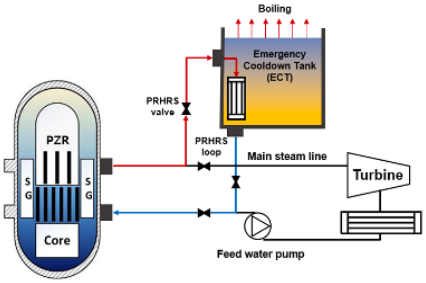
Preliminary Investigation of Pressure Effect of the Emergency Cooldown Tank on Accident Grace Period of Small Moudular Reactors

Jae Hyung Park[a], Doyoung Shin[a], Hoichul Jung[a], Sung Joong Kim[a, b*]
[a]Department of Nuclear Engineering, Hanyang University, 222 Wangsimni-ro, Seongdong-gu, Seoul 04763 Republic of Korea
[b]Institute of Nano Science & Technology, Hanyang University, 222 Wangsimni-ro, Seongdong-gu, Seould 04763 Republic of Korea
*Corresponding author: sungjkim@hanyang.ac.kr

Introduction

● **Passvie residual heat removal system (PRHRS)**

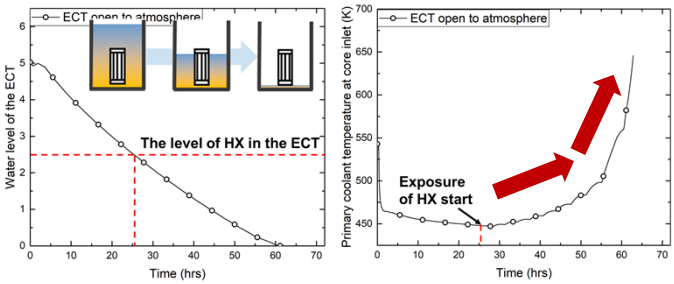


Accident situation heat transfer

1) Core
2) Steam generator
3) PHRHS loop
4) HX in the ECT
5) Water
Sensible heat + Vaporization

● **Importance of water level in the ECT**

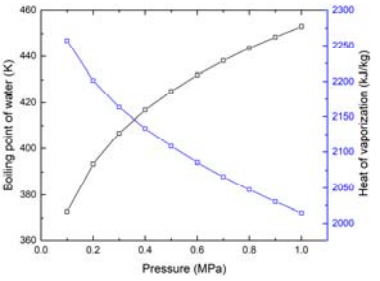
✓ Accident scenario: **Station Blackout (SBO)**.



✓ If the heat exchanger in the ECT is exposed to air, the heat removal efficiency is deteriorated.
→ **Water level of the ECT is a critical parameter in determining the safety performance of the PRHRS!**
✓ It is needed to mitigate the water vaporization inside the ECT.

● **Closed ECT concept**

✓ Keep the generated vapor inside the ECT by a closed system
→ Pressurization of the ECT by thermal expansion and boiling of water



Total heat removed by the PRHRS
Sensible heat + latent heat

Pressurization
Boiling point
Heat of vaporization

✓ The pressure effect of the ECT on the grace period of the PHRRS designed for a SMR called ATOM was investigated.

MARS-KS modelling

● **MARS-KS nodalization of the PRHRS with relief valves**

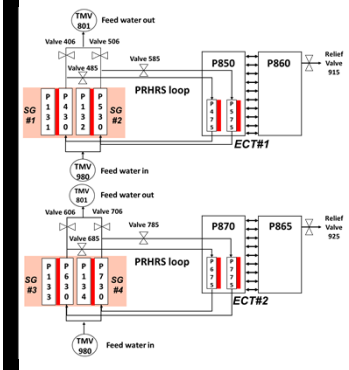


Table 1. Design parameters of the reference

Parameter	Value
Reactor parameters	
Reactor type	Integral PWR
Thermal power (MW_t)	330
Electrical power (MW_e)	100
Fuel material	UO_2
Fuel assembly	17×17
Operating pressure (MPa)	15
Core inlet temperature (K)	546
Core outlet temperature (K)	588
Core mass flow rate (kg/s)	1428.5
SG type	Helical tube
SG pressure (MPa)	4.42
PRHRS parameters	
ECT area (m^2)	20
Initial water level of ECT (m)	5
Length of HX-ECT (m)	2.5
Heat transfer area of HX-ECT (m^2)	28.3×4

✓ For base case, PIPE 850, 860, 865, 870 are connected to atmosphere
✓ More details of the MARS-KS model are explained in the reference *.

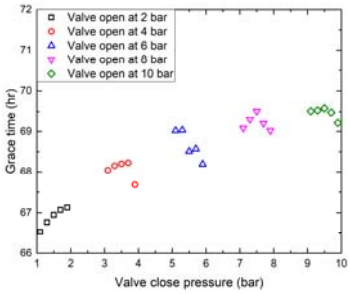
Table 2. Relief valve open/close pressures

Open pressure (bar)	Close pressure (bar)
2	1.1 / 1.3 / 1.5 / 1.7 / 1.9
4	3.1 / 3.3 / 3.5 / 3.7 / 3.9
6	5.1 / 5.3 / 5.5 / 5.7 / 5.9
8	7.1 / 7.3 / 7.5 / 7.7 / 7.9
10	9.1 / 9.3 / 9.5 / 9.7 / 9.9

* Na et al., Nuclear Engineering and Technology, Vol. 52, pp. 964-974, 2020.

Results

● **Effect of valve open/close pressure on the grace period**

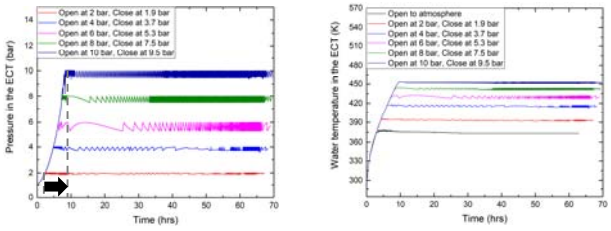


Valve open pressure ↑
→
Grace period ↑

Table 3. The longest grace period cases

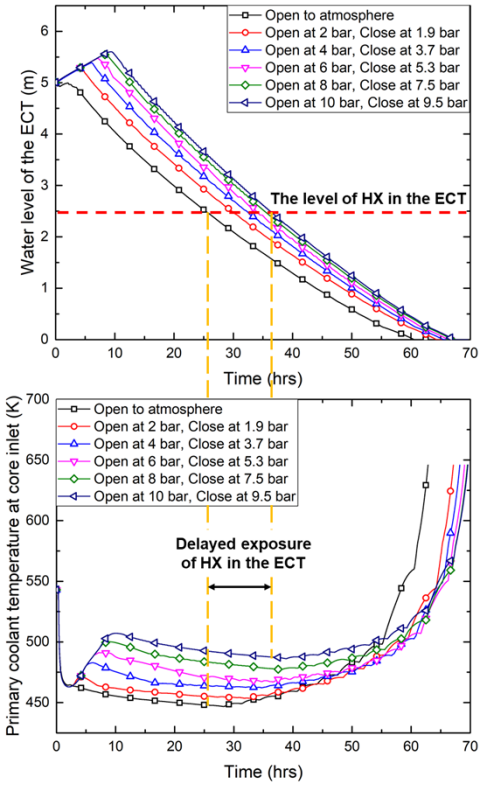
Open pressure (bar)	Close pressure (bar)
2	1.9
4	3.7
6	5.3
8	7.5
10	9.5

● **The open/close valve operation**



✓ For the higher open pressure, the first open time valve was delayed.
✓ The valve open/close operated at set threshold pressures.
✓ More frequent valve operation were observed at the higher pressure.

● **Cooling performance of the PRHRS with the Closed ECT**



Pressurization
Boiling point
Sensible heat
Time to reach boiling point
Density
Latent heat
Decreasing rate of water level
→
Grace period
Coolant Temp.

Conclusion

✓ The larger initial increase in water level in higher pressure condition was resulted from the increased boiling point of water. The relief valve also began to open later.
✓ In higher pressure condition, the water level decreasing rate was faster due to smaller latent heat and density of water.
✓ **The temperature of the coolant in primary system increased** as the temperature inside the ECT increased due to pressurization.
✓ **The time to complete loss of cooling capability of the PRHRS was delayed by a few hours with the higher pressure of the ECT.**