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Current Status of Kijang Research Reactor Project

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1. Introduction

The Kijang Research Reactor Project (KJRR) is meaningful as it is using a high density U-Mo fuel as a driver fuel for the first time in the world and produce fission moly (molybdenum-99) for stable supply in Korea. Through a successful irradiation test of the KJRR fuel, the fuel structural integrity and fuel performance will be demonstrated by post-irradiation test.

2. Licensing

Regarding research reactor licensing, construction permit and operation permit have been separated since 2014. The construction permit has been submitted November 2014 and the main review by KINS, the regulatory body has been started from October 2015. According to the review plan of KINS the review period was about 18 months but the earthquake at Gyeongju required a long-term in-depth investigation, which resulted in a major delay of construction permit.

Gyeongju earthquake of ML 5.8 occurred on Sept. 12, 2016 and the re-evaluated site seismic safety analysis has been submitted to KINS on Sept. 27, 2017. The earthquake has been measured at Kori power plants 50 km apart from the seismic origin and close to KJTT site. The peak shutdown acceleration was about 0.005 g, which is far below safe shutdown earthquake, 0.2 g and operating basis earthquake, 0.1 g. The power plants maintained in the normal operation mode. The average of maximum acceleration is 0.06g calculated from the maximum potential earthquake, which is well below the design value of 0.3 g. The design value of power plant, APR1400 is also 0.3g. The Pohang earthquake, however, happened on Nov. 15, 2017 and KINS issued another questionnaire on this earthquake on Dec. 28, 2017. This Q&A is carried on in parallel with operation permit licensing of Shinkori 3&4 and the answer for those two power plants submitted in Feb. 2018. This seismic issue is the only one left for KJRR licensing of construction permit.

After the KINS review, the nuclear safety special committee will review this issue which is holding the meeting every month. Eventually, NSSC (Nuclear Safety and Security Commission) will review and approve the construction permit of KJRR.

3. U-Mo Fuel Qualification

U-Mo fuel qualification test has been being implemented with the co-operation of Idaho National Lab (INL) and Argonne National Lab of U.S.A. The irradiation test of lead test assembly (LTA) of U-Mo fuel has been started in Oct. 2015 when it was loaded at ATR of INL. The post-irradiation examination (PIE) has been started in Feb 2018 and the PIE report is expected to be issued at the end of 2018.

Since the KJRR fuel will be the first kind of an engineering of U-Mo fuel for commercial utilization, it requires a license to be granted and a qualification of the fuel by demonstrating the mechanical integrity, geometric stability, acceptable dimensional changes, and assurance that the performance of fuel meat and fuel assembly (FA) are stable and predictable during irradiation period.

KAERI had plans for the licensing and qualification of the new fuel using 3 ways of data acquisition for relevant irradiation properties; 1) 16 mini-plates irradiation in the High-flux Advanced Neutron Application Reactor (HANARO) and post-irradiation examination(PIE) at KAERI, 2) a lead test assembly (LTA) irradiation test at the Advanced Test Reactor (ATR) and PIE at Idaho National Laboratory (INL), and 3) using available irradiation and PIE data obtained from plate-wise irradiation and PIE programs such as RERTR or European U-Mo development programs.

Apart from the irradiation tests, out-of-pile flow test and mechanical tests have been performed to provide the properties of fuel plate and FA. As manufactured, fuel properties will be provided during the process of fuel licensing and fuel qualification. All test results and fuel properties will be integrated and compiled to issue a qualification report which demonstrates that the fuel design is adequate, manufacturing technology is acceptable and fuel performance is predictable under certain limits in reactor operation conditions.

3.1 mini-plates irradiation tests in HANARO

As the irradiation hole (OR-3, etc.) of the HANARO reactor is not sufficiently big to accommodate a full size KJRR fuel plate or the FA, mini-plate irradiation tests designated HAMP-1, 2, and 3 were planned as part of the qualification of the new fuel. Among them, HAMP-1 irradiation test with 8 mini-plates (Fig.1) have been completed successfully up to local peak burn-up of 65%

[1, 2]. HAMP-1 irradiation test was performed during four cycle irradiation (cycle 92~95, from Jan.27 to June 18, 2014 at the HANARO reactor). Post-irradiation examinations were performed during Oct. 2014 to end of 2015. Unfortunately, soon after the completion of the HAMP-1 irradiation, the construction for the reinforcement of HANARO building wall has been started to satisfy the seismic design. The reinforcement work ended at 2017 and HAMP-2 and HAMP-3 tests are ready to commence with resuming operation of HANARO.

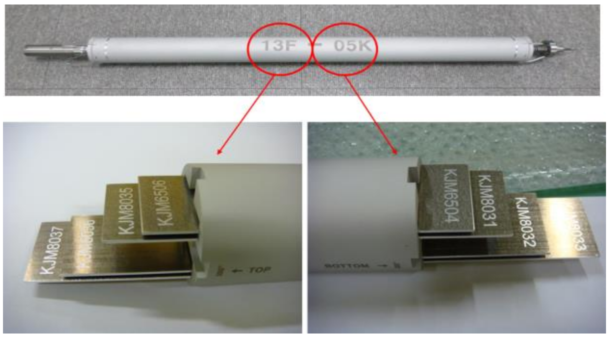

Fig. 1. Irradiation capsule and mini-plates of HAMP-1 test.

3.2 KJRR-LTA irradiation test at ATR

Two LTAs were fabricated and one of them was irradiated through four cycles at ATR for a total of 216.6 full power days to the end of February 2017. The irradiation proceeded as planned without major problem. Visible surfaces of the KJRR fuel assembly were characterized by underwater video in the adjacent storage canal during outages. The fuel assembly showed acceptable performance with no major indications of problematic fuel performance. Detailed nuclear and thermal modeling was performed based on ATR's as-run power history for the concerned cycles in order to determine irradiation conditions for the fuel assembly. The highest power fuel plate, number 20, was calculated by Monte Carlo method to achieve a peak local heat flux of 182 W/cm^2 and plate average heat flux 160 W/cm^2 from the surface of the fuel meat at beginning of life (See Fig.2). By depletion modeling, calculated is the FA average burn-up of about 70% U-235 depletion and the peak local burn-up at plate 20 to reach 83.1% U-235 depletion at the end of life. The irradiation appears to be successful in demonstration of the fuel assembly's performance.

The cooling in the ATR canal about 11 months after irradiation was finished. The post-irradiation examinations on the irradiated LTA has been undergoing currently. Future PIE also will add to the information of the fuel properties and behavior of the fuel during irradiation for the fuel licensing and qualification.

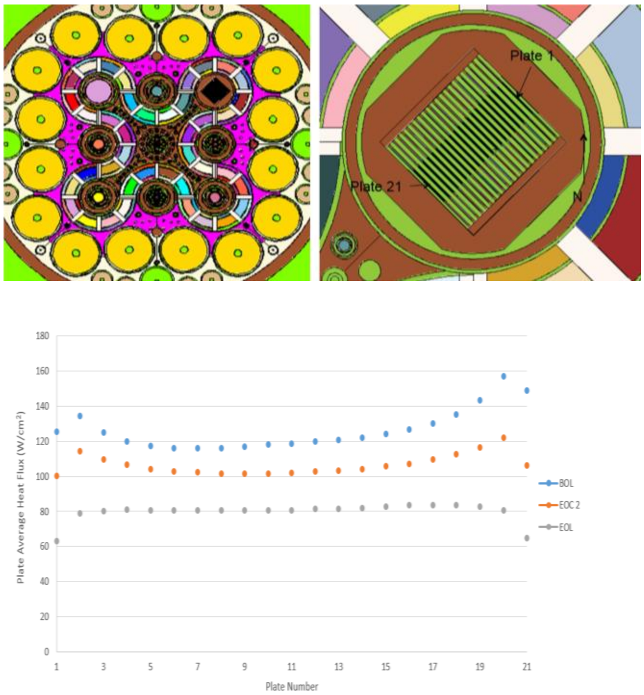

Fig. 2. Calculated irradiation data from MCNP Model of ATR Core and KJRR-LTA irradiation test

4. Fission Moly Production Technology

KAERI is developing its own process for Mo-99 production to be implemented in the KJRR. Construction of the full-scale mock-up (Fig. 3) to establish optimized Mo-99 production system has been completed in last year. First hot test for the verification of the process is scheduled in 2018 in HANARO. KAERI's process facility handling of the intermediate-level liquid wastes and reduces purification steps from the Mo-99 production. Additionally, compact chilled carbon column concept has been developed to mitigate xenon emission from the Mo-99 production for CTBT purpose. Cold test runs for the developed fission Mo-99 process have been achieved in full-scale. Hot production test in HANARO is on standby.

The hot test of fission moly (FM) target is waiting for the restart of HANARO, a research reactor at KAERI. The activity of 2 target plates after 7 days of irradiation will be 10.84 Ci by MCNP6 calculation. The normal FM target will have 8 plates. The intermediate-level liquid radioactive waste treatment is one of the main design issues in the KJRR facility. About 3 m3/yr of radioactive waste is produced during radioisotope production.

Fig. 3. Full-scale cold mockup of the Mo-99 production system.

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