The Numerical Sensitivity Study of Cold Leg Top Slot Break for ATLAS

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성 해 정

Contents

1. Introduction

- Top Slot Break (issued by NRC as draft RAI, ML14134A347)
  - ✓ NRC Concern
    - Loop seal reformation may occur during post-reflood due to deep loop seal design.
  - ✓ Scenario
    - Top slot break at cold leg (SB/MB break size maybe the concern)
    - Primary steam condensation by SG heat transfer or SIP, SIT water flooding (reverse flow to loop seal)
    - Four loop seal reformation occurs (possibly).
    - Pressure increase at the top core region due to the steam release blockage.
    - Core water level decrease.
    - Partial core uncover may occur.
- Objectives for this study
  - ✓ To review the possibilities for loop seal reformation until simultaneous injection of APR1400 using ATLAS.
  - ✓ To evaluate cladding temperature increase during loop seal reformation.
  - ✓ To determined the worst case in terms of loop seal reformation.

2. RELAP5 Modeling (1/3)

- **Code environments**
  - ✓ RELAP5/MOD3.3 Patch04
  - ✓ Intel Xeon processor under the Microsoft Windows environment
- **Assumptions**

	ATLAS modeling
Break size for base case	0.1016 m (4 in.)
Core power	102 % rated power
Decay heat	ANS73 * 1.2
Heat loss	Not considered
Break condition	Top slot break (offtake model)
Break model	Henry-Fauske model
SG cool-down operation	Not credit, but MSSVs operate
SIP	4 SIP
SIT	4 SIT

- Break Sizes addressed in the present study are given based on the break size of the APR1400.

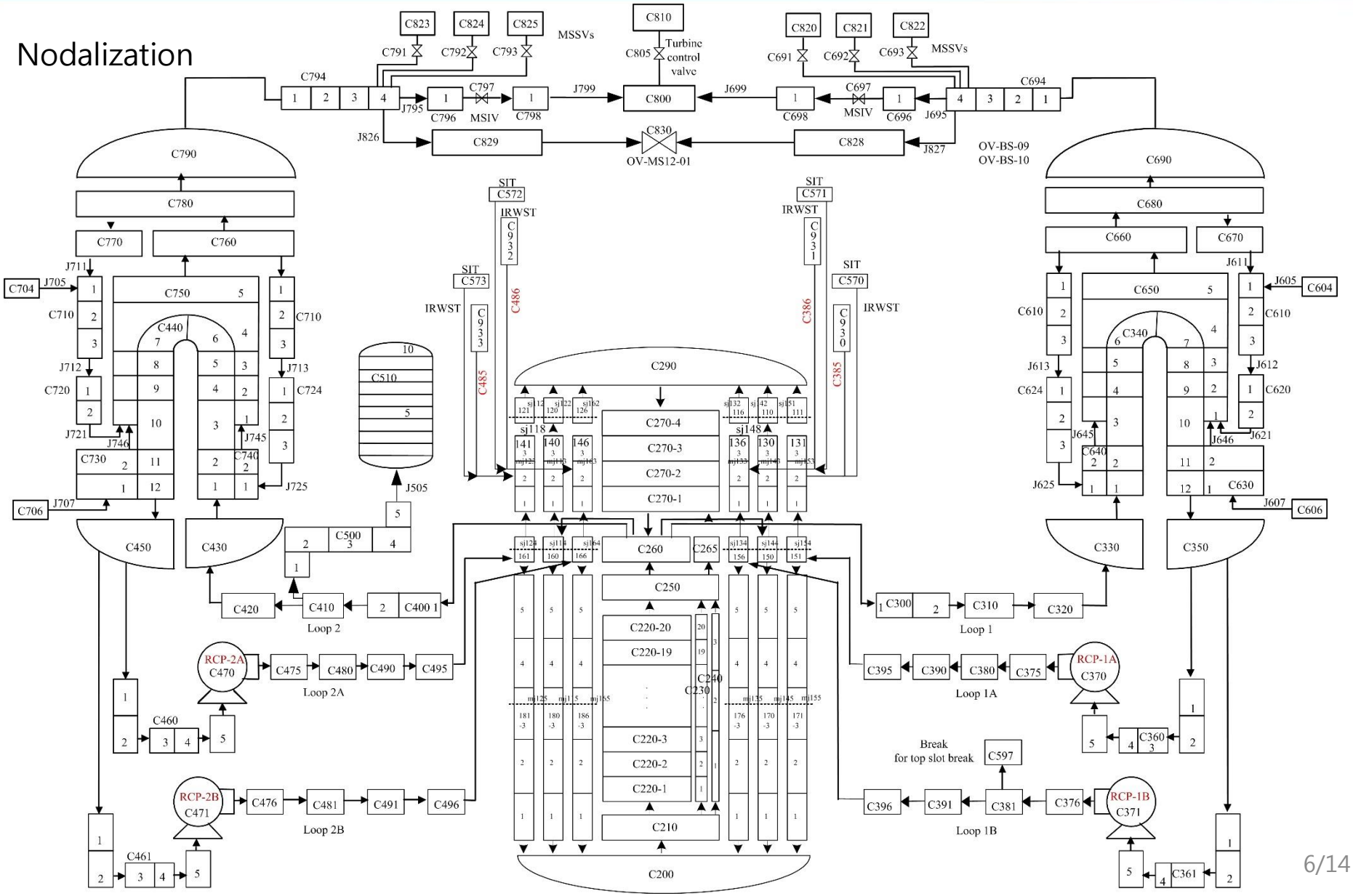
2. RELAP5 Modeling (2/3)

- **Logic setting**

	Set point
Primary logic	
Cold leg break	300 sec (Break initiation as soon as transient calculation starts.)
LPP	PT-PZR-01 < 12.48 MPa
Reactor scram / RCP trip / Turbine trip / MFIV and MSIV close	LPP + 0.0 sec
SIP on	PT-PZR-01 < 10.7 MPa + 28.0 sec delay
SIT on	PT-DC-01 < 4.03 MPa
Secondary logic	
MSSV1,2-01 open MSSV1,2-01 close	PT-SGSD1,2-01 > 8.1 MPa PT-SGSD1,2-01 < 7.7 MPa
MSSV1,2-02 open MSSV1,2-02 close	PT-SGSD1,2-01 > 8.3 MPa PT-SGSD1,2-01 < 7.9 MPa
MSSV1,2-03 open MSSV1,2-03 close	PT-SGSD1,2-01 > 8.48 MPa PT-SGSD1,2-01 < 8.05 MPa
Aux. feed water open Aux. feed water close	LT-SGSDRS2-01 < 2.76 m LT-SGSDRS2-01 > 3.61 m
Aux. Feed Water Flow rate	0.2 kg/sec

2. RELAP5 Modeling (3/3)

- Nodalization



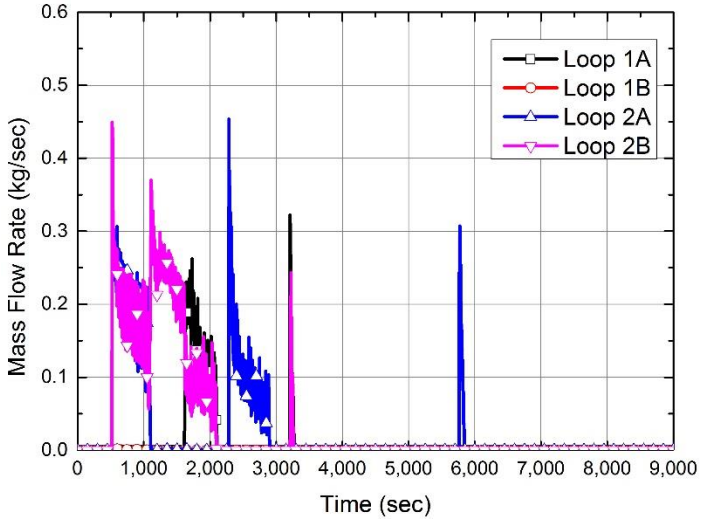
3. Base Case (1/3)

- **Sequence of Transient Events**

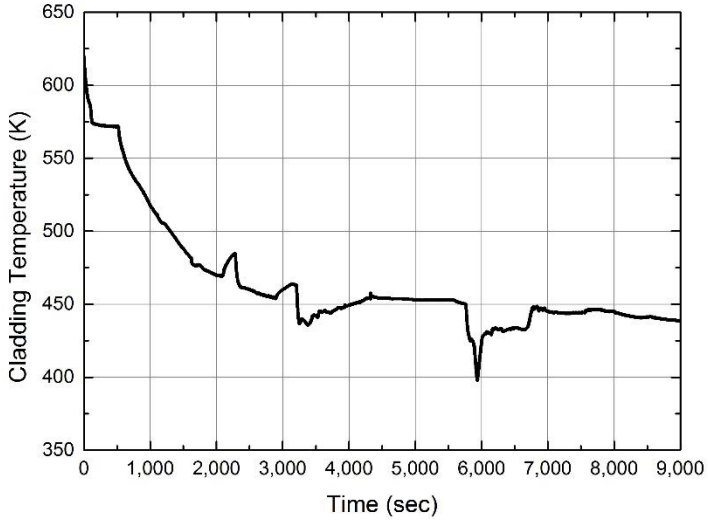
Event	Calculation	Remarks
Cold leg break	300.0 sec	
Low pressurizer pressure	326.0 sec	PT-PZR-01 < 12.48 MPa
Reactor scram / RCP trip	326.0 sec	LPP + 0.0 sec delay
SIP on	384.0 sec	PT-PZR-01 < 10.7 MPa + 28.0 s ec delay
SIT on	1,198.0 sec	PT-DC-01 < 4.03 MPa
MSSV1,2-01 open MSSV1,2-01 close	331.0 sec 513.0 sec	PT-SGSD1,2-01 > 8.1 MPa PT-SGSD1,2-01 < 7.7 MPa
MSSV1,2-02 open MSSV1,2-02 close	-	PT-SGSD1,2-01 > 8.3 MPa PT-SGSD1,2-01 < 7.9 MPa
MSSV1,2-03 open MSSV1,2-03 close	-	PT-SGSD1,2-01 > 8.48 MPa PT-SGSD1,2-01 < 8.05 MPa
Aux. feed water open Aux. feed water close	-	LT-SGSDRS2-01 < 2.76 m LT-SGSDRS2-01 > 3.61 m

3. Base Case (2/3)

✓ Steam Mass Flow Rates at Loop Seals



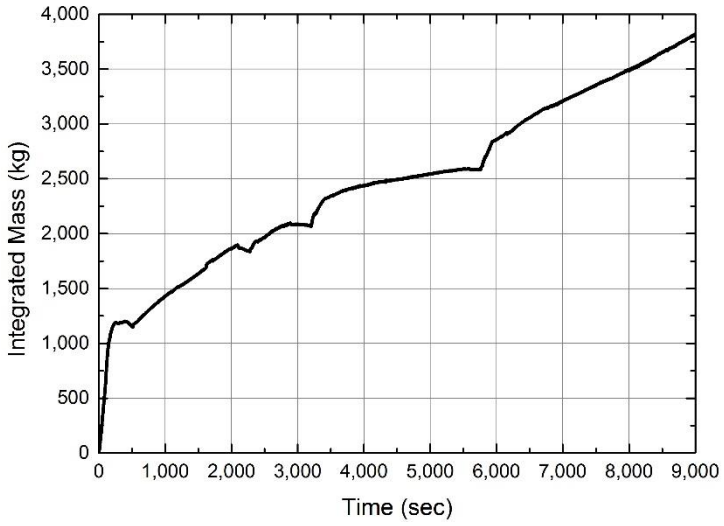
✓ Cladding Temperature at Peak Node



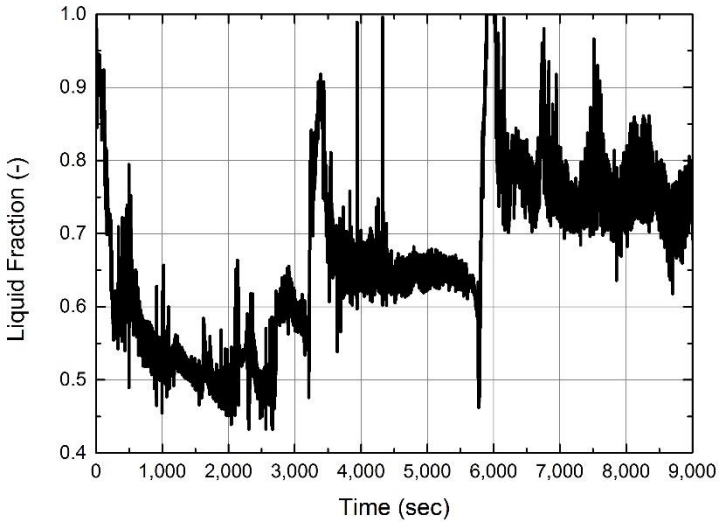
- Four loop seal blockage occurs
  - ✓ 2,109 sec ~ 2,278 sec
  - ✓ 2,904 sec ~ 3,200 sec
  - ✓ 3,269 sec ~ 5,758 sec
  - ✓ 5,843 sec ~
- The characteristics of cladding temperature at peak node
  - ✓ Cladding temperature at peak node is intermittently increases during loop seal reformation until 5,843 sec.
  - ✓ Cladding temperature is not continuously increased after 5,843 sec even though loop seal is maintained from 5,843 sec to 9,000 sec.

3. Base Case (3/3)

✓ Accumulated Mass into Lower Plenum



✓ Liquid Fraction at Active Top Core



- The characteristics of accumulated mass into lower plenum
  - ✓ Accumulated mass into lower plenum is decreased while loop seal is being blocked by safety injection water.
  - ✓ However, safety injection water is continuously injected regardless of loop seal reformation.
- The characteristics of void fraction at active top core
  - ✓ Liquid fraction at active top core is maintained over 0.4 regardless of loop seal reformation.
  - ✓ It means that core uncover does not occur.

4. Sensitivity Studies (1/4)

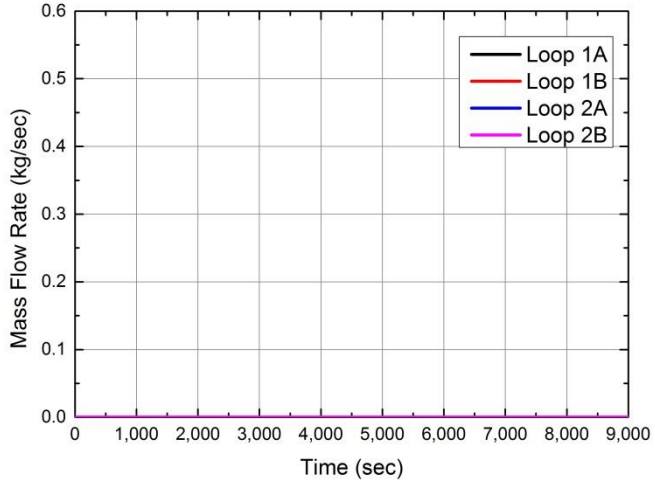
- **Test Matrix**
  - ✓ Break size sensitivity

	APR1400 (m)	ATLAS (m^2)		APR1400 (m)	ATLAS (m^2)
Case 1	0.0635 (2.5 in)	1.55546E-5	Case 4	0.2159 (8.5 in)	1.79811E-4
Case 2	0.0762 (3.0 in)	2.23987E-5	Case 5	0.2286 (9.5 in)	2.01588E-4
Case 3	0.1016 (4.0 in)	3.98198E-5			

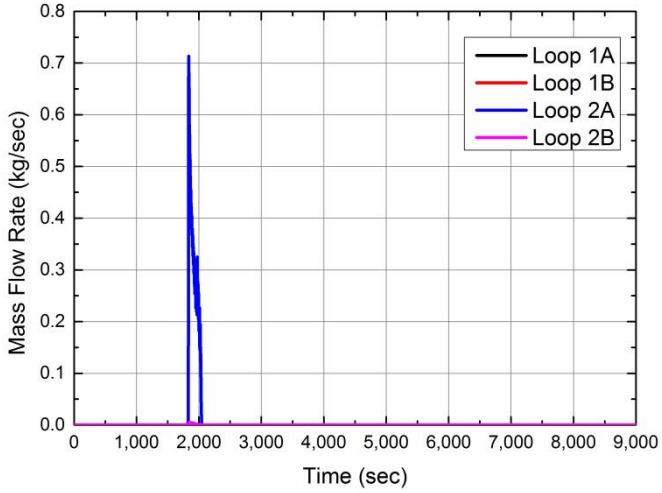
  - ✓ Sensitivity of Break Distance from Vessel
    - C376 (Intermediate Leg), C381, C391, C396 (Vessel)
  - ✓ Pressurizer Location Sensitivity
    - C380 (Loop 1A), C381 (Loop 1B), C480 (Loop 2A), C481 (Loop 2B)

4. Sensitivity Studies (2/4)

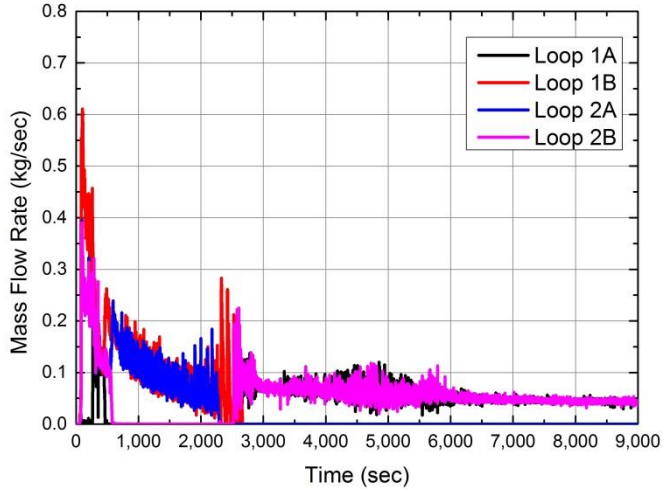
- **Break Size Sensitivity**
  - ✓ 0.0635 m (2.5 in.)



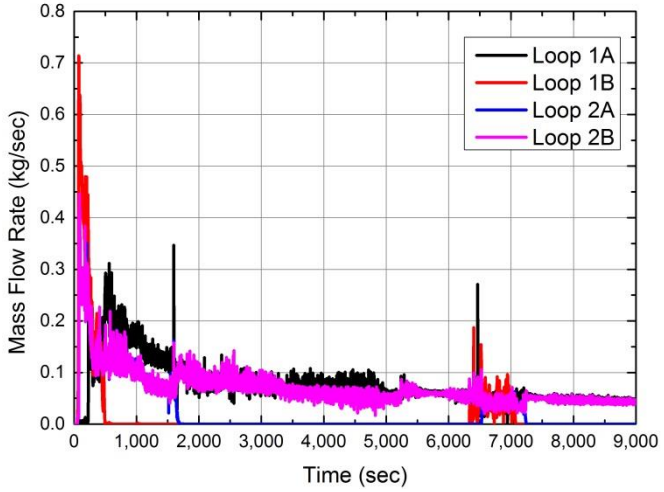
  - ✓ 0.0762 m (3.0 in.)



  - ✓ 0.2159 m (8.5 in.)



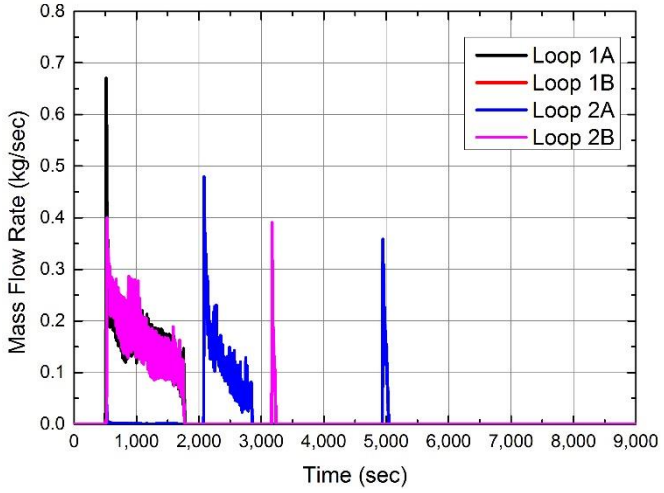
  - ✓ 0.2286 m (9.0 in.)



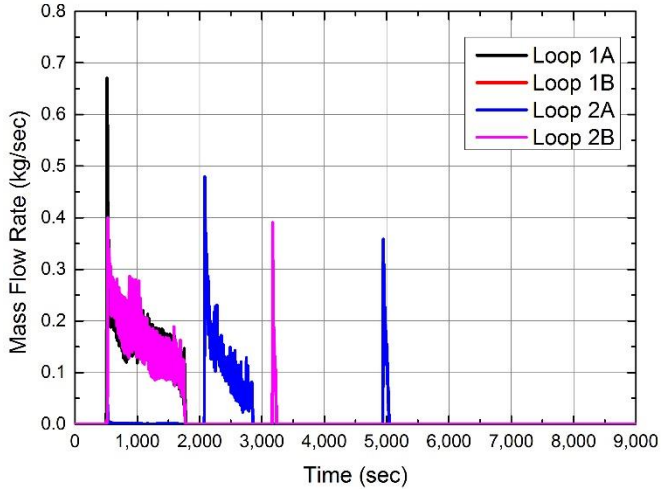
4. Sensitivity Studies (3/4)

- **Sensitivity of Break Distance from Vessel**

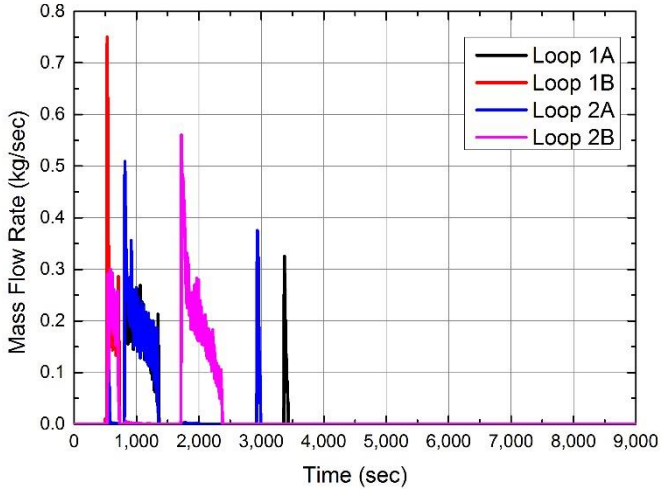
✓ C376 (Intermediate Leg)



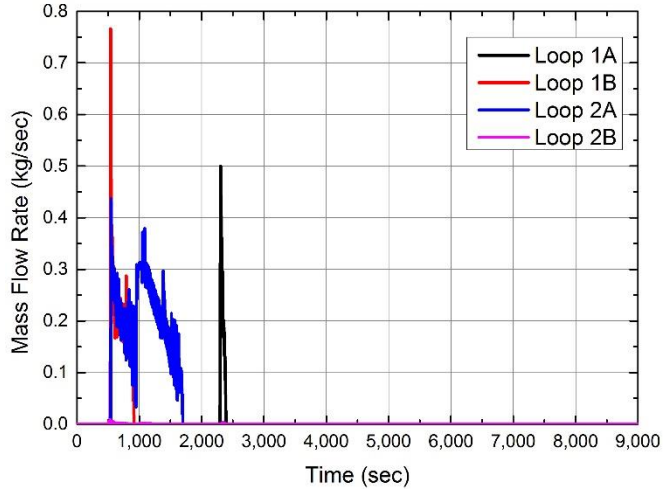
✓ C381



✓ C391



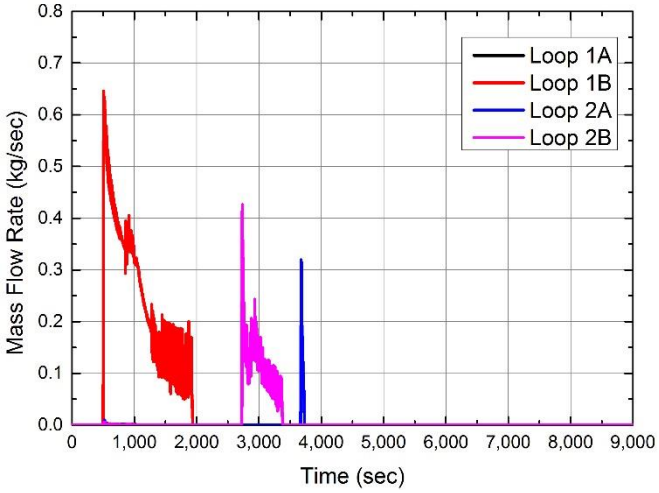
✓ C396 (Vessel)



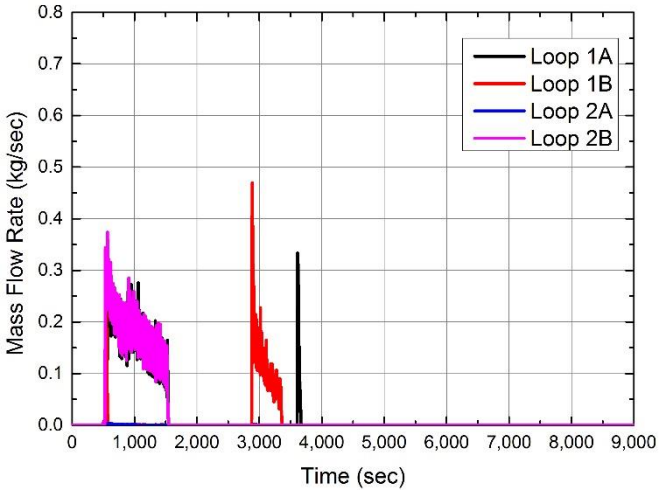
4. Sensitivity Studies (4/4)

- **Pressurizer Location Sensitivity**

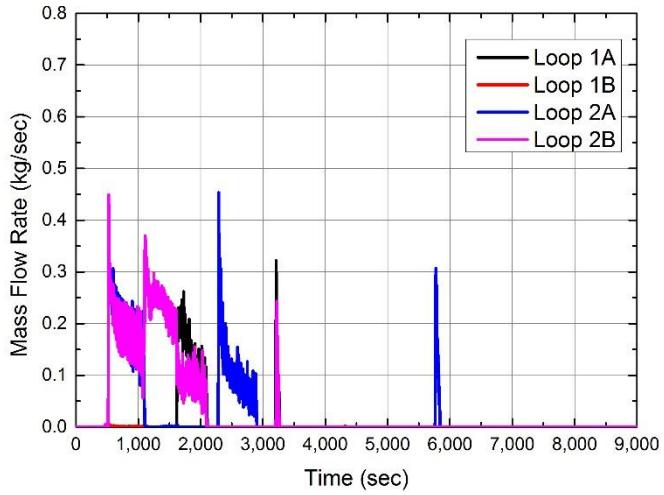
✓ C380 (Break: Loop 1A)



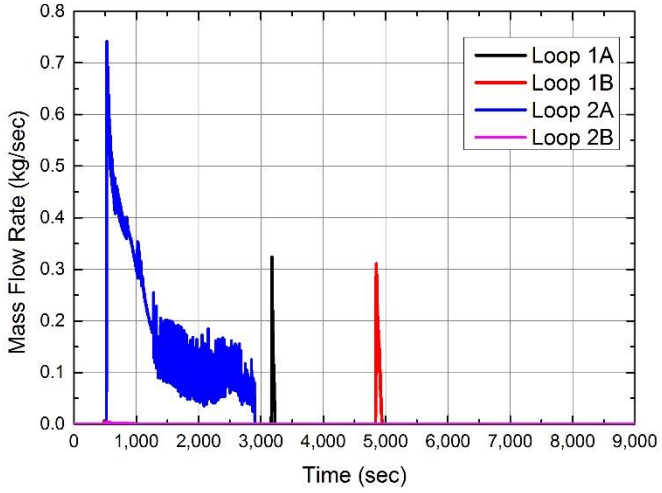
✓ C381 (Break: Loop 1B)



✓ C480 (Break: Loop 2A)



✓ C481 (Break: Loop 2B)



5. Summary

- Base Case (4.0 in.)
  - ✓ Cladding temperature intermittently increases during loop seal reformation.
  - ✓ However, cladding temperature increasing is limited by core void fraction.
- Sensitivity Studies
  - ✓ Break Size Sensitivity
    - 4 loop seal blockage cases are observed for break sizes ranging from 0.0762 m (3.0 in.) to 0.2286 m (8.5 in.).
    - The results can be categorized into three: 1) no loop seal clearing occurs, 2) loop seal clearing occurs and loop seal is reformed, 3) loop seal clearing occurs but loop seal is not reformed.
  - ✓ Sensitivity of Break Distance from Vessel
    - In terms of loop seal reformation, the break which is adjacent to vessel seems conservative since loop seal reformation lasts from 2,393 sec to 9,000 sec.
  - ✓ Pressurizer Location Sensitivity
    - Pressurizer location does not have an important impact on the loop seal reformation.