§38. Experimental Work to Estimate Tritium Leak Rate through Recovery Loop in Falling Liquid LiPb Blanket of Laser Fusion Reactor

Fukada, S. (Kyushu Univ.),
Norimatsu, T. (Osaka Univ.), Sagara, A.

In this collaboration work, LiPb-H_2 or -D_2 solubility and diffusivity, their isotope effects, a design study of LiPb loop and estimation of leak rate from the Li-Pb system are performed in 2011 [1-4]. Koyo-fast is a conceptual design for laser fusion reactor. Its total heat power is 1GWt, and Li-Pb circulates to protect its reactor chamber wall from high-intensity neutron irradiation. $Li_{15.8}Pb_{84.2}$ has a liquid metal with the eutectic temperature at 235°C. The Li-Pb flow rate is 18.3t/s, and the inlet and outlet temperatures are 300°C and 500°C. In order to achieve self-sufficiency of tritium in the fusion reactor system, tritium generation rate in the reactor chamber is 1.5MCi/day. The tritium concentration in Li-Pb is estimated 9.6×10^{-9}T/LiPb, and the equilibrium pressure is 1.8×10^{-3}Pa. Li-Pb is supplied from the top of the reactor chamber, and goes out from the bottom. The whole system is illustrated in Fig. 1. Heat generated by the D-T and Li-n reactions is recovered by the Rankine cycle through the LiPb-H_2O heat exchanger. The heat-transfer coefficient determined from the Dittus-Boelter equation is 5×10^3 W/m^{2}K. Then, the surface area of the heat exchanger is estimated 690m^2.

Tritium generated by the Li-n reaction is present as an atomic form in the Li-Pb flow. Since the tritium solubility is comparatively low, the Sieverts' law is held between tritium and LiPb. Tritium generated in the LiPb flow diffuses through a liquid boundary layer and reaches at the LiPb-metal interface. Then tritium is dissolved in metallic walls of the heat exchanger and diffuses through it to the secondary flow. Tritium atoms recombine to a molecular form and disperse in the secondary flow. The tritium permeation is a function of tritium diffusion through Li-Pb boundary layer and permeation through tube walls. The former is estimated from the mass-transfer coefficient of the LiPb boundary layer and the latter is correlated in terms of permeability. In especial, the former is a function of the velocity of Li-Pb flow and correlated in terms of Raynolds number and Sherwood number. The Sherwood number, Sh, is defined as $Sh=k_{T,LiPb}d/D_{T-LiPb}$, where d is a diameter of heat-exchanger tube. Figure 2 shows the tritium permeation rate as a function of the Sherwood number and the tritium concentration in Li-Pb. The present design values are considered proper judging from the overall tritium permeation rate and the design scale of heat exchanger.

Papers presented in 2011
1) T. Norimatsu, H. Saika, H. Homma, M. Nakai, S. Fukada; Leakage control of tritium through heat cycles of conceptual-design, laser-fusion reactor Koyo-F, Fusion Science and Technology, 60 (2011) 893-89.
2) S. Fukada, Y. Edao; Unresolved issues on tritium mass transfer in Li-Pb liquid blankets, Journal of Nuclear Materials, 417 (2011) 727-730.
3) Y. Edao, H. Okitsu, H. Noguchi, S. Fukada; Permeation of two-component hydrogen isotopes in lithium-lead eutectic alloy, Fusion Science and Technology, 60 (2011) 1163-1166.
4) Y. Edao, H. Noguchi, S. Fukada; Experiments of hydrogen isotope permeation, diffusion and dissolution in Li–Pb, Journal of Nuclear Materials, 417 (2011) 723-726.

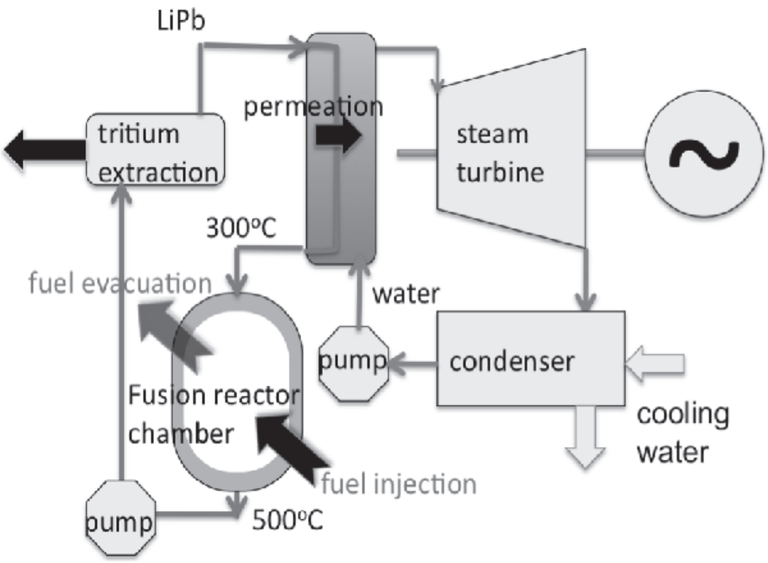

Fig. 1 LiPb loop for Laser fusion reactor and steam Rankine cycle

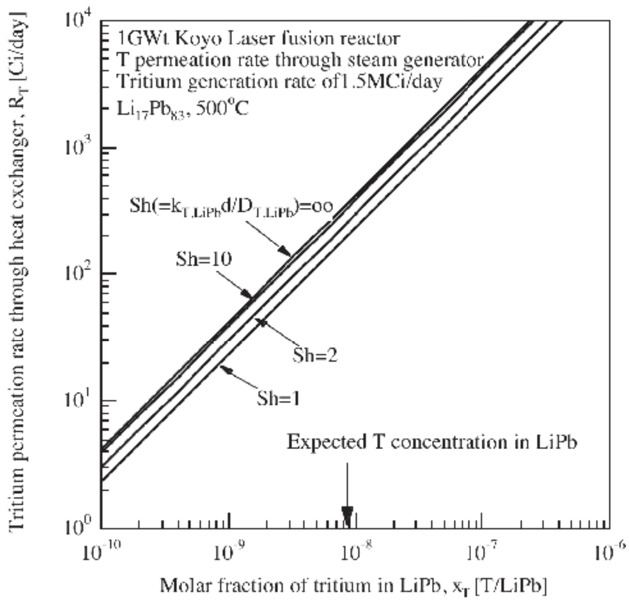

Fig. 2 Tritium permeation rate through heat exchanger tube