Uncertainty Analysis of Source Term for OPR1000 Station Blackout Accident

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Introduction

Introduction

- **In Nuclear Safety Act in Korea, probabilistic source term goal is included.**
  - The sum of the frequency of accident sequences with radionuclide Cs-137 release exceeding 100 TBq must be less than 1.0E-6/RY.
  - Cs-137 100 TBq
    - ✓ Cs-137 specific activity : 3.2 TBq/g
    - ✓ 100TBq/3.2 g = 31.25g
    - ✓ Cs-137 31.25g release = 100TBq
    - ✓ w/o duration

- **Until now, the amount of Cesium released had not been analyzed using uncertainty methods.**

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Plant Modeling

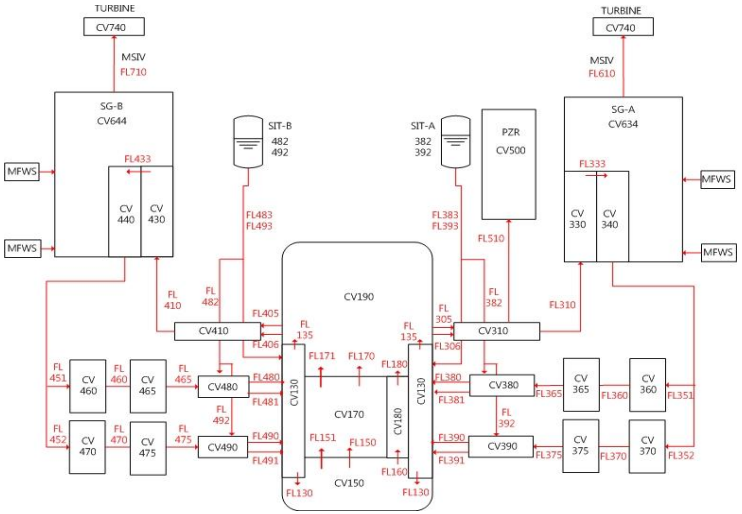
OPR1000 Nuclear Power Plant

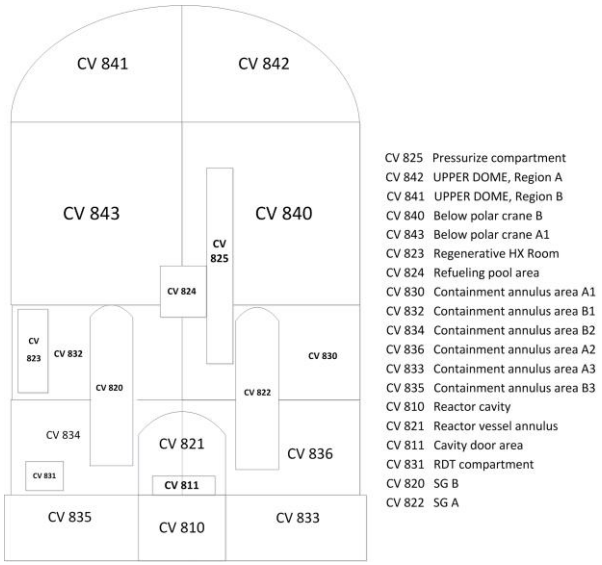
- OPR1000 : Korean Standard Nuclear Power Plant
  - Reactor Power : 2815 MWt
  - Electrical Power : 1000MWe
  - Reactor Coolant System
    - Two Hot Leg, Four Cold Leg, Four Reactor Coolant Pump
    - Two Steam Generator
    - Operating Pressure / Average Temperature : 15.5 Mpa / 311.6°C
  - Secondary System
    - Two Steam Generator, Four Steam Line
    - Operating Pressure / Average Temperature : 7.4 Mpa / 285°C

MELCOR Modeling of OPR1000

- MELCOR Model
  - Typical MELCOR Model
  - 100% Steady State calculation
- Long-Term Station Blackout w/o Operator actions

Parameter	Value	Simulated
Reactor Power	2815 MWt	2815 MWt
Core flow rate	15.3 t/s	15.1 t/s
Coolant operating pressure	15.5 MPa	15.5 MPa
Coolant inlet temperature	295.8°C	294.9°C
Coolant outlet temperature	327.3°C	328.1°C
Steam pressure	7.4 MPa	7.4 MPa
Steam temperature	285 °C	282 °C

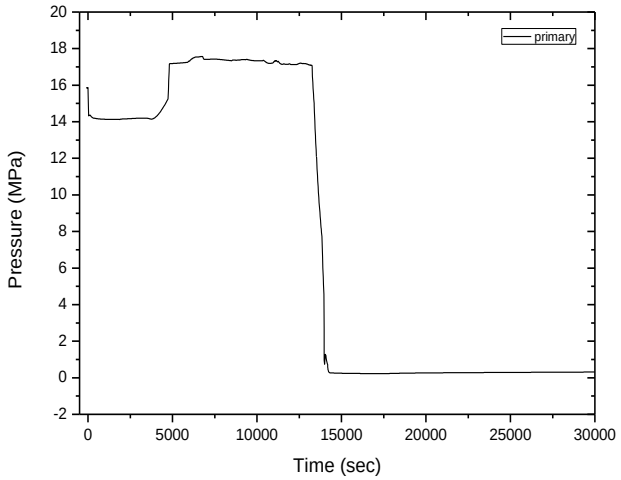


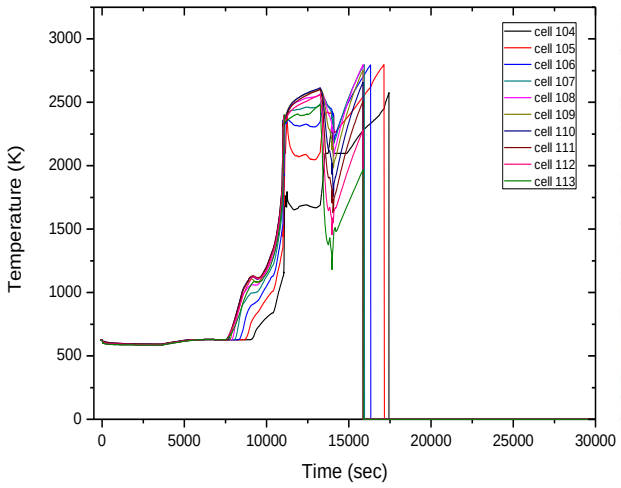


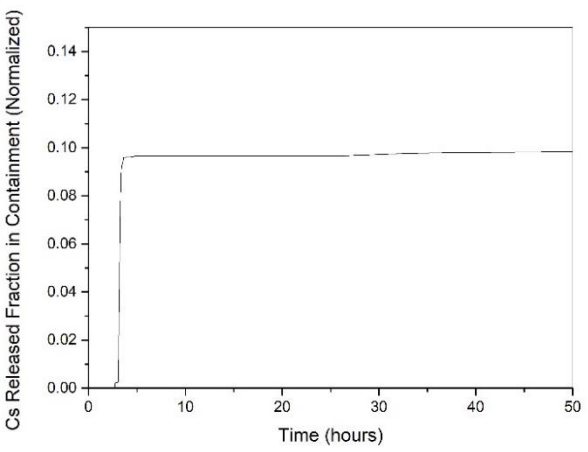
Long-Term Station Blackout

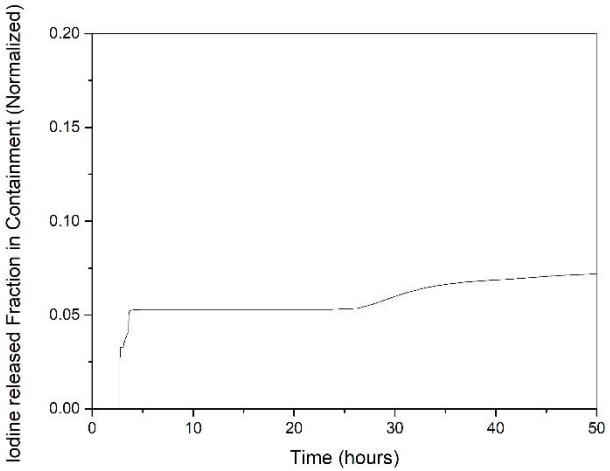
- OPR1000 LTSBO
  - w/o operator action

Time (sec)	Event
0.0	Accident Start (SBO)
3550.0	SG-A, B Dryout
4814.0	SRV(PRZ) First Open
7470.0	Fuel Uncovered
9280.0	Core Dryout
10963.0	Start to Melt Cladding
13794.0	Debris Ejection to Cavity
13964.0	SIT Injection









MELCOR Uncertainty Parameters

- Uncertainty Parameters
  - Selected based on SOARCA reports
  - 99 calculations with Monte-Carlo Sampling

No	Variables	Distribution	Remarks
1	Molten Zircaloy Melt Break-through Temperature	Triangular	2100K 2400K 2540K
2	Core (Fuel) Component Failure Parameters	Triangular	2400K 2500K 2700K
3	Candling Heat Transfer Coefficients	Linear	6750. 7500. 8250.
4	Candling Secondary Material Transport Parameters	Triangular	0. 0.2 0.5
5	Molten Clad Drainage Rate	Triangular	0.1 0.2 1.0
6	Time Constants for Radial Debris Relocation	Triangular	180. 360. 720.
7	Containment Convection Heat Transfer Multiplier	Triangular	1.0 1.4 2.0
8	Chemical Form of Iodine	log-normal	μ=-9.94, σ=0.28
9	Chemical Form of Cesium	Beta (0<; <1.0)	α=9, β=3
10	Dynamic Shape Factor	Beta	α=1, β=5

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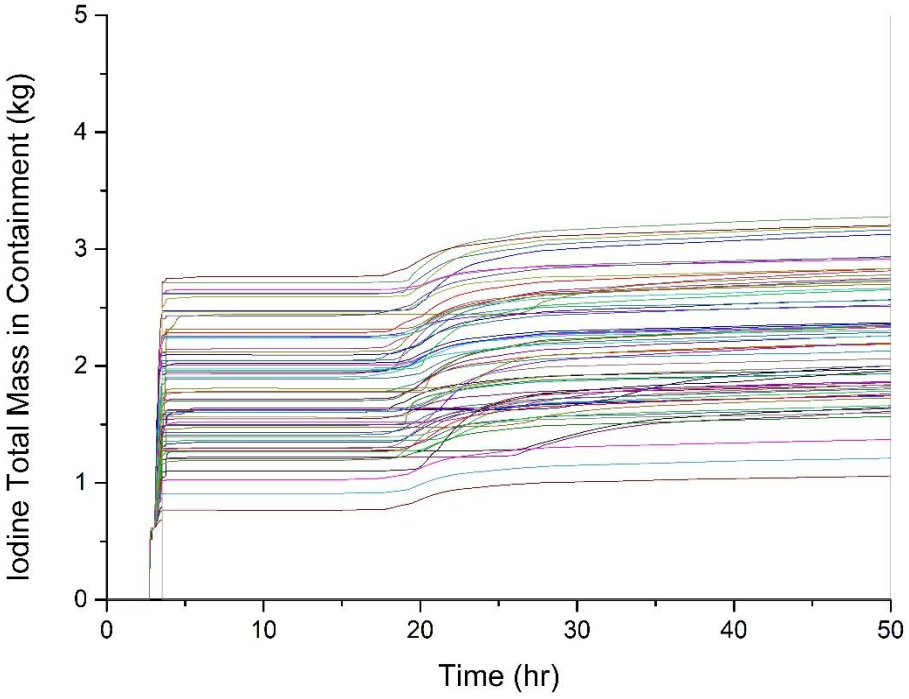
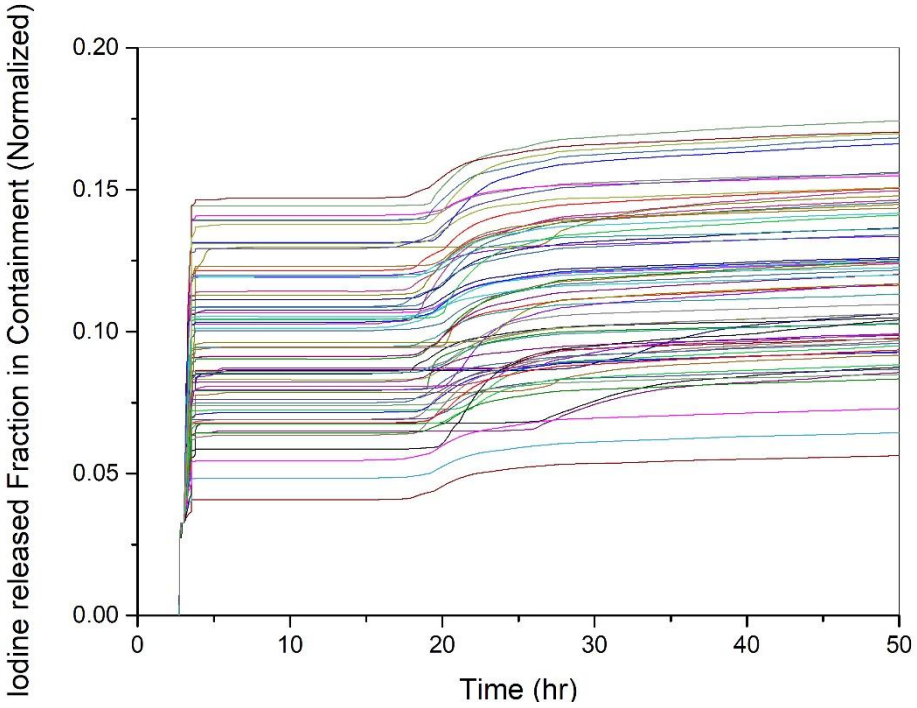
Calculation Results

Calculation Results – Base Case

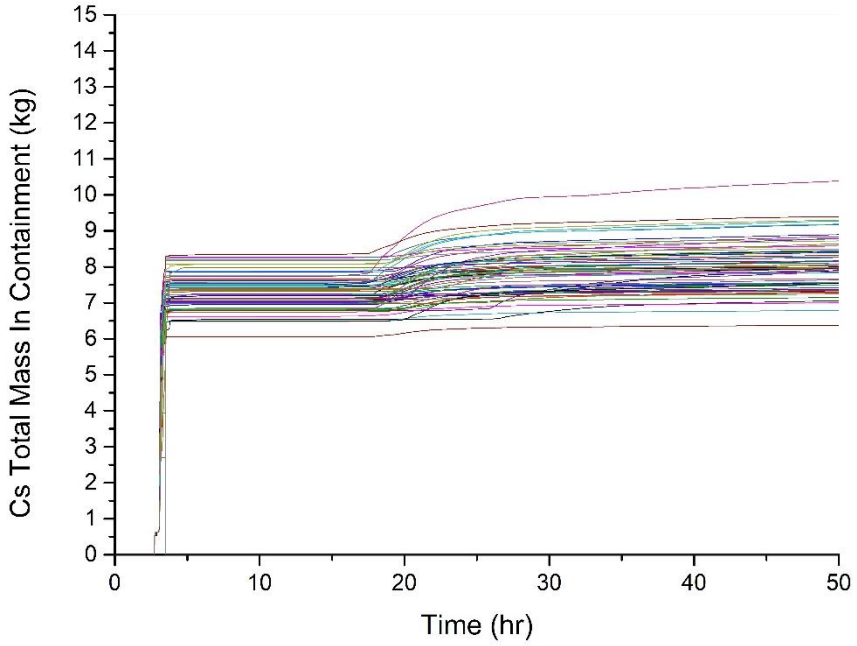
- Release combination of Cs/Mo was not considered.
- Iodine
  - Iodine Total Mass in Containment
  - Iodine release Fraction in Containment

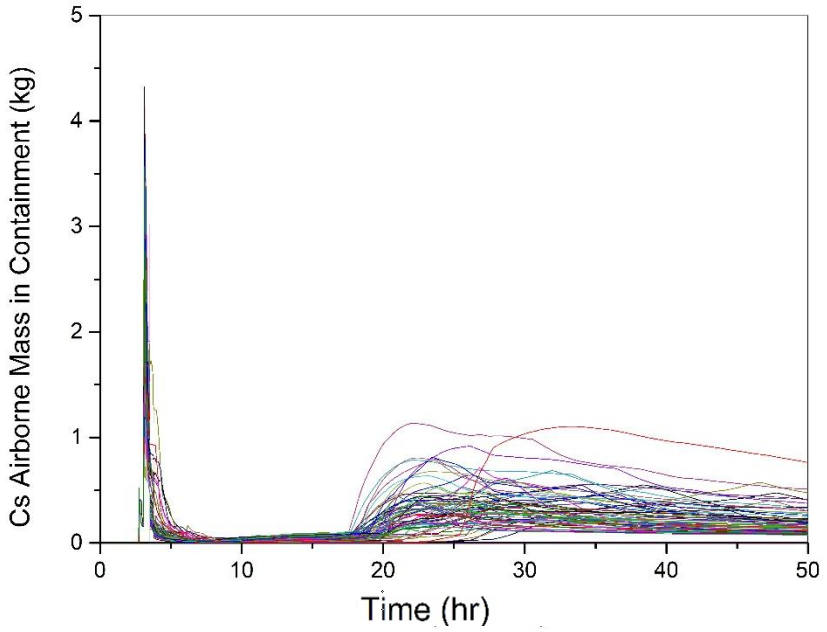




Calculation Results – Base Case

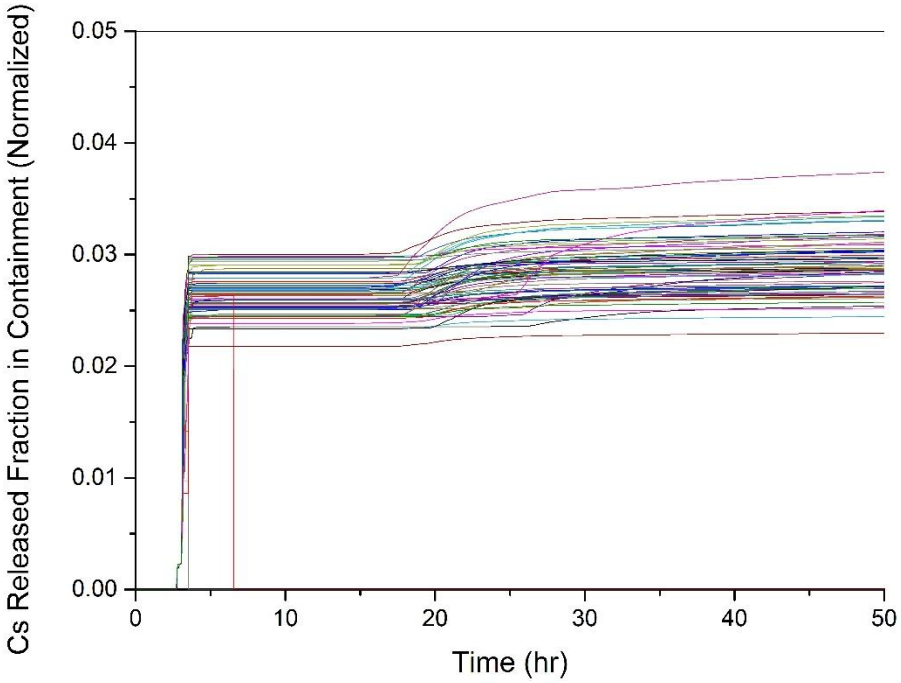
- Cesium
  - Cs Total Mass in Containment
  - Cs Total Airborne Mass in Containment
  - Airborne mass / Total mass ≈ 1/20 = 0.05

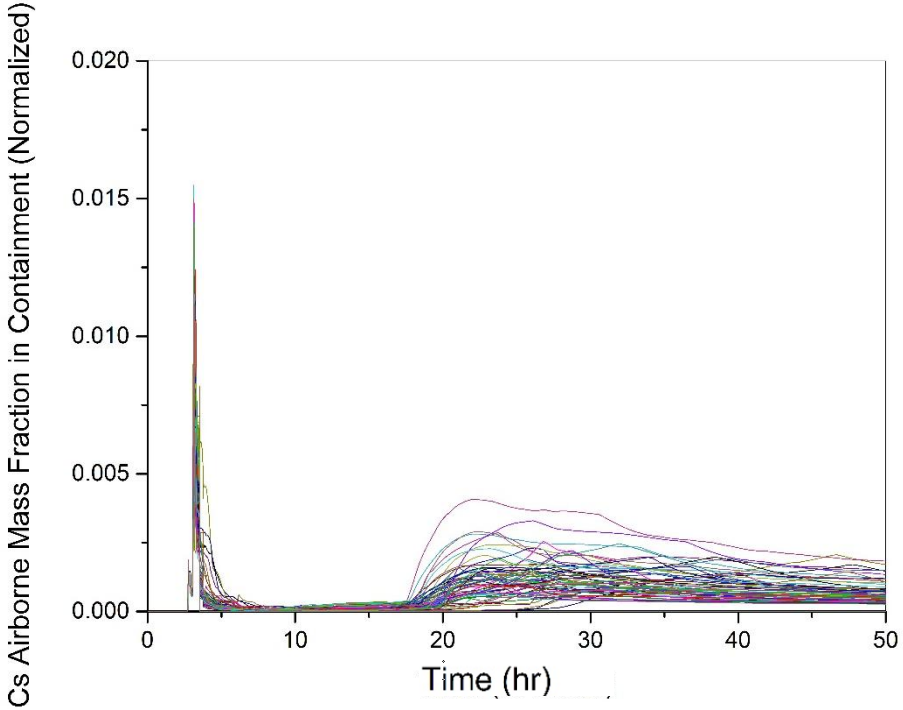




Calculation Results – Base Case

- Cesium
  - Cs Total Mass Fraction in Containment
  - Cs Total Airborne Mass Fraction in Containment
  - CsI (group 16)



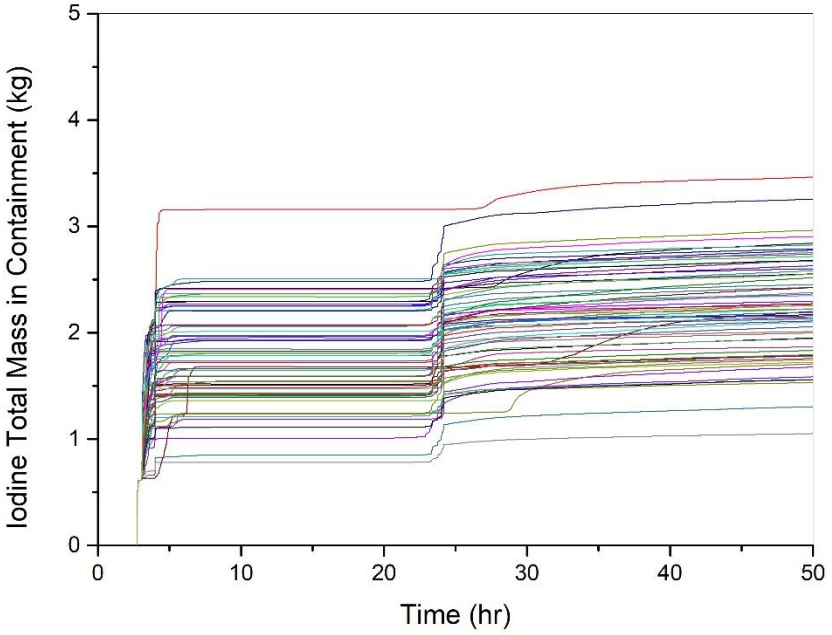


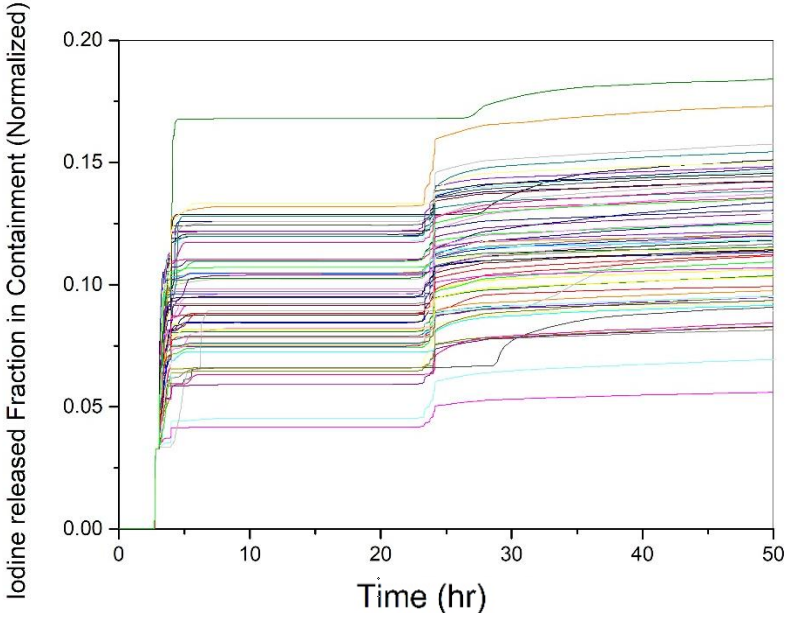
Evaluation of Cesium Criteria – Base Case

- Amount of Cesium, Iodine & Molybdenum in OPR1000 Core (EOL)
  - Total Cesium Class Mass : 278.3 kg
  - Total Iodine Class Mass : 18.8 kg
  - Total Molybdenum Class Mass : 357.7kg
- Cesium inside Containment
  - Maximum : ~9kg
  - Maximum Airborne : ~0.5kg
- Cs release from containment w/o failure
  - Amount of Cesium released (Total Mass based)
    - 9kg * 0.001 = 9g /day
    - 3 days : 27g
  - Amount of Cesium released (Airborne Mass based)
    - 0.5kg * 0.001 = 0.5g /day
    - 60 days : 30g

Calculation Results – Add RNCLS

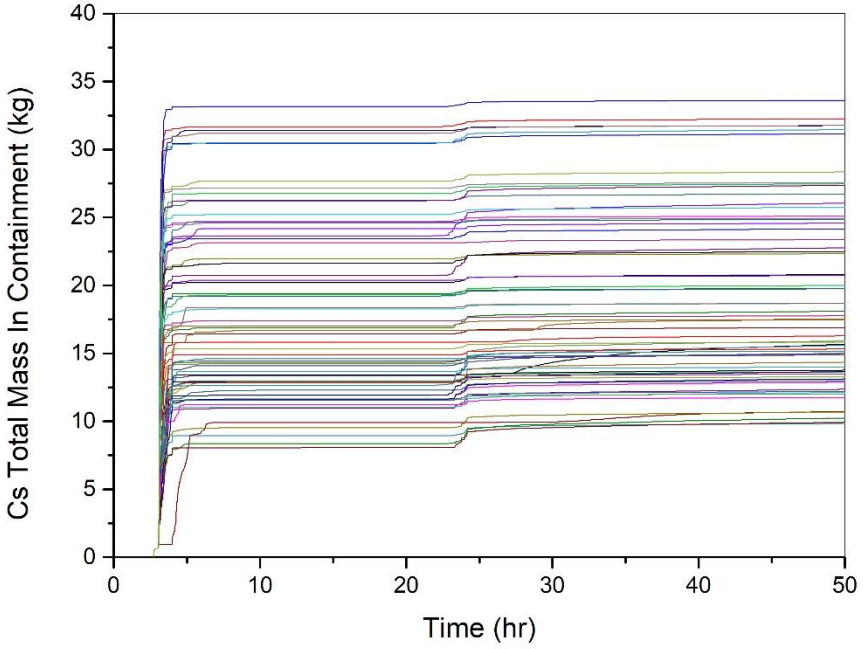
- Release combination of Cs/Mo was considered.
- Iodine
  - Iodine Total Mass in Containment
  - Iodine release Fraction in Containment

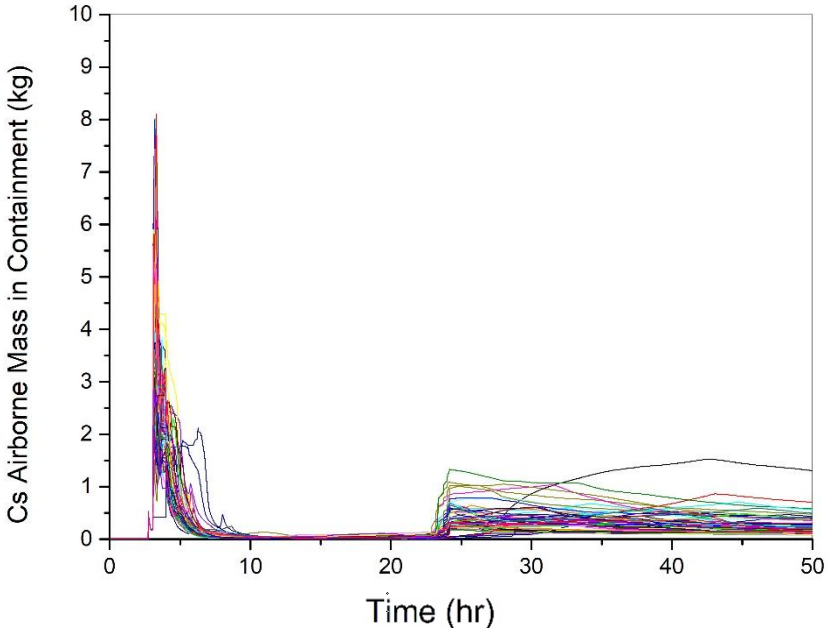




Calculation Results – Add RNCLS

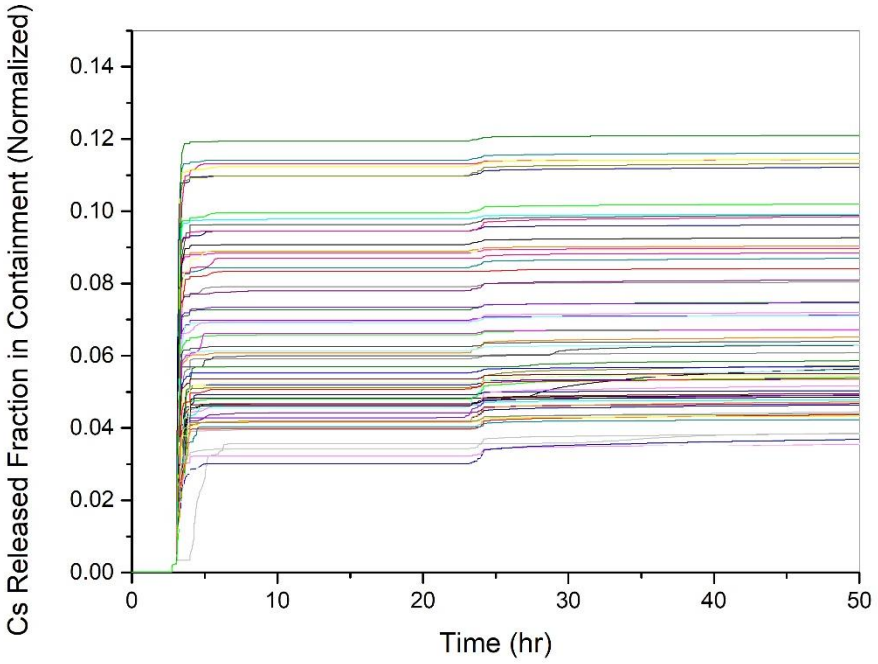
- Cesium
  - Cs Total Mass in Containment
  - Cs Total Airborne Mass in Containment
  - Airborne mass / Total mass ≈ 1/15 = 0.07

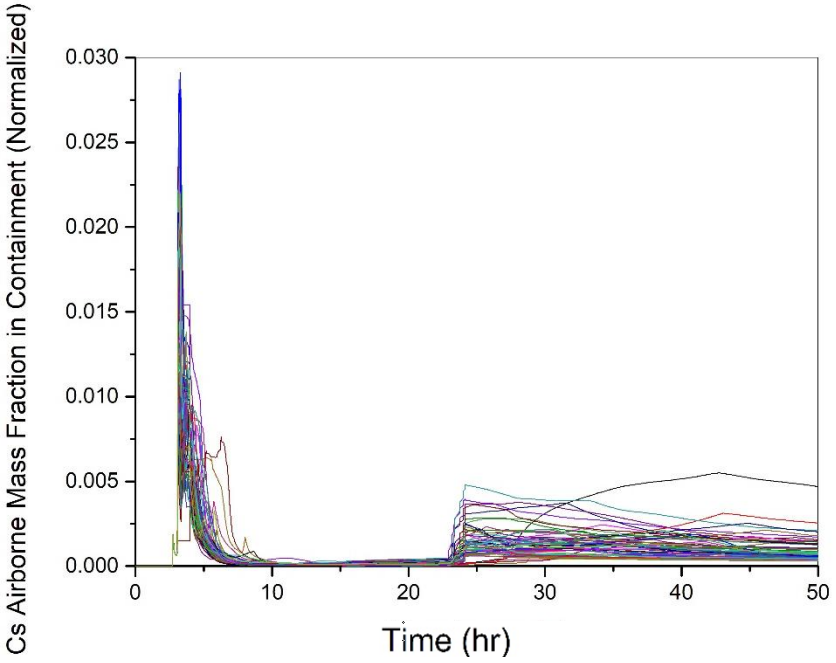




Calculation Results – Add RNCLS

- Cesium
  - Cs Total Mass Fraction in Containment
  - Cs Total Airborne Mass Fraction in Containment
  - CsI (group 16), Cs_2MoO_4 (group 17)





Evaluation of Cesium Criteria – Add RNCLS

- Amount of Cesium, Iodine & Molybdenum in OPR1000 Core (EOL)
  - Total Cesium Class Mass : 278.3 kg
  - Total Iodine Class Mass : 18.8 kg
  - Total Molybdenum Class Mass : 357.7kg
- Cesium inside Containment
  - Maximum : 30kg
  - Maximum Airborne : 1.5kg
- Cs release from containment w/o failure
  - Amount of Cesium released (Total Mass based)
    - 30kg * 0.001 = 30g /day
    - 1 day : 30g
  - Amount of Cesium released (Airborne Mass based)
    - 1.5kg * 0.001 = 1.5g /day
    - 20 days : 30g

Sensitivity Study Summary for RNCLS

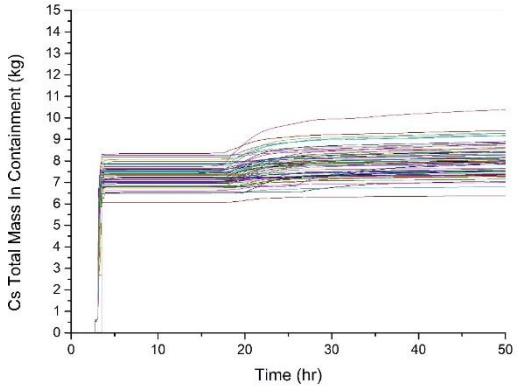
- RNCLS
  - Class combination : [Cs : Mo]
  - Cs_2MoO_4 : 2 Cs + 1 Mo => [1 : 0.5] or [2 : 1]

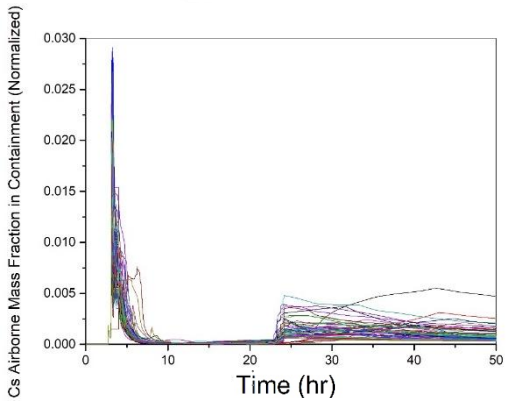
- Cs Total Mass / Mass Fraction in Containment Summary

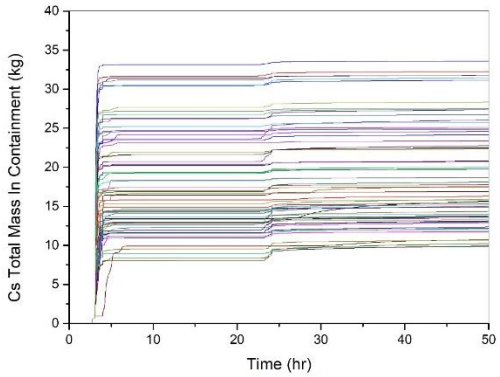
Cs : Mo	Total mass of Cs in containment (kg)	Mass Fraction of Cs in Containment to total Cs inventory	Mass Fraction of Cs in Containment air to total Cs inventory
N/A	~10	~0.035	~0.0025
1 : 0.5	**~33**	**~0.12**	**~0.003**
1 : 1	~29	~0.105	~0.003
0.5 : 1	~25	~0.09	~0.003
2 : 1	~33	~0.12	~0.003

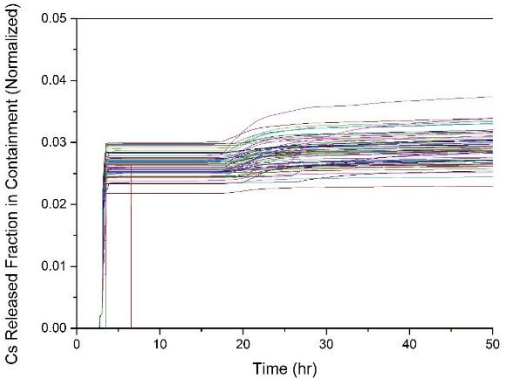
Sensitivity Study for RNCLS

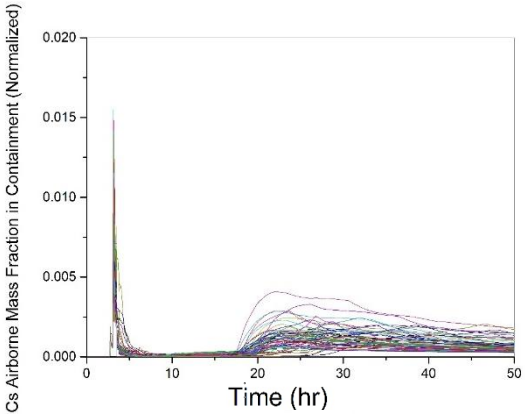
- Cs Total Mass / Mass Fraction in Containment

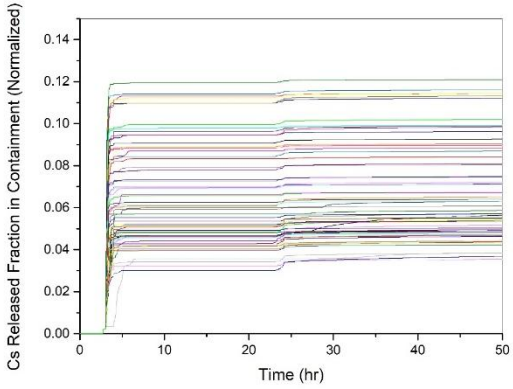










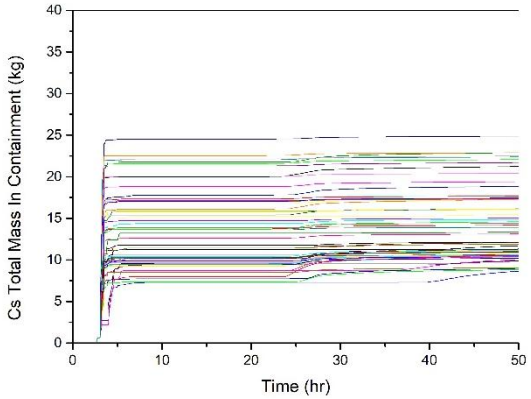


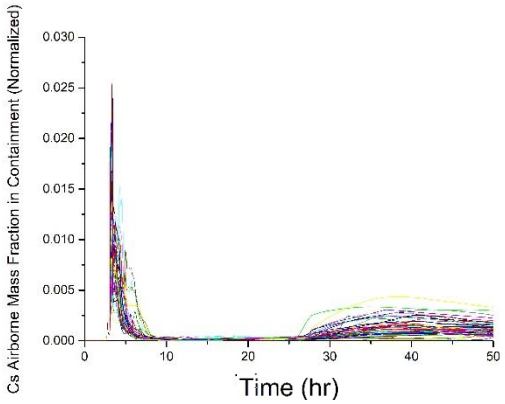
Cs : Mo = N/A

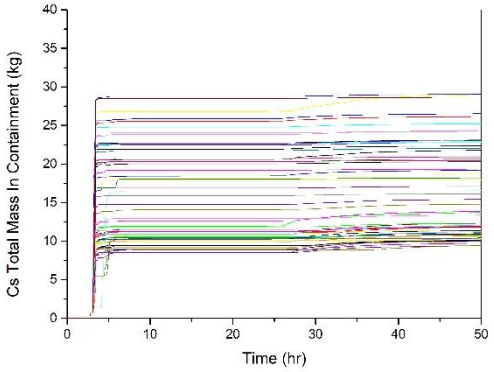
Cs : Mo = 1 : 0.5

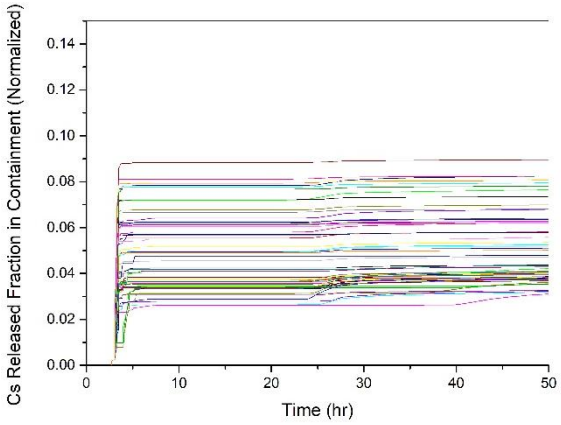
Sensitivity Study for RNCLS

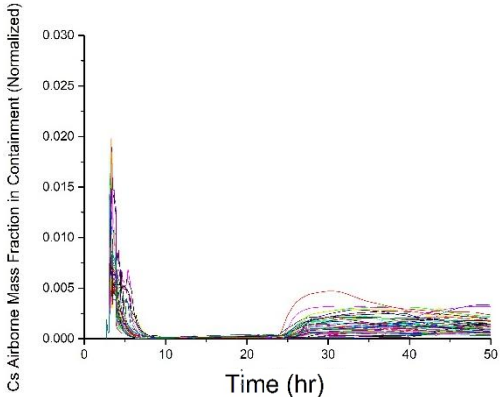
- Cs Total Mass / Mass Fraction in Containment

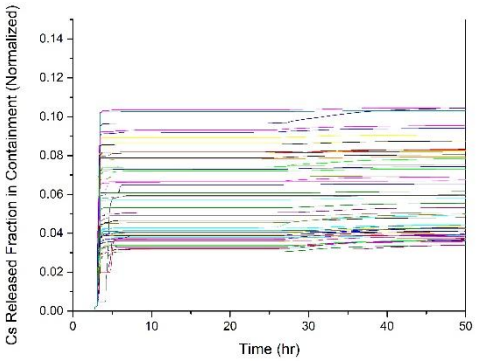












Cs : Mo = 0.5 : 1

Cs : Mo = 1 : 1

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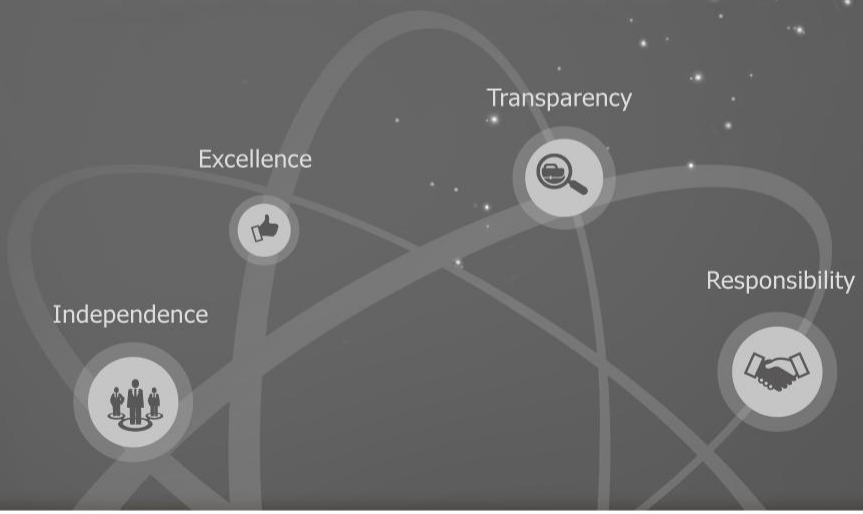
Concluding Remarks

Concluding Remarks

- MELCOR source term uncertainty calculation had been performed preliminary.
- MELCOR default values with descriptions are needed : **Release combination** of Release Model.
  - RN Combo Class 1 : CS, I2 => CsI
  - RN Combo Class 2 : CS, MO => Cs_2MoO_4
- OPR1000 severe accident source term was analyzed in view of Cesium compared to Cs release goal in Korean Nuclear Safety Act.
- In future, well-modified MELCOR input will be used to final calculation including accident management operator actions.

원자력 안전
KINS가 만들어 갑니다!

Thank You



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