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Loss of Power Accident Analysis for HCCR-TBS by using GAMMA-FR code

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1. Introduction

Loss of power accident is one of the postulated events in the ITER. Each ITER member develops Tritium Breeding Modules (TBMs) with different designs according to their specific concepts. The TBM is a key component designed to demonstrate the process of heat extraction for tritium breeding module and electricity production in nuclear fusion system. Korea had developed a helium Cooled Ceramic Reflector (HCCR) TBM[1] and safety analysis during this process had been conducted using GAMMA-FR, a thermo-hydraulic analysis computer code, developed by the Korea Atomic Energy Research Institute (KAERI)[2].

Figure 1 is a schematic diagram of HCCR-HCS, which system is pressure of 8MPa. Helium coolant inlet temperature is 300℃ and when it exits the TBM, it becomes about 450℃. The coolant that enters through the connection pipe is cooled as it passes through the recuperator where heat exchange occurs, and it is cooled once more as it passes through the cooler. The cooler is connected to CCWS-1, component cooling water system of ITER. The cooled state enters the circulator, the flow is divided at two bypass junctions, and they are combined at the mixer and then enter the TBM inlet again.

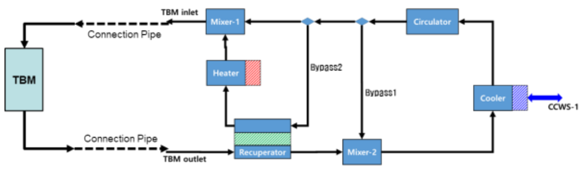

Figure. 1 Schematic Diagram for HCCR-HCS

2. Analysis Assumptions

Electrical power shutdown in loss of power accident affects not only the HCCR-TBS but also the entire ITER machine. When the power is shutdown, the circulator and cooler in the HCS loop stop operating, and the plasma generation of the TBM also stops. At plasma shutdown a plasma disruption is assumed to occur without any consequence in terms of failure. Once plasma shutdown is completed, the TBM decay heat is cooled by radiative heat transfer. It is assumed that the disruption load occurs 0.3GW/m^2 for 0.001s and 0.3MW/m^2 up to 0.1s. This series of accident effects of HCS increases the temperature of the system and decreases the flow rate. But the disruption does not cause any leak or breach on the HCS component.

3. Nodalization and Test cases

Figure 2 shows the nodalization for safety analysis based on normal operational conditions.

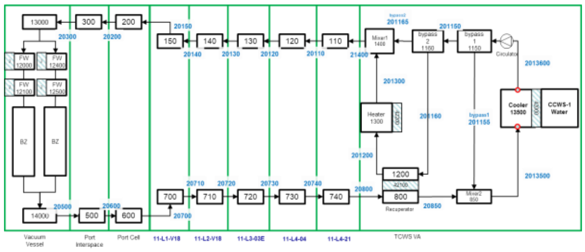

Figure. 2 Nodalization of Loss of Power

In Case 1, the accident proceeds without additional power supply while a loss of power accident occurs. In Case 2, power is supplied 90 seconds after the loss of power accident, and the circulator is restarted. In Case 3, the cooling effect by the stagnated coolant in CCWS-1 is considered in Case 2 situation.

3. Analysis Results

Power to the HCS components is lost at 0.0 s due to the loss of power accident. At this time the HCS circulator begins to coast down and the HCS heater and cooler cease to function. In Figure 3, the FW temperatures shown according to the three cases are compared. In the event of an accident, the temperature is 570℃ by the disruption load. It exceeds 550℃ set as the design temperature. However, the temperature decreases due to radiation. After a second, it falls below 550℃, which is unlikely to have a damage on the structure caused by the accident. In addition, comparing case 1 and 2, the temperature of the TBM FW decreases faster because the Class III-IP backup power is supplied after 90 seconds in case 2 and the circulator restarts. Comparing case 2 and 3, it is shown that case 3 converges at a lower temperature because of cooling by CCWS-1 in the Cooler.

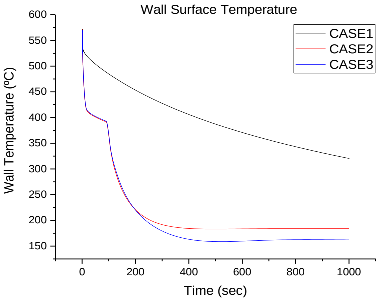

Figure. 3 Comparison of First Wall Temperature (CASE 1,2,3)

In case 1, as the circulator stops operating immediately, the flow rate decreases rapidly, and heat transfer of the coolant occurs by conduction. In Figure 4, at the cooler inlet & outlet there is no change because the convective heat transfer is limited and conductional heat transfer is slow process. In Figure 5, since the circulator restarts after 90 seconds and there is no cooling through CCWS-1, the heat of the TBM spreads throughout the system. The temperature of the cooler inlet reaches 180℃ in 287 seconds and converges to 184.3℃. In Figure 6, the temperature decreases and converges to 161.5℃ after reaching 171.1℃ in 264 seconds under the condition that the circulator and cooler restart.

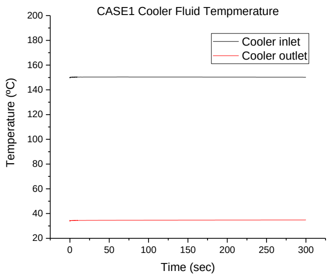

Figure. 4 Cooler inlet & outlet temperature (CASE1)

Figure 10 shows the temperature of the cooler structure in loss of power situation and Figure 11 shows the temperature of CCWS-1 connected to the cooler. The volume of CCWS-1 coolant used in the accident analysis is only 0.243m^3, which is assumed to be a stagnant coolant. Therefore, the temperature of the circulator inlet may be determined by the volume of the coolant.

4. Conclusion

In this paper, safety analysis of a loss of power accident in the HCCR-TBS was conducted. The analysis utilizes a one-dimensional model. The results indicate that heat transfer in the HCS slows down when the circulator stops and accelerates upon the circulator's a one-dimensional model. The results indicate that heat transfer in the HCS slows down when the circulator stops and accelerates upon the circulator's restart.

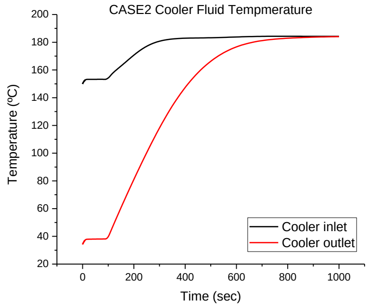

Figure. 5 Cooler inlet & outlet temperature (CASE2)

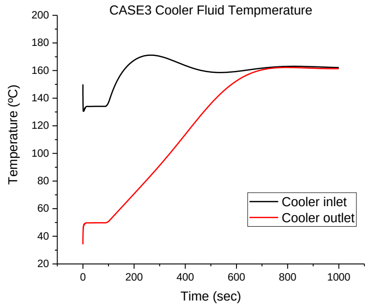

Figure. 6 Cooler inlet & outlet temperature (CASE3)

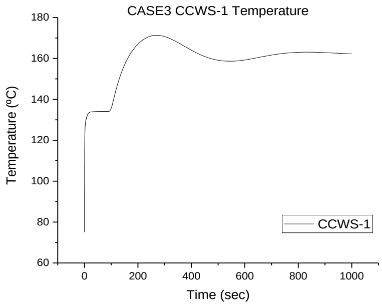

Figure. 11 Temperature of CCWS-1 (CASE3)

When the circulator is restarted using emergency power, the temperature at the circulator inlet must be considered. Consequently, the temperature at the circulator inlet is determined by whether cooling occurs in the cooler.

5. Acknowledgement

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[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] Hyung Gon Jin, “HCCR-TBS Accident Analysis Report” ,QQL5TP V1.0 (2015)