Fusion reactor technology, focused on tritium safety handling

核融合炉工学最前線　―　トリチウム関連を中心として　―

Takumi Hayashi
林　　巧

Directorates of Fusion Energy Research, Japan Atomic Energy Agency
801-1, Mukouyama, Naka city, Ibaraki Pref., 311-0193, Japan
（独）日本原子力研究開発機構･核融合研究開発部門　〒311-0193　茨城県那珂市向山801-1

The recent progress of fusion technology is summarized focused on tritium safety handling. Typical design concept of fusion fuel cycle for DEMO reactor is presented with the tritium distribution in the reactor site, comparing with that for ITER. Effective accountancy of tritium, widely distributed within the reactor site, will be a key issue for safety and economical point of view. Multiple tritium confinement concept and effective detritiation system design are also key issues regarding all life-cycle operation of fusion reactor at normal & abnormal conditions, in order to receive the public acceptance.

1. Introduction

In the fusion reactor, effective and careful handling of DT fuel is a key issue from the economical and safety point of view. This presentation summarizes the progress of fusion technology focused on the tritium safety handling, such as 1) overall design concept of fusion fuel cycle, 2) tritium distribution & its accountancy, and 3) tritium confinement & detritiation.

2. Design concept of fusion fuel cycle

Figure 1 shows the typical configuration of fusion fuel cycle for DEMO in comparison with that for ITER, which can handle a few kg of tritium. Tritium cycle mainly consists of main fuel processing cycle loop and blanket tritium recovery loop. The purpose of main fuel processing cycle loop is to recover/purify DT fuel from plasma exhaust and to reuse them as a fuel again, because the one-through burning ratio of DT fuel will be only about 5% even in DEMO. In the fusion reactor with 3GW thermal output, about 450 g of tritium is burned every day. Therefore, the main fuel loop should process at least more than 9 kg of tritium every day. Because more than 450 g of tritium should be generated and recovered within

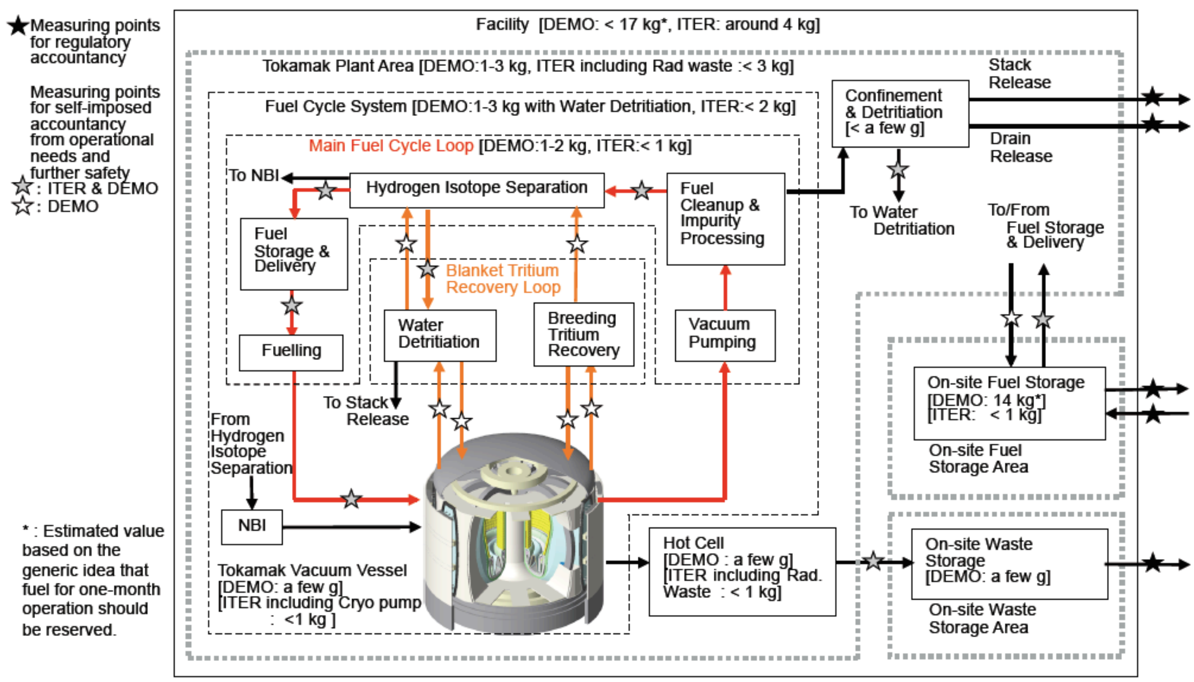

Fig. 1　Typical configuration of fusion fuel cycle for ITER and DEMO with tritium distribution in the site

the blanket tritium recovery loop every day.

The fuel processing loop mainly consists of fuel clean up (to purify hydrogen, to process impurity), isotope separation, and fuel storage & delivery sub-systems. To purify hydrogen gases from plasma exhaust, palladium silver membrane diffuser will be used. If it is required, the purified hydrogen gases will be separated to each isotope gases by cryogenic distillation columns. Hydrogen isotopes, existed as impurities like water or various hydrocarbons, are converted to hydrogen gases at first by oxidation & reduction, water gas shift, cracking, or isotope exchange reactions. Then, the hydrogen gases are recovered by the above membrane diffuser. Recovered/purified DT fuel is accounted and delivered again after adjustment of the isotope composition by metal hydride fuel storage beds, such as uranium and/or zirconium cobalt etc.

The blanket tritium recovery loop should optimize depending on the breeding blanket system. Though there are many design concepts for breeding blanket system, in case of water-cooled ceramic breeder blanket, the bred tritium is purged out by helium gas. Therefore, it is important how to recover effectively the bred tritium from the purge gas under very low partial pressure of tritium (~1Pa). Hydrogen pump technology will be applied for this recovery using proton conductor. Because the bred tritium can transfer to cooling water, R&D of effective barrier to protect the transfer is very important, as well as the design optimization of water detritiation system (CECE : Combined Electrolysis & Catalytic Exchange) to recover tritium from tritiated cooling water.

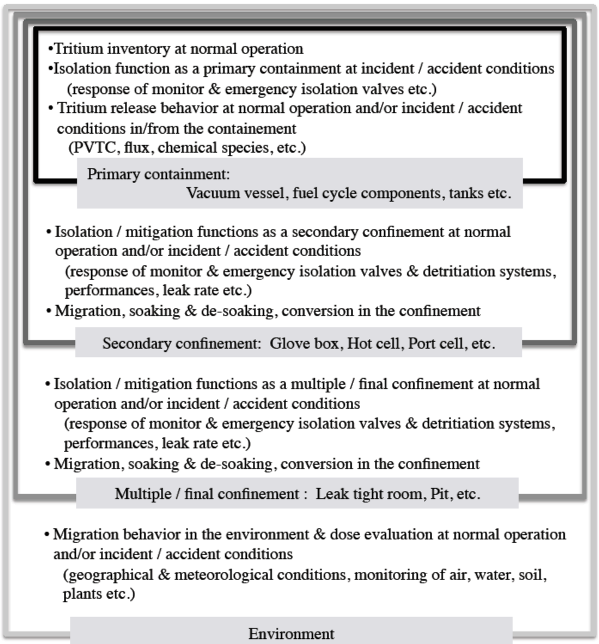

Fig. 2 Multiple barrier concept for tritium confinement and its safety related investigation items.

3. Tritium distribution and accountancy

As also shown in the Fig. 1, tritium will exist in various locations in the site. Site inventory of tritium will be determined by the concept of fuel storage. Normal thermal power plant will store the fuel for one month's operation, so, applying the same concept, about 14 kg of tritium is required to store in the fusion reactor site. In this figure, various measuring points for tritium accountancy are indicated separating for regulatory purpose and for operation purpose. How to control / treat the accounting uncertainty (accuracy, precision) will be further discussion point.

4. Tritium confinement and detritiation

In the fusion research facilities, tritium has been handled safely under the multiple barrier concept, as shown in Fig. 2. This concept is applied to ITER and also will be applied to DEMO. Primary barrier has a function of physical containment, however, secondary or tertiary barriers has each confinement functions with using various active components, such as isolation valves, dumpers, monitors, HVAC, and detritiation systems, etc.

Figure 3 shows conceptual flow diagram for detritiation systems in case of ITER Tokamak complex building. MSDS is typical detritiation system for normal operation, which uses oxidation by low (423K) and high (773K) temperature catalytic reactor, and water adsorption by molecular sieves dryer. SCDS is emergency detritiation system, which uses oxidation by room temperature hydrophobic catalyst and wet scrubber column. In order to keep enough redundancy, multiple modules are arranged for tritium release accident, regarding blackout, fire, and maintenance etc.

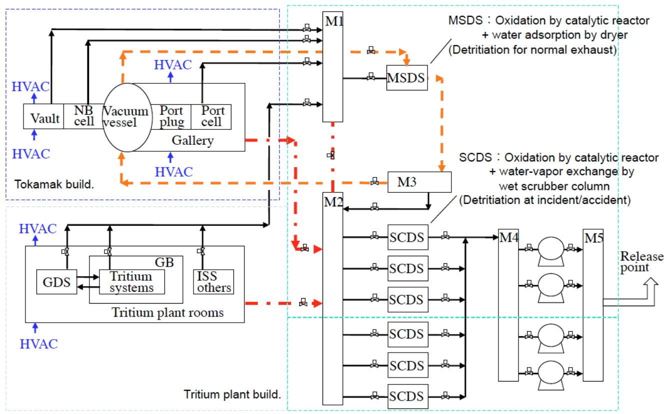

Fig.3 Conceptual flow diagram for the detritiation systems in case of ITER Tokamak complex building.