# Development of Metal Fuel Cycle Technology for Practical Application

## Background and Objective

In the fast reactor fuel cycle technology development project (FaCT Project) in Japan, the fuel cycle utilizing oxide fuel and aqueous reprocessing has been selected as the main concept for commercialization. The metal fuel cycle is determined to be a long-term option because it has potential to be superior to the main concept but less domestic experience. The metal fuel cycle is an innovative fast reactor fuel cycle, where a uranium-plutonium alloy is used as fuel and metallurgical processes are adopted for reprocessing (pyroprocess) and fuel-fabrication (injection casting). The metal fuel cycle has several advantages: high fuel-burnup capability; inherent reactor safety due to high thermal conductivity of metal fuel; high proliferation-resistance because of inseparability of plutonium in pyroprocess technology; less environmental burden due to capability of recovery and transmutation of long-lived minor actinides (MA: Neptunium, Americium and Curium); high cost performance of the whole system. CRIEPI has been developing the metal fuel cycle technology in collaboration with domestic, US and European organizations. Research and development of the metal fuel cycle have also been conducted in developing Asian countries such as South Korea, China and India.

The current issues in the metal fuel cycle development are fuel irradiation tests, pyroprocessing tests with irradiated fuel, and accumulation of demonstration data by conducting engineering-scale equipment development.

## Main results

### 1. Fuel fabrication for the first metal fuel irradiation test in Japan

A metal fuel irradiation test is planned in the experimental fast reactor Joyo in order to confirm the metal fuel viability at the practical high cladding temperature condition. The U-20wt.%Pu-10wt.%Zr alloy rod fabricated by using the injection casting apparatus developed by CRIEPI were clad with ferritic-martensitic steel, and six test fuel pins were produced (Fig. 1). The fuel pin has passed the regulatory authority's inspection. The irradiation will begin after the restart of Joyo operation.

### 2. Engineering-scale cycle tests for practical application of pyroprocess

The equipments were designed and manufactured for pyroprocess cycle tests in the scale of 5kg of uranium (U) per day (Fig. 2). About 6kg of $UO_2$ was converted to about 5kg of U metal in an electrochemical reduction apparatus (Fig. 3). The U metal was refined and recovered at 200g per hour in an electrorefining apparatus (Fig, 4). Injection casting test was done successfully, in which 70% of loaded U and Zr was recovered as U-10wt.%Zr (another 30% can be reused in a next batch). An extraction apparatus with a 6-stage countercurrent extractor and molten salt and molten Cd supply system was manufactured and the extraction test was started (Fig. 5). The performances of these apparatuses were demonstrated through these experiments. It was confirmed that the practical recovery yield of U and others could be achieved and the material balance including the process losses could be controlled accurately. These R&D results were reflected in the intermediate evaluation of FaCT project, which expected steady promotion of this R&D for final evaluation in 2015.

*Part of this work is the result of “Development of metal fuel cycle technology for closing FBR fuel cycle” entrusted to CRIEPI by the Ministry of Education, Culture, Sports, Science and Technology (MEXT).

**Fig. 1 Metal fuel pins（$\phi$8×600mm）for an irradiation test in the experimental fast reactor Joyo**

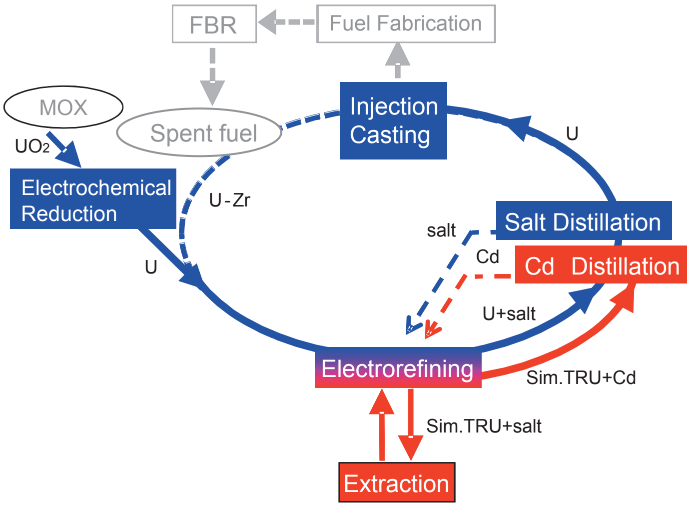


**Fig.2 Repeated cycle tests of pyroprocess for metal fuel**

Repeated cycle tests with 5kg of U per day are carried out for (1) reduction to metal, (2) electrorefining, (3) salt distillation and (4) injection casting (blue part in the figure). The tests of (5) Cd distillation and (6) countercurrent extraction are done using rare earth elements substituted for actinides (red part in the figure).

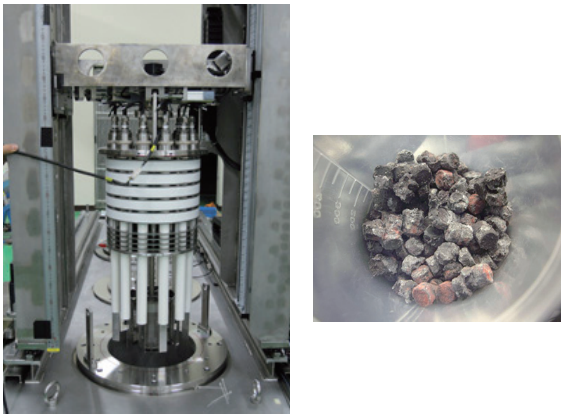

**Fig.3 The electrochemical reduction apparatus (left) and reduction product (right)**

Max. 5.7kg of $UO_2$ are loaded into cathode baskets and reduced to metal in the electrochemical reduction apparatus.

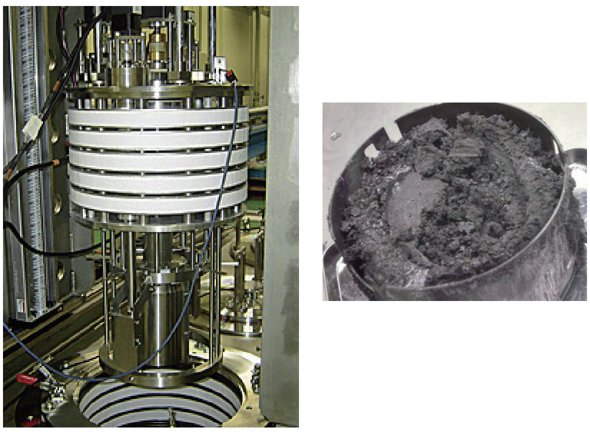

**Fig.4 The electrorefining apparatus (left) and cathode deposit (right)**

Max. 5kg of U metal are loaded into anode baskets and are deposited onto a solid cathode. The deposit is removed from the cathode by a cutter and recovered in a catch pan.

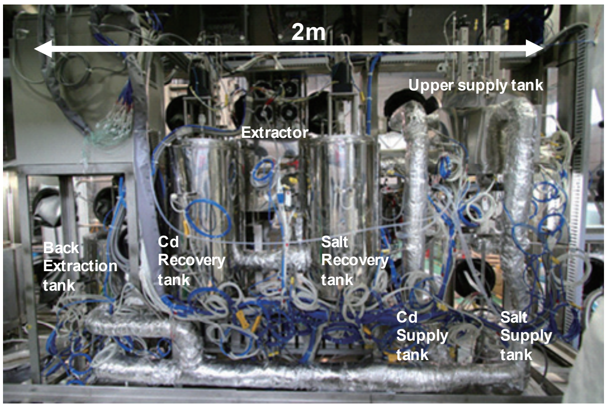


**Fig.5 Countercurrent extraction equipment**

Countercurrent extraction equipment contains (1) supply tanks for salt and Cd, (2) pumps for salt and Cd, (3) upper supply tank, (4) 6 stages countercurrent extractor, (5) recovery tanks for salt and Cd, (6) back-extraction tank for recycle of used salt and Cd and (7) tubes. The tanks and tubes are heated up around 500 degree C. Molten salt and molten Cd flow continuously in the system.