HCCR TBS LOCA & ICE into small confined volume

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1. Introduction

KAERI has participated in the development of HCCR (Helium Cooled Ceramic Reflector) TBS (Test Blanket System) as a member of the KO TBM Team. Conceptual design review of this system had been performed in 2015 and after resolving the chits, the final approval was achieved in March 2016. This safety issue is one of the category II chits in the CDR and resolution strategy was already approved, however, safety analysis should be done until PDR (Preliminary Design Review). In this paper, model and nodalization for the accident are given and preliminary result is included.

2. Model and Nodalization

2.1 HCCR TBM

The HCCR-TBS comprises TBM with shield, i.e. TBM-set and its ancillary systems such as Helium Cooling System (HCS), Tritium Extraction System (TES), Coolant Purification System (CPS), Pipe Forest (PF), Ancillary Equipment Unit (AEU), Neutron Activation System (NAS), Tritium Accountancy System (TAS) and Instrumentation & Control (I&C). The HCCR-TBS schematic is shown in Figure 1.

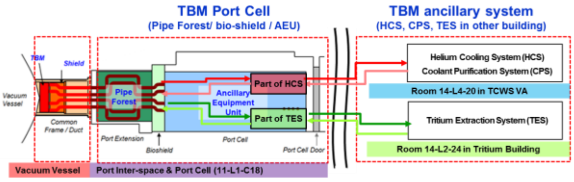

Fig. 1 Schematics of HCCR-TBS

2.2 Description of the accident

LOCAs are assessed and show no problems in vault/PC. But recent calculations of LOCA into the port interspace results in excessive pressures. Venting through the bioshield into the PC must be assured (design of the bioshield). ICE into the main VV have been analyzed. Spill into the interspace between TBM and shield need to be assessed in addition, because the TBM will prevent relieve to the VV (flow through gap between TBM and frame) and the pressure could increase above the 2 bar design pressure of the frame and first vacuum boundary. Schematic diagram of this accident is given in Figure 2.

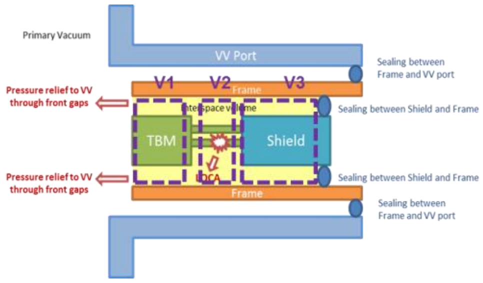

Fig. 2. Schematic diagram of the accident

In the conceptual design phase, KO TBM Team prepared the preliminary safety report which presents a comprehensive view of the HCCR TBS safety assessment [1]. And the accident analysis report was prepared for the conceptual design review to provide consequence of the reference accidents including in-vessel LOCA and ex-vessel LOCA to the Port Interspace [2]. According to these, it is confirmed that the consequence of the accidents is safely mitigated and there is no significant impact on the ITER VV and Building (TCWS Vault, Port Cell, etc.). However, it was suggested that LOCA to small confined volume should be assessed whether excessively pressurized. This analysis will be addressed before the preliminary design review.

2.4 Model and nodalization

For this analysis, GAMMA-FR code, which is Korea domestic safety analysis code for fusion reactor was used, and Figure 3 is the nodalization for the simulation. This accident is happening in port inpterspace where one of HCS loops rupture takes place and this volume is divided into three sub volumes (V1: TBM, V2: pipes, V3: shield). Each interspace volume was provided from the CAD design of the HCCR TBM.

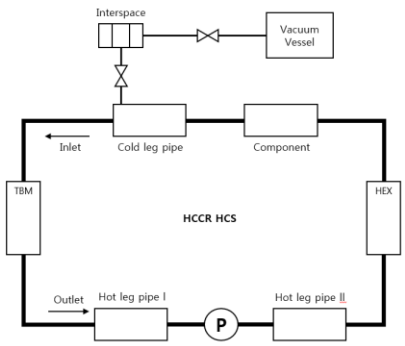

Fig. 3. Schematics of GAMMA-FR nodalization

Key governing parameters are VV (Vacuum Vessel) volume, interspace volume, gap between frame and TBM, and beak size. For the break size, two kinds of break (small and large) were assumed and large break means double-ended pipe rupture.

3. Results

Nominal design pressure of HCS loop is 8 MPa, therefore, as indicated in the figure below. During the break of cooling pipe between TBM and Shield, the high pressure coolant will ingress to the "interspace" between TBM, Shield and Frame. The coolant will be released through the front gaps between TBM and Frame towards VV primary vacuum.

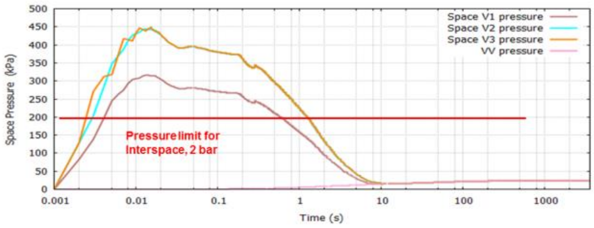

Fig. 4. Pressure at interpace volume and VV (Large break)

The pressure in space will exceed the limit during large sized break. But the overpressure only lasts for very short time (less than 2s). The load for Frame and shield flange need to be updated.

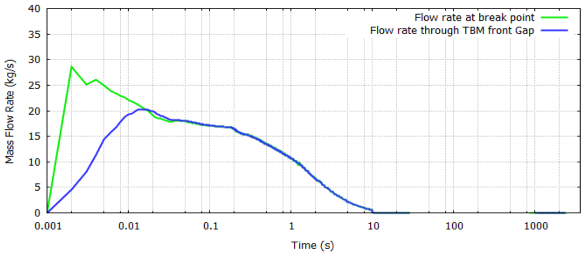

Fig. 5. Mass flow rate at break point and TBM front Gap (Large Break)

For small sized leakage, the pressure will remain below limit.

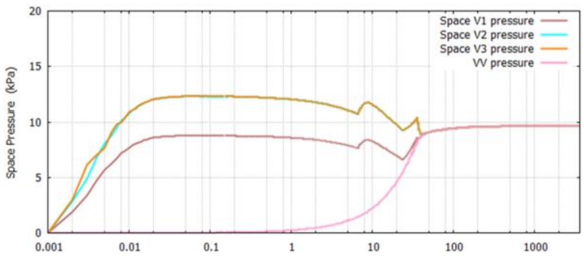

Fig. 6. Pressure at interpace volume and VV (Small break)

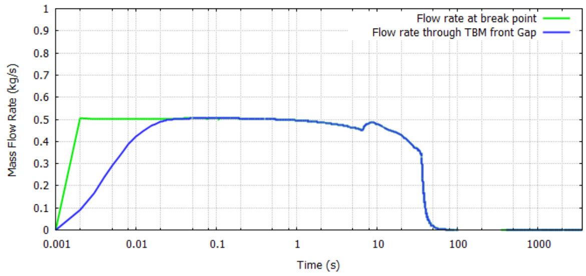

Fig. 7. Mass flow rate at break point and TBM front Gap (Small Break)

3. Conclusions

Accident analysis about HCCR TBS LOCA & ICE into small confined volume has been done successfully. Inverspace volume is compatibly small volume for 8MPa helium loop rupture, which causes fast pressure build-up the space but it decrease within 10 seconds. It is expected that other type of TBM has almost the same behavior. Safety judgment to this temporary over press should be discussed with IO.

4. Acknowledgement

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