# Loss of Heat Sink Accident Analysis for PD-2 HCCR-TBS

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## 1. Introduction

This paper presents sensitivity analysis results of the LOHSA (Loss of Heat Sink Accident) for the PD-2 phase design of a Helium Cooled Ceramic Reflector (HCCR) Test Blanket System (TBS). A failure of the heat exchanger (HX) housing in the Helium Cooling System (HCS) is considered, which degrades heat removal capability and leads to temperature and pressure transients in the loop. In the PD-2 LOHSA analysis, the accident is detected by the temperature difference between the inlet and outlet of the HX (dT of HX). Upon detection, the plasma shutdown request is sent and the HCS isolation valve closes to separate the isolated and non-isolated zones. This paper evaluates the PD-2 HCCR-TBS LOHSA response by varying two operational parameters: the HX temperature-difference detection threshold (dT of HX) and the isolation-valve closing time to support design optimization of the HCCR-TBS. [1-3]

## 2. Safety Analysis Code

Accident transients are computed using GAMMA-FR (General Analyzer for Multi-component and Multi-dimensional Transient Application - Fusion Reactor), developed at KAERI. GAMMA-FR is a system code to predict thermo-hydraulic phenomena expected to occur during thermo-fluid transients and it has been used for safety assessment of the HCCR TBS.

## 3. Parameters and nodalization

The design pressure of the HCS is 8 MPa, and the representative temperatures consistent with PD-2 operation are 300 °C from the HX outlet to the TBM inlet, and 450 °C from the TBM outlet to the HX inlet. Isolation & detection points. The isolation valve is located between Port Cell (FB200/FB600) and 11-L1-V18 (FB150/FB700). The LOHSA detection is based on the HX inlet–outlet temperature difference (dT of HX) as indicated in Figure. 1.

- Detection threshold (dT of HX): 40 / 60 / 80% of the steady-state HX temperature difference.
- Isolation-valve closing time: 3 / 5 / 10 s.

The nine cases are denoted LOHSA4003…8010 using the (dT, closing) convention.

Figure 1 shows the nodalization for the PD-2 LOHSA analysis. The 'Cooler (FB13500)' represents the HX and the accident is detected when the HX inlet–outlet temperature difference decreases below the specified fraction of the steady-state value (dT of HX). Once detected, a plasma-off request is issued and, after 3 s, fusion power is terminated by FPSS; the isolation valve is actuated simultaneously with detection.

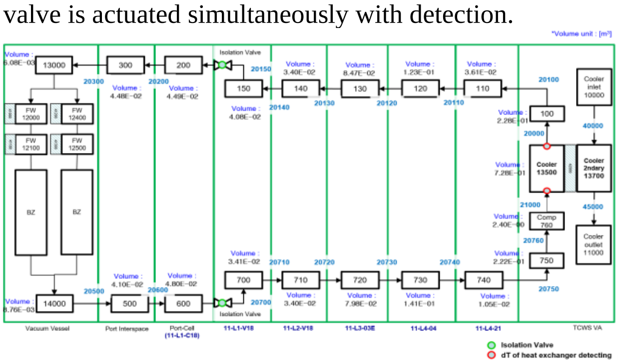


Fig. 1. Nodalization of the LOHSA analysis

Table I: LOHSA test matrix

| Test Index. | Accident | *dT of HX | Isolation time (s) |
|---|---|---|---|
| LOHSA4003 | LOHSA | 40% | 3 |
| LOHSA4005 | LOHSA | 40% | 5 |
| LOHSA4010 | LOHSA | 40% | 10 |
| LOHSA6003 | LOHSA | 60% | 3 |
| LOHSA6005 | LOHSA | 60% | 5 |
| LOHSA6010 | LOHSA | 60% | 10 |
| LOHSA8003 | LOHSA | 80% | 3 |
| LOHSA8005 | LOHSA | 80% | 5 |
| LOHSA8010 | LOHSA | 80% | 10 |

## 4. Results

Figure 2 presents the first-wall (FW) temperature transient for the same cases. After the loss of heat sink, the FW temperature increases and shows rapid excursions due to the subsequent disruption loads following plasma shutdown. In general, a longer valve closing time provides residual cooling before full isolation and tends to reduce the long-term FW temperature. However, when the valve is fully closed near the disruption-load period (e.g., LOHSA6003), a higher temperature/pressure state can be trapped in the isolated zone.

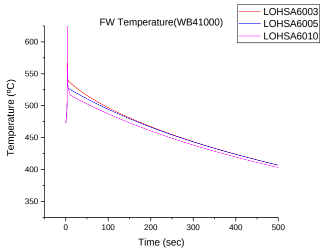


Fig. 2. FW temperature transient in LOHSA (dT of HX = 60%)

Figure 3 summarizes the sensitivity to the HX detection threshold with the isolation time fixed at 3 s. A larger dT of HX threshold results in lower FW and isolated-zone temperatures at 500 s. During the 0.3 MW/m² disruption-load phase, the FW peak temperatures are 593.2 ℃ (40%), 566.4 ℃ (60%), and 548.6 ℃ (80%).

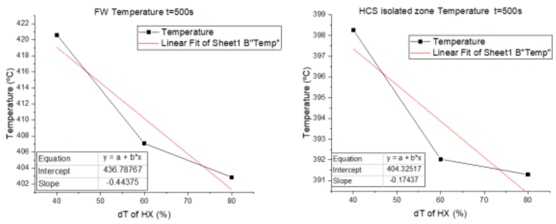


Fig. 3. FW and HCS isolated-zone temperatures at 500 s vs. dT of HX

With dT of HX fixed at 60%, the pressure response is examined as a function of valve closing time. Figure 4 shows that the isolated-zone pressure rises following the loss of heat sink and then decreases after plasma-off and isolation; the case isolated at the disruption-load period shows the highest pressure. Figure 5 compares FW temperature and isolated-zone pressure at 500 s, indicating decreasing trends with longer closing time and limited additional benefit between 5 s and 10 s for the pressure when the valve closure occurs after the disruption-load phase.

The observed trends highlight a trade-off between early/fast isolation for confinement and the residual-cooling benefit of delayed closure for thermal mitigation, which should be considered in setting sensing and actuation logic.

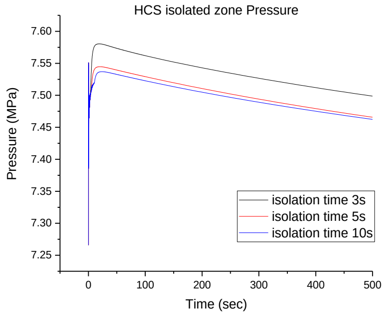


Fig. 5. HCS isolated-zone pressure transient in LOHSA (dT of HX = 60%)

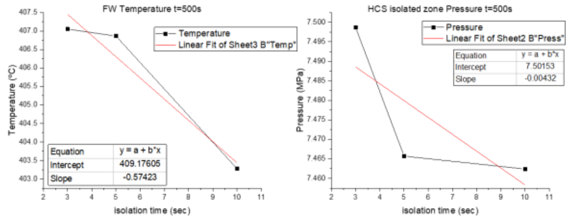


Fig. 6. FW temperature and isolated-zone pressure at 500 s vs. isolation time

## 5. Conclusion

A LOHSA sensitivity study was performed for the PD-2 HCCR-TBS using GAMMA-FR by varying the HX temperature-difference detection threshold (dT of HX) and the isolation-valve closing time. Earlier detection (larger dT of HX threshold) reduces FW and isolated-zone temperatures by initiating plasma shutdown and isolation sooner, while longer closing time can provide additional residual cooling before full isolation and may reduce long-term FW temperature. The timing of full isolation relative to the disruption-load period can, however, increase trapped temperature /pressure in the isolated zone. The current model does not include heat conduction within the HX, which can affect the predicted detection time; future work will incorporate HX conduction effects to refine sensing /actuation requirements.

## REFERENCES

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