# The Current Status of Electrolytic Reduction Processes in Pyroprocessing Development

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## 1. Introduction

Pyroprocessing is a type of recycling technology that aims to use high-temperature molten salts as electrolytes to electrochemically recover U and transuranic elements from spent oxide fuel. These recovered elements can then be recycled as metal fuels for fast nuclear reactors. Additionally, pyroprocessing helps to separate non-recyclable fission products from the spent oxide fuel, resulting in a reduction in the volume of waste that needs to be disposed of.

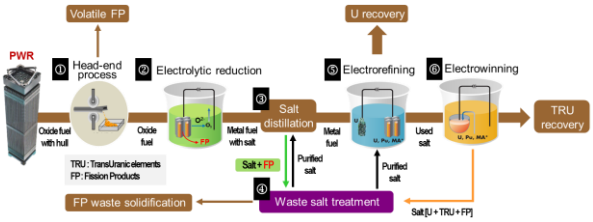


Fig. 1. Pyroprocessing flow diagram.

The pyroprocessing method presented in Fig. 1 illustrates the flow diagram developed by the Korea Atomic Energy Research Institute (KAERI). The process comprises a head-end process, several electrochemical processes (namely, electrolytic reduction, electrorefining, and electrowinning), and a waste-salt-treatment process [1-6].

## 2. Electrolytic reduction process

To convert spent-oxide fuel into its metallic form, the head-end process is used to prepare it before undergoing electrolytic reduction. This process, also known as oxide reduction (OR), occurs in molten $Li_2O$-LiCl salt at a temperature of 650 °C. During the OR reaction, $MO_2$ is decomposed into M and $O_2$, while fission products like Sr dissolve into the salt and form chlorides. The OR reations are as folllows (Fig.2) [7]:

*Cathode:*

$$Li^+ (salt) + e^- \rightarrow Li\,(salt) \quad (1)$$

$$MO_2 + 4e^- \rightarrow M + 2O^{2-}\,(salt) \quad (2)$$

$Li_2O$, which is produced by reaction (3) in molten LiCl, dissociates into $Li^+$ and $O^{2-}$:

$$Li_2O \rightarrow 2Li^+ + O^{2-} \quad (3)$$

*Platinum anode:*

$$2O^{2-}\,(salt) \rightarrow O_2\,(gas) + 4e^- \quad (4)$$

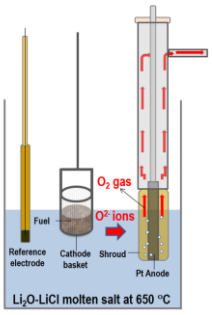


Fig. 2. Schematic diagram of OR cell containing salt, cathode, anode, and reference electrode [8].

KAERI has made significant progress in the development of pyroprocessing technology. One of our achievements has been the creation of electrolytic reducers in different sizes (0.6 kg, 17 kg [9] and 50 kg) to improve the efficiency and economics of the process. The 0.6 kg-scale electrolytic reducer (Fig.3) was designed for employment in hot cell experimentation involving spent nuclear fuel. The previous study [10] establishes the successful operation of an electrolytic reducer at a scale of 0.6 kg. The demonstration involved the conduct of ten successive runs utilizing simulated oxide fuel. The experimental setup remained unchanged, with the retention of the molten LiCl salt and Pt anode throughout the testing phase.

Fig. 3. Photographs of electrolytic reducer installed in M8 hot cell (KAERI).

The electrolytic reducer with capacity of 50 kg/batch (Fig. 4) was developed to facilitate the validation of engineering-scale equipment [11]. Additionally, we have been researching stable materials and operating conditions that can endure long-term operation of the OR process. An electrolytic reducer equipped with

automation features was developed to test the viability of unattended operation in industrial settings (Fig.5).

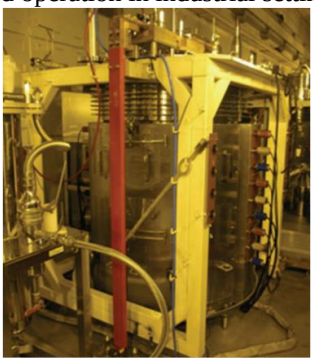

Fig. 4. Photographs of electrolytic reducer with a capacity of 50 kg/batch installed in PRIDE (KAERI) [11].

Fig. 5. Photographs of electrolytic reducer equipped with automation features (KAERI).

Another notable success in recent years has been the development of an alternative anode that can replace the costly Pt. Numerous candidates have undergone thorough scrutiny as potential substitutes for the Pt anode [12–17]. Carbon, in particular, has garnered attention due to its economical price point and commendable electrical and mechanical characteristics. The graphite anode has demonstrated its superiority over the conventional Pt anode of a comparable reactor in terms of its ability to facilitate a current that is 6-7 times greater [18].

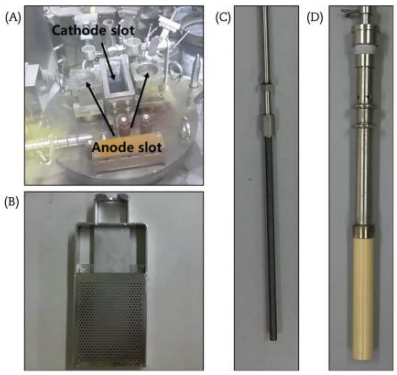


Fig. 6. Electrolytic reducer and electrodes. (A) Flange. (B) Cathode basket. (C) Graphite anode. (D) Anode shroud [18].

This presentation intends to provide a comprehensive overview of the electrolytic reduction research achievements of KAERI, while also presenting the current status of overseas research and development in the field.

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