§25. Transmutation of High-Level Wastes in a FLiBe-Cooled Spherical-Tokamak Reactor

Tanaka, Y. (Nagoya Inst. of Tech.), Nagayama, Y.

In the previous publication [1], transmutation of high-level wastes (HLW) in a water-cooled spherical-tokamak (ST) reactor was discussed. In the following, transmutation of HLW in a FLiBe-cooled ST reactor will be discussed.

We have performed a neutron transport calculation [2] on a model of ST shown in Fig. 1. The model has a cylindrical symmetry with respect to the left side as its symmetry axis. The sizes are given in cm. They are referred to the Aries-ST [3]. The area for transmutation is 414 m^2, which occupies 63% of the first wall.

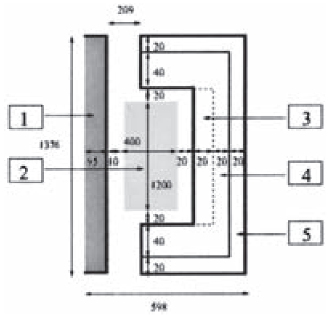

FIG. 1: Model for a ST reactor.

The plasma region is denoted by [2]. The fuel zone [3] is composed of HLW (30vol%), Zr-cladding (10vol%) and F_2Li_4Be (60vol%). The tritium-breeding zone [4] is composed of F_2Li_4Be (100vol%). The neutron reflector [5] is composed of natural carbon. The walls and shield are made of Ferritic steel (Fe_9Cr_2W).

The loaded spent fuel has the composition taken from Ref. [4]. The reprocessed waste is composed 0.1% of uranium and plutonium isotopes, 100% of the minor actinides and 100% of the fission products of the spent fuel. The resulting waste is concentrated by 50 times in order to restore its normal density.

In a fusion-driven transmuter, a fusion neutron must be bred via the (n,f) and/or (n,2n) reactions because the fusion neutron is spent for both tritium-breeding and nuclear transmutation. In addition, the power of a fusion reactor is inevitably high. The fusion power should not be amplified much by the fission energy. Therefore a fusion-driven transmuter must meet the following criteria; The tritium breeding ratio (TBR) must be greater than one. A reasonable amount of nuclear transmutation must occur. The (n,f) reaction must be suppressed well.

We found that the reprocessed waste with FLiBe coolant meets these criteria. The FLiBe coolant provides fast neutrons for nuclear transmutation. Fast neutrons are suited to suppress the (n,f) reaction and enhance the (n,2n) reaction. Reprocessed waste also helps to suppress the (n,f) reaction because the major actinides, which are dominant fission energy generators, are involved only a little in the reprocessed waste. However, highly enriched ^{6}Li must be used for the FLiBe coolant in order to make the TBR greater than one.

Table I shows reaction rates per fusion neutron and the estimated mass of nuclide in kg transmuted annually by the FLiBe-cooled 1 $GW_{(th)}$ ST reactor.

TABLE I: Transmutation of the reprocessed waste in the FLiBe-cooled 1 $GW_{(th)}$ ST reactor. The column RWeF denotes the FLiBe coolant composed of 100% enriched ^{6}Li, while the column RWnF denotes the FLiBe coolant composed of natural Li. The column PWR shows the mass of nuclide in kg produced annually in the 1 $GW_{(e)}$ pressurized water reactor [4].

	RWeF		RWnF		PWR
k_{eff}	0.068		0.076		
fission energy (MeV)	6.19		6.84		
number of fissions	0.033		0.037		
number of fission neutrons	0.130		0.141		
number of ^{9}Be(n,2n)	0.084		0.088		
tritium-breeding ratio	1.11		0.67		
	(n,f)	(n,γ)	(n,f)	(n,γ)	
^{234}U	0.0	0.0	0.0	0.1	6.4
^{235}U	1.4	0.3	4.2	1.5	···
^{236}U	0.2	0.2	0.2	1.0	130.2
^{238}U	23.4	19.2	24.3	102.6	···
^{237}Np	55.8	66.3	60.9	352.3	19.6
^{238}Pu	0.1	0.0	0.1	0.1	6.0
^{239}Pu	1.1	0.2	2.7	1.5	174.6
^{240}Pu	0.2	0.1	0.3	0.4	71.6
^{241}Pu	0.1	0.0	0.2	0.1	11.6
^{242}Pu	0.1	0.0	0.1	0.1	15.1
^{241}Am	95.6	10.3	104.5	59.0	29.8
^{242m}Am	0.6	0.1	1.8	0.2	0.1
^{243}Am	9.7	3.2	10.9	26.1	3.9
^{244}Cm	1.7	0.5	2.0	3.9	0.5
^{245}Cm	0.5	0.1	1.6	0.3	0.1
^{93}Zr	···	20.0	···	223.2	28.7
^{99}Tc	···	27.0	···	127.7	25.0
^{129}I	···	3.9	···	26.1	6.1
^{135}Cs	···	1.5	···	17.8	13.1
^{137}Cs	···	0.6	···	4.5	21.5

[1] Y. Tanaka, K. Arita, Y. Nagayama and S. Kiyota, IEEJ Trans. FM, Vol. 125 (2005) 953.
[2] MCNP4C2, Rsicc Computer Code Collection, Oak Ridge National Laboratory (2000).
[3] F. Najmabadi and The ARIES Team, Fusion Eng. Design, Vol. 65 (2003) 143.
[4] DOE/EIS-0250D, U. S. Dept. of Energy, Vol. II (1999) A17.