Simulation of a Reactor Coolant Pump Asymmetric Transient occurred in Vandellòs II NPP

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- **Summary**
  1. The 3D TH Vessel Model.
  2. Steady State.
  3. Simulation of a Reactor Coolant Pump Asymmetric Transient.
     1. Comparison of the results.
     2. Study of Asymmetric Flows in the Vessel
  4. Current works: Developing of a detailed Lower Plenum.
  5. Conclusions.

1. The 3D TH Vessel Model – Why (1/1)

Full 1D Model of Vandellós II NPP → Used for safety and operation predictions → Satisfactory Results

Need of study of asymmetric phenomena taking place in the Vessel during Aymmetric Transients

• Existing 1D does not show detailed asymmetric phenomena

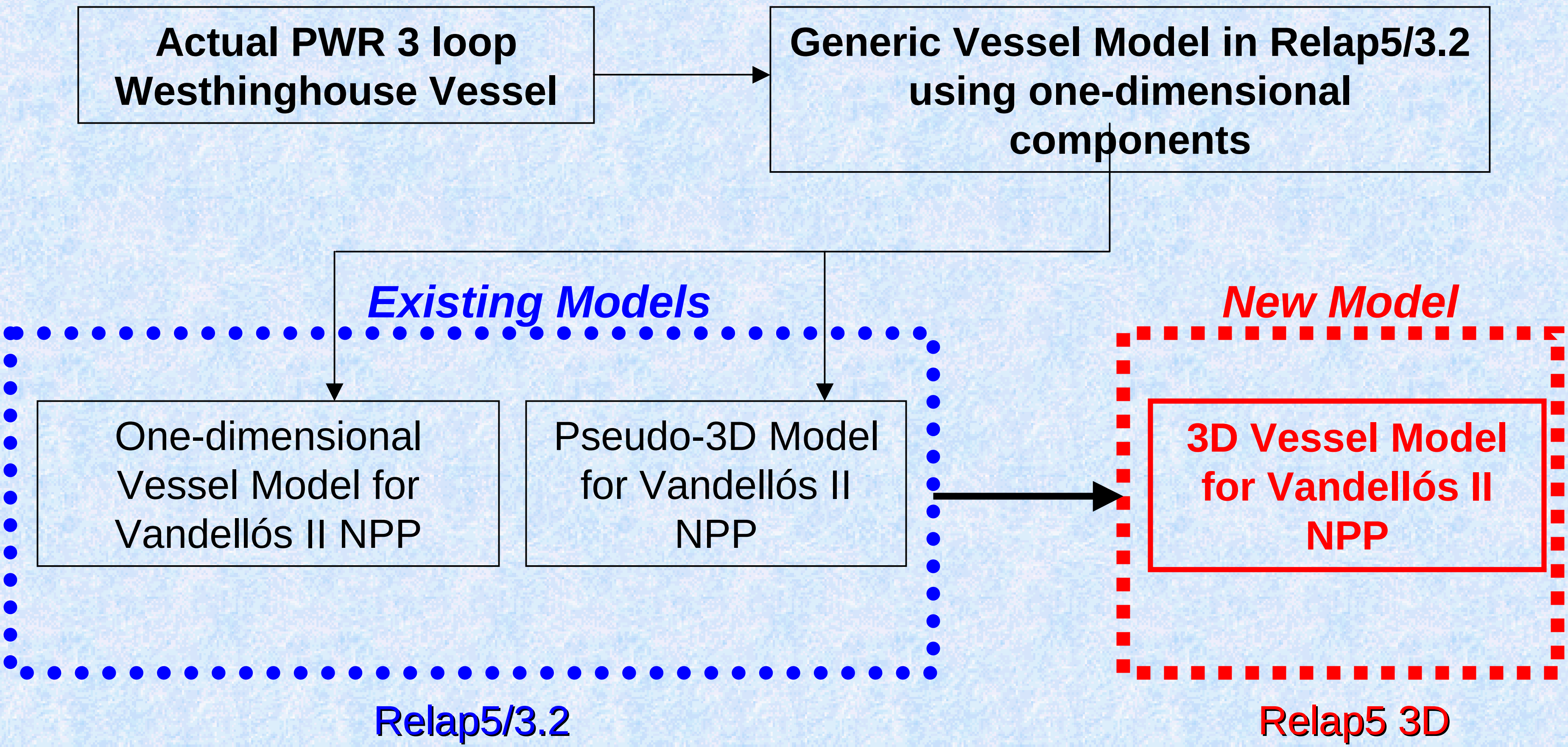
↓

• Developing of a pseudo-3D Vessel Model using 1D components and crossed junctions

→ Relap5 3D

3D Vessel Model for Vandellós II NPP

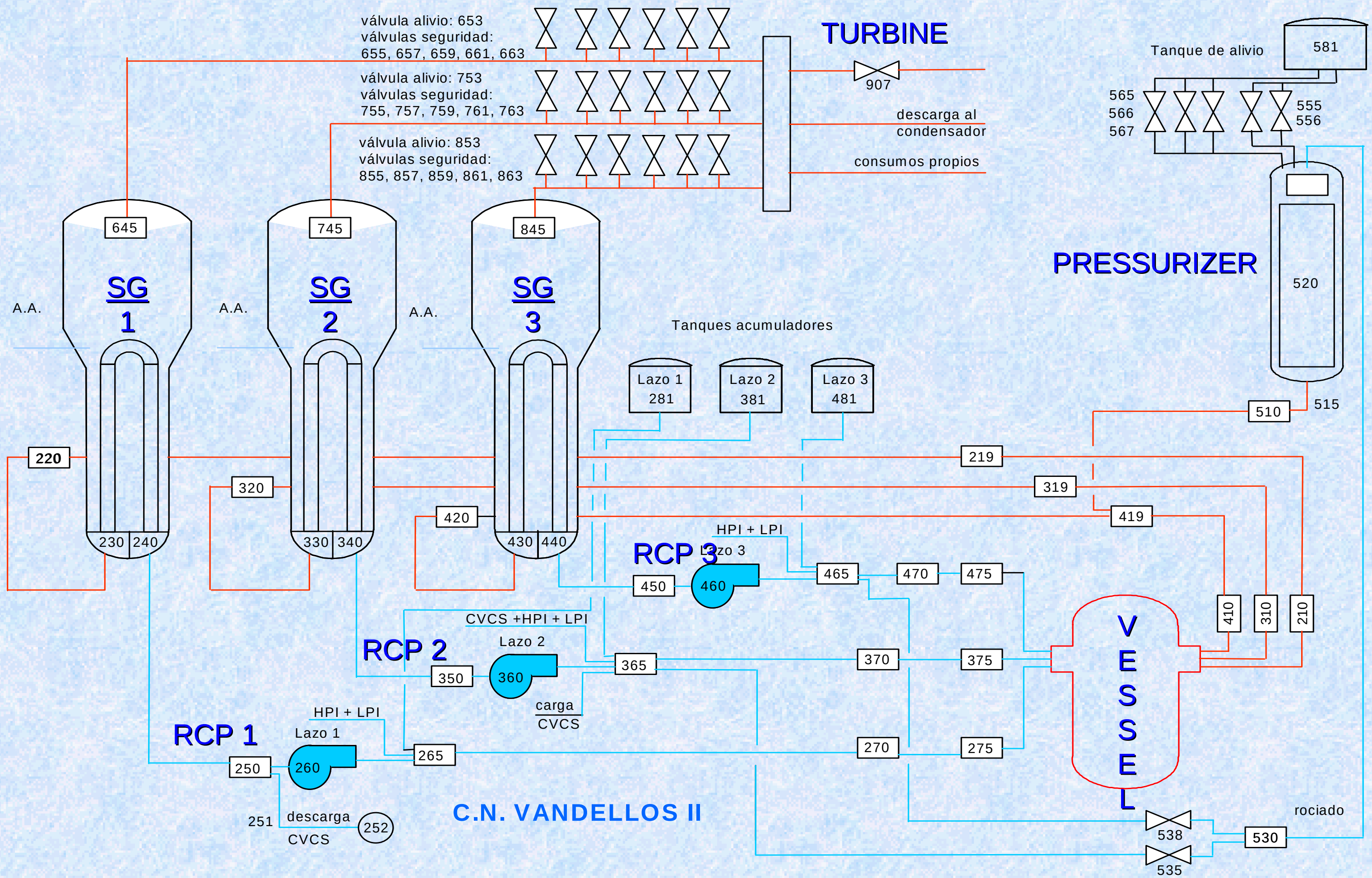
1. The 3D TH Vessel Model – How (1/2)



1. The 3D TH Vessel Model – How (2/2)

– Use of a total of 5 multidimensional components and 7 multiple junctions to nodalise the vessel.
– Study of the real lay-out of heat structures inside the vessel.
– Integration of the new 3D TH vessel model in the 1D plant model (Balance of plant components, kynetics, controls,...).

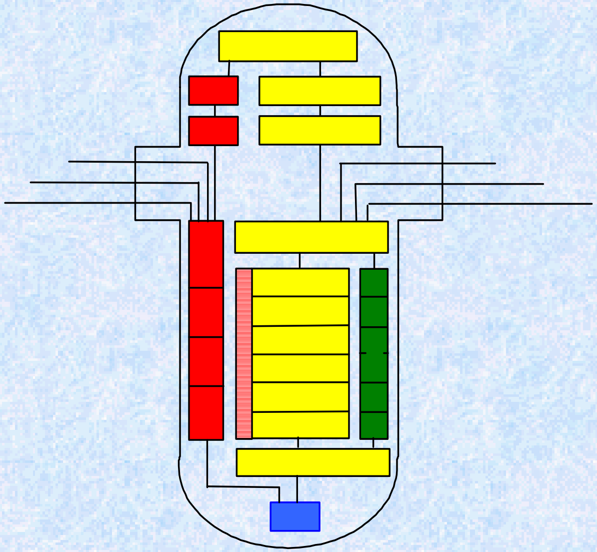
1. The 3D TH Vessel Model



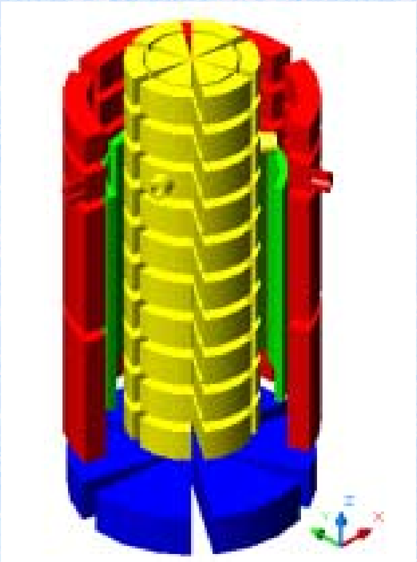
1. The 3D TH Vessel Model

Actual Vandellós II NPP Vessel

1D Vessel Model for Relap5/3.2

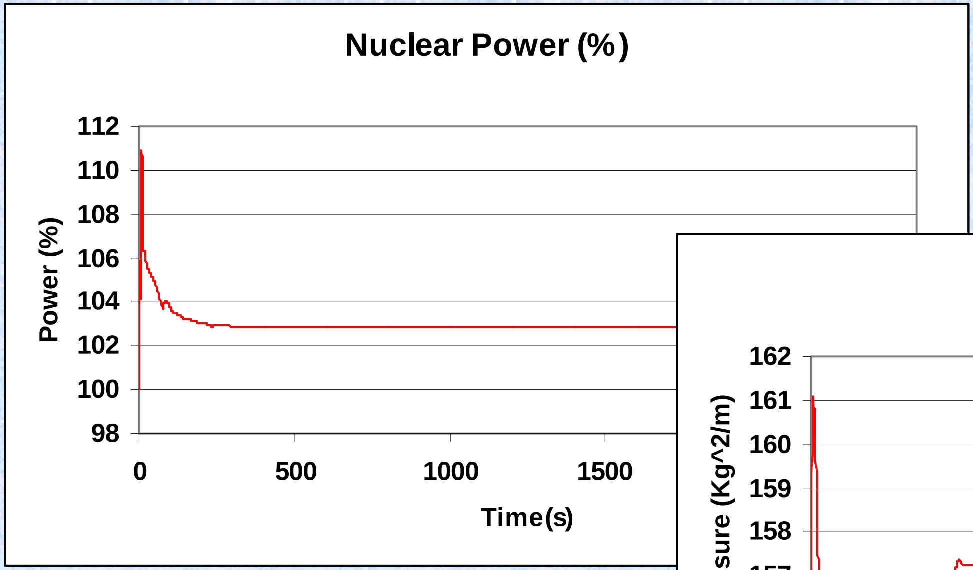


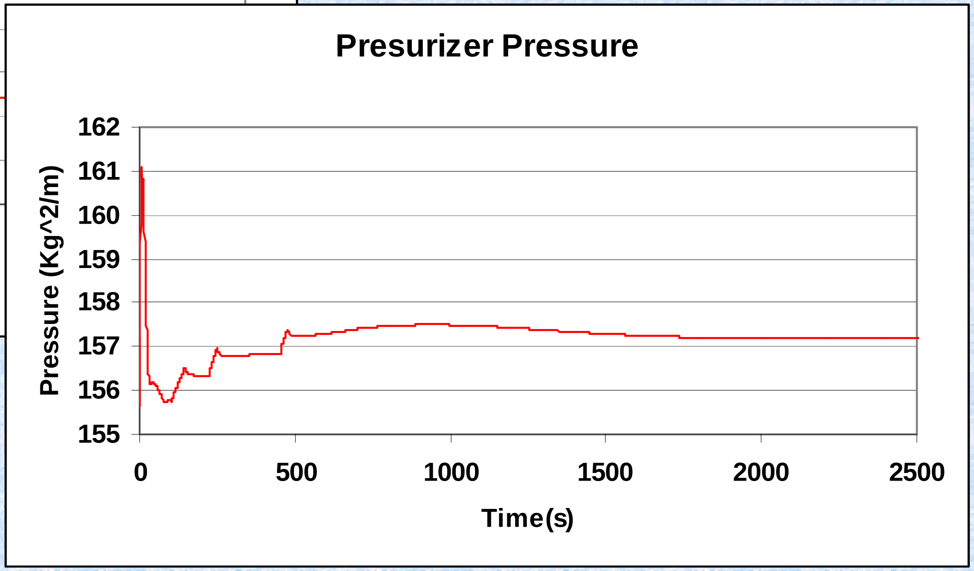
3D Vessel Model for Relap 3D



2. Steady State of the New Model

– 5000s of simulation in steady state → Model is stable by itself from second 1500





3. Simulation of a Reactor Coolant Pump Asymmetric Transient (1/12)

1 0” Reactor in Nominal Conditions

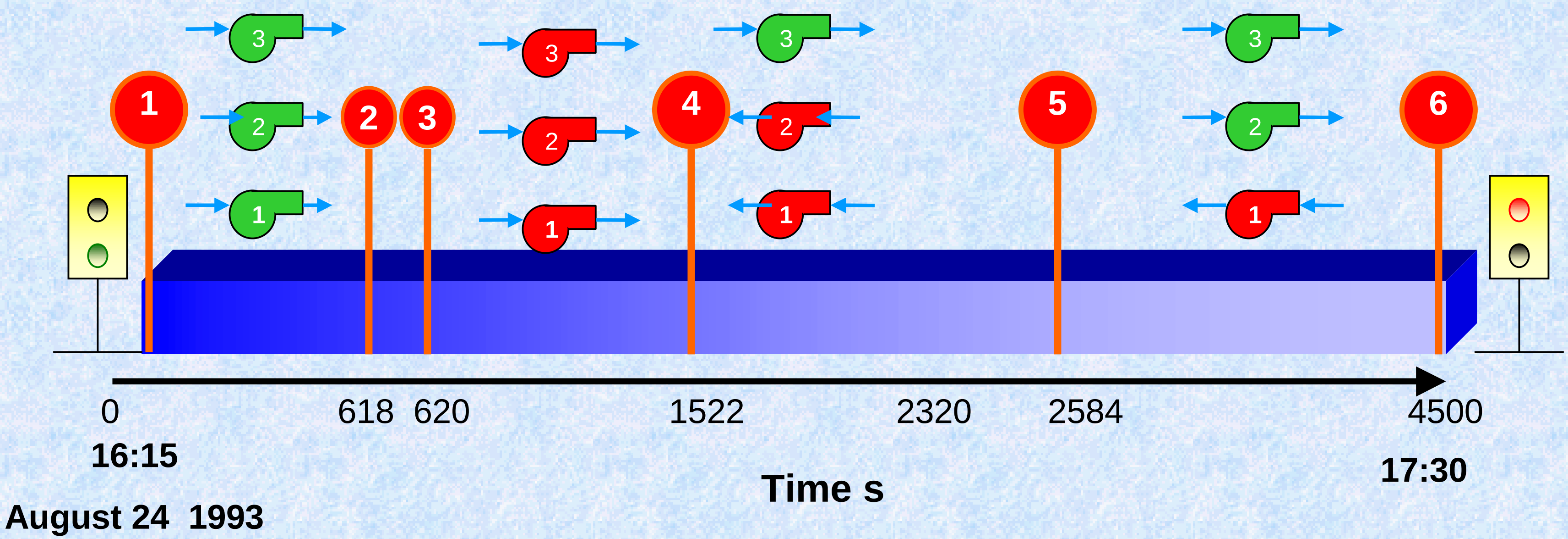
2 618” Lost of Offsite Power

3 620” Trip of the three Reactor Coolabt Pump – Trip of the Reactor and the Turbine

4 1522” RCP 3 Starts working

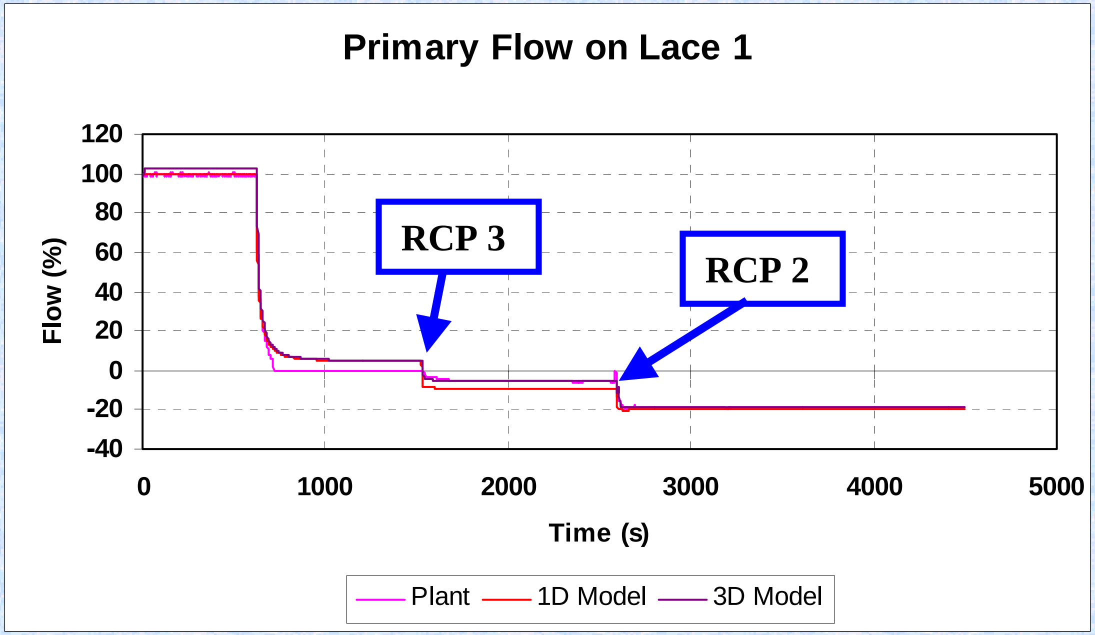
5 2584” RCP 2 Starts working

6 4500” End of data



3. Simulation of a Reactor Coolant Pump Asymmetric Transient (2/12)

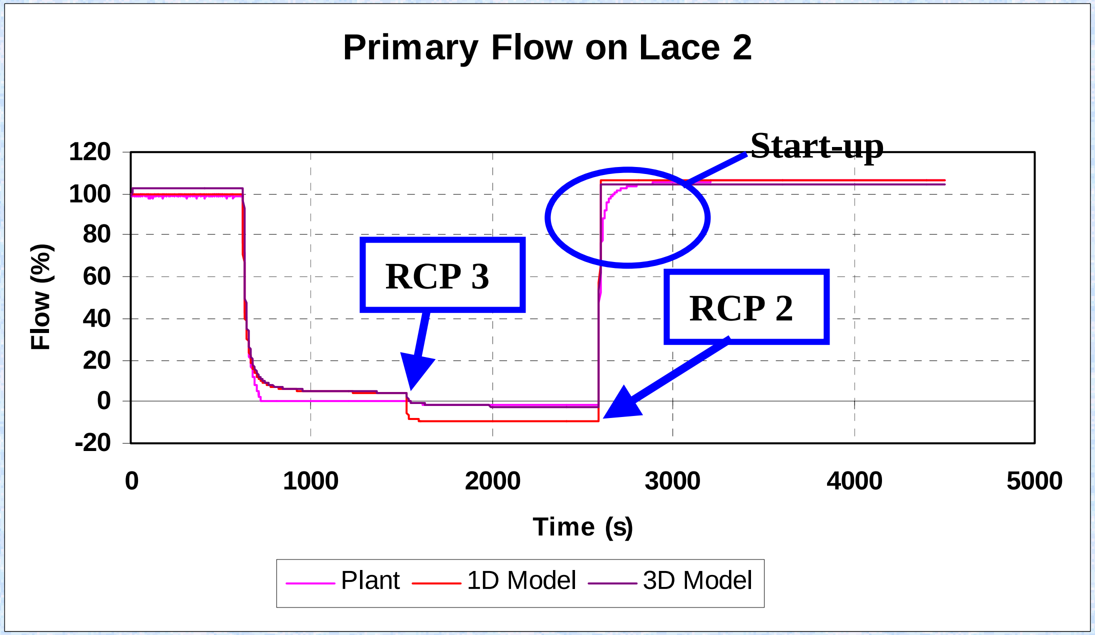
- **Comparison of Results with 1D Model and to Plant Data.**



- **Negative flows appear when pumps start working.**
- **Plant flow falls to 0 → Reason: Range of measuring instruments**
- **Similar results**

3. Simulation of a Reactor Coolant Pump Asymmetric Transient (3/12)

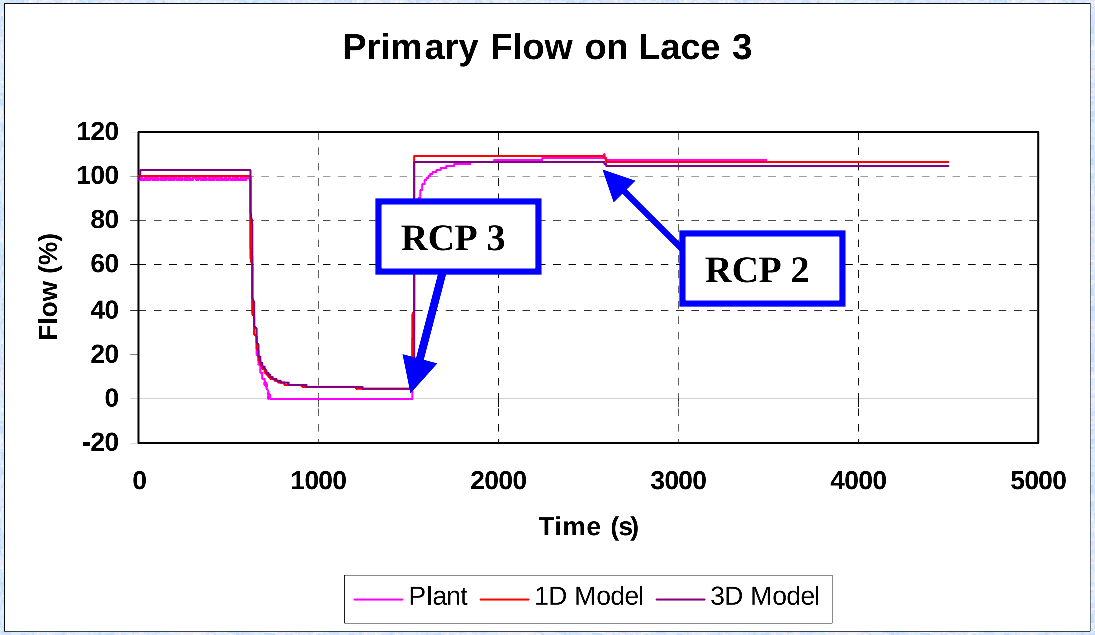
- **Comparison of results with 1D model and to plant data.**



•Start-up in models takes place instantly → Reason: Pump modeling

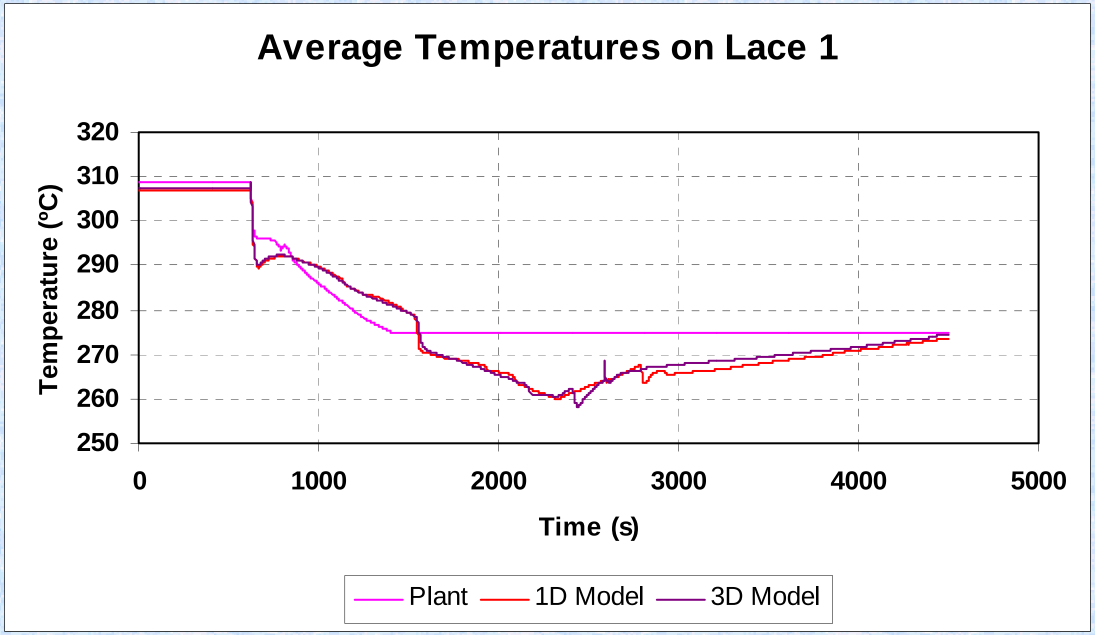
3. Simulation of a Reactor Coolant Pump Asymmetric Transient (4/12)

- **Comparison of results with 1D model and to plant data.**



3. Simulation of a Reactor Coolant Pump Asymmetric Transient (5/12)

- **Comparison of Results with 1D Model and to Plant Data.**



- **The average temperature decrease is similar in all three loops.**
- **The main differences are again due to the instruments range.**

3. Simulation of a Reactor Coolant Pump Asymmetric Transient (6/12)

- **Comparison of Results with 1D Model and to Plant Data.**

→ The results show that the new 3D TH Vessel Model, integrated in a 1D Plant Model, simulate in a correct way the temporal behaviour of the plant in this kind of transient.

3. Simulation of a Reactor Coolant Pump Asymmetric Transient (7/12)

- **Detailed study of asymmetic flows inside the vessel**

→ **The short term objective of developping the 3D vessel model and the simulation of this transient: investigate multidimensional flows appearing on the vessel.**

→ **Study all components with potential multidimensional flows.**

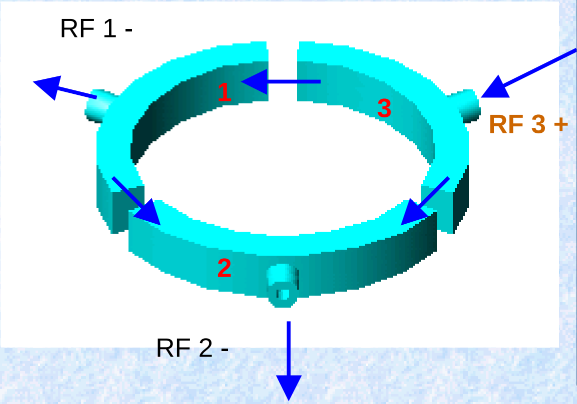
- **Downcommer**
- **Lower Plenum**
- **Core Entrance**
- **Core**
- **Core Exit**

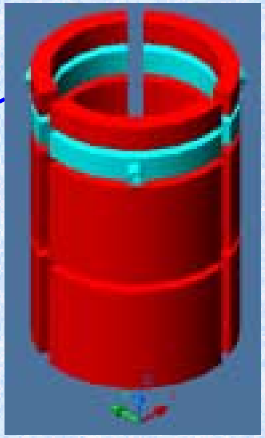
3. Simulation of a Reactor Coolant Pump Asymmetric Transient (8/12)

- **Detailed study of asymmetic flows inside the Vessel – Downcommer**

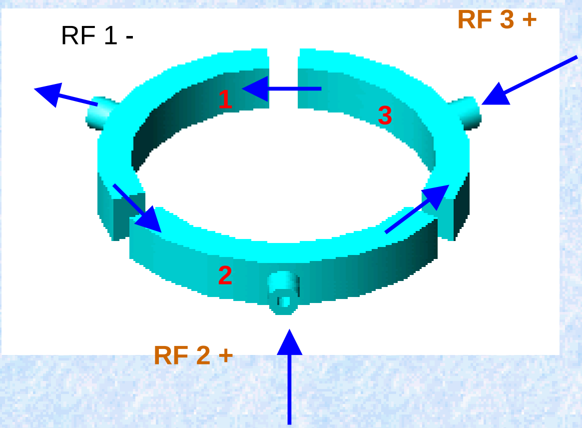
  - **The flow distribution at the downcommer entrance appears reasonable.**

Only Pump 3 Working



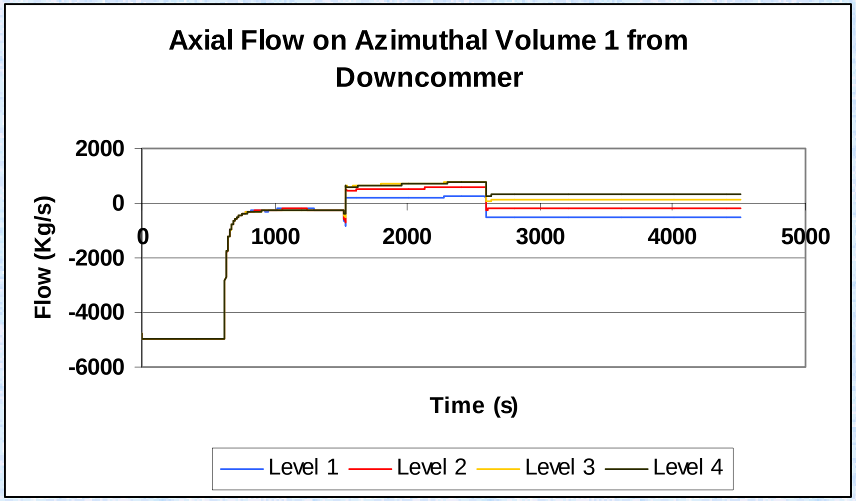


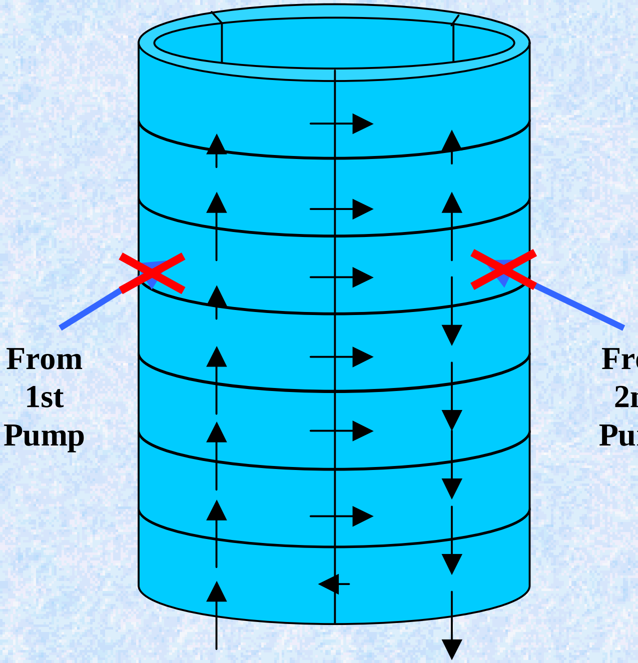
Only Pump 2 and 3 Working



3. Simulation of a Reactor Coolant Pump Asymmetric Transient (9/12)

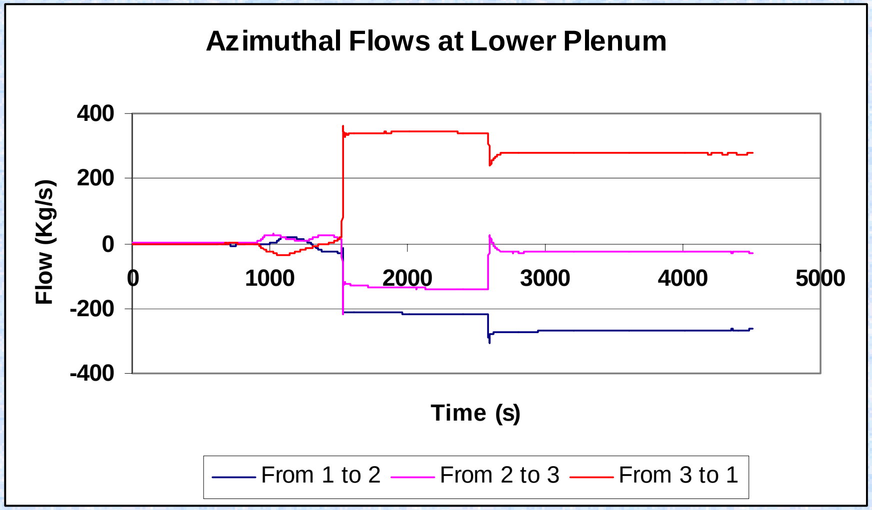
- **Detailed study of asymmetic flows inside the Vessel – Downcommer**
  - **Appearing of up-comming axial flows**





3. Simulation of a Reactor Coolant Pump Asymmetric Transient (10/12)

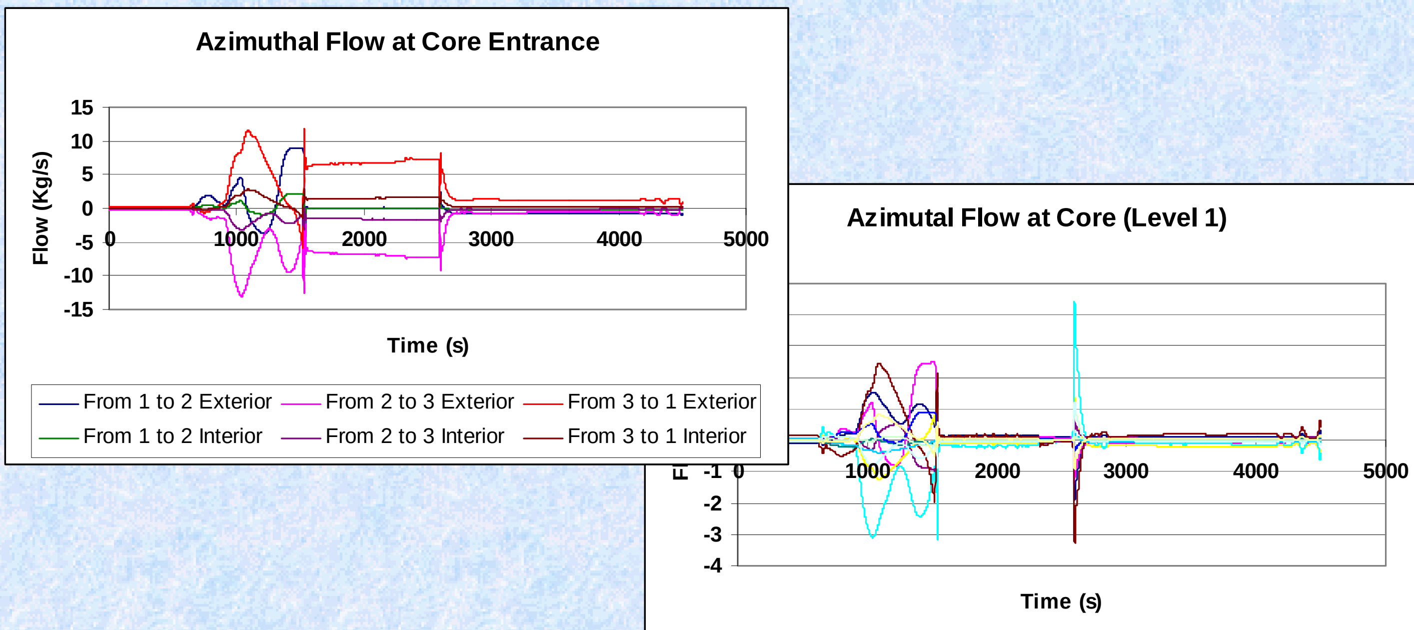
- **Detailed study of asymmetic flows inside the Vessel – Lower Plenum**
  - **Appearing of Azimutal Flows at Lower Plenum.**



  - **These flows need to be lowered before entering the core to assure proper cooling.**

3. Simulation of a Reactor Coolant Pump Asymmetric Transient (11/12)

- **Detailed study of asymmetic flows inside the Vessel – Lower Plenum – Core Entrance – Core**
  - **The Lower plenum and the Core entrance work to correct those azimutal flows.**



3. Simulation of a Reactor Coolant Pump Asymmetric Transient (12/12)

- **Chapter Conclusions**

Asymmetric Flows appearing in this kind of transient are corrected at the Lower plenum and at the Core entrance before entering the core, assuring proper cooling of the core.

Therefore, the Lower Plenum and the Core Entrance play a very important role in this kind of asymmetric flow transients from safety standpoint.

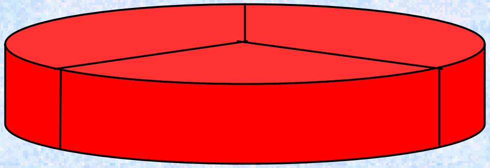
This is consistent with Lower Plenum design criteria.

4. Current Works. Developping of a detailed Lower Plenum.

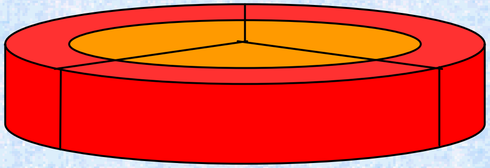
- Next short term objective → Simulation of thermal asymmetric transients in order to study asymmetric thermal phenomena inside the vessel.
- Design data show the importance of the Lower Plenum in flow mixing and thermal stabilisation → Works towards a detailed modelisation of the Lower Plenum.
- To test the Lower Plenum in this kind of thermal asymmetric transients a MSLB will be simulated.
- Study of the temperature distribution inside the core.

4. Current Works. Developping of a detailed Lower Plenum.

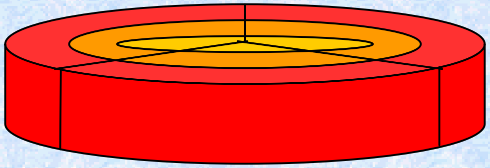
- Current Lower Plenum Model: 3 azimuthal sectors, 1 radial sector



- 3x2 Lower Plenum Model 1: 3 azimuthal sectors, 2 radial sectors

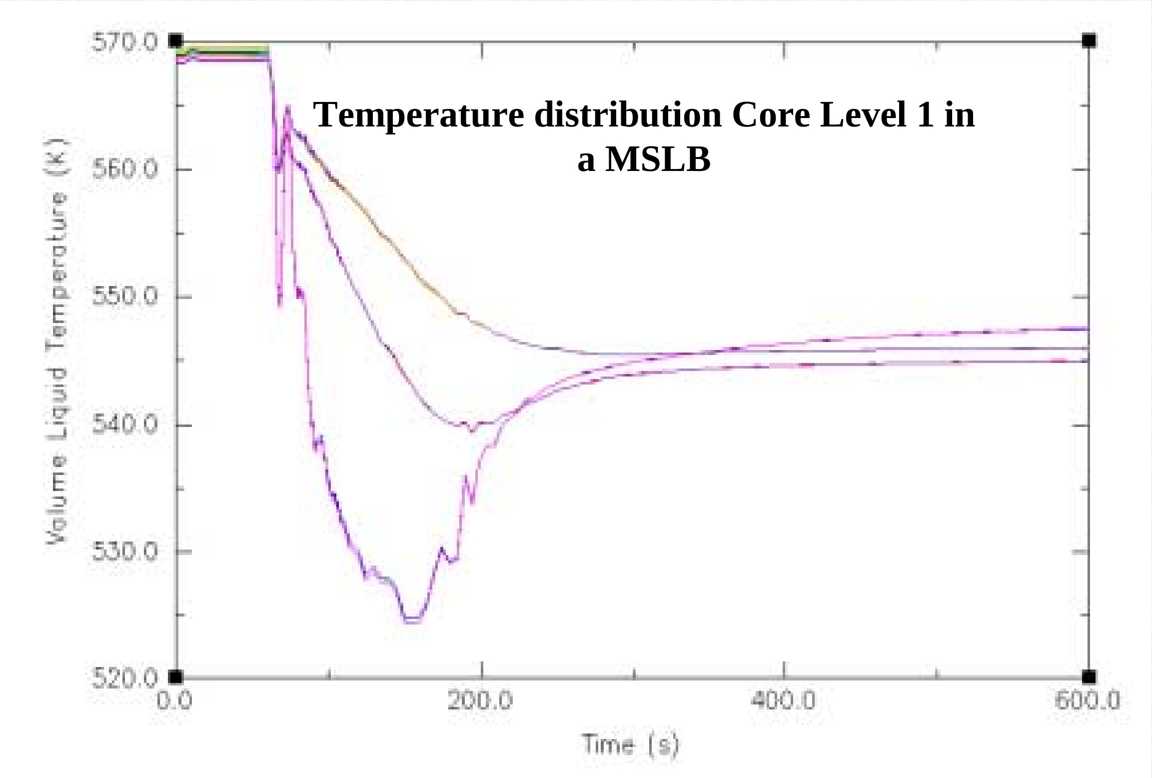


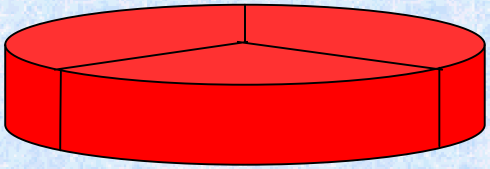
- 3x3 Lower Plenum Model 2: 3 azimuthal sectors, 3 radial sectors



4. Current Works. Developping of a detailed Lower Plenum.

- Current Lower Plenum Model: 3 Azimuthal sector, 1 Radial Sector.

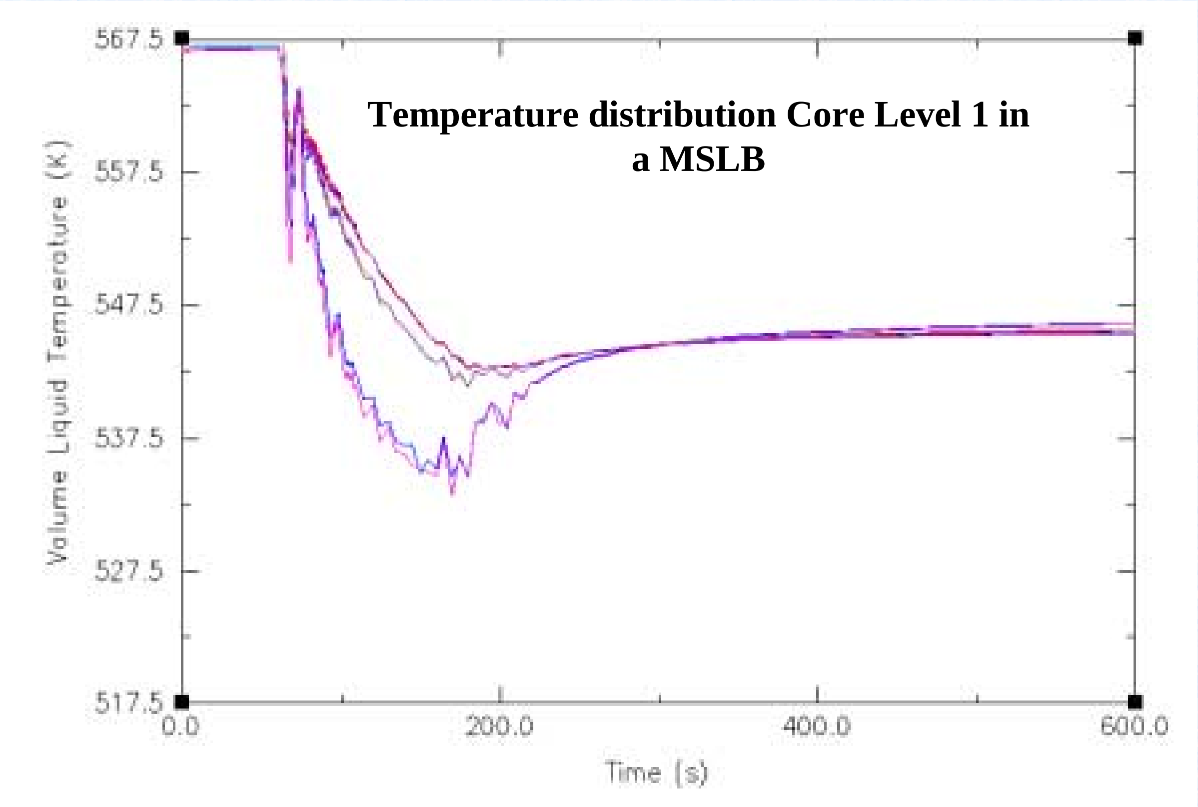


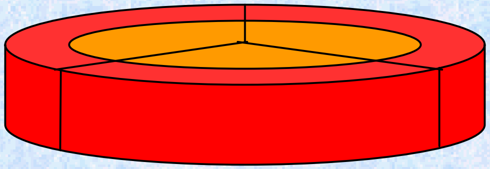


- Three different channels are appreciated, therefore, the mixing should be improved.

4. Current Works. Developping of a detailed Lower Plenum.

- 3x2 Lower Plenum Model 1: 3 Azimuthal sector, 2 Radial Sectors.

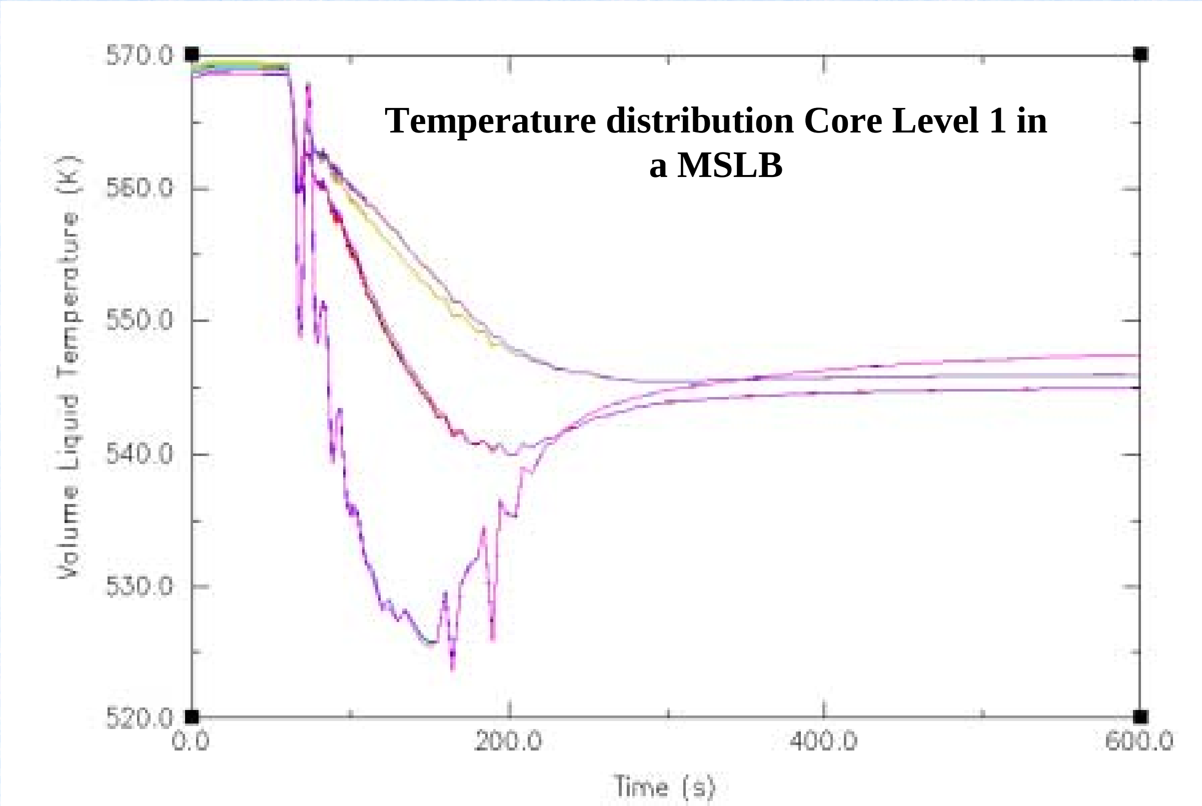


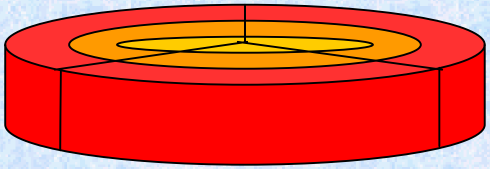


- The flow from the downcommer enters the Lower Plenum through its outer radial sector and exits towards the core entrance through its inner radial sector. → This way, radial mixing flows are assured.

4. Current Works. Developping of a detailed Lower Plenum.

- 3x3 Lower Plenum Model 2: 3 Azimuthal sector, 3 Radial Sector





- In the same way as the previous Lower Plenum Model, radial mixing flows appear. Azimuthal mixing flows were also expected in this model in order to improve the mixing, but the results were not as expected.

4. Current Works. Developping of a detailed Lower Plenum.

- As seen, the way of having a proper mixing is to have radial and azimuthal flows that appear in this kind of transients.
- The importance of a proper nodalisation of the Lower Plenum has been revealed.
- Future works will try to establish, through proper nodalisation, fully mixing flows in the Lower Plenum in order to assure the proper simulation of its design function.

5. Conclusions.

- The new 3D Model simulates correctly the temporal behaviour of the plant.
- In addition, the new 3D Model allows the study of asymmetric phenomena taking place inside the vessel, phenomena that previous models could not reveal.
- An asymmetric hidrodynamic transient has been simulated with satisfactory results. The first short term objective has been successfully reached.
- In the study of the second short term objective (thermal transients), the importance of the Lower Plenum has been revealed, showing the need of a proper nodalization of this component.