

Distillation of Cadmium for the Recovery of Actinides from Liquid Cadmium Cathode

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1. Introduction

It is needed to separate long-lived actinides from the rest of the spent nuclear fuel to recycle them in a transmutation process [1]. The long-lived actinides could be extracted and fabricated into a fuel for use in advanced reactors. In addition, the extraction of actinides from a spent fuel will significantly reduce the radioactivity of the spent fuel and the volume of the spent fuel to be buried in a repository.

Pyroprocessing has received many attentions for the separation of the long-lived elements due to its advantages of compactness, nuclear proliferation resistance, and a reduction of the secondary waste generation [1].

Electrorefining is a key step in the pyroprocessing. Electrorefining process is generally composed of two recovery steps— deposit of uranium onto a solid cathode and the recovery of the remaining uranium and TRU elements simultaneously by a liquid cadmium cathode. After the recovery step of actinides by the liquid cadmium cathode, cadmium is separated from actinide products in liquid cadmium cathode by distillation process [2].

Besides the nuclear industry, cadmium distillation process has other applications in purification of cadmium and waste treatment of spent Ni-Cd battery [3,4].

In this study, experimental set-up is developed and distillation experiments were carried out to examine the behavior of cadmium distillation for the development of an actinide recovery process from the liquid cadmium cathode.

2. Experimental

Fig. 1 shows a layout of the experimental set-up for the cadmium distillation. The experimental set-up is composed of an evaporator, a condenser, a control unit, an off gas treatment system. The evaporation area is surrounded by a carbon dome. The maximum heating temperature is 1,500°C.

The temperature in the carbon dome was measured using a thermocouple that is connected to the center of the dome. A Kanthal super heating element is used for the heating of the evaporator.

The loading capacity is 1kg-Cd/batch. Cadmium ingot sealed in pouch was used as received without any further treatment. The cadmium ingot has the purity of 99.99 wt. %. The condenser is connected to the rotary

vacuum and diffusion pumps. The absolute vacuum pressure can be reached below 1×10^{-3} torr. Weight loss of cadmium in the crucible was measured by a load cell. The distillation experiments were performed in vacuum at various temperatures in the range of 400- 700°C.

The ceramic filter was placed before the vacuum pump to avoid the entrainment of cadmium vapor to the pump. The off gas from the distiller was treated in the wet scrubber before release to the atmosphere.

The cadmium crucible with about 170g of cadmium is bottom loaded into the carbon dome by raising the bottom assembly until seated. The evaporator was evacuated and heated up to the distillation temperature. The temperature was held until the complete evaporation of the cadmium. Cadmium vapor was transported to the condenser through the 2" diameter pipe which is preheated by a jacket heater. Cadmium is recovered by allowing the vapor strike a cold receiving crucible, where it condenses.

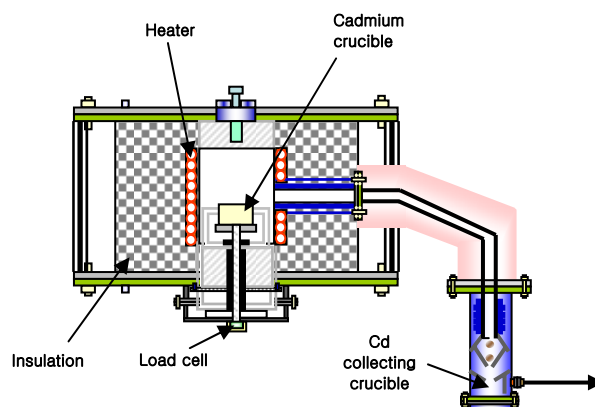


Fig. 1. Experimental set-up for the cadmium distillation experiments.

3. Results and Discussion

Cadmium distillation experiments were carried out to examine the behavior of cadmium distillation for the development of an actinide recovery process from the liquid cadmium cathode. Cadmium was effectively distilled and separated from the rare earth metal solute.

Fig. 2 shows profiles of cadmium weight loss and temperature during evaporation experiment at 500°C. The distillation rate of cadmium increased with increasing temperature.

The distillation rate of cadmium was varied from 5 to 35 g/cm²/h in the temperature range of 400- 700°C. Due to this low rate, 400°C seems to be too late to adopt the

distiller operating temperature. It was reported that the distillation temperature of 400 °C was too low to evaporate 10g of Cd metal in the limited time of 2h [5].

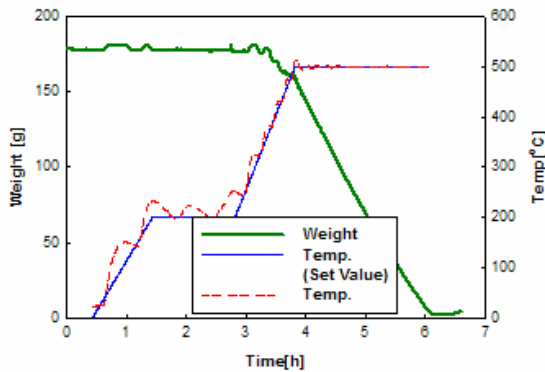


Fig. 2. Weight loss profile during the cadmium distillation experiment at 500 °C.

The measured evaporation rate was compared with the values calculated by a Hertz-Langmuir equation. The vaporization rate of the metal can be expressed by the Hertz-Langmuir relation (Eq. (1)) based on the kinetics of gases

$$M = (P_i - P_a) / (2\pi mRT)^{1/2} \quad (1)$$

where M is the net vaporization rate, m is the molecular weight, R is the gas constant, T is temperature, P_i is the saturation vapor pressure of the gas i in the ambient space, and P_a is the partial pressure of the gas i in the ambient space.

Fig. 3 shows the amount of evaporated cadmium calculated by Hertz-Langmuir relation. This theoretical value calculated by the Hertz-Langmuir relation is much higher than experimental value of evaporated cadmium. This high value is probably explained that the model does not consider the effects such as transfer of vapor, heat transfer. This deviation is compensated by an evaporation coefficient (α) obtained empirically. The evaporation coefficient was a function of temperature.

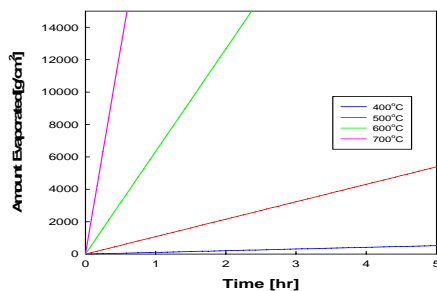


Fig. 3. The amount of evaporated cadmium calculated by Hertz-Langmuir relation.

Distillation experiments of cadmium were carried out to develop an actinide recovery process from the liquid cadmium cathode in the laboratory scale cadmium distiller. The theoretical value calculated by the Hertz-Langmuir relation is higher than experimental value of evaporated cadmium. This high value is probably explained that the model does not consider the effects such as transfer of vapor, heat transfer. This deviation is compensated by an evaporation coefficient (α) obtained empirically. The evaporation coefficient was a function of temperature.

REFERENCES

- [1] J. J. Laidler, J. E. Battles, W. E. Miller, J. P. Ackerman, and E. L. Carls, Progress in Nuclear Energy, Vol. 31, p131, 1997.
- [2] B. R. Westphal, J. C. Price, D. Vaden, R. W. Benedict, J. Alloys and Compounds, 444-445, 561, 2007.
- [3] S. T. Ali, J. V. Rao, K. S. Varma, T. L. Prakash, Bull. Mater. Sci. 25, 479, 2002.
- [4] A. Cox, D. J. Fray, Trans. Inst. Min. Metall., 108, C153, 1999.
- [5] T. kato, M. Iizuka, T. Inoue, T. Iwai, Y. Arai, J. Nucl. Mater., 340, 259-265, 2005.

4. Summary