Multilayer Porous Crucibles for the High Throughput Salt Separation from Uranium Deposits

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1. Introduction

Pyroprocessing is a promising way for the recovery of actinide elements from the used nuclear fuel. Electro-refining is a key technology of pyroprocessing and the electro-refining is generally composed of two recovery steps – deposit of uranium onto a solid cathode and the recovery of actinide elements by a liquid cathode.

Solid cathode processing is necessary to separate the salt from the cathode since the uranium deposit in a solid cathode contains electrolyte salt.

A physical separation process, such as a distillation separation, is more attractive than a chemical or dissolution process because physical processes generate much less secondary process. Distillation process was employed for the cathode processsing due to the advantages of minimal generation of secondary waste, compact unit process, simple and low cost equipment [1,2]. The basis for vacuum distillation separation is the difference in vapor pressures between salt and uranium. A solid cathode deposit is heated in a heating region and salt vaporizes, while nonvolatile uranium remains behind [3].

It is very important to increase the throughput of the salt separation system owing to the high uranium content of spent nuclear fuel and high salt fraction of uranium dendrites [4,5]. The evaporation rate of the LiCl-KCl eutectic salt in vacuum distiller is not so high to come up with the generation capacity of uranium dendrites in an electro-refiner. Therefore, a wide evaporation area or high distillation temperature is necessary for the successful salt separation.

In this study, it was attempted to enlarge a throughput of the salt distiller with a multilayer porous crucibles for the separation of adhered salt in the uranium deposits generated from the electrorefiner. The feasibility of the porous crucibles was tested by the salt distillation experiments.

2. Experimental

Figure 1 shows an experimental set-up for the investigation of the porous crucible. The set-up is composed of a distillation tower with an evaporator, a condenser, a control unit, and an off gas treatment system.

The salt separation experiments were carried out with surrogate uranium deposits, where the content of the salt in the deposits was about 50 wt%. The surrogate deposit is made of steel chip and LiCl-KCl eutectic salt to enhance the effect of liquid salt separation.

The crucible was hung under the load cell through the top flange of the tower. The crucible was made of a stainless steel mesh

The distillation behaviors for the conventional crucible and the perforated crucible were compared by the distillation experiments. The crucibles were made of stainless steel.

Fig. 1. Experimental set-up for the salt separation experiments.

3. Results and discussion

In this study, a system of multilayer porous crucibles was proposed to increase a throughput of the salt distiller as shown in Fig. 2.

The salt evaporation behaviors were compared between the conventional nonporous crucible and the porous crucible.

The feasibility of liquid salt separation was examined by salt separation experiments on a stainless steel sieve. Figure 3 shows a crucible and surrogate deposits for the salt separation experiments.

Figure 4 shows the profiles of the temperature and weight of the samples during the experiment. Two step weight reductions took place in the porous crucible, whereas the salt weight reduced only at high temperature by distillation in a nonporous crucible.

In Fig. 4(b), the first weight reduction was caused by the liquid salt penetrated out through the perforated crucible during the temperature elevation until the distillation temperature. The salt weight reduction was started at about 450°C. After the liquid salt flew out through the perforated crucible, the weight was kept constant until the salt evaporation temperature. The second sample weight reduction was started at about 650°C. The weight reduction stopped after most of the salt evaporated.

The remaining salt in the uranium deposits was further separated by evaporation in the bench scale salt distiller for two hours at 900 °C.

Besides the porous crucible, the concept of multiple crucibles (multilayer) was also proposed. Multilayer porous crucibles have a benefit to expand the evaporation surface area.

It was found that the amount of salt to be distilled could be reduced by the introduction of the porous crucible since the liquid salt separation prior to the salt distillation.

From the above results, it could be concluded that the multilayer porous crucibles is an effective way for the achievement of a high throughput performance in the salt separation process because the liquid salt of the uranium deposits can be separated during temperature elevation for the distillation and high surface area for salt evaporation.

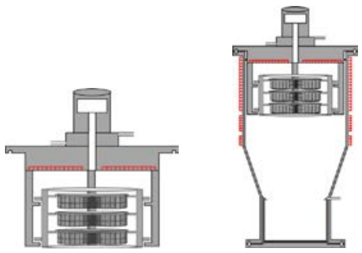


Fig. 2. Schematic of porous crucible for the high throughput salt separation system.

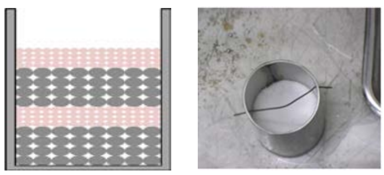
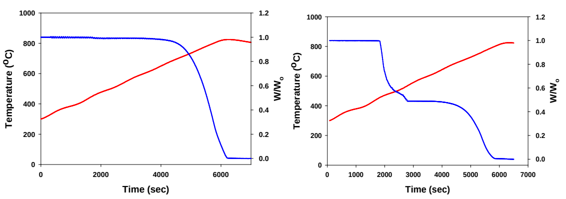


Fig. 3. Crucible and deposits for the salt separation experiments.



(a) (b)

Fig. 4. Temperature and salt weigh profiles during salt separation experiment [(a) nonporous crucible and (b) porous crucible].

4. Conclusions

In this study, the salt distiller with multilayer porous crucibles was proposed and the feasibility of liquid salt separation was examined to increase a throughput. It was found that the effective separation of salt from uranium deposits was possible by the multilayer porous crucibles.

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