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核融合原型炉の事故時における
最終障壁による放射性物質閉じ込め安全方策の検討
A Study of Safety Strategy to Confine Radioactive Materials at the Final Barrier in Accident Conditions of a Fusion DEMO Reactor

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1. Introduction

Reactor building is the final confinement barrier for radioactive materials involved in a fusion reactor. In a variety of postulated accidents, break of the primary coolant pipe, i.e. ex-vessel loss-of-coolant accident (ex-VV LOCA), will be critical because it causes the large pressure load, caused by the discharge of the coolant, onto the final confinement barrier.

We previously studied thermohydraulic responses of a fusion DEMO reactor to the ex-VV LOCA [1], but radiological consequences of the ex-VV LOCA were not analyzed. The purpose of this study is to develop confinement strategies at the final barrier against accident release of the coolant in terms of pubic dose consequences as well as structural integrity.

2. Analysis method and conditions

The DEMO reactor analyzed is that being conceptually developed in QST. The fusion power is 1.5 GW; the primary coolant is the pressurized water with the temperature of ~300 °C, the pressure of 15.5 MPa and the volume of 240 m^3/loop.

The postulated accident is double-ended break of one primary first wall/blanket cooling loop of four in the primary coolant systems vault (PCSV). The break is assumed to happen at the pipe section with the largest diameter of 0.73 m. The concentration of the tritium permeated into the coolant is assumed to be 1 TBq/liter.

The thermohydraulic transients in the final confinement areas and the amount of the tritium released to the environment are simulated by MELCOR [2]. The early public dose due to the released tritium is calculated by UFOTRI [3] under the worst weather case.

3. Analysis results

We have compared several confinement strategies. Reported here are the results of two strategies shown in Fig. 1. In Option A, the pressure in the PCSV is relieved to the large upper tokamak hall (UTH) and the steam in the UTH is released to the environment via the stack with filtering. In Option B, a pressure suppression system (PSS) is implemented to the PCSV. If the PSS is pressurized, the gas in the PSS is relieved to the UTH.

Examples of the simulation results on the tritium released to the environment and resultant early public dose are presented in Fig. 2. It indicates that the amount of the released tritium and the dose in Option B is much smaller than those of Option A. This is because the pressurization caused by the ex-VV LOCA is reduced in Option B thanks to the PSS and then the tritium release due to leak is also reduced. For both options, the resultant public dose is below the guideline of 50 mSv that may trigger the need for public evacuation.

In the presentation, the sensitivities of the consequences on the design parameters are presented. Other confinement options not reported here are also discussed.

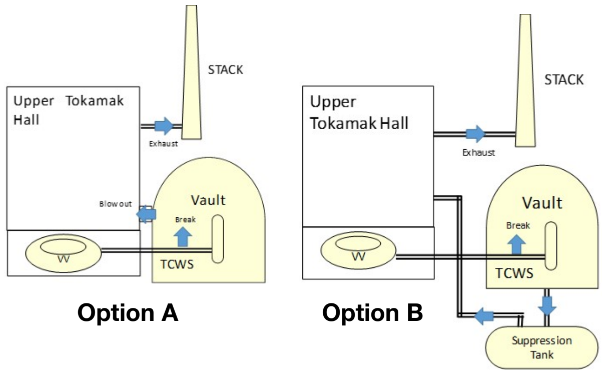

Fig. 1 Schematics of the confinement options analyzed

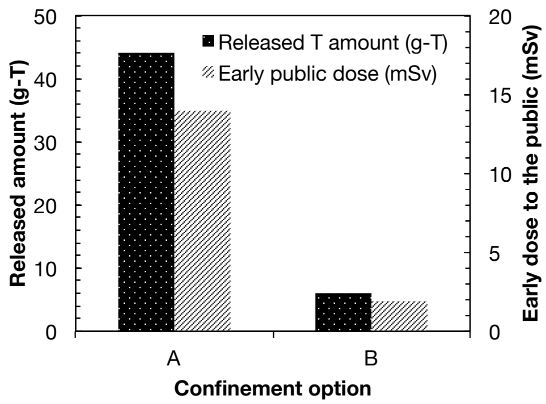

Fig.2 Tritium release and resultant early public dose

[1] M. Nakamura, et al., Nucl. Fusion, **55** (2015) 123008; M. Nakamura, et al., IEEE Trans. Plasma Sci., **44** (2016) 1689.
[2] B.J. Merrill, et al., Fusion Eng. Des., **85** (2010) 1479.
[3] W. Raskob, KfK-5194 (1993).