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 circulated 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 9.6x10$^{-9}$T/Li-Pb, and the equilibrium pressure is 1.8x10$^{-3}$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$_2$O heat exchanger. The heat-transfer coefficient determined from the Dittus-Boelter equation is 5x10$^3$ 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 special, the former is a function of the velocity of Li-Pb flow and correlated in terms of Sherwood number and Sherwood number. The Sherwood number, $Sh$, is defined as $Sh=\frac{kT_{LiPb}d}{D_T_{LiPb}}$, 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.