Transmutation Effects in CTR Blankets

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TRANSMUTATION EFFECTS IN CTR BLANKETS*

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The effect of neutrons on the blanket structure of a controlled thermonuclear reactor (CTR) include both scattering processes that lead to radiation damage and transmutation reactions which lead to stable and radioactive nuclei. The present calculations have been performed to determine the effects of transmutation reactions for 316 stainless steel, as well as niobium and vanadium, in the blanket structure of the 1140 MW_{th} Tokamak design presented by the Wisconsin Group[1].

The neutron spectra were calculated[1] using the ANISN code and cross sections were taken from ENDF/B-III, as processed by MACK[2].

The transmutation results for the first wall of the UWCTR are shown in Table I. The calculations for 316 SS shows only the major reactions. In 20 years, it is calculated that 1.2% of the Fe, 1.2% of the Mn and 0.2% of the Ni is converted to other isotopes. A small amount of V (0.2%) is produced but the amount of other materials present are small and at this wall loading, metallic transmutation presents no problem. The production of an additional 1.5% Zr in the NB-Zr alloy is significant, but not a serious problem. However, if the wall loading were to increase to 10 MW/m^2 serious problems would arise. Vanadium-20 Ti seems to present no particular problems.

Gas production is largest in the 316 SS system and is so severe that the wall lifetime could be limited by ductility considerations to a few months. Vanadium and niobium systems are much better in this regard although data on systems with several hundred ppm helium is sorely needed.

The radioactivity of the entire blanket is shown in Figure 1. The important characteristics are that the radioactivity levels are high and initially differ for the various systems by only a factor of five. Both 316 SS and niobium decay away rather slowly and vanadium is by far the best material on this count. To obtain farther insight, each material must be investigated in detail. For example, the radioactivity from niobium has a contribution from ^{89}Sr which, because of its low m.p.c. has a much greater significance than its radioactivity would indicate.

1) University of Wisconsin Study Team, "Preliminary Conceptual Design of a Tokomak Reactor", University of Wisconsin FDM 36, November 1972.

2) M. A. Abdou, C. W. Maynard, R. Q. Wright, "MACK; A Program to Calculate Neutron Energy Release Parameters (Fluence-to-Kerma) and Multigroup Neutron Reaction Cross Sections from Nuclear Data in ENDF Format", UW FDM 37.

TABLE I

Transmutation Reactions in Potential CTR First Wall Materials at 0.53 MW/m^2 Wall Loading

		Net Production Rate atomic $ppm/MW/m^2$ yr	After 20 years Atomic Percent	After 20 years Percent Change
316 SS	Fe	-1220	-1.2	-2.0
	Ci	+ 24	+0.024	+0.13
	Ni	- 177	-0.18	-1.3
	Mn	+ 1.16	+1.2	+58
	V	+ 177	+0.18	+80
	Ti	+ 45	+0.045	+390
	H	637	6370*	NA
	He	279	2790*	NA
Nb-1 Zr	Nb	-1490	-1.5	-1.5
	Zr	+1470	+1.5	+150
	Y	+ 11.7	+0.012	NA
	H	114	1140*	NA
	He	36.2	362*	NA
V-20 Ti	V	- 162	-0.16	-0.2
	Cr	+ 99	+0.099	+260
	Ti	+ 53	+0.053	+ 0.27
	Sc	+ 9.1	+0.0091	NA
	H	219	2190*	NA
	He	71.8	718*	NA

*at ppm

NA Not applicable

FIGURE 1

BLANKET RADIOACTIVITY AFTER SHUTDOWN

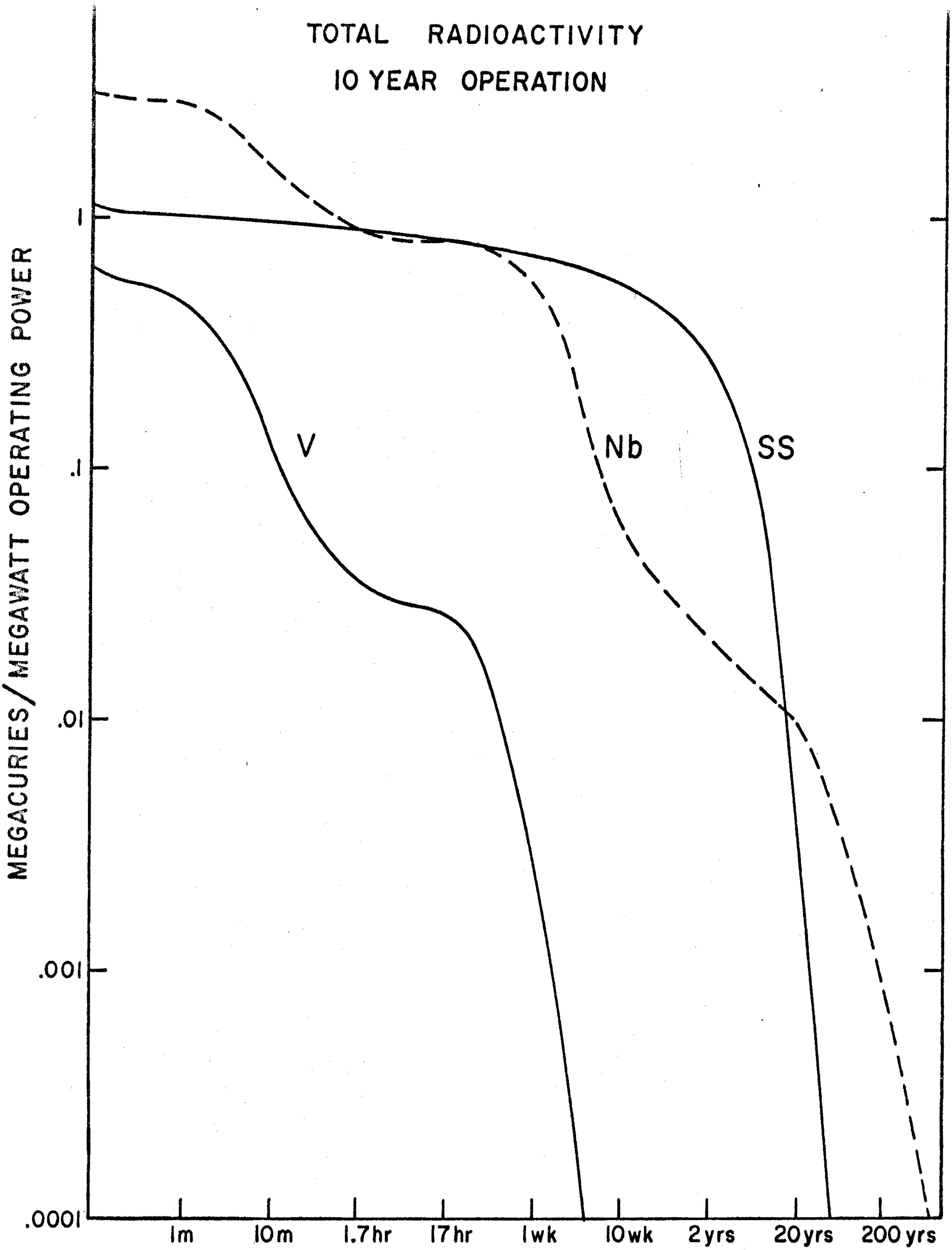
TOTAL RADIOACTIVITY
10 YEAR OPERATION
MEGACURIES/MEGAWATT OPERATING POWER
1
.1
.01
.001
.0001
V
Nb
SS
1m
10m
1.7hr
17hr
1wk
10wk
2yrs
20yrs
200yrs
TIME AFTER SHUT-DOWN

FIG. 1