Status of Tritium Permeation Analysis Tool for HCCR TBS

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1. Introduction

Korea has been developing a Helium Cooled Ceramic Reflector (HCCR) TBM to be tested in the ITER [1]. It consists of two major systems, which are HCS (Helium Cooling System) and TES (Tritium Extraction System) (Fig. 1). Important safety issue is tritium permeation of the system. Tritium is one of the most highly permeable molecules on earth, therefore tritium permeation takes place from TES to HCS in the TBM. Permeated tritium migrates along the system pipes, thus tritium inventory should be considered with respect to entire TBS. Simplified steady state tritium analysis models and codes were developed by KO TBM team (Fig.1), which can accommodate parameter change of each design stage, such as PD-1, -2 and 3 etc. Tritium analysis code has been developed since 2015 and this paper shows current status of the achievement.

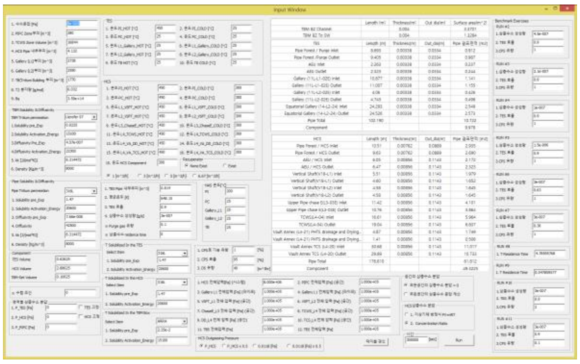

Fig. 1. Schematics of HCCR-TBS.

2. Characteristics of the Code

The simplified tritium permeation model has following characteristics:

TBS sub-systems fully interconnected, the tritium concentration, tritium generation and losses are calculated together for all concerned sub-systems. The tritium mass conservation is ensured. Tritium is assumed in T2 form in all fluid, and tritium transport mechanisms in solid materials limited to the diffusive regime, which means the surface phenomena is not taken into account. The system is modelled as connection networks of volumes. 0-D lumped model is used, which means the interior properties like tritium concentration, temperature, pressure etc. are assumed to be uniform in each volume. Steady state assumption, which means the generation and loss of tritium are in balance, all the parameters do not change by time. No multi-physics phenomena modelled, the flow distribution of main fluid and temperature distribution in structure materials are inputs of the analysis.

3. Input Data Set of the Code

Table 1 is summary of boundary condition which is applied to HCCR TBS calculation and Fig. 2 is pipe length and operational temperature information of each room which HCCR-TBS is allocated. Design of HCCR-TBS is evolving and this data reflects recent update of PD-1 phase. [2]

Table 1. Summary of boundary condition

Tritium Production Rate	25.9 mg/day (continuous back to back with duty 0.25)
PI/PC Volume	280.264 m^3
TCWS VA Volume	500 m^3 (considering occupied by HCCR HCS/CPS)
TES Pipe Thickness	3.68 mm
HCS Pipe Thickness	8.56 mm (Vertical shaft pipe thickness 8.56 mm)
BZ Pipe Thickness	4.0 mm
N-DS at PI/PC	40 m^3/h
HVAC at TCWS	1 Vol/hr, i.e. 500 m^3/h

4. Result Screens

Examples of result screen is given as Fig. 2. IO (ITER Organization) requests various kinds of tritium permeation analysis results and each result screen is optimized for that specific issue, for example, Fig. 2 is the output of tritium analysis for CDR (Conceptual Design Review) of HCCR TBS.

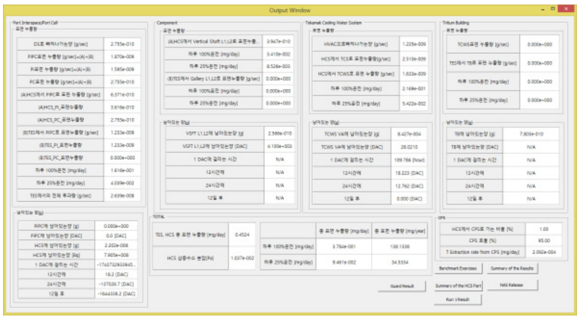

Fig. 2. Tritium release analysis result screen for CDR.

And Fig. 3 is the result screen for the tritium benchmark analysis of each TBS. This result is one of related outcomes of TF-TPSD (Task Force on the TBM Program Safety Demonstration) and sensitivity study had been performed.

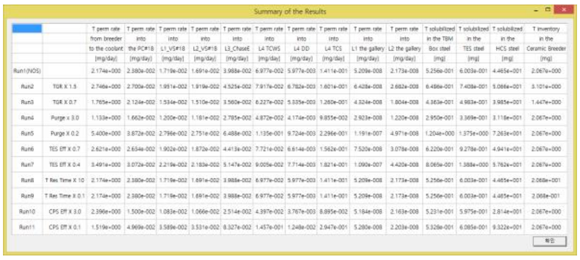

Fig. 3. Tritium release analysis result screen for tritium benchmark analysis for each TBS.

Fig. 4 is based on the given tritium permeation model and boundary conditions, tritium release rate from NAS (Neutron Activation System) of HCCR TBS is presented, which is estimated values after 500 cycles of operations. Continuous operation 500 cycles postulate equivalent load over ten days of 3-shift back to back operation, which is nearly one campaign (11 days operation + 3 short term maintenance). Tritium concentration at the end of 500 cycles is 2.48E-01 Pa, however, it is drastically decreased in real situation. Because service vacuum system of ITER is continuously venting the used driving gas in NAS tubes.

5. Further Works

Developing tritium analysis tool is successfully on going work, which will adopt latest design of the HCCR TBS and estimate tritium release rate at each ITER building room. At this stage of development, using simplified 1D is the most efficient approach to draft tritium release estimation, however, it is expected that multi-D or multi-effect model should be used for precise result.

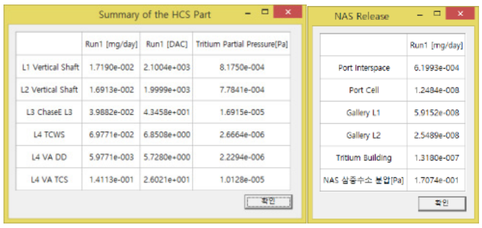

Fig. 4. Tritium release analysis result screen for NAS.

ACKNOWLEDGEMENT

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