft.	1.0	15.3	233	70	63

Thulium Targets

<u>Target</u>	<u>Target to driver ratio</u>	<u>w/o Oralloy in drivers</u>	<u>Kg Weapons Plutonium/yr.</u>	<u>Kg Tm-170/yr.</u> <u>@ 1 watt/gram</u>
Thulium-169 94 g/ft.	1.0	15.3	233	46

VI. ACKNOWLEDGEMENTS

The author expresses sincere thanks to those people who helped prepare this document. Valuable contributions were provided by R. H. Meichle, who suggested the method of analysis; D. E. Bush, who designed the fuel elements; R. M. Fulsaa, who prepared all the graphs.

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APPENDIXTable 1Fuel element dimensions used in study

<u>Reactor Type</u>	<u>Tube Power</u>	<u>Increase in tube power above base (%)</u>	<u>O.D. Clad</u>	<u>O.D. Uranium</u>	<u>I.D. Uranium</u>	<u>I.D. Spire</u>
B	1640 KW	130	1.420 in.	1.330 in.	0.468 in.	0.368 in.
B	1890	150	1.369	1.269	0.581	0.481
B	2270	180	1.331	1.231	0.653	0.553
B	2520	200	1.308	1.208	0.674	0.574
C	1770	130	1.389	1.289	0.537	0.437
C	2040	150	1.344	1.244	0.626	0.526
C	2450	180	1.296	1.196	0.661	0.561
C	2720	200	1.271	1.171	0.692	0.572
K	2355	130	1.485	1.395	0.650	0.535
K	2720	150	1.460	1.360	0.618	0.518
K	3260	180	1.434	1.329	0.686	0.576
K	3625	200	1.387	1.267	0.784	0.664

Base tube powers were 1260 KW, 1360 KW, and 1812 KW for B, C and K respectively.

Table 2Target element dimensions

<u>Reactor</u>	<u>Element O.D.</u>	<u>O.D. Target Material</u>
K	1.600 in.	1.510 in.
B	1.460 in.	1.360 in.
C	1.480 in.	1.380 in.

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