CONF-790602--33

UC-20D
WFPS:TME-79-008
PREPRINT
JANUARY 25, 1979

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SUBMITTED FOR PRESENTATION AT THE
ANS 1979 ANNUAL MEETING, ATLANTA GA
JUNE 3-8, 1979

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DISCLAIMER

ACKNOWLEDGEMENT

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Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price: Printed Copy \$3.50; Microfiche \$3.00

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SUMMARY

The multiplication of 14 MeV D-T fusion neutrons via (n,2n), (n,3n), and fission reactions by ^{238}U is well known and established. This study consistently evaluates the effectiveness of a depleted (tails) UO_2 multiplier on increasing the production of ^{233}U and tritium in a thorium/lithium fusion-fission hybrid blanket. Nuclear performance is evaluated as a function of exposure and zone thickness.

Nuclear performance of the blanket/shield was calculated using a one-dimensional infinite cylindrical model with the cylinder axis along the plasma centerline. The plasma source of radius 1.2 m is surrounded by a void (scrape-off) layer of 0.2 m and a vacuum vessel/first wall of 0.4 cm thickness. These regions are surrounded by a 1 m thick blanket/shield composed of a UO_2 zone, a ThO_2 zone for breeding ^{233}U, a Li_2O zone for tritium breeding, and a shield of boron carbide and stainless steel. These dimensions are similar to those chosen for a Demonstration Tokamak Hybrid Reactor (DTHR)[1]. The blanket contains UO_2 and ThO_2 fuel rods with Zircaloy-4 as a clad and structural material. These fuel rods are cooled by wet steam with a density of 0.064 $gm \cdot cm^{-3}$ to maintain a hard neutron spectrum. The Li_2O zone and shield are helium cooled. The plant factor averaged neutron wall loading was 1.2 $MW \cdot m^{-2}$.

Twenty-seven group P_3-S_8 calculations were performed using ANISN[2] with group constants collapsed from the 171 group CTR library[3]. Resonance effects were accounted for by using the self-shielding capabilities of the library. Burn-up and depletion were analyzed using a combination of the CINDER[4] and HIC[5] codes which were appended[6] to the ANISN code. Five time steps of one year each were used in the calculations. For each time step, ANISN supplies collapsed five group fluxes and cross sections to the CINDER-HIC module. CINDER-HIC then calculates the burn-up and isotope depletion and returns the new number densities and a lumped fission product concentration to ANISN for the next time step.

The thickness of the UO_2 multiplier was varied from 0-15 cm. For each multiplier, calculations were performed for ThO_2 zone thicknesses of 0, 5, 10, and 15 cm. The Li_2O zone thickness was adjusted to maintain a small and nearly constant neutron leakage from the Li_2O zone to the shield. The tritium breeding ratio

(TBR) and the net ^{233}U and ^{239}Pu atoms produced per fusion neutron (F^{233} and F^{239}) were plotted as a function of ThO_2 zone thickness at beginning-of-life (BOL) and end-of-life (EOL) (five years or 6 $MW \cdot yr \cdot m^{-2}$ of exposure). For a TBR of 1.1, F^{233}, F^{239} and the corresponding thickness of ThO_2 were determined. A plot of the data as a function of UO_2 multiplier thickness is presented in Figure 1. Similar plots were generated for TBR = 0.8, 0.9, and 1.0.

The peak in F^{233} in Figure 1 clearly indicates the effect of the UO_2 multiplier on maximizing ^{233}U production. The shift in the peak between BOL and EOL is due to increased fissioning and absorptions by the isotopes produced during blanket irradiation. To maintain an average TBR of 1.1 during irradiation, the optimal zone thicknesses were found to be ΔUO_2 = 3 cm, ΔThO_2 = 9.5 cm, and ΔLi_2O = 67 cm.

The nuclear fuel production of this blanket with and without the use of the 3 cm multiplier is presented in Figure 2. Net ^{233}U production is increased by an average of 14.3% during exposure. Net fissile production is increased by 48.7% and the TBR is maintained at an average of 1.1. In addition, the energy multiplication in the blanket is increased by a factor of about 1.5 with the multiplier.

The overall conclusions from this study indicate that the use of a uranium multiplier can produce a small increase in ^{233}U production but significantly larger increases in total fissile and energy production.

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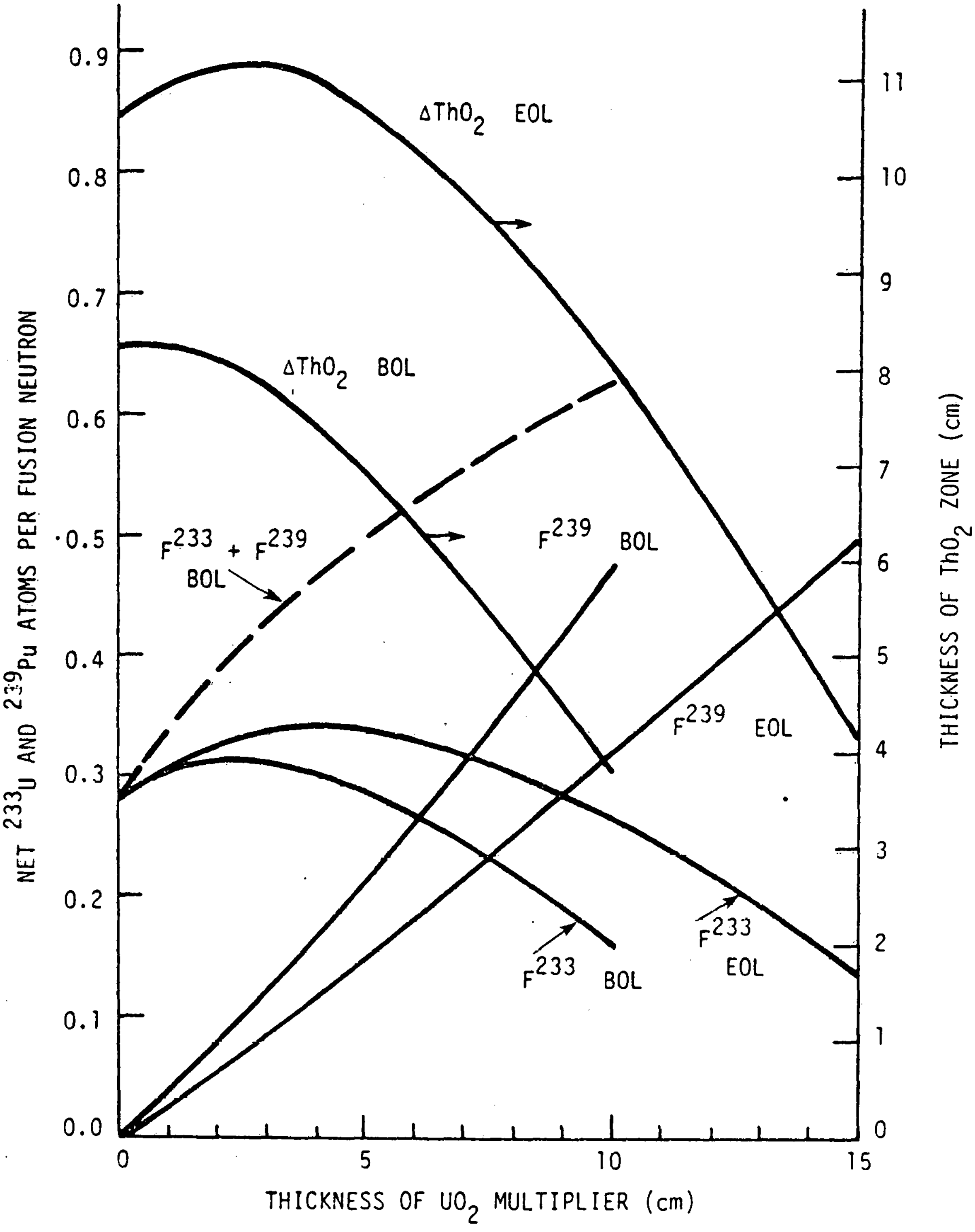

Figure 1. Hybrid Blanket Parameters for TBR = 1.1.

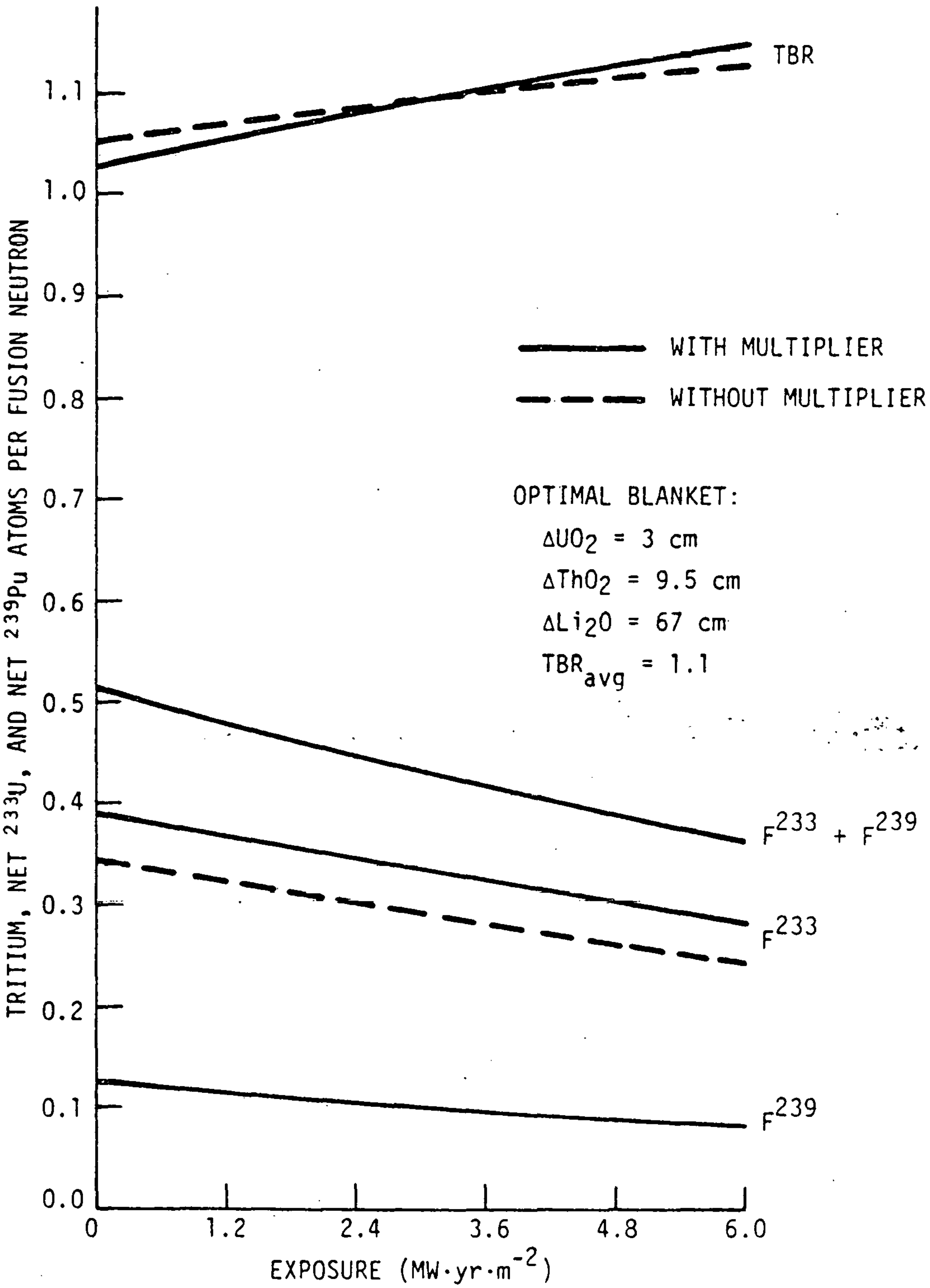

Figure 2. Nuclear Fuel Production of Optimal Uranium/Thorium/Lithium Hybrid Blanket for TBR = 1.1.