



# Simulation of Flow Behavior in the HANARO Reactor Pool by Using the MARS Code

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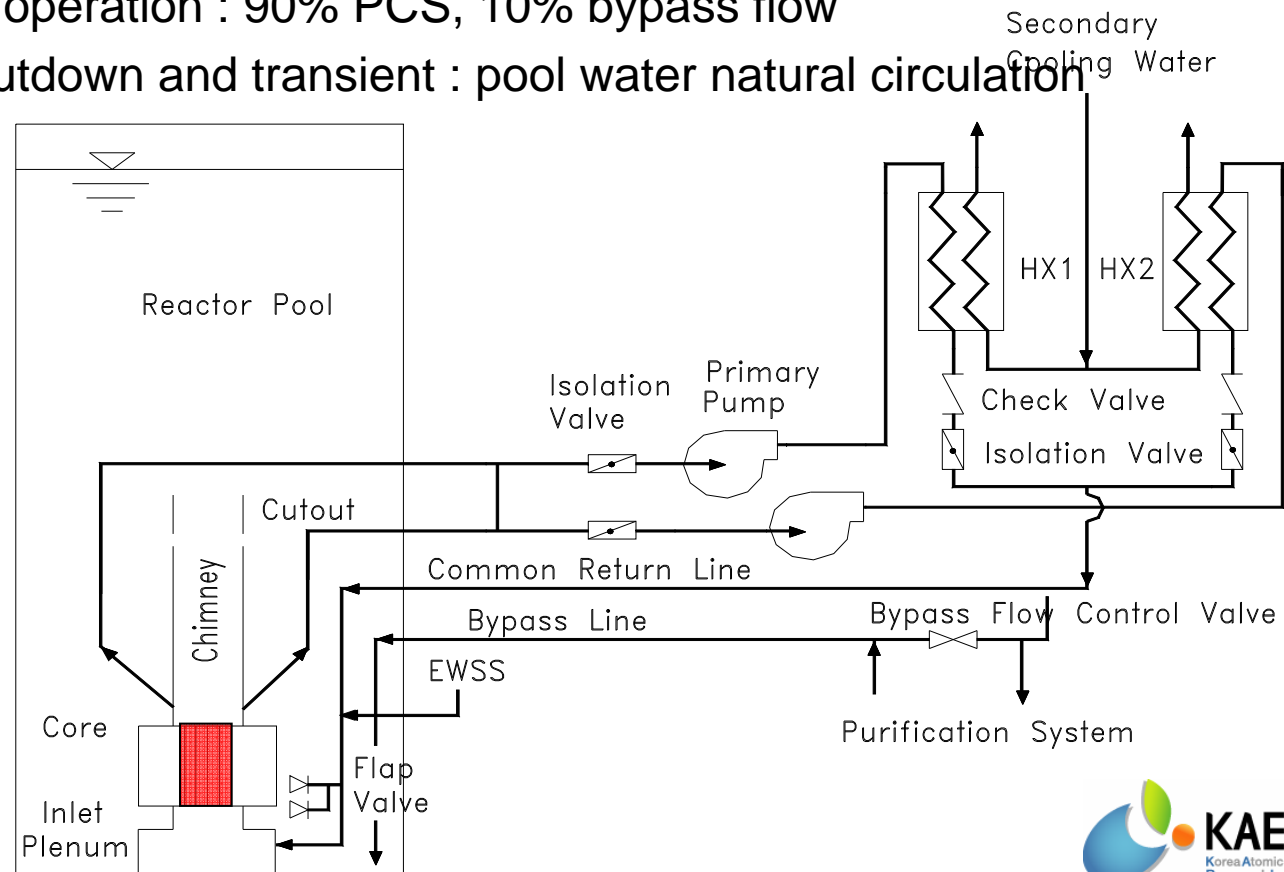
# Outline

- **Introduction**
- **Flow behaviours in the HANARO pool**
  - ❖ **Measurements**
  - ❖ **CFD analysis**
- **Simulation of the HANARO pool by MARS code**
- **Concluding remarks**

# Introduction (1/3)

## □ PCS of the HANARO

- ❖ Open-tank-in-pool type RR with 30MWth
- ❖ Upward forced convection cooling system
  - ◆ At normal operation : 90% PCS, 10% bypass flow
  - ◆ During shutdown and transient : pool water natural circulation



# Introduction (2/3)

## ❑ Concerned areas for 3D flow behaviors in HANARO

### ❖ Inlet Plenum

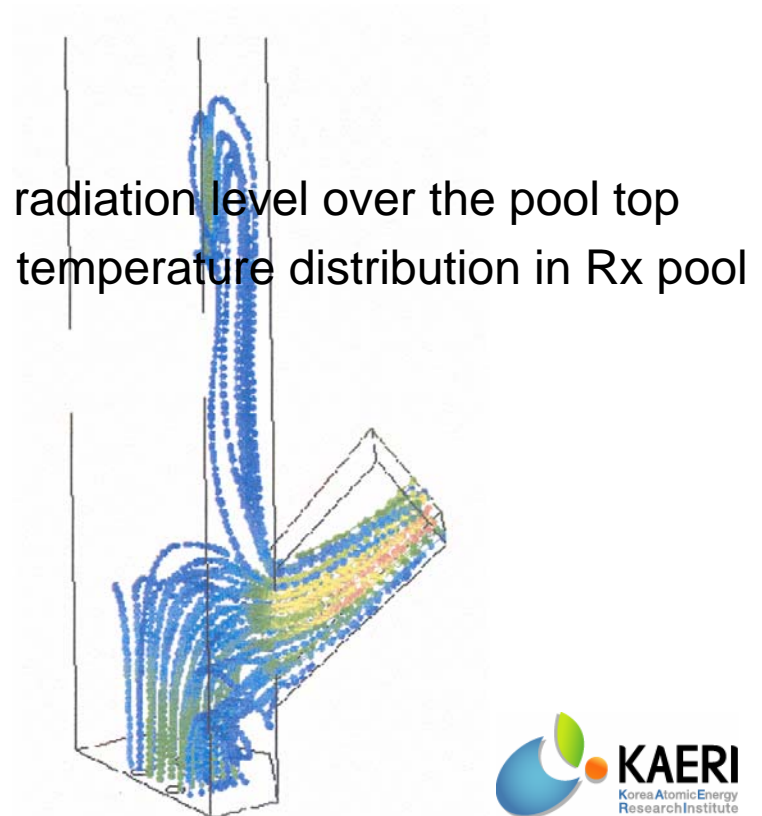
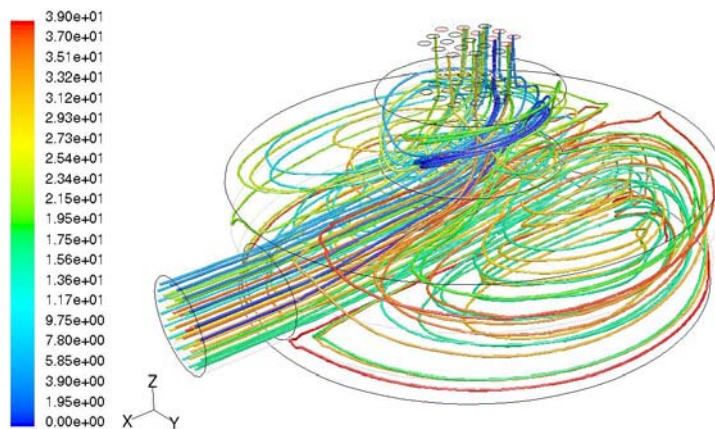
- ◆ Generation of vortex → a possible cause of fuel wearing

### ❖ Chimney

- ◆ Suppression of upward core flow

### ❖ Reactor pool

- ◆ Behavior of bypass flow in the pool → radiation level over the pool top temperature distribution in Rx pool



# Introduction (3/3)

## ❑ Multi-Dimensional T/H System Analysis Code, MARS

- ❖ Unification of RELAP5 (1D Module) and COBRA-TF (3D Module)
  - Multi-Dimensional TH Analysis Capability
- ❖ Coupled calculation capabilities
  - Three-Dimensional Reactor Kinetics Code, MASTER
  - Containment Analysis Code, CONTEMPT4 and CONTAIN

## ❑ Objective

- ❖ To simulate the HANARO reactor pool by MARS code from the viewpoint of practical operation and safety

# Flow behaviors in the HANARO pool (1/5)

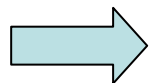
## □ Estimation from measurements

### ❖ In commissioning test,

- ◆ Core jet is suppressed by the bypass flow with  $> 5\%$  of PCS flow
- ◆ Radiation level at near pool surface : Measured  $>$  Calculated
  - One of reasons is bypass flow.
- ◆ Installation of a hot water layer (HWL) system

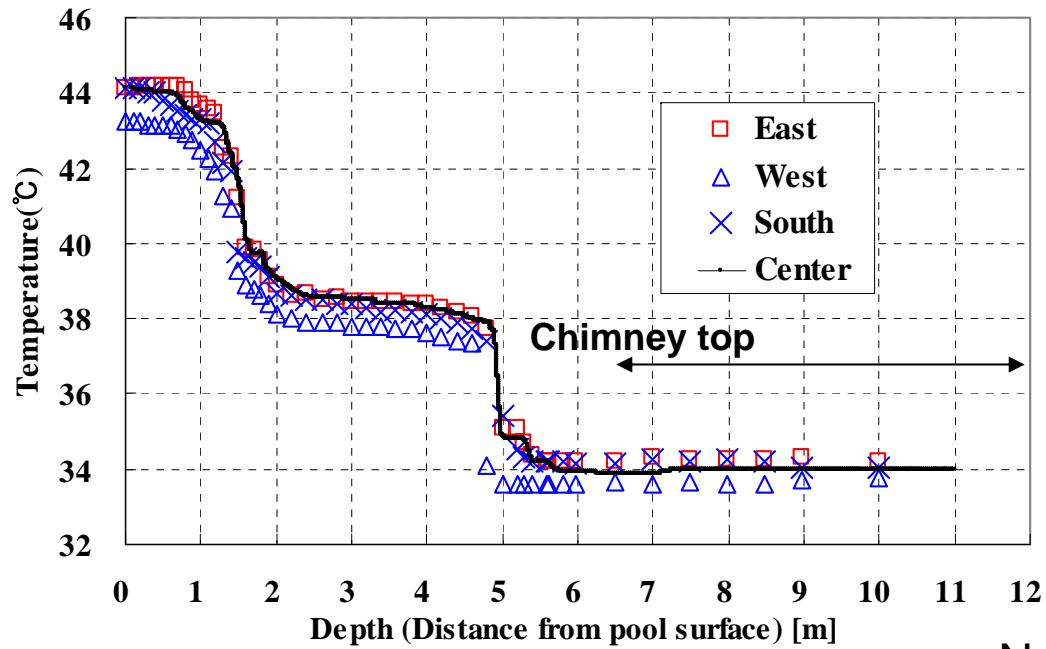
### ❖ Temperature and Na-24 Activity distributions in the pool

- ◆ 3 regions with different temperature
- ◆ Distribution of Na-24 activity

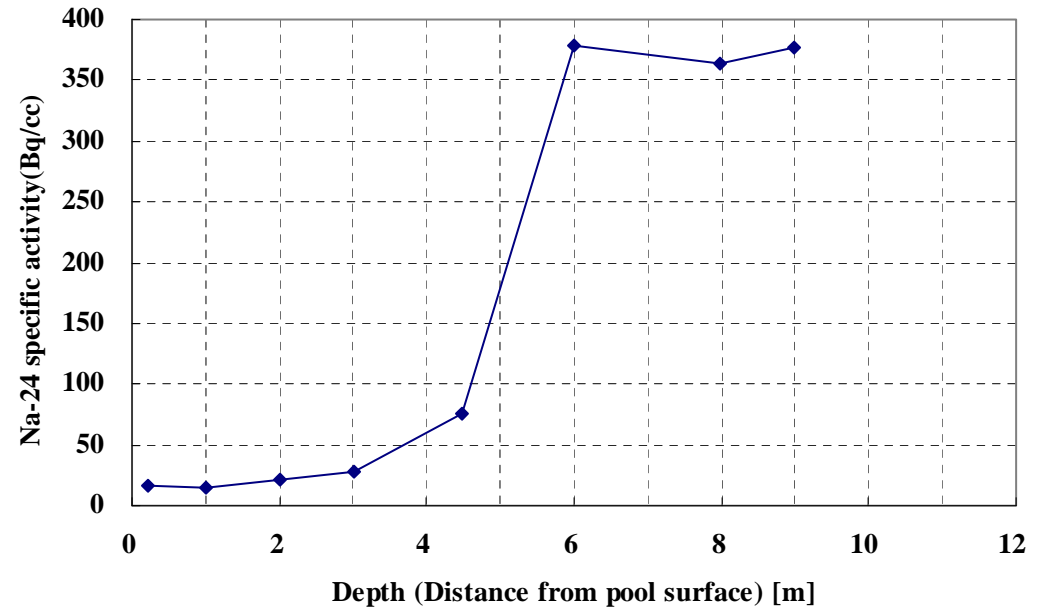


- Most of bypass flow is sucked into the chimney at near chimney top.
- Mixing the hotter water in HWL and the cooler pool water
- Asymmetric flow below 6 m

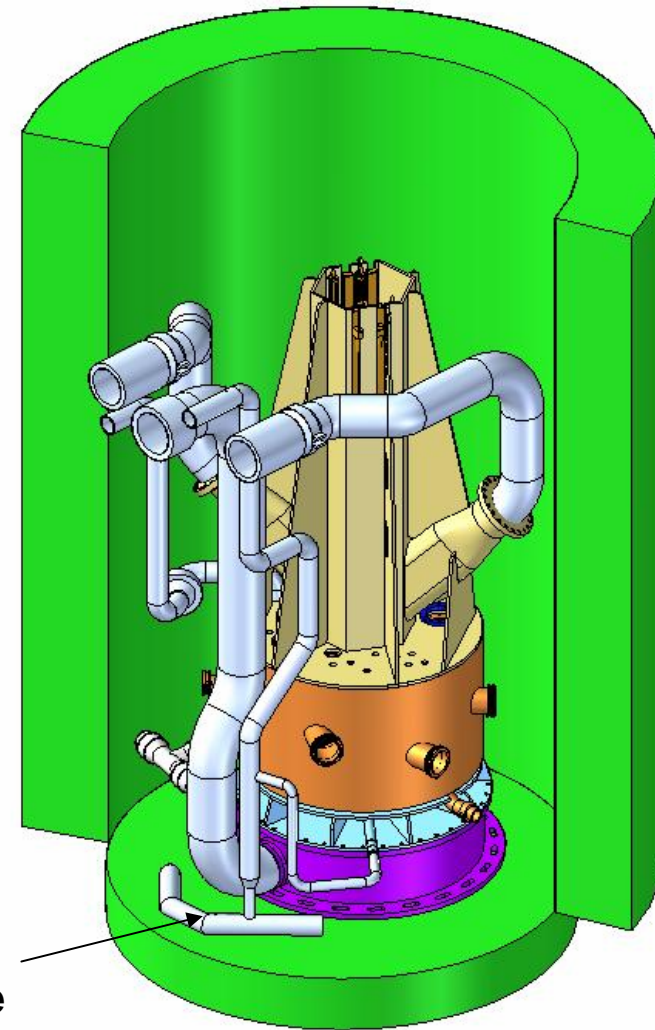
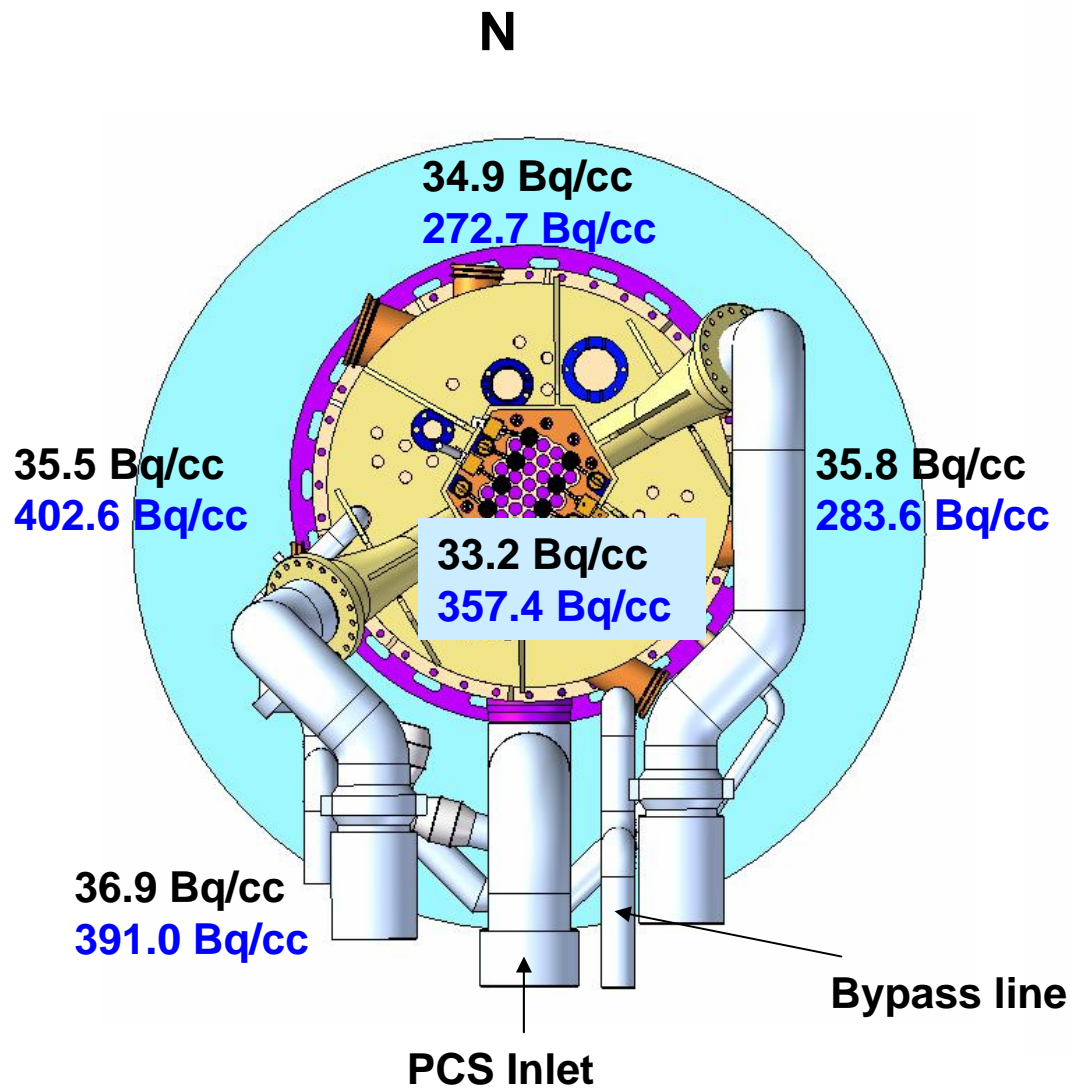
# Temperature distribution in the reactor pool



# Na-24 distribution in the reactor pool



# Flow behaviors in the HANARO pool (3/5)





# Flow behaviors in the HANARO pool (4/5)

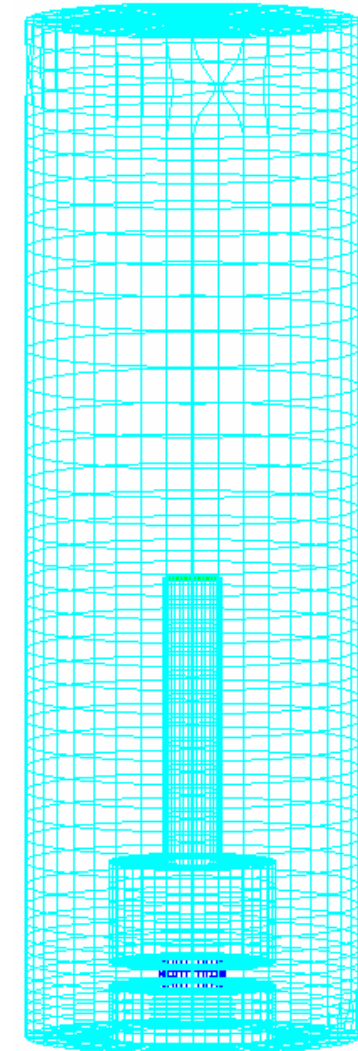
## □ CFX simulation

### ❖ Modeling

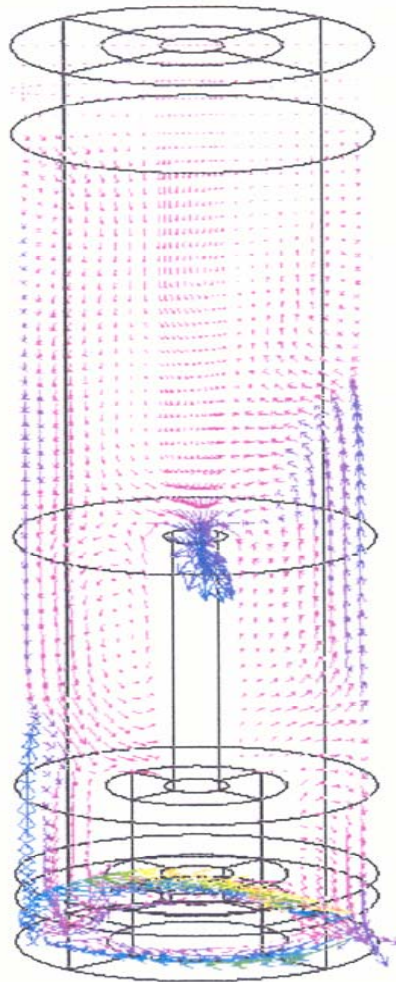
- ◆ Cell number : 17,620 & 28,600
- ◆ Flow split : 1 vs 1.5
- ◆ How water layer : 45 °C

### ❖ Results

- ◆ Most of bypass flow are sucked into the chimney.
- ◆ But, a part rises upwards to the pool surface, forming a counter clockwise outer circulating flow.
- ◆ Show similar temp. distribution with the measurement
- ◆ HWL is well maintained if the .

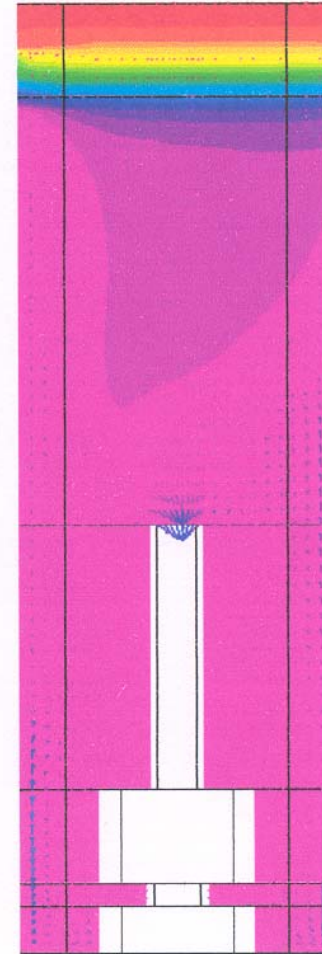
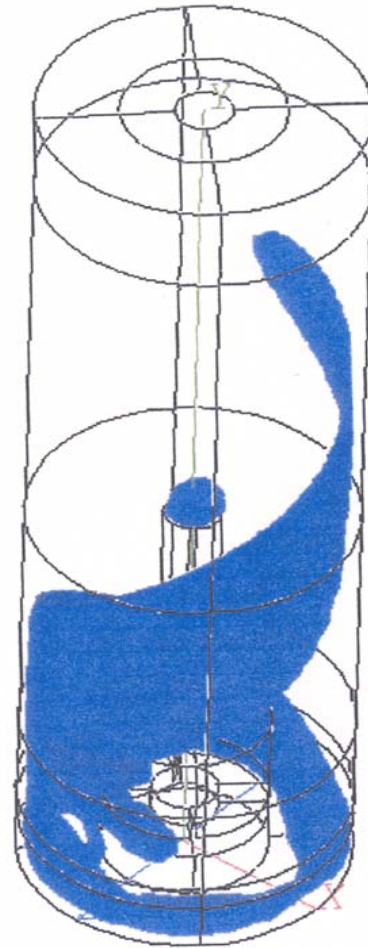


# Flow behaviors in the HANARO pool (5/5)



8.1074E-01  
6.7562E-01  
5.4050E-01  
4.0537E-01  
2.7025E-01  
1.3512E-01  
0.0000E+00

speed\_zp

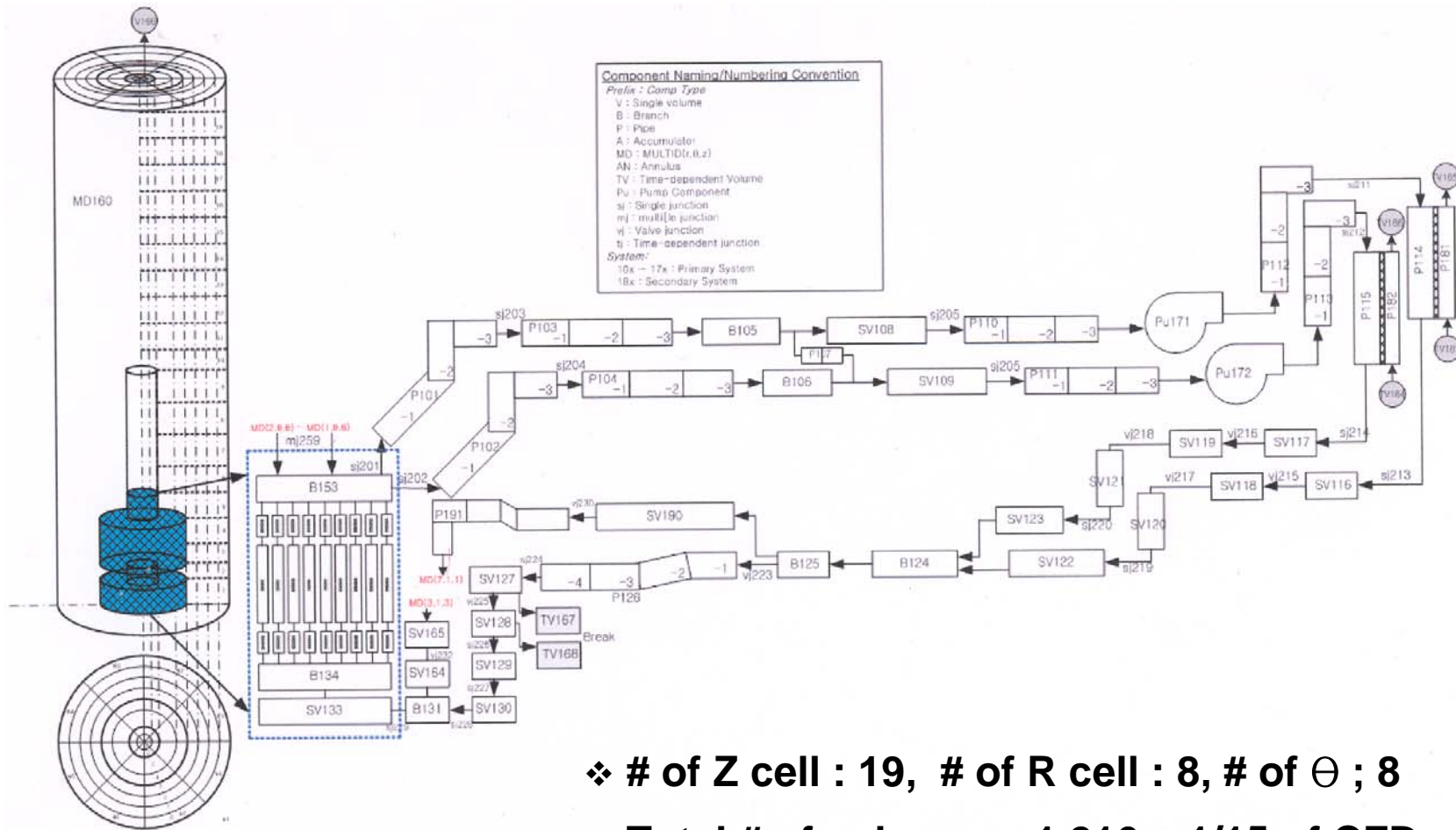


3.1577E+02  
3.1447E+02  
3.1318E+02  
3.1188E+02  
3.1059E+02  
3.0929E+02  
3.0800E+02

RxPool

# MARS simulation of the HANARO Pool (1/3)

## □ Nodalization of the HANARO



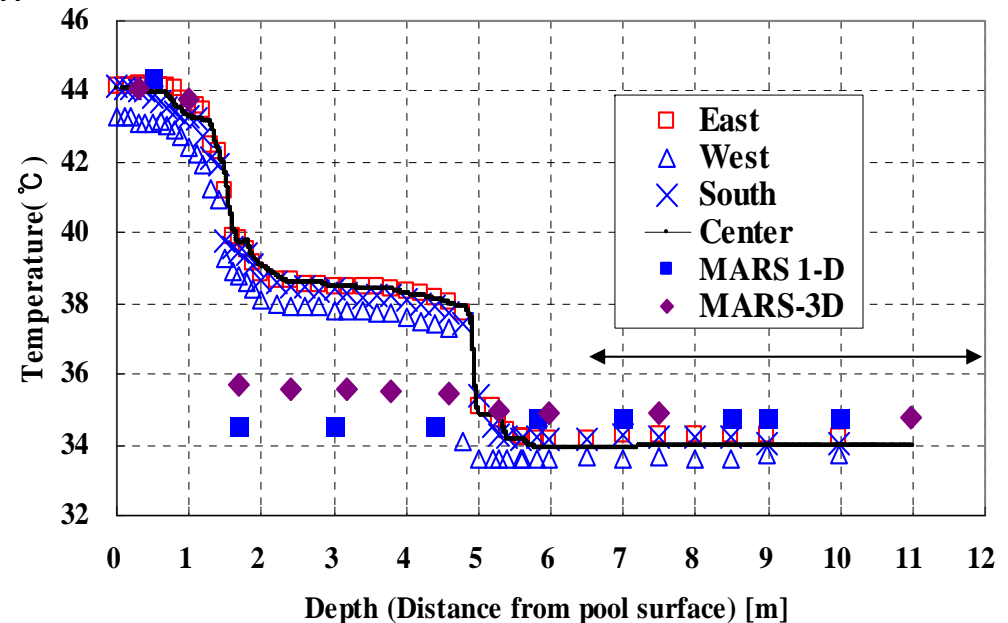
❖ # of Z cell : 19, # of R cell : 8, # of  $\Theta$  ; 8

❖ Total # of volumes : 1,216 < 1/15 of CFD

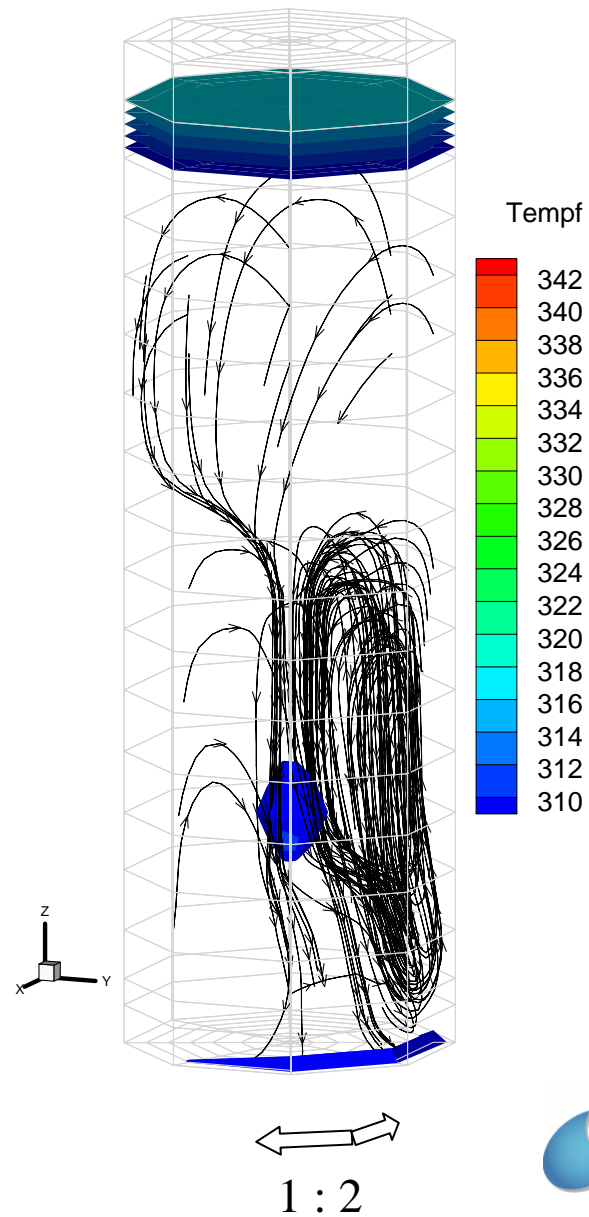
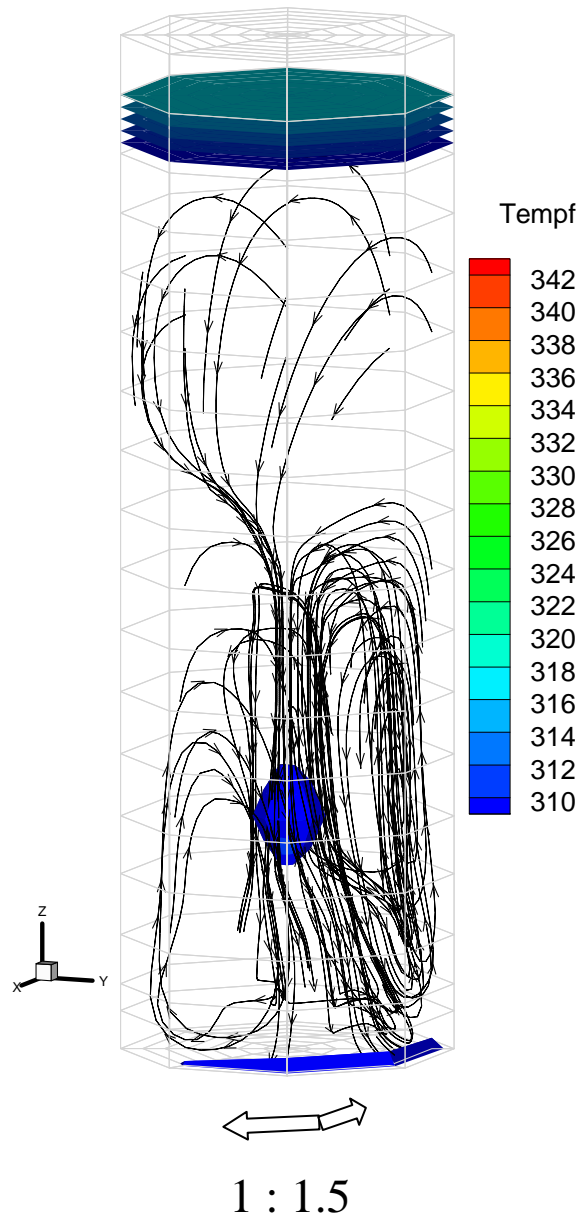
# MARS simulation of the HANARO Pool (2/3)

## □ Simulation results

- ❖ Simulation
  - ◆ With a typical 1-D Nodalization for reactor pool
  - ◆ With 3-D Nodalization
- ❖ In overall, similar flow pattern with actual conditions
- ❖ Axially dominant flow, less circulating flow than that by CFD
  - ◆ Relatively smaller nodes
  - ◆ 1-D based solution method
- ❖ But, increased temperature in the middle region for calculation with 3-D nodalization



# MARS simulation of the HANARO Pool (3/3)



# Concluding Remarks

- ❑ **Understandings of 3-D flow behaviours in the HANARO pool**
- ❑ **Simulation by the MARS code showed**
  - ❖ the possibility to give reasonable prediction for the 3-D flow behaviour in the HANARO reactor pool
  - ❖ the necessity to consider 3-D behaviour for 1-D calculation
- ❑ **This capability may be useful to predict the effect of 3-D flow phenomena in a RR on**
  - ❖ the core thermal margin during flow reversal transient
  - ❖ the establishment of natural circulation



Thank you for your attention !!!

