§23. Study of Fuel Particle Balance in a Fusion DEMO Reactor: Aspect of Tritium Safety Management

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Conceptual design studies of the LHD-type helical DEMO reactor FFHR-d1 have been conducted by integrating wide-ranged R&D activities on core plasmas and reactor technologies. As for the reactor systems, the establishment of the fuel cycle system is one of key issues for a fusion DEMO reactor. The first step to consider the fuel cycle system would be estimated the fuel particle balance and the flow in the fusion reactor system. In order to understand the behavior of tritium balance in the FFHR DEMO reactor, the simple steady state tritium particle balance model has been developed on the basis of Takenaga et al.[1,2] Then, we estimated the tritium particle balance using the helical type fusion reactor FFHR2m2 design parameter as a test case.

In this model, it is assumed that tritium is fueled by only pellet injection in the main plasma. Then, we introduce parameters of the fuel efficiency "α" of pellet injection, tritium loss ratio by permeation "R_p" from the wall, retention in the vacuum vessel "R_r", the fueling rate in the main plasma "S_F", the recycling rate "S_R", the total number of particles in the main plasma "N", the sink rate due to fusion reaction "S_L", the divertor pumping fraction "f_{pump}", the recovery ratio for tritium processing system "R_T", the blanket tritium recovery system "γ_T", the particle confinement times for the main and edge plasma "τ_c" and "τ_e".

From the viewpoint of the tritium safety handling, the amount of the tritium loss from the fuel cycle system and by the retention in the materials should be reduced. Figure 1 indicates the tritium loss per day from the fuel cycle system of both the blanket system and the tritium processing system for vacuum exhaust gas as the functions of the decontamination factor [DF] where it is assumed that f_{pump} is 0.05, α is 0.85, R_r is 5×10^{-5}, and R_p is 5×10^{-5}. According to the section 3.2, the DFs of 10^4 for R_T and 10^2 for γ_T are able to satisfy the fuel balance. In these parameters, the tritium loss from the system is estimated to be about 10 g/day. To reduce the tritium loss from the fuel cycle system, the DF for the tritium processing system has to be high, because the processing of vacuum exhaust gas is the main stream for fuel cycle. However, the tritium loss from the fuel cycle is not able to restrain as long as the DF of the tritium recovery system for the blanket is low. From the standpoint of tritium safety management, the DF for both the fuel cycle and the blanket system should be high more than 10^7.

In order to satisfy the fuel balance and protect occupationally exposed workers, it is necessary to restrict the amount of tritium retention in the wall. Figure 2 shows the tritium retention in vacuum vessel as the functions of the pumping fraction and the tritium loss ratio, assuming that α is 0.85, R_T is 0.9999, γ_T is 0.99, and R_p is 10^{-5}. The amount of tritium retention increases as the pumping fraction is reduced. It means that the recycling in the edge region is enhanced by the reduction of pumping fraction and the particle fluxes to the divertor plate increase. It is important for satisfying the tritium balance in a fusion reactor and the safety aspect to suppress the tritium retention less than the acceptable level. To satisfy the safety limit of tritium inventory in the vacuum vessel, e.g. 1 kg for the ITER, the retention loss ratio R_r has to be less than 5×10^{-6} in the range of between 0.05 and 0.1 for pumping fraction.

The replacement of components such as the first wall and the blanket materials may involve a significant impact of the tritium inventory. Also, tritium could permeate through the wall and eventually into the atmosphere as HT and the cooling water as HTO. Thus the developments of the permeation barrier and the tritium processing for the gaseous and liquid effluents and the tritium decontamination technique of wastes will require improvement toward the DEMO from the viewpoint of the tritium safety management.

1) Takenaga, H., et al., Fusion Sci. Technol., **57**, (2010), 94.
2) Sagara, A., et al., Fusion Sci. Technol., **60**, (2011), 3.

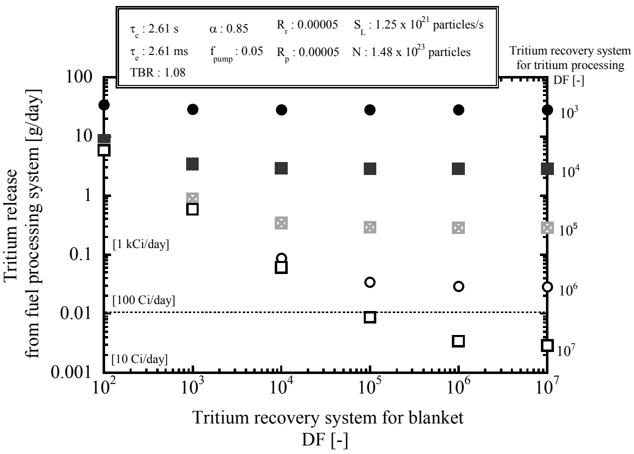

Fig. 1. Tritium loss from the tritium recovery system as the functions of decontamination factor for blanket system and tritium processing system for vacuum exhaust gas.

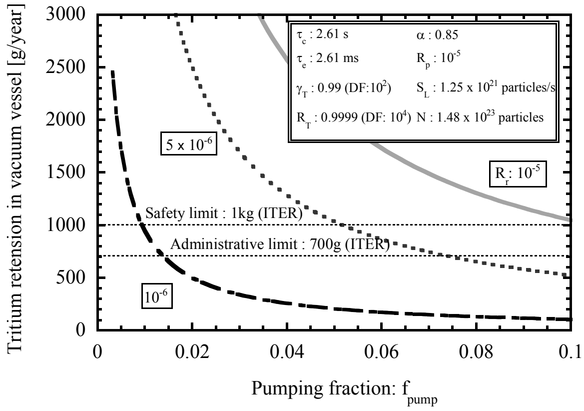

Fig. 2. Tritium retention in the vacuum vessel as the functions of pumping fraction and tritium loss ratio by retention in the vacuum vessel, R_r.