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ANALYSIS FOR 13% AND 17% BREAK SIZES OF INTERMEDIATE BREAK LOSS OF COOLANT ACCIDENT IN OPR1000 WITH MARS-KS

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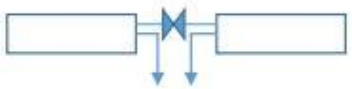
Model and Analysis

- Evaluating the OPR1000 thermal hydraulic response during an IBLOCA using MARS-KS.
- Simulation of the rupture is 13% and 17% of coolant flow area in cold leg. Available systems: HPIS, accumulators, LPIS
- RCPs are tripped with reactor trip signal. (Low Pressurizer Pressure Signal)
- Break model is Double Ended as shown below. One side connects to Vessel and other side connects to Pump.



- Break sizes set as 13% and 17% of breaking flow. Break area of each side set as A/2. (6.5%+6.5%, 8.5%+8.5%)

Slow drain SBLOCA	$A_{break} < 3\%$
Rapid drain SBLOCA	$3\% < A_{break} < 11\%$
IBLOCA	$11\% < A_{break} < 25\%$
LBLOCA	$A_{break} > 25\%$.

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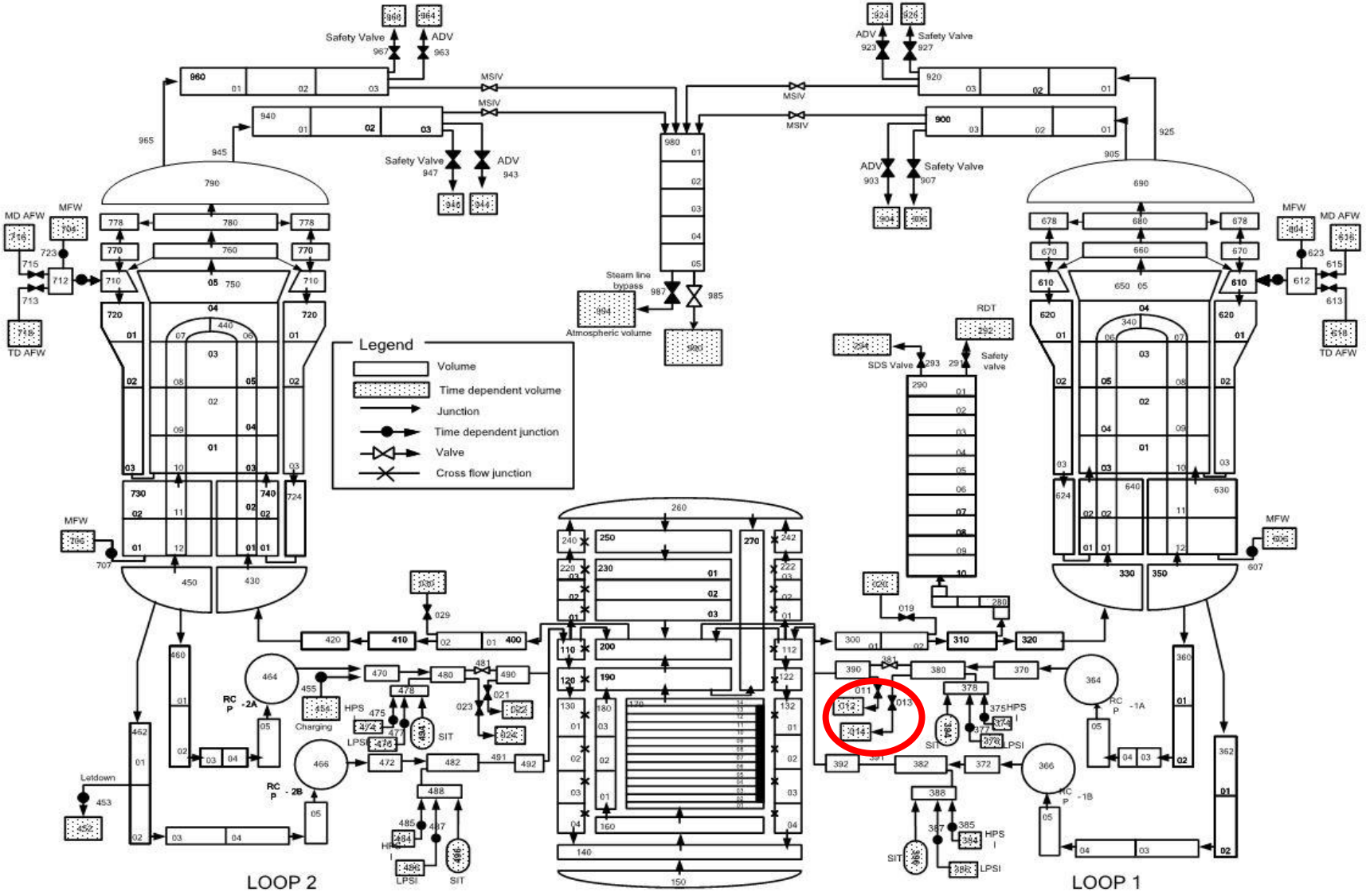

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Phases of IBLOCA

Blow down & Rapid depressurization

- Critical flow at the break and rapid depressurization (flashing) due to inventory loss.
- Reactor power decreases due to moderator density feedback .

Loop seal clearing & Core boil-off

- HPSI/SIP injection starts by PZR pressure low signal with time delay (boron worth)
- Loop seals are formed but all of them are cleared by flashing.
- Depending on break size, PCT starts to increase as core water level decreases due to continuous boil-off in the core.

ECCI & Long-term cooling

- SIT/ACC injection, quick core reflooding & PCT turnaround with time lag (Maximum PCT).
- Break & injection flow balanced, and primary pressure is stabilized.
- LPSI actuation for long term cooling.

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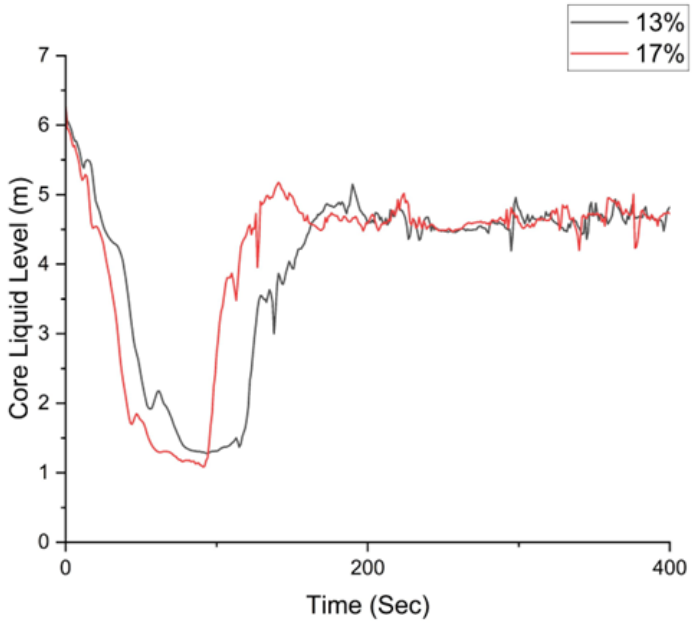
Pressure of Primary Side

- Intermediate breaks are characterized by an RCS pressure transient that does not make significant natural circulation period. Because break flow is sufficiently large, natural circulation phase does not persist, and pressure falls to the accumulator trip pressure.



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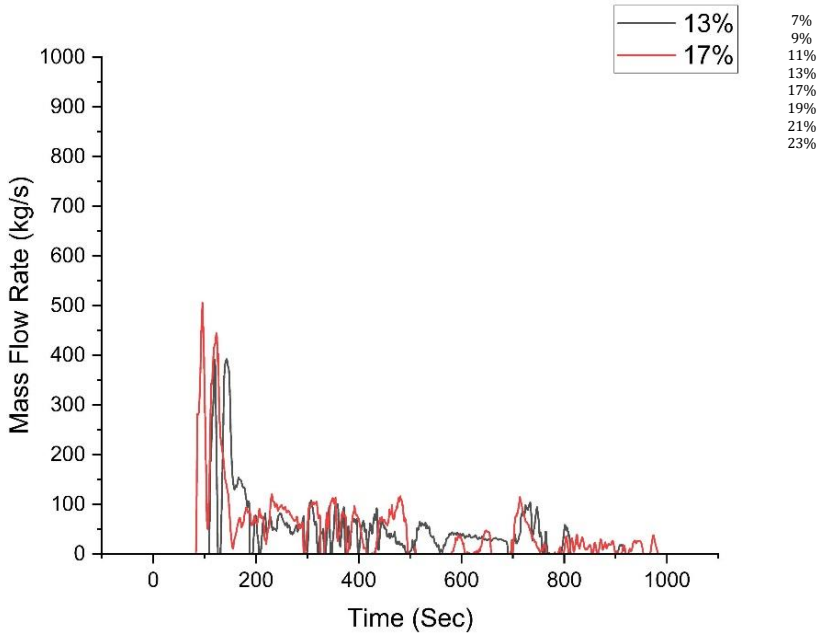
Core Liquid Level

- Rapid Drain SBLOCA cases shows not completely core uncover period and refilling starts late.
- ACC injection helps recovering the core in IBLOCA cases.
- In LBLOCA cases, core becomes uncovered fast.



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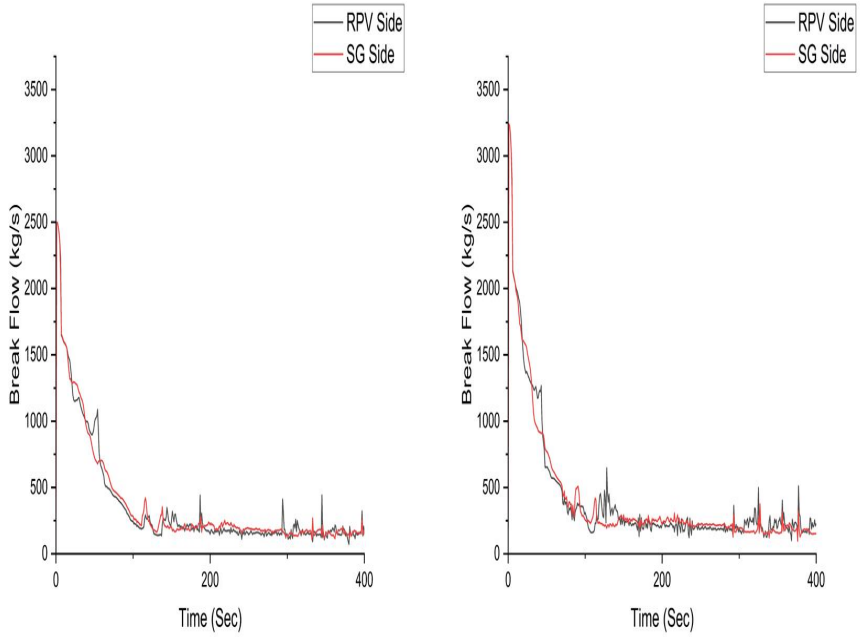
Core Liquid Level

- Characteristic of these breaks is a period in which there is nearly complete or complete core uncovery and clad heat-up.
- Because of the rapid depressurization and significant amount of flashing that occur in the vessel and loops, there is a single core uncovery period.



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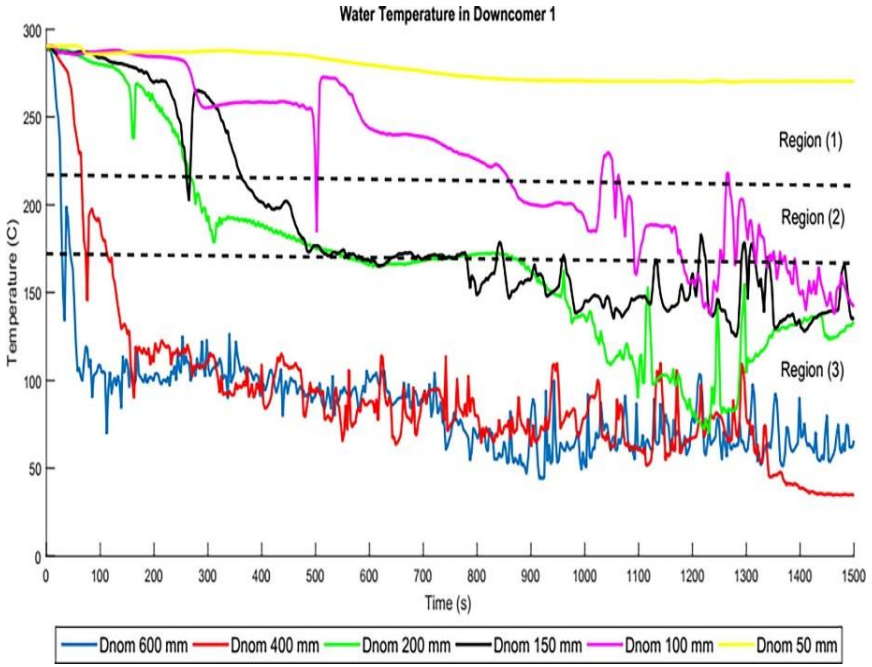
SIT Injection

- During this last phase, only pumped SI flow will be available to maintain core cooling. (SIP + SIT Injection)
- 3rd phase and the transient are considered complete when SI flow consistently exceeds break flow, and the core is quenched.



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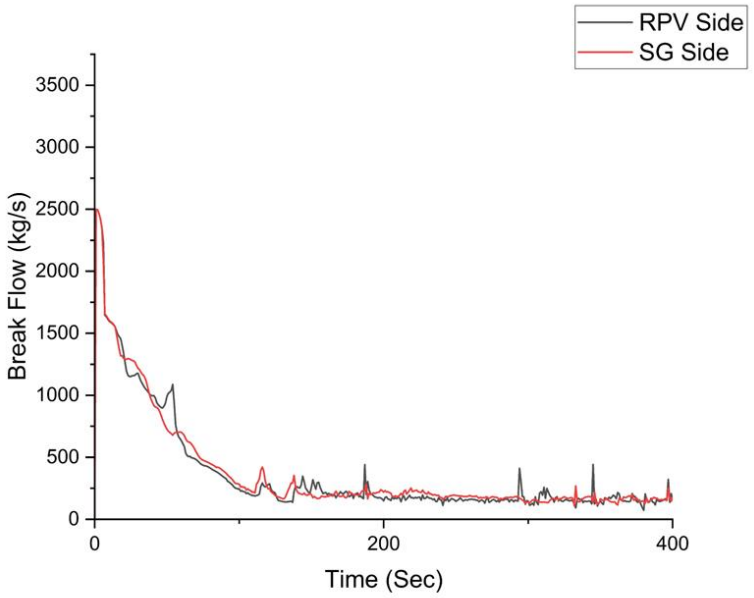
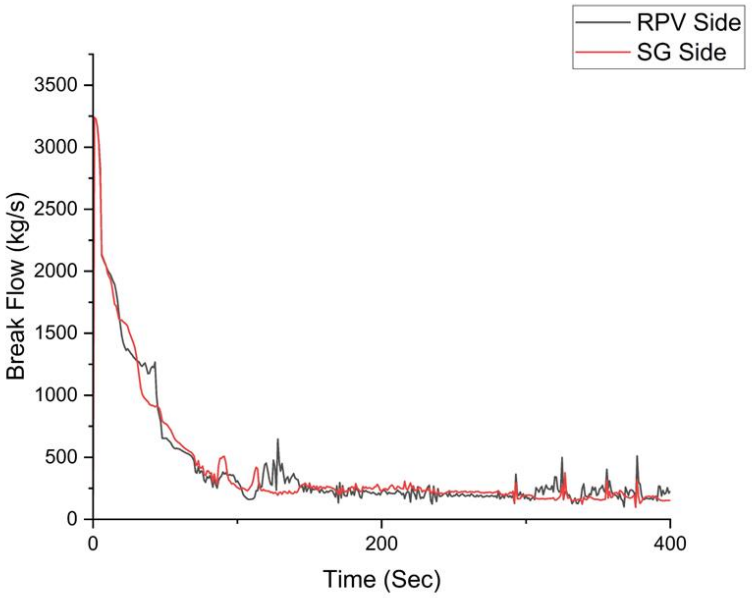
Break Mass Flow

- As the RCS liquid becomes saturated, and flashing occurs, the transition to two-phase break flow leads to a reduction in break mass flow. When this occurs, the depressurization rate also reduces.



13% IBLOCA



17% IBLOCA

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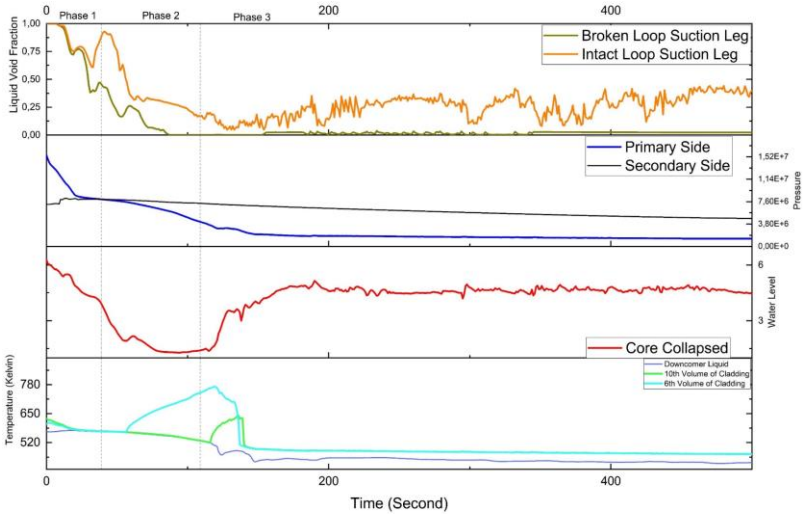
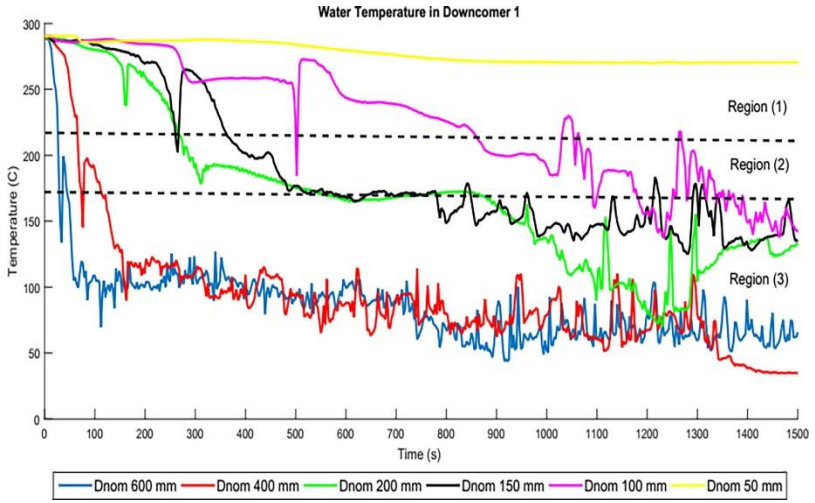
Liquid Temperature in Downcomer

- This comparison shows the LOCA identification using downcomer water temperature.

*(M. Ghafari, M.B. Ghofrani, F. D'Auria, Boundary identification between LBLOCA and SBLOCA based on stratification and temperature gradient in two-phase PTS)

- 13% and 17% IBLOCA scenarios represents 275mm and 314mm break diameter, respectively.





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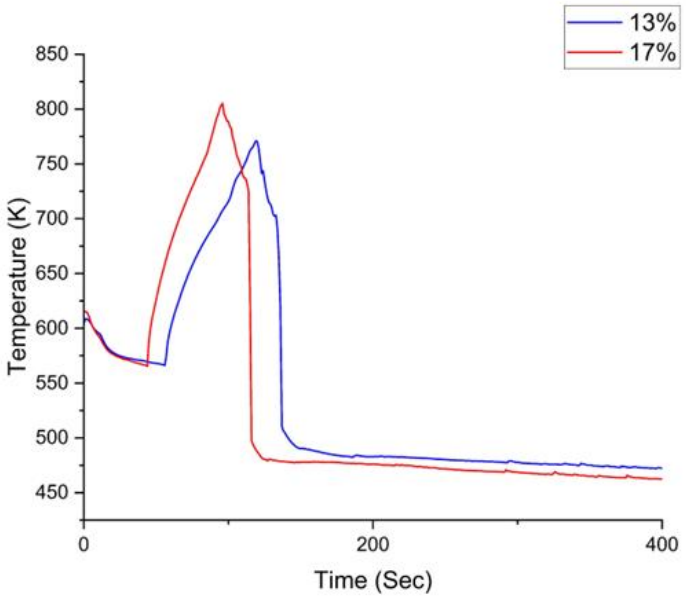
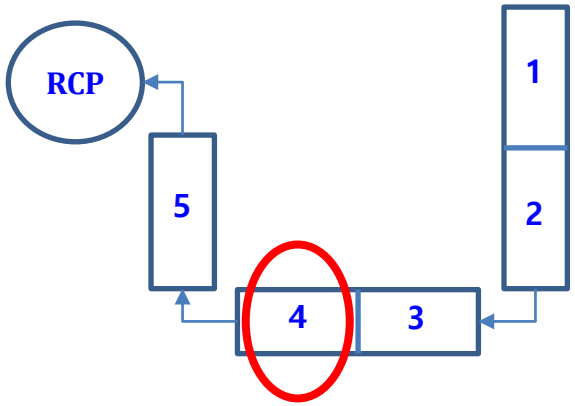
Peak Cladding Temperature

- PCTs vary considerably with break area and can be considered as functions of the RCS rate of depressurization and the plant SI system.
- There is a time lag between the start of accumulator injection and the PCT turnaround time because of the relatively long period of time it takes to fill the downcomer, which is nearly empty at the start of injection.



Loop Seal Clearing

- Rapid recovery of the core liquid level occurred after LSC, and ACC injection and the fluid level was maintained the core.
- The decrease in the SG U-tube downflow-side collapsed liquid level continued down to the crossover leg, which caused loop seal clearing (LSC) for each loop.



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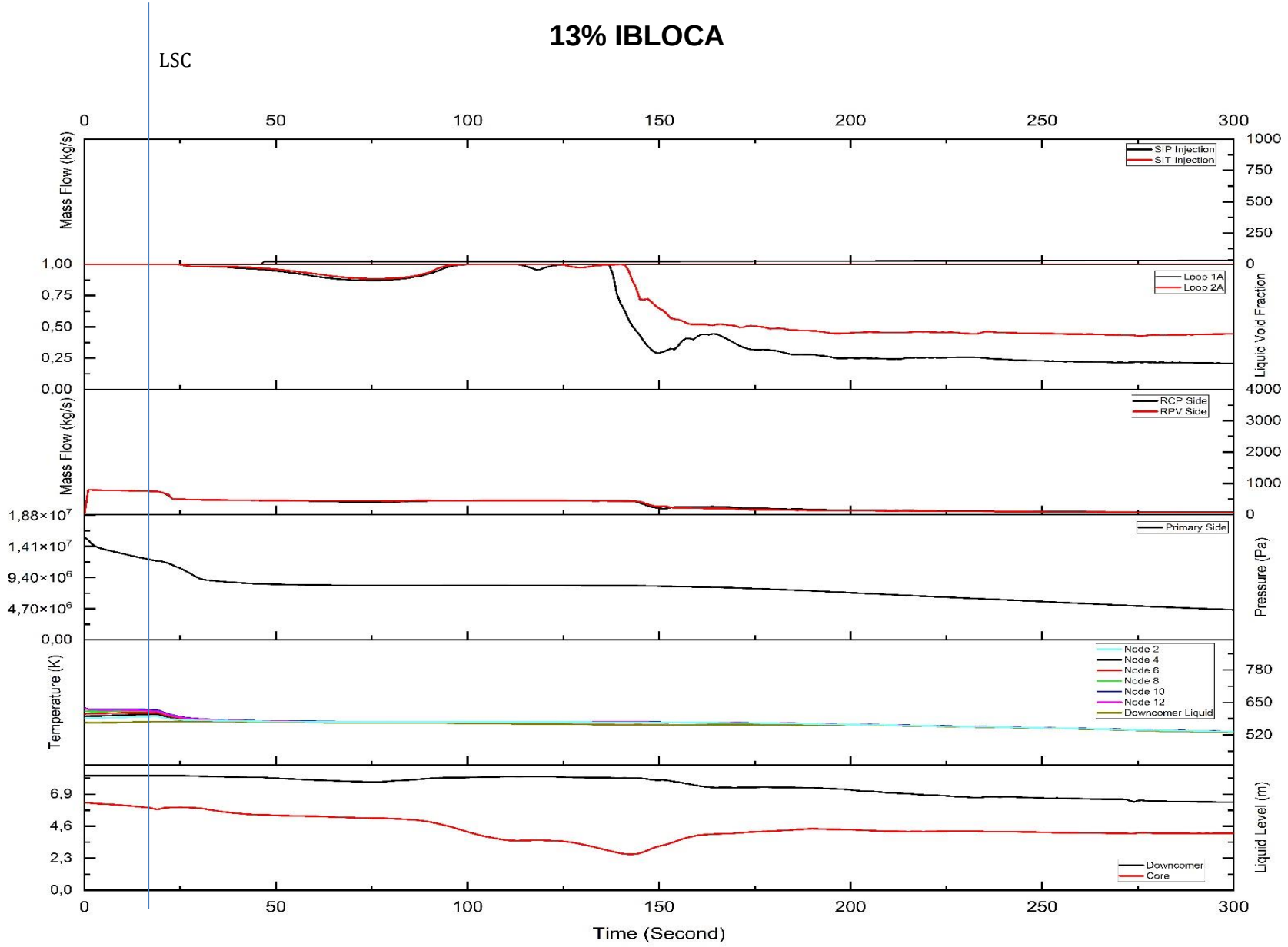
13% IBLOCA



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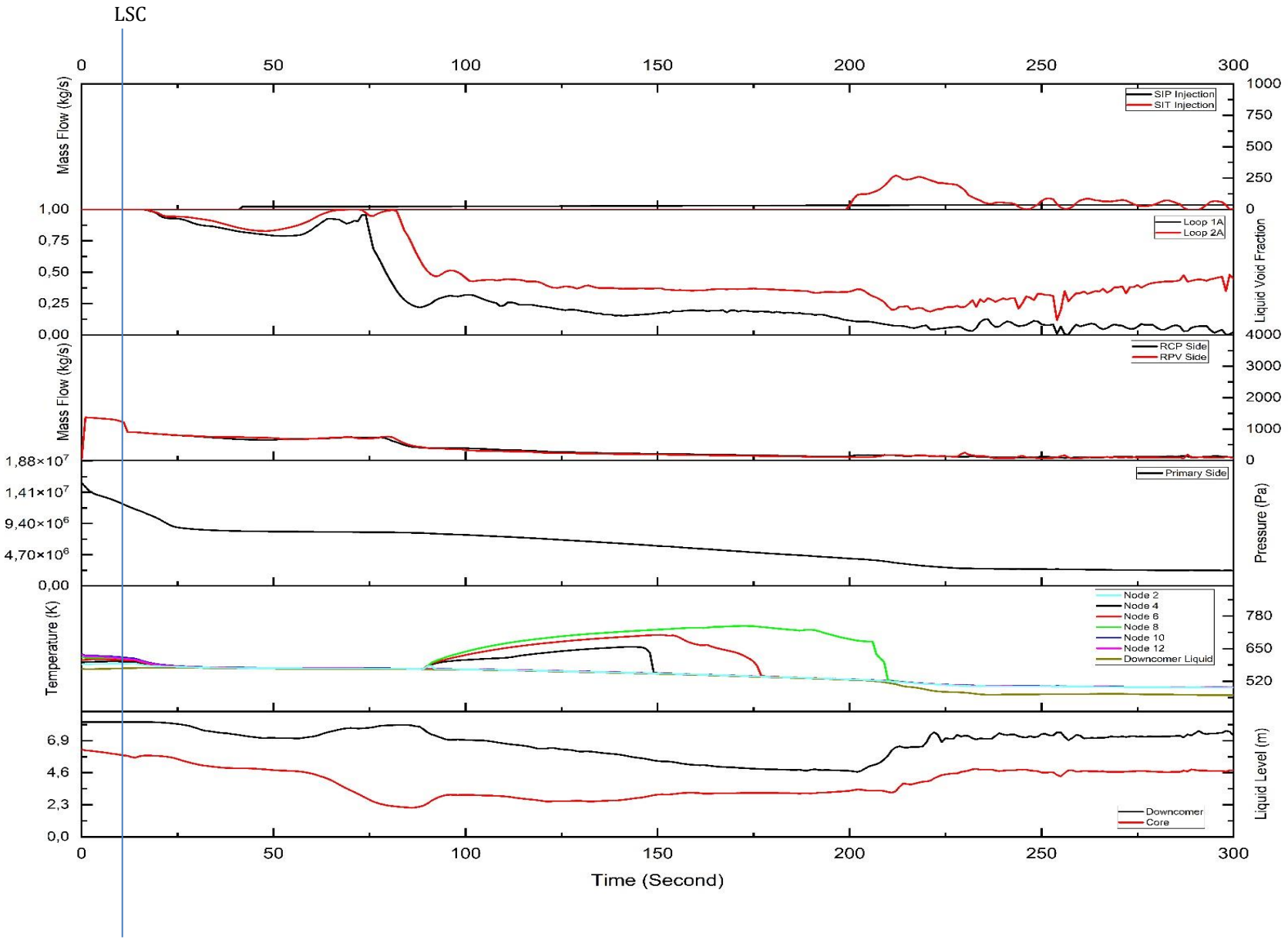
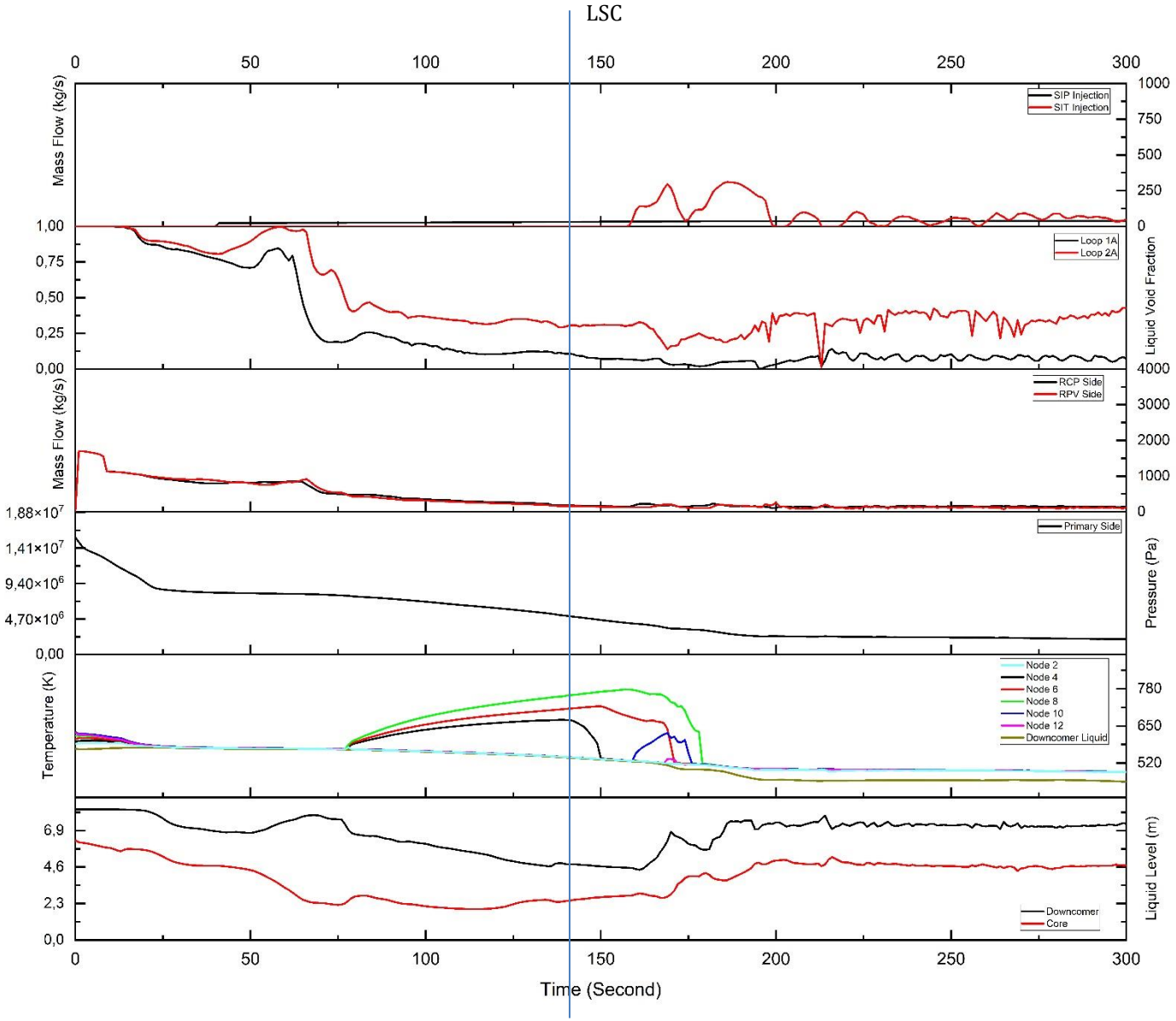
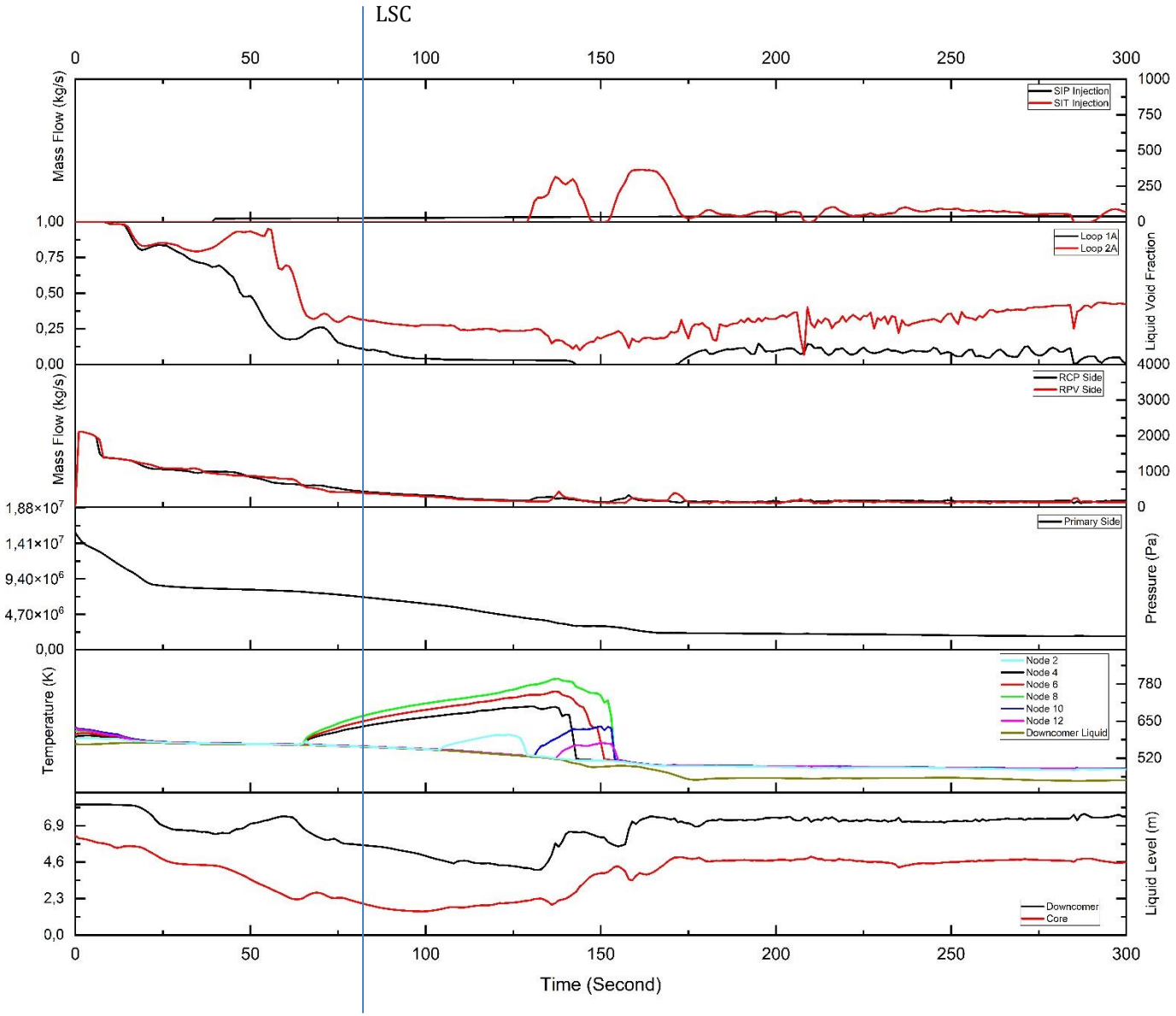
17% IBLOCA




LSC
Mass Flow (kg/s)
SIP Injection
SIT Injection
Liquid Void Fraction
Loop 1A
Loop 2A
RCP Side
RPV Side
Primary Side
Pressure (Pa)
Temperature (K)
Node 2
Node 4
Node 6
Node 8
Node 10
Node 12
Downcomer Liquid
Liquid Level (m)
Downcomer
Core
Time (Second)

4% LOCA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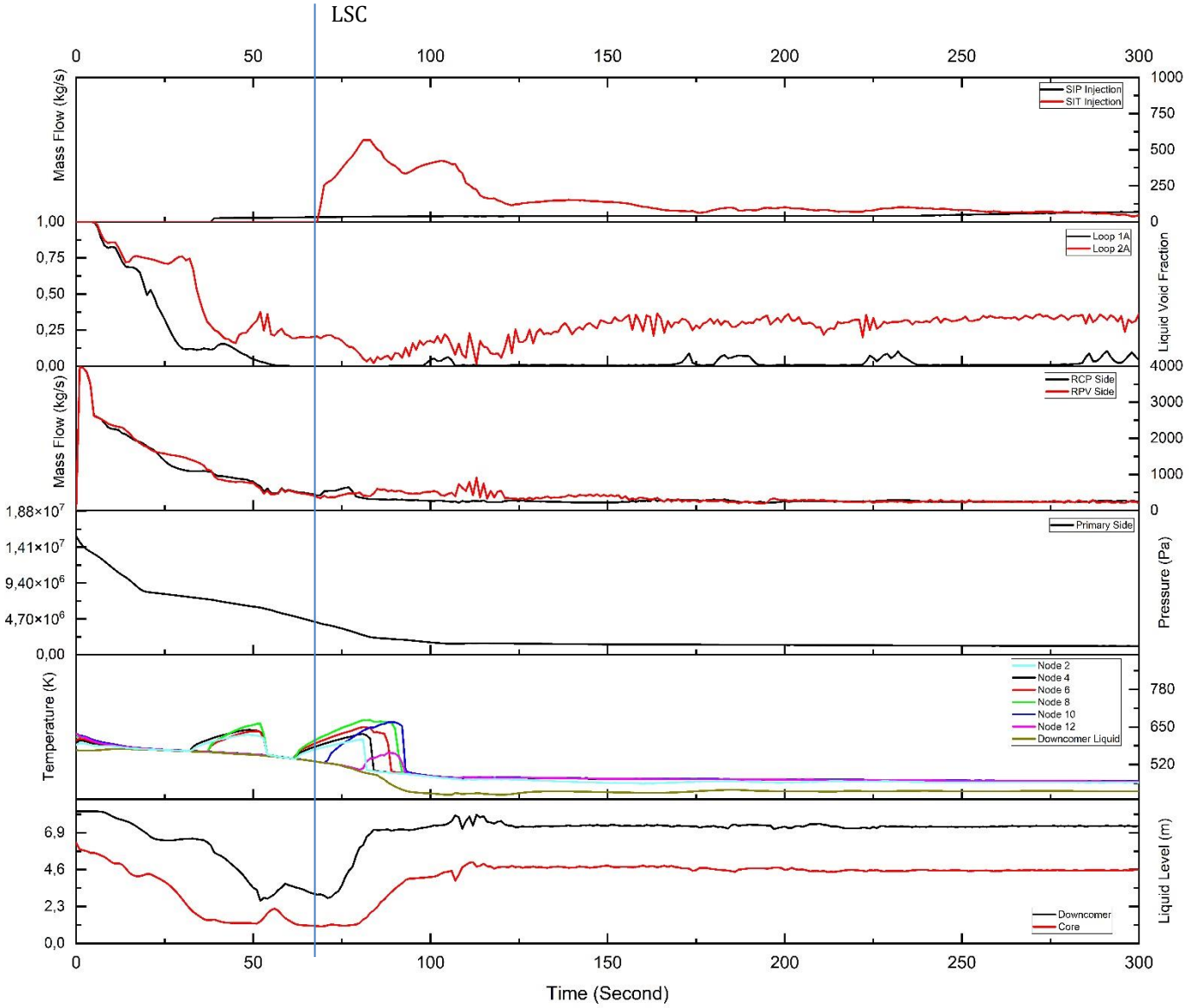
7% LOCA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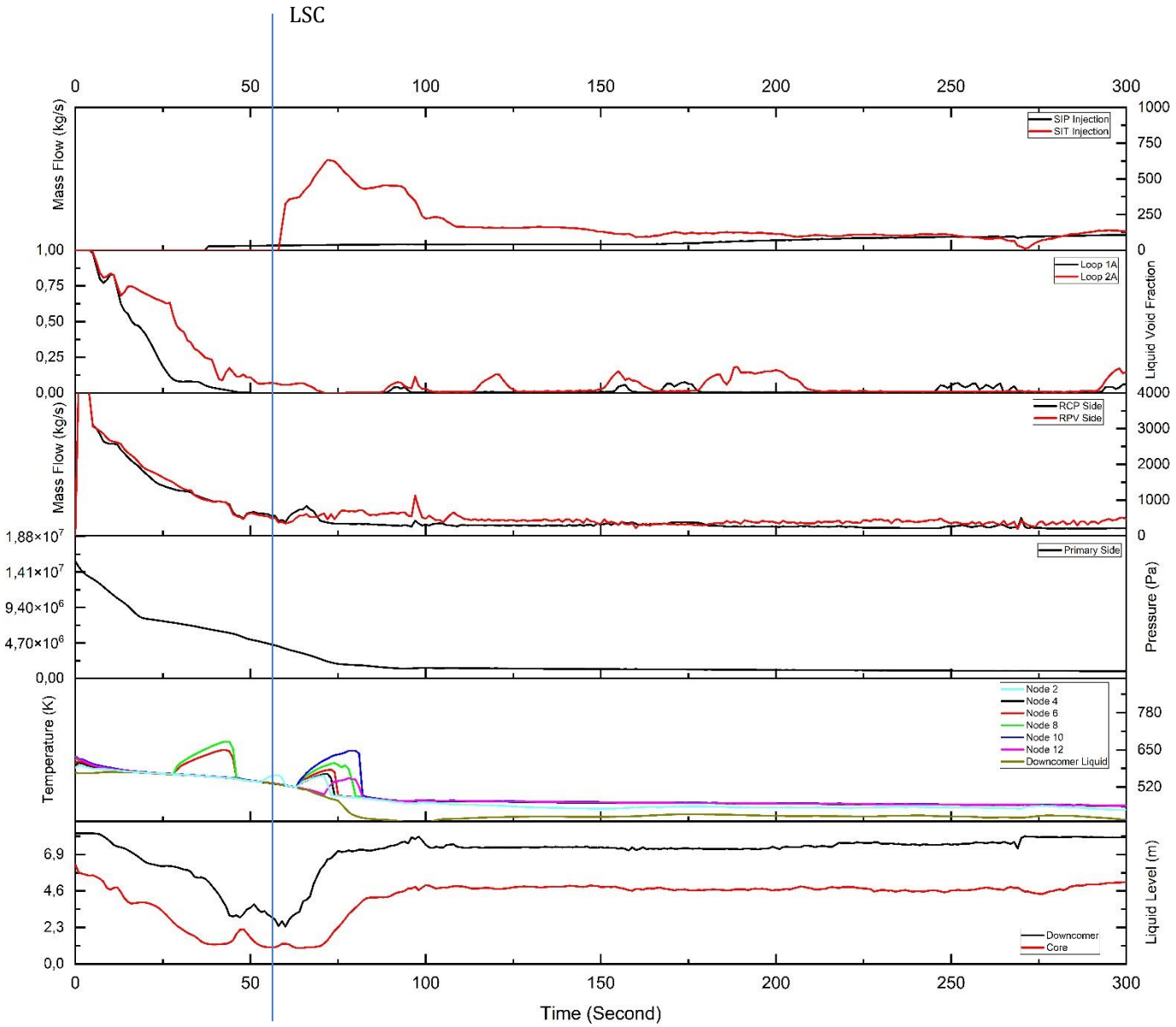
9% LOCA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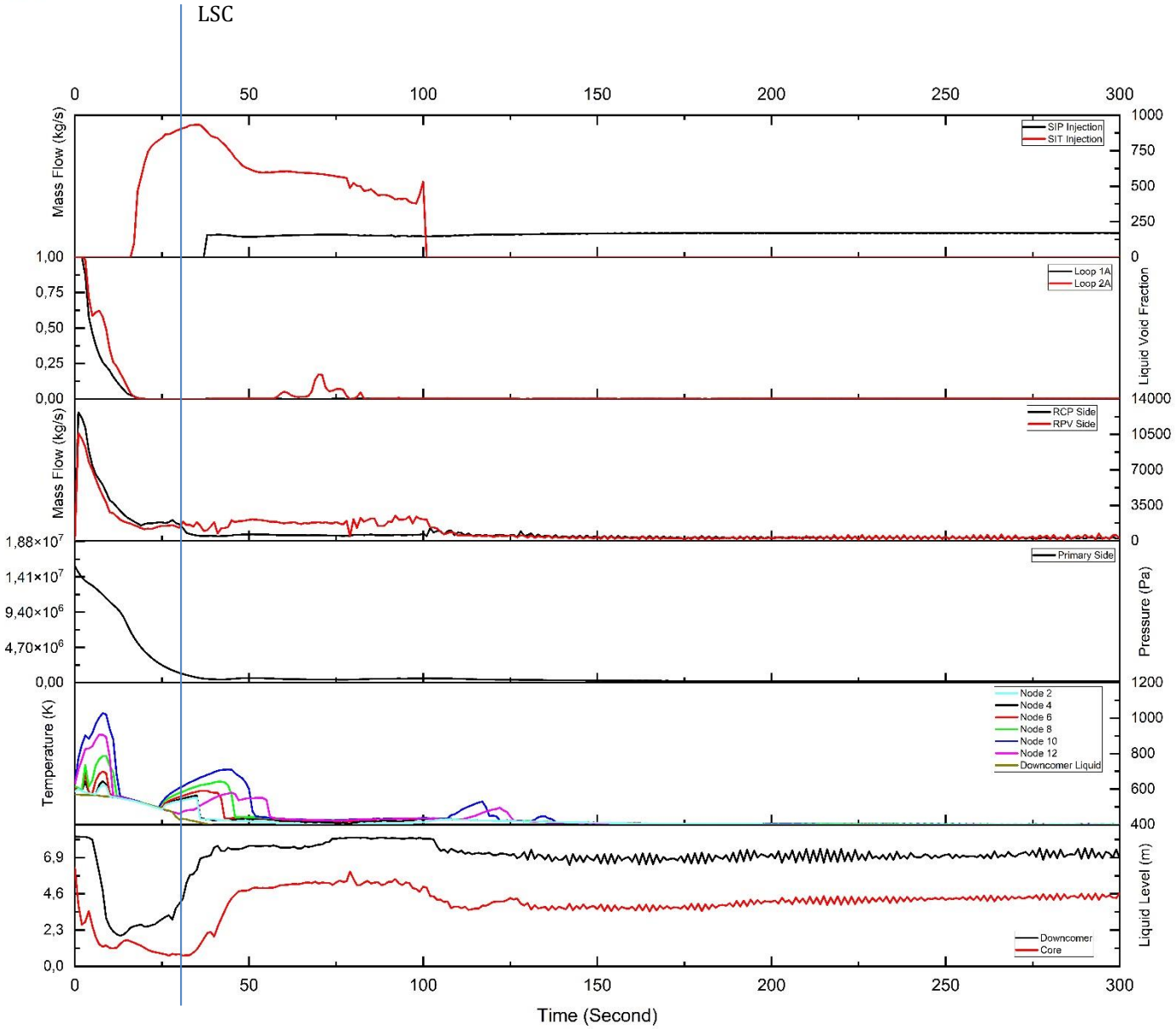
Time (Second)

11% LOCA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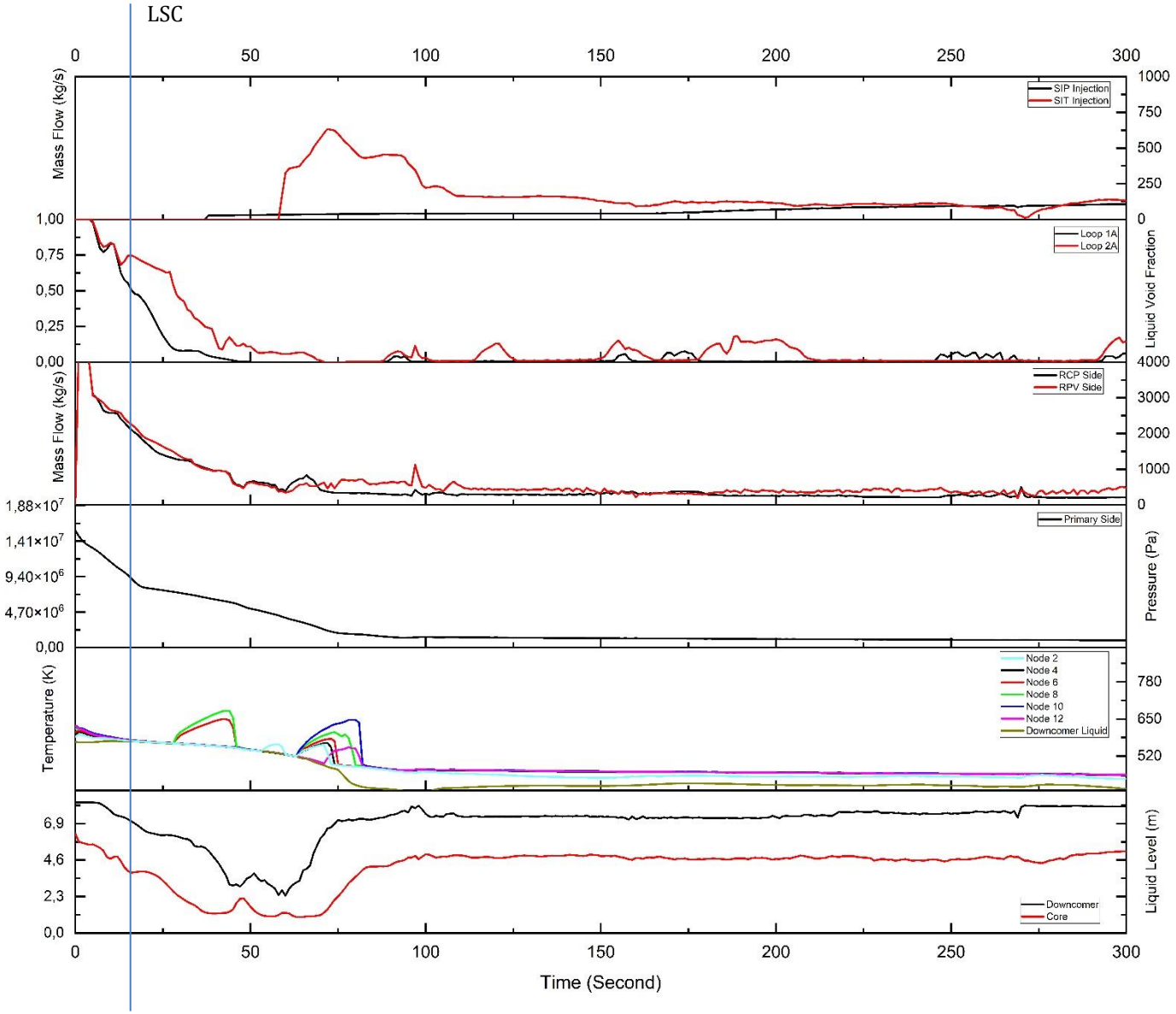
Time (Second)

21% LOCA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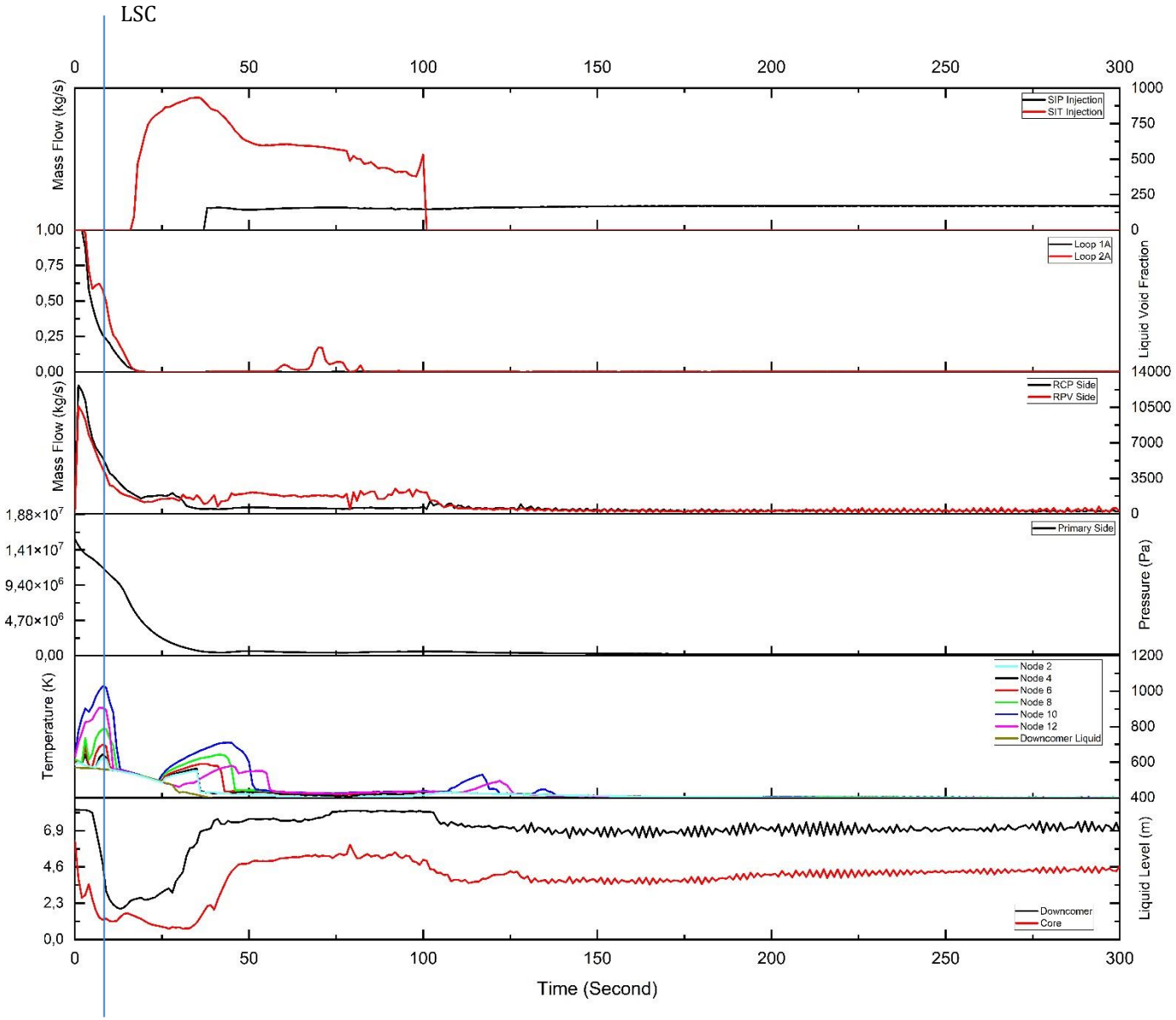
Time (Second)

25% LOCA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Time (Second)

100% LOCA

Conclusion

- Both cases are in the IBLOCA for OPR1000 because all phases have occurred in line with expectations.
- PCT increases with increasing break size. Highest PCT occurred in 17% IBLOCA. All PCT results doesn't exceed the regulation limit temperature.
- Core recovered simultaneously by SIT injection, so ECCS affects directly core cooling and recovering.
- With result of this research, we can say that IBLOCA range for OPR1000 is between 11% and 21%.

Slow drain SBLOCA	$A_{break} < 3\%$
Rapid drain SBLOCA	$3\% < A_{break} < 11\%$
IBLOCA	$11\% < A_{break} < 25\%$
LBLOCA	$A_{break} > 25\%$.

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Thank you