The Loss of Spent Fuel Pool Cooling Analysis during Plant Outage for OPR1000

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Kim, Cheolwoo

(cwkim@kepco-enc.com)

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KEPCO E&C

NSSS Division

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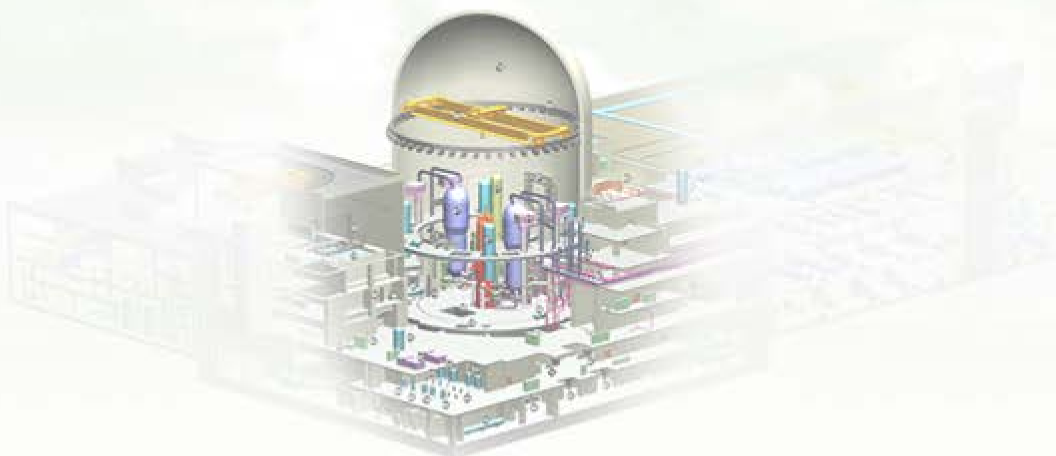


1. Introduction

❖ Recent Requirement

- Spent Fuel Pool (SFP) Analysis during Plant Outage
  <- Fukushima disaster

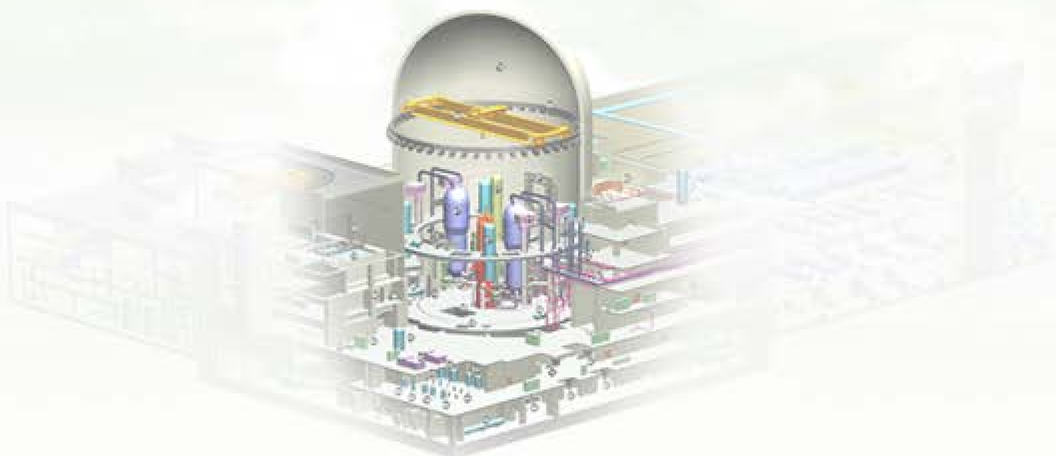
❖ Purpose

- To Establish the Success Criteria for the Probabilistic Safety Assessment (PSA)
- Thermal-Hydraulic (TH) Analysis of a Loss of Spent Fuel Pool Cooling (LOSFPC) during the Refueling Period (POS 8)
- To Investigate the Incipient Boiling Time, Time to Uncover, Time of Fuel Cladding Failure

❖ Reference Plant

- OPR1000: Hanul Nuclear Power Plant Units 3&4 (HUN 3&4)

2. Analysis Method of LOSFPC

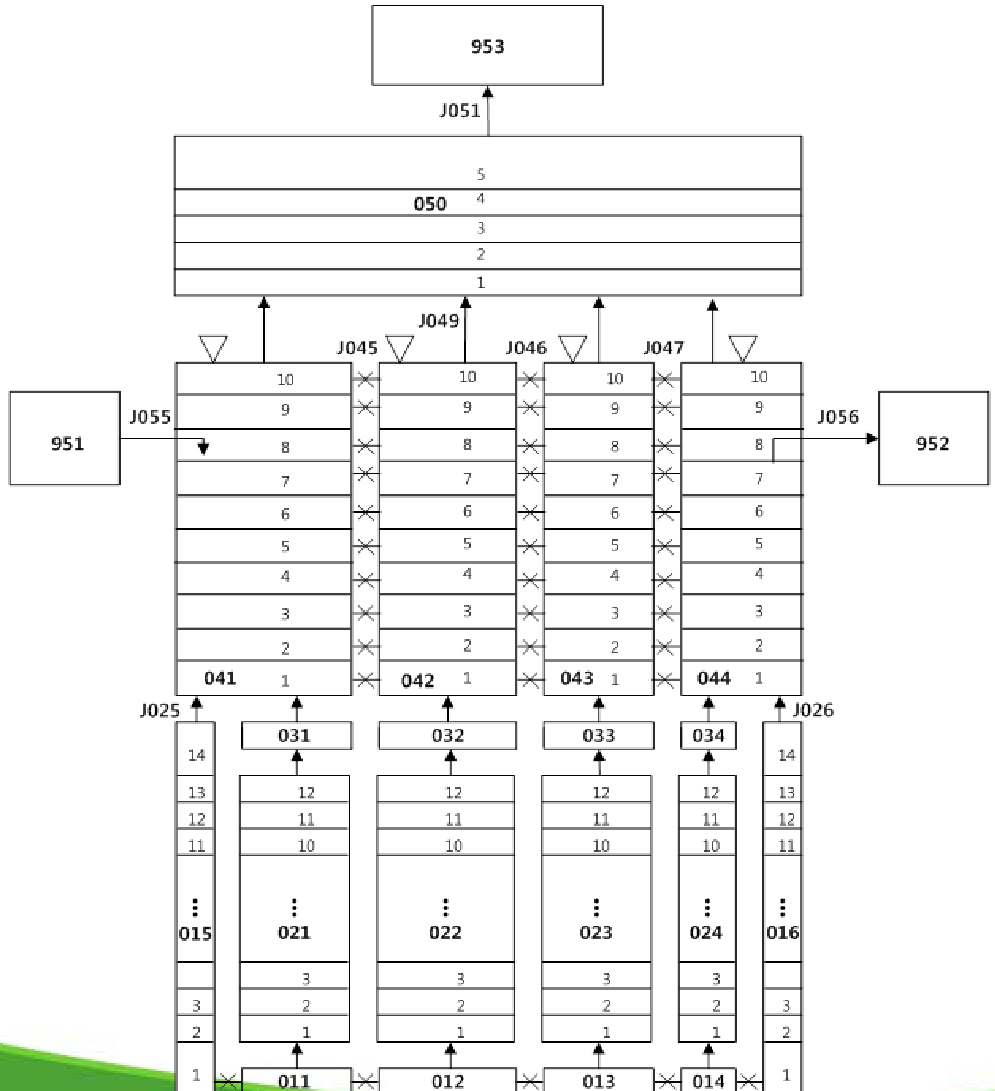


2. Analysis Method of LOSFPC

- Realistic and Best Estimate Analysis Method
- Reasonable Operating Conditions for Realistic PSA Model
- Computer Code: RELAP5/MOD3.3-Patch 4
- 20 Years of SFP for HUN 3&4 with Full Core Discharge
  - 12-month cycle: 6 batches
  - 15-month cycle (transition from 12-month to 18-month): 3 batches
  - 18-month cycle: 7 batch including full core discharge
- Plant Design States
  - Replacement of SG and Power Uprated
  - High Density Stored Racks

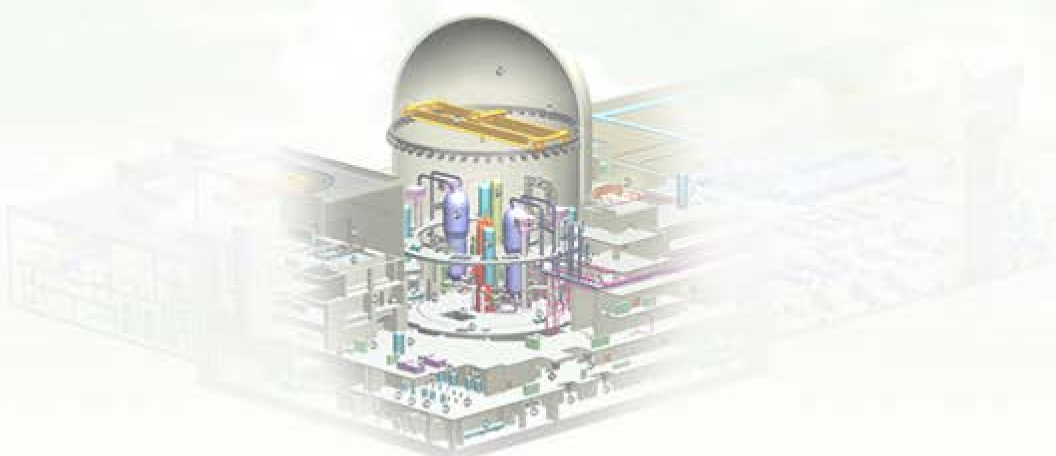
2. Analysis Method of LOSFPC

❖Node Diagram (Fig.1)



Nodes 21: Racks for Prev. Spent Fuels (Region-II)
Nodes 22: empty racks
Nodes 23: Avg FAs (Region-I)
Nodes: 41~44: Spent Fuel Pools above Racks

3. Assumptions and Initial Conditions



3. Assumptions and Initial Conditions

❖ Major Assumptions

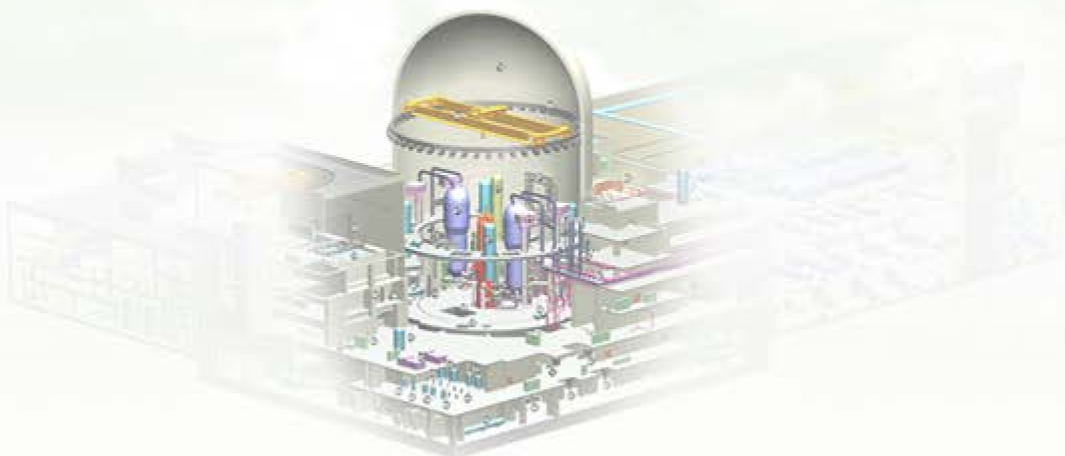
- Full Core is Discharged to Region-I for Refueling
- New Fuel Assemblies for Refueling is in Region-I
- All Gates are Closed
- Newly Discharged Full Core Fuels: 200 hrs after Rx Shutdown (vs. 233.7 hrs from PSA group)
- Previous Spent Fuels are All 54,000 MWD/MTU (54 months or 3 cycles of 18-month fuels) Stored in Region-II
- ANS2005 Standard Decay Heat with 2 sigma uncertainty (8%)
- Considered Nuclides: U^{235}(0.46), U^{238}(0.07), Pu^{239}(0.38), Pu^{241}(0.09) for Plus 7 Fuel
- Maximum FA of 68 for Each Batch
- No Heat Transfer through Metals except Fuels
- No Mass & Heat Transfer through Water Surface
- Constant Heat Generation of Stored Spent Fuels
- No Cross Flow between Racks
- No Radiation Heat Transfer
- Flat Axial Power Shape of Fuels

3. Assumptions and Initial Conditions

❖ Initial Conditions

Parameters	Values	Remark
SFP Surface Pressure	101,325 Pa (1 atm)	-
SFP Surface Temperature	60 °C (333.15 K)	Max
Elevation of SFP Bottom	100.5 ft	-
Elevation of SFP Water Surface	142 ft (7.896 m above racks)	Nom
Decay Heat from SFs for 20 years	1.3547 MWt	-
Decay Heat from Full Core Discharge	9.167 MWt	
SFPC HX Flow Rate	2850 gpm (178 kg/s)	Min

4. Analysis Results



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4. Analysis Results

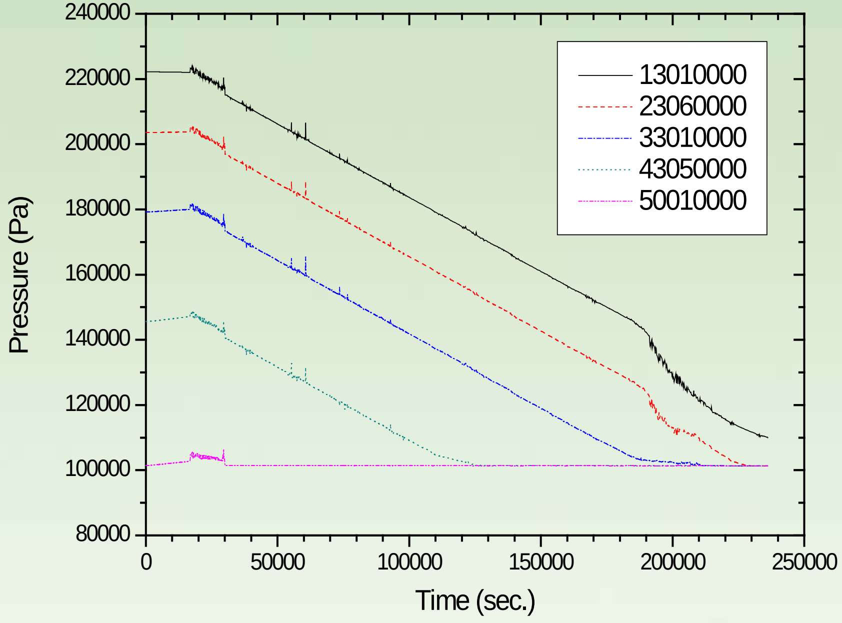


Fig.2 Pressure Distribution of SFP

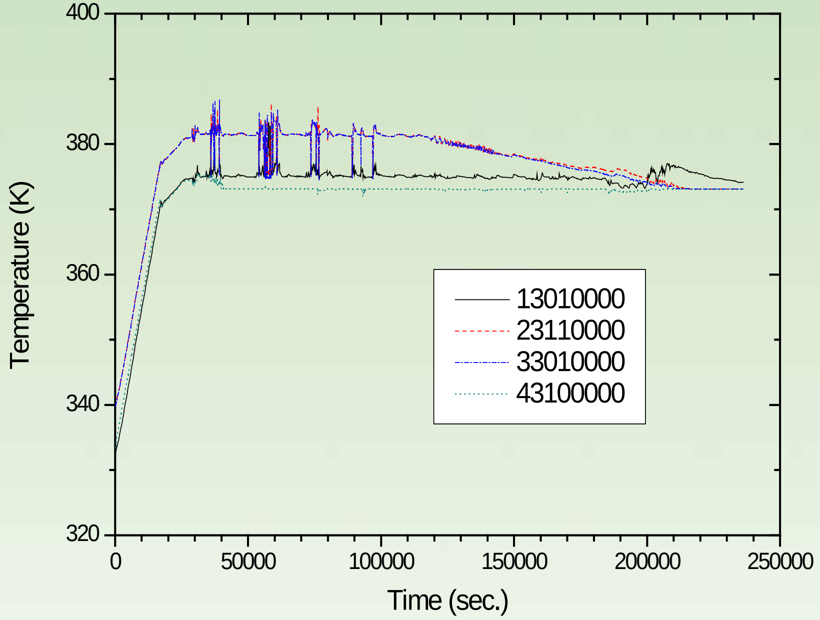


Fig.3 Temperature Distribution of SFP

4. Analysis Results

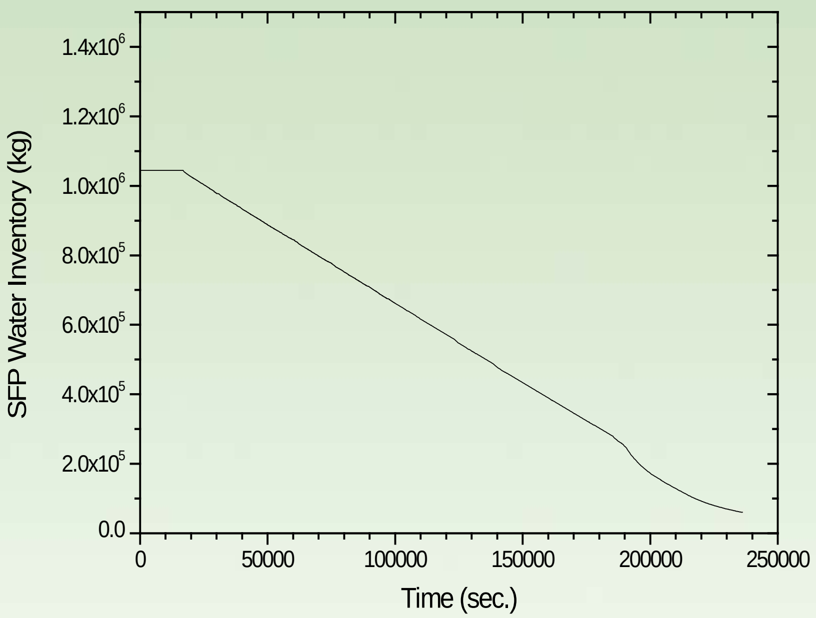


Fig.4 Water Inventory in SFP

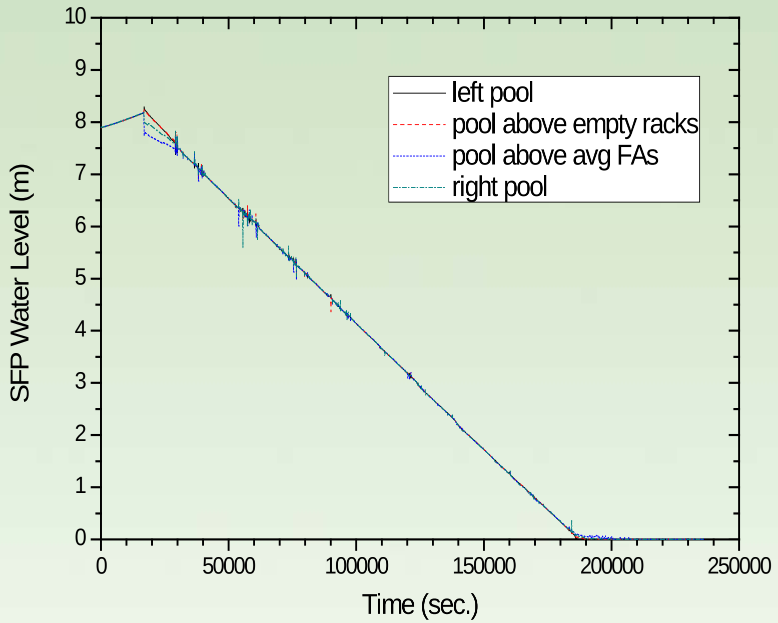


Fig.5 Water Level of Pool Above Racks

4. Analysis Results

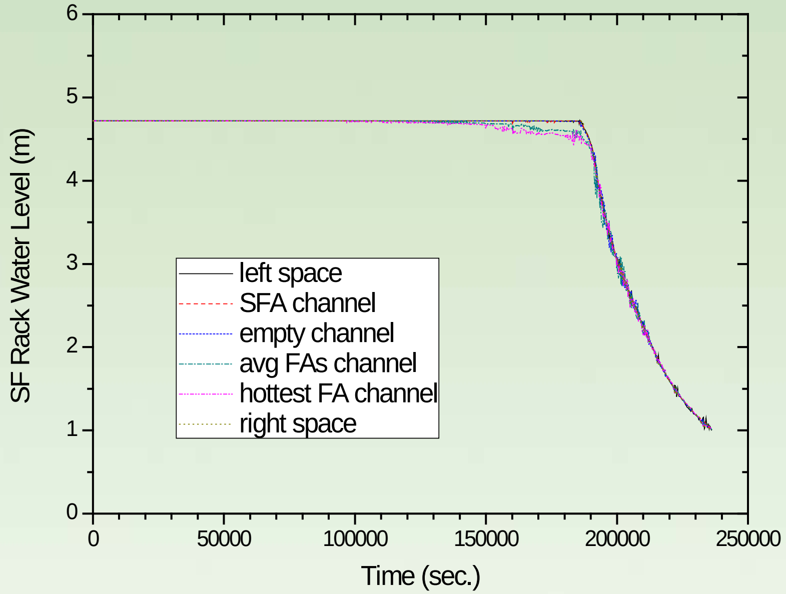


Fig.6 Water Level of SF Racks

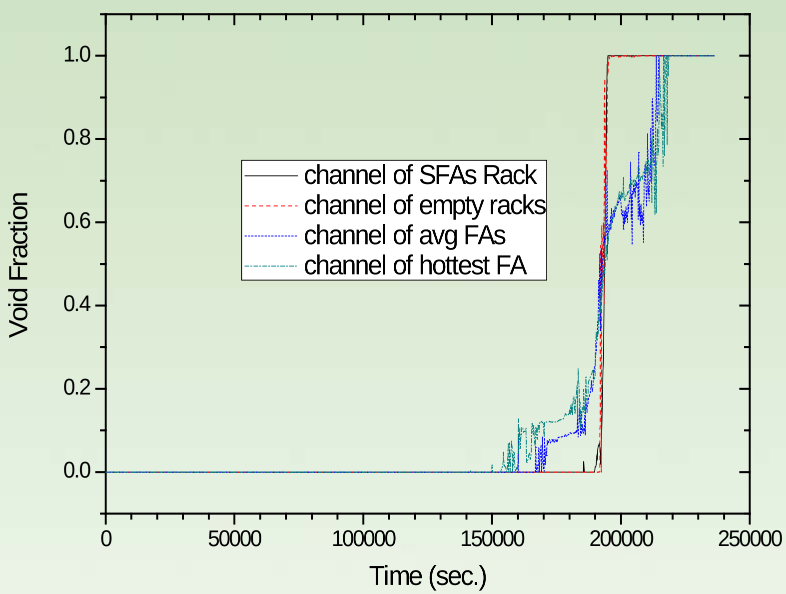


Fig.7 Comparison of Void in Fuel Racks

4. Analysis Results

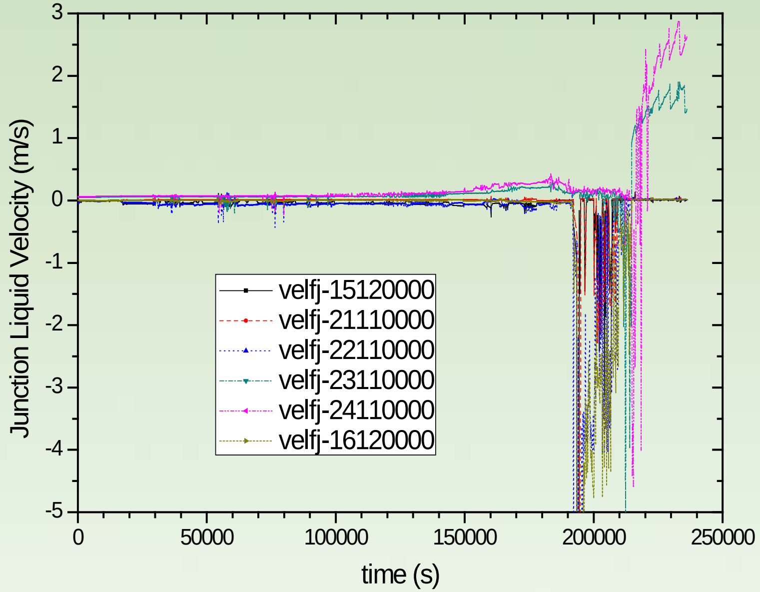


Fig.8 Liquid Velocity of SF Racks

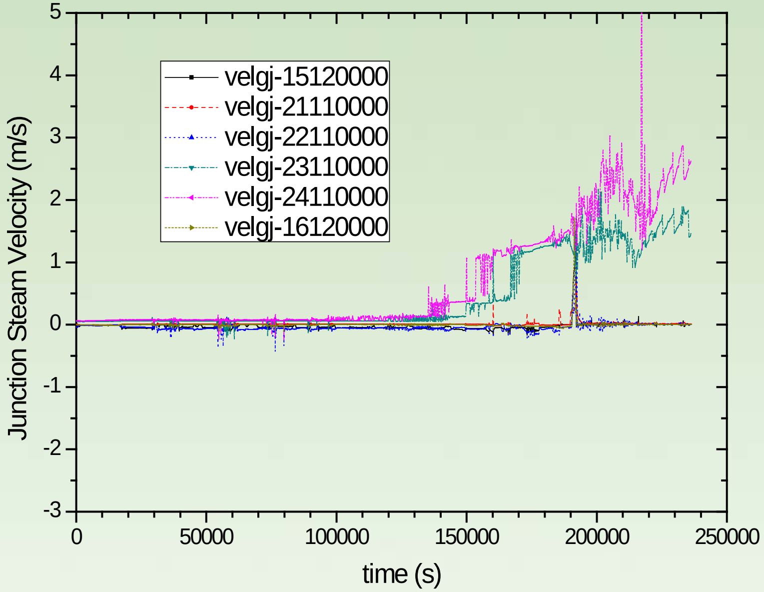


Fig.9 Steam Velocity of Fuel Racks

4. Analysis Results

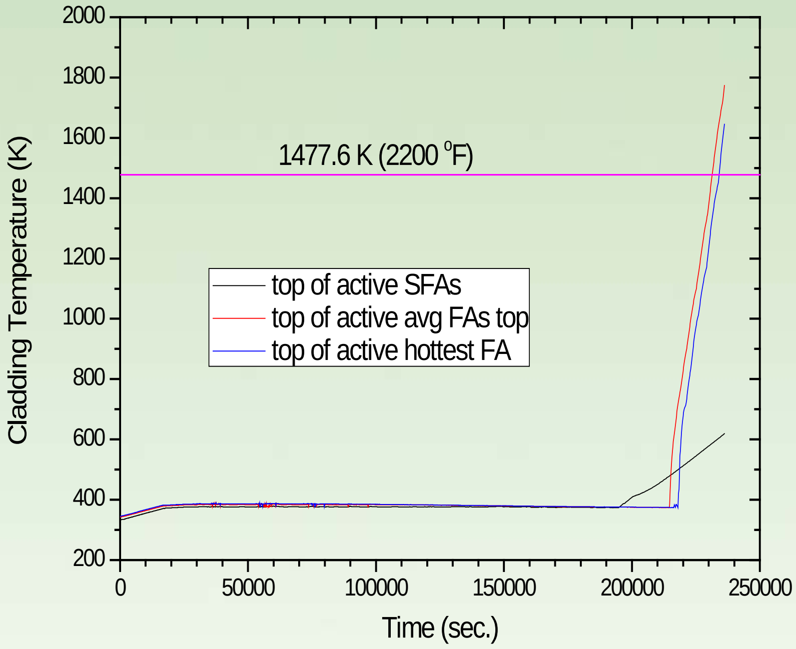


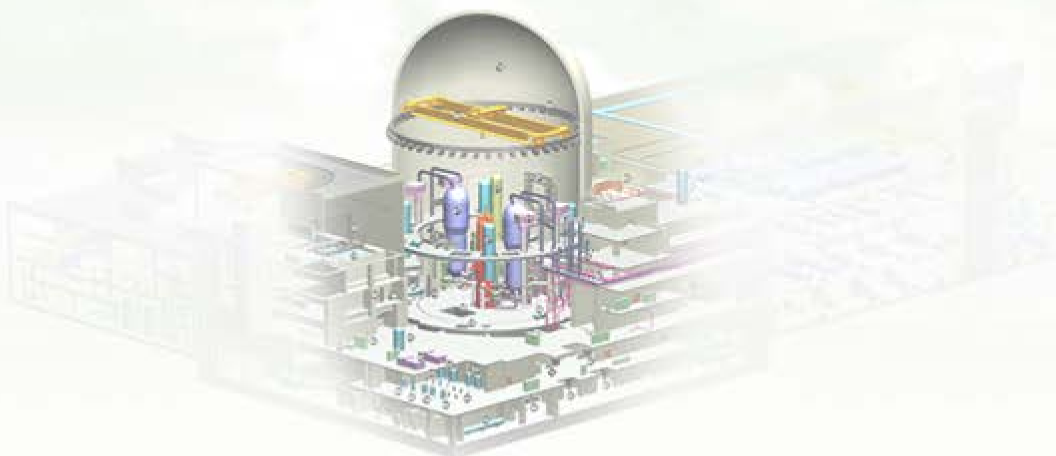
Fig.10 Comparison of Peak Cladding Temperatures

4. Analysis Results

Summary of Results

Time to	Description	Time (sec./hr)
SFP Boiling	Time of boiling at top surface of pool	17,000 (4.7)
Empty of Pool Water	Time of pool level less than 0.1 m (at pool above hottest FA)	185,600 (51.6)
Incipient Boiling at Top of Active Core	Based on continuous void formation at hottest FA channel	153,300 (**42.6**)
	At average FAs channel (newly discharged)	166,800 (46.3)
Fuel Uncover	Time to sharp increase of fuel cladding temperature (hottest FA)	218,000 (60.6)
	At channel of average FAs (newly discharged)	214,600 (**59.6**)
Fuel Damage	Time to PCT > 1477 K, at hottest FA	234,100 (65.0)
	At average FAs (newly discharged)	231,400 (**64.3**)

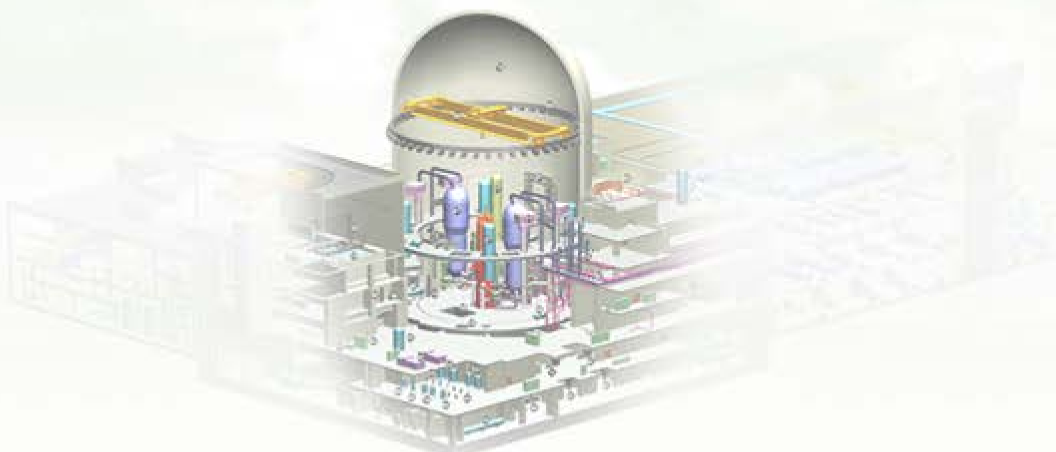
5. Conclusion



5. Conclusion

- Applicability of RELAP5/MOD3.3 for T-H Behaviors of LOSFPC during Refueling
- Incipient Boiling: 42.6 hrs
- Fuel Uncover: 59.6 hrs
- Fuel Cladding Failure: 64.3 hrs
- Sufficient Time for Operator Action for the Success Criteria of PSA

Thank You!



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