§19. Estimation of Technological Measures to Decrease Tritium Permeation and to Increase Tritium Recovery through Flibe Blanket of Fusion Reactor

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Flibe is a mixed molten salt of 2LiF and BeF_2, which melting point is 459°C. Because of its high stability at blanket temperature, low tritium solubility and low electric conductivity, Flibe is designed as self-coolant blanket system of FFHR-2. When it is used for tritium breeder, two large issues have to be solved. One is corrosion of Flibe-contacting metallic tubes and the second is suppression of tritium permeation through the tubes. When Flibe is irradiated by neutron, the chemical form of tritium generated is TF. Since TF is a strong acid, its chemical form is changed to molecular one by using the chemical reaction of $Be+2TF \rightarrow BeF_2+T_2$, which is performed by inserting metallic Be rod into Flibe. Then, tritium is dissolved in Flibe as a molecular form of T_2. The corrosion can be mitigated by the redox control reaction. The reaction was proved experimentally under the Japan-US collaboration work named JUPITER-II. The reaction is second-order, and the reaction constant and Be dissolution rate are determined. In addition, Watanabe and Nagasaka *et al.* investigated a new surface coating to protect corrosion on metallic tube.

The second issue is suppression of tritium permeation through Flibe-contacting ferrite-steel tubes. Fliba has a low tritium solubility and high tritium equilibrium pressure. When 1 ppm T is dissolved in Flibe, its equilibrium pressure is around 0.1 MPa. Therefore it is important to estimate the tritium permeation rate through ferrite-steel tubes.[1)]

In order to estimate overall tritium permeation rates correctly, several elementary transfer processes have to be taken into consideration as follows:

(1) Tritium generation in neutron-irradiated Flibe
(2) T_2 diffusion through fluidized Flibe
(3) Dissociation of T_2 to T on metallic surfaces
(4) T diffusion through metallic tube
(5) Recombination to T_2 on metallic surfaces
(6) T_2 diffusion through surrounding gas

The six processes shown in Fig. 1 are involved in the tritium overall permeation one simultaneously. Since their respective reactions and diffusion processes are complicatedly related with the overall process, the rate-determining step is different from condition to condition. When the tritium concentration in Flibe is low, the surface reaction rate becomes comparatively low. This is because the surface reaction is not linear but second-order, while the diffusion process is linear regardless of the tritium concentration. On the other hand, when the tritium concentration is high, the surface reaction becomes comparatively fast. Therefore, the rate-determining step changes to diffusion process. The overall permeation rate is calculated for a shell&tube-type heat exchanger, which is designed to recover all heat generated in Flibe self-breeder. The inlet and outlet temperature are 500°C and 600°C. In order to recover all tritium in Flibe, around 200 m^2 area is necessary for the self-cooled blanket system as shown in Fig. 2.

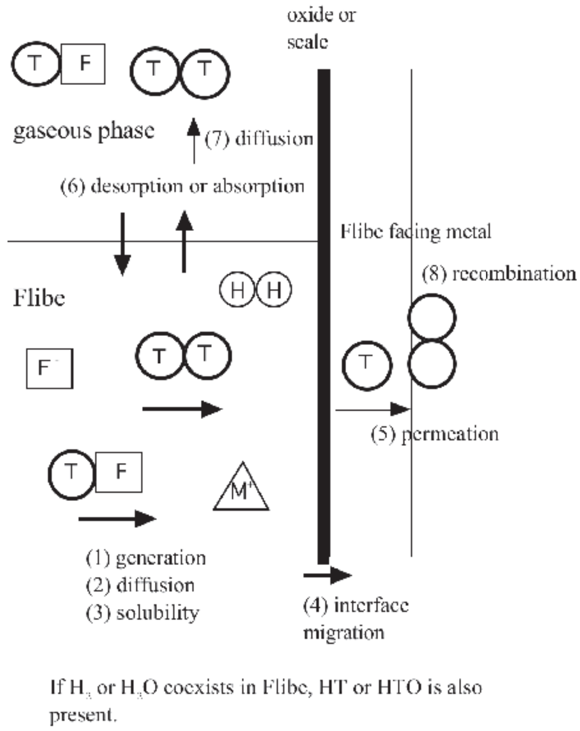

Fig. 1 Tritium transfer process through Flibe

1) Fukada, S.: invited presentation in Proc. 15th International Conference on Emerging Nuclear Energy Systems, "Tritium recovery from liquid blanket systems of fusion reactor", May 15-19 (2011) San Francisco, USA.

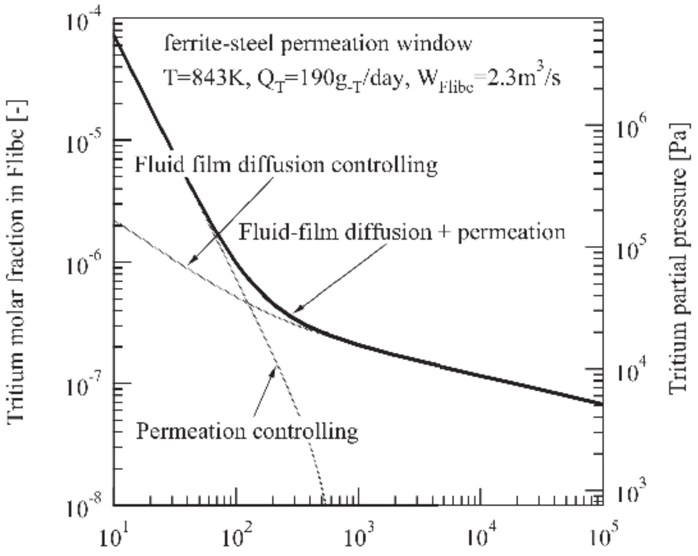

Fig. 2 Estimation of T permeation through Flibe-contacting tubes