A Study on RVCS Performance with 3D Thermal Hydraulics Analyses

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Introduction

- As the development of small modular reactors and Generation IV reactors progresses, the shape of the reactor is also changed. One of these, a pool-type reactor, reactor core, reactor coolant pump, and heat exchanger include in a reactor vessel. A prototype gen-IV sodium cooled fast reactor (PGSFR) is one of pool-type reactors. Any safety system which uses water can be used at PGSFR. A reactor vault cooling system (RVCS) can enhance the safety of the reactor by removing the decay heat through the natural convection of the air in the system. In this paper, when RVCS is analyzed at 3-dimensional geometry, the performance of this component is analyzed to determine whether it is an effective safety system for accident scenarios.

Model description

- In this study, TRACE code was used to analyze the performance of RVCS
- The reactor pool component is modeled at 17 axial levels, 7 radial rings, and 10 azimuthal sectors
- PGSFR generates 392.2 MWt heat at the normal operating condition

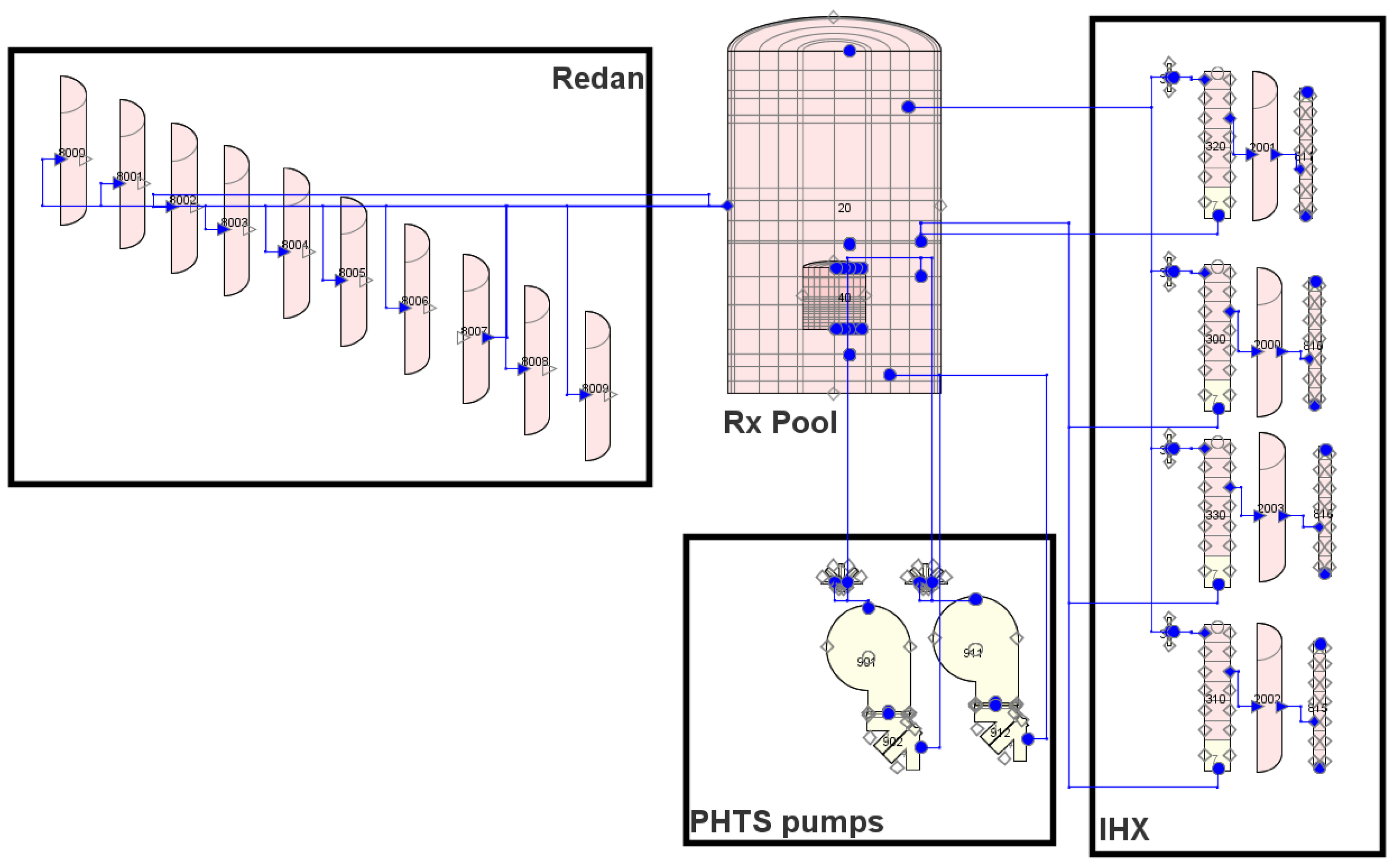

Fig. 1. TRACE nodalization for PGSFR model

Table I. Comparison of the PGSFR design parameter and normal operating conditions of TRACE model

Parameter	Design value	TRACE normal operating conditions
Thermal power [MW_t]	392.2	392.2
Coolant flow rate [kg/s]	1,989	1,932
Core inlet temperature [℃]	390	412
Core outlet temperature [℃]	545	572

Result 1

- **Transient analyses without RVCS**
  - In this study, to evaluate the performance of RVCS, an unprotected loss of heat sink (ULOHS) is considered.
  - The ULOHS scenario reduces the heat removal rate of the intermediate heat transfer system by stop of all IHXs.
  - This reduction of heat removal rate increases cold pool temperature and core average temperature.
  - The increase of cold pool temperature causes positive reactivity due to the expansion of the reactor vessel. The increase of core temperature inserts negative reactivity due to fuel expansion, doppler effect, and reduction of sodium density.
  - This reactivity reduces the core power, and it becomes similar to decay heat level after approximately 2,000 seconds.
  - As the core power reduces, the difference of coolant temperature between core inlet and outlet is decreased.
  - However, the decay heat is accumulated in the reactor and the coolant temperature is increased.
  - At approximately 70,000 seconds, the sodium is boiled.

Result 1

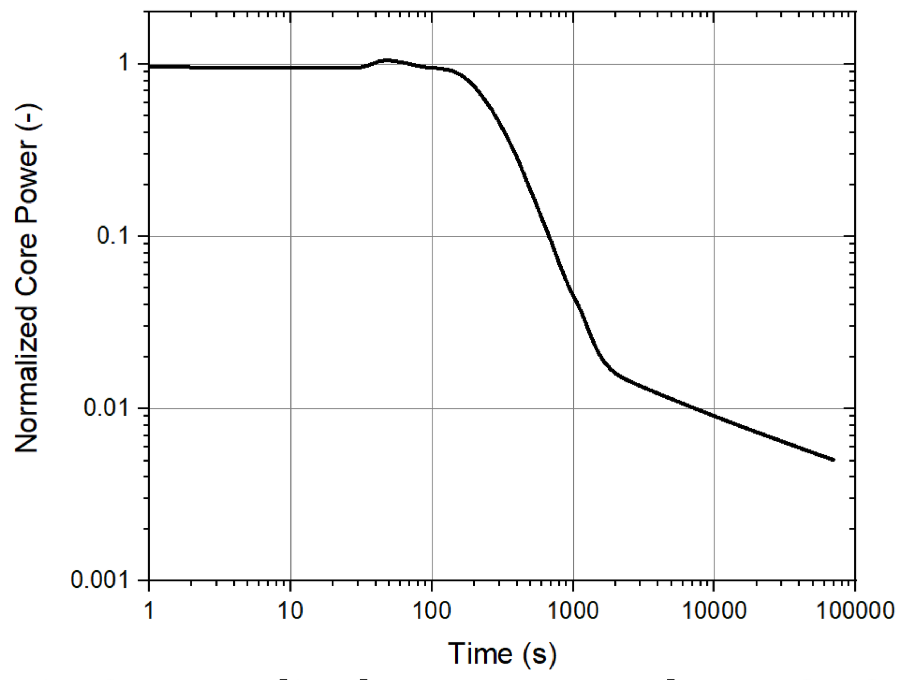

Fig. 2. Normalized core power under ULOHS scenario without RVCS.

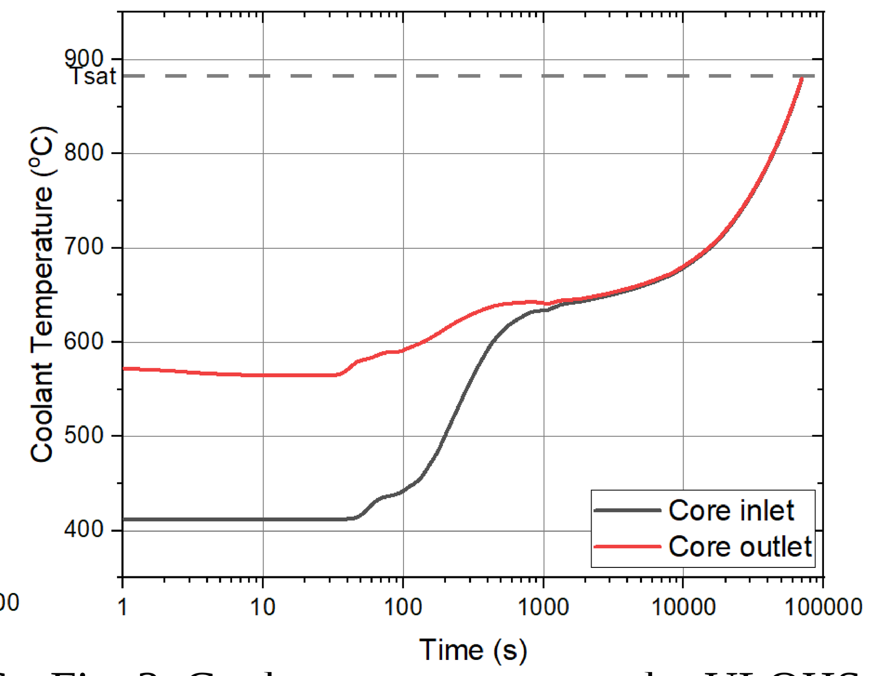

Fig. 3. Coolant temperature under ULOHS scenario without RVCS.

Result 2

- **Transient analyses with RVCS**
  - RVCS is modeled for heat removal through the reactor vessel on the outer wall of the reactor pool. The heat loss of the RVCS is 0.7 MWt at the normal operating condition.
  - Average coolant temperature is increased slower than without RVCS due to the heat loss of the RVCS.
  - The coolant temperature is remained about 650 ℃ after 1,000 sec from the accident.
  - The sodium can not reach the saturation point until 100,000 seconds.

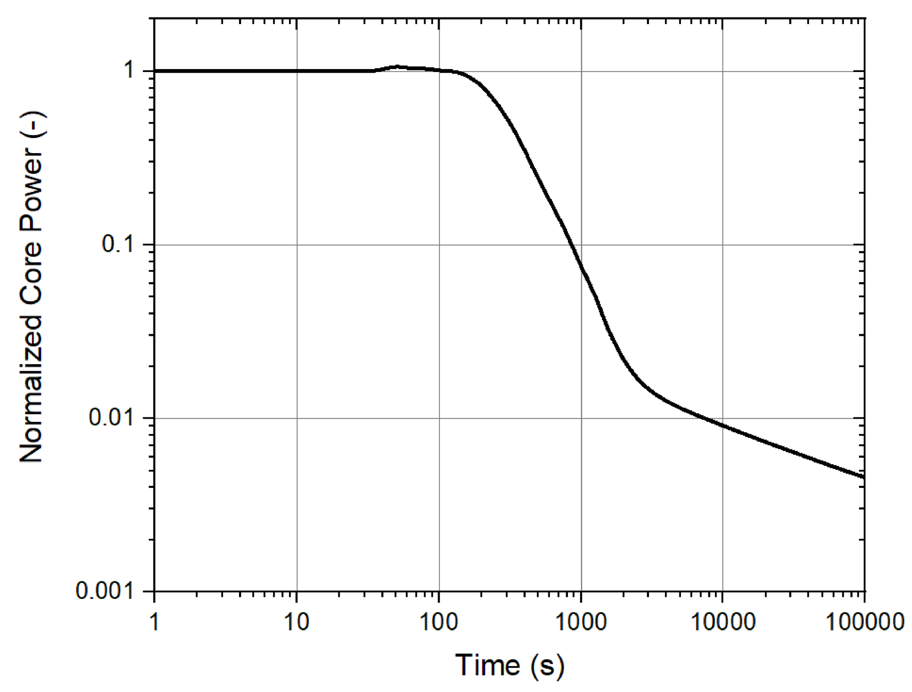

Fig. 4. Normalized core power under ULOHS scenario with RVCS.

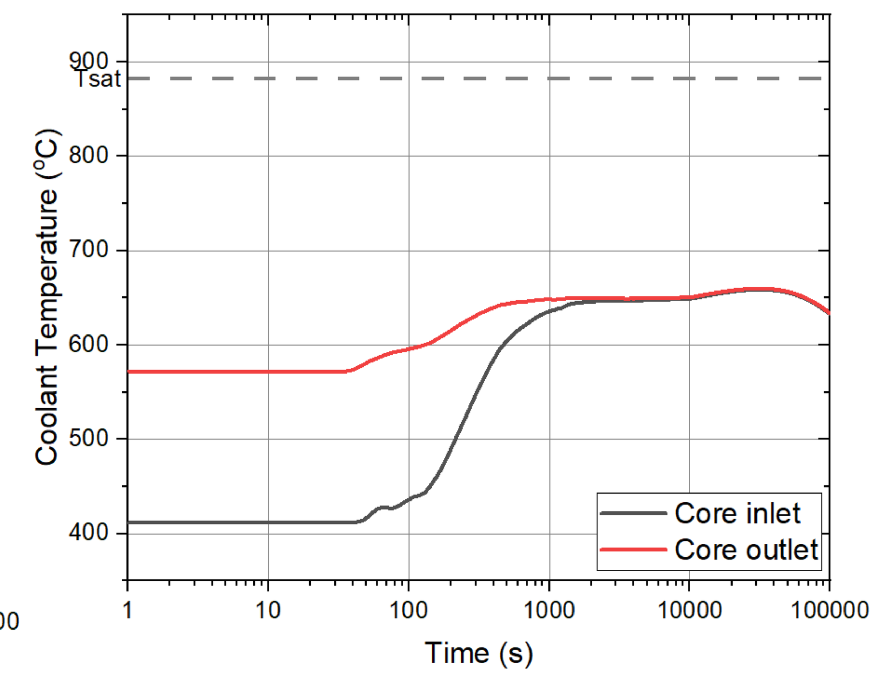

Fig. 5. Coolant temperature under ULOHS scenario with RVCS.

Conclusions

The performance of RVCS was analyzed at 3-dimensional geometry. For the ULOHS scenario, with or without RVCS, the reactor core power could be reduced to the decay heat level in less than an hour. RVCS reduced the reactor vessel temperature and decrease the positive reactivity of reactor vessel expansion. Therefore, the operation of RVCS could avoid the evaporation of sodium.

Reference

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