HELIUM COOLED CERAMIC BREEDER TESTING BLANKET SYSTEM HEAT RELEASE AND TRITIUM RELEASE FOR THE ITER NEW BASELINE DT-1 SCENARIO IN THE PORT CELL

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1. INTRODUCION

International Thermonuclear Experimental Reactor (ITER) has established an updated baseline (v2024) to address emerging technical challenges with 3 operational phases: AFP, DT-1, and DT-2 [1][2]. Within this framework, the Helium Cooled Ceramic Breeder Testing Blanket System (HCCB TBS) will operate in ITER from DT-1 [3][4]. The shared Port Cell 18 (PC#18) including Piping Forest (PF) and Auxiliary Equipment Units (AEU) between Chinese and Japanese systems requires coordinated integration of piping components from both parties. High-temperature pipes in Helium Cooling System (HCS) and Tritium Extraction System (TES) traversing the PF and AEU present 2 challenges: (1) heat dissipation from the pipes potentially exceeding the thermal management capacity of PC#18, and (2) TES transports tritium from the breeding zone via purge gas, while a fraction of tritium permeates through the partition wall into HCS, and tritium within these pipes may subsequently permeate through the high-temperature pipe walls in PC#18, potentially releasing into the external environment. So that it is necessary to analyze heat release and tritium release from CN HCCB TBS pipes to PF and AEU to integrate with Japanese data, and assess compliance with design requirements. In this paper, the heat release and tritium release of PC#18 from HCCB TBS components in DT-1 is simulated by TriSim to support the Port Cell #18 integration design.

2. DESCRIPTION OF THE MODELING

In the previous work[5], to meet the requirements of the dynamic tritium analysis in HCCB TBS and its auxiliary systems, a tritium analysis coupled thermohydraulic tool "TriSim" is developed using a unified object-oriented simulation language Modelica, including zero-dimensional (0-d) control volume and one-dimensional (1-d) solids models.The typical characteristics of dynamic tritium transport for HCCB TBS can be simulated commendably. The tool has been verified preliminarily.The TriSim framework is illustrated in Fig.1(a). The main fluid flow models within the 0-d control volumes encompass mass balance, energy balance, and pressure drop equations. These models are unidirectionally coupled with tritium models through the transport of the dilute species of hydrogen isotopes[6]. The behavior of tritium within the fluid is modulated by isotope exchange, decay, and source of tritium. The coupling between the 0-d control volumes and the 1-d solid models is established through the convective heat transfer, the dissolution and recombination equations[7]. The heat conduction equation in the solid phase governs temperature variations and distribution, thereby affecting tritium diffusion. Additionally, tritium distribution is subject to the influence of the plasma implantation equation[8].

The pipes and equipment within PC#18, which are included in the simulation, pertain to various subsystems of the HCCB TBS, such as the HCS, Coolant Purification System (CPS) and TES. Due to the small diameter (~9 mm) and relatively low temperature (~100° C) of the NAS pipe, its impact on heat release and tritium release is negligible and thus excluded from consideration. The simplified model of HCCB TBS in TriSim is shown in Fig.1(b).

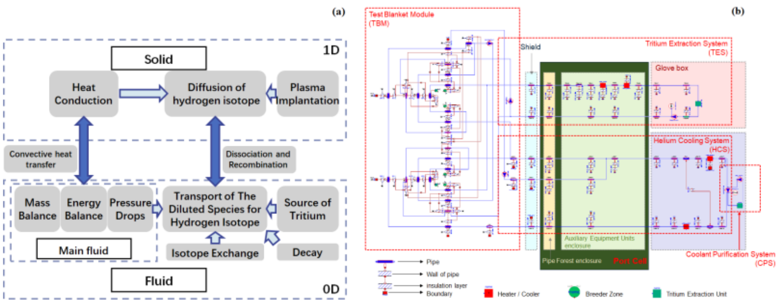

Fig.1 (a) Structure of TriSim (b) Simplified HCCB TBS model in TriSim

3. RESULT AND DISCUSSION

The results of HCCB TBS heat release and tritium release for the ITER v2016 baseline and v2024 baseline DT-1 scenario in the #PC18 are simulated and compared in this paper.

This study quantitatively evaluates the variations in heat release and tritium release resulting from the changes if the input for ITER, including the change of power, flat top time and heat flux on surface. Under these conditions, the heat release remains within the ITER-specified limit (<31 kW), To obtain improved steady-state tritium partial pressure parameters additional cases were performed, including scenarios involving a reduced flow rate in the HCS and add electrical heater in Test Blanket Module (TBM). In these cases, the heat release remains ＜ 31 kW. Additionally, tritium release calculations for the aforementioned scenarios in PC18 were conducted, yielding tritium release profiles and demonstrating that the tritium concentration in PC18 in DT1 scenario remains ＜1DAC (in compliance with ITER requirements).

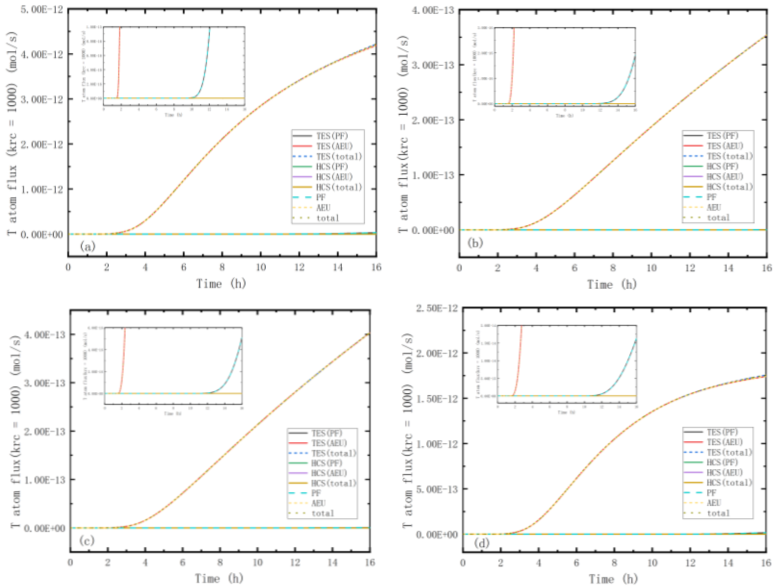

Fig.3 Tritium release result of HCCB TBS pulse operation in PC#18 for (a) v2016 baseline (b) v2024 baseline (c) v2024 baseline with reducing mass flow in HCS (d) v2024 baseline with adding electrical heater in TBM (pulse heating) reducing mass flow in HCS

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