Tritium Inventory Estimation for HCCR-TBS at PD-1 Phase

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1. Introduction

Korea has developed a Helium Cooled Ceramic Reflector (HCCR) TBM to be tested in the ITER [1-4]. It consists of two major loops, which are HCS (Helium Cooling System) and TES (Tritium Extraction System) (Fig. 1). Tritium is one of the most highly permeable molecule 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 take into account with respect to entire HCCR TBS. This paper presents assumption of the estimation, boundary condition and summary of the results.

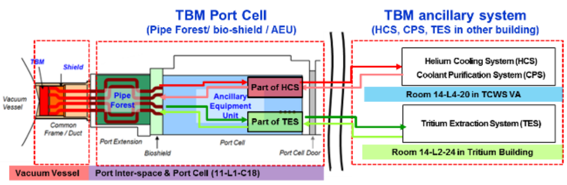

Fig. 1. Schematics of HCCR-TBS.

2. Assumptions

To estimate the tritium inventory of HCCR TBS, followings were assumed.

- Tritium production is given by neutronics calculation. (No extra tritium flux from plasma)
- Continuous back to back plasma pulse with duty factor 0.25.
- Steady state condition (instantaneous tritium diffusion to the purge gas isotropically)
- Averaged tritium generation rate (constant over the time and uniform in the TBM volume)
- Transport mechanism through structural materials is bulk diffusion.
- Tritium in NAS tube is accumulated over time. (No service vacuum system)
- Tritium concentration in space is constantly zero to estimate conservative release rate.
- Averaged temperature and pressure for each region

3. Material Properties

Material properties were given by benchmark guideline [5], therefore, Eurofer's properties were used for TBM steel instead of Korea RAFM steel (ARRA)'s one, and AISI-316L were chosen for estimation of diffusivity, solubility and permeability of hydrogen isotopes in the pipes. For the benchmark exercise Li_2SiO_4 residence time was used.

Table 1. Material properties

Parameter	Value/correlation	unit of measurement
Sieverts' constant Eurofer/T	$2.25\cdot10^{-2}\cdot exp(-15100/RT)$	$mol\cdot m^{-3}\cdot Pa^{-0.5}$
Diffusivity Eurofer/T	$4.57\cdot10^{-7}\cdot exp(-22300/RT)$	$m^2\cdot s^{-1}$
Sieverts' constant AISI-316L/T	$1.47\cdot exp(-20600/RT)$	$mol\cdot m^{-3}\cdot Pa^{-0.5}$
Diffusivity AISI-316L/T	$7.66\cdot10^{-8}\cdot exp(-42500/RT)$	$m^2\cdot s^{-1}$
Tritium residence time in Li_2SiO_4	$1.28\cdot10_{-5}\cdot exp(9720/T)$	h

4. Boundary Conditions

Equations should be placed on separate lines and numbered:

Table 2. 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

5. Geometrical Information

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.

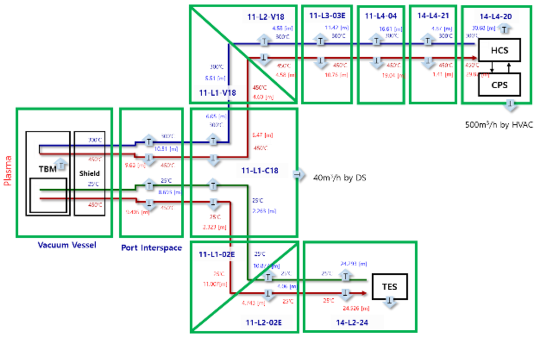

Fig. 2. Pipe length and temperature of HCCR-TBS.

6. Inventory Estimation Results

This result is one of outcomes of TF-TPSD (Task Force TBM Program Safety Demonstration), which includes tritium release, inventory and benchmark analysis. It has been provided for CP-SDD (Connection Pipe System Design Description) as an input data set of HCCR-TBS. Table 3 is a summary the results which consists of four parts (TBM box steel, TES steel, HCS steel and ceramic breeder) and tritium partial pressure of each sub system as an information.

Table 3. Summary of tritium inventory results

Tritium partial pressure in HCS (Pa)	0.0104
Tritium partial pressure in TES (Pa)	0.202
Tritium solubilized in the TBM box steel (mg)	5.25E-01
Tritium solubilized in the TES steel (mg)	6.00E-01
Tritium solubilized in HCS steel (mg)	4.46E+01
Tritium inventory in ceramic Breeder (mg)	2.07E+00

7. Conclusion

Tritium inventory of the PD-1 phase HCCR-TBS has been estimated. One important thing for this result is degree of conservatism/margin of estimated tritium inventory is huge due to oxide layer of the surface, isotope effect caused by existence of hydrogen in coolant and operational scenario. Tritium Tritium inventory issue in fusion facility is critical and has huge uncertainty to get realistic release rate. Practically it is expected that tritium amount in human access area for fusion reactor is negligible or manageable, however, dynamic and multi-dimensional tritium inventory analysis including operational scenario could be a solution for detail estimation

8. Acknowledgement

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