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Degree of conservatism/margin of estimated tritium releases for HCCR-TBS

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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) (figure 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 and tritium release in port cell and port interspace area is one of important safety issues for human access. Tritium is radioactive molecule which is 12.3 years of half-life. It is difficult to find good property reference for the HCCR TBS and other fusion application. Most of experimental data is performed by using hydrogen and deviation between data is 1~2 order of magnitude difference. And also permeation is highly depend on material surface condition such as oxide layer and temperature. This paper summarizes degree of conservatism/margin of estimated tritium releases for HCCR-TBS.

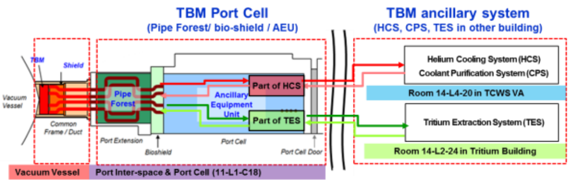

Figure. 1 Schematics of HCCR-TBS

2. Assumptions

To estimate the tritium release of HCCR TBS, followings were assumed.[5]

- 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. Tritium release result of HCCR TBS

Figure 2 is tritium release summary of each room which HCCR TBS is allocated.

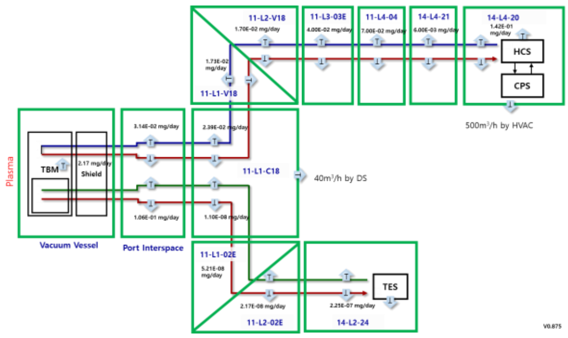

Figure. 2 Tritium release of HCCR TBS

This calculation reflects recently updated geometrical information of the system such as pipe's length and diameter.

4. Degree of conservatism/margin

To evaluate conservatism and margin of tritium permeation, four kinds of possible contributions are taken into account, which are permeation reduction factor caused by oxide layer on pipe's surface, isotope effect, realistic temperature distribution and TES, CPS performance increase.

4.1 Oxidation layer

PRF causes the biggest uncertainty. It has been known that it varies from 1 to 1000 with respect to surface condition. Because most of experimental data does not give a notice about oxide layer thickness, it is hard to quantify direct relationship between them. But it has been published that tritium permeation through the heat exchanger in ITER was evaluated and for gaseous permeability, 100 PRF was suggested. [6]

4.2 Isotope Effect

Isotope effect means blocking effect by dissolved hydrogen atoms on metal surface. For steady sate, the rate of adsorption and desorption of hydrogen is higher than the rate of atomic diffusion of tritium. Thus, Tritium atoms do not reach the metal surface due to the more active hydrogen adsorption and desorption on the surface. Helium with 0.1% hydrogen fluid will be used for the TES and it is expected that reduce factor would be 10.

4.3 Realistic temperature distribution

Operation temperature affects tritium permeation, therefore, temperature distribution in HCS and TES give direct impact on the rate and it would be about factor of two.

4.4 TES, CPS performance increase

Current HCCR TBS design is shown in table 1 in terms of system pressure and mass flow rate. TES tritium extraction efficiency and CPS tritium purification efficiency are 90% and 95% respectably at this moment.

Sub-system	**TES**	**HCS**	**CPS**
Fluid	Helium	Helium	Helium
Pressure	0.1 MPa	8 MPa	8 MPa
Flow rate	0.1 g/sec	1.14 kg/sec	1% of HCS Flow

Table.1 Design parameter of HCCR TBS

As a kind of benchmark analysis, test runs of TES, CPS performance increase have been simulated. Detail test conditions are given below,

(A) Purge gas flow rate 0.1 g/s → 0.3 g/s increase

(B) TES efficiency 90% → 99% increase

(C) CPS flow rate 1% → 3% increase

Calculation results are summarized in the table 2. Run#1 is reference case, which means current design condition. TES and HCS tritium partial pressure are 0.2015 and 0.0104 Pa respectably. Applying (A) design option change, purge gas flow rate increases three times larger than reference, which makes tritium partial pressure decrease for the given tritium generation rate. Regarding test run (A)+(B), three time larger purge gas flow rate and TES efficiency 99% have been applied. Lastly, CPS flow rate was increased, which is the case (C). These three cases are possible design changes at the moment and tritium release rate into the port cell can be reduced by factor of two as well.

	TES T Partial pressure (Pa)	HCS T Partial pressure (Pa)	T perm rate into the coolant (mg/day)	T per rate into the PC (mg/day)
run #1	0.2015	0.0104	2.17	0.050
(A)	0.0701	0.0054	1.20	0.033
(A)+(B)	0.0639	0.0051	1.14	0.032
(A)+(B)+(C)	0.0635	0.0022	1.28	0.026

Table. 2 Impact of TES, CPS performance increase

5. Conclusion

Degree of conservatism/margin of estimated tritium releases for HCCR-TBS has been assessed with respect to possible items. TES and CPS performance increase methods give big impact on entire HCCR TBS design, therefore, it is just possible design option at this level of detail. In this regard, 20 ~ 2000 of conservatism/margin could be suggested in total.

Item	**factor**
Oxidation layer (Permeation reduction factor)	1~100
Existence of hydrogen in purge/coolant	10
Realistic temperature distribution in HCS components	~2
TES, CPS performance increase (design options)	~2
Total	**20~2000**

Table.3 Degree of conservatism/margin

Tritium permeation issue in fusion industry is critical and has huge uncertainty to get realistic release rate. It is the fact that permeability is highly depended on operational temperature and surface condition. Practically it is expected that tritium amount in human access area for fusion reactor is negligible or manageable, however, dynamic and multi-dimensional tritium release analysis could be a solution for detail estimation.

6. Acknowledgement

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7. References

[1] D.W. Lee, et. al., “Current Status and R&D Plan on ITER TBMs of Korea,” Journal of Korean Physical Society, 49 S340-S344 (2006).
[2] D.W. Lee, et. al., “Preliminary Design of a Helium Cooled Molten Lithium Test Blanket Module for the ITER Test in Korea,” Fusion Eng. Des. 82, 381-388 (2007).
[3] D.W. Lee, et. al., “Helium Cooled Molten Lithium TBM for the ITER in Korea,” Fusion Sci. and Tech. 52, 844-848 (2007).
[4] D.W. Lee, et. al., “Design and Preliminary Safety Analysis of a Helium Cooled Molten Lithium Test Blanket Module for the ITER in Korea,” Fusion Eng. Des., 83, 1217-1221 (2008).
[5] I. Ricapito, TBM Project team, F4E “Guideline for the Benchmark Exercise on Tritium Modelling of TBSs”, TM9J3Q (2016)
[6] I. Ricapito, TBM Project team, F4E “Guideline for the Benchmark Exercise on Tritium Modelling of TBSs”, TM9J3Q (2016)