KO-CN Tritium Analysis Benchmark for HCCR and HCCB 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) (figure 1). 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 TBM teams, including KO and CN, for the analysis of tritium balance and tritium permeation release from TBSs. Considering the importance of the tritium data for the safety analysis of TBSs, the quality of the calculation should be ensured and verified.

HCCR and HCCB TBSs both consist of helium cooled ceramic breeder TBM, helium cooling system, tritium extraction system using low pressure helium, and coolant purification system. With these similarities, the developed model for one TBS can be easily used to the tritium analysis for another TBS. This allows good opportunities for a benchmark between 2 models. This paper presents comparison results of the analysis.

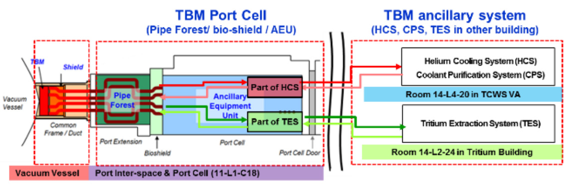

Fig. 1. Schematics of HCCR-TBS.

2. Progress of Benchmark Activities

The KO-CN Tritium Permeation Model Benchmark Analysis was proposed by CN on 2016.11.29, and was agreed by KO on 2016.12.02. Input data sets was exchanged between each other during December 2016. CN finished calculation for HCCR TBS using CN code and KO input data in March 2017. The results were compared with KO HCCR calculation. The results were in same order of magnitude, but with some differences. In order to solve the differences piece by piece, several kinds of hand calculation verifications were proposed by CN. After discussions through video-meetings and e-mails in March and April. KO updated the calculation and the results are almost consistent now. KO finalized benchmark analysis and presented the result during KO-CN TBM workshop on May 2018.

3. Characteristics of the codes

The simplified KO and CN tritium models have 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.

4. Input data set of the Benchmark

Table 1 is summary of boundary condition which is applied to HCCR TBS calculation and Figure 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

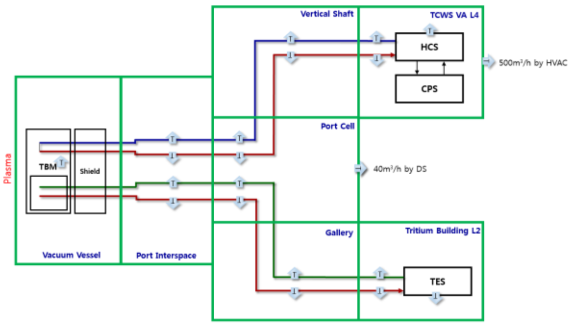

Fig. 2. Pipe length and temperature of HCCR-TBS.

5. Comparison Results

This result is one of outcomes of KO-CN collaboration which includes tritium release, inventory and benchmark analysis. Table 2 and 3 are a summary of the results which consists of KO and CN calculation results and its comparison.

KO provided HCCR TBS's design information (pipe length, diameter and etc.) to CN. CN performed tritium release analysis of HCCR TBS by using CN tritium release code. Both two codes show good agreement with each other, which result is shown in the table 2.

Table 2. Tritium Analysis Benchmark for HCCR TBS

Rooms	CN results (mg/day)	KO results (mg/day)	KO/CN
HCS to Port Interspace	2.89E-02	3.14E-02	1.09
TES to interspace	1.04E-01	1.06E-01	1.02
HCS to Port Cell	2.19E-02	2.39E-02	1.09
TES to port cell	1.05E-08	1.10E-08	1.05
V18-L1	1.71E-02	1.73E-02	1.01
V18-L2	1.67E-02	1.70E-02	1.02
L3-03E	3.92E-02	4.00E-02	1.02
L4-04	6.82E-02	7.00E-02	1.03
L4-21	5.84E-03	6.00E-03	1.03
L4-20	1.37E-01	1.42E-01	1.04
Gallery 11-L1-02E	5.12E-08	5.21E-08	1.02
Gallery 11-L1-02E	2.14E-08	2.17E-08	1.02
14-L2-24	2.20E-07	2.25E-07	1.02

The other way around, CN provided HCCB TBS's design information (pipe length, diameter and etc.) to KO. KO performed tritium release analysis of HCCB TBS by using KO tritium release code. Both two codes show good agreement with each other. Based on these results, technical memo will be reported to IO.

Table 3. Tritium Analysis Benchmark for HCCB

CN	CN results (mg/FPD)	KO results (mg/FPD)	KO/CN
Interspace	7.12E-02	7.02E-02	0.986
Interspace	2.84E-02	2.86E-02	1.009
Port Cell	1.62E-01	1.60E-01	0.985
Port Cell	6.50E-02	6.53E-02	1.006
Vertical Shaft	2.51E-01	2.48E-01	0.986
TCWS VA	4.72E-02	4.65E-05	0.986
TCWS VA	9.77E-04	9.67E-04	0.989
TCWS VA	8.35E-06	8.30E-06	0.993
Gallery	1.04E-07	1.06E-07	1.018
TES Room	2.50E-08	2.54E-08	1.018

6. Conclusion

Tritium benchmark analysis has been done successfully, which shows less than 10% and most of cases less than 5% deviation between two countries. One important thing for this result is degree of conservatism/margin of estimated tritium release is huge because detail logic of each code is different. Specially pipes which is high temperature during operation generate bigger deviation. KO and CN have long term tritium research plan for their TBSs and this type of benchmark analysis can help demonstrate safety of the systems.

ACKNOWLEDGEMENT

This work was supported by the R&D Program through the National Fusion Research Institute (NFRI) funded by the Ministry of Science and ICT of the Republic of Korea (NFRI-IN1803).

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