§43. Continuous Recovery of Tritium and Heat from Laser Fusion Reactor, Koyo-fast

Fukada, S., Katayama, K., Muneoka, D., Yoshimura, R. (Kyushu Univ.), Edao, Y. (JAEA), Norimatsu, T. (Osaka Univ.), Sagara, A., Tanaka, T., Yagi, J.

A conceptual design of a laser fusion reactor called Koyo-fast is proposed as shown in Fig. 1, which is composed of a reaction chamber, a tritium recovery system and a heat exchanger. A system of falling $Li_{17}Pb_{83}$ liquid film is designed so as to act as a coolant and tritium breeder to protect a reactor chamber from strong neutron and heat flow. The Li-Pb flow works not only as a protector of the first wall from strong neutron beam but also as a tritium breeder. The inlet and outlet temperatures are designed between 300 and 500^{o}C. Material durability is expected within the operating conditions of temperature and radiation. Recovery of heat and tritium outside of the vacuum chamber is designed and experimented in this work.

Although there were several previous researches on the solubility and diffusivity of $Li_{17}Pb_{83}$, there are few researches on tritium recovery under fluidized state. The first candidate method to recover tritium continuously from the fluidized Li-Pb loop will be a dispersed liquid drop contact tower, where Li-Pb flow and He (or vacuum) counter-currently in a packed tower. In order to obtain basic mass-transfer parameter for the tritium recovery, a bubbling tower for Ar-LiPb direct contact is set up in our laboratory and H_2 transfer experiment is performed[1-3].

When an inert gas bubble is ejected from an inserted tube with diameter of D (m) and moves upward in liquid, the diameter of gas bubble, d (m), and the terminal rising velocity of the bubble, u_m (m/s), are estimated from the balance of surface tension, σ (N/m), the gravitational force and the drag force as follows:

$$d = [6\sigma D/(\rho_L - \rho_G)g]^{1/3} \quad (1),$$

$$u_m = [4dg(1-\rho_G/\rho_L)/3C_D]^{1/2} \quad (2),$$

where ρ_L and ρ_G (kg/m^3) are densities of liquid and gas, g (m/s^2) is gravity, and C_D (-) the drag coefficient. The values of d=3.6 mm and u_m=0.31 m/s are estimated under the present Ar-LiPb experiment.

The T_2 (or H_2) transfer rate from bubbles to liquid or vice versa in a liquid-gas contact tower is described by the equation under the assumption of uniform T_2 (or H_2) concentration, c_m (mol/m^3), in liquid:

$$V\frac{dc_m}{dt} = k(c_m - c_S)S \quad (3)$$

where k (m/s) is a mass transfer coefficient and V (m^3) is a volume of the contact tower. The T_2 or H_2 transfer rate per one bubble passing through the liquid-gas contact tower with a height of L (m) is estimated by the equation:

$$\Delta p_S/\mathrm{RT} = k(c_m - c_S)(6L/du_m) \quad (4)$$

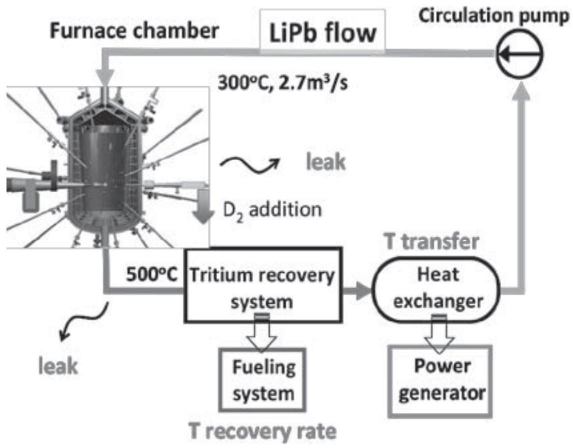

Fig. 1 $Li_{17}Pb_{83}$ loop for KOYO-fast

where Δp_S is change of T_2 (or H_2) partial pressure in gas bubble tower. It is found that the order of the term $6kL/du_m$ appearing in Eq. (4) is the order of unity in the present experiment. Therefore the left hand side in Eq. (4) becomes much smaller than c_m. In other words, the bubble becomes a saturation condition immediately after passing through the gas-liquid tower, which means the Sieverts' law of $c_S=p_S^{0.5}$ in the bubble tower. In addition, the following relation is held between the gas flow rate, Q (m^3/s), and the total surface area of bubbles, S (m^2):

$$S = 6LQ/du_m \quad (5)$$

Fig. 2 compares experimental data of H_2 desorption from a Li-Pb layer with calculations by Eq. (3). The k values are determined from the comparison. Comparatively good fit is obtained. The reversal process of H_2 absorption in Li-Pb is also performed, and reversible absorption and desorption is confirmed. The k value is deeply related with H diffusivity in Li-Pb, $D_{H\text{-}LiPb}$, and is correlated to theoretically the dimensionless parameter of $Sh=kd/D_{H\text{-}LiPb}$.

1) Okada, M. et al.: J. Appl. Nucl. Sci. Tech., **5** (2012) 112.
2) Fukada, S. et al.: Fus. Sci. Technol. **64** (2013) 636.
3) Fukada, S. et al.: Materials Trans., **54** (2013) 425.

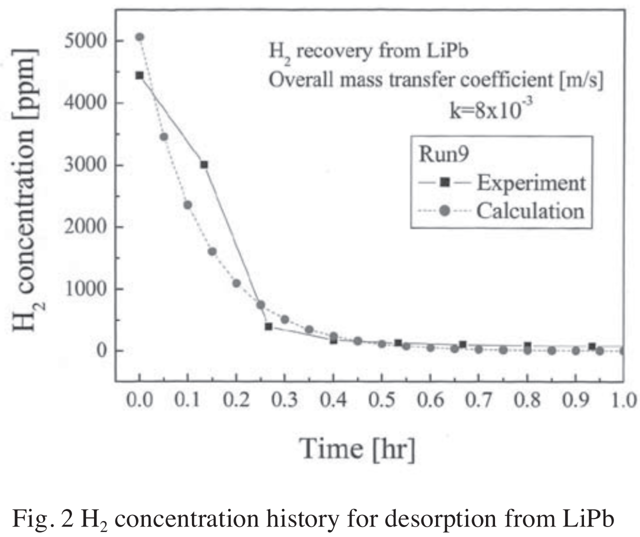

Fig. 2 H_2 concentration history for desorption from LiPb