TRACTEBEL Engineering
GDF SUEZ

Qualification of the TE MELCOR models

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CHOOSE EXPERTS, FIND PARTNERS

Contents

Introduction

- Context

  Development of a MELCOR qualification report requested by Safety Authorities

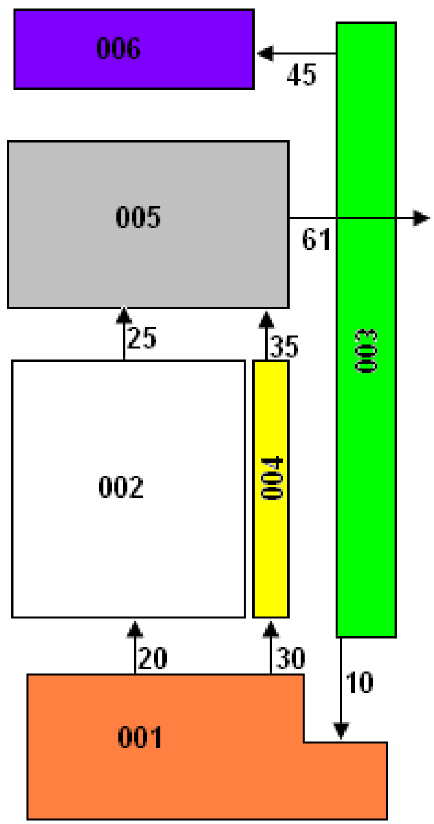
  → Realization of different assessments with MELCOR 1.8.5 and 1.8.6

  - TMI-2 accident
  - PHEBUS FPT-1 experiment
  - QUENCH-06 experiment
  - Code to code comparison with ASTEC
  - …

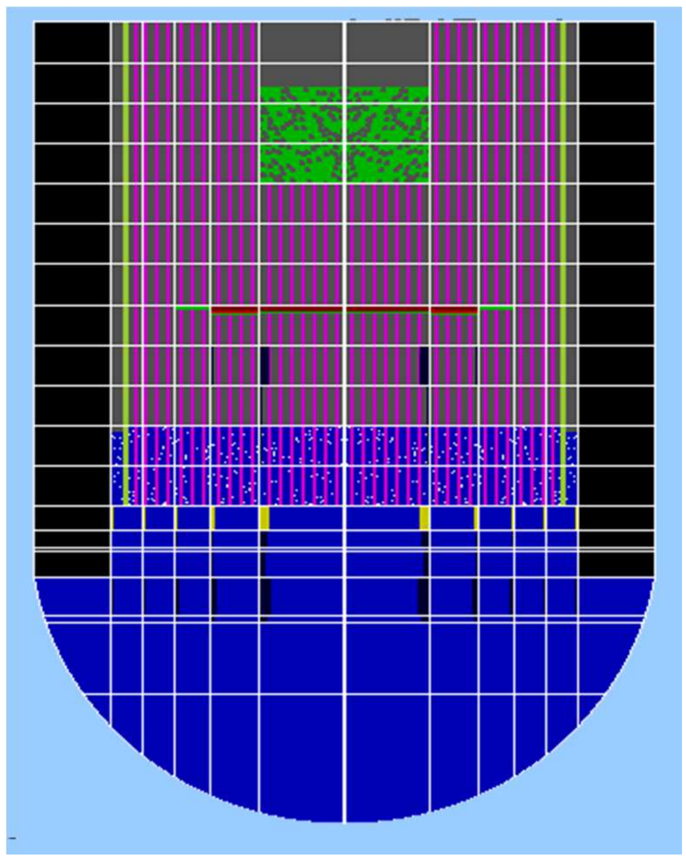
- Purposes of the calculations
  - Test Tractebel modelization process: simple nodalizations to reduce the computation time which is important for industrial purposes
  - Provide sufficient information to prove that Tractebel handles the code properly

TMI-2 accident

Model nodalization – Reactor Pressure Vessel



VESSEL



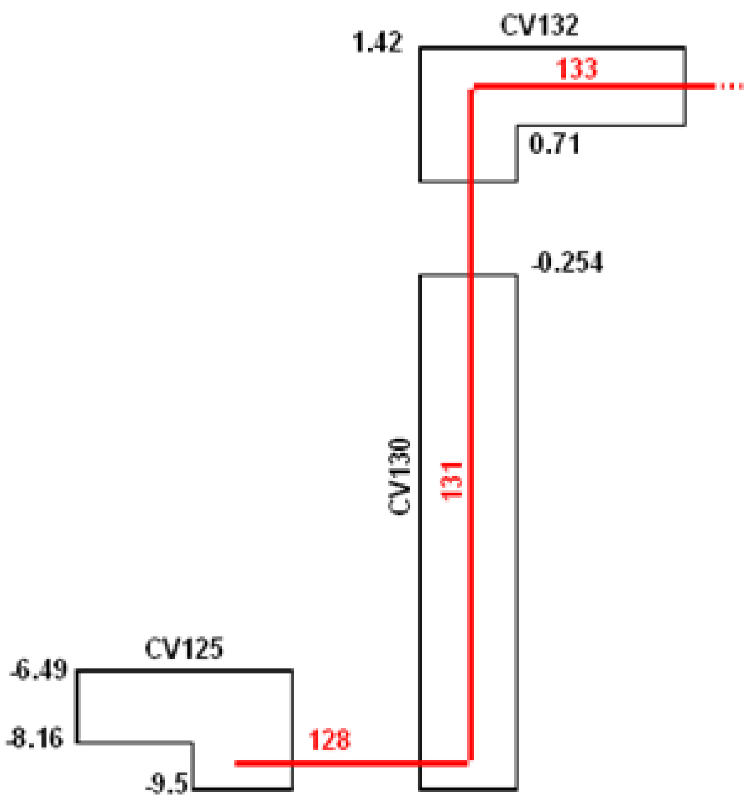
CORE

- 20 axial levels
  - 8 in the Lower Plenum
  - 12 in the active part of the core
- 6 radial rings
- Supporting structure at the core bottom (level 8)

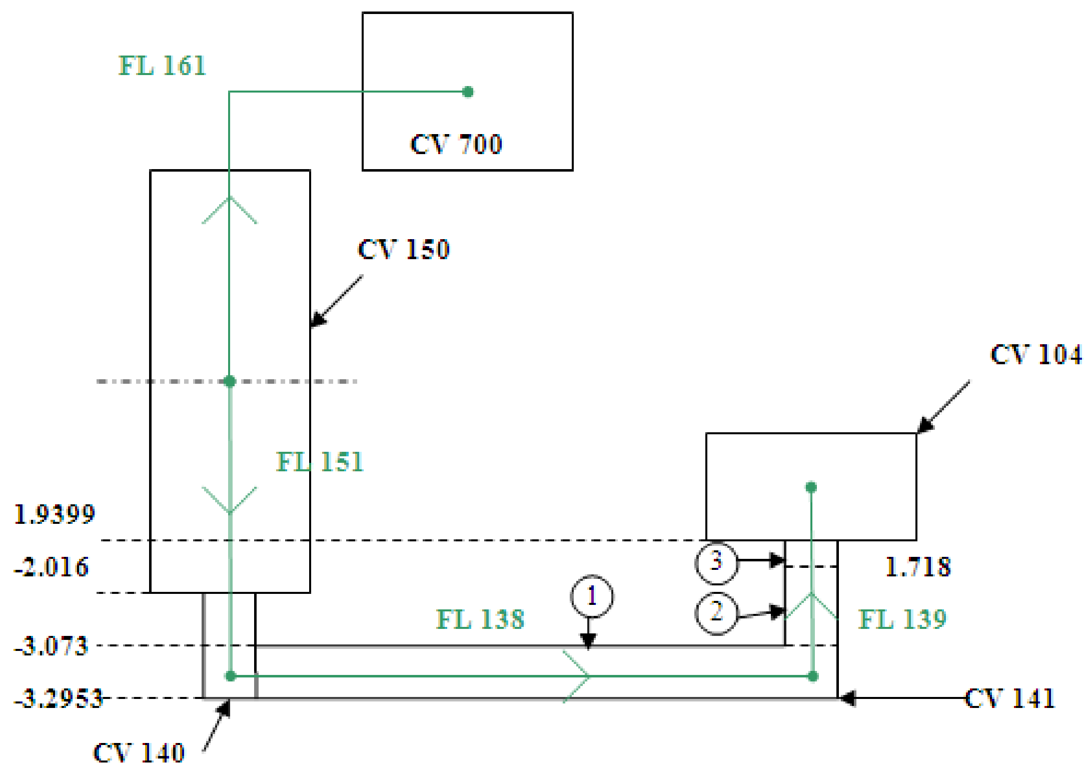
TMI-2 accident

Model nodalization – Primary Loops

U-LEG



PRESSURIZER



TMI-2 accident

Model nodalization – Steam Generators

PRIMARY SIDE

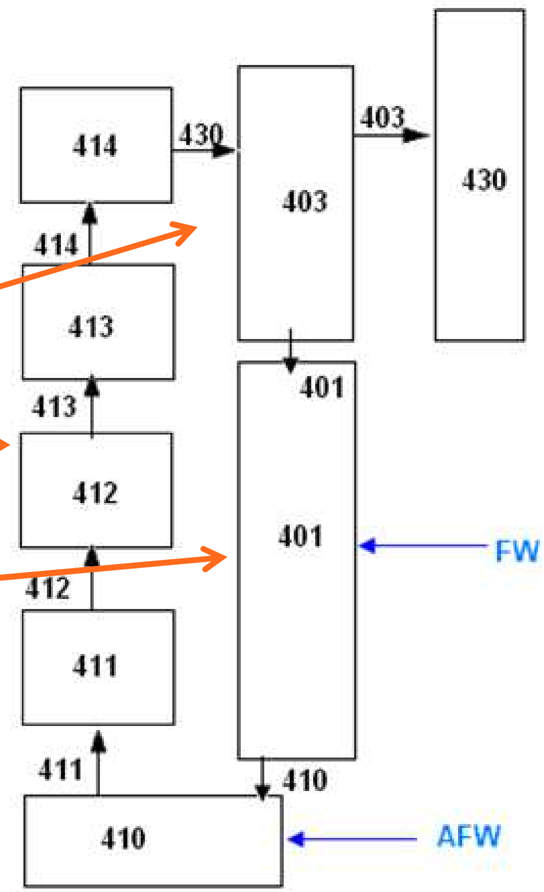
- **1 CV INLET**
- **5 CV's for SG Tubes**
- **1 CV OUTLET**

SECONDARY SIDE

3 CV's OUTLET

3 CV's RISER

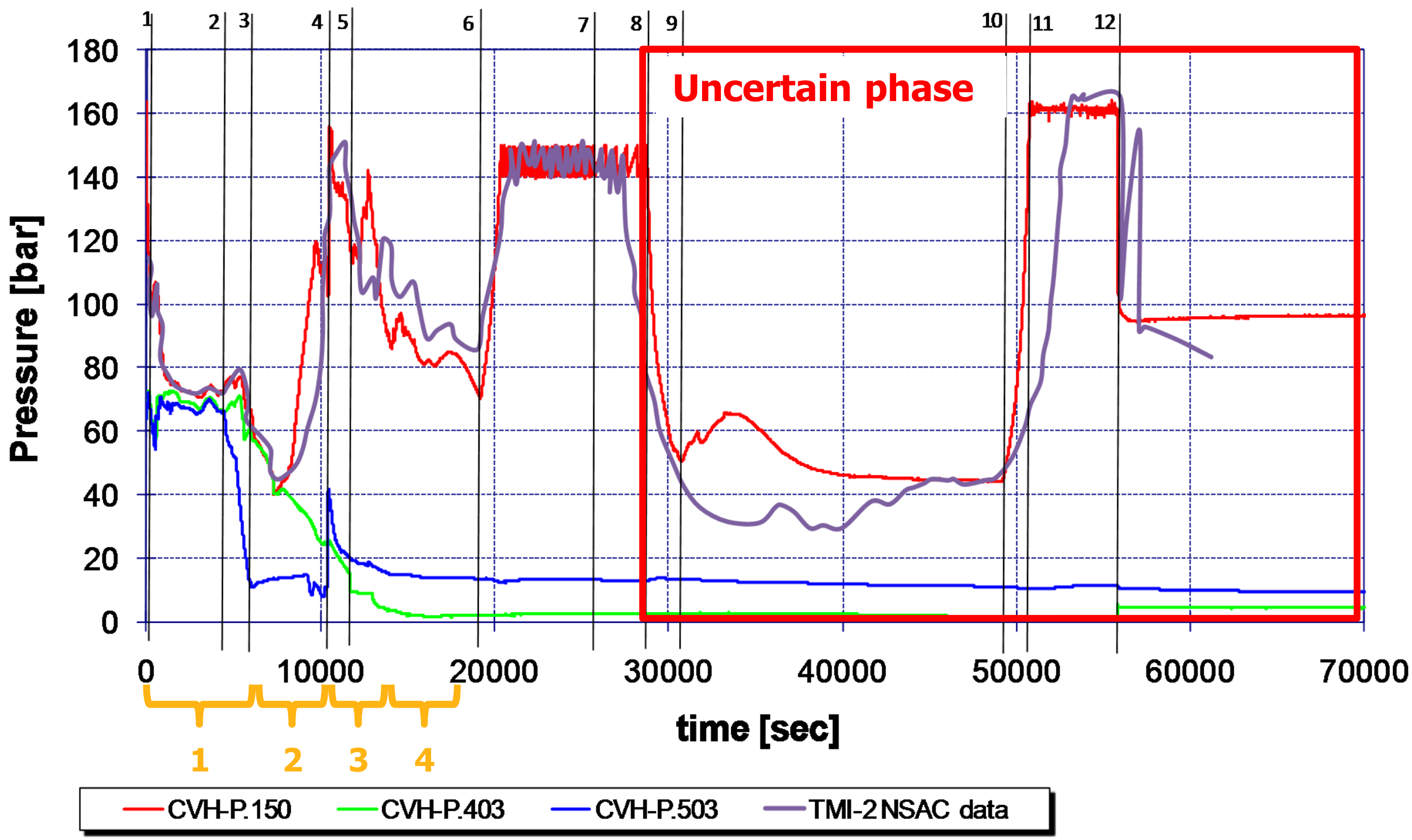
1 CV DOWNCOMER



TMI-2 accident

Results of the calculation

Thermal hydraulics – Primary and secondary pressures

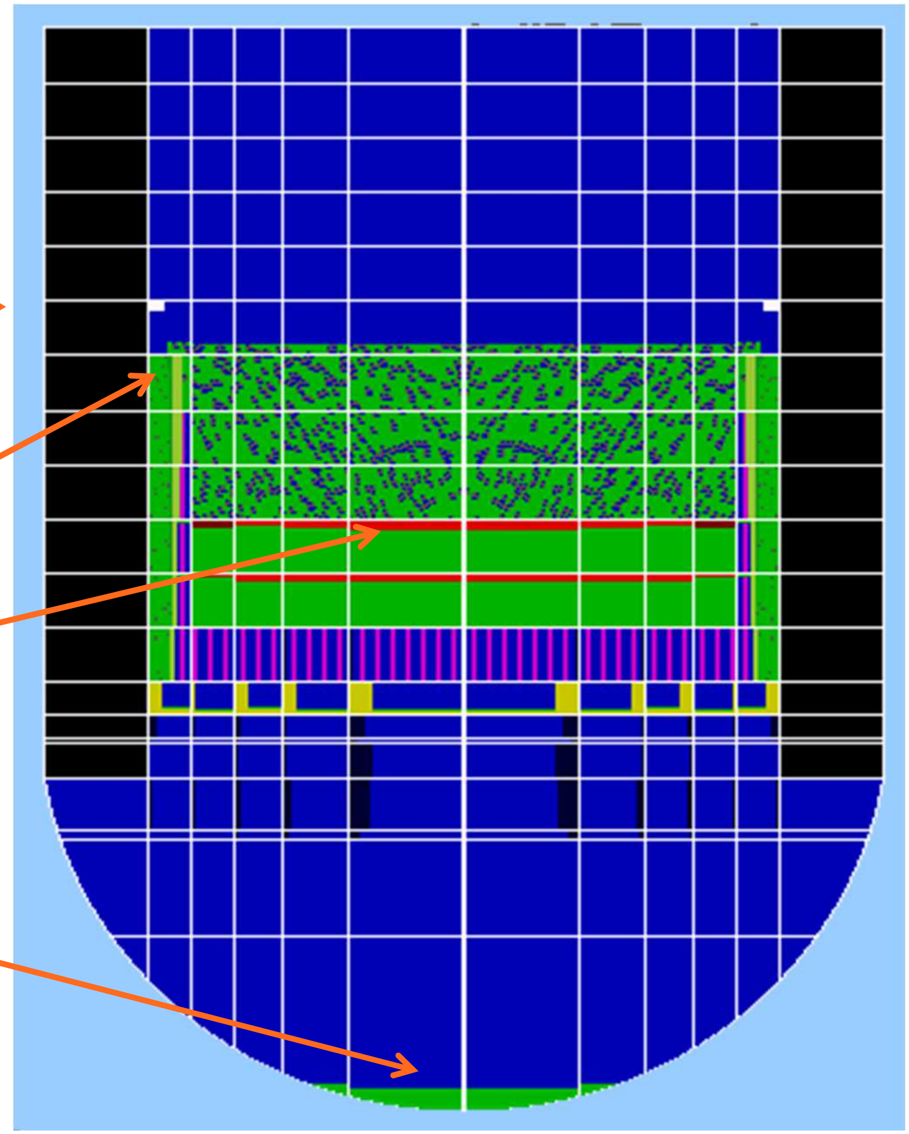


TMI-2 accident

Results of the calculation

Core degradation

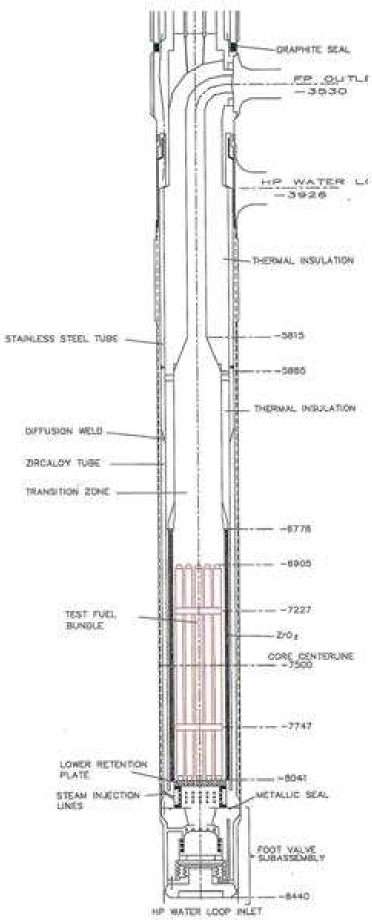
- Core degradation stopped: final state at 70 000 seconds
- Baffle failure and corium relocation in the bypass
- Presence of a molten pool
- Relocation of a small part of the corium in the lower plenum

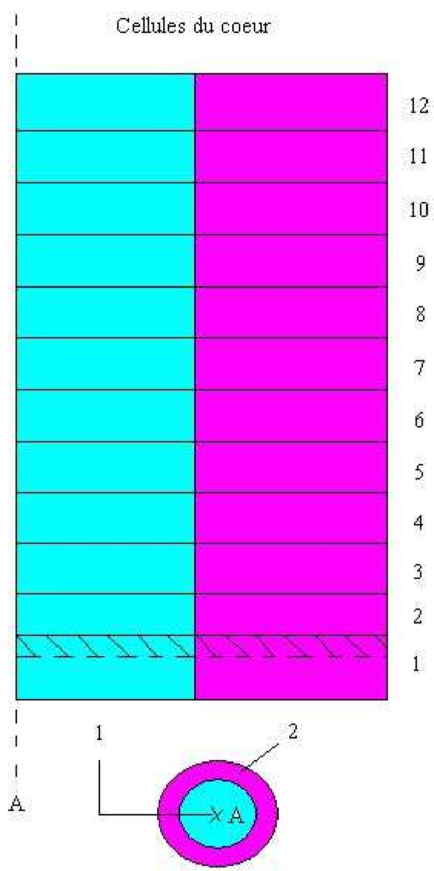


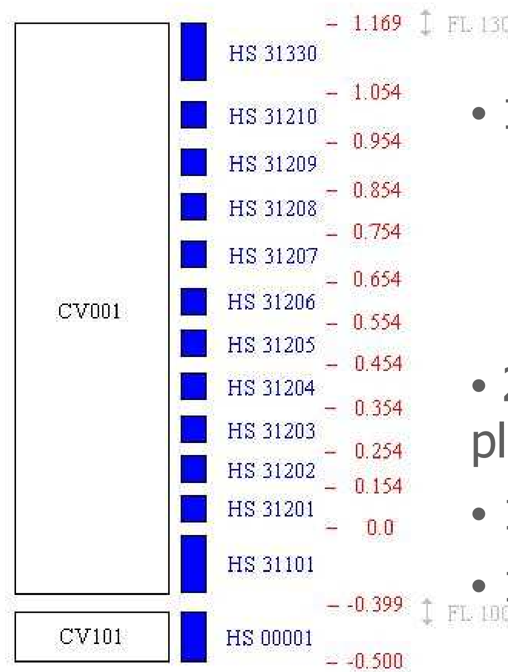
PHEBUS FPT-1 experiment

Model nodalization – Core

Vertical section of the FPT1 test train



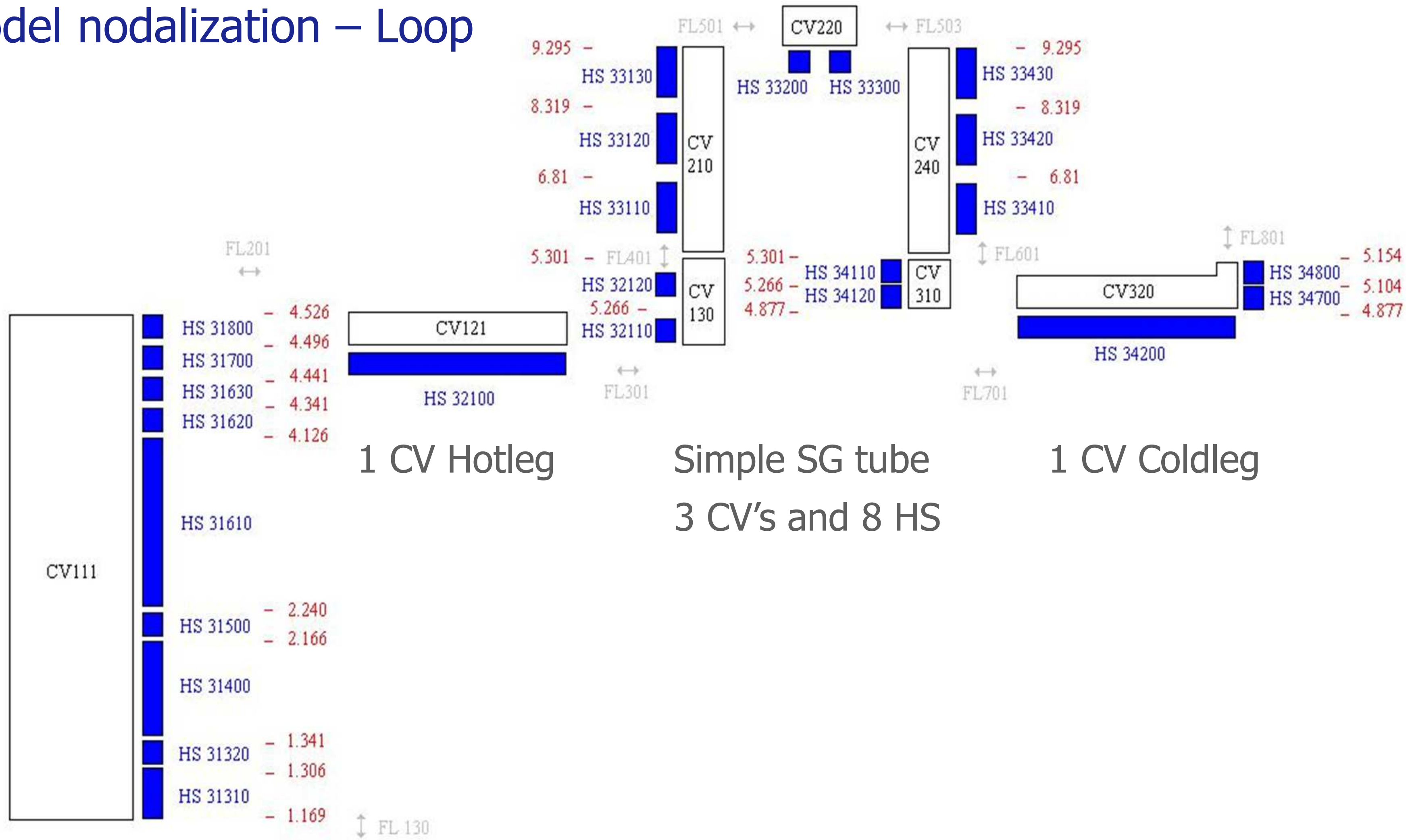




- 12 axial levels
  - 1 in the Lower Plenum
  - 11 in the active part of the core
- 2 radial rings (much smaller than plant application)
- 1 CV for the core
- 1 CV for the lower plenum

PHEBUS FPT-1 experiment

Model nodalization – Loop



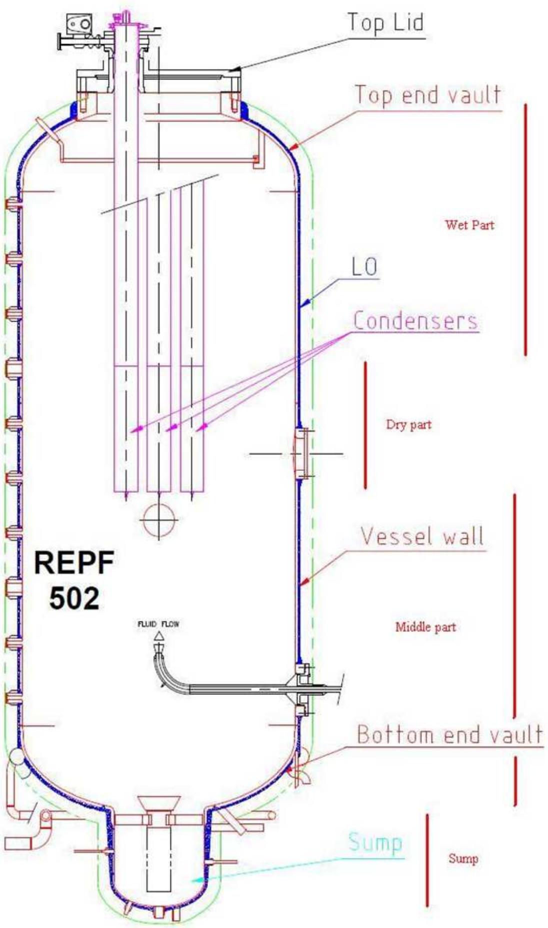
1 CV Hotleg

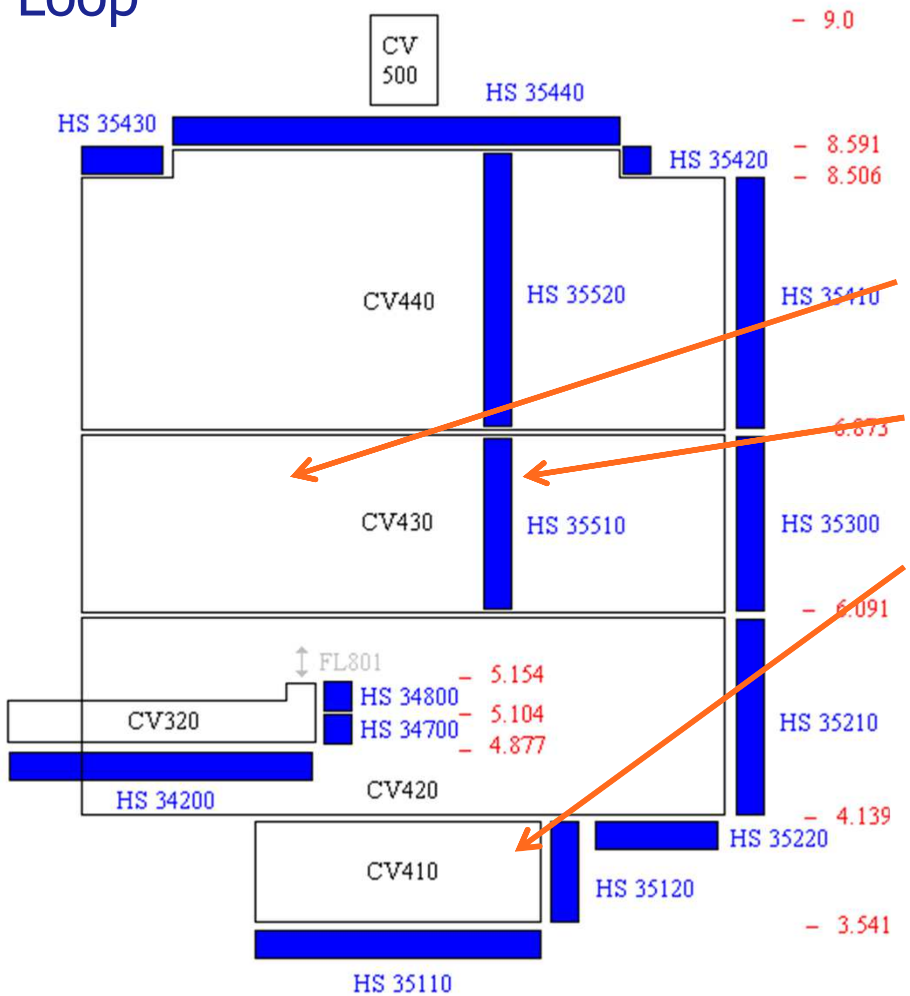
Simple SG tube
3 CV's and 8 HS

1 CV Coldleg

PHEBUS FPT-1 experiment

Model nodalization – Loop

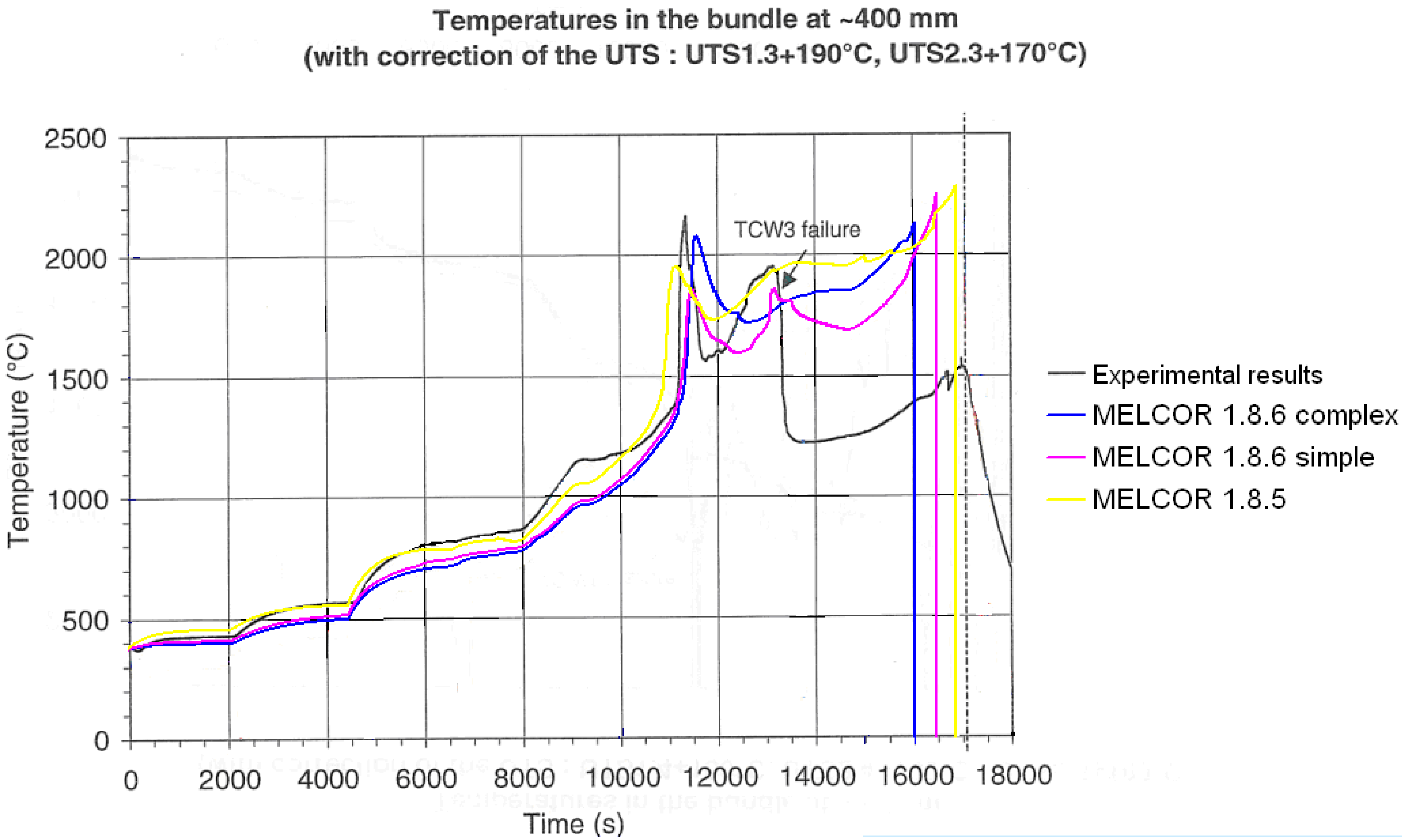




- 3 CV’s containment
- 2 HS Condensers
- 1 CV sump

PHEBUS FPT-1 experiment

Results of the calculations
Thermal hydraulics – Bundle temperature



PHEBUS FPT-1 experiment

Results of the calculations

Core degradation timings

- Significant difference for the control rod failure
- Good reproduction of the control rod cladding failure
- Significant difference for the fuel rods failure
- No improvements for the fuel cladding failure

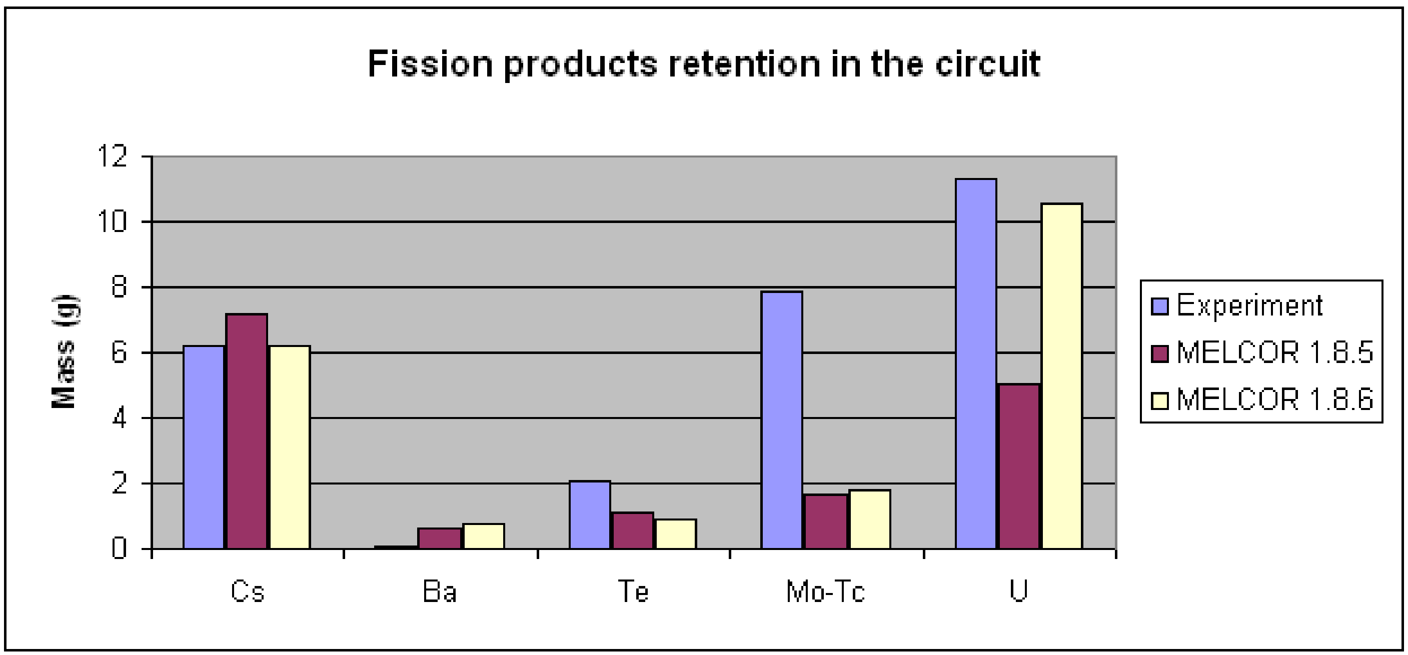
Failures	Experimental	Melcor 1.8.5	Melcor 1.8.6 complex	Melcor 1.8.6 simple
Control Rod	~ 7900 s	~ 10600 s	~ 5300 s	~ 5100 s
Control Rod Cladding	~ 11060 s	~ 10700 s	~ 10800 s	~ 10900 s
Fuel Rod	~ 11060 s	~ 15000 s	~ 11200 s	~ 11200 s
Fuel Cladding	~ 7900 s	~ 10 650 s	~ 11200 s	~ 11200 s

PHEBUS FPT-1 experiment

Results of the calculations - Fission products behavior

Less encouraging results due to:

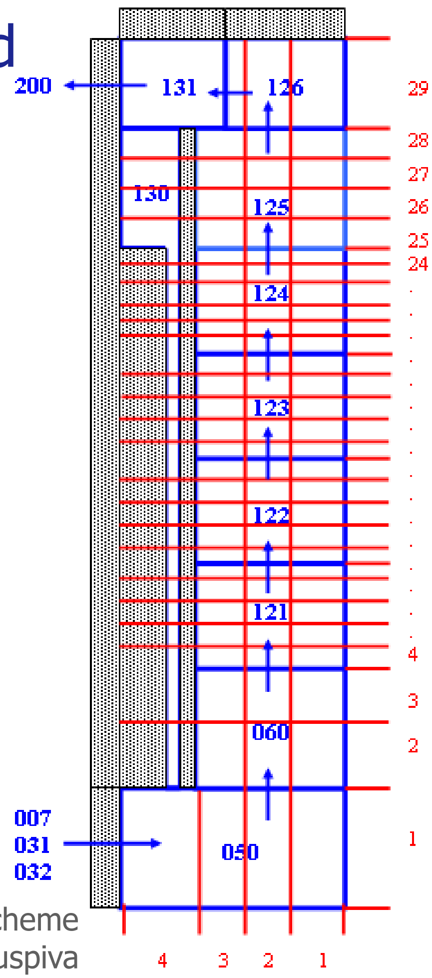
- Models uncertainties
- Lack of data on the initial FP inventory to develop the model



QUENCH-06 experiment

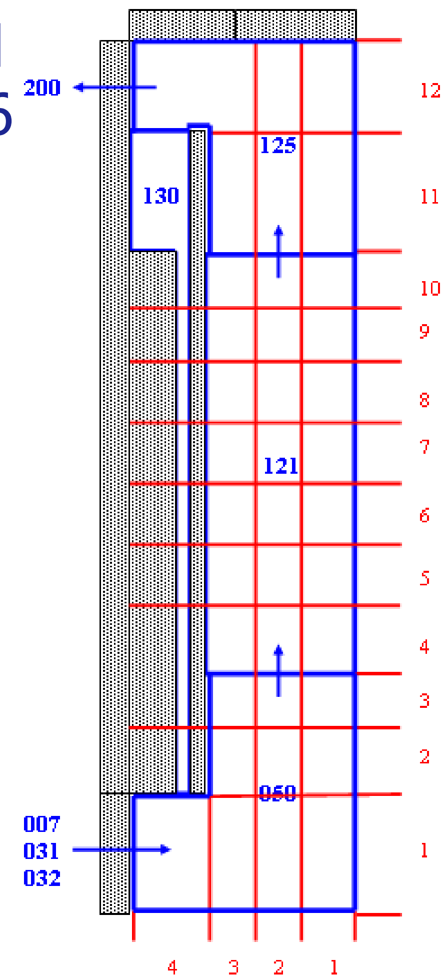
Models nodalization

- Complex model used with MELCOR 1.8.6
  - 2 volumes in the LP
  - 3 volumes in the UP
  - 4 volumes in the core
  - 29 axial levels
  - 4 radial rings



Based on QUENCH-11 Nodalization Scheme for MELCOR 1.8.6 by Jiří Duspiva

- Simple model used with MELCOR 1.8.6 and MELCOR 1.8.5
  - 1 volume in the LP
  - 1 volume in the UP
  - 1 volume in the core
  - 12 axial levels
  - 4 radial rings



QUENCH-06 experiment

Experiment phases

- **Simulation approach**
  - Blind like simulation: no tuning of the parameters to keep the validity of the study
  - Stabilization of the model based on the initial values of the experiment
  - Reproduction of the transient
  - Analysis of the results on the quenching phase

Time	Event	Phase
0	Start of data acquisition	> Stabilization (600 °C)
30	Heat up to about 1500 K	Pre-oxidation
1965	Pre-oxidation at about 1500 K	
6010 6620	Initiation of power transient Initiation of pull-out of corner rod (B)	Power transient
7179	Quench phase initiation Shut down of steam supply Onset of fast water injection Start of quench water pump Detection of clad failure First temperature drop at TFS 2/1	Reflood
7181 7205 7221 7430	Steam mass flow rate zero Onset of electric power reduction Decay heat level reached Onset of final power reduction	Quench
7431 7431 7435 11420	Shut down of quench water injection Electric power < 0.5 kW Quench water mass flow zero End of data acquisition	Post-reflood

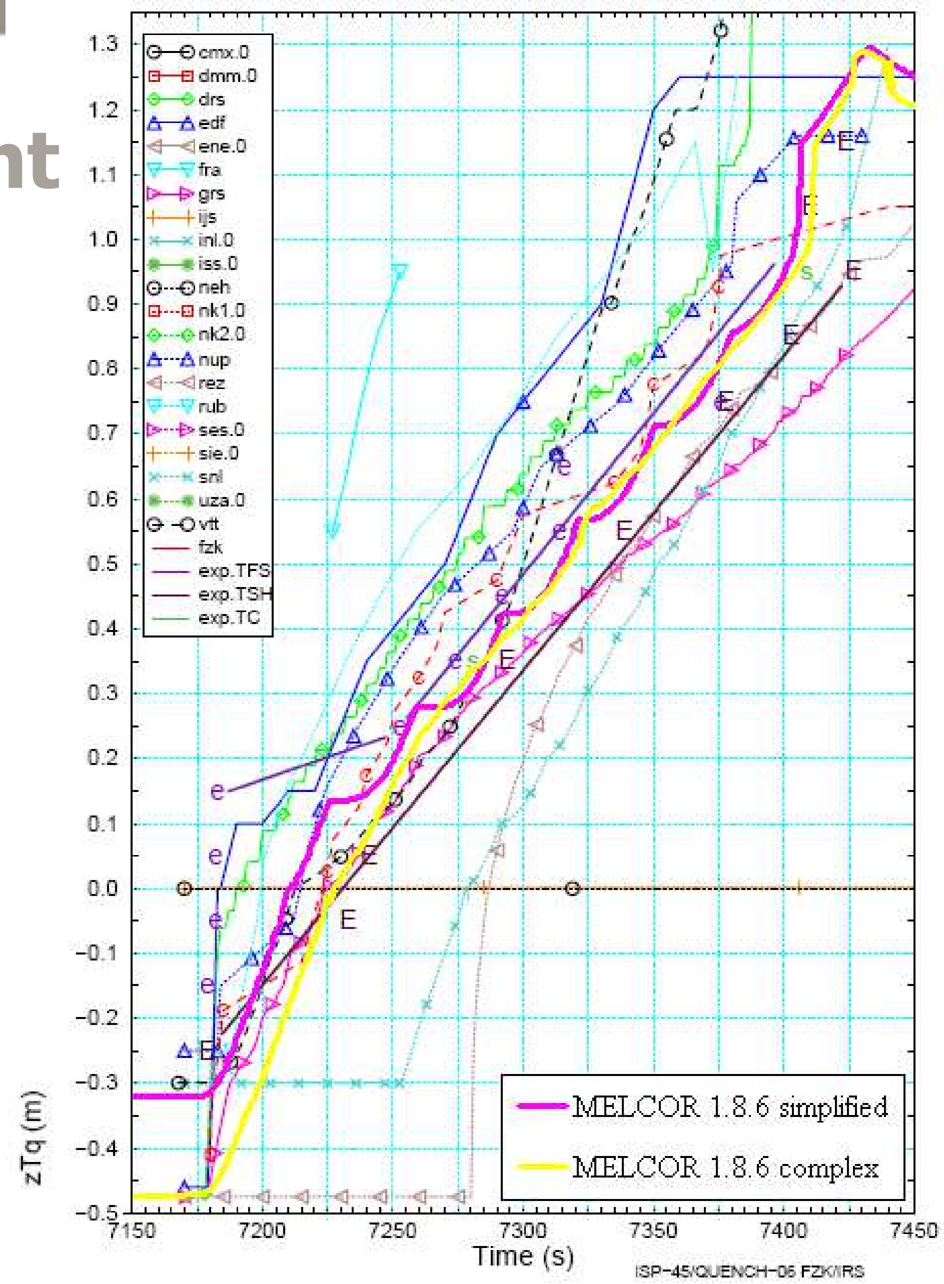
QUENCH-06 experiment

Results of the calculations

- Thermal hydraulics

Quench front

- No MELCOR 1.8.5 curve
- Not much differences between the two models
- Close to experimental values



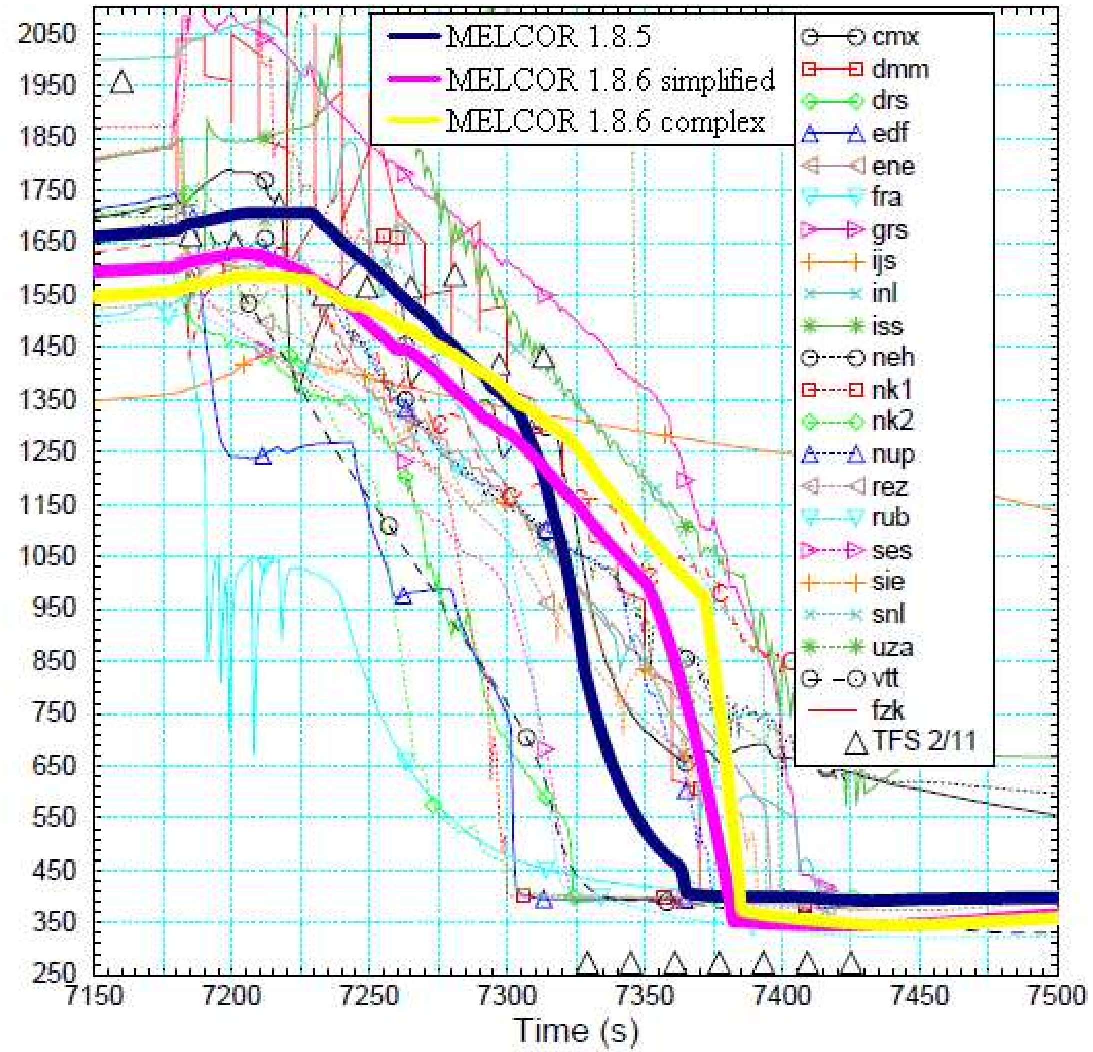
QUENCH-06 experiment

Results of the calculations

- Thermal hydraulics

Cladding temperature

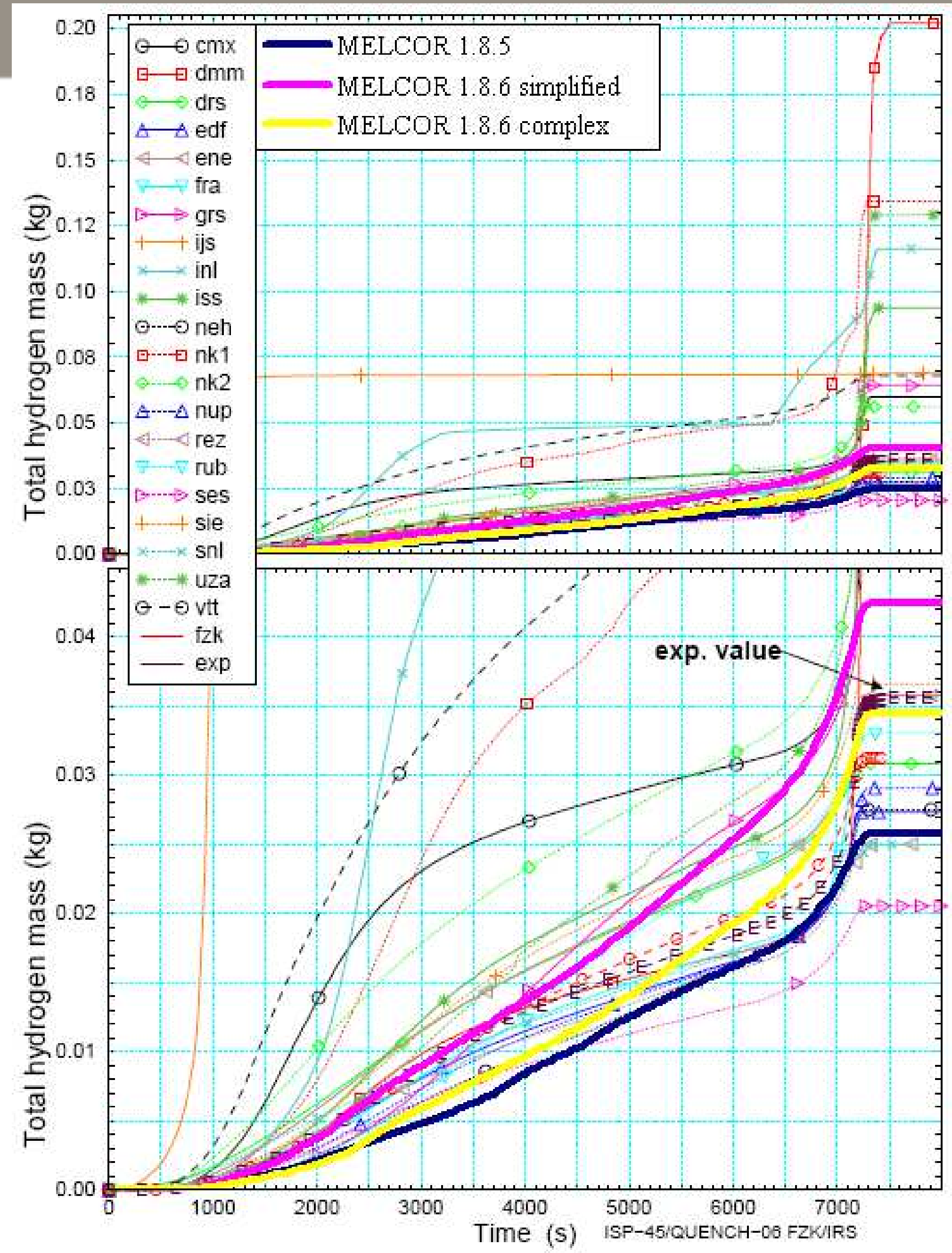
- Not much differences between the two MELCOR 1.8.6 models
- Close to experimental values
- Bigger differences with MELCOR 1.8.5



QUENCH-06 experiment

Results of the calculations

- Hydrogen production
  - Very good results for the complex model
  - Overestimation with the simplified 1.8.6 model
  - Under estimation with the simplified 1.8.5 model
  - Differences still acceptable compared to other MELCOR simulations



Code to code comparison with ASTEC

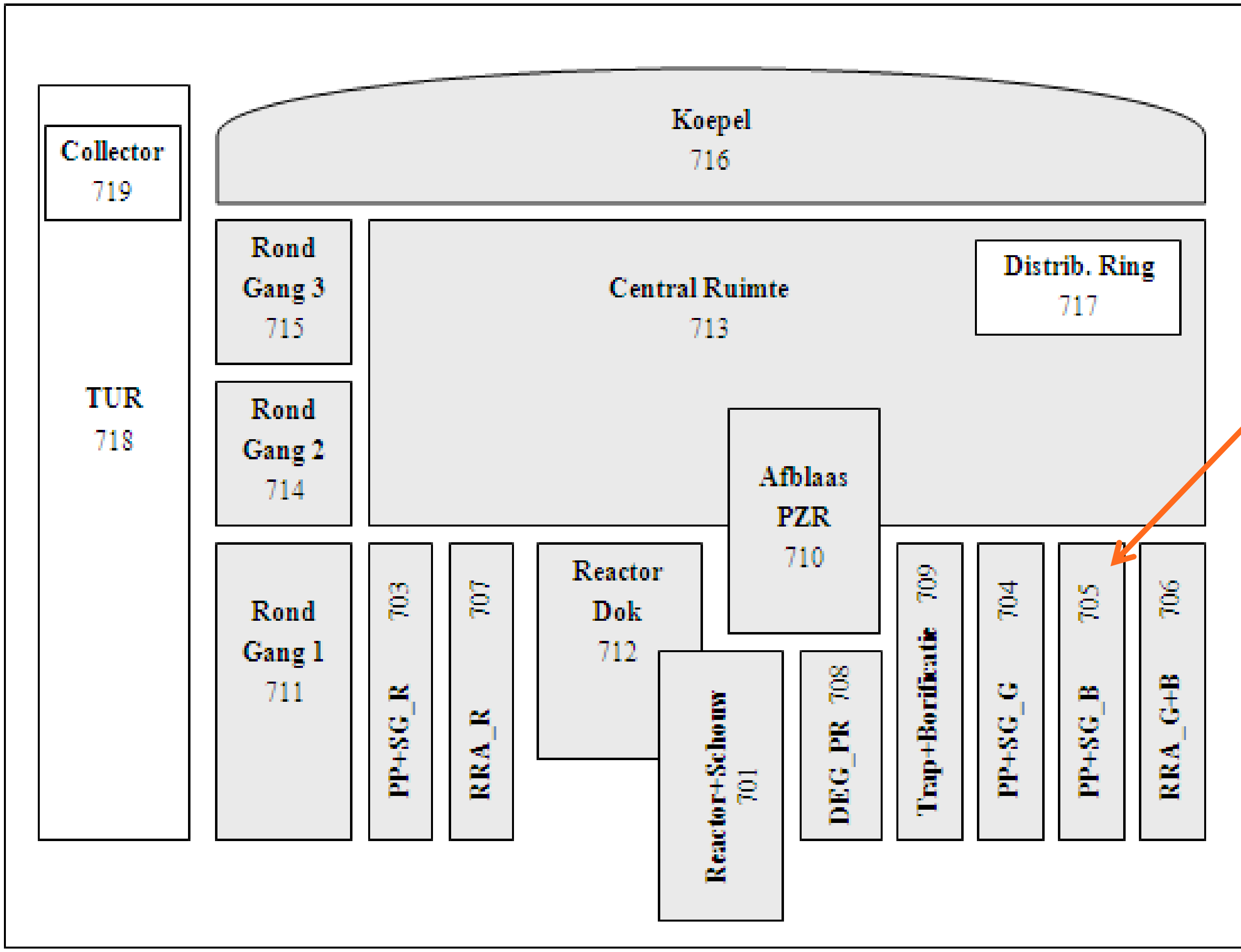
Benchmark on a 3-loop Westinghouse 1000 MWe

- Codes version:
  - **ASTEC v1.1 r.0**
  - **MELCOR 1.8.5**
- Accident scenario:

  SBLOCA (2 inch) at the bottom of the U-leg (loop without the pressurizer)
- Analysis based on the containment behavior:
  - **Timeframe of 8880 seconds**
  - **No vessel failure -> No MCCI phenomena modeled**

Code to code comparison with ASTEC

Model nodalization – Containment



- 16 CV's for the containment
- 2 CV's for the Annular space
- Break discharging in volume 705

Code to code comparison with ASTEC

Results of the calculations

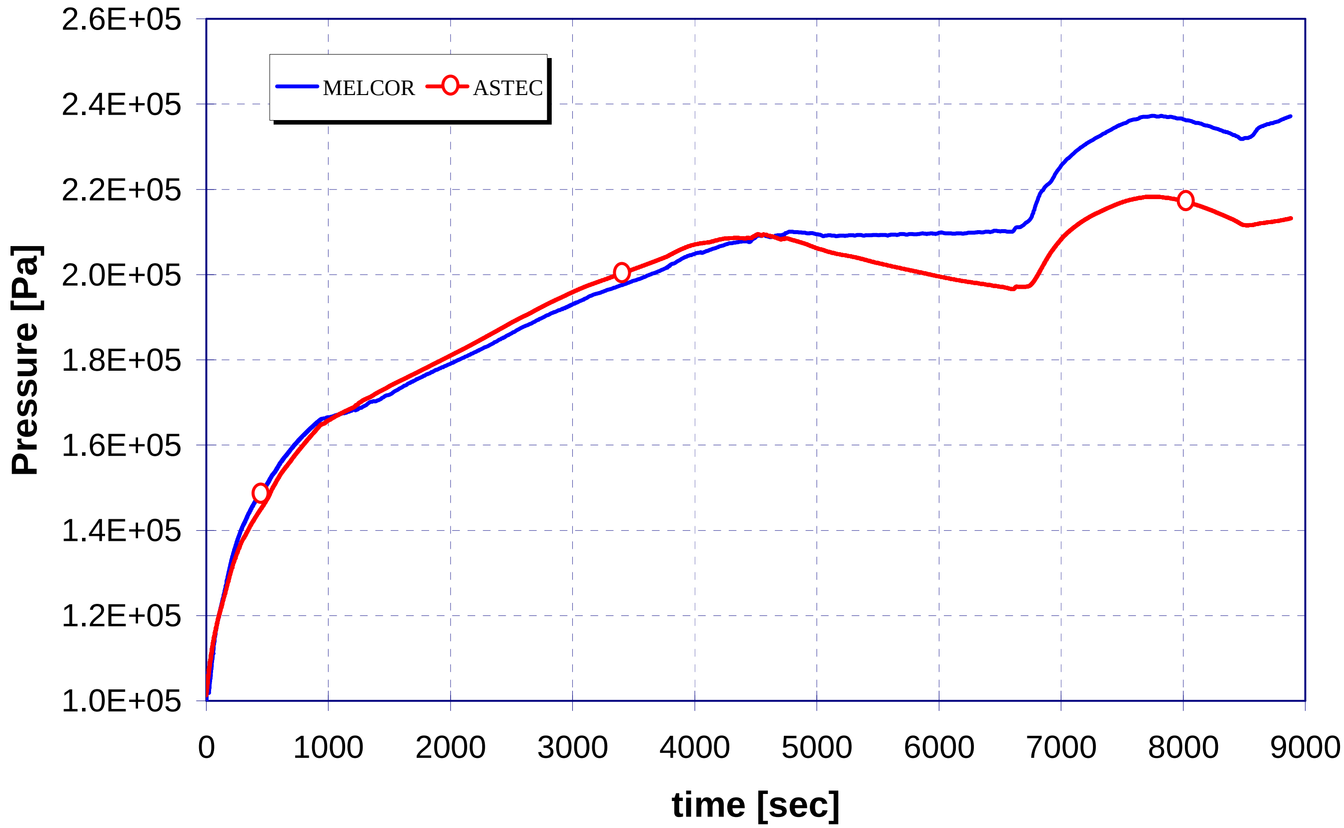
- Main events occuring during the accident

Transient time [sec]	Description of main events
0.0	**Postulated SBLOCA (2") in ULeg of LOOP 3**
35.8	Reactor SCRAM on low PRZ pressure signal - Reactor Coolant Pumps tripped
55.2	Very low PRZ pressure: SI, TT, FW & AFW signals
185.7	High containment pressure (>1.3bara):MSIV isolation
3780.0	T_{exit}(core) > 650°C **(start of SAMG)**
3860.0	Hydrogen concentration > 2% in break location compartment
4413.0	Accumulators start discharging
6715.0	Core support plate failure
8880.0	Reactor Vessel Lower Head failure - END of transient

Code to code comparison with ASTEC

Results of the calculations

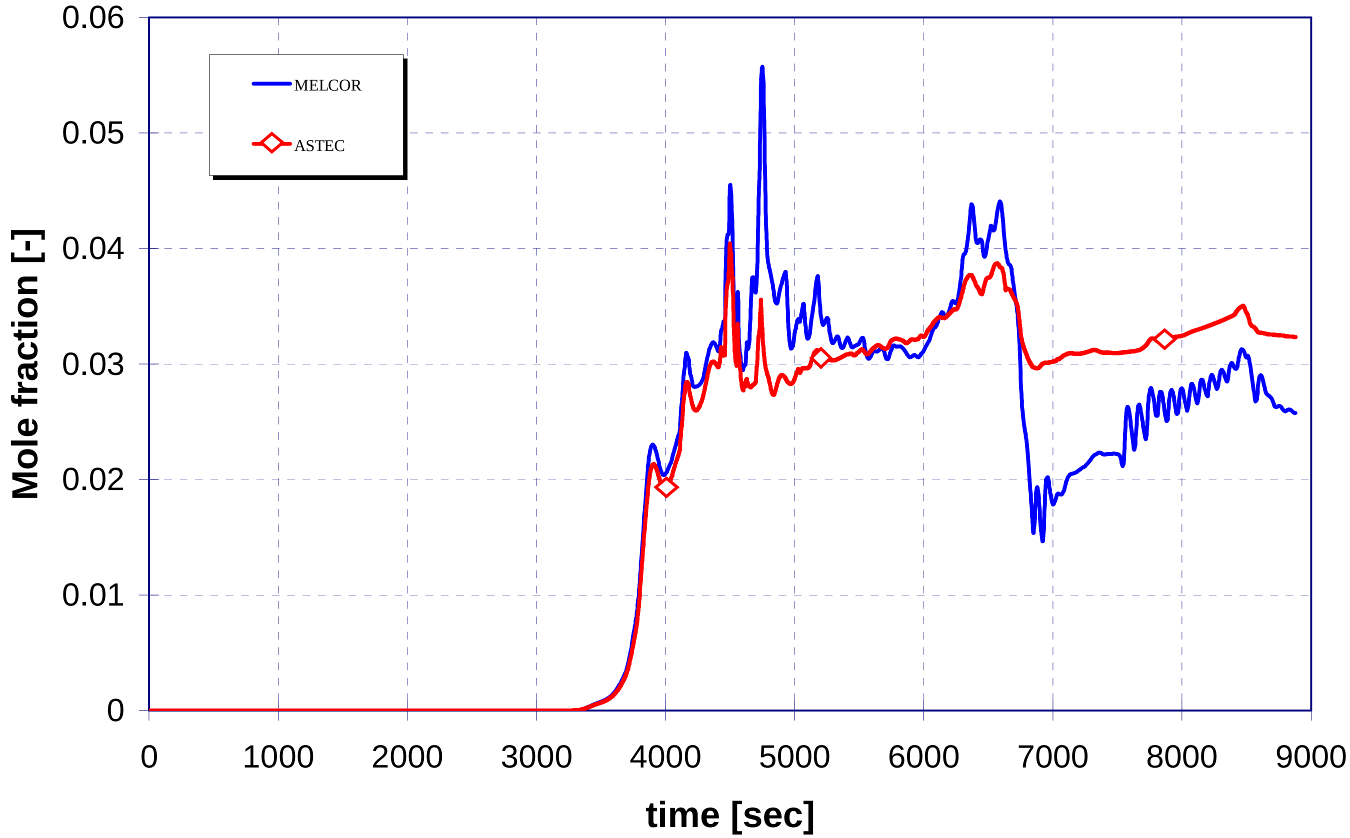
- Pressure in RCPSGR (705) compartment



Code to code comparison with ASTEC

Results of the calculations

- Hydrogen concentration in RCPSGR (705) compartment



Conclusion

- The different performed calculations show good agreement with accident, experiments or other code results even with a simplified nodalization
- The remaining uncertainties on code results are known and taking into account in the analyses
- TE MELCOR models (and modelization process) are qualified to be used in various industrial studies

Thank you for your attention