# Preliminary Analysis on Decay Heat Removal Capability of Helium Cooled Solid Breeder Test Blanket Module

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## 1. Introduction

One of the main ITER goals is to test and validate design concepts of tritium breeding blankets relevant to DEMO or fusion power plants. Korea Helium-Cooled Solid Breeder (HCSB) Test Blanket Module (TBM) has been developed with overall objectives of achieving this goal. The TBM employs high pressure helium to cool down the First Wall (FW), Side Wall (SW) and Breeding Zone (BZ) [1]. Therefore, safety consideration is a part of the design process. Each ITER Party performing the TBM program is requested to reach a similar level of confidence in the TBM safety analysis. To meet ITER's request, Failure Mode and Effects Analysis (FMEA) studies have been performed on the TBM to identify the Postulated Initial Event (PIE) [2]. Although FMEA on the KO TBM has not been completed, in-vessel, in-box and ex-vessel Loss Of Coolant Accident (LOCA) are considered as enveloping cases of PIE in general. In this paper, accidental analyses for the three selected LOCA were performed to investigate the decay heat removal capability of the TBM. To simulate transient thermo-hydraulic behavior of the TBM for the selected scenarios, RELAP5/MOD3.2 code was used.

## 2. Nodalization

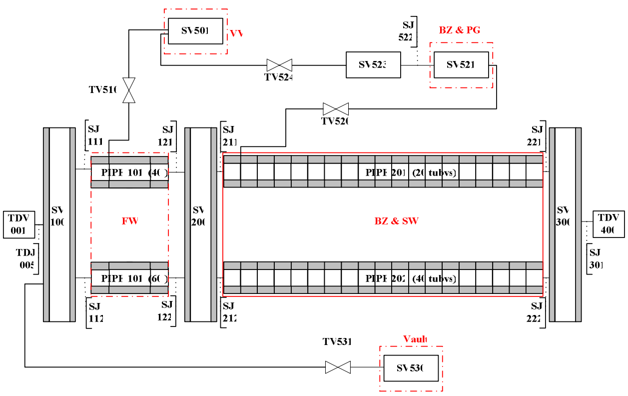


Figure 1. RELAP nodalization of the TBM

Figure 1 shows the nodalization of the HCSB TBM with 43 volumes and 55 junctions. To simulate the possible non-uniform distribution in the back manifolds, a total of 100 cooling channels in the FW and 60 tubes in the BZ are divided into 40 / 60 channels and 20 / 40 tubes respectively, and they are grouped to four pipe-components. Time Dependent Volume (TDV) and Time Dependent Junction (TDJ) were applied to the TBM inlet. The TBM outlet was modeled as TDV. This is for controlling pressure at the inlet / outlet and mass flow rate. Heat structures are modeled with the decay heat data obtained from nuclear analysis [3].

## 3. Results

### *3.1 In-vessel LOCA*

The first LOCA case is in-vessel LOCA. This occurs when one or more channels in the FW are damaged or ruptured. We considered 5% of cooling channels, i.e. five channels, broken. In-vessel LOCA leads to passive plasma shutdown with the disruption load. In this study, disruption load induced by LOCA is assumed to be 1.8 $MW/m^2$ for one second, same as the maximum disruption thermal load of FW in ITER blanket [4]. The temperature distribution along the radial build is shown in Figure 2. It is shown that the decay heat is effectively cooled by radiative cooling.

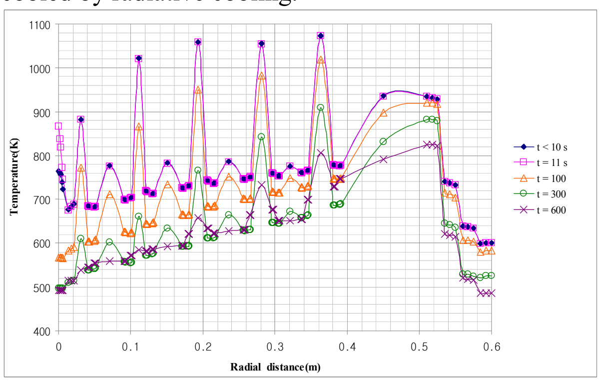


Figure 2. Temperature distribution (in-vessel LOCA)

### *3.2 In-box LOCA*

As the second LOCA case, in-box LOCA is considered. If the cooling tubes in the BZ are broken, the helium coolant flows into the BZ and then goes to the Purge Gas (PG) manifold. This can endanger the Tritium Extraction System (TES), which should be maintained with low pressure. Therefore, a combination of isolation valves, pressure reducing valves, check valves with rupture disks is required. In this analysis, it is assumed that a series of valves instantly protect the TES after the accident, rather than modeling the whole TES and valves, and a rupture disk vents the helium coolant into the Vacuum Vessel (VV) to avoid over-pressure in the box structure when the pressure in the PG reaches 6 MPa. This leads to passive shutdown of the plasma. We considered 5% of the tubes, i.e. three tubes, broken. The temperature distribution along the radial build is shown in Figure 3. It shows that the decay heat removal capability is sufficient.

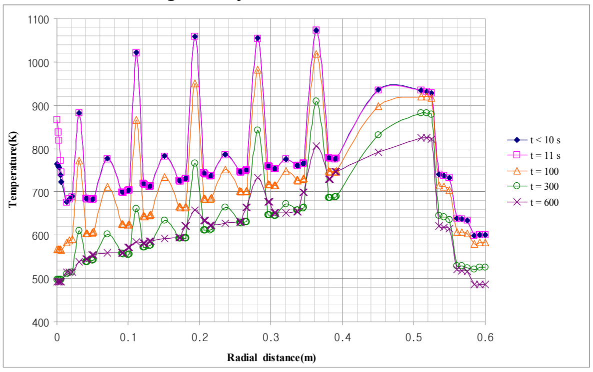


Figure 3. Temperature distribution (in-box LOCA)

*3.3 Ex-vessel LOCA*

Ex-vessel LOCA is considered as the last accident case. The plasma is active until the beryllium armor melts at the melting temperature of 1283 $^{o}$C [3]. If the temperature of the FW reaches 1539 $^{o}$C which is the melting temperature of Eurofer, one of RAFM developed by EU-Party, then it leads to in-vessel LOCA. Figure 4 shows the temperature distribution along the radial build. After reaching the maximum, the temperature on the plasma surface is slowly decreased. It shows that the decay heat is cooled by radiative heat transfer. The maximum temperature of the RAFM is calculated to be 1344.0 $^{o}$C. Therefore, no melting of the FW occurs and it does not proceed to in-vessel LOCA.

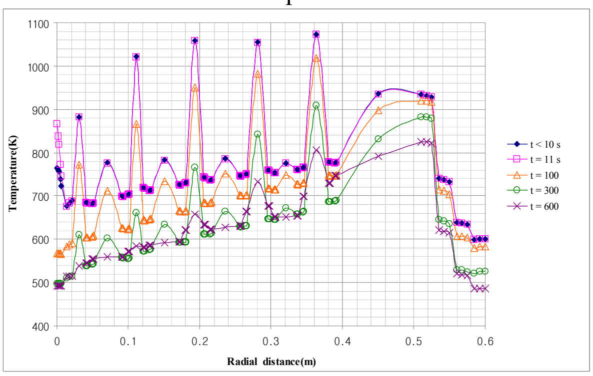


Figure 4. Temperature distribution (ex-vessel LOCA)

## 3. Conclusion

To investigate the decay heat removal capability, accident analyses on the Korea HCSB TBM were performed for three LOCA cases that are considered to be enveloping cases. All the results show that the TBM is designed with sufficient capability of decay heat removal for three cases. While the analyses proved the robustness of the design, further computation with complete modeling of the helium cooling loop including other ancillary systems is necessary.

**Acknowledgements**

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## REFERENCES

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[4] ITER, Safety Analysis Data List, Version 5. 1. 1, 2006.