Jožef Stefan Institute

R4 Reactor Engineering Division

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Analysis of Severe Accident in Safety Upgraded Krško NPP

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Outline

- Introduction
- Analyzed SA scenarios
- Krško NPP MELCOR model
- Simulation results
- Discussion
- Conclusions

Krško NPP

2-loop Westinghouse PWR with 1,994 MW_{th} and 696 MW_{el}

Analyzed SA scenarios

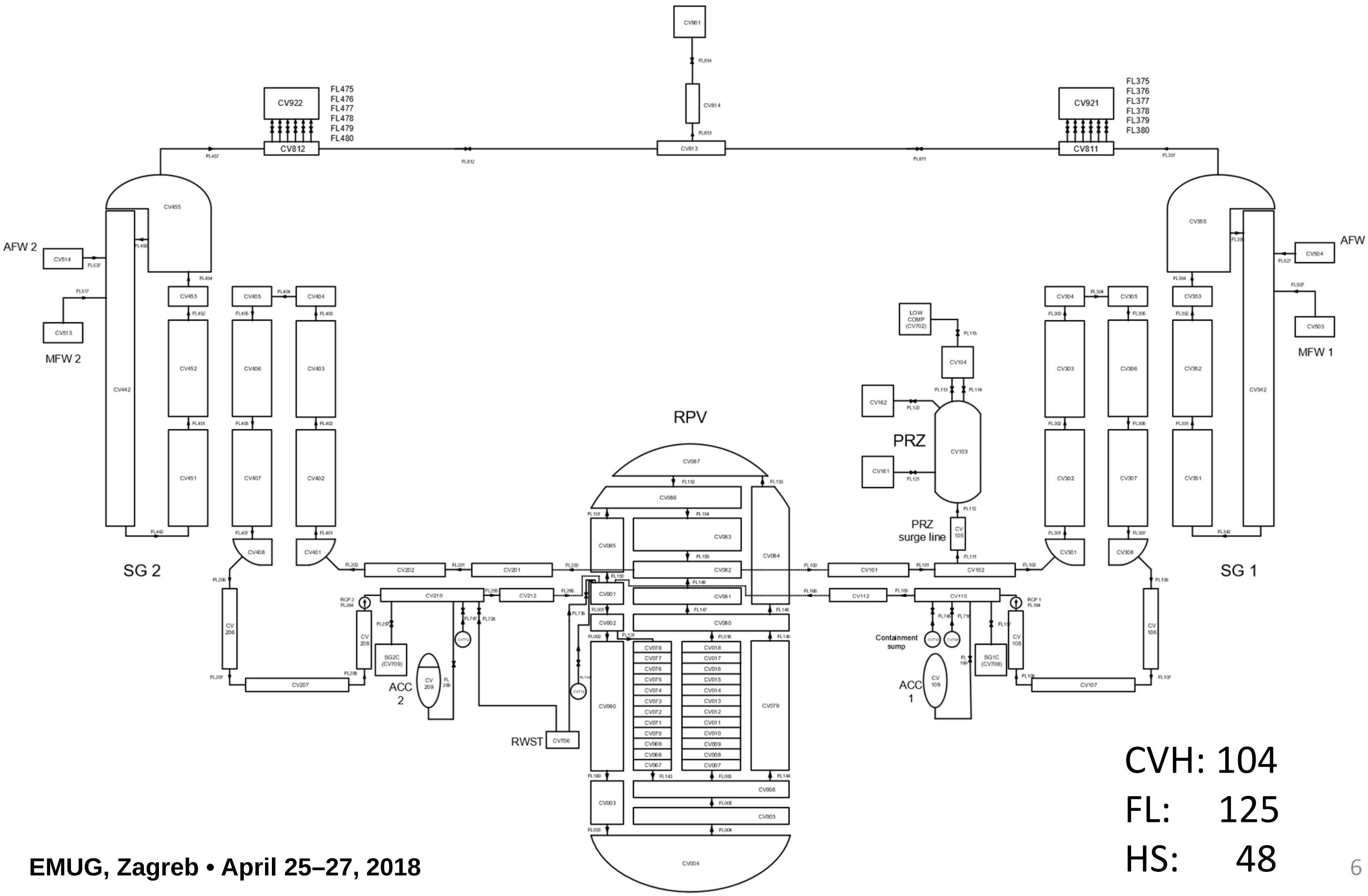
Initial event: Strong earthquake resulting in simultaneous SBO and LBLOCA

Analyzed three scenarios:

1. Without DEC alternative safety systems
2. 24 h after accident coolant injection through containment sprays using alternative ACI system
3. 24 h after accident coolant injection in RCS using alternative ASI system

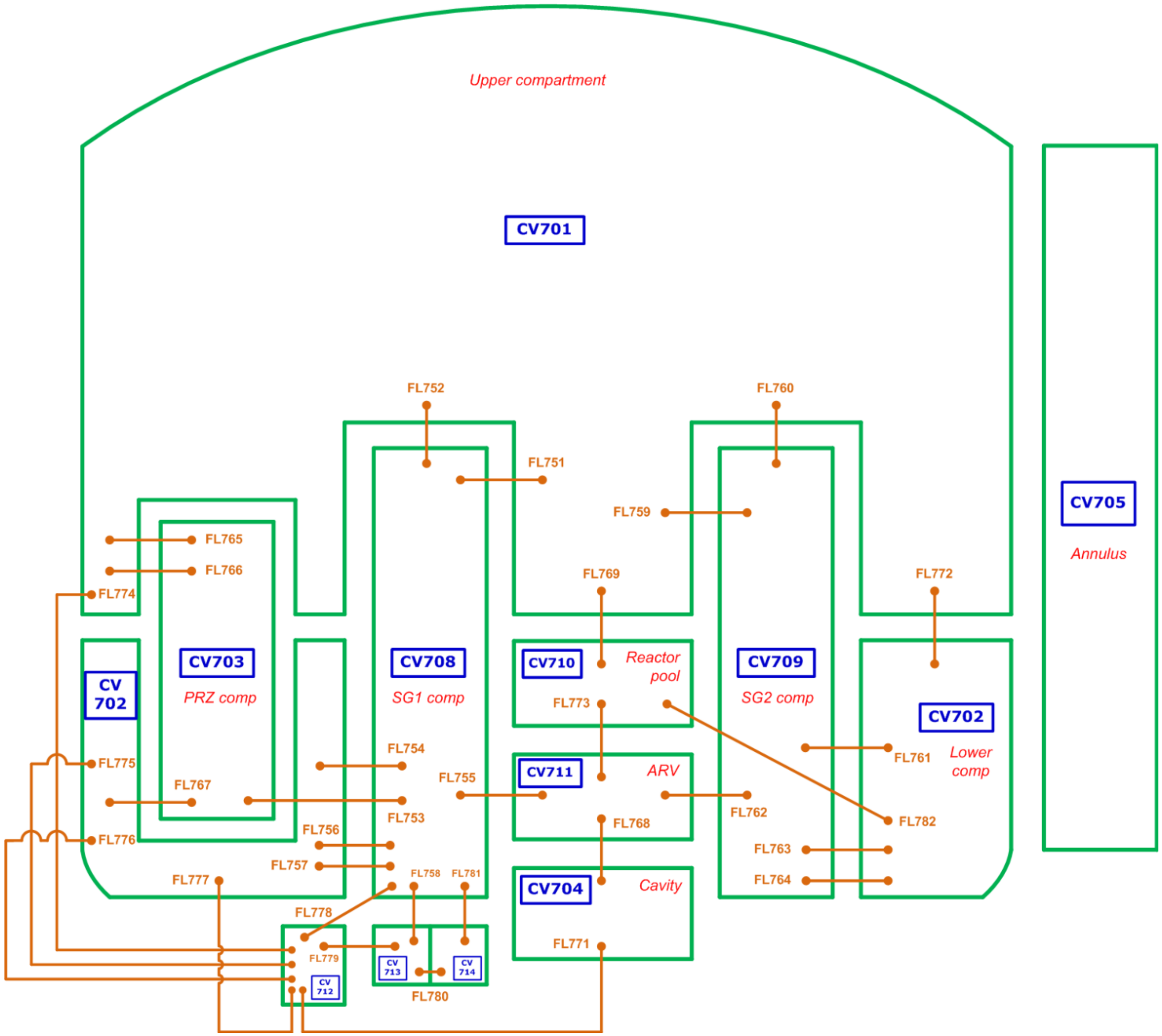
Simulations performed with MELCOR 1.8.6 revision 4073

Krško NPP primary and secondary systems nodalization



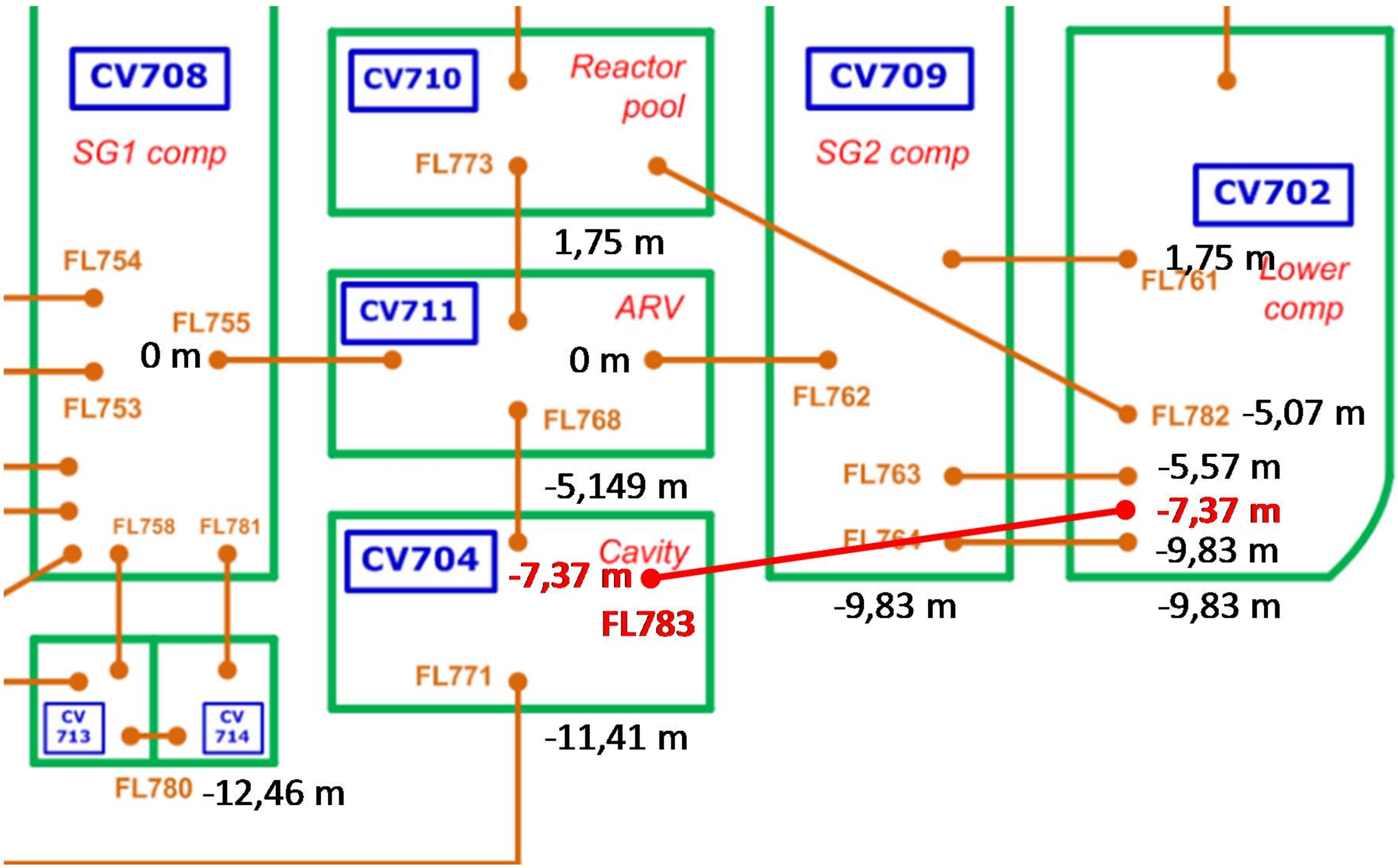
CVH: 104
FL: 125
HS: 48

Krško NPP containment nodalization



CVH: 12
FL: 30
HS: 20

Flow path through reactor cavity ventilation duct



Performed simulations

- 3 scenarios (noASS, ACI, ASI)
- Without and with flow path through ventilation duct (VD)
- Together 2 x 3 = 6 calculations
- 300,000 s (3.5 days) of accident

Denotation	Scenario	DEC equipment	Injection	Ventilation duct
noASS	1	No	/	No
ACI	2	Yes	Containment	No
ASI	3	Yes	RCS	No
noASS_VD	1	No	/	Yes
ACI_VD	2	Yes	Containment	Yes
ASI_VD	3	Yes	RCS	Yes

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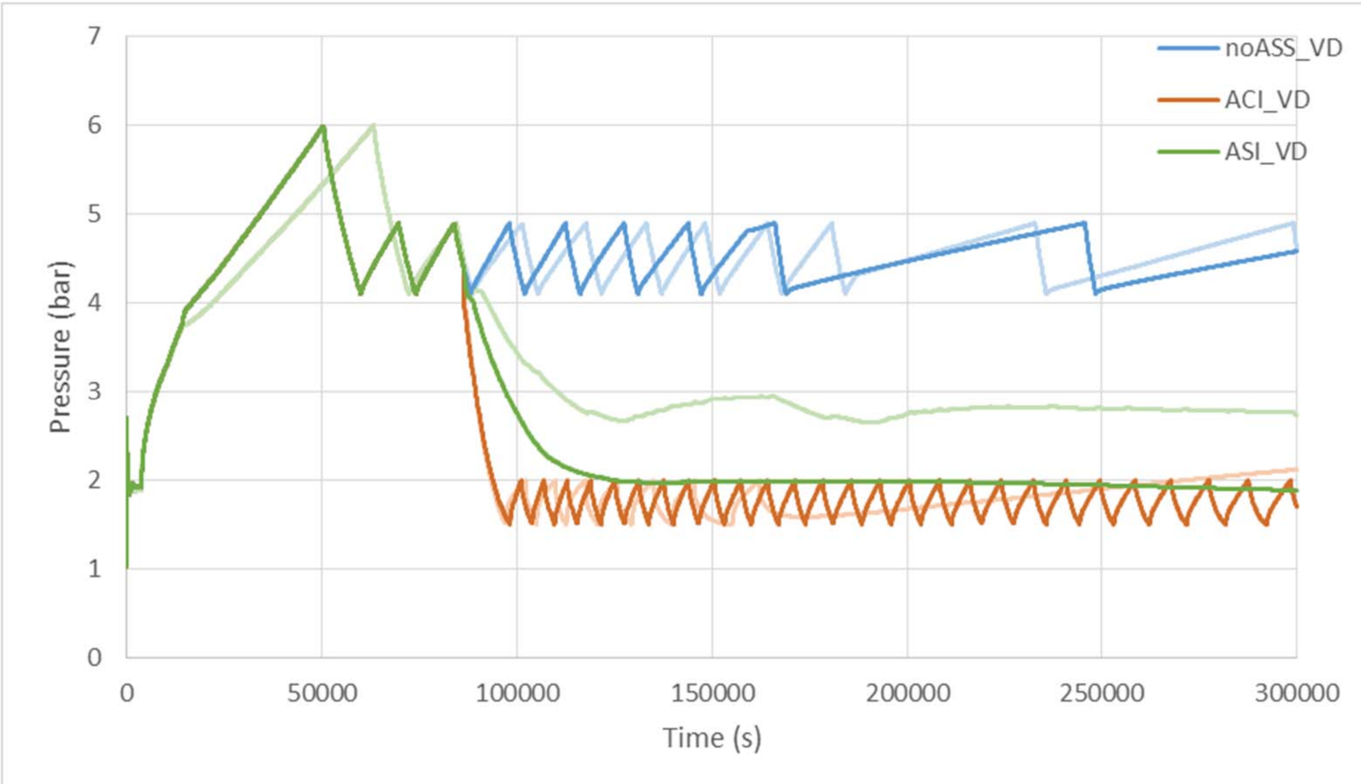
Containment pressure



Natural circulation with VD: improved heat transfer from melt to containment atmosphere → faster temperature increase of cont. atmosphere → faster increase of cont. pressure

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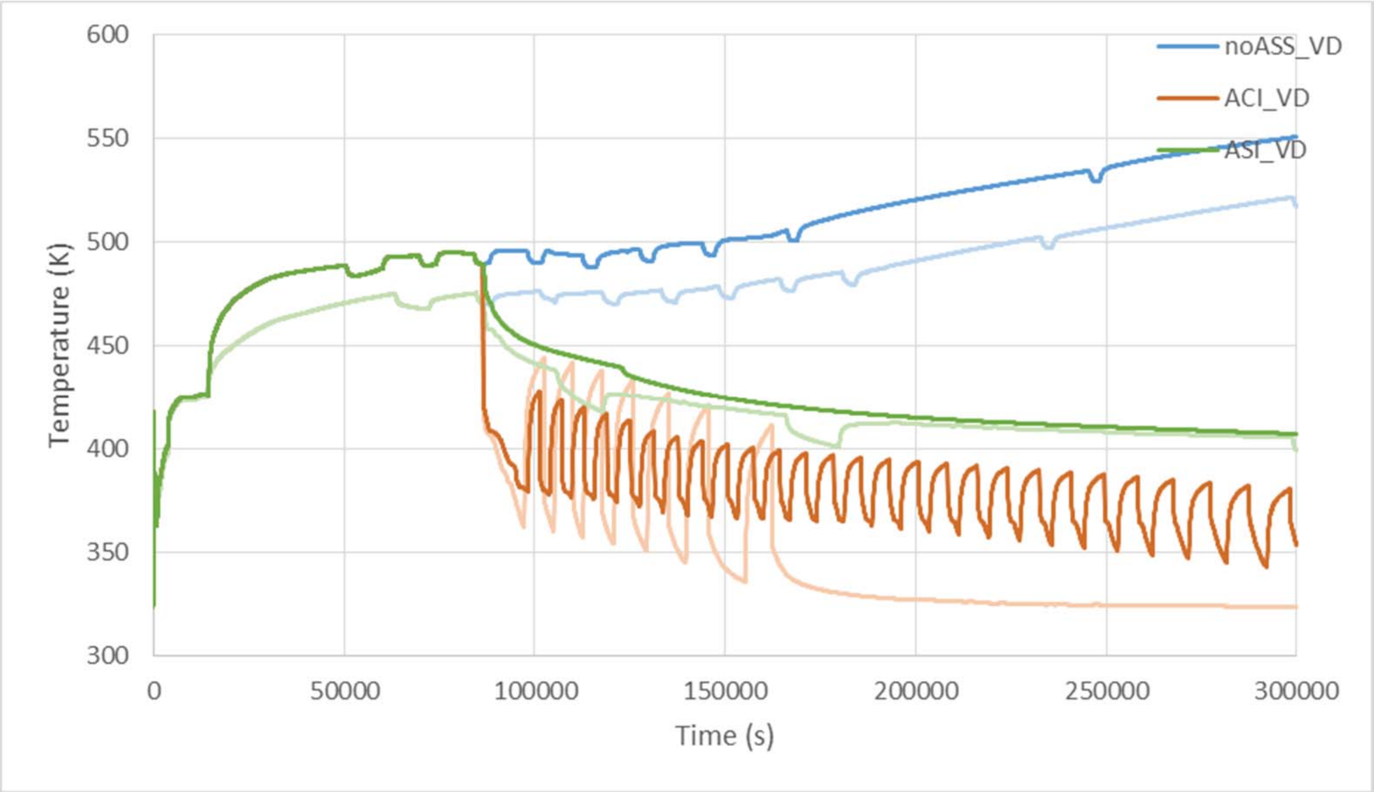
Containment temperature



Natural circulation with VD: improved heat transfer from melt to containment atmosphere
→ faster temperature increase of cont. atmosphere

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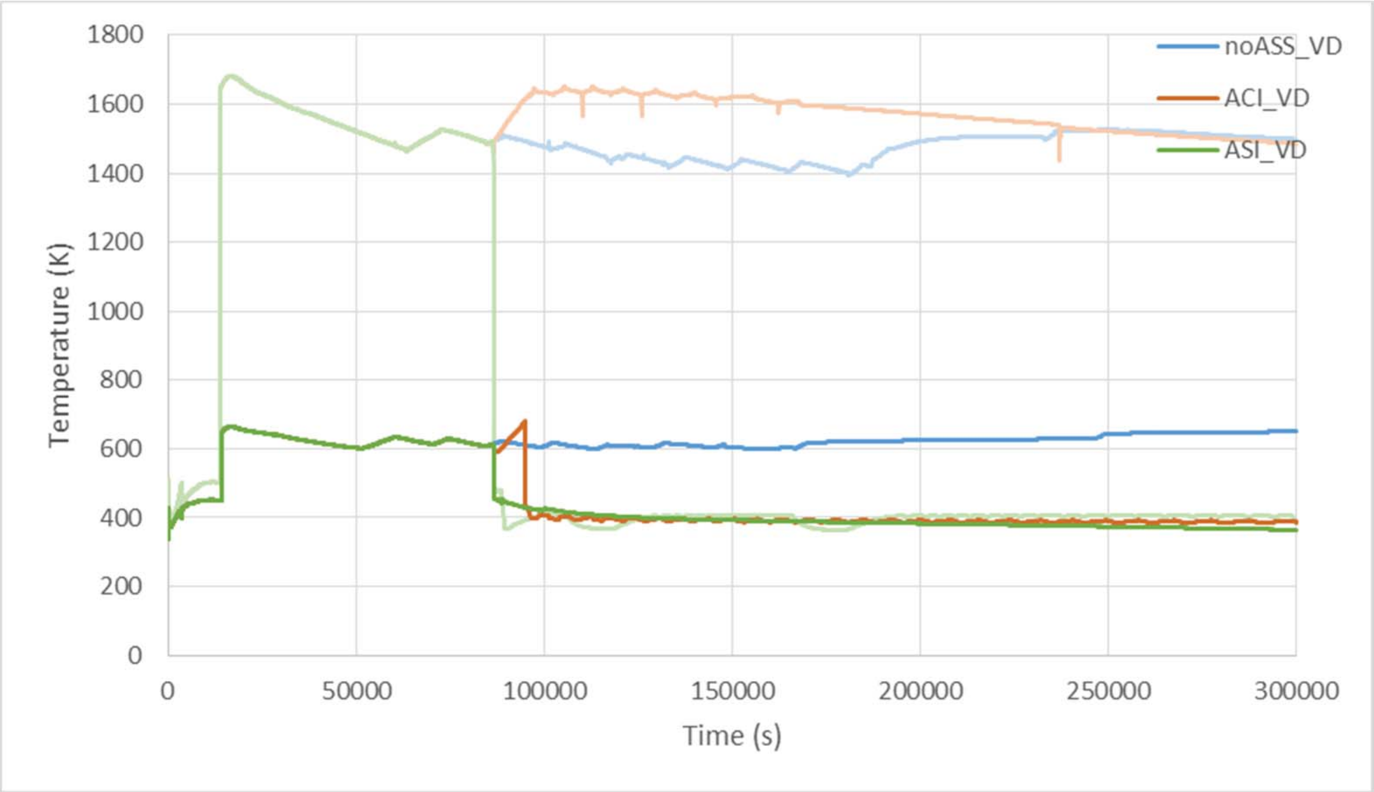
Temperature of cavity atmosphere



Natural circulation with VD: lower temperature of cavity atmosphere

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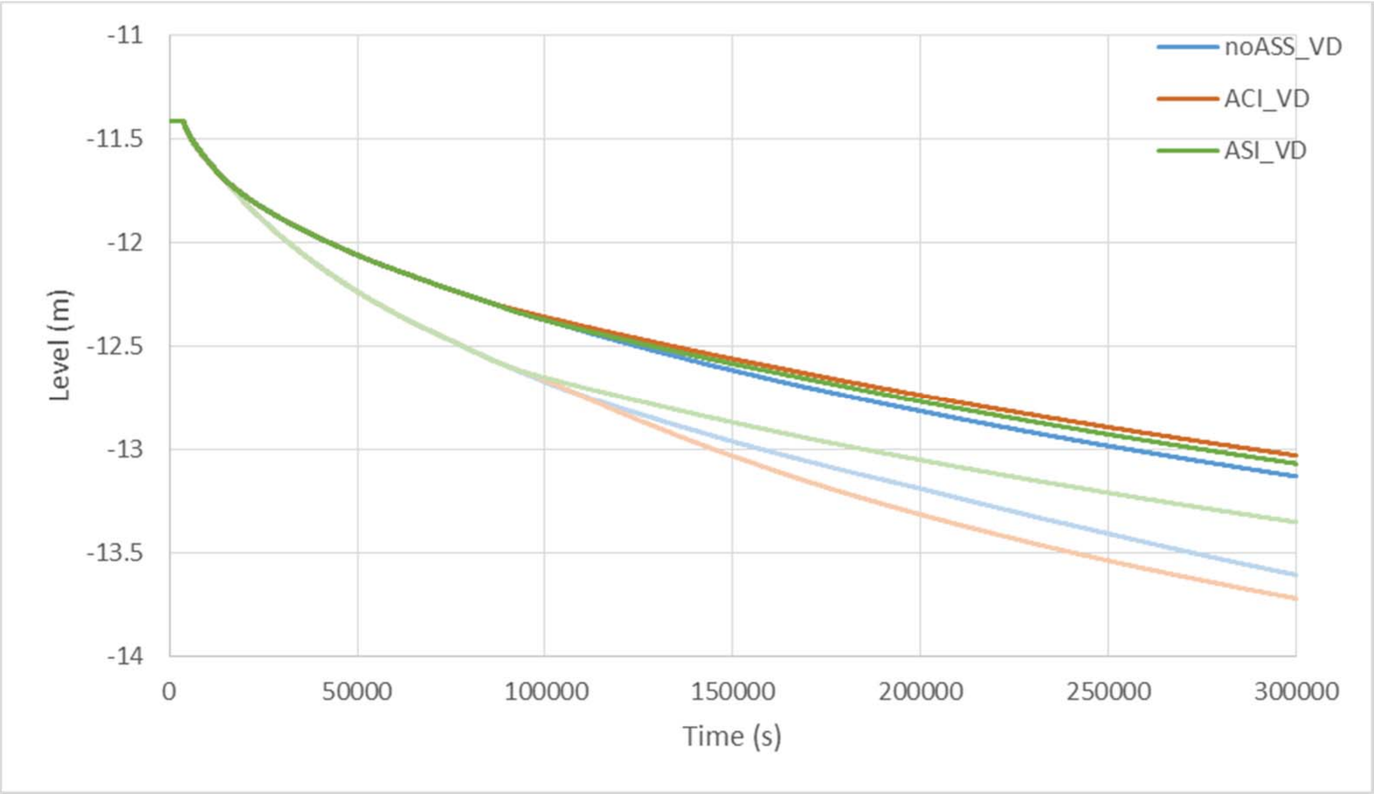
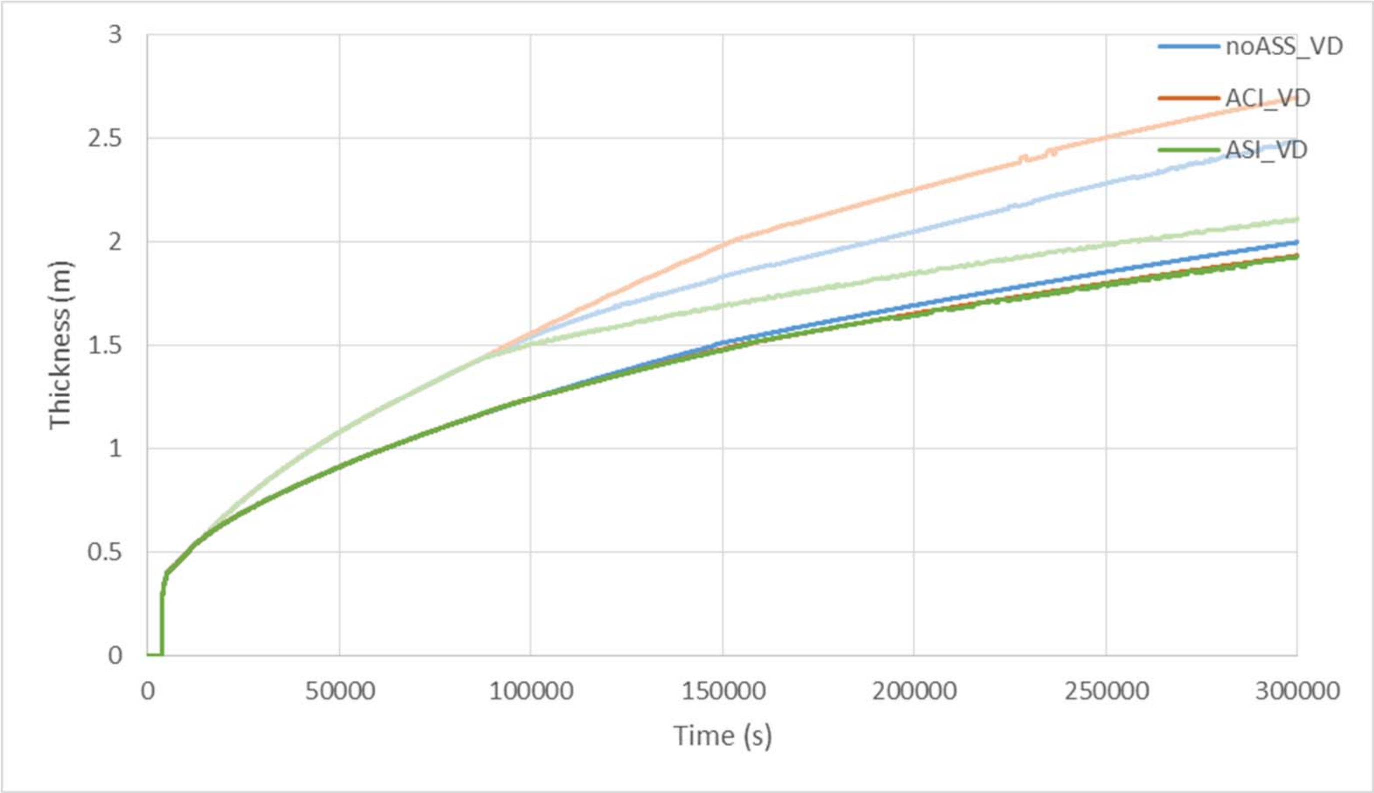
Bottom of eroded cavity



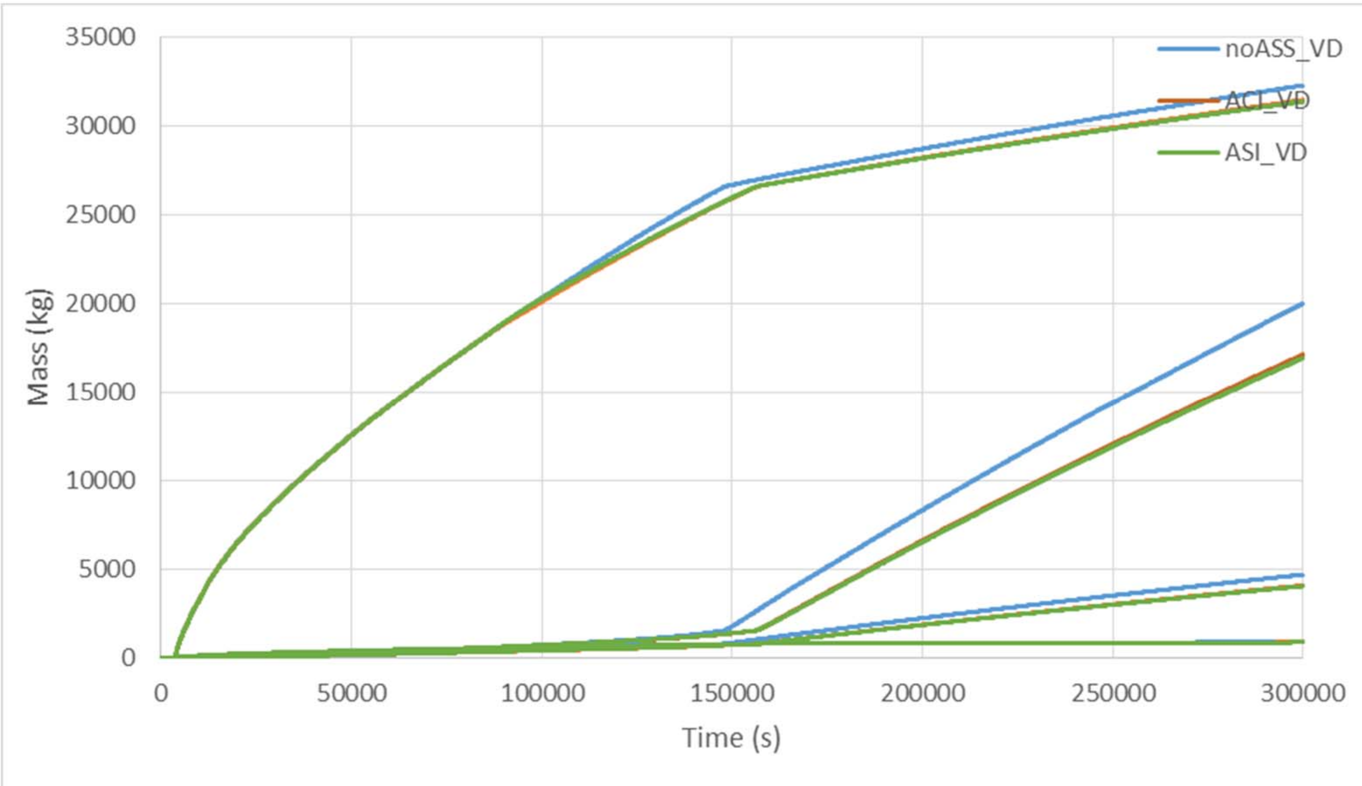
Natural circulation with VD: improved heat transfer from melt to containment atmosphere

Thickness of corium-concrete layer



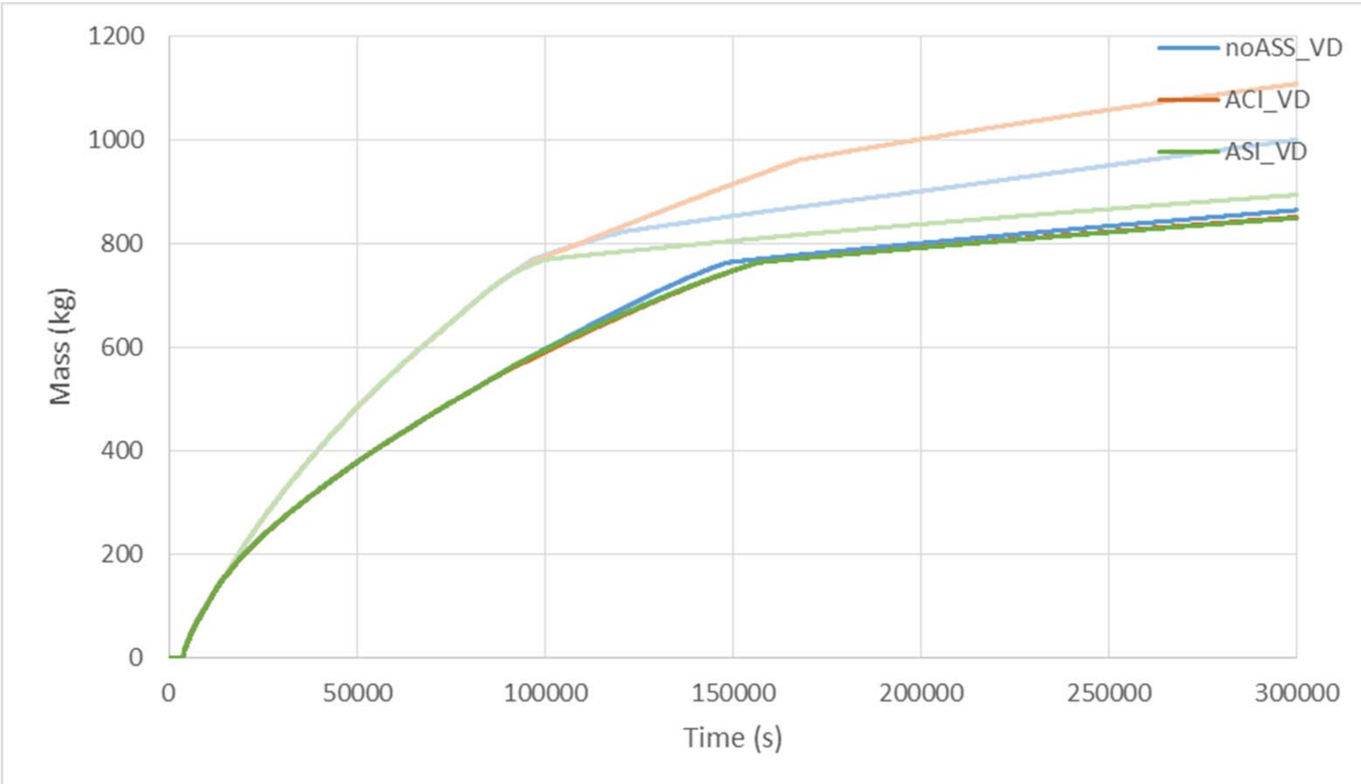
By heat conduction through corium crust only ~8 cm thick melt layer may be cooled

Mass of released gasses



In decreasing order: CO, CO_2, H_2O, H_2

Mass of H_2 released during MCCI



In-vessel about ~170 kg H_2 is released

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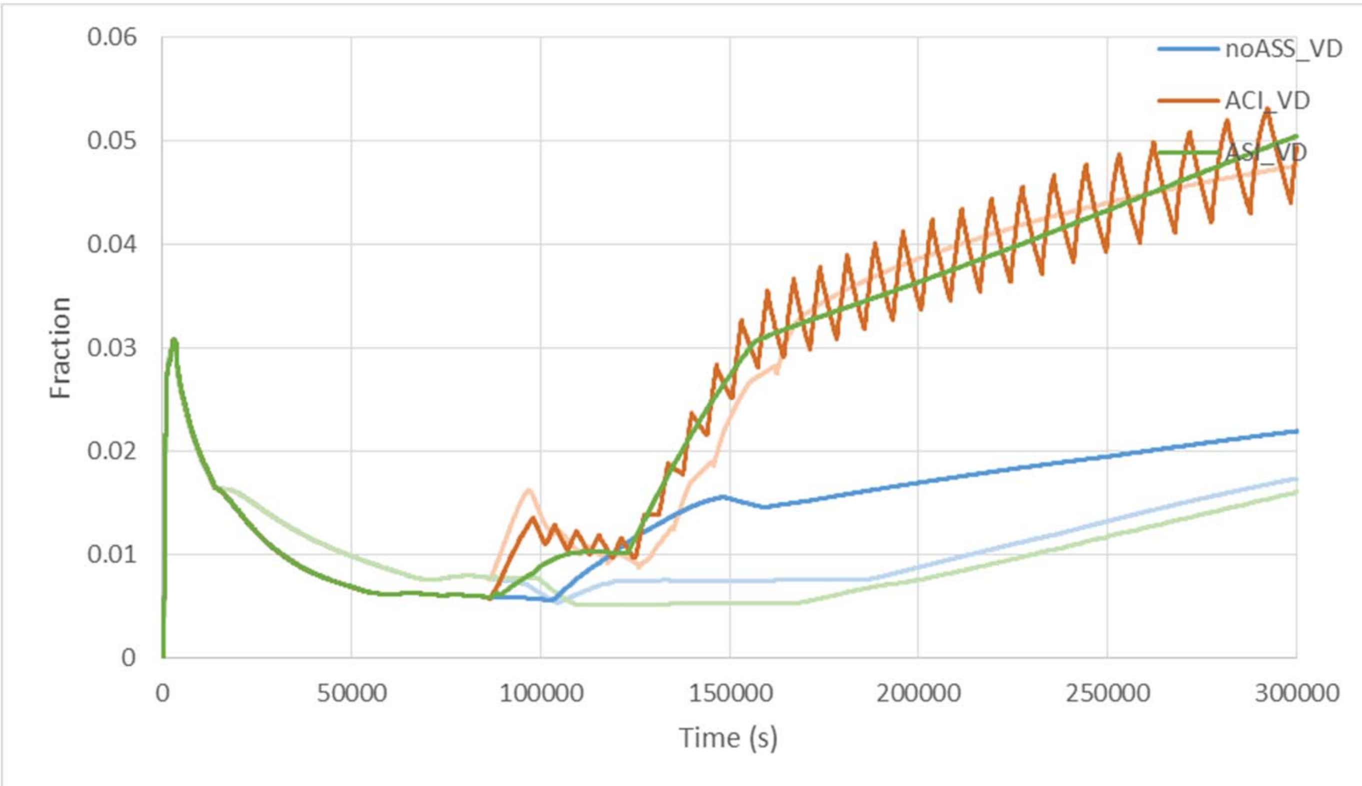
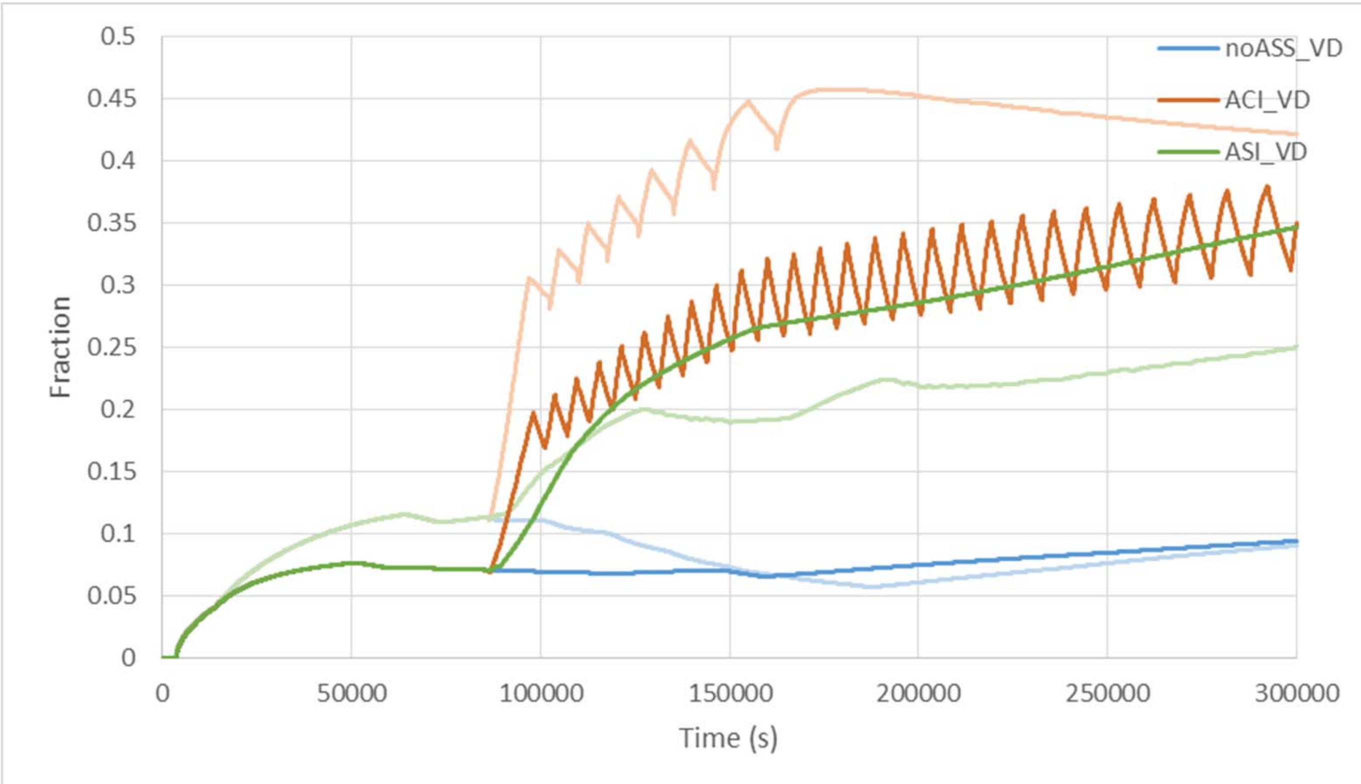
H_2 fraction



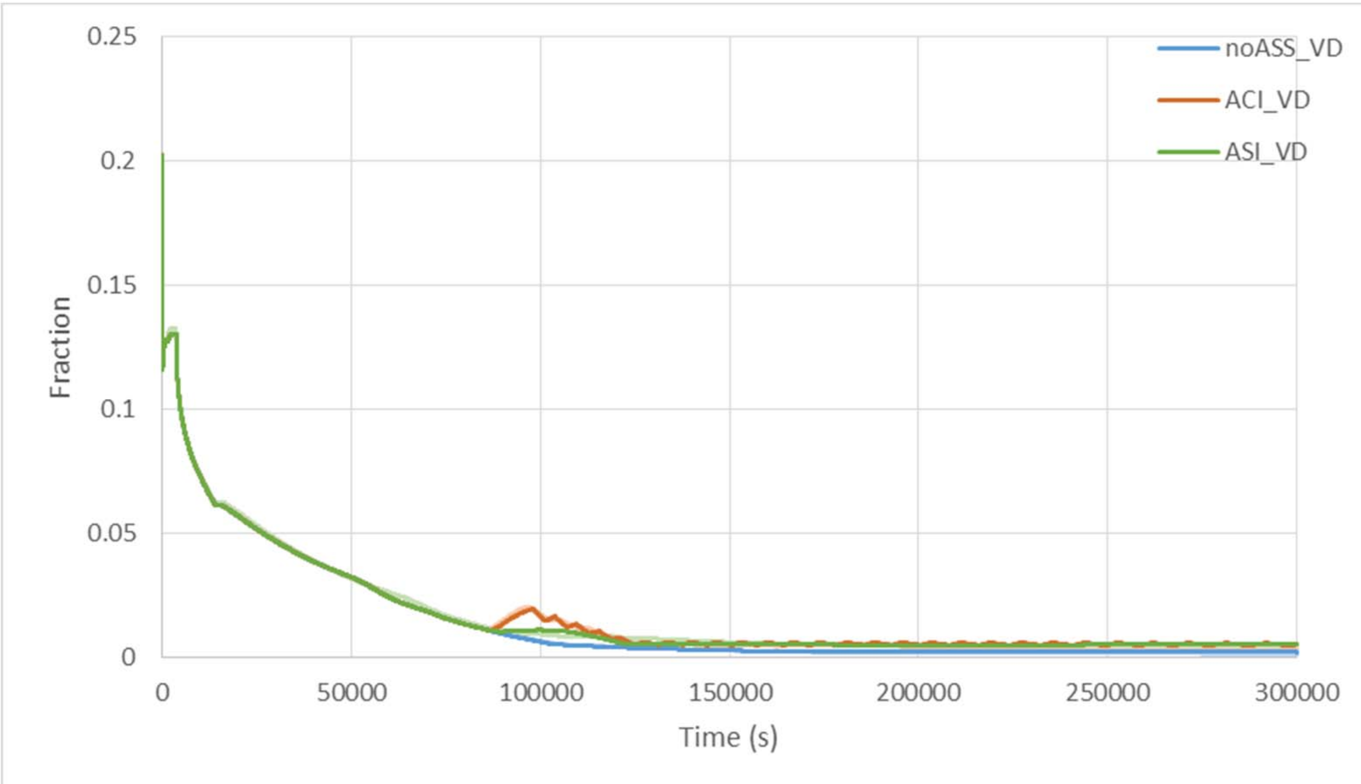
Global H_2 fraction is typically below 5% limit for combustion due to PARs

CO fraction



Global CO fraction may be high, but when O_2 level is already low

O_2 fraction



O_2 fraction is in general low due to oxidation processes (mainly due to PARs operation)

Discussion

- Calculation results show that despite operation of DEC alternative safety equipment MCCI in cavity can not be stopped

- In MELCOR 1.8.6 heat transfer from flooded corium melt to water is treated conservatively in regard to MCCI
  - Heat transfer only by conduction through crust
  - It is expected that cooling will be more effective due water ingression and melt eruption

- Added flow path through ventilation duct significantly influences course of severe accident in all scenarios
  - Natural circulation of atmosphere through cavity established, which importantly improves heat transfer from corium melt
  - Consequently temperature of containment atmosphere increases

- Best SA mitigation measure is ASI strategy
  - Corium melt flooded earlier than with ACI strategy
  - With ACI strategy regular operators actions needed (containment underpressure)

Discussion / Conclusions

- MELCOR 1.8.6 and MAAP 4.07 results differ significantly
  - Different conclusions regarding best SA mitigation strategy
- MAAP 4.07
  - After corium melt flooding MCCI stops immediately
  - Turbulent boiling after melt flooding → may exceed PCFVS capacity
  - Best SA mitigation measure is ACI strategy, where due to spraying containment pressure first decreases
- Difficult to judge which results and conclusions regarding SA mitigation strategy are more credible
- Planned to repeat the study with new version MELCOR 2.2
  - New insight into SA understanding and modelling incorporated
  - More realistic modelling of heat transfer from flooded corium melt, considering water ingression and melt eruption

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