§7. A Study on the Design of the Tritium Recovery System from a Liquid Blanket of a Fusion Reactor

Fukada, S. (Kyushu University),
Sagara, A.

A liquid blanket has an advantage of a self-cooled, simple structure, and so it is used in the conceptual design of FFHR-II. The molten salt blanket shows the good performances of low MHD effect, TBR > 1 with the addition of Be, low induced radioactivity, low tritium inventory and low reactivity with oxygen or water vapor. However, there were few design studies on the tritium recovery from the molten salt blanket. In the present study, we investigated the tritium recovery system as the design study of the NIFS collaboration work of FFHR-II.

Necessary conditions imposed on the tritium recovery from the molten salt blanket are as follows; (1) all tritium generated in the blanket (190 g-T/day) is transferred by a Flibe coolant and is recovered by a tritium removal system, this means a steady-state operation, (2) very low (permissible) tritium leak to the environment (10 Ci/day in the present study), (3) simple apparatus and easy to operate, (4) operation over the melting temperature, (5) high operation safety and to use materials compatible with HF and (6) operation under a low water vapor condition. Additional assumptions for the design are; (7) no isotope effect in physical properties, (8) no decomposition of Flibe by a VxB force. We focused on whether or not tritium can be recovered by a realistic scale of the apparatus of a permeation window, a counter-current He-Flibe extraction tower and a vacuum disengager.

If there is no barrier for the tritium leak from the recovery system or the heat exchanger, the leak rate is estimated 5 MCi/day. The value is huge. Therefore, it is considered to be impossible to lower the tritium leak rate below 10 Ci/day without a tritium barrier. On the other hand, if the heat exchanger or the tritium recovery system is surrounded by a stagnant Flibe (or Flinak) layer, the tritium leak rate is estimated to be 1.6 Ci/day as shown in Fig. 1. The rate is permissible. If other reliable tritium barriers, e.g. alumina film, with a degradation factor of 10^6 is used, it can work.

Fig. 2 shows the permeation window operated at the tritium concentration of 0.2 ppm where it satisfies the 10 Ci/day limit and 190 g/day recovery rate. The resistance of Flibe-film diffusion is controlling, and the permeation resistance gives a small effect on the overall permeation rate. When the tritium concentration is greater than 0.2 ppm, the permeation area becomes smaller but the leak rate does larger than the reference design.

A 5 m packed tower of Flibe-He counter-current extraction makes the decontamination of 10^5 possible. Tritium of 190 g/day can be recovered by one extraction tower. The tritium can be also recovered by a vacuum disengager. In the disengager, Flibe drops freely fall from the top and dissolved tritium is desorbed by a vacuum pump. The calculation was carried out under the condition of no surface recombination resistance. Drop formation energy and pumping power for perforation were small compared to the 1 GW fusion power.

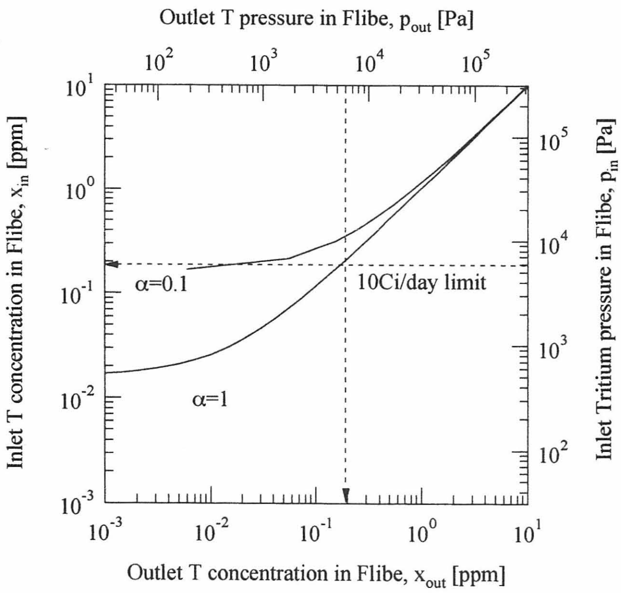

Fig. 1 Inlet tritium concentration to satisfy the permissible tritium leak to the environment (10 Ci/day) where α is a bypass ratio to the recovery system

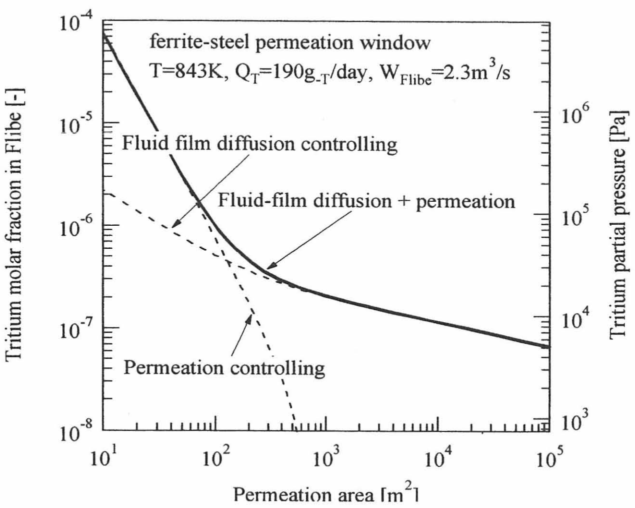

Fig. 2 Permeation area vs. tritium molar fraction in Flibe

The conclusions of the present design are as follows; (1) A tritium barrier to control the tritium leak below 10 Ci/day is necessary; (2) The tritium leak rate can be lower than the permissible level, e.g. by a stagnant Flibe layer; Arranging the tritium recovery system in a by-pass line is effective; (3) The recovery systems of a permeation window, an extraction column and a vacuum disengager are realistic-scale apparatuses; (4) Diffusion in fluid Flibe is the rate-determining step in the permeation window and the He-Flibe counter-current column; (5) In order to raise the accuracy of the design, the mass-transfer coefficient from Flibe to He should be clearly determined.

References

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