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TO: Those Listed

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FROM: Ralph Balent

AEC-D-4090

SUBJECT: Neutron Economy of Various Converter Reactor Designs

The present concept of the Converter Reactor is briefly described by the following: The core is made up of approximately 3 inch square assemblies of fuel and thorium stacked side by side to form a square cylindrical reactor. Each assembly will be made up of flat plates, clad with aluminum, and separated by a water gap. The maximum thickness of the thorium plate was fixed by heat transfer considerations to be approximately 1 cm ($3/8"$ was used in all calculations). The water gap in the MTR (i.e., 3 mm) was used as a reasonable minimum value. Three fuel plate thicknesses (i.e., 0.5, 1.0, and 1.5 mm) with various fuel to thorium ratios are being studied, and the weight percentage of uranium in the uranium aluminum alloy is being limited to 30%.

It is of interest in the various designs to know how many neutrons are being absorbed in the various components, how many neutrons leak from the reactor and the breakdown between fast and thermal leakage. Also, it is desirable to determine how many neutrons are absorbed in thorium in the resonance region, at thermal energy, and in the blanket. In order to determine these various quantities, the following neutron accounting system was used:

- a. If q_f neutrons are produced per unit volume and time in the core, and it is assumed that fast leakage takes place before resonance absorption, the number of neutrons which leak at energies above thermal is given by:

$$q_f (1 - e^{-K^2 L_f^2})$$

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b. The resonance capture in thorium is:

$$q_f \cdot e^{-\mu^2 L_f^2} (1 - p)$$

c. The number which get to thermal energy is:

$$q_{th} = q_f \cdot p \cdot e^{-\mu^2 L_f^2}$$

d. The number of neutrons which leak at thermal energy is:

$$q_{th} \left(\frac{L^2 \mu^2}{1 + L^2 \mu^2} \right)$$

e. The number absorbed in various components is:

$$(1) \text{ in uranium} = q_{th} \left(\frac{1}{1 + L^2 \mu^2} \right) \cdot f$$

$$(2) \text{ in thorium} = q_{th} \left(\frac{1}{1 + L^2 \mu^2} \right) \cdot \frac{\sum a (th)}{\sum a (total)}$$

$$(3) \text{ in Al} = q_{th} \left(\frac{1}{1 + L^2 \mu^2} \right) \cdot \frac{\sum a (Al)}{\sum a (total)}$$

$$(4) \text{ in water} = q_{th} \left(\frac{1}{1 + L^2 \mu^2} \right) \cdot \frac{\sum a (H_2O)}{\sum a (total)}$$

$$(5) \text{ in (Xe + Sm)} = q_{th} \left(\frac{1}{1 + L^2 \mu^2} \right) \cdot \frac{\sum a (Xe + Sm)}{\sum a (total)}$$

f. The number which are absorbed in thorium in the blanket is just the sum of the fast and thermal leakage times the assumed blanket catching efficiency. Three catching efficiencies have been used in all calculations, namely, 70%, 80% and 90%.

g. The internal conversion ratio is:

$$C. R. (Internal) = \frac{(\text{resonance capture} + \text{thermal capture}) \text{ in Th}}{\text{absorption in uranium}}$$

h. The external conversion ratio is:

$$C. R. (external) = \frac{\text{catching efficiency} \times \text{total leakage}}{\text{absorption in uranium}}$$

i. Total conversion ratio is sum of g and h.

Table No. 1 lists some of the constants for a few of the designs under consideration and Table No. 2 gives the neutron accounting for these designs. Each design will produce the required 10 Kg (23)/month. It is to be noted, that Reactor Types A to F are for increasing uranium and thorium concentration. The order of the Reactor Types give higher critical mass along with higher conversion ratios.

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Table No. 1

Converter Reactor Designs to
Produce 10 Kg (23)/Month

<u>Reactor Type</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>	<u>F</u>
1. Fuel: Thorium	3.5	3	2.5	2.5	2	2
2. Thickness of U-Al Alloy (mm)	0.5	0.5	0.5	1.0	1.0	1.5
3. Weight % U in U-Al Alloy	19.5	22.8	27.3	17.8	23.3	19.9
4. Vol. Fraction (H ₂ O)	.568	.555	.540	.492	.474	.438
5. Vol. Fraction (Al)	.273	.265	.255	.303	.286	.321
6. Vol. Fraction (Th)	.156	.176	.201	.201	.235	.235
7. Vol. Fraction (U)	.00292	.00341	.00408	.00433	.00560	.00629
8. p	.866	.848	.824	.808	.773	.757
9. k _∞	1.114	1.121	1.122	1.124	1.123	1.134
10. L ² (cm ²)	2.05	1.83	1.61	1.68	1.39	2.96
11. L _T ² (cm ²)	58.1	59.4	61.2	67.1	69.6	75.4
12. D ₀ (ft)	4.50	4.50	4.55	4.70	4.75	4.85
13. M ₀ (Kg of U ²³⁵)	98	112	133	159	217	245
14. Power (MW)	317	310	297	295	285	280
15. Specific Power (MW/Kg)	3.23	2.77	2.23	1.86	1.31	1.14
16. nv	7.11×10^{13}	6.09×10^{13}	4.91×10^{13}	4.09×10^{13}	2.88×10^{13}	2.51×10^{13}

Table No. 2

Neutron Economy for the Various Converter Reactor
Designs Given in Table No. 1

Note: The values given are based on 100 fission neutrons, so the numbers in each column can be considered as the percentage of all neutrons produced which go to the various processes.

<u>Reactor Type</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>	<u>F</u>
1. Fast leakage	9.93	10.52	10.68	10.81	10.73	11.44
2. Resonance Absorption in Th	12.02	13.59	15.74	17.08	20.26	21.56
3. Thermal leakage	0.287	0.259	0.218	0.206	0.155	0.318
4. Thermal Absorption						
a. in Uranium*	47.4	—	—	—	—	—
b. in Thorium	18.85	18.17	17.33	16.34	14.74	13.11
c. in Water	6.80	5.70	4.62	3.97	2.96	2.43
d. in Aluminum	2.09	1.74	1.40	1.56	1.14	1.14
e. in Xe and Sm	2.62	2.62	2.62	2.62	2.62	2.62
Total	100	—	—	—	—	—
5. *Absorbed in Th in Blanket	8.17	8.62	8.72	8.81	8.71	9.41
6. Total absorbed in Th	39.0	40.4	41.8	42.2	43.7	44.1
7. Internal Conversion Ratio	.651	.670	.698	.705	.738	.732
8. External Conversion Ratio	.172	.182	.184	.186	.184	.198
9. Total Conversion Ratio	.823	.852	.882	.891	.922	.930
10. Parasitic capture losses	11.51	10.06	8.64	8.15	6.72	6.19
11. Leakage losses	2.05	2.16	2.18	2.21	2.18	2.35

*For criticality the number absorbed in Uranium times η must equal 100.

**Based on an assumed catching efficiency of 80%.