The 8th EMUG meeting

Sensitivity Analysis of the Containment Venting Time of Nordic BWR

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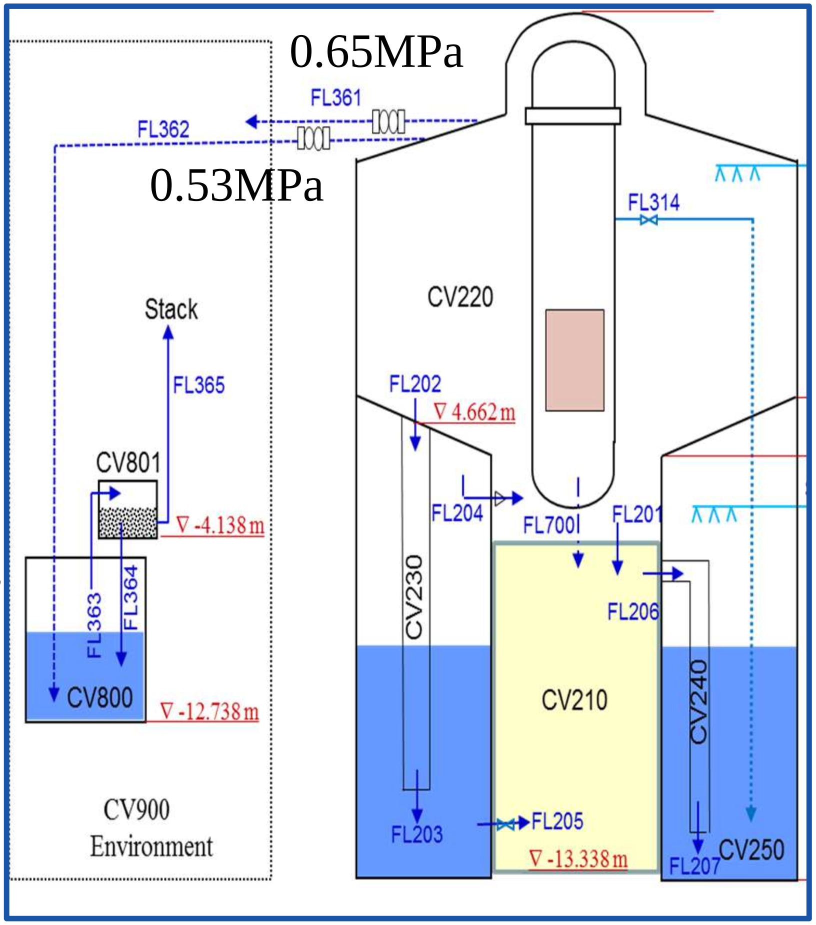
Outline

- Introduction
- Results comparison between MELCOR & MAAP
- MELCOR sensitivity calculation
- Concluding Remarks

Introduction

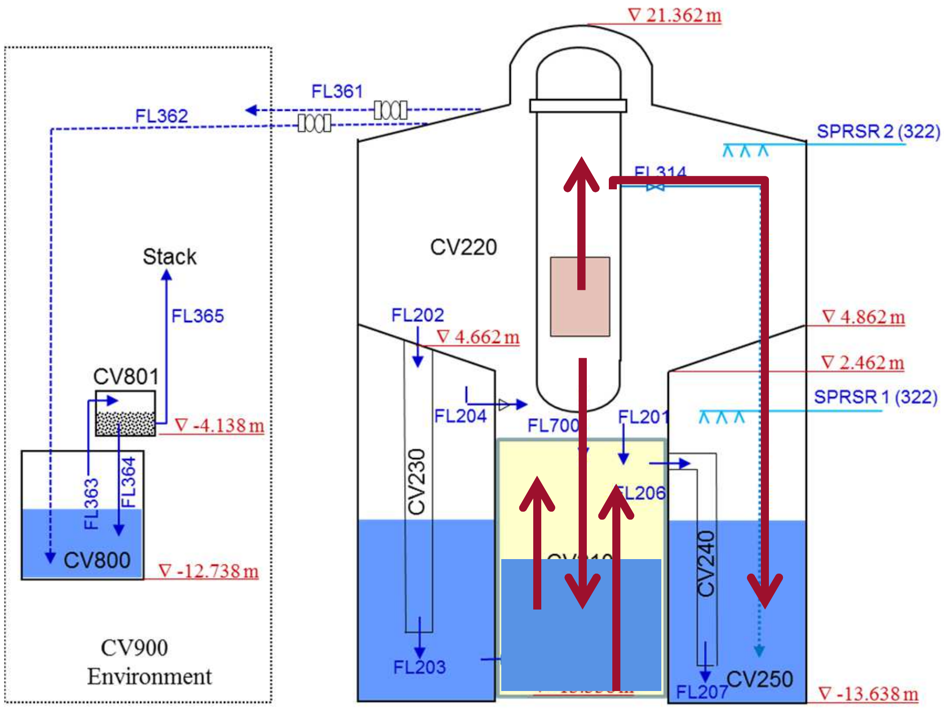
- The containment filtered venting system was widely installed in Nordic Plants, which can efficiently prevent containment overpressure.
- Although most fission products can be filtered, there is still some FP escaping to environment.
- The later the venting triggered, the less source term releases, thanking to:
  - Deposition of the radionuclide
  - Decay of the radionuclide
- The slower the containment pressure builds up, the longer time available for recovering the containment spray system.
  - Firetruck
  - Emergency Diesel



Introduction (2)

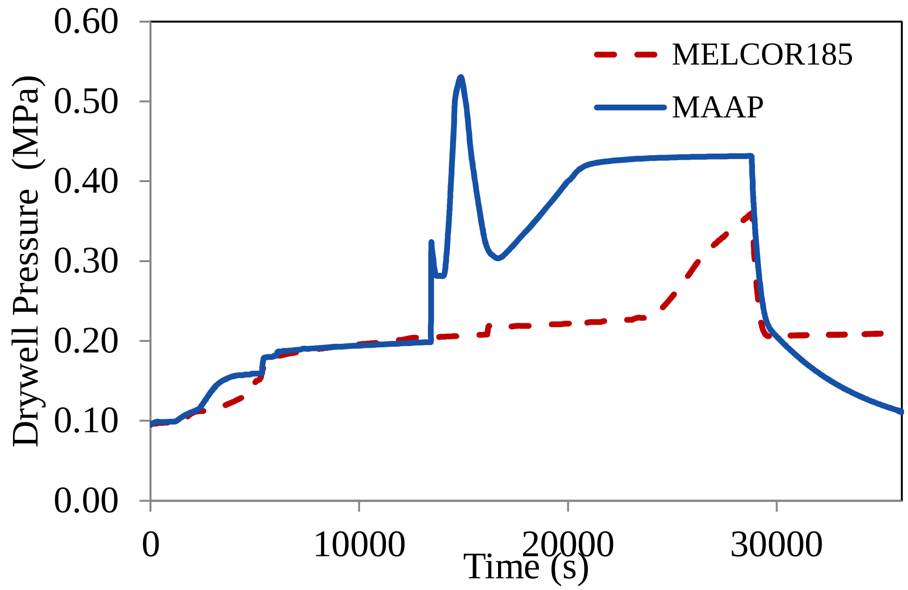
- Containment pressurization transient of Nordic BWR can be divided into 4 phases, according to the main contributors of mass and energy release sources.

- 1st Phase:
  - Steam discharge through safety release valves & automatic depressurization system
- 2nd Phase:
  - In-vessel hydrogen
- 3rd Phase:
  - Ex-vessel FCI, H_2 & steam
- 4th Phase:
  - Evaporation in cavity and MCCI(if occur) (CO, H_2)



MAAP & MELCOR comparison

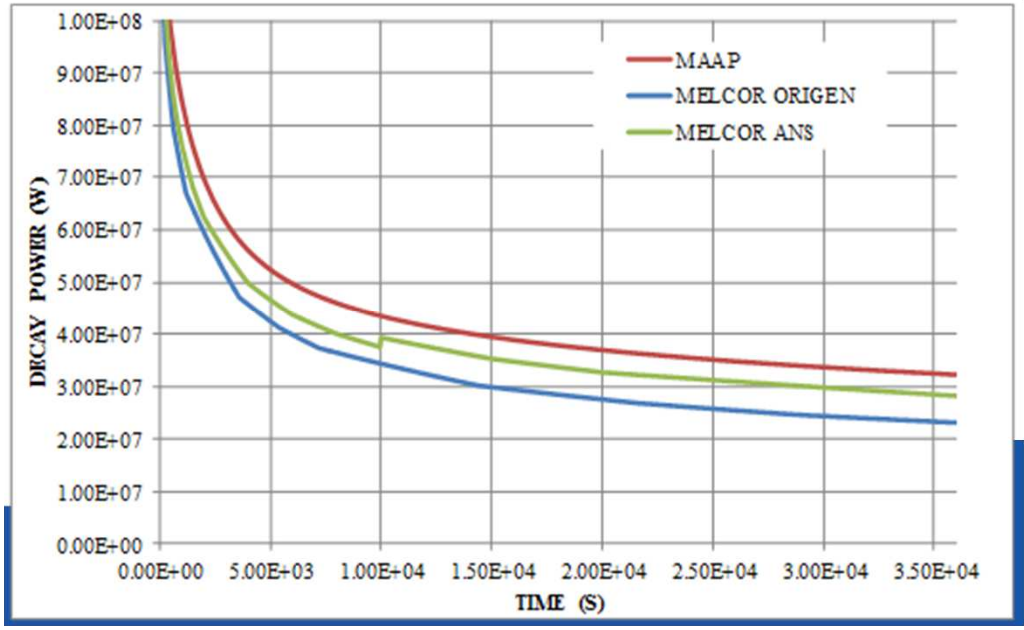
- Previously, the MAAP and MELCOR calculations for a same SBO scenario show a significant difference of the containment pressurization and the venting time.

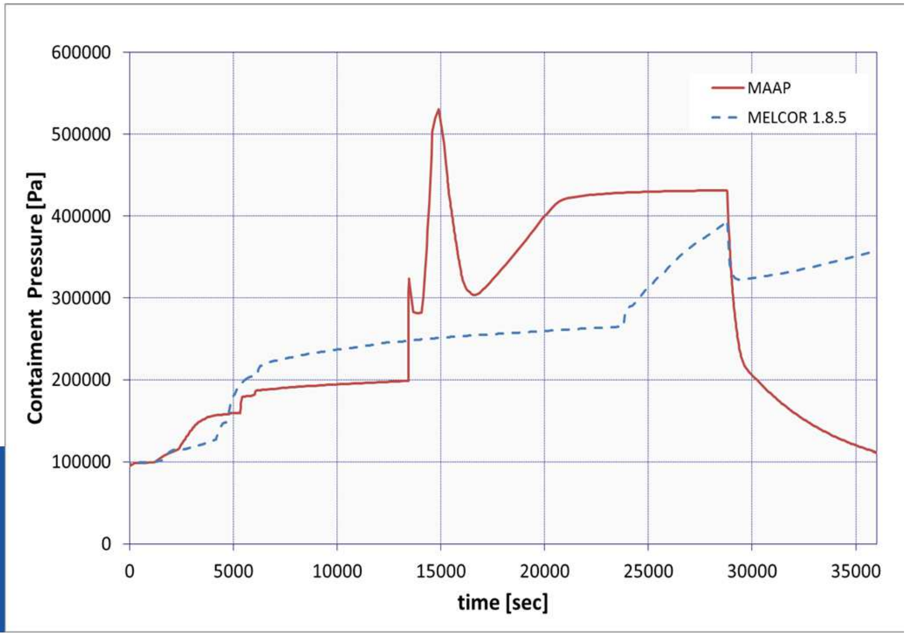


MAAP	Earlier venting triggered after about 4 hours
MELCOR185	Venting did not occur due to slower pressure build-up and recovery of containment spray after 8 hour.

MAAP & MELCOR comparison (2)

- A scrutinized comparison of MELCOR and MAAP results shows that this significant difference is mainly caused by :
  - Different decay heat power(larger in MAAP)
  - The hydrogen generated during ex-vessel FCI (~25% Zr oxidized in MAAP vs. no H_2 in MELCOR)





Sensitivity Calculation

Scenario:

- SBO

Code:

- MELCOR 2.1

Sensitivity cases:

- 13 uncertain parameters and their possibility distribution were selected based on the experiments and engineering judgements.
- Totally 240 calculation cases were generated by using the MELCOR uncertainty engine.
- Calculations are divided into 3 groups (80 cases in each group) by considering the decay heat and reactor vessel failure mode.
  - Group1: ANS decay heat correlation without modeling the penetration
  - Group2: ORIGEN decay heat correlation without modeling the penetration
  - Group3: Group2 + modeling one CRGT penetration

Sensitivity Calculation

Uncertainty parameters setting

		Variables	Probability distribution
Ex-vessel FCI hydrogen	1	Metallic Zr oxidation fraction during FCI	0 to 25% *, uniform
Core degradation and in-vessel hydrogen	2	Zircaloys melt breakout temperature	2100,2400,2550, triangle
	3	Molten cladding drainage rate	0,1,0.2,1 log triangle
	4	Fuel rod collapsing temperature	2400,2500,2800, triangle
	5	Radial solid debris relocation time	180,360,720, log triangle
	6	Radial molten debris relocation time constant	30,60,120, log triangle
	7	radiation view factor in the core region	0.02,0.18, uniform
Debris cooling in LP and vessel failure	8	Characteristic debris size in core region	0.002,0.01,0.05, log triangle
	9	Characteristic debris size in LP region	0.01,0.025,0.06, log triangle
	10	Porosity of fuel debris beds	0.1,0.38,0.5, triangle
	11	Heat transfer coefficient for fuel debris falling through water filled lower plenum	125,400, uniform
	12	Penetration failure temperature	1200,2200, uniform
MCCI and non-condensable gas	13	heat transfer enhancement factor due to overlying water intrusion in MCCI	1,20, uniform

*According to the ZREX experiment. up to 26% of metallic zirconium was oxidized during the FCI in the case of no steam explosion

FDI Model in MELCOR

The heart of the LPME model that has been incorporated into MELCOR was developed by Corradini at the University of Wisconsin. In this model, heat is transferred from the molten debris to the water pool (if present in the associated control volume) as it breaks up and falls to the cavity floor.

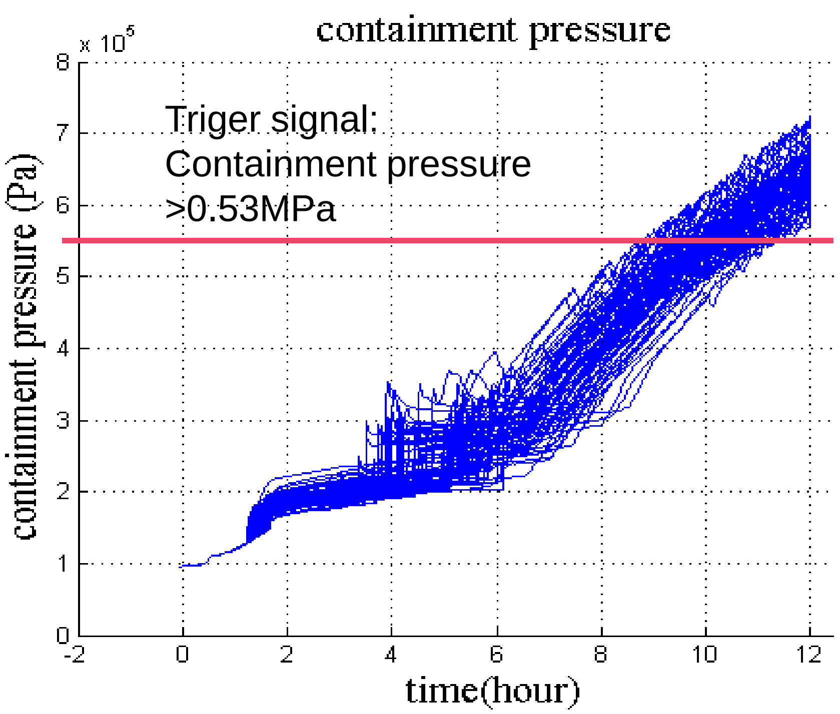
The heat transfer is normally dominated by radiation, but a lower bound determined by conduction through a vapor film (the Bromley model for film boiling) is also considered.

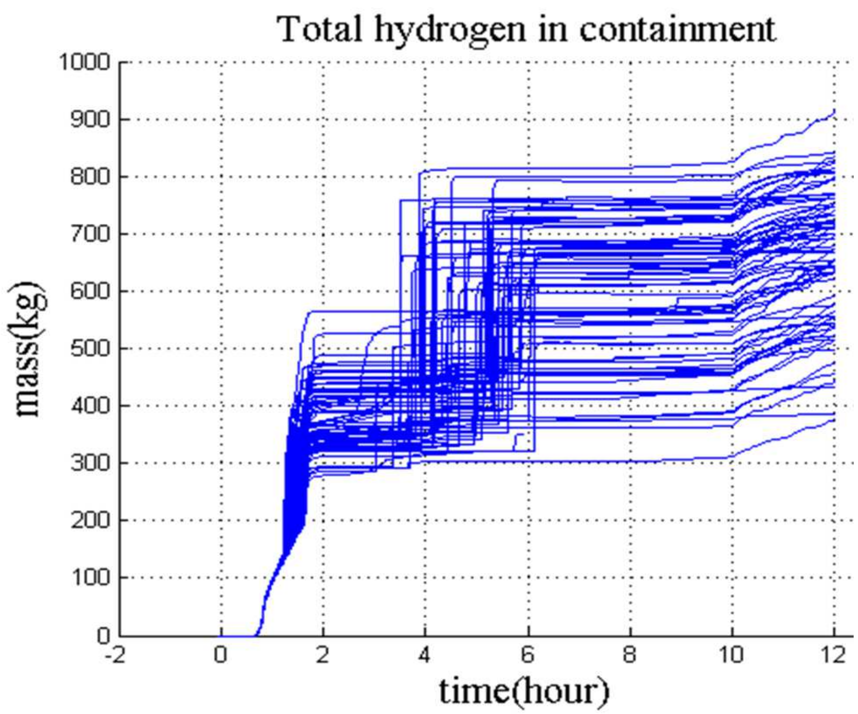
The LPME model does not consider oxidation of the metallic elements in the ejected debris.

The variables retrieved from the TP package by the FDI package include the mass, composition and temperature of the debris ejected from the vessel during the timestep and the velocity and diameter of the ejection stream (see COR reference manual for a description of the calculation of these variables).

The rate of heat transfer from the debris to the water is determined primarily by the interfacial surface area, which is a function of the debris particle size.

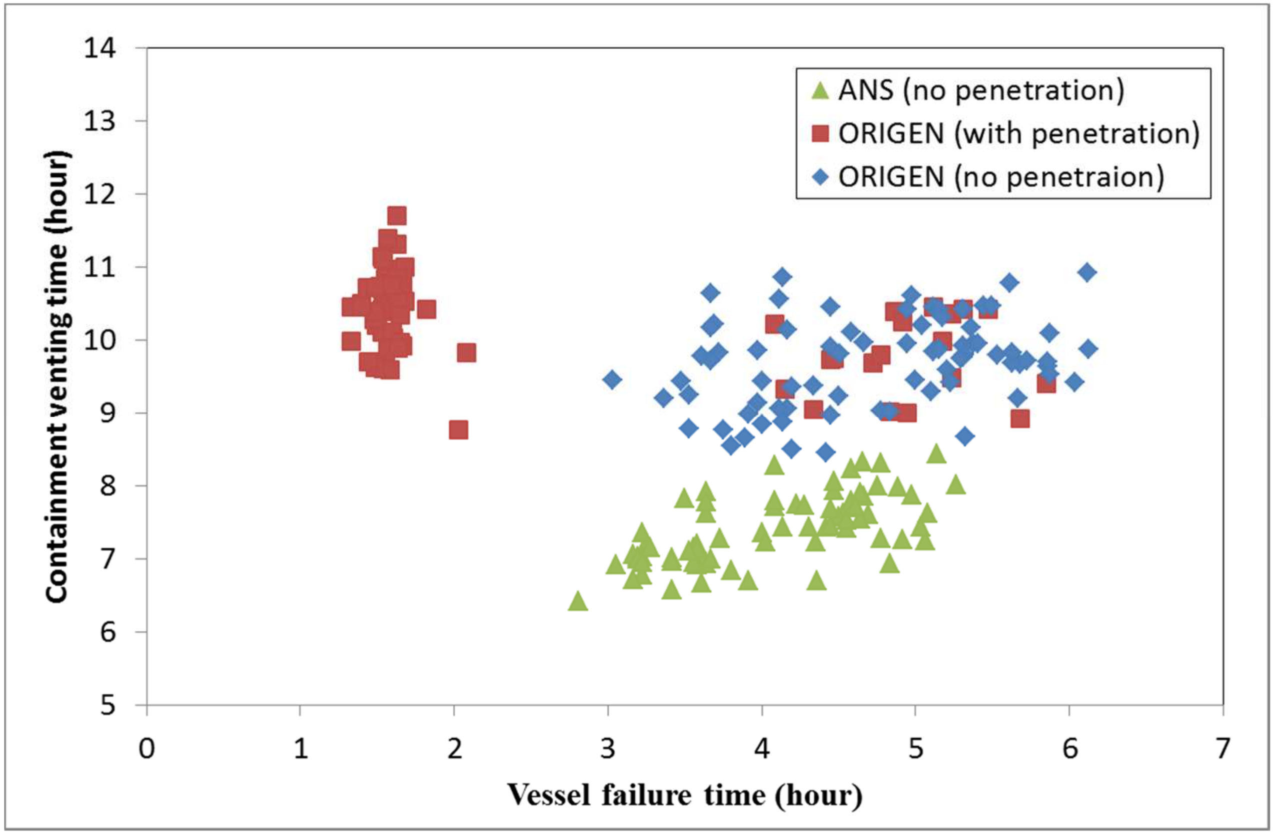
Sensitivity Calculation



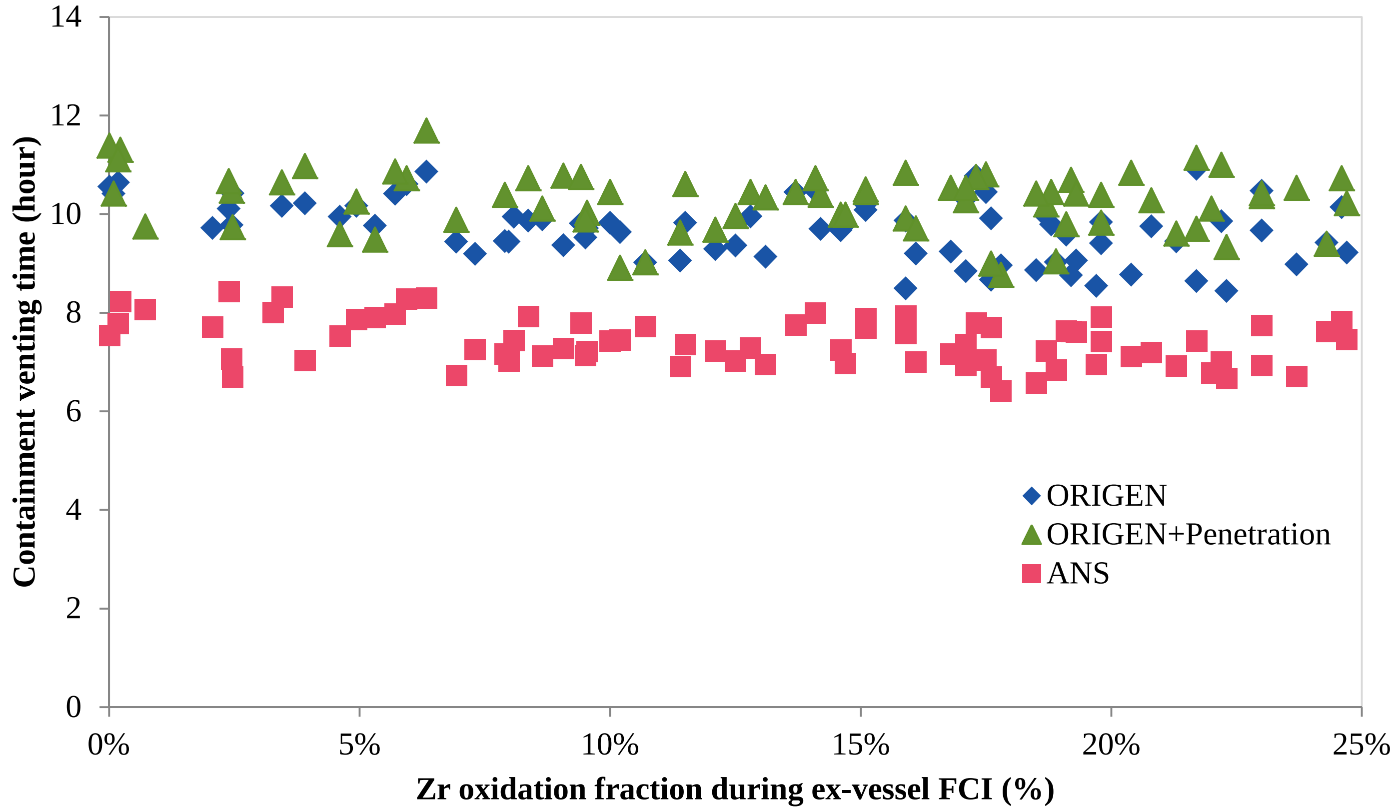


Group2: ORIGEN decay heat correlation without modeling the penetration

Sensitivity Calculation

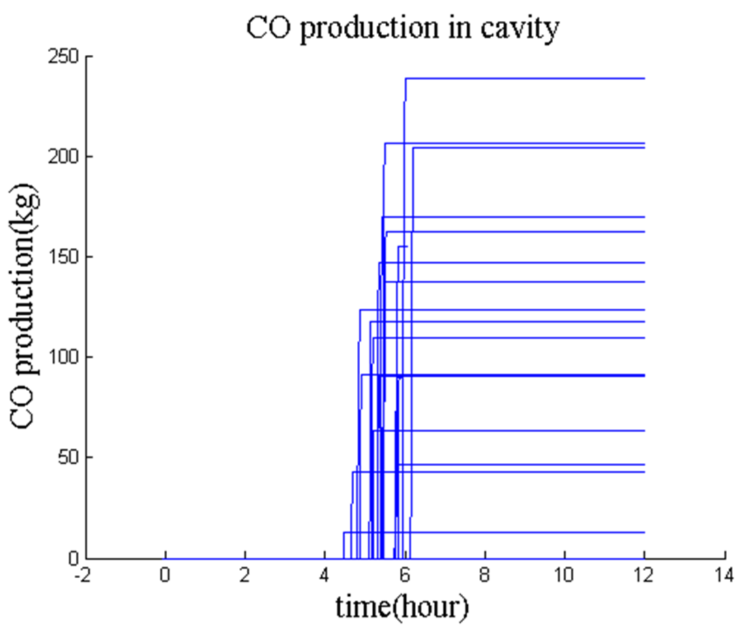


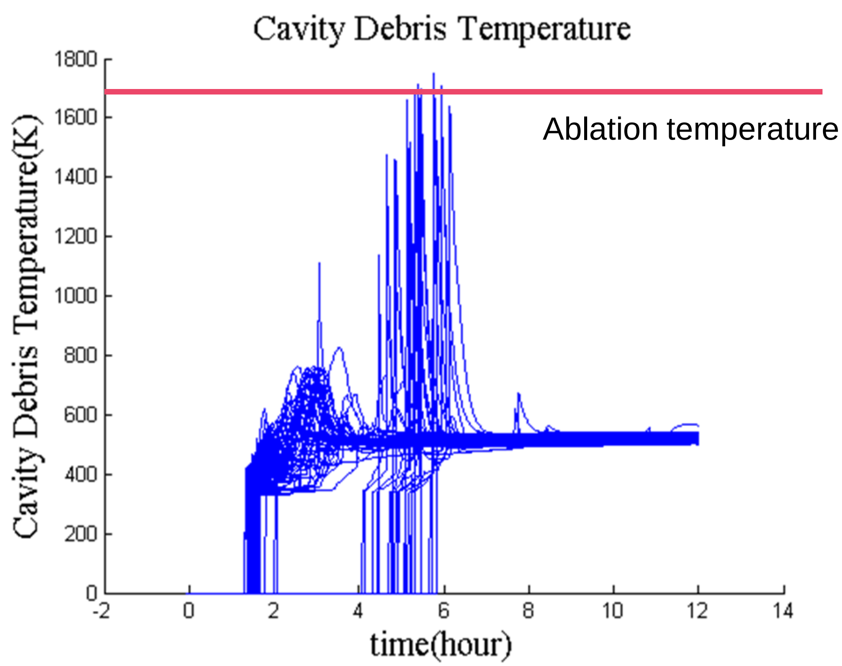
Sensitivity Calculation



Sensitivity Calculation

MCCI occurred only in the cases of vessel creep failure, but not happened in the cases of penetration failure

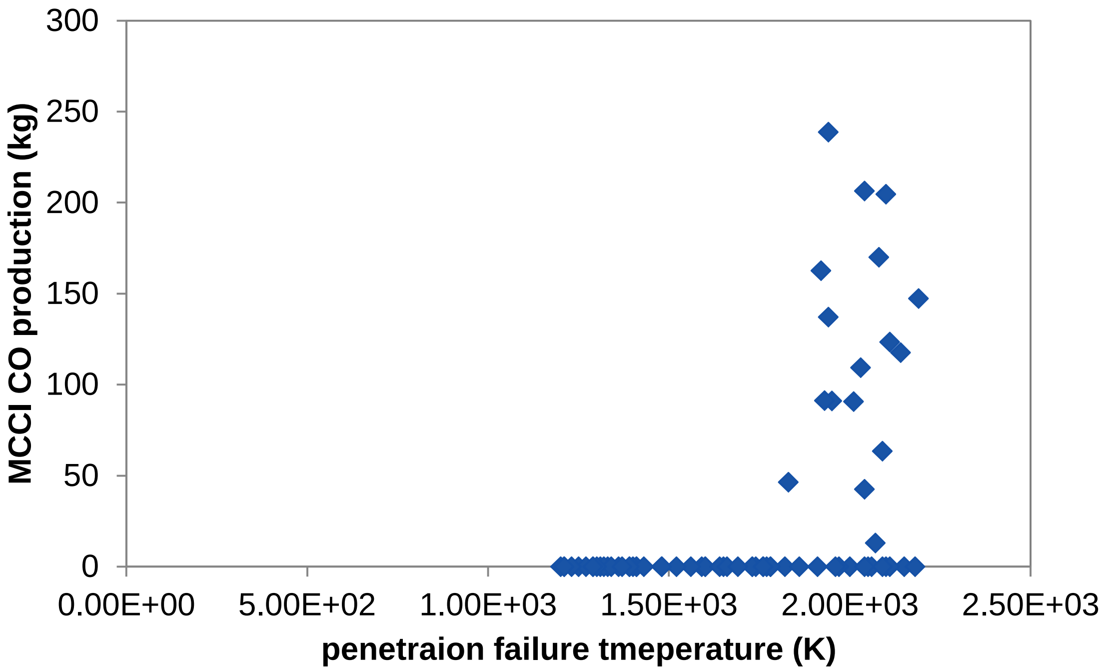


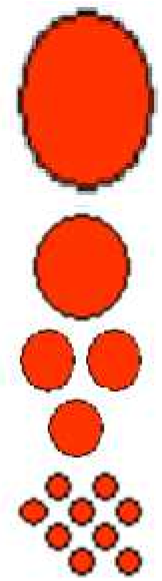


Group3: ORIGEN decay heat correlation with modeling the penetration

Sensitivity Calculation

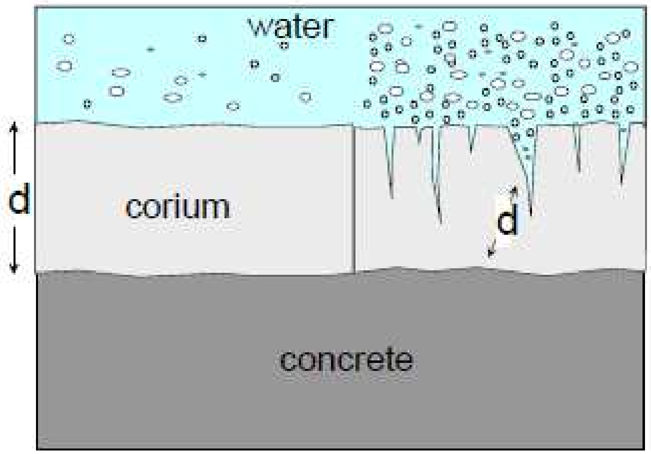
The vessel creep failure may make a larger break area in the vessel as well as a wider corium jet which cannot be efficiently cooling down during its descending through the water in the cavity

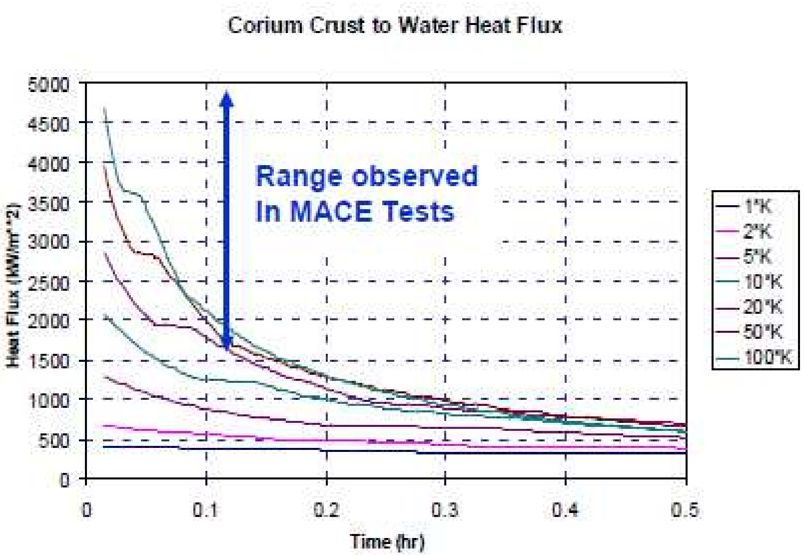




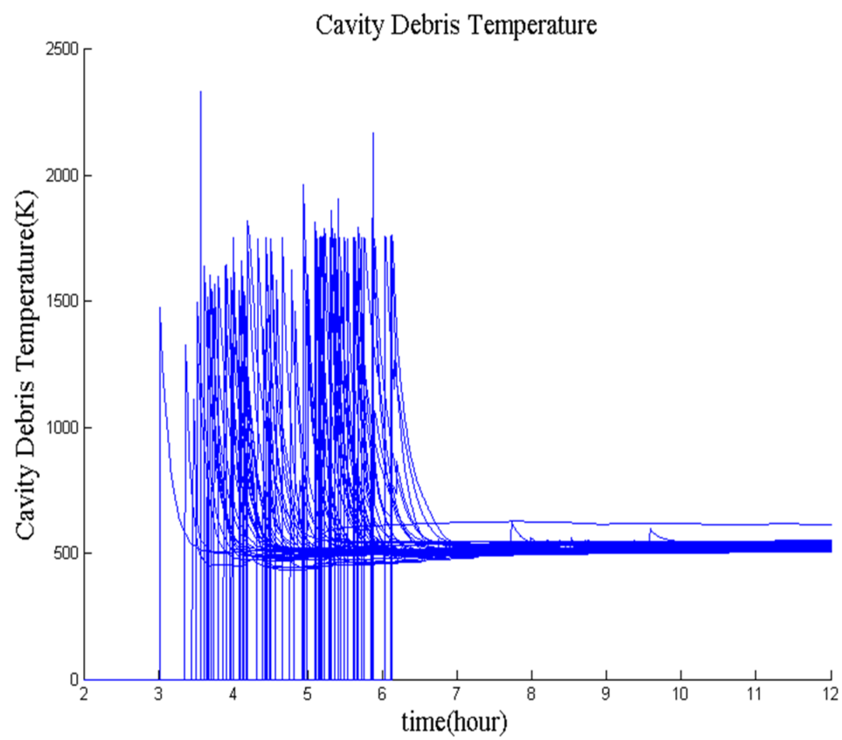
Group3: ORIGEN decay heat correlation with modeling the penetration

Sensitivity Calculation





The MCCI will be quickly terminated due to the intrusion of the overlaid water in all the cases



Concluding Remarks

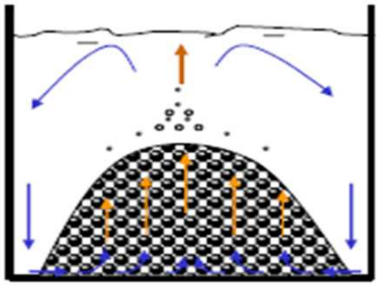
- The decay heat played a key role in the buildup of containment pressure.
  - Since decay heat power depends on the plant operation time and refuel scheme, its uncertainty should be considered.
- The hydrogen generated during the ex-vessel FCI will accelerate the containment pressurization process, which is not considered in the MECLOR FDI package. Here this phenomena is simply represented by using a control function of oxidation fraction without considering the physics details, e.g. the jet shape/temperature, etc.
  - Since BWR plants have a larger amount of zirconium in the core and a smaller containment volume than PWR plants, this issue is more pronounced for BWRs.

Concluding Remarks

– MCCI occurred only in the cases of vessel creep failure, but not happened in the cases of penetration failure. It can be explained that the vessel creep failure may make a larger break area in the vessel as well as a wider corium jet which cannot be efficiently cooling down during its descending through the water in the cavity. The hot corium accumulated on the cavity floor will cause MCCI. Whereas in the cases of penetration failure, the corium jet from the vessel break is smaller and can be cooling down below the onset MCCI temperature when it arrives at the cavity floor.

Concluding Remarks

– The MELCOR calculation shows that the MCCI will be quickly terminated thanks to the intrusion of the overlaid water in all the cases. However it may be too optimistic. Previous experiments and mechanism code calculations showed that the debris bed may re-melt and cause MCCI in the cases of adverse cooling conditions, e.g. low porosity in the debris bed.



Thanks for your listening