Development of Two-Phase Flow CFD Code to Improve Core-Catcher Cooling Performance

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Introduction

The CE-PECS (Cooling Experiment-Passive Ex-vessel corium retaining and Cooling System) experiment conducted by KAERI simulates the natural circulation of such cooling system. A schematic diagram of the CE-PECS experiment can be seen in Figure 1. Heat flux from the core melt to the core catcher was realized by the electrical HBs(Heating Blocks).

The code used in this study was developed to simulate the flow inside the core catcher due to the heat flux of corium based on the OpenFOAM CFD tool.

To verify the code, benchmark simulations of CE-PECS T8-4 experiments were performed.

CFD model

- A solver for simulating was developed based on **chtMultiRegionTwoPhaseEulerFoam** in OpenFOAM.
- Wall Heat Flux
  - convective, evaporating, quenching

Total wall heat flux $q_w'' = q_w^{c''} + q_w^{e''} + q_w^{q''}$

Evaporation heat flux $q_w^{e''} = \frac{\pi}{6} d_w^3 \rho_v f N'' \left(i_{g,sat} - i_l\right)$

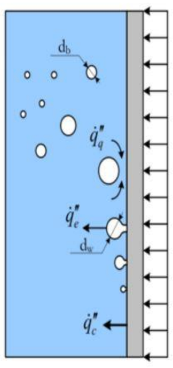
Nucleation site density (LemmertChawla) $N'' = \left[210\left(T_w - T_{sat}\right)\right]^{1.805}$

Bubble departure frequency (Cole) $f = \sqrt{\frac{4g(\rho_f - \rho_g)}{3D_d\rho_f}}$

Bubble departure diameter (Tolubinski-Kostanchuk) $d_{ref} exp\left(\frac{-T_{sat} - T_l}{45}\right)$

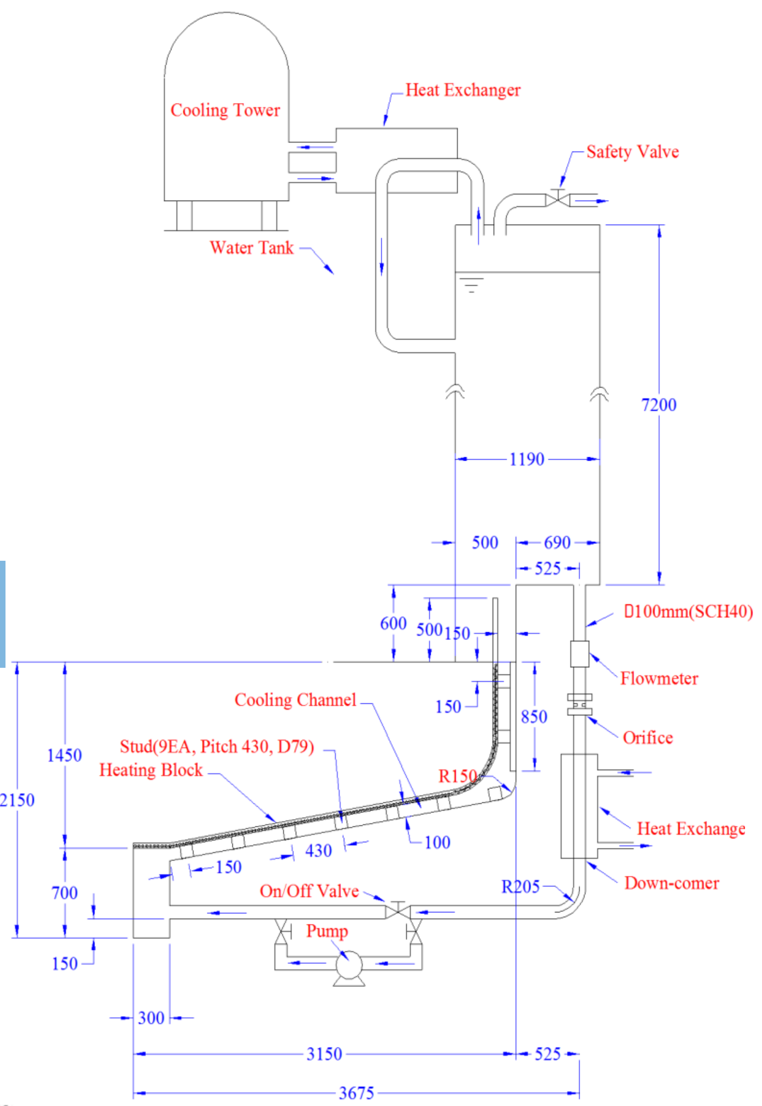
Quenching heat flux $q_w^{q''} = A_q \frac{2\lambda_l(T_w - T_l)}{\sqrt{\frac{\pi}{f}\frac{\lambda_l}{\rho_l c_{pl}}}}$

Convective heat flux $q_w^{c''} = (1 - A_q)h_c(T_w - T_l)$



CE-PECS

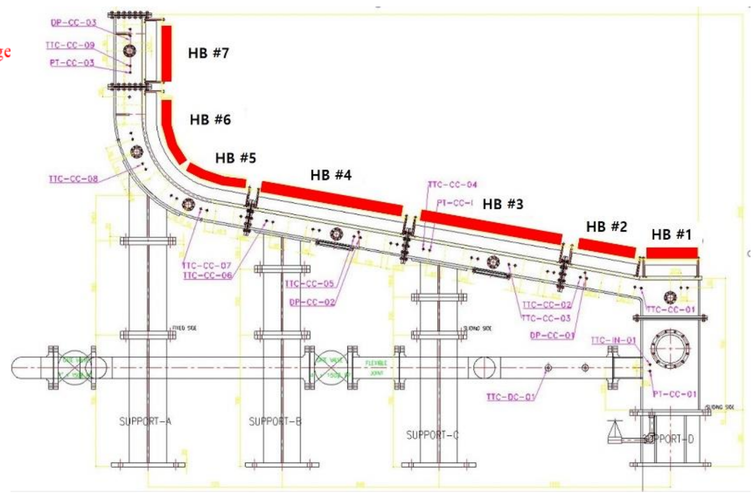
- Schematic of the CE-PECS test facility



- CE-PECS T8-4 experiment condition

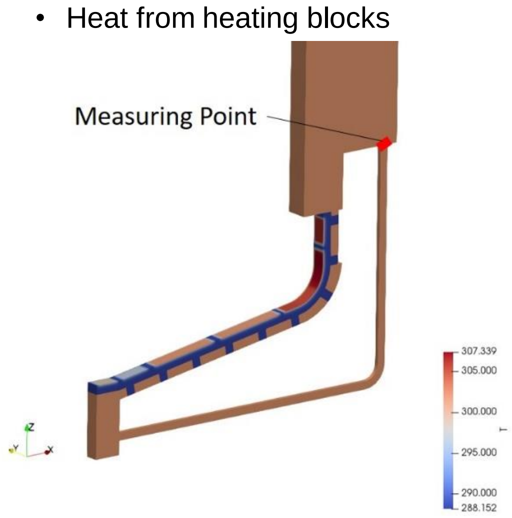
Coolant level	7.56 m
Initial coolant temperature	89 ℃
Total heating time	2830 s
Total power	123.3 kW (75%)
Average heat flux in HB #1	60.9 kW/m^2
Average heat flux in HB #2	46.4 kW/m^2
Average heat flux in HB #3	89.1 kW/m^2
Average heat flux in HB #4	98.3 kW/m^2
Average heat flux in HB #5	150.3 kW/m^2
Average heat flux in HB #6	220.9 kW/m^2
Average heat flux in HB #7	261.0 kW/m^2

- Location of HBs

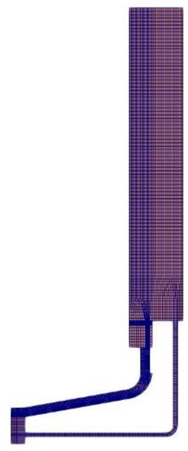


Method and Result

- Temperature and mass flow rate of cooling water measured and compared at the 'Measuring Point'.
  - Heat from heating blocks

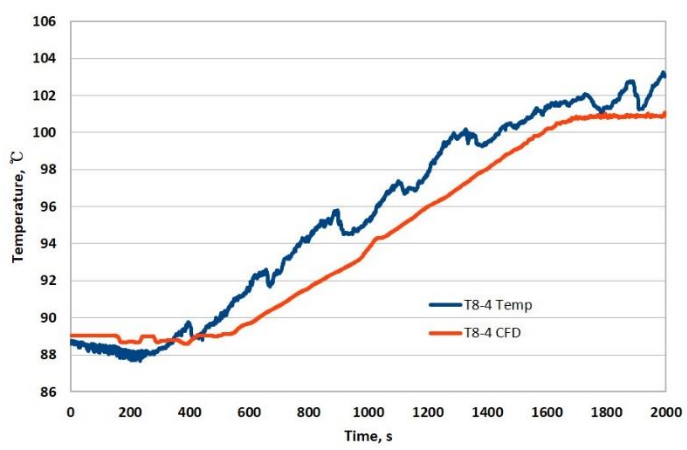


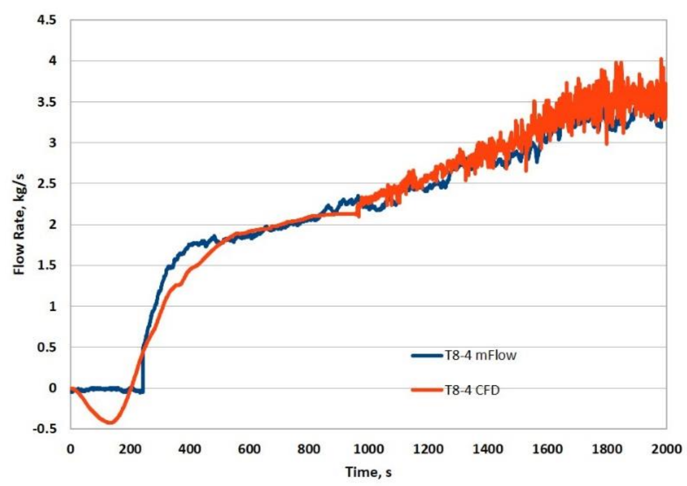
  - Mesh used in CFD simulation



- The mesh consists of about 50,000 fully hexahedral cells and is divided into three parts: flow, catcher and stud.

- Results





Conclusion

- As a result of benchmarking and simulating the CE-PECS T8-4 experiment, the flow rate and temperature rise trends were well predicted within a maximum error of 7%.
- We expect to find ways to improve the cooling performance of the core catcher by using this code and to predict possible variables.