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

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$Li_{17}Pb_{83}$ (Li-Pb) is one of the most promising tritium (T) breeder for DEMO or the next-stage fusion reactor. The Koyo-fast laser fusion reactor also adopts a wet wall concept of Li-Pb flow to protect 1st wall from strong *n* and γ irradiation, to breed T and to generate heat. Tritium of 150 g/day (R=5.8x10^{-4} mol/s) per 1GW heating rate is bred by the Li^6(n,α)T reaction to satisfy the condition of self-sufficient T supply.

Efficient T recovery from a fluidized Li-Pb breeder flow is demanded under conditions of low external T permeation through heat exchanger walls. The present study proposes a bubbling tower to recover T continuously from a flowing Li-Pb loop. The overall scheme of a bubbling tower is shown in Fig. 1. Liquid of a volume of V (m^3) is held in a bubbling tower and its height is L (m). Li-Pb is continuously supplied from the top of the tower and flows out of the bottom with a flow rate of W (m^3/s), and its inlet T molar fraction is $x_{T,in}$ (-). The inert gas bubbles are ejected from the bottom nozzles with a uniform diameter of D (m), and effluent gas is exhausted from the top. Its flow rate is Q (m^3/s).

Taking into consideration of surface tension, σ, and time delay when bubbles depart from a nozzle edge, the diameter, d, of bubbles ejected from the bottom nozzle is estimated from the equation:

$$d = \left[\frac{6\sigma D}{(\rho_L-\rho_G)g}\right]^{1/3}\left[1+\frac{5(\rho_L-\rho_G)}{3\pi\sigma}\sqrt{\frac{g}{D}}Q\right]^{1/3} \quad (1).$$

where g is gravity, and ρ_L and ρ_g are the densities of Li-Pb and gas. Bubbles rise upward inside the Li-Pb vessel and approach to a terminal velocity within a short distance. The terminal velocity, u_t, is estimated from balance between the buoyancy force and drag one:

$$u_t = \sqrt{4dg/3C_D} \quad (2).$$

Taking into consideration of internal flow in a bubble based on the Hadamard-Rybczynski formula, the drag force coefficient C_D is expressed as follows:

$$C_D = 8(2\mu_L + 3\mu_G)/\mathrm{Re}(\mu_L+\mu_G) \quad (3),$$

where Re is the bubble Reynolds number defined as $Re=\rho_L u_t d/\mu_L$. Under the diffusion-limiting condition and well-mixed bubbling tower one, the overall T transfer rate is determined by the following equation:

$$\sqrt{\frac{p_{T_2,m}}{p_{T_2,m,0}}} = \exp\left(-\frac{k_{LiPb}S}{V}t\right) \quad (4),$$

where $p_{T2,m}$ (Pa) is the average T_2 pressure inside bubbles, k_{LiPb} (m/s) is the mass-transfer coefficient for the Li-Pb boundary layer, which is determined from experiment. S is the total surfaces area between bubbles and Li-Pb and is estimated by the following equation:

$$S = 6QL/du_t \quad (5).$$

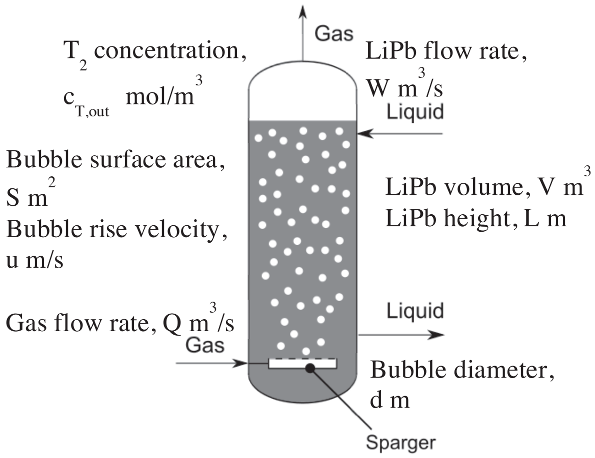

Fig. 1 Schematic diagram of bubbling tower operation

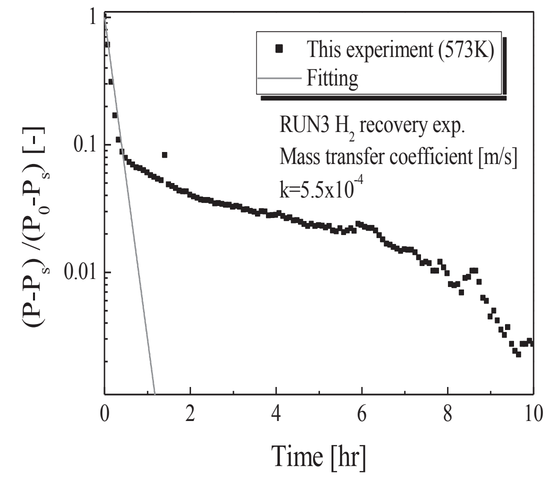

Fig. 2 Comparison of variations of gaseous H_2 concentration with time between experiment and calculation for desorption run at 300ºC.

Hydrogen recovery from Li-Pb is experimentally investigated, where the Li-Pb volume is V=693 cm^3, the Ar flow rate is Q=83.3 cm^3/s, the Li-Pb height is L=26.9 cm and temperature is T=300, 400, 500 and 600ºC. A result is shown in Fig. 2. The estimated bubble diameter is d=4.3mm and the terminal velocity is u_t=0.31m/s. Re is 1.0x10^4. Comparatively good agreement is obtained in the earlier time region and the value of k_{LiPb}=5.5x10^{-4}m/s is determined. Almost 90% H is recovered. The latter part shows that H is desorbed from the solid wall region contacted with Li-Pb. The rate of H release in the rest part is correlated by another exponential relation similar to Eq. (4). The rate constant is around 10 times smaller than the earlier one.

When the values of k_{LiPb}=5.5x10^{-4} m/s, d=4.3 mm, u_t=0.31 m/s determined from experiment are applied to a design of a bubbling tower for Koyo-fast, where the values of V=20 m^3, L=10 m, Q=0.1 m^3/s, the parameter of $k_{LiPb}S/V$=0.12 1/s and the contact time of t=32 s are estimated. With use of the above design values, the necessary condition for T recovery of R=5.8x10^{-4} mol/s is achieved.