The 8th meeting of EMUG

Safety Analysis of Severe Accident of Spent Fuel Pool

Zheng Huang

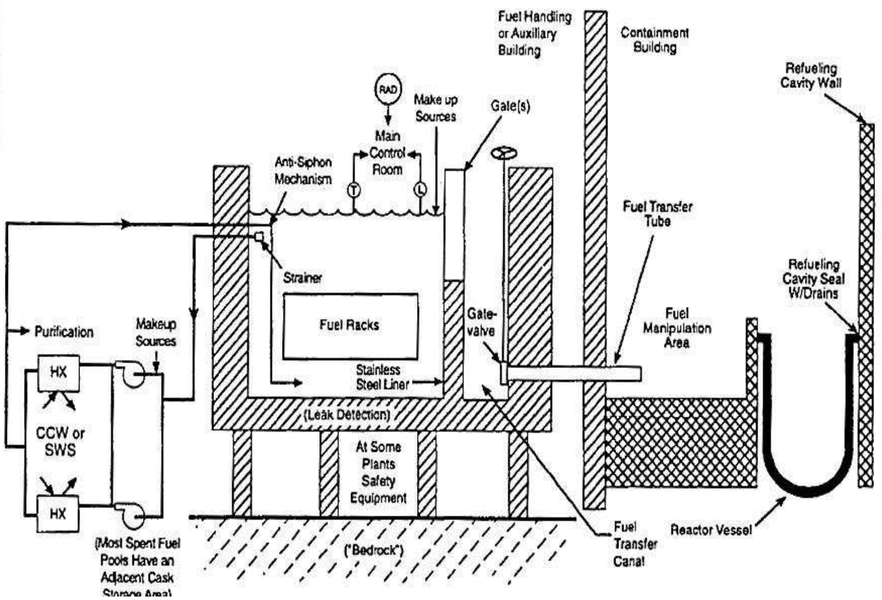
Royal Institute of Technology (KTH), Nuclear Power Safety Division

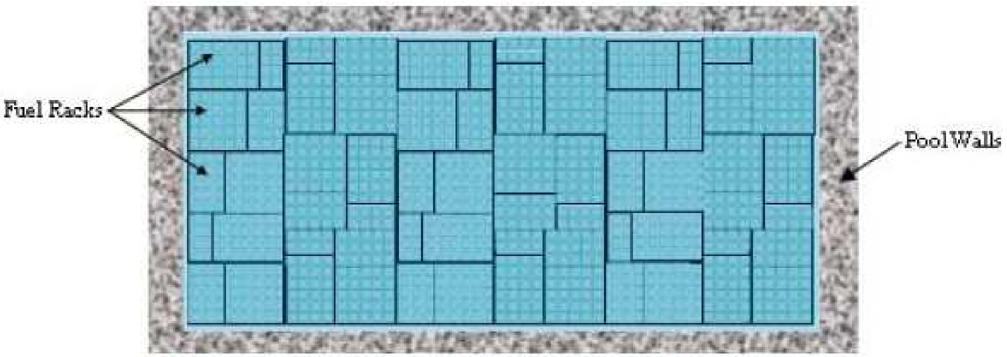
Outline

- Introduction
- Modeling
- Accident analysis
- Passive cooling system
- Concluding remarks

Introduction

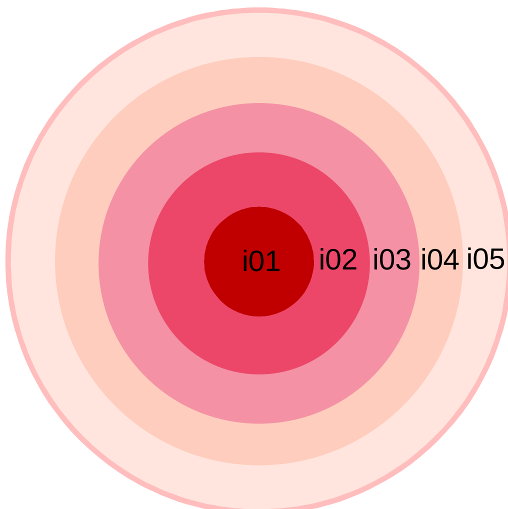
- The safety and risk assessment for beyond design basis accident (BDBA) in SFP is increasingly concerned after Fukushima accident.
- SFP design for PWR
- Representative initiating events:
  - loss of cooling
  - Loss of coolant (partial / complete)



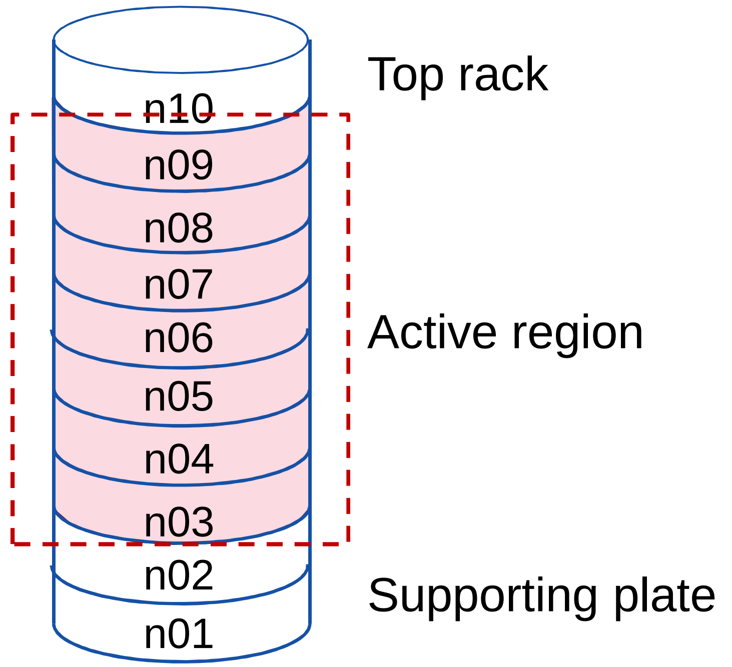


Modeling

Core nodalization



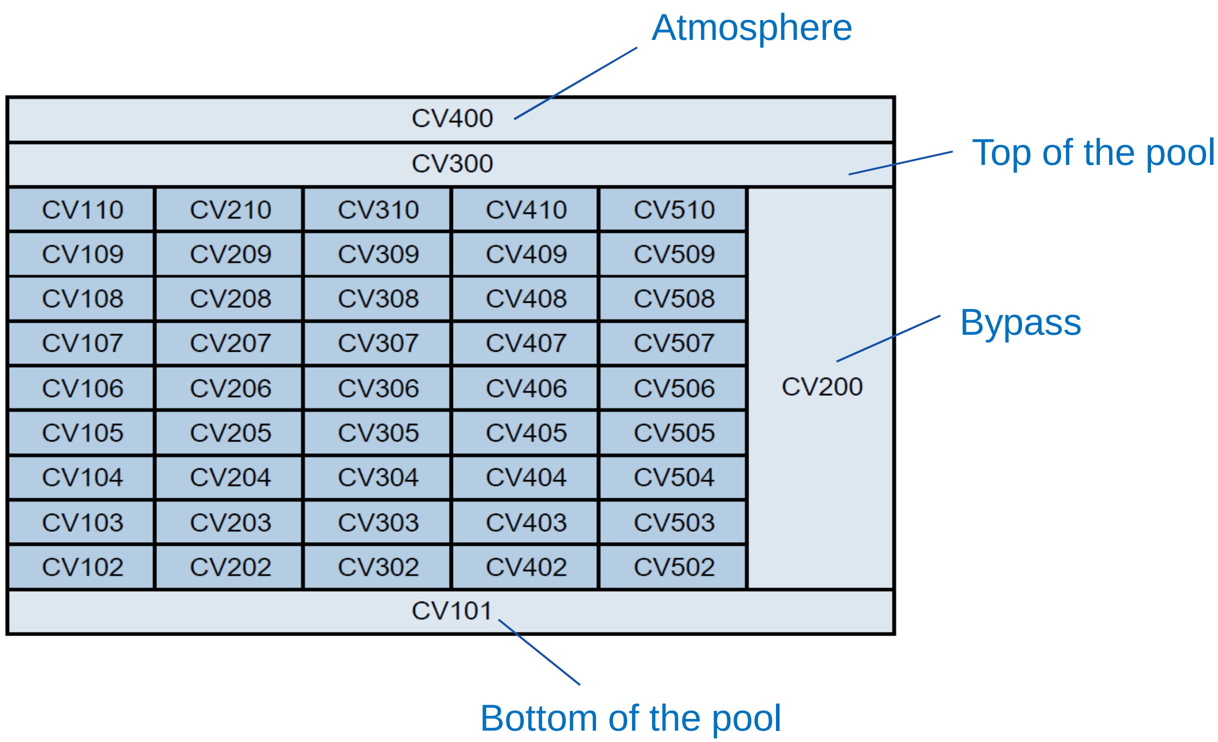
(a) radial



(b) axial

Modeling

Hydraulic CV nodalization



Accident analysis

Calculation matrix

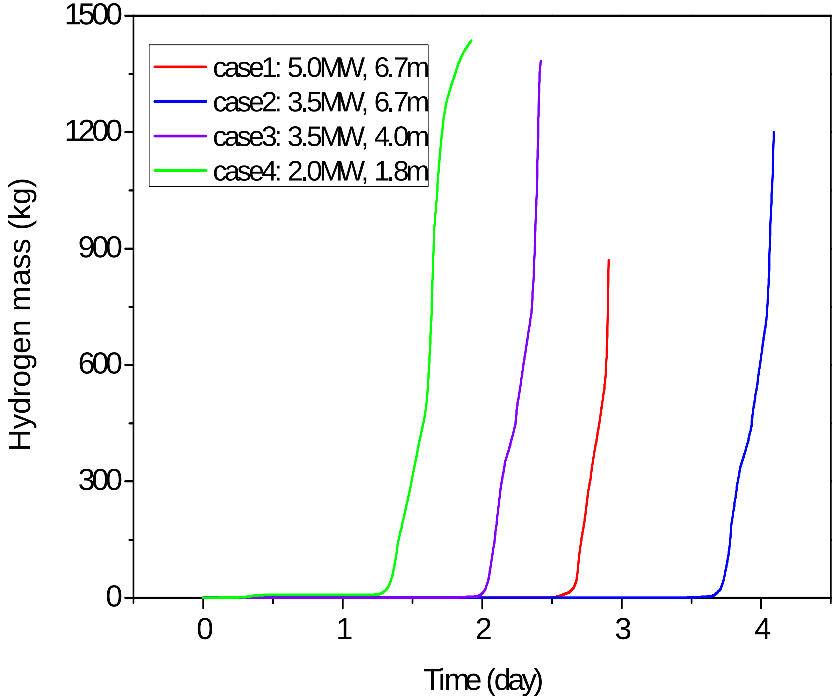
4 cases were selected, regarding the decay power level and initial water level.

Case	Decay power (MW)	Initial water level (m)
1	5.0	6.7
2	3.5	6.7
3	3.5	4.0(*)
4	2.0	1.8

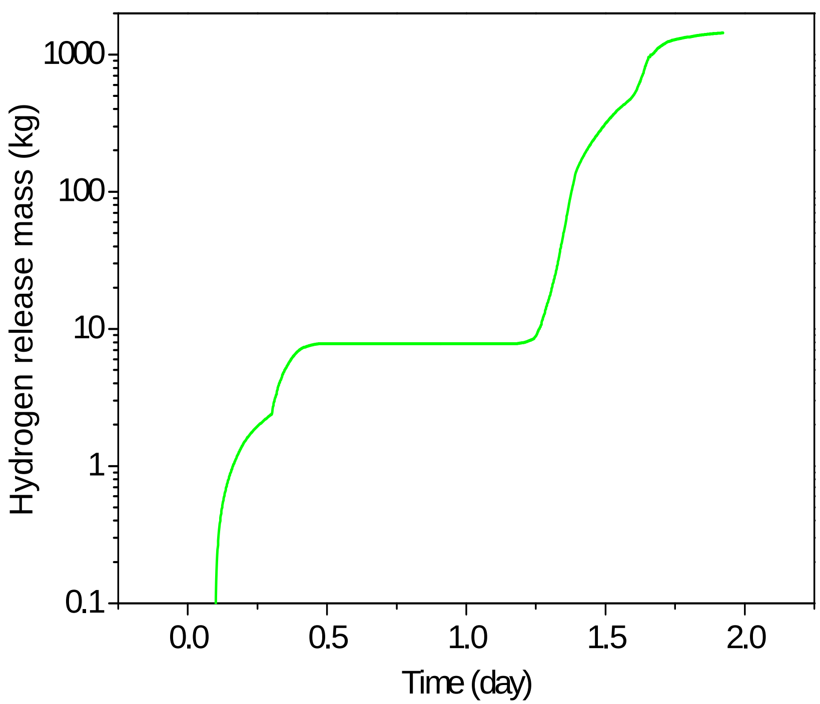
(*) 4.0m is the elevation of the top of the fuel assembly.

Accident analysis

Transient results



(a) For all cases

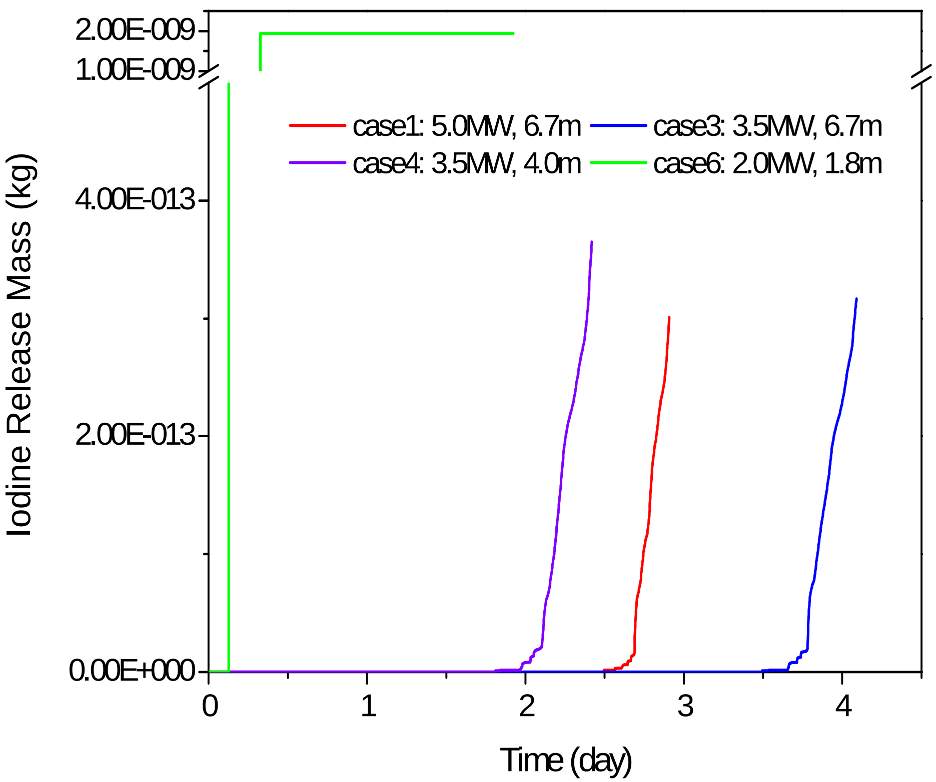


(b) Closeup of case 6

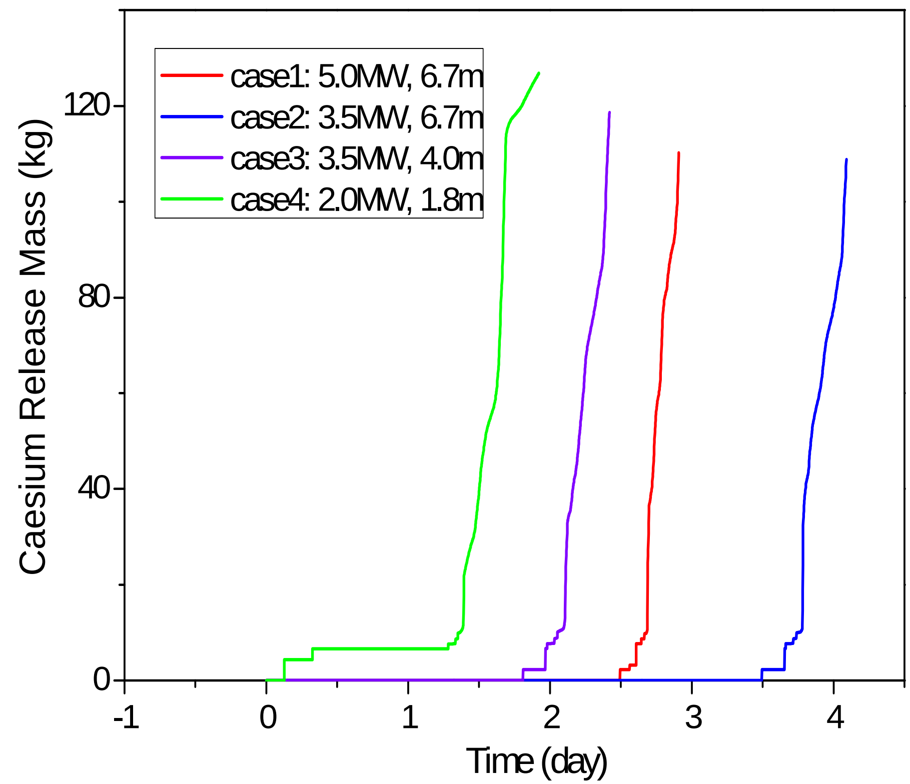
Accumulated mass of released hydrogen

Accident analysis

Transient results



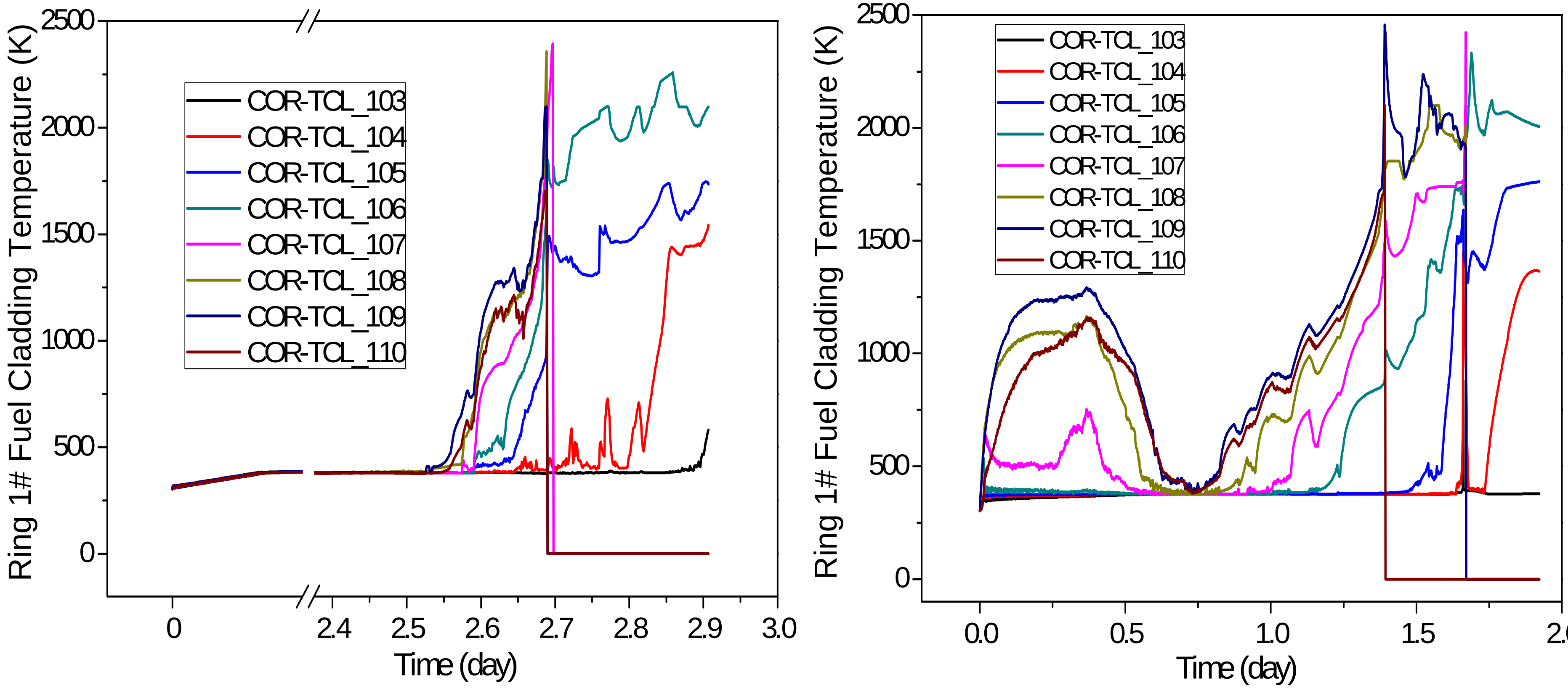
(a) Iodine Release Mass



(b) Cesium Release Mass

Accident analysis

Transient results



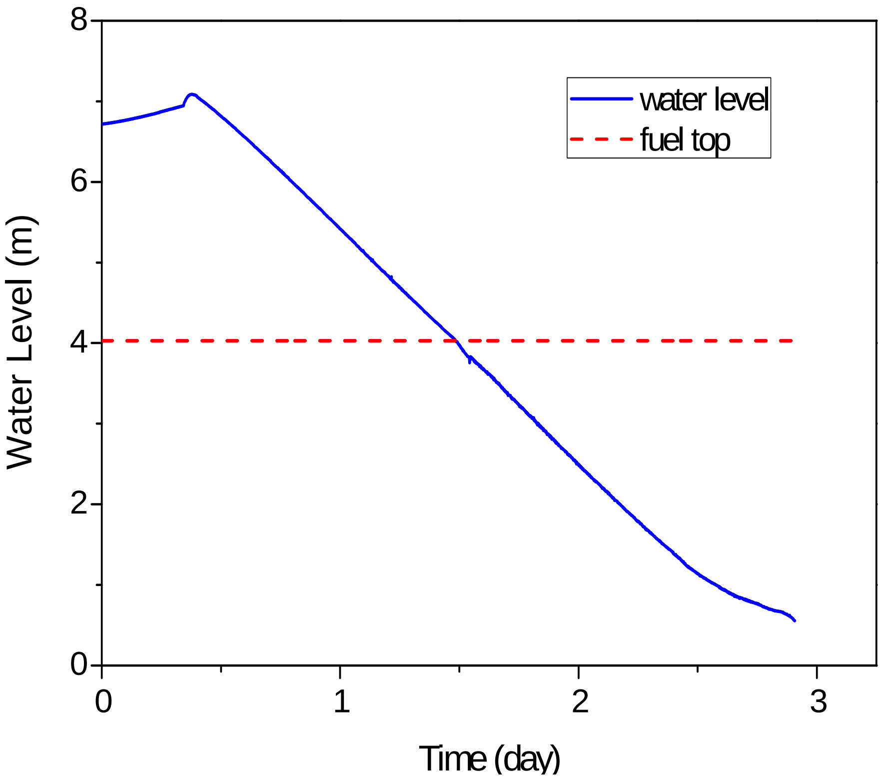
(a) Case 1

(b) Case 6

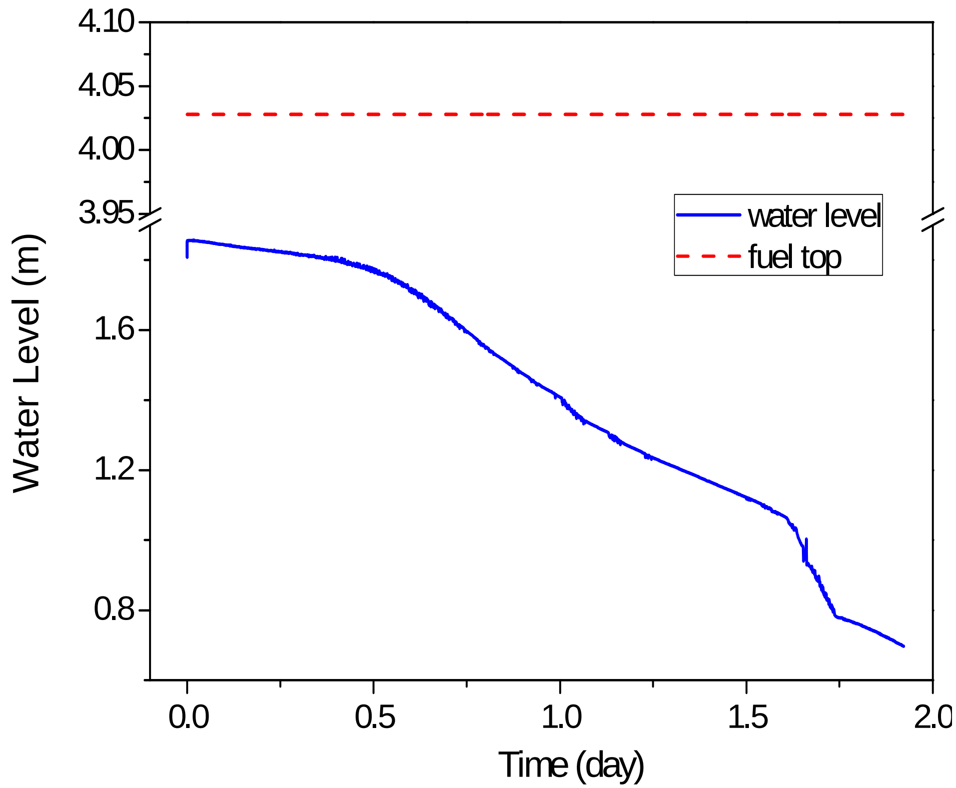
Cladding temperature of ring 1 of the core

Accident analysis

Transient results



(a) Case 1



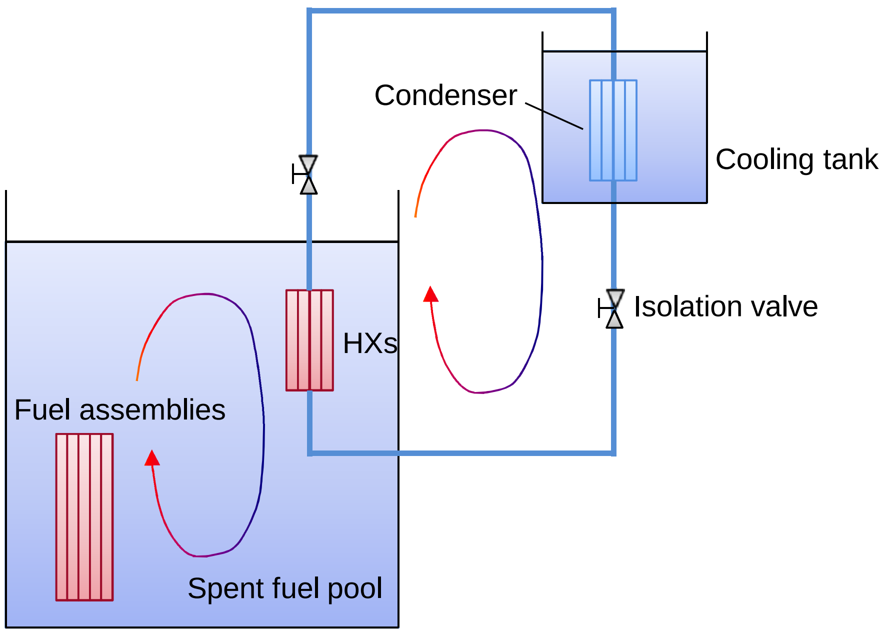
(b) Case 6

Water level in the SFP

Passive cooling system

Objectives and system

maintain the cooling under the SBO scenario up to at least 72 hrs

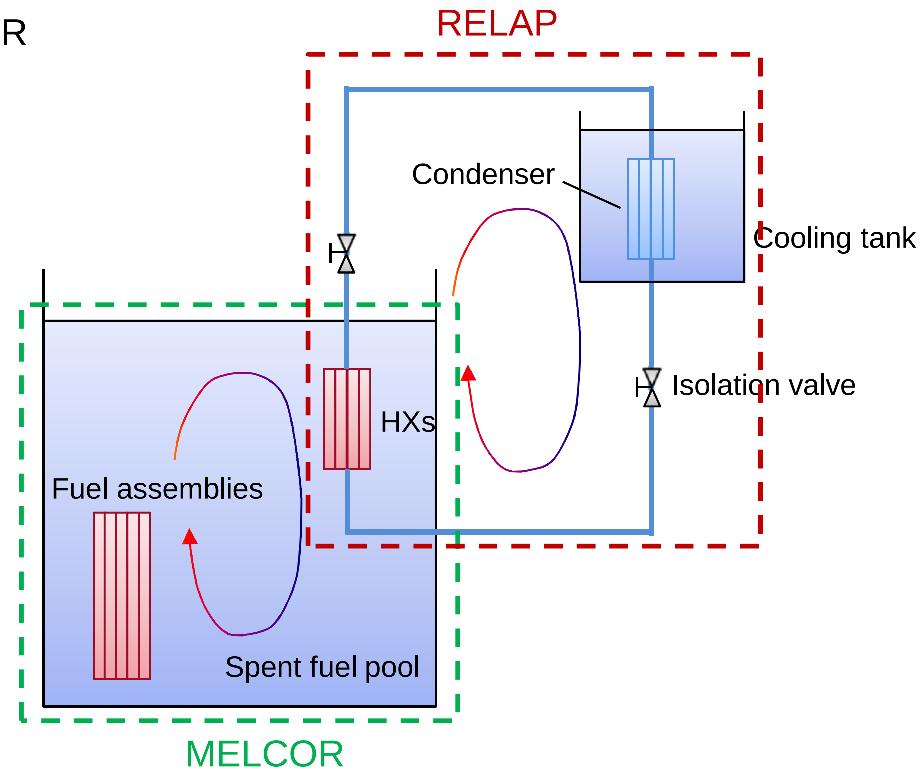


Schematics of the passive cooling system (PCS)

Passive cooling system

Coupling model

- The transient responses of the SFP and natural circulation loop (NCL) are calculated simultaneously by coupling MELCOR and RELAP.
- SFP: MELCOR
- NCL: RELAP

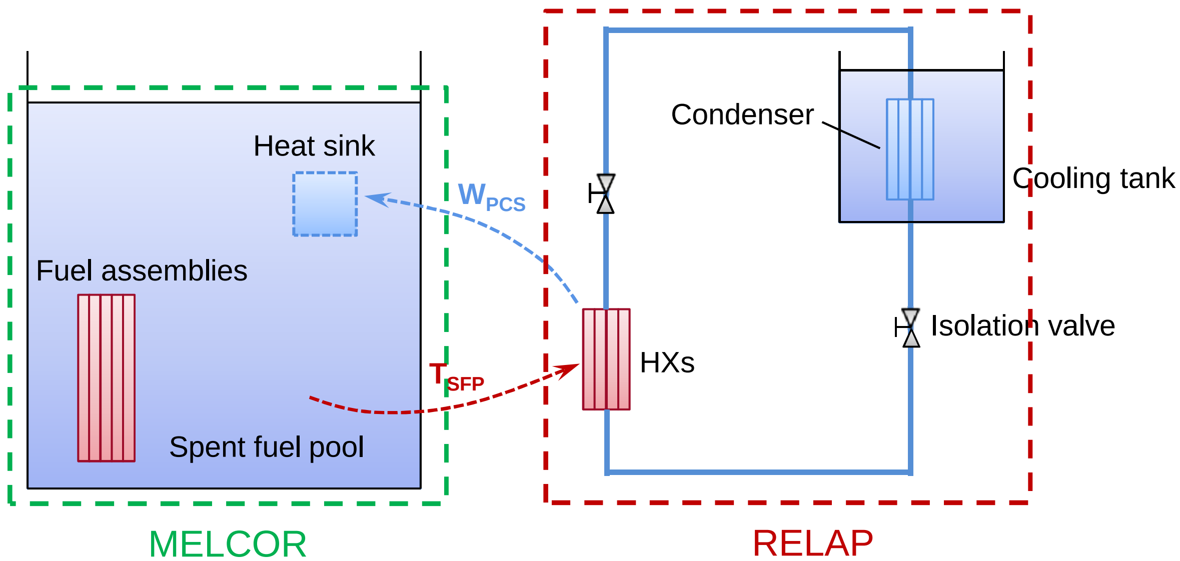


Passive cooling system

Coupling model

Variables to be exchanged:

- Temperature of the SFP (T_{SFP})
- Heat removal power of the PCS (W_{PCS})



Scheme of the coupling model

Passive cooling system

Coupling model

- Data communication: Named Pipes mechanism

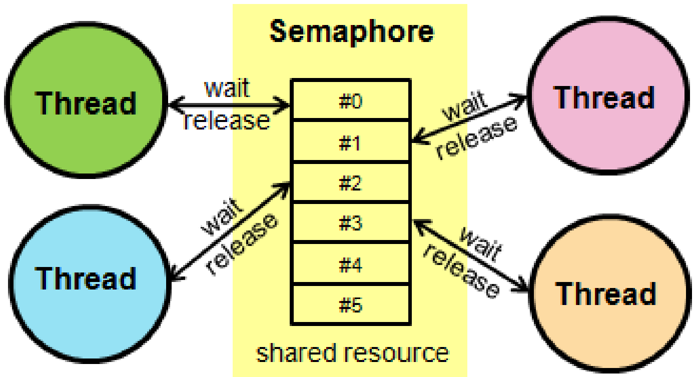
  A named pipe is a named, one-way or duplex pipe for communication between the pipe server and one or more pipe clients, which is one of the methods of inter-process communication (IPC).

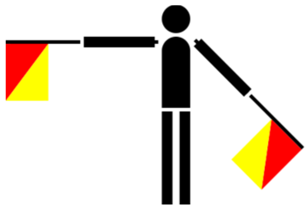
```
CF00100   ‘Ttank'  FUN1    5     300.0
CF00110   1.0      0.0       TIME
CF00111   1.0      0.0       CVH-TLIQ.200
CF00112   0.0      0.0       TIME
CF00113   0.0      0.0       TIME
CF00114   0.0      0.0       TIME
```

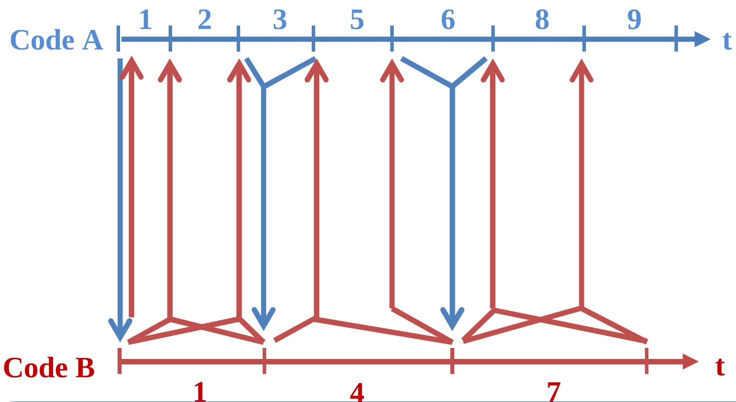
Passive cooling system

Coupling model

- Synchronization: Semaphore



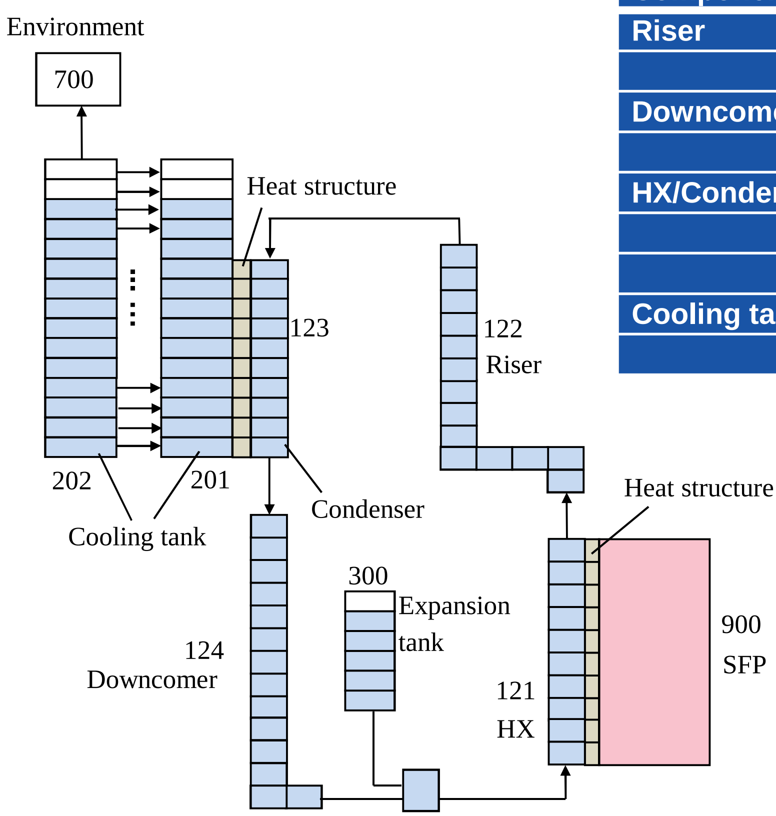




- During the calculation, one code will be forced to halt and wait if its current time is larger than counterpart's until it is surpassed.
- The data is obtained by interpolating the two most neighboring values.

Passive cooling system

Model of passive cooling system



Component	Parameters	Values
Riser	Diameter	0.45 m
	Length	10.0 m
Downcomer	Diameter	0.40 m
	Length	10.0 m
HX/Condenser	Diameter of tube	0.034
	Total heat transfer area	300 m^2
	Tube material	Stainless steel
Cooling tank	Depth	7.5 m
	Nominal Volume	1000 m^3

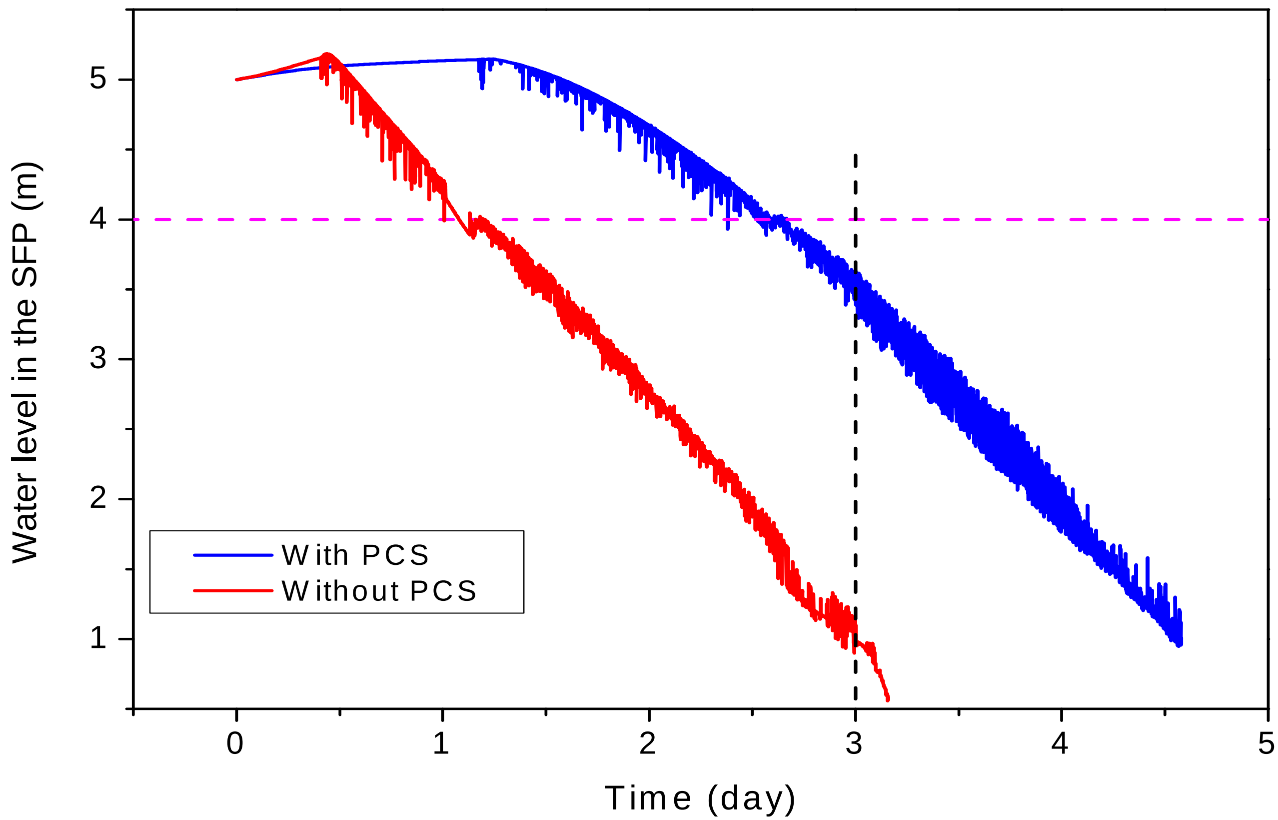
Passive cooling system

Calculation case

- The initial water level of SFP is 5.0m;
- The decay heat power if 3.0MW;
- The initial temperature of the loop and SFP is 30.0℃;
- The PCS is actuated at the time 0.0 sec;
- The fluid in the NCL of the PCS is initially stagnant.

Passive cooling system

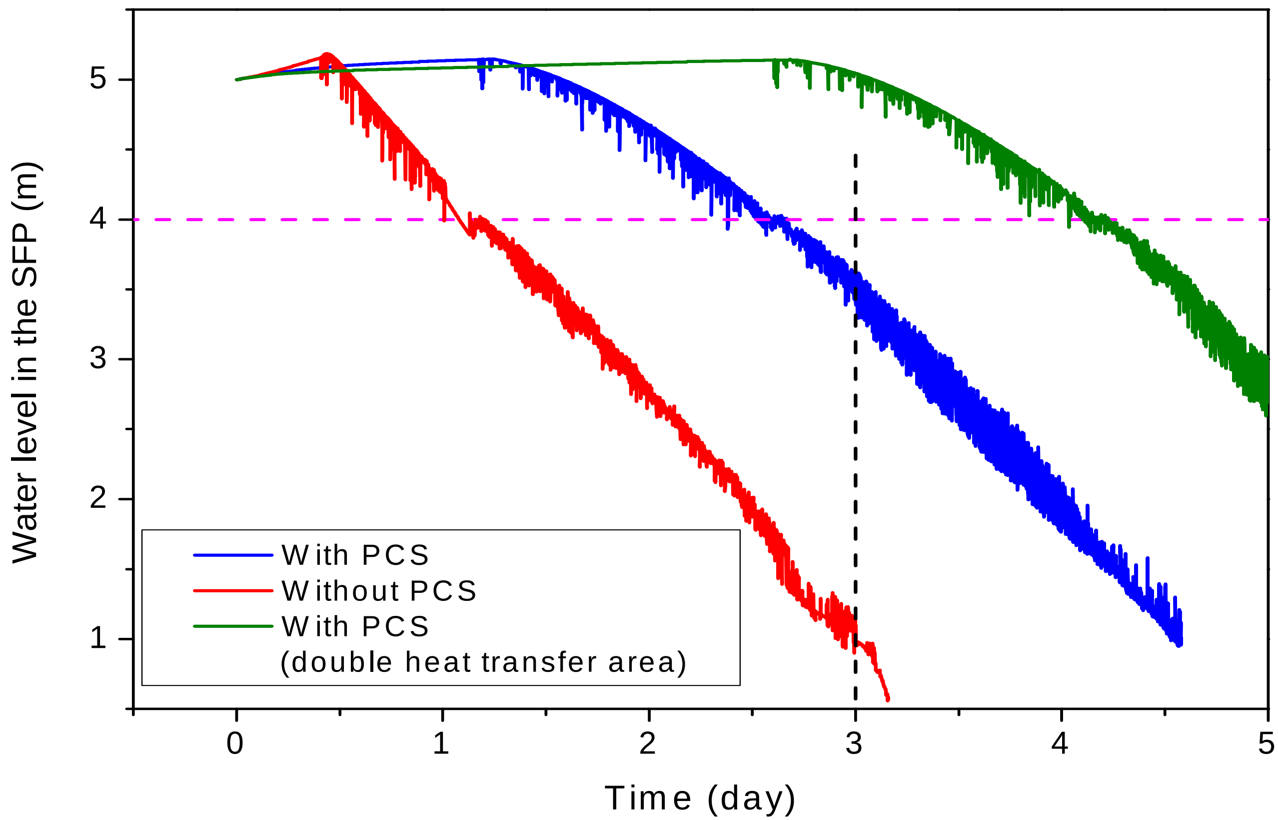
Simulation results



Water level (compared with the case without PCS)

Passive cooling system

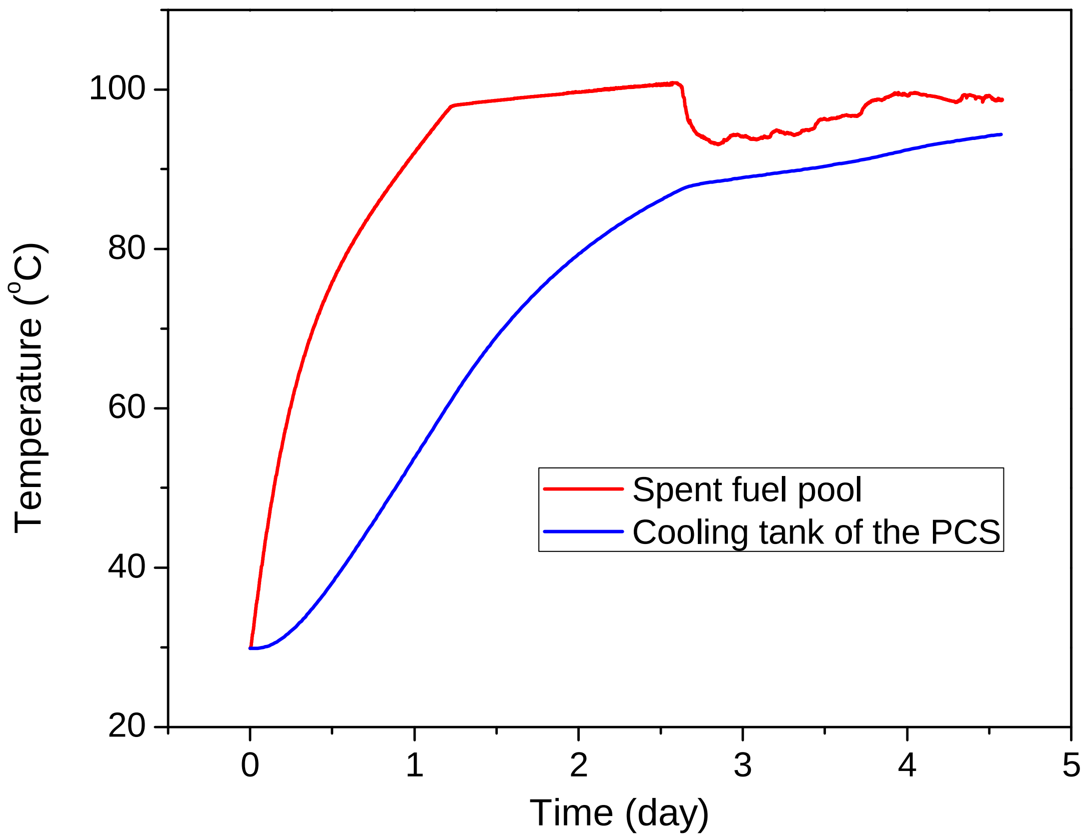
Simulation results



Water level (compared with the case without PCS)

Passive cooling system

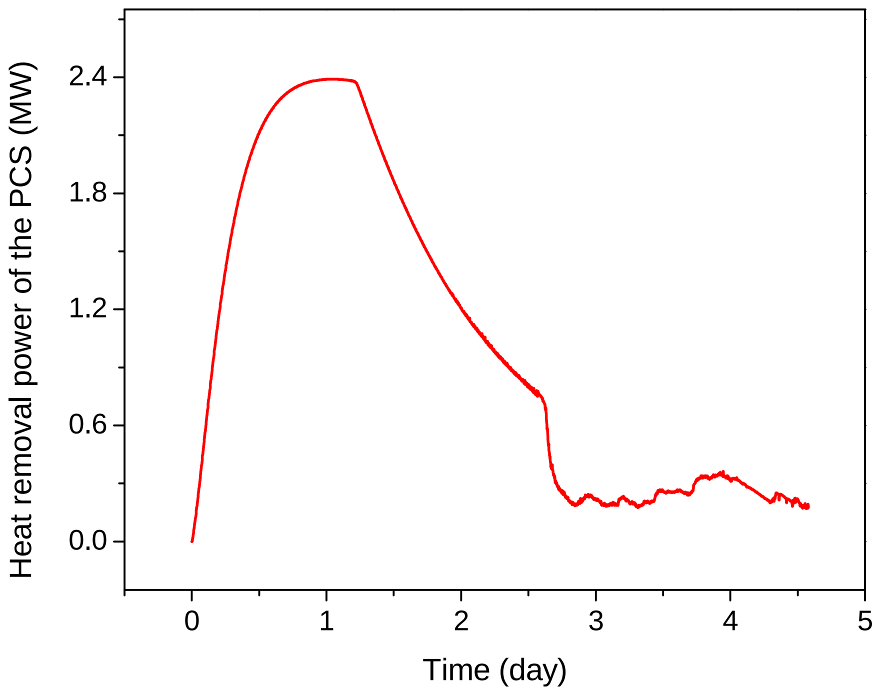
Simulation results



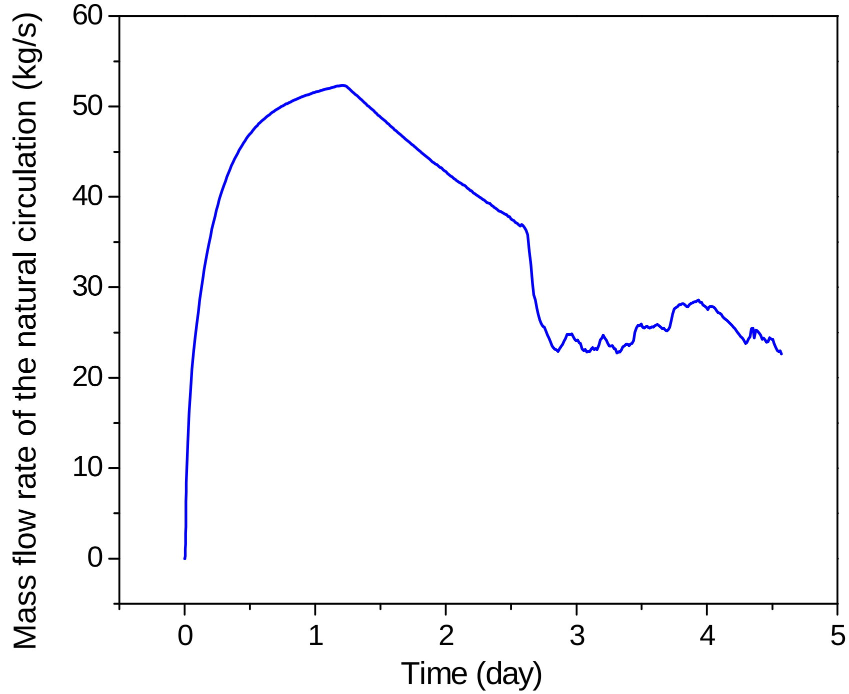
Temperature of SFP and PCS cooling tank

Passive cooling system

Simulation results



(a) PCS heat removal power



(b) Mass flow rate of NC of the PCS

Concluding remarks

- Simulation of a severe accident of the spent fuel pool of a prototypical was carried out. Generally, the calculation results are physically reasonable.
- To cope with the SBO, a passive cooling system design featuring a natural circulation loop is proposed, and evaluated by using coupling MELCOR and RELAP model. Results show that the PCS is able to effectively remove the heat and delay the early exposure of the fuel assemblies.
- However, due to the decrease of the temperature difference, the efficiency of the passive system decreases in the long term period. Further measures can be taken to enhance its performance:
  - Enlarge the heat transfer area of the HX and the condenser;
  - Increase the vertical height of the natural circulation loop;
  - Enlarge the pipe diameter to reduce the flow resistance;
  - Increase the volume of the cooling tank;
  - Refill and cool down the cooling tank water of PCS;

Thanks for your attention!