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Post Analysis of Two Phase Natural Circulation Mass Flow Rate for CE-PECS

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1. Introduction

The ex-vessel core catcher of the PECS (Passive Ex-vessel corium retaining and Cooling System) is installed to retain the corium in the reactor cavity of the EU-APR1400 [1]. When the reactor vessel fails, the reactor cavity is flooded by the gravity driven flow from the IRWST (In-containment Refueling Water Storage Tank) after the molten corium spreads on the core catcher body during a severe accident. Decay heat and sensible heat of the relocated and spread corium are removed by the natural circulation flow at the bottom and side wall of the core catcher and the top water cooling of the corium combined with the dedicated containment spray system.

The coolant in the inclined channel absorbs the decay heat and sensible heat transferred from the corium through the structure of the core catcher body and flows up to the pool as a two phase mixture. On the other hand, some of the pool water will flow into the inlet of the downcomer piping, and will flow into the inclined cooling channel of the core catcher by gravity. The engineered cooling channel is designed to provide effective long-term cooling and stabilization of the corium mixture in the core catcher body while facilitating steam venting. To maintain the integrity of the ex-vessel core catcher, however, it is required that the coolant be circulated at a rate along the inclined cooling channel sufficient to avoid CHF (Critical Heat Flux) on the heating surface of the cooling channel. For this reason, a verification experiment on cooling capability of the EU-APR1400 core catcher had been performed in the CE (Cooling Experiment)-PECS's facility, which is shown in Fig. 1[2]. In this study, post simulations of two phase natural circulation in the CE-PECS have been performed to evaluate two phase flow characteristics and the natural circulation mass flow rate in the flow channel using the RELAP5/MOD3 computer code [3].

2. RELAP5 Input Model

Fig. 2 shows a RELAP5/MOD3 input model for the two phase natural circulation analysis in the flow channel of the CE-PECS. The coolant supplied by the outer tank (Time Dependent Volume No. 400) circulates from the cooling channel of the CE-PECS (Pipe No. 45, 50, 60, 70, 80, 90, 100, and 110) through downcomer (Pipe 140, 160). The electrical heater body is simulated by RELAP5 heat structure. The heater source is simulated as a boundary condition of the heat flux at the left side of the heat structure number 100. The generated steam is vented to the atmosphere (Time Dependent Volume No. 310). In all simulations, the initial conditions are assumed to be ambient pressure with no coolant mass flow rate. The coolant level of the reactor cavity maintains a constant value by the outer water.

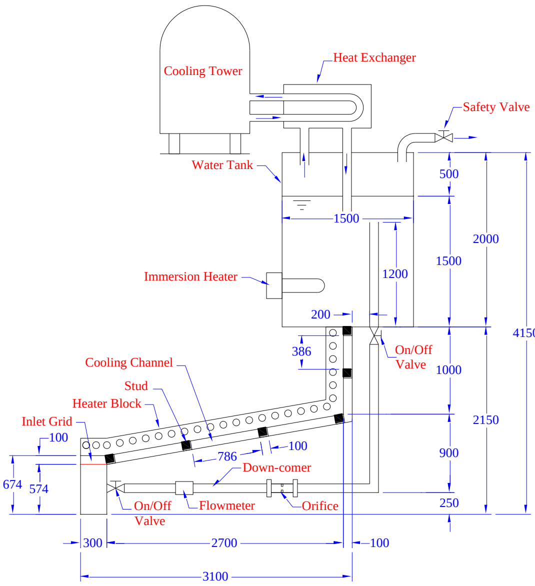

Fig. 1 Schematic of the CE-PECS test facility.

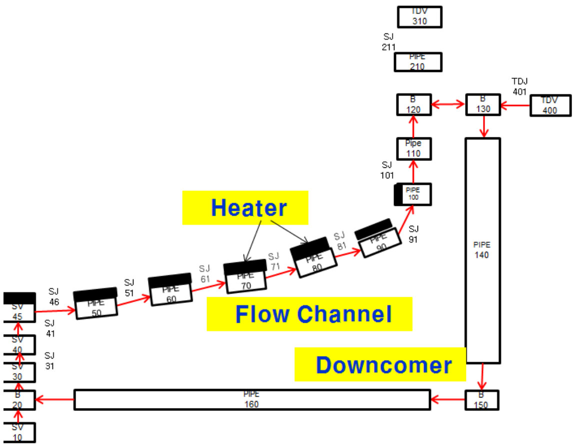

Fig. 2. RELAP5/MOD3 input model for the CE-PECS.

3. Results and Discussion

Fig. 3 shows the RELAP5 results on the water circulation mass flow rate in the base case. An oscillatory coolant flow was generated. The RELAP5/MOD3 results have shown that the water circulation mass flow rate is approximately 8.7 kg/s.

Fig. 4 shows the local pressure distribution. A small oscillatory was generated. Fig. 5 shows the local void fraction distribution in the flow channel. An oscillatory coolant flow was generated and the exit void fraction was approximately 0.57.

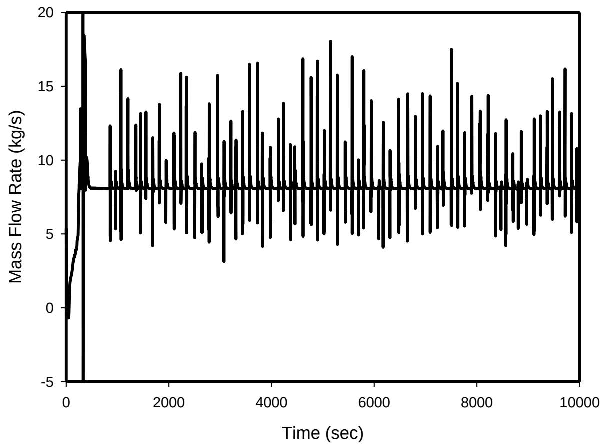

Fig. 3. RELAP5 result of the natural circulation mass flow rate.

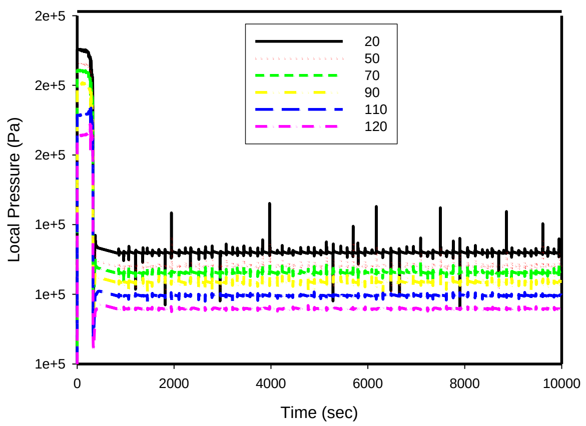

Fig. 4. RELAP5 results on the local pressure in the flow channel.

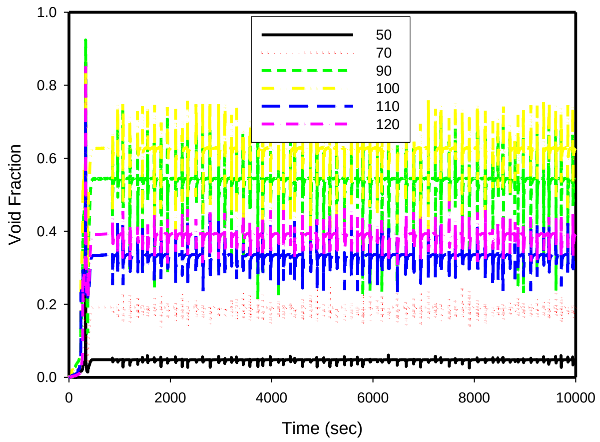

Fig. 5. RELAP5 results on the local void fraction in the flow channel

Figs. 6&7 show the comparison of present results with CE-PECS experimental results on the water circulation mass flow rate in the low (0.5 m) and high (5.0 m) water level cases, respectively. The present RELAP5 results are very similar to the CE-PECS experimental results. An increase in the heat flux on the outer surface wall leads to an increase in the water circulation mass flow rate. From a comparison of Fig. 6 with Fig. 7, an increase in the water level in the core catcher leads to a decrease in the water circulation mass flow rate.

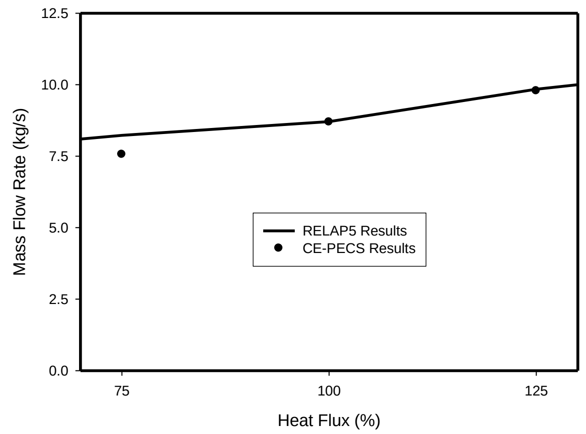

Fig. 6. Comparison of present results with CE-PECS experimental results on the water circulation mass flow rate in the low water level case (0.5 m).

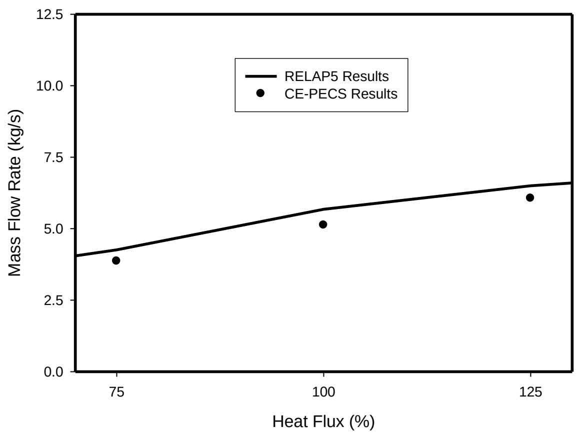

Fig. 7. Comparison of present results with CE-PECS experimental results on the water circulation mass flow rate in the high water level case (5.0 m).

4. Conclusion

Post simulations of two phase natural circulation in the CE-PECS have been conducted to evaluate two phase flow characteristics and the natural circulation mass flow rate in the flow channel using the RELAP5/MOD3 computer code. The RELAP5/MOD3 results have shown that the water circulation mass flow rate is approximately 8.7 kg/s in the base case. The present RELAP5 results are very similar to the CE-PECS experimental results. An increase in the heat flux on the outer surface wall leads to an increase in the water circulation mass flow rate. An increase in the water level in the core catcher leads to a decrease in the water circulation mass flow rate.

ACKNOWLEDGMENTS

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[2] K. S. Ha, B. W. Rhee, R. J. Park, Coolability of an Ex-vessel Core Catcher by Natural Circulation Flow, ICAPP2014, Charlotte, USA, April 6-9, 2014.

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