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Assessment of CATHARE 3D model in predicting the mixing phenomenon in a PWR reactor pressure vessel

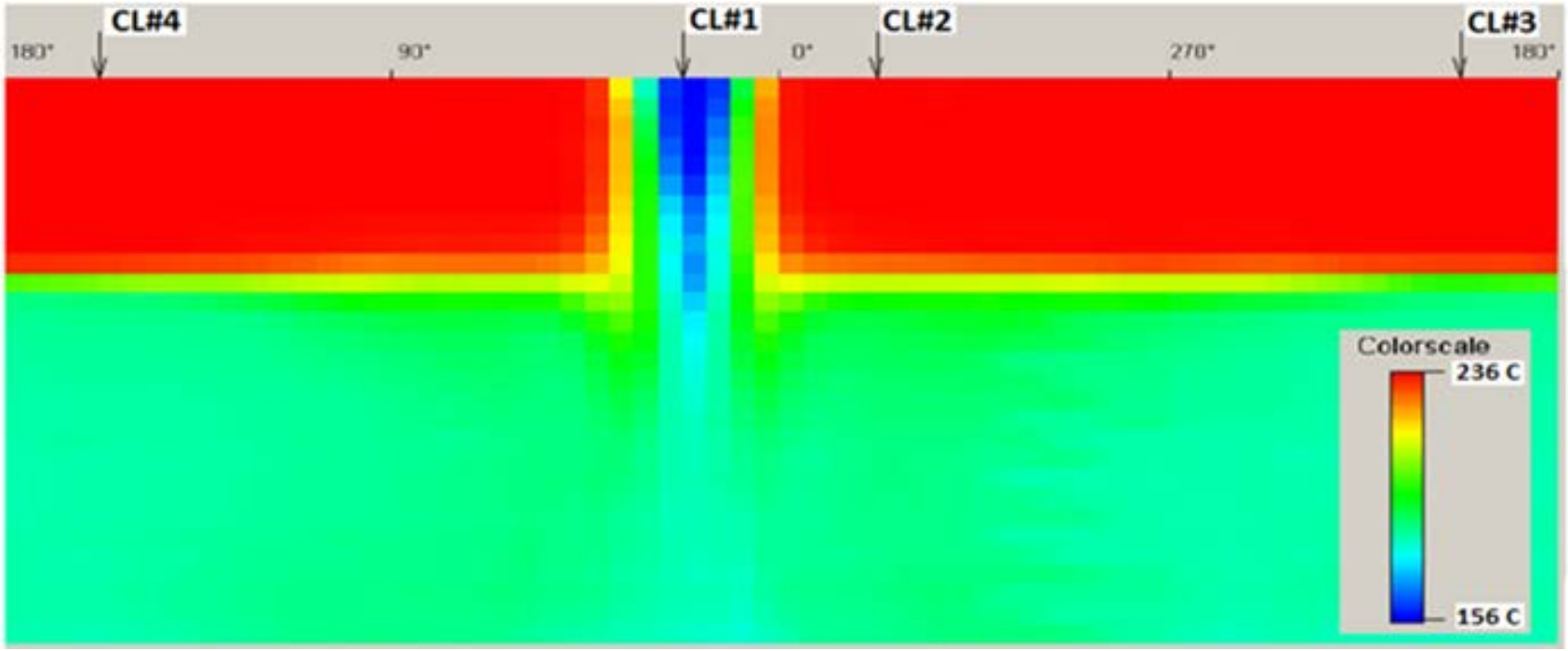
Summary

- Introduction
- OECD/PKL-2 ROCOM test
- CATHARE 3D modeling
- Experimental vs. Calculation results
- Conclusion

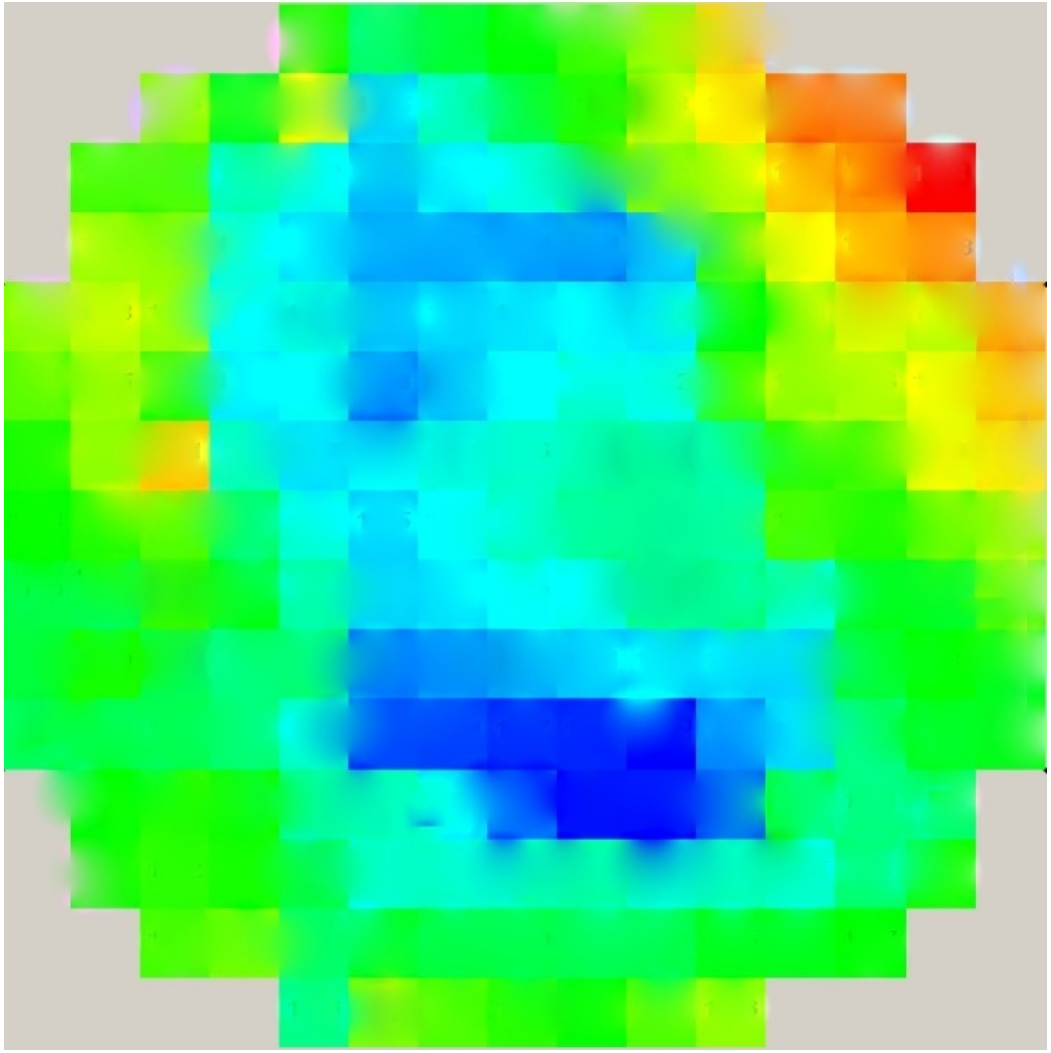
Phenomena occurring during Natural Circulation flows

	Forced Circulation	Natural Circulation
1	Driving force: External	Driving head: Intrinsic
2	Mass flow rate: Unique solution	Mass flow rate: Multiple solution (bifurcation)
3	Stratification : Not encountred	Stratification: Commonly encountered
4	Instabilities occurrence: Low	Instabilities occurrence: High

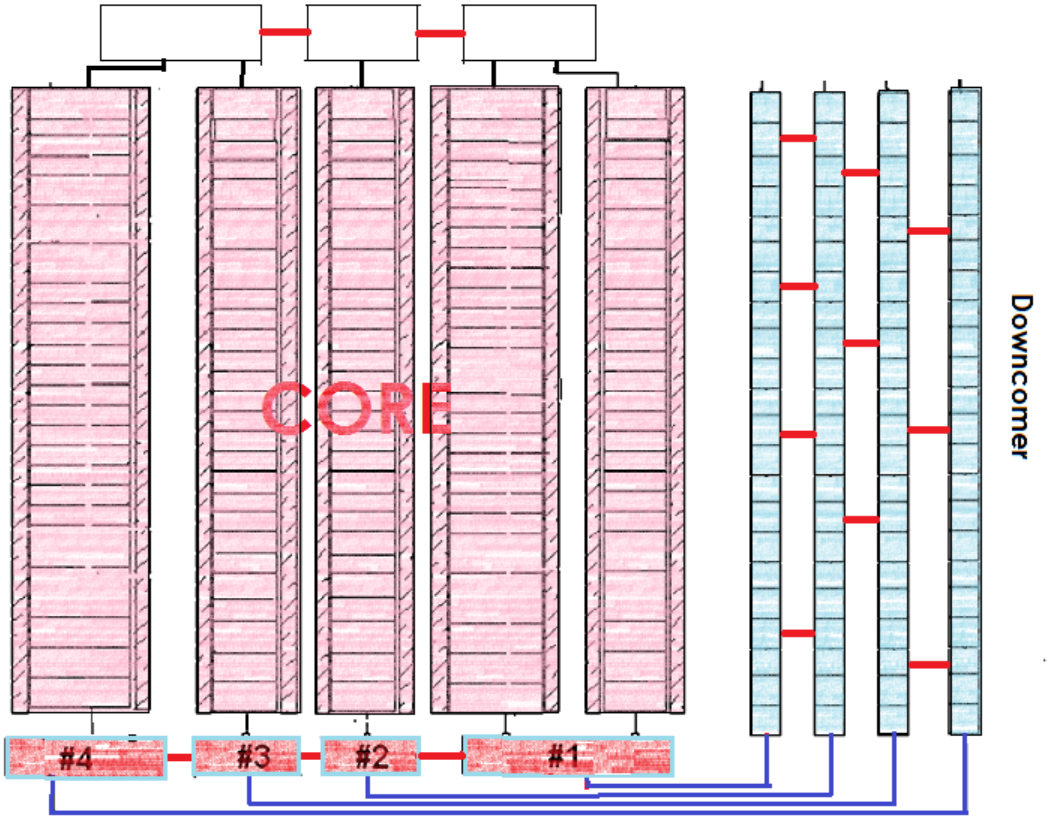
Flow mixing/stratification in the pressure vessel downcomer

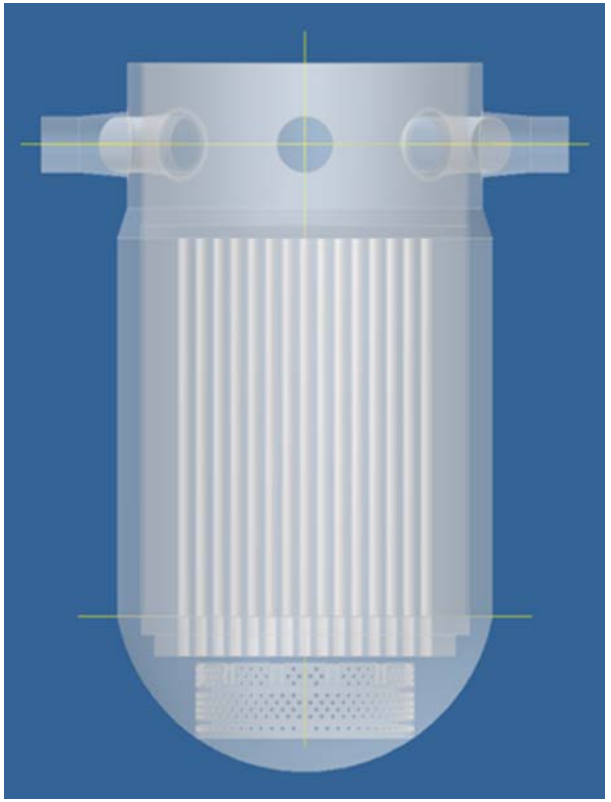


Flow mixing/stratification: Return to criticality



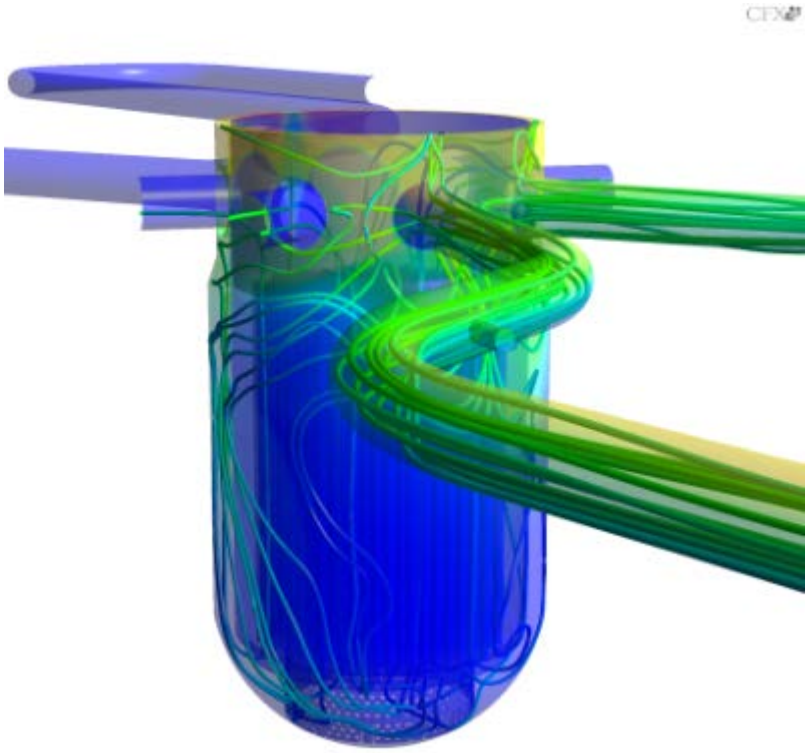
Mixing evaluation using 1D thermal-hydraulic system codes

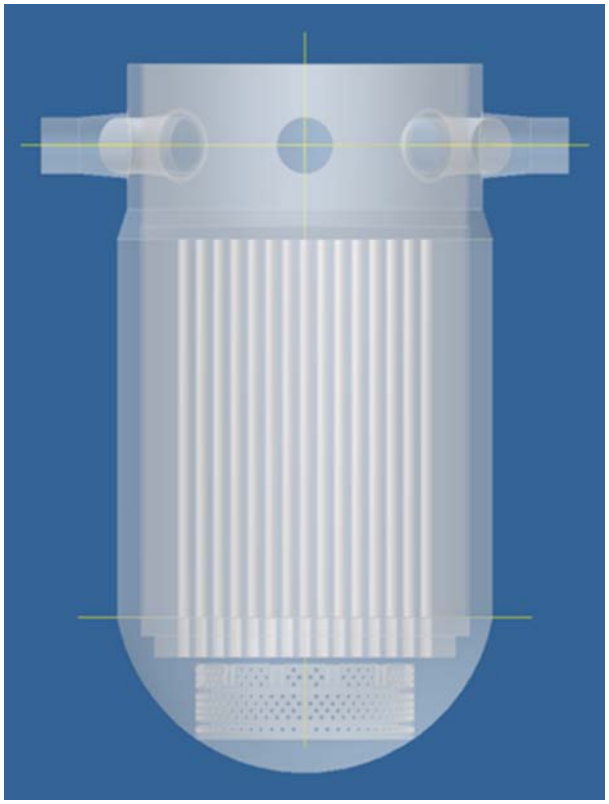




Cross flow not adequate for all flow regimes

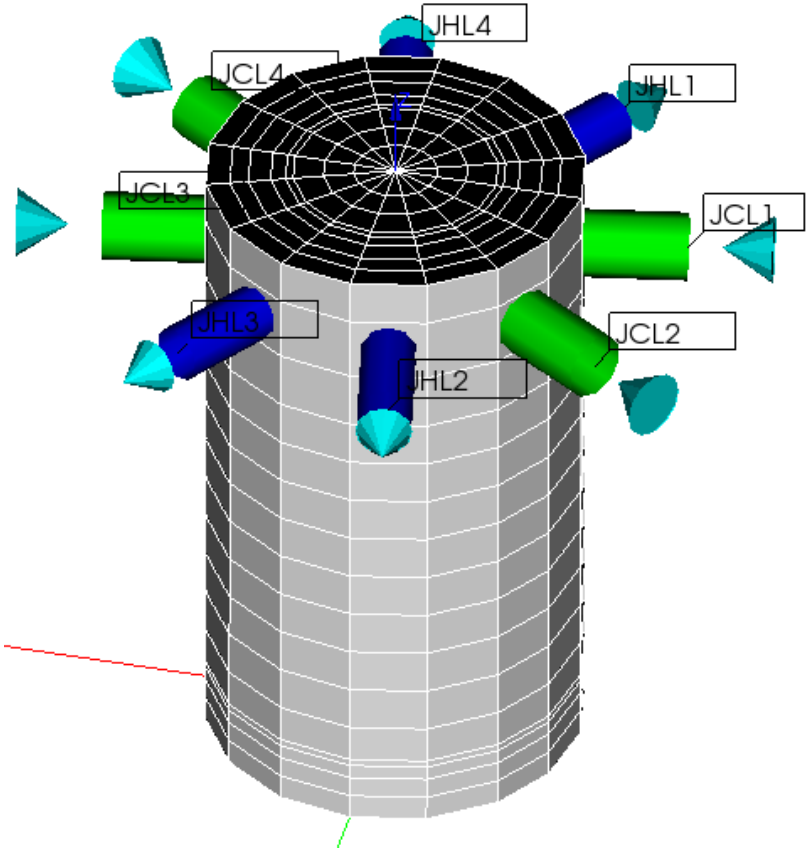
Mixing evaluation using CFD codes

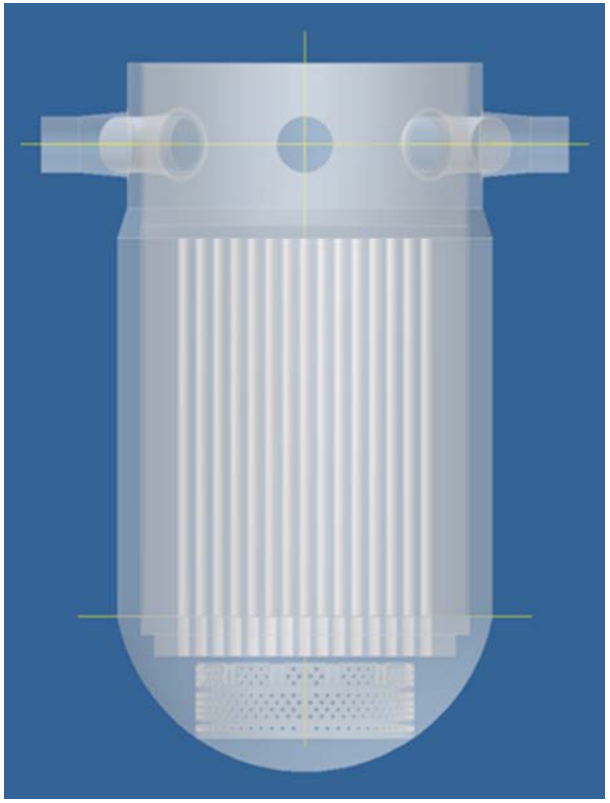




Millions of nodes, huge CPU times

Mixing evaluation using 3D thermal-hydraulic system codes





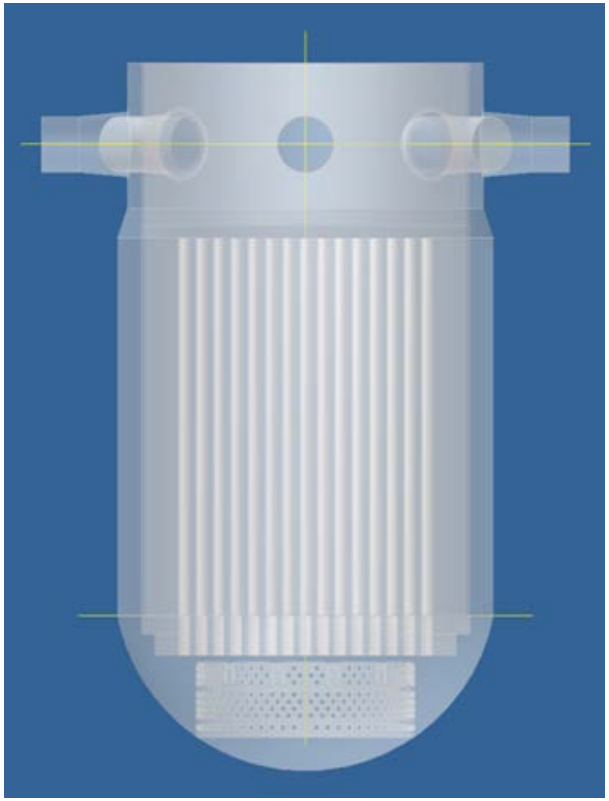
Thousands of nodes, less computational resources

ROCOM facility instrumentations

Assess the Mixing Scalar (MS)

$$MS_{measured}(r,\theta,z) = \frac{\sigma_{measured}(r,\theta,z) - \sigma_{intact-loops}}{(\sigma_{affected-loop} - \sigma_{intact-loops})}$$

- RPV downcomer and
- Core inlet plenum

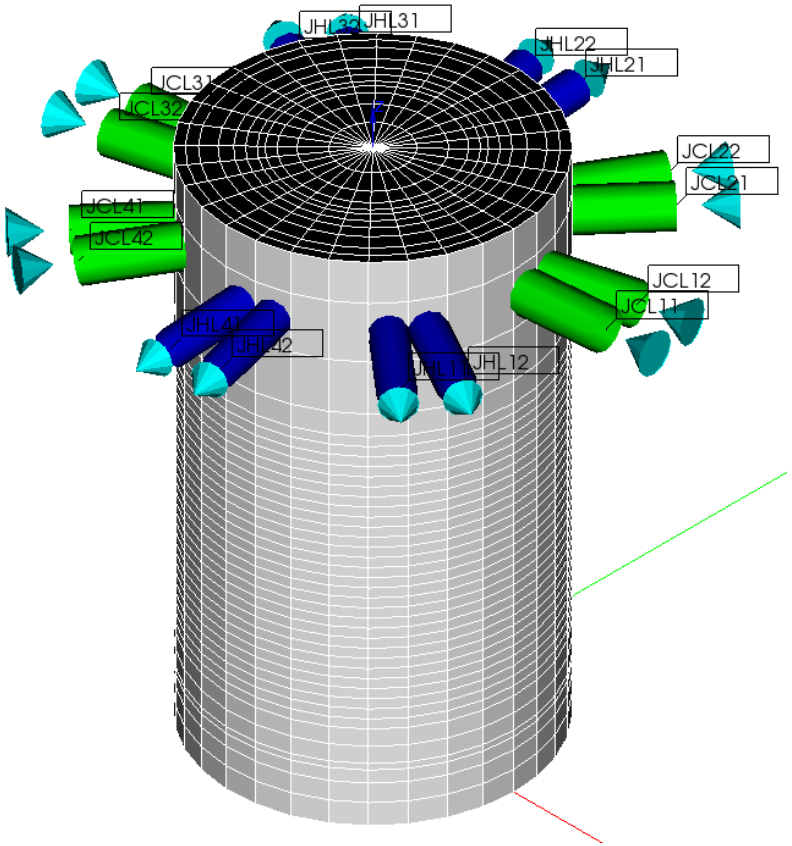


64 Azimuthal & 29 Axial sensors

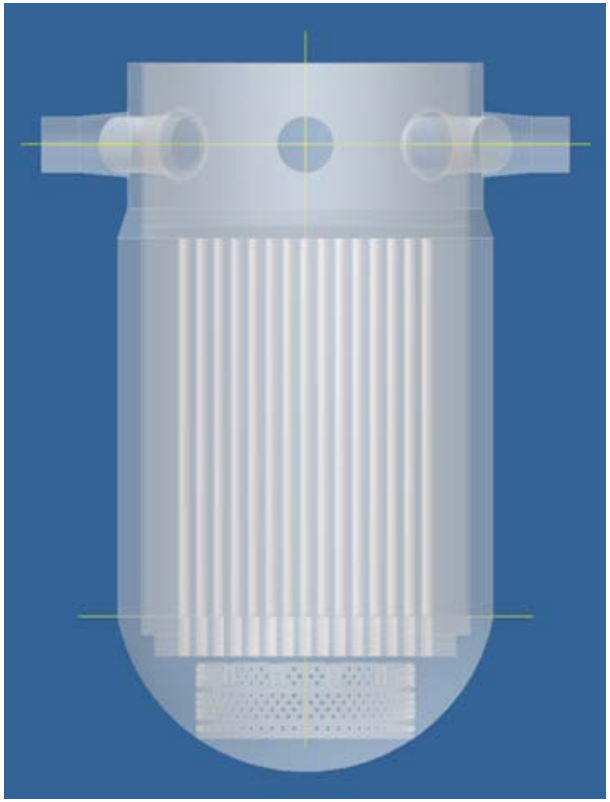
193 sensors at the core inlet

CATHARE 3D RPV model for ROCOM facility

32 Azimuthal, 39 Axial nodes



32 Azimuthal x11 Radial nodes

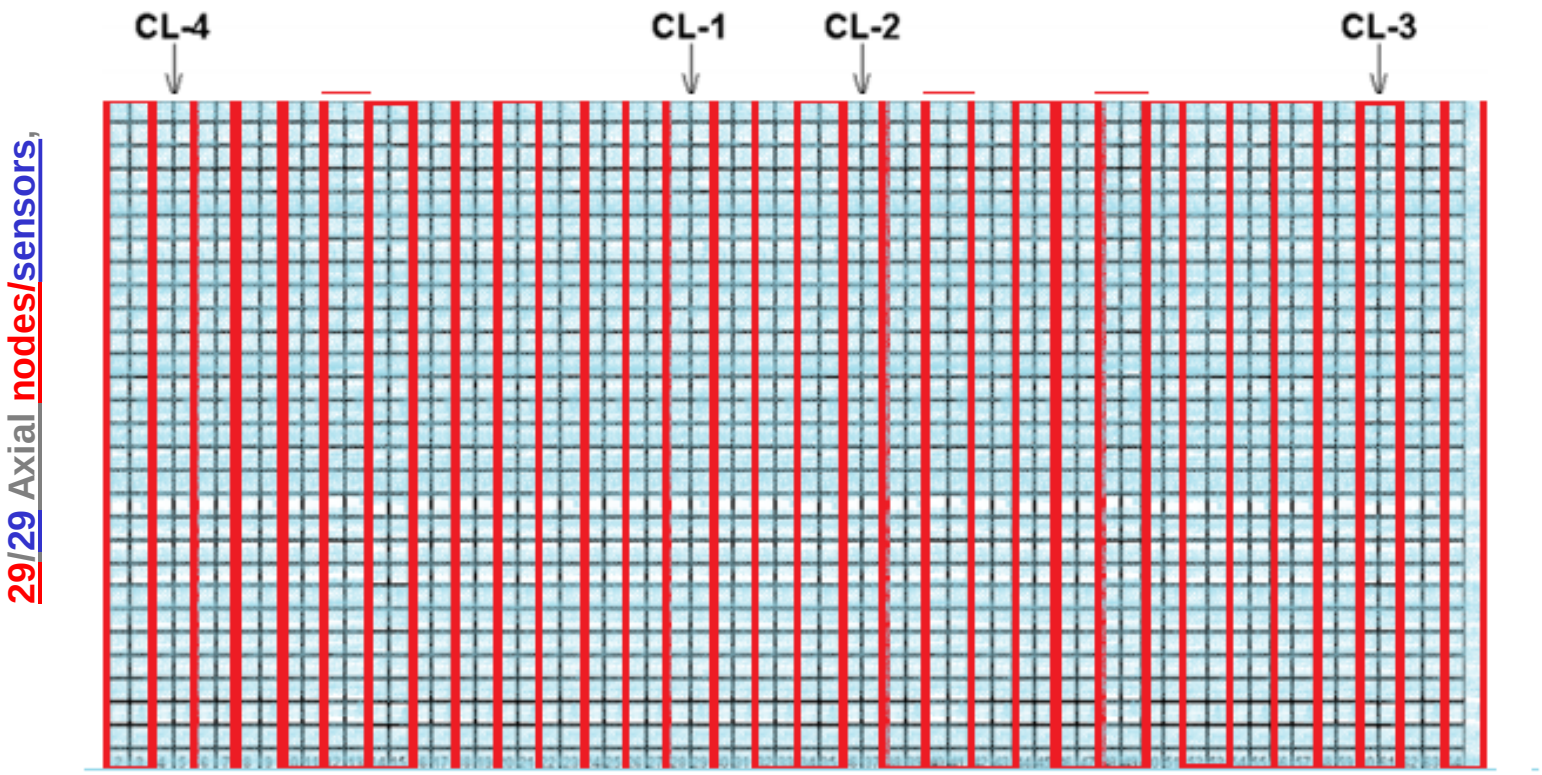


64 Azimuthal & 29 Axial sensors

193 sensors at the core inlet

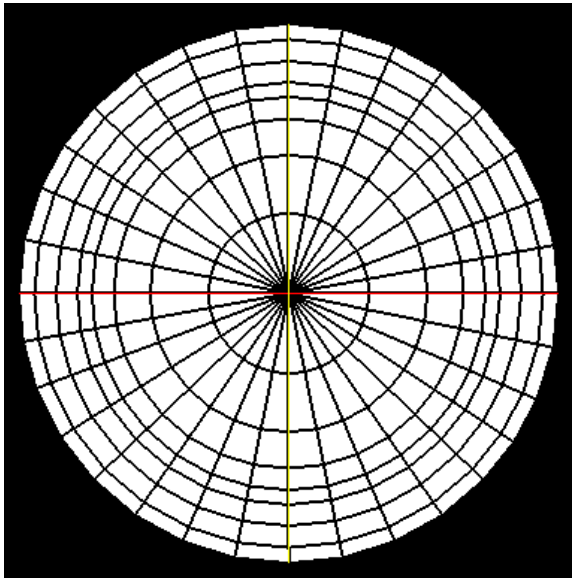
CATHARE 3D RPV model for ROCOM facility: Downcomer

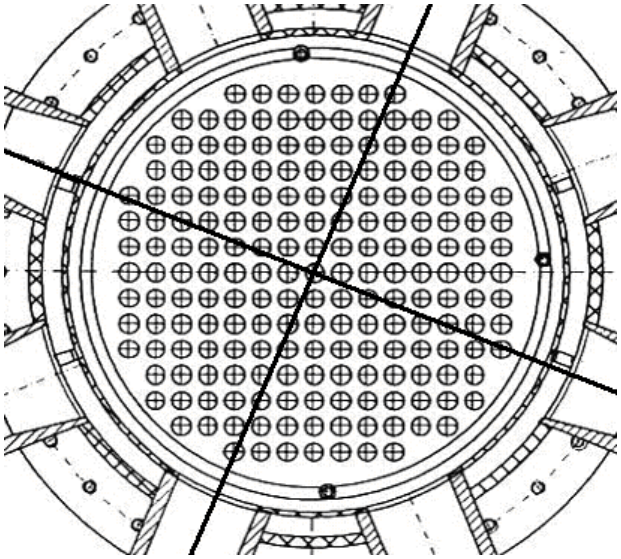
32 /64 Azimuthal nodes/sensors,



CATHARE 3D RPV model for ROCOM facility: Core lower plenum

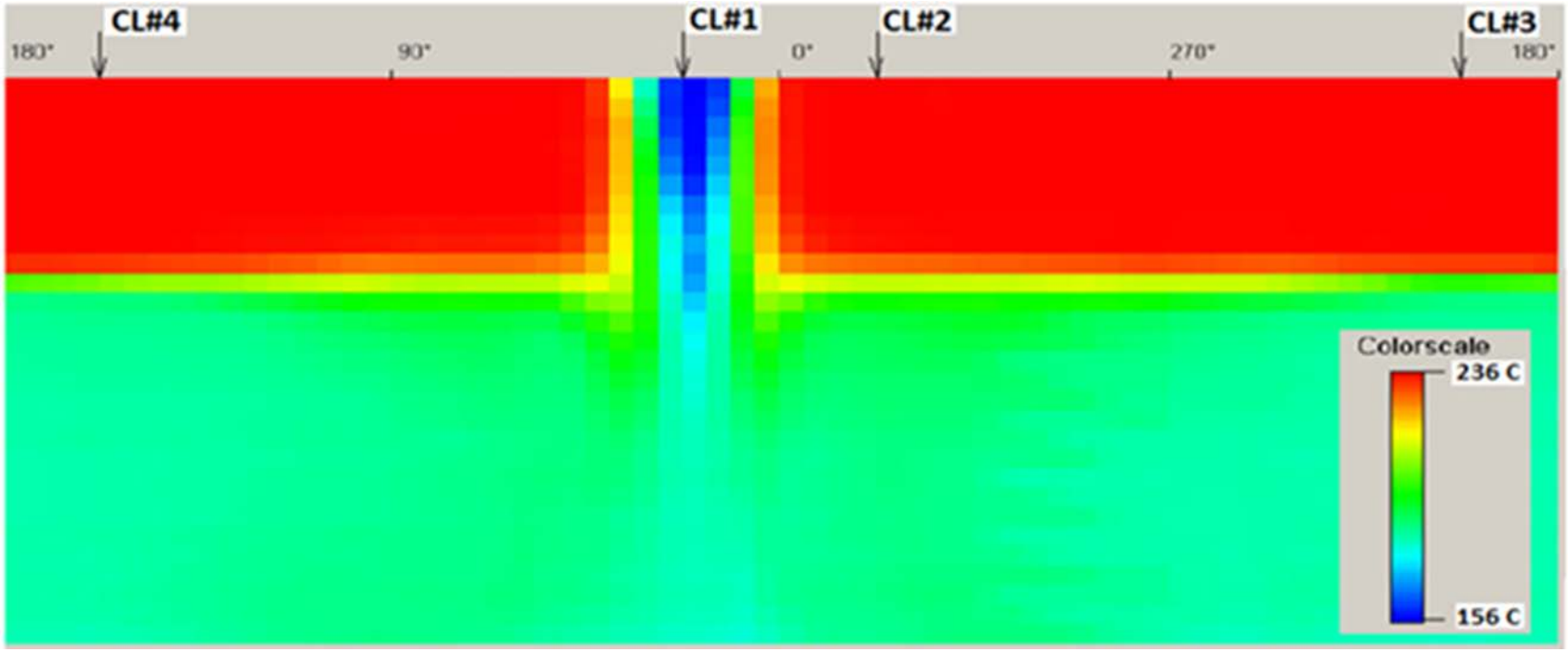
256 nodes/ 192sensors,



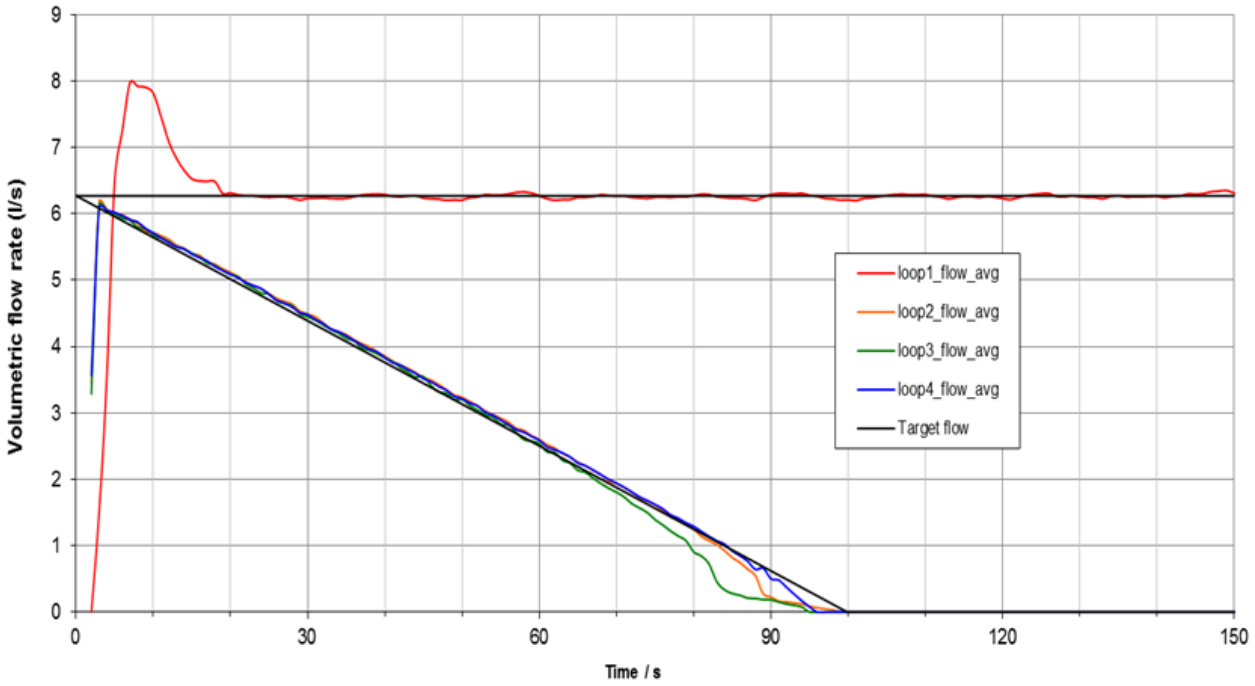


Objectives of the ROCOM T2.2 experiment

Assess the impact of the flow and temperature asymmetry between loops on the evolution of the mixing level in the RPV downcomer.

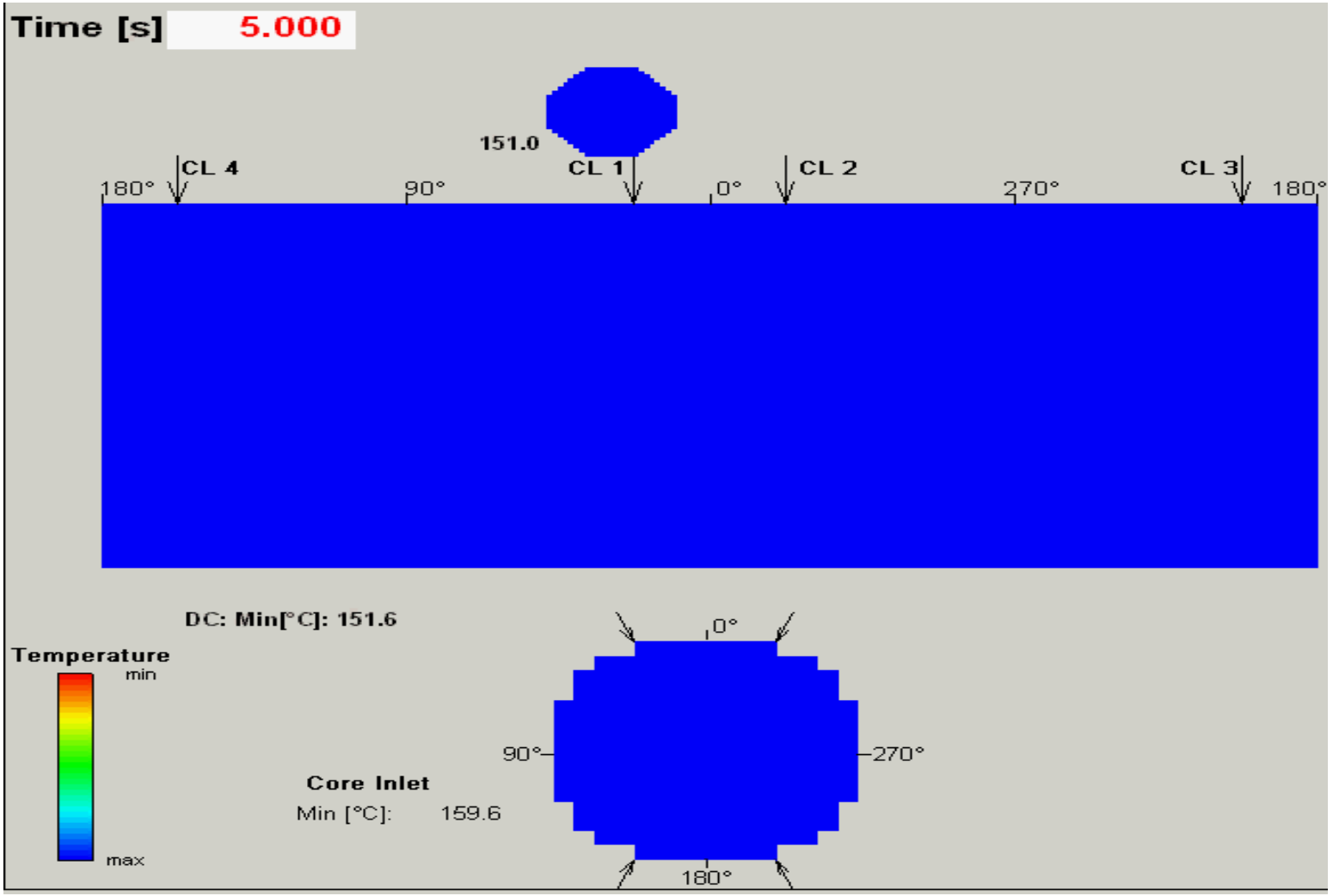


ROCOM T2.2 experiment: Boundary and initial conditions

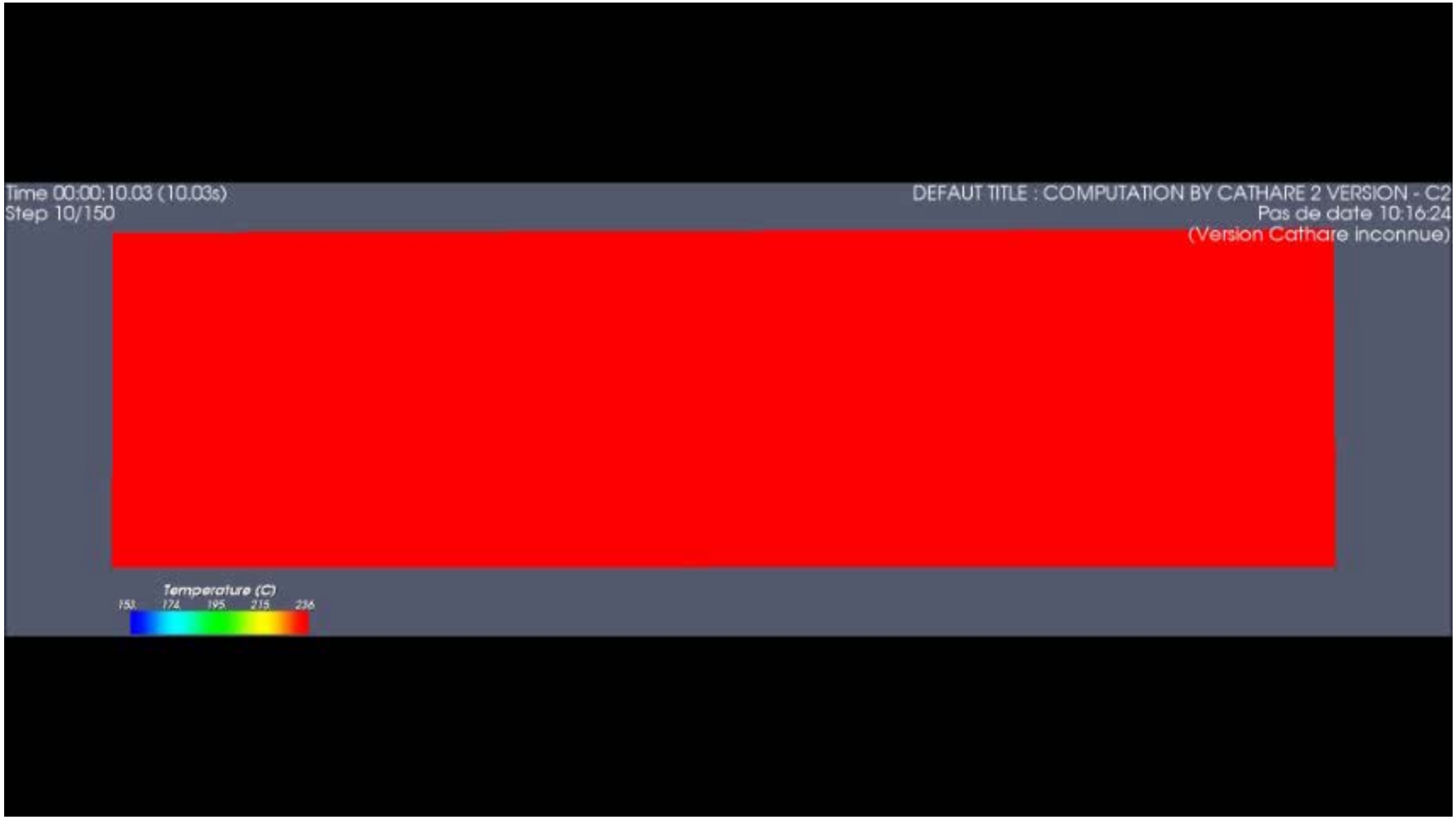


Loop number	1	2, 3, 4
Volumetric flow rate (l/s)	0.0	6.27
Relative density	1.12	1.0

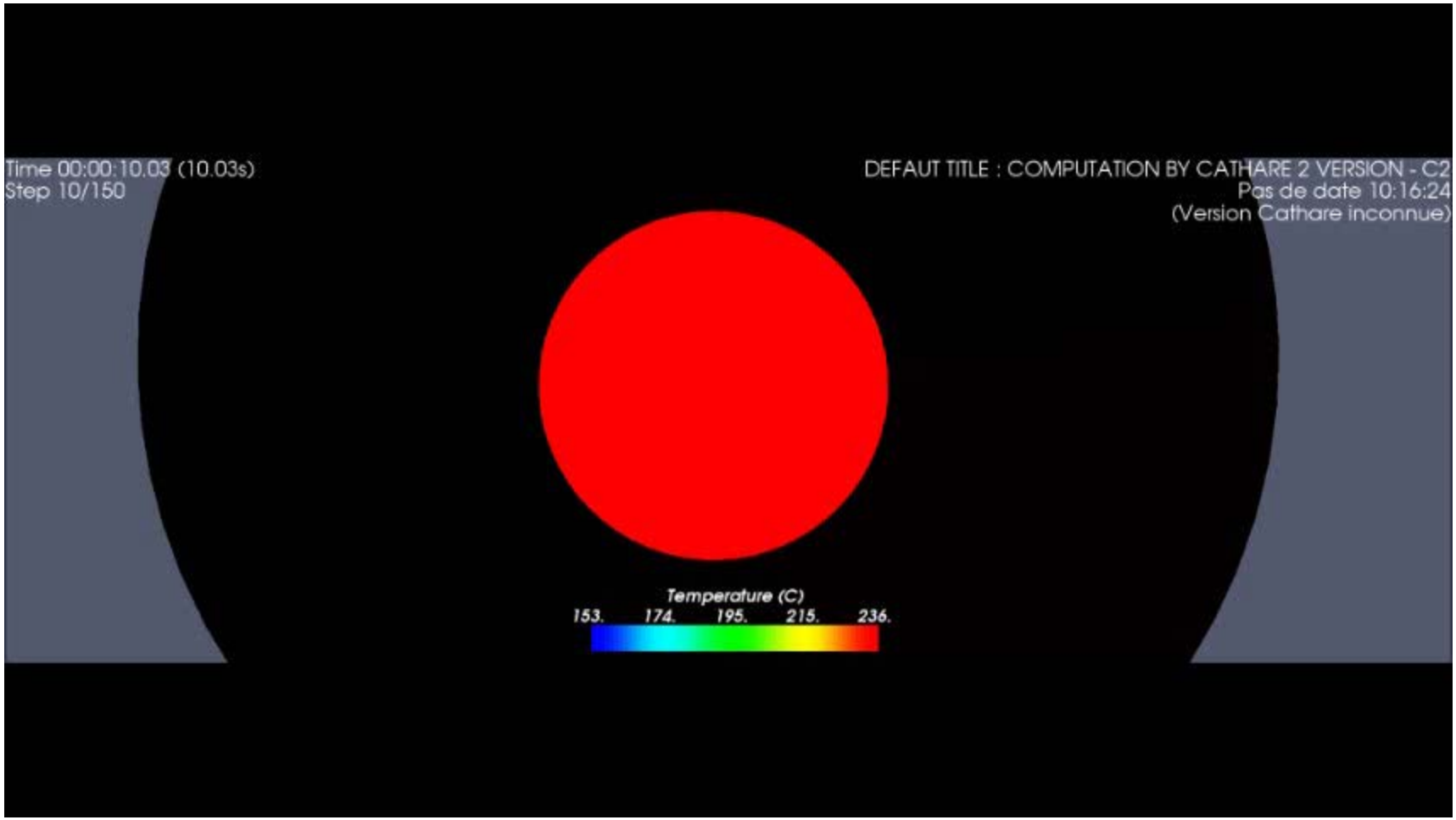
Measured ROCOM T2.2 test



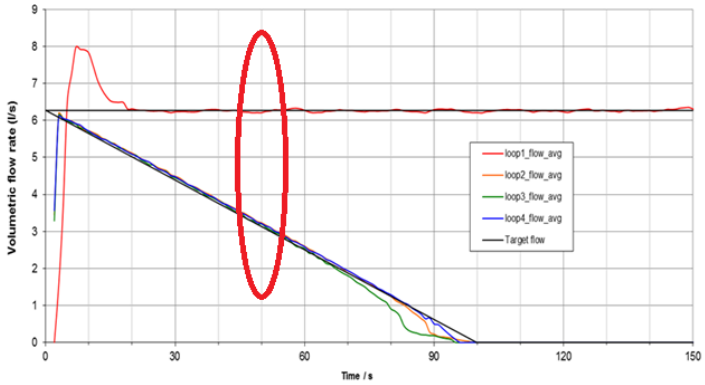
CATHARE prediction of the ROCOM T2.2 test
RPV downcomer

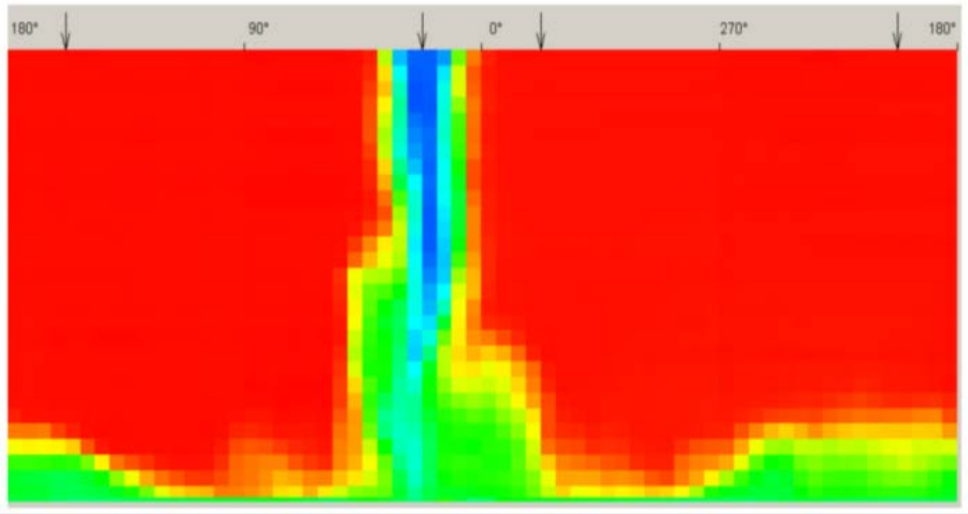


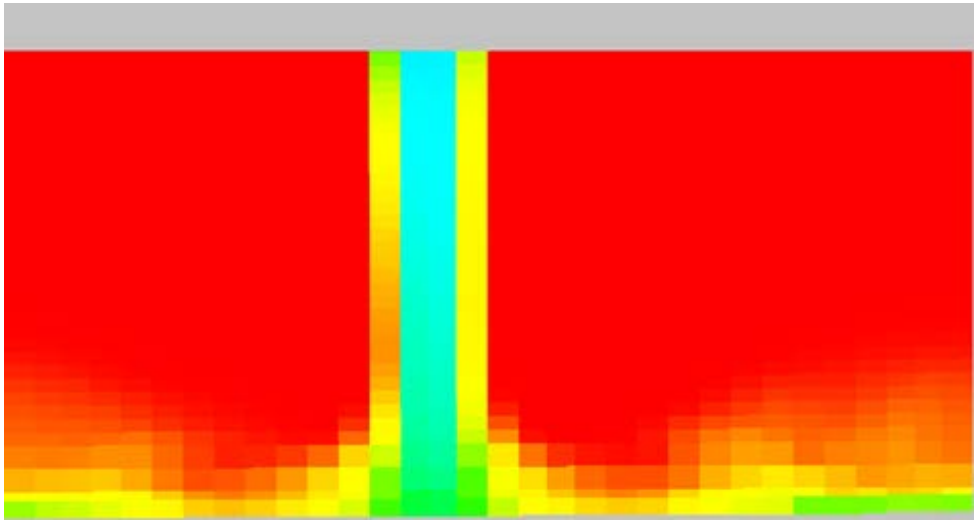
CATHARE prediction of the ROCOM T2.2 test
Core lower plenum



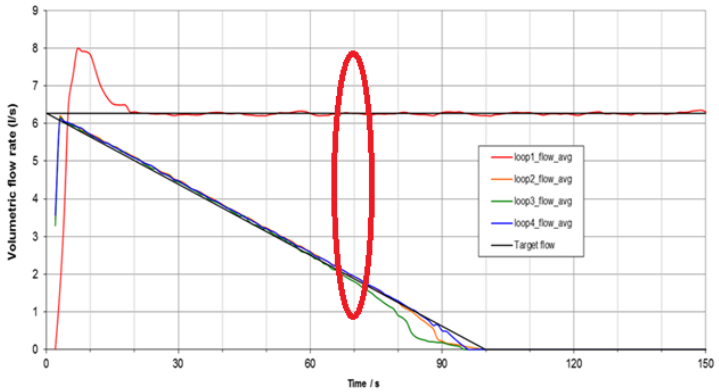
Snapshots of the mixing level evolution
Time = 50s

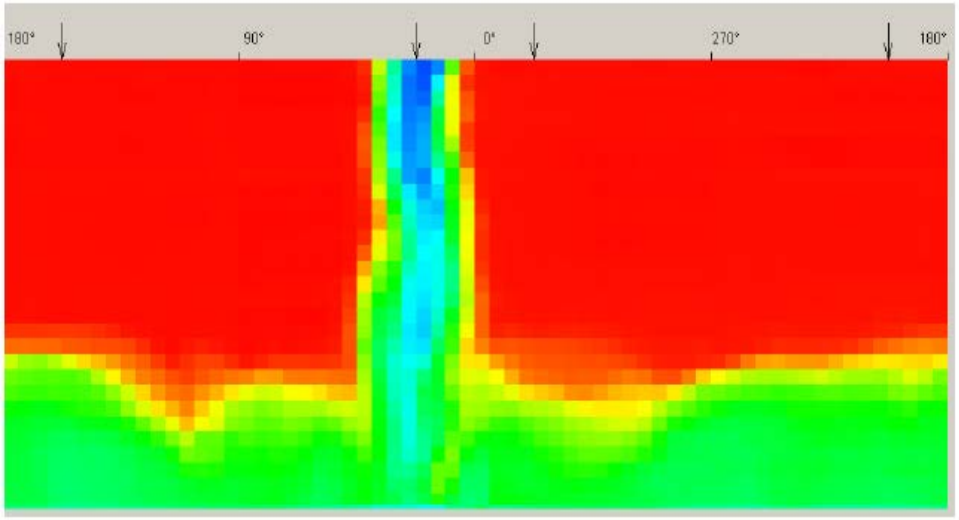


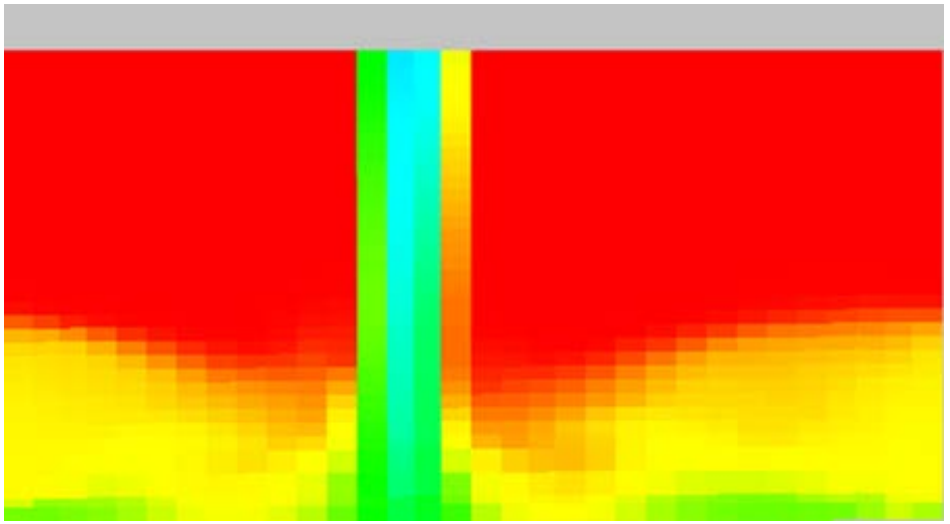




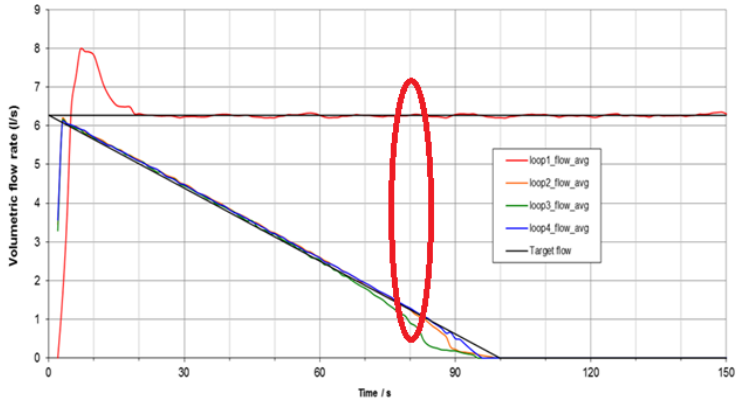
Snapshots of the mixing level evolution
Time = 65s

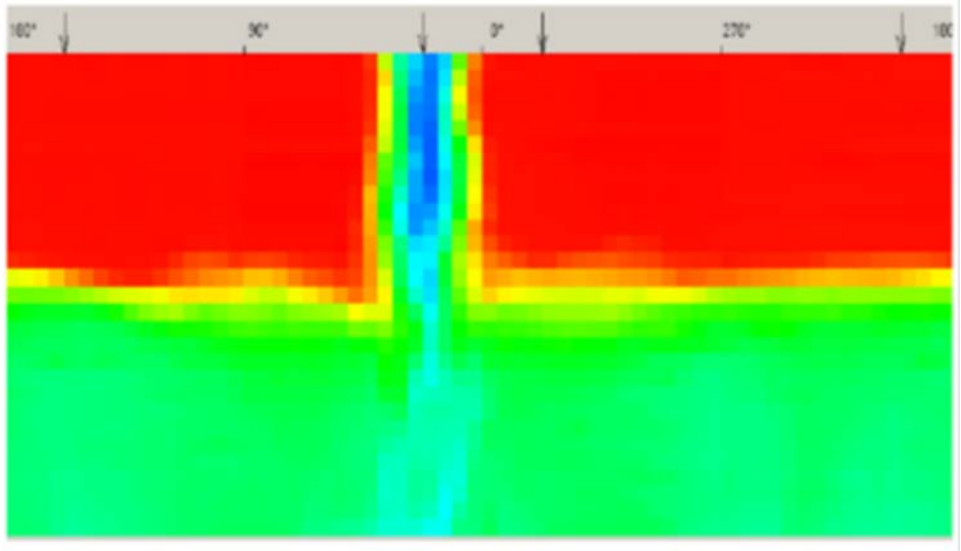


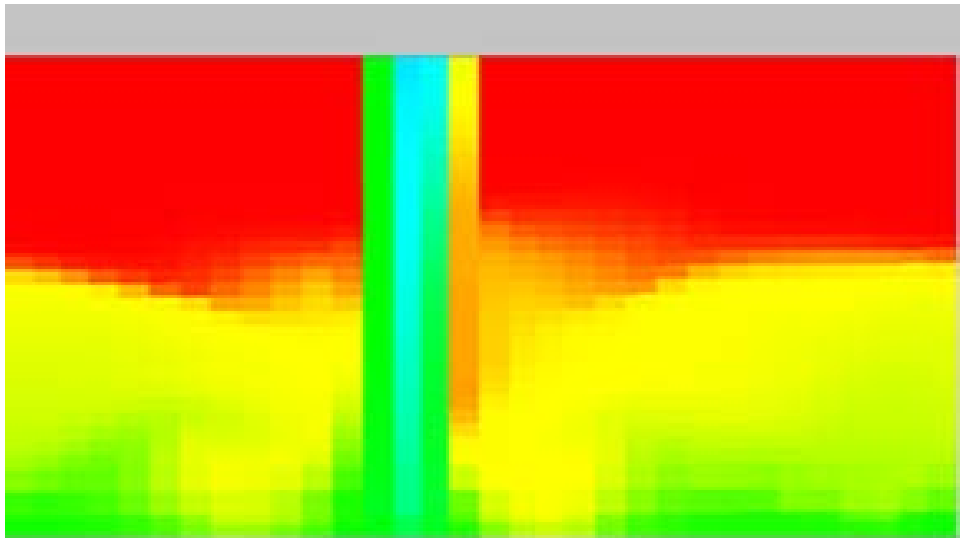




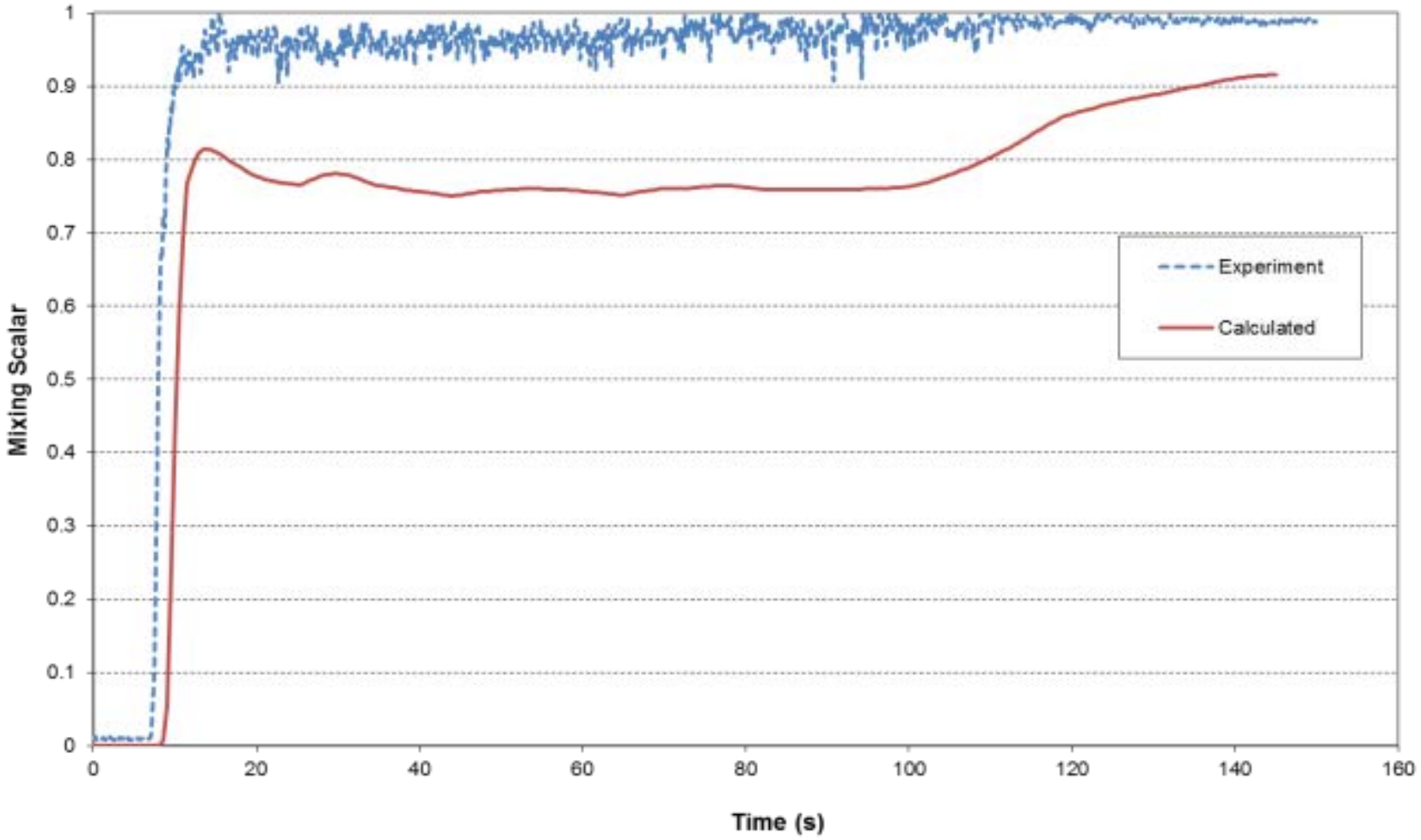
Snapshots of the mixing level evolution
Time = 80s



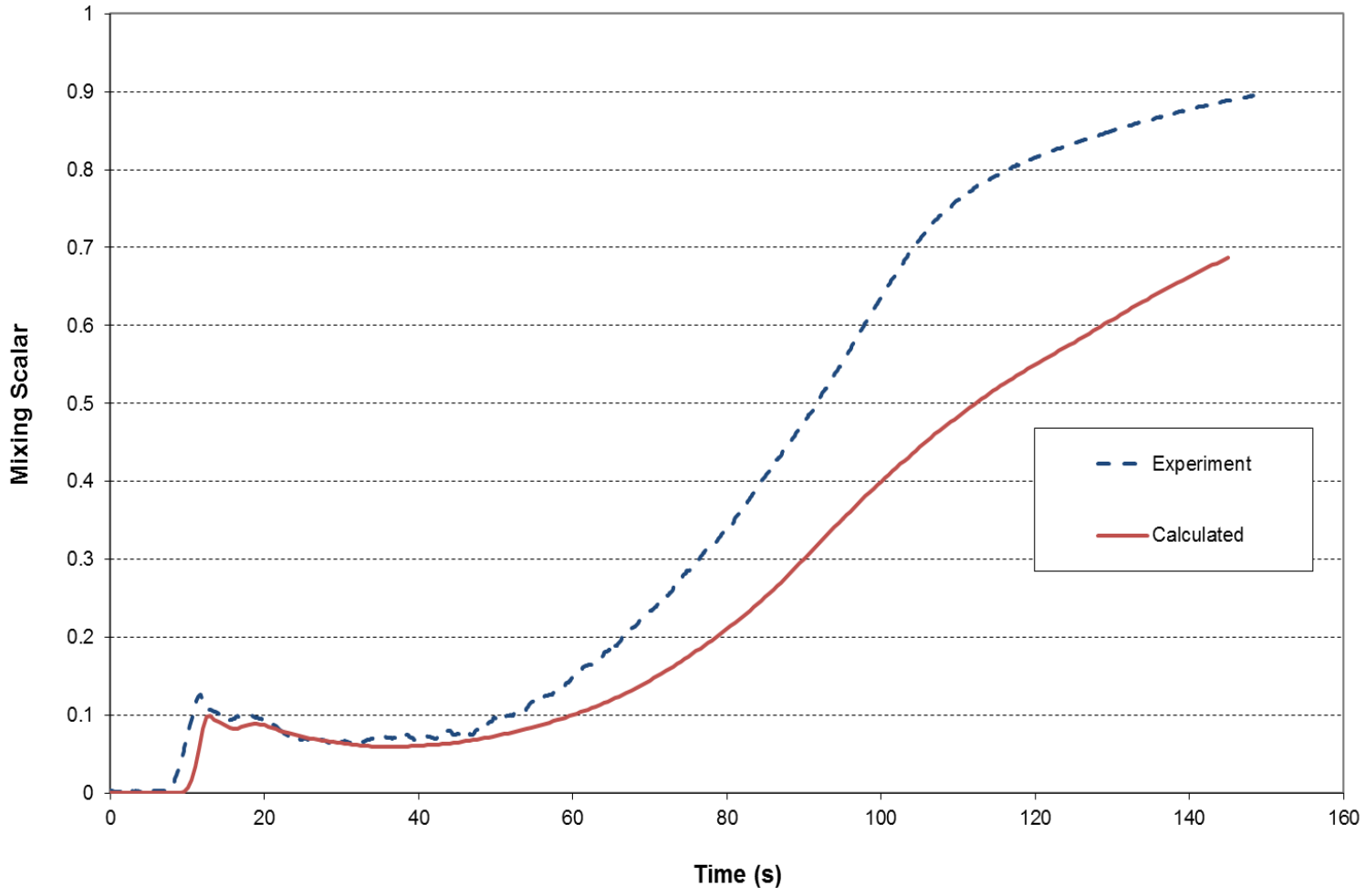




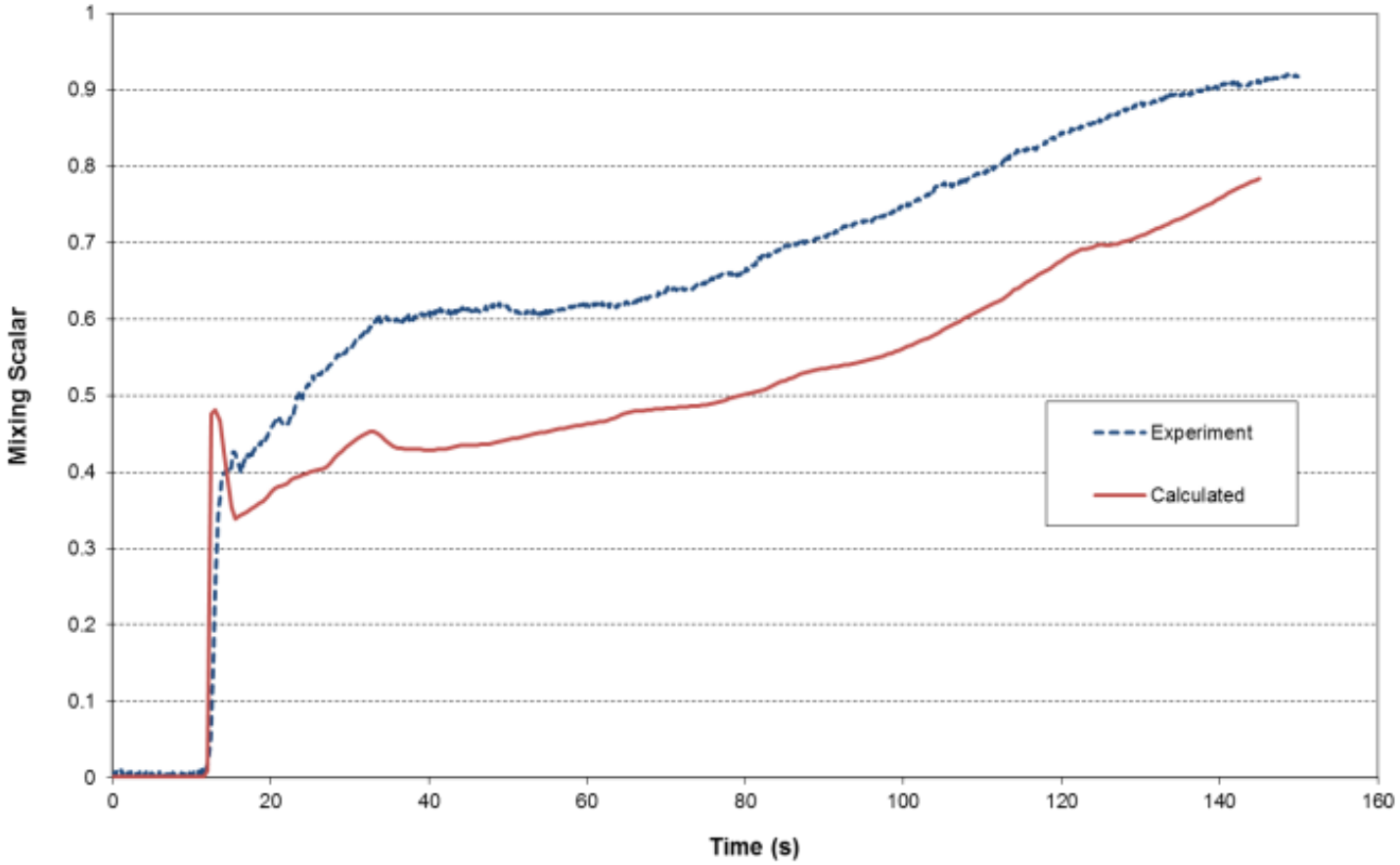
Experimental vs. CATHARE predictions
Mixing Scalar (max.) : RPV Downcomer



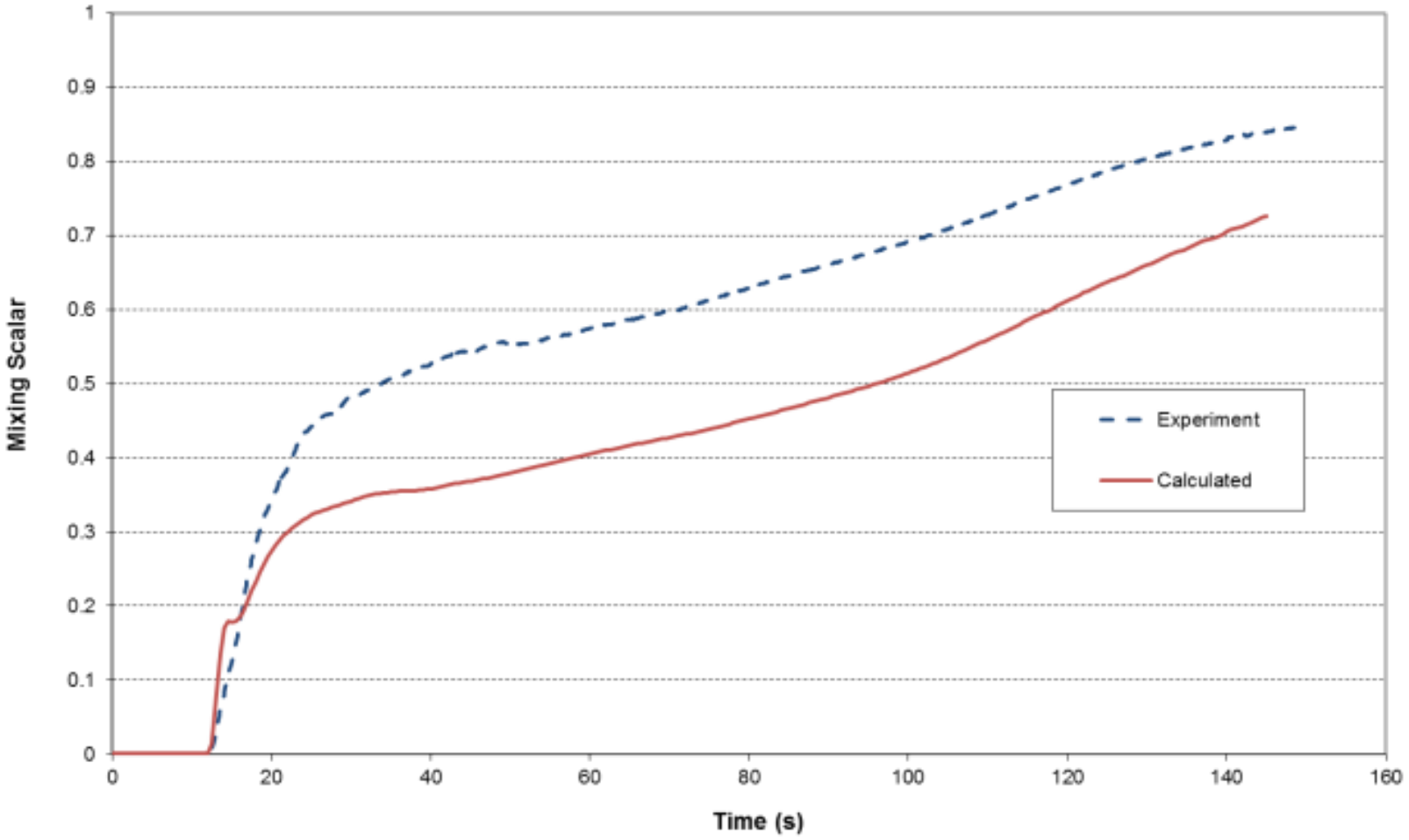
Experimental vs. CATHARE predictions
Mixing Scalar (mean) : RPV Downcomer



Experimental vs. CATHARE predictions
Mixing Scalar (max.): RPV Downcomer



Experimental vs. CATHARE predictions
Mixing Scalar (mean) : Core Lower Plenum



CPU time

Azimuthal Node number	32	64
TOTAL CPU TIME	**5 h**	**53 h**

Summary

- ✓ **The calculation and the measurement show acceptable agreements with experimental data:**
  - **The main phenomena occurring during the transient are well reproduced especially the dynamic evolution of the mixing level in the downcomer.**
  - **Quantitatively, the temperature discrepancy of 15% is observed.**
- ✓ **Validation and Verification of the CATHARE 3D model activities are under progress.**