§49. Molten-salt FLIBE System Design for FFHR

Tanaka, S., Terai, T., Suzuki, A. (Dept. Quantum Eng. & Systems Sci., Univ. of Tokyo)
Sagara, A., and Motojima, O.

Liquid tritium breeding materials have many advantages such as no irradiation damage, easy control of chemical composition, and continuous replacement in the blanket. Among liquid breeder candidates, the molten mixture of lithium fluoride and beryllium fluoride (60%LiF-40%BeF_2 denoted as FLIBE) is a promising material for the blanket in FFHR because of its chemical stability, large fluidity and low electric conductivity to reduce MHD pressure drop. The applicability of FLIBE molten-salt as the tritium breeding material for FFHR was discussed to design the most suitable and advanced blanket. We investigated some aspects such as heat transfer, materials, tritium breeding and tritium recovery in a FLIBE cooling system with no intermediate loop to point out the insufficiencies of basic studies for FLIBE.

The FLIBE temperatures at the inlet and the outlet of the blanket were determined to be 723 K and 823 K, respectively, based on the melting point of FLIBE and the creep behavior of JFL-1 considered as a structural material. 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. In order to keep high efficiency of the heat exchanger, the outlet temperature of the boiling water in the secondary loop should be close to that of the inlet FLIBE. However, for low pumping power, it would be better to keep the temperature difference enough high between the primary and the secondary fluids, because the heat transfer coefficient of FLIBE is much lower than that of the sodium in LMBR or the pressurized water in PWR. The heat transfer coefficient of FLIBE is expected to be $10^{2\text{-}3}$ W/m^{2}K, but further studies are necessary to determine the coefficient, which is very important for the possibility of a simple heat transfer system with no intermediate loop.

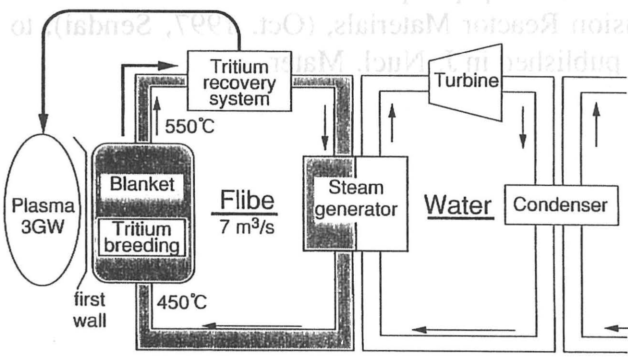

Fig. 1. Heat transfer and tritium cycle in FLIBE loop system with no intermediate loop.

It is considered that beryllium loaded inside the FLIBE flow in the blanket for high TBR may reduce HF contained as an impurity in FLIBE and TF produced by the nuclear reaction of LiF with neutron. By the reduction of HF, the corrosion for the structural materials is considered to be moderated, but this means the corrosion of beryllium metal is promoted. Thus, we can predict the corrosion behavior only from the thermodynamics, but further experimental investigations for solution and corrosion behavior of beryllium and structural materials are necessary to predict the advantage of the HF reduction by beryllium. On the other hand, the TF reduction to produce T_2 is expected by the existence of beryllium. From the point of tritium inventory and corrosion behavior, T_2 or HT is more favorable than TF, and TF concentration should be kept as low as possible in the blanket system. Because the rate of the chemical reaction of TF with H_2 dissolving in FLIBE to produce HT is not enough high to keep TF concentration low, experimental investigations for the reaction rate of TF with beryllium to produce T_2 are very important.

HT and T_2 having a large release rate coefficient to the gas phase are considered to permeate easily through the structural materials to the environment, which should be prevented for safety and high efficiency of tritium recovery. Because the tubing walls for FLIBE should be the first barrier for tritium permeation, it is necessary to use a chemical barrier between the first and the second tubing walls of a double-wall tube. For example, if He + O_2 gas is used as a chemical barrier, chemical form of tritium permeating through the first tubing wall changes from T_2 to T_2O, which hardly permeates through the second tubing walls at all. The heat exchange wall must also have a chemical barrier to reduce tritium permeation to the secondary loop. The chemical barrier for the heat exchange wall must transfer heat at a large rate with tritium permeation at a small rate. Flowing liquid metal or pressurized gas is considered as the tritium permeation barrier having a high heat transfer coefficient, but the further investigations for the materials are required.

To increase the release rate of HT and T_2 from FLIBE, it is useful to make the liquid FLIBE to spray with a lot of small nozzles of submillimeters to increase the surface area of FLIBE droplets. With the advantage of this concept, we can design a FLIBE blanket loop system, whose tritium inventory is less than 0.1 g in 500 ton of FLIBE. However, we must note that investigations about the interfacial energy of FLIBE are necessary to discuss about the possibility of producing such small droplets.

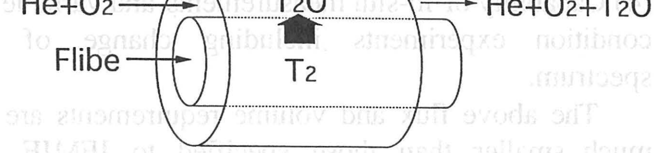

Fig. 2. Cross section of the double-wall tube as a tritium permeation barrier.