Engineering scale development of electrometallurgical reprocessing

Background

Basic process flow sheet of the electrometallurgical process for metal fuels has been established from the results obtained in fundamental experiments on laboratory scale. In order to confirm practicalities of the proposed process, total performance of the process must be estimated from the viewpoint of process speed or mass balance using the developed engineering scale equipments.

Objectives

For engineering scale demonstration of processing speed or recovery rate of nuclear fuel material in important processes that affect the total performance of the reprocessing plant, the following developments were conducted, ①High U recovery rate at electrorefiner, ②High recovery rate of actinide elements, ③More rational treatment for salt waste. The targets of each development were set as shown in Table 1 and the five detailed items shown in Table 1 and Fig.1 were conducted.

Principal Results

(1) High U recovery rate in electrorefining process

With alteration of scraper mechanism for cathode deposit (recovered U) and also newly designed anode basket for spent fuels, the U recovery rate attained 789 g-U/h by using one electrode assembly of 30 cm diameter. This value is about 93% of the target value (Fig.2). This performance corresponds to the throughput of 3.16t U per year (operation condition: 20h/day, 200days/year) using only one set of the same electrode assembly, and adequate processing speed for commercial equipments can be demonstrated.

(2) Simulated fuel fabrication for electrorefining tests

In order to fabricate the simulated metal fuels supplied to above mentioned electrorefining tests, 10 fabrication tests with U-10wt%Zr alloy fuel were conducted using engineering scale injection casting furnace. A total of about 500 pieces of U-Zr slug were fabricated and the feasibility of the injection casting technology was demonstrated by attaining practical product quality and high product yield.

(3) Actinide recovery from spent salt

Counter-current extraction tests in the single stage extractor with relatively slow speed agitation were conducted (Fig.3) and the obtained results and the model calculation assessments suggested that the target recovery rate of actinide elements could be attained by using 6-stage extractor system. Multi-stage counter-current extraction tests were also conducted and the easy controlled extractor with simple structure was found to have adequate performance for the reductive extraction process even in engineering scale.

(4) Close tracking of actinides and fission products in the electrorefiner

Filtered samples of salt and Cd, core samples of salt/Cd interface and deposits on dipped test pieces were collected from the electrorefiner operated at US Idaho National Laboratory (INL). Very little amount of solid particles of oxide of actinide elements were found in these samples. The material loss attributing to formation of the solid actinide oxide particles from the electrorefiner was found to be very small. Some Pu was captured in the interface layer between irradiated fuel meat and the cladding, this Pu was recovered in electrorefining process. The obtained results are shown in Table 2 and the loss of fuel material is estimated to be lower than the target value.

(5) Development of more rational treatment of salt waste

Glass-bonded sodalite waste was produced from the salt occluded zeolite with crystal mold waste arising from the above fuel fabrication process (added as glass binder) and with sodium in the fuel pin as bond Na. The produced solid waste had an adequate property for final disposal (Fig.4).

We confirmed that our proposed basic process has an adequate performance at engineering scale by estimating the processing speed and the mass balance in the engineering scale test equipments and those in operation with the actual spent fuels.

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Future Developments

Engineering demonstration of connected processes of reprocessing system and hot examination using irradiation fuels.

Main Researcher: Takeshi Tsukada,
Senior Research Scientist, Advanced Nuclear Fuel Cycle Sector, Nuclear Technology Research Laboratory

Reference

JFY2002-2006 Annual Progress Report on “Development and Improvement of Electrometallurgical Process” (in Japanese)

Table 1 Development targets and items

Objectives	Development target	Items(Fig.1)
① High speed U recovery in electrorefining process	① 4 times higher U (2 times higher HM) recovery rate than traditional design ER	(1) (2)
② High recovery rate of actinide elements	②-1 More than 99.5% actinide recovery at engineering scale equipment	(3)
	②-2 Less than 0.5% actinide loss from electrorefining process	(4)
③ More rational treatment of salt waste	③ Fabrication method of ceramic waste form that contains waste salt, molds and bond Na	(5)

Table 2 Loss rate of actinide elements from electrorefiner

Generation point	Generation status and material	Amount of generation	Loss Rate
Solid particles in salt	Mainly U and Cd, Al, Si, too	0.007 - 0.03wt%(per unit salt weight)	0.005 - 0.02wt% (Estimated from total amount of salt and accumulated amount of U treated)
Solid on the wall of electrorefiner	Compound of U and Cd	0.34 - 0.36g/cm^2(per unit area)	No loss under the normal operation
Hull (Interaction layer)	Pu captured in Interaction layer can be recovered in electrorefining process. Attached salt contains some Pu and U.	0.002 - 0.004g/cm (U+Pu/per unit length of crud)	0.04 - 0.1wt% (Loss rate per unit weight of fuel meat including the attached salt)

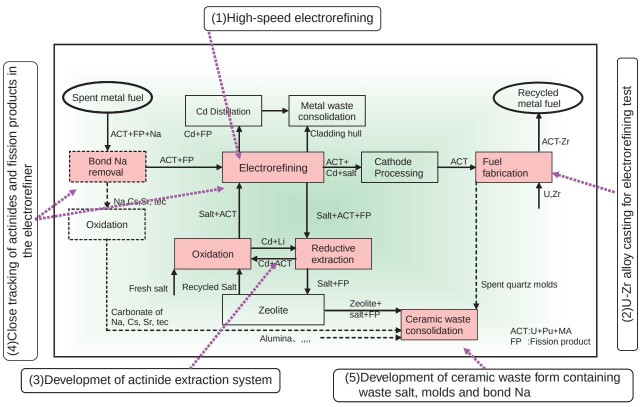

Fig.1 Electrometallurgical process for metal fuel and development items

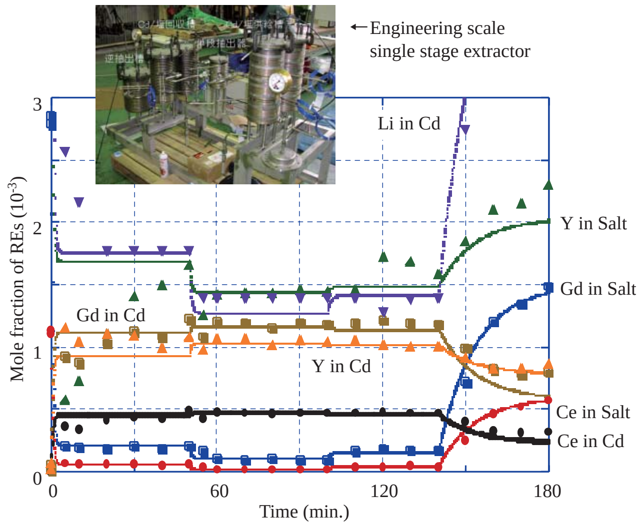

Fig.3 Concentration profiles of rear earth elements and Li in the engineering scale single stage reductive extraction tests. Comparison between experimental data and calculated values.

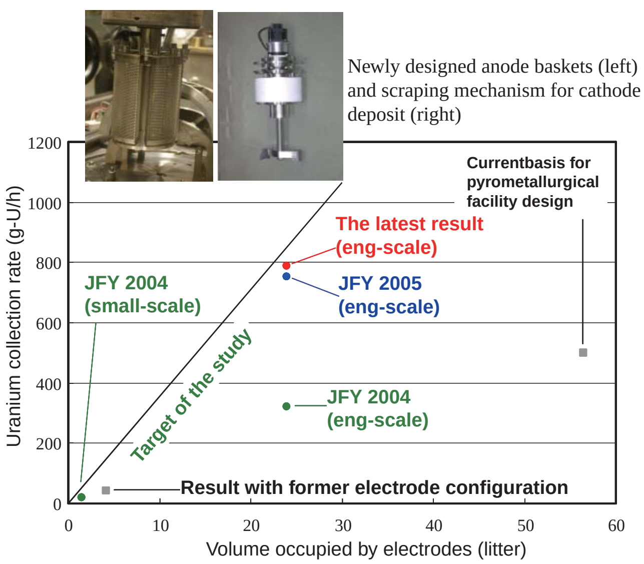

Fig.2 U recovery rate of engineering scale electrorefiner

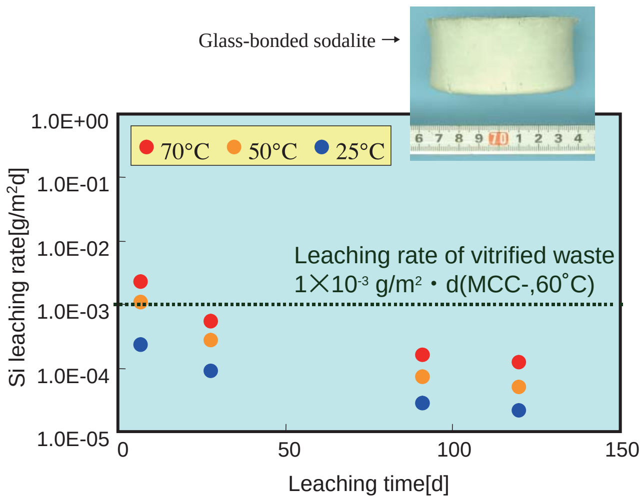

Fig.4 Leaching rate of glass-bonded sodalite