§3. A Design Study on Recovery of Tritium from Molten Salt Flibe Blanket of Fusion Reactor

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Molten salt Flibe ($2LiF+BeF_2$) blanket has several attractive advantages of simple blanket structure, easy maintenance, a stable salt, low MHD effect and so on. Relating with tritium behavior including tritium recovery and tritium leak from a molten salt Flibe blanket of FFHR, the control of chemical forms of tritium in Flibe is a critical issue and, therefore, has being intensively investigated in JUPITER-II program [1,2]. When the chemical state of tritium in Flibe is successfully controlled by use of Be, the tritium chemical form is considered T_2 or HT in Flibe. In this collaboration study, a design of a tritium recovery apparatus and a way to control of tritium leak were investigated for the FFHR design.

Vacuum disengager is a promising way to recover tritium from a Flibe flow. Liquid Flibe is dispersed to drops by a percolator with small pores located at the top of the disengager. Tritium dissolved in Flibe drops is desorbed by evacuation while drops falling through the disengager tower. The work per time, W, to make Flibe pass through the pore of the percolator with diameter, d, with the flow velocity, u, is expressed by $W=\frac{\pi}{4}d^2uN\Delta p$. Pressure drop through the percolator, Δp, is estimated by $\Delta p=\frac{32\eta lu}{d^2}$. Here, l is the length of the pore through the percolator. Surface tension energy to make a Flibe drop is $\pi d^2\sigma$, where σ is surface tension. Tritium recovery ratio, R, from Flibe between the column top and the bottom is determined by

$$R\left(=\frac{x_{T,in}-x_{T,out}}{x_{T,in}}\right)=1-\frac{6}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{n^2}\exp\left(-\frac{4n^2\pi^2 D}{d^2}\sqrt{\frac{2h}{g}}\right) \quad (1)$$

Here, g is gravity and h is the height of the tower.

The results are shown in **Table 1**. With a decrease in diameter of the Flibe drop, the tritium recovery ratio increases but, at the same time, energy for Flibe passing through the percolator, the surface tension energy and the pressure difference also increase. The optimum condition was estimated d=200μm. Although energy to make Flibe into small drops was much smaller than the fusion power, the upstream pressure when l = 1cm was much higher than the internal pressure of the force-free Flibe flow. If a percolator with l=1mm is applicable, Δp becomes 4.4 atm. The latter condition can make it easier to design the vacuum disengager. If the upstream pressure of the vacuum disengager is higher than the Flibe coolant pressure, the disengager should be put in the by-pass line.

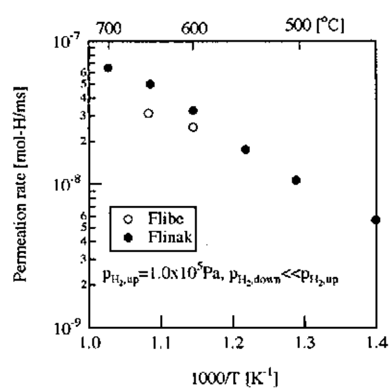

Fig. 2 Permeation flux of Flibe and Flinak

Our estimation of tritium leak from ducts between the blanket and a heat exchanger was greater than its target level, 10 Ci/day. Stagnant molten salt Flibe or Flinak (a mixture of LiF + NaF + KF) layer was here investigated in order to lower the rate of tritium leak from the FFHR Flibe loop under 10 Ci/day. Flinak was a coolant used for a molten salt reactor which physical properties were similar to Flibe. Permeation rates of hydrogen through Flibe and Flinak experimentally determined were compared in **Fig. 1**. It was found that the permeation rates through Flinak and Flibe were also similar. Consequently, the Flibe or Flibe layer with 0.1m in thickness can work as tritium permeation barrier necessary to lower the tritium leak rate below 10 Ci/day. Even in this condition, tritium leaking from the secondary heat exchanger tubes is still higher than 10 Ci/day. The present calculation was carried out under the condition where the tritium chemical form is T_2. If the chemical form of tritium is TF, the tritium permeation rate will become low. However, corrosion of wall materials are becomes severe.

Table 1. Energy and recovery ratio of spray tower for Flibe-T disengage

Diameter of dispersed Flibe drop	100 μm	200 μm	1000 μm
Energy of Flibe passing through percolator	140 W	8.7 W	14 mW
Pressure difference through percolator	700 atm	44 atm	0.07 atm
Surface tension energy of dispersed Flibe drops	11 kW	5.6 kW	1.1 kW
Tritium recovery ratio by 10 m spray tower	100 %	100 %	21 %

Reference

(1) S. Fukada et al., Fus. Sci. Technol., 44 (2003) 410-414.
(2) S. Fukada et al., Proc. IEA Int. WS on Be Technol., (2003) 275-286.