## §12. Transmutation of High-level Wastes by Using Volume Neutron Source

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Nuclear power plants are indispensable to the present day life. However, the problem of high-level wastes (HLW) remains unsolved. Transmutation of long-lived radioactive isotopes into short-lived or stable ones will dramatically reduce the needed period of time in the geologic repository. In the present report, we investigate fusion-driven transmutation of HLW using spherical tokamak volumetric neutron source. Owing to the nearly cylindrical shape of the blanket, the outboard side of the blanket may be used for transmutation of HLW. It is suited to load and unload the fuel-assembly type of HLW.

In a fusion-driven transmuter, (1) minor actinide is destroyed by the fission (n,f) reaction, (2) fission products are transmuted to stable nuclei by the (n,γ) reaction, and (3) tritium should be bred from lithium. In the spent fuel, many stable nuclei are contained, and they consume neutrons. So, nuclei including radio active isotopes (Pu, Np, Am, Cm, Sr, Zr, Tc, Pd, I, Cs) should be separated and be transmuted. Actinide nuclei are transmuted by fission reaction and some become heavier nuclei by absorbing neutrons. So, transmutation is carried out in the order of Pu, Np, Am and Cm, then finally all actinide are transmuted to fission products (FP). Since FPs have short life time, transmutation is not required.

Burn-up analysis was performed on the model of Fig. 1. The model simulates the Aries-ST reactor (R=5.3m). It has a cylindrical shape with respect to the left side as the rotational axis. The size is given in cm. We assume fusion power of 1 $GW_{th}$, i.e., $4.4 \times 10^{20}$ fusion neutrons per second. The coolant is PbLi with 100% $^6$Li. The transmutation blanket shares 1/12 of the whole blanket area. In the transmutation blanket, 7.8 tons of minor actinide (Np, Am, Cm), 1.5 tons of Zr cover and 8 tons of PbLi coolant are installed. In this case, the tritium breeding ratio is TBR=1.5-2.0, neutron breeding ratio is $k_{eff}$=0.62-0.72, and the thermal power is increased by 32-52 % due to the fission reaction.

In this calculation, we employed the database[1] of the atomic composition of the pressurized water reactor (PWR) fuel for the spent fuel (SF). Fission products are calculated by using ORIGEN2 code. The burn-up is calculated by using the Monte-Carlo burn-up code MONTEBURNS[2]. MONTEBURNS links to the Monte Carlo N-particle transport code MCNP with the radioactive decay and burn-up code ORIGEN2.

Figure 2 shows the time evolution of nuclear products from 8 tons of americium with the neutron irradiation of first 3 years in the fusion reactor blanket. During the irradiation (3 years), Am241 linearly decreases. Other actinides can be also decreased by neutron irradiation. Most of them are transmuted to Pu and Am242m. Pu should be burned out in the fission reactor. Am242m can be transmuted by the neutron irradiation in the fusion reactor blanket. One year operation of a fusion reactor of 1 $GW_{th}$ can transmute Np237 of 4.1 PWRs, Am241 of 5.3 PWRs and Am243 of 5.9 PWRs. Since spent fuel has been accumulated in Japan for 50 (reactors) x 30 (years) =1500 reactor-years, it takes 400 years to transmute all of them.

This study has presented that a ST fusion reactor can work as a transmuter of the minor actinides from fission reactor with good tritium breeding ratio.

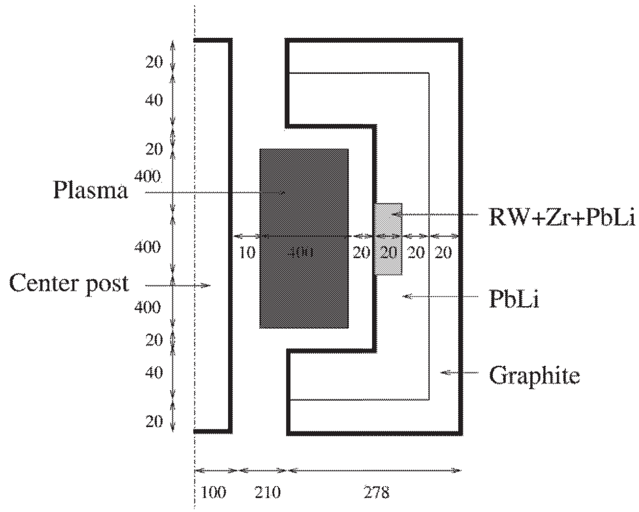


Fig. 1. Model of ST plasma neutron source and blanket. Unit is cm.

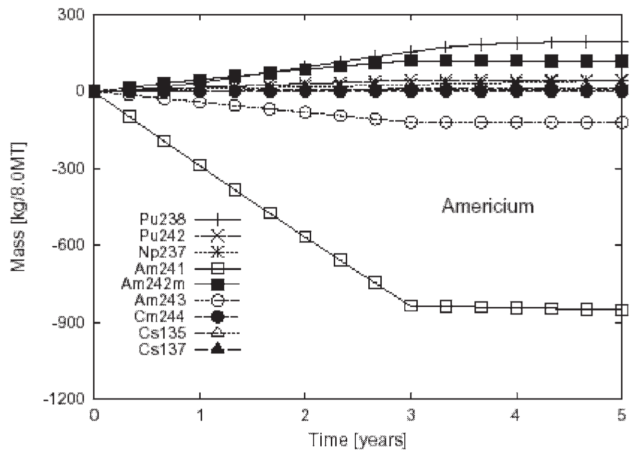


Fig. 2. Time evolution of nuclear products from 8 tons of americium with the neutron irradiation of first 3 years.

1) DOE/EIS-0250D, "Draft Environmental impact statement for a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain, Nye County, Nevada", Vol. II, A17 (1999)

2) MONTEBURNS 1.0, "An Automated, Multi-Step Monte Carlo Burnup Code System", Rsicc Peripheral Shielding Routine Collection, Oak Ridge National Laboratory (2001)