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# Numerical Demonstration of an Unmanned Reactor Based on Passive Infinite Cooling System

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## 1. Introduction

Recently, an innovative concept for an unmanned reactor was proposed using passive infinite cooling (Fig. 1) [1]. Additional cooling systems for safety injection and spray cooling are not required. For more information, refers to [1]. Figure 2 depicts a design example under normal operation. The reactor system consists of two small containments and is located underwater to take an advantage of ultimate heat sink.

Figure 3 shows the coolant distribution in the early stage in case of LOCA. A steam siphon tube plays an vital role in rapid cooling in the early stage. Figure 4 shows the long-term situation in which the decay heat is completely removed by natural circulation.

The present study is to demonstrate the passive infinite cooling in the long-term stage through numerical simulations.

## 2. Simulation conditions

Figure 5 shows the initial distribution of the coolant in the simplified reactor geometry. Figure 6 indicates the heating and cooling regions. The steam siphon tube is placed in the upper cooling region.

The simulation was performed based on the mixture equations with evaporation and condensation. Lee model was used to compute the rate of phase change.

$$\dot{m}=\begin{cases}0.1\alpha_l\rho_l\dfrac{T-T_{sat}}{T_{sat}}, & \text{if } T\ge T_{sat}\ \text{(evaporation)}\\[2ex] 1.0\alpha_g\rho_g\dfrac{T-T_{sat}}{T_{sat}}, & \text{otherwise (condensation)}\end{cases}$$

(1)

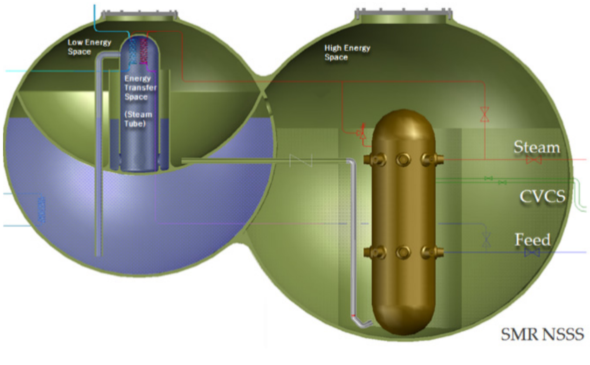

Fig. 1. Concept of innovative reactor system based on thermos-siphon pump

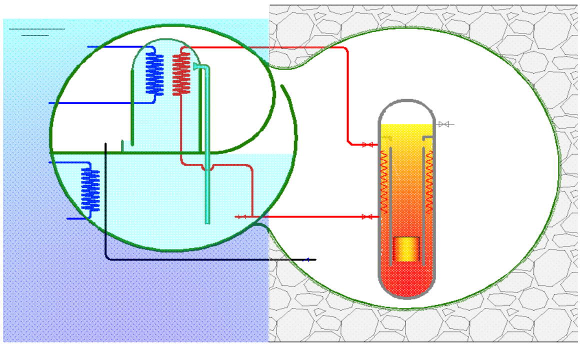

Fig. 2. Normal operation state

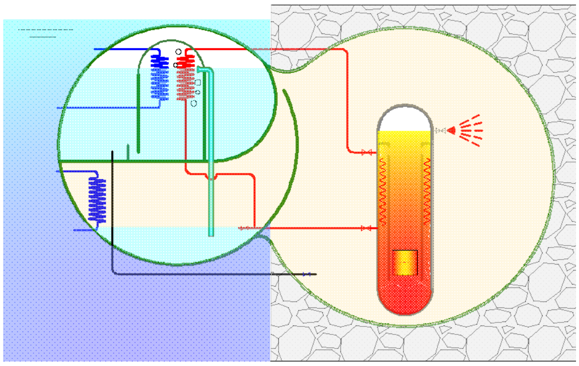

Fig. 3. Early stage in case of LOCA

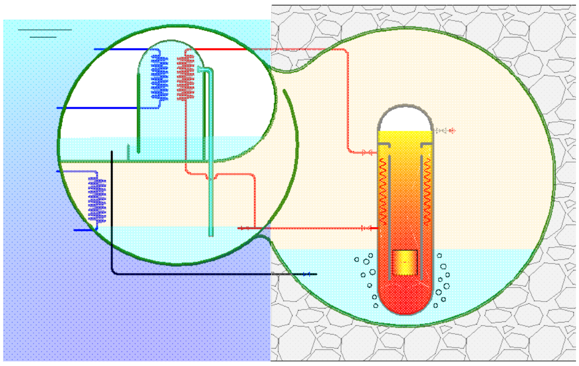

Fig. 4. Long-term stage in case of LOCA

## 3. Results

Figure 7 shows the void fraction distribution at 40 s after break. The vapor release increases the containment pressure up to 1.5 bar. However, because the pressure in the upper cooling region (the steam siphon tube is placed in this region) is low, a rapid cooling occurs there in the early stage. At 40 s, a check valve placed between low and high energy spaces opens, and the coolant starts to flow toward the high energy spaces. Figures 8 and 9 show the void fraction distributions at 80 s and 1000 s, respectively. The reactor core is completely covered by the coolant.

The mass flow rate through the valve is plotted in Fig. 10. One can see a unidirectional flow after 340 s. This means that the natural circulation occurs in the long-term period. Figure. 11 shows the time histories of the containment pressures. The pressure increases continuously due to the evaporation in the reactor core. However, the situation approaches a steady state. This result demonstrates that the proposed concept is working well accompanied by passive infinite cooling.

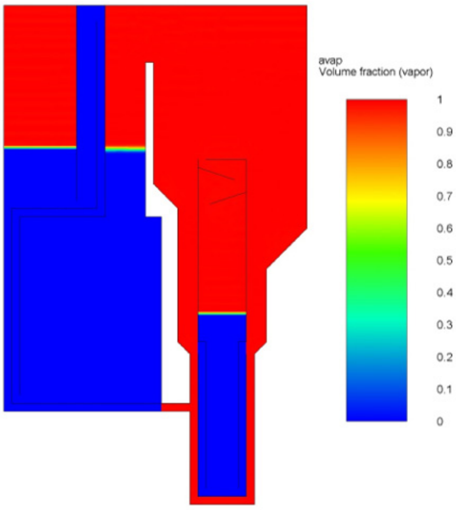

Fig. 5. Initial distribution of the coolant

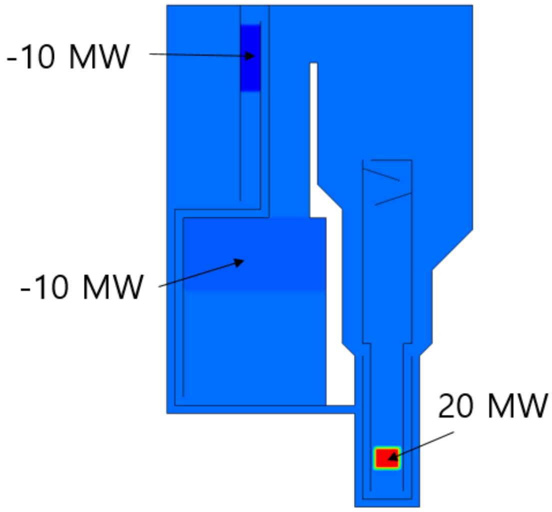

Fig. 6. Decay heat and heat removal

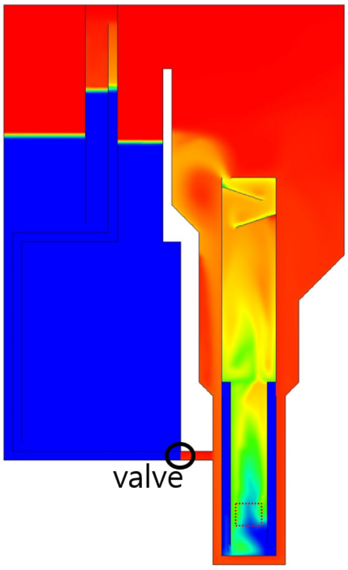

Fig. 7 Void fractions at 40 s after break

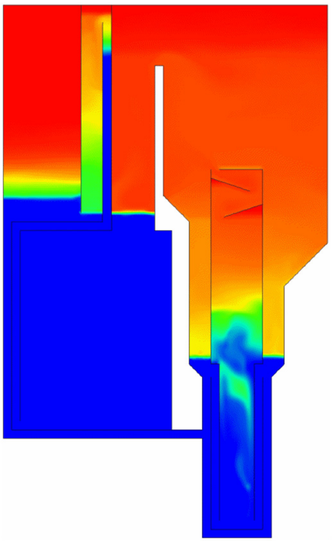

Fig. 8 Void fractions at 80 s after break

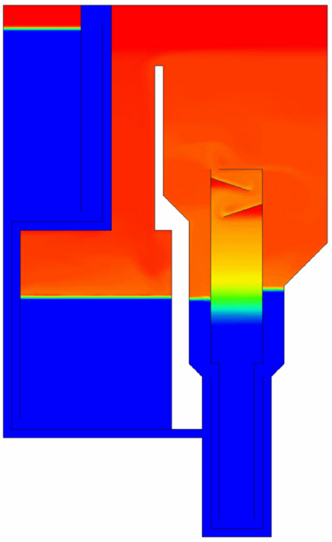

Fig. 9 Void fractions at 1000 s after break

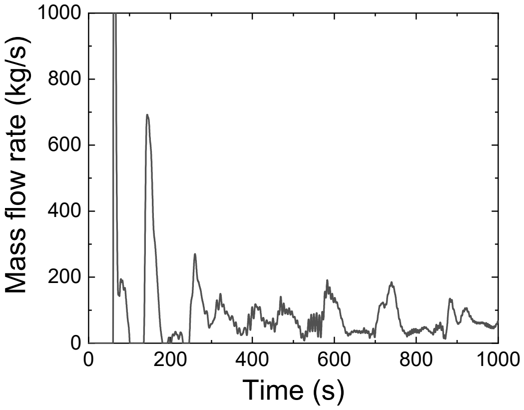

Fig. 10 Mass flow rate through the valve

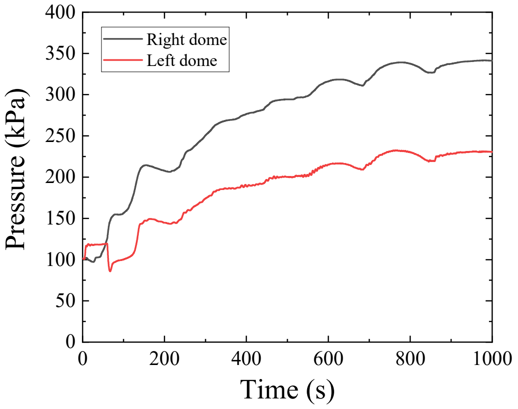

Fig. 11 Variation of the containment pressures

## 3. Summary and Future Works

A new reactor concept was proposed to provide rapid cooling in the early stage by the help of steam siphon tube. In the long-term stage, the decay heat is completely removed by the natural circulation. This numerical work has showed the feasibility of the new reactor concept.

The steam siphon tube plays a vital role in rapid cooling in the early stage. Hence, its heat transfer characteristics must be investigated in detail. In this work, the steam siphon tube was simply modeled as a volumetric heat sink. The heat transfer of the steam siphon tube will be studied in the near future.

## ACKNOWLEDGEMENT

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## REFERENCES

[1] S.-J. Yi, C.-H. Song, H.-S. Park, PX–An Innovative Safety Concept for an Unmanned Reactor, Nuclear Engineering and Technology, 48(1) (2016) 268-273.