§75. Molten-salt FLiBe System Design for FFHR

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A primary design of a FLiBe cooling system with no intermediate loop for FFHR was performed focusing on heat transfer and tritium mass transfer.

The inlet FLiBe temperature to the blanket is 723 K and the outlet temperature is 823 K, because the maximum Flibe temperature is determined from creep strength of JLF-1, which is considered as a structural material, and the minimum temperature is limited by the melting point of FLiBe. The flow rate of FLiBe is determined to be about $7m^3/s$ by the heat transfer when the thermal power of the reactor is 3 GW. We discussed the possibility of a simple heat transfer system with no intermediate loop. In order to keep high efficiency of the heat exchanger, the outlet temperature of boiling water in the secondary loop should be close to that of the inlet FLiBe. But, for low pumping power, it would be better to keep the temperature difference between the primary and the secondary fluids because the heat transfer coefficient of FLiBe (400-1300 W/m^2K) is much lower than that of the sodium in LMBR or the pressurized water in PWR. As a result, the outlet temperature of boiling water in the secondary loop should be kept low (550 K), because the excessive pumping power caused by a small temperature gradient in case of boiling water at high temperature is almost equal to the excessive electric energy obtained by high thermal efficiency.

Figure 1 shows the tritium migration in the FLiBe coolant. Tritium permeation to the environment should be kept low in order to keep high efficiency of tritium recovery. Because beryllium loaded inside the FLiBe flow to keep high TBR may reduce TF, the chemical form of tritium in the FLiBe is considered to be T_2. The structural material contacting FLiBe should be the first barrier for tritium release, but T_2 having low solubility in FLiBe easily permeates through the first structural wall almost at the same rate as it releases to the gas phase. Tritium permeation through the plasma-side wall has no significant problem, because the permeating T_2 is utilized as a fuel directly. For the tubing wall, to locate a chemical barrier for tritium permeation, $He+O_2$ gas can be utilized effectively. The $He+O_2$ gas made to flow between the first and the second tubing walls of a double-wall tube changes the tritium chemical form from T_2 to T_2O, which permeates through the second tubing wall at very low rate (under 1 Ci/day for all the tubing). The heat exchange wall must also have a chemical barrier to reduce tritium permeation to the secondary loop to the rate under 10 Ci/day. The low heat transfer coefficient of FLiBe, however, can afford to use a tritium barrier having a low heat transfer coefficient. A contact medium between the primary loop and the secondary loop, such as thick ceramic coatings on the surface of the structural wall or flowing liquid metal or gas between the walls in the double-wall system in the heat exchanger is expected to transfer heat at a large rate with tritium at a very low rate.

To recover tritium we consider three recovery systems: a double-wall tubing system, a contact medium in the heat exchanger and the third system located between the blanket and the heat exchanger. In the third system, the liquid FLiBe is made to spray with a lot of small nozzles of submillimeters to increase the surface area. Because T_2 is released effectively through the large surface of the FLiBe drops, the inlet tritium pressure in FLiBe to the liquid spray system is about 760 Pa and the outlet one is under 10 Pa, and the tritium inventory is less than 0.1 g in 500 ton of FLiBe.

However, we must note that at present the basic data of FLiBe concerning its interaction with tritium and corrosion to structural materials are not sufficient to estimate the possibility of the simple FLiBe loop. Thus, further basic studies are required to make a detailed design.

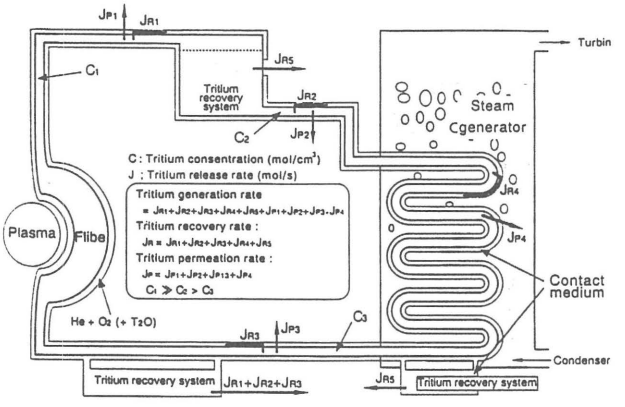

Fig. 1. Tritium migration in a FLiBe coolant loop.