Studies on Accelerator-driven System in JAEA and Transmutation Experimental Facility Program

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Abstract: *After Fukushima accident, reduction of radioactive wastes got much attention. To realize it, Partitioning-Transmutation technology is noted at the national fuel cycle policy. To perform basic studies, Japan Atomic Energy Agency has promoted to construct the Transmutation Experimental Facility and performed design within the framework J-PARC project.*

1. Introduction

Due to the Great East Japan Earthquake and ensuing tsunami, Fukushima-Daiichi Nuclear Power Plant have been seriously damaged and many nearby residents are still forced to be evacuated. The cabinet of Japan decided to reduce the dependency to nuclear power generation. The Science Council of Japan suggests prioritizing research and developments (R&Ds) to reduce the radiological burden of high level wastes (HLW).

Japan Atomic Energy Agency (JAEA) precedes R&Ds to reduce the radiological hazard of HLWs by Partitioning and Transmutation (P-T) technology[1]. Within the framework of the J-PARC project, JAEA also promoted to construct the Transmutation Experimental Facility (TEF) to study the minor actinide (MA) transmutation by both fast reactors and accelerator driven systems (ADS)[2]. TEF locates at the end of LINAC, which is also important components to be developed for future ADS, and share the proton beam with other experimental facilities in J-PARC. R&Ds for important technologies required to build the facilities are also performed, such as requirement of MA bearing fuel into the critical assembly, spallation product removal method especially for the polonium, and so on. The objectives and construction schedule of the facilities, the latest design concept, and key technologies to construct TEF are described.

2. Description of JAEA Proposed ADS

JAEA's reference design of ADS[2] is a tank-type subcritical reactor, where lead-bismuth eutectic (LBE) alloy is used as both the primary coolant and the spallation target, as shown in Fig. 1. The spallation target region locates at a central part of the core. In the target region, LBE is flowing from the core bottom along to the dedicated wrapper tube and flow guide. About 1.5 GeV-30 MW proton beam is supplied from the accelerator to operate the ADS.

A tank-type system is adopted to take advantage to eliminate the necessity of heavy primary piping. All primary components, including two primary pumps and four steam generators are set up in the reactor vessel. The heat generated in the target and the core is removed by forced convection of the primary LBE, and transferred through the steam generators to a secondary water/steam system for power conversion. The inlet and outlet coolant temperatures were set to 300 and 407 ºC, respectively, to prevent material corrosion by LBE.

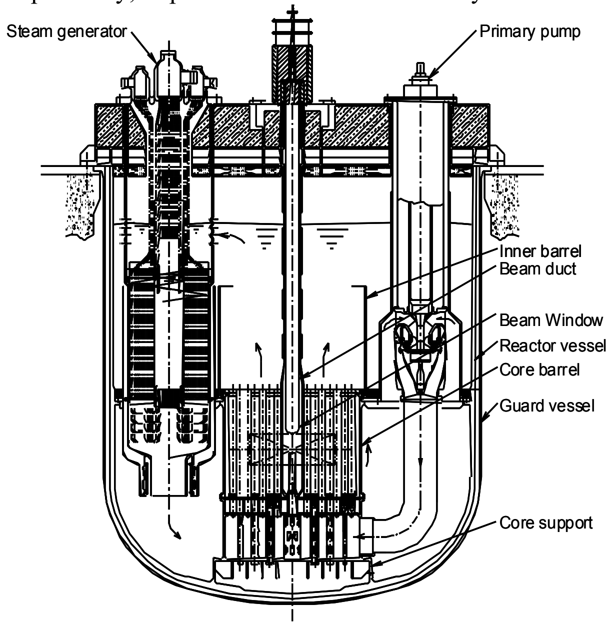

Fig. 1 ADS for transmutation of MA proposed by JAEA

Nitride fuel, which is suitable for reprocessing for ADS, is selected. To minimize the burnup reactivity change and the power peaking, the fuel region is divided into several zones with the different fuel composition. About 2,500 kg of MA is loaded in the core and 10% of them can be transmuted annually. The maximum k_{eff} during whole burnup cycles was set to 0.97. The burnup swing in whole cycles is about 3 % $\Delta k/k$.

3. Outline of Transmutation Experimental Facility

As shown in Fig.2, TEF consists of two individual buildings; ADS Target Test Facility (TEF-T)[3] and Transmutation Physics Experimental Facility (TEF-P)[4].

Two buildings are connected by beam transport line with low power beam extraction mechanism using laser beam. TEF-T is planned as a material irradiation facility which can accept a maximum 400 MeV-250 kW proton beam into LBE spallation target. It also has an availability to use various purposes such as measurement of the reaction cross sections of MA and structural materials, medical isotope production and so on. TEF-P is a facility with critical assembly to study neutronics and controllability of ADS. Using these two facilities, basic physical properties of subcritical system and engineering tests of spallation target will be studied. R&Ds for several important technologies required to build the facilities are also performed, such as laser charge exchange technique to extract very low power beam for reactor physics experiments, remote handling method to load MA bearing fuel into the critical assembly, spallation product removal method especially for the polonium, and so on.

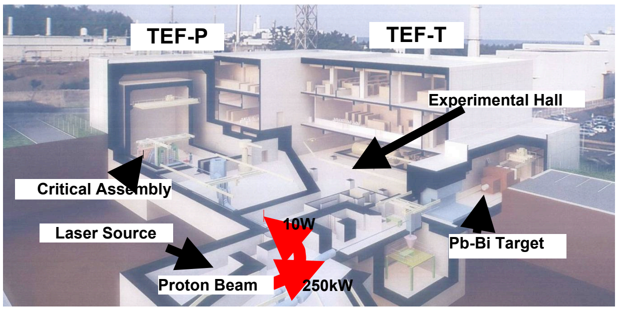

Fig. 2 Transmutation Experimental Facility

3.1 R&Ds for TEF-T

The main purpose of TEF-T is to obtain the data to evaluate the actual lifetime of beam window. TEF-T mainly consists of a spallation target, a cooling circuit, and hot cells to handle the spent target and irradiation test pieces. A proton beam current density of 20 μA/cm^2, which is almost same as future ADS design, was adopted as a reference. The irradiation performance of reference case was evaluated around 8 DPA/yr by 400MeV-250kW beam irradiation. Further optimization of the target design to increase DPA is underway.

When LBE is irradiated by high-energy proton or neutrons, polonium isotopes will be accumulated and it should be carefully controlled. The removal method of polonium was studied for the design of exhaust circuit of TEF-T. An equilibrium vaporization test of polonium from liquid Pb-Bi was performed and equilibrium vaporization characteristics were measured by transpiration method with LBE which was irradiated at the JAEA/JMTR[5]. It was shown that at the low temperature around 450 ºC, which considered as a standard operational condition of TEF-T and future ADS, most accumulated polonium were remained in LBE as a chemical compound with Pb or Bi which is much hard to evaporate than elemental polonium.

Another experiment to recover evaporated polonium in exhaust circuit was performed[6]. LBE samples were irradiated at the JAEA/JRR-4 and were heated in special vacuum vessel up to 690 ºC. By adopting multi-layered filter, which consists of two different finenesses stainless steel mesh, escaped polonium can be decreased to 1/400.

3.2 R&Ds for TEF-P

The present accuracy of nuclear data is not sufficient for ADS design. To improve the accuracy of the nuclear data especially for MA, both the differential experiments and the integral experiments are necessary, while the integral experiments on MA are more difficult than those on the major actinides. One of the main purposes of TEF-P is to perform integral experiments using MA.

TEF-P is designed referring to existing Fast Critical Assembly (FCA) in JAEA/Tokai to keep consistency of previous huge experimental data. The effectiveness of MA-loaded experiments with certain amount of MA was discussed[15,25)]. In the procedure, imaginary experimental data using TEF-P are assumed to estimate the reduction of the errors in the effective cross sections. The data by TEF-P was assumed to be equal to the calculation result, and experimental error taken from the past experiments in FCA. By using certain amount of MA, which is about order of kg, typical improvement was observed.

4. Conclusions

JAEA has been promoting various R&Ds on ADS. As for the basic experimental studies necessary for future ADS construction, plan to build Transmutation Experimental Facility has been proposed. The design optimization of TEF-T to improve irradiation performance, R&D for polonium management was carried out. The effectiveness of TEF-P experiments using certain amount of MA was assessed quantitatively.

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