Contribution to Large Break LOCA analysis for commercial NPP using RELAP5-3D

Francesc Reventós, Lluís Batet, Carme Pretel, Marina Pérez

TECHNICAL UNIVERSITY OF CATALONIA - UPC

1. Introduction
    1. BEMUSE project
    2. Goals of this study
2. 1D and 3D nodalizations
3. Steady-state
4. Transient
    1. Blowdown peak
    2. Core quenching
5. Conclusions

1. INTRODUCTION

The results presented are part the activities carried out at UPC in order to consolidate RELAP5-3D models of commercial PWR for safety and operational analysis.

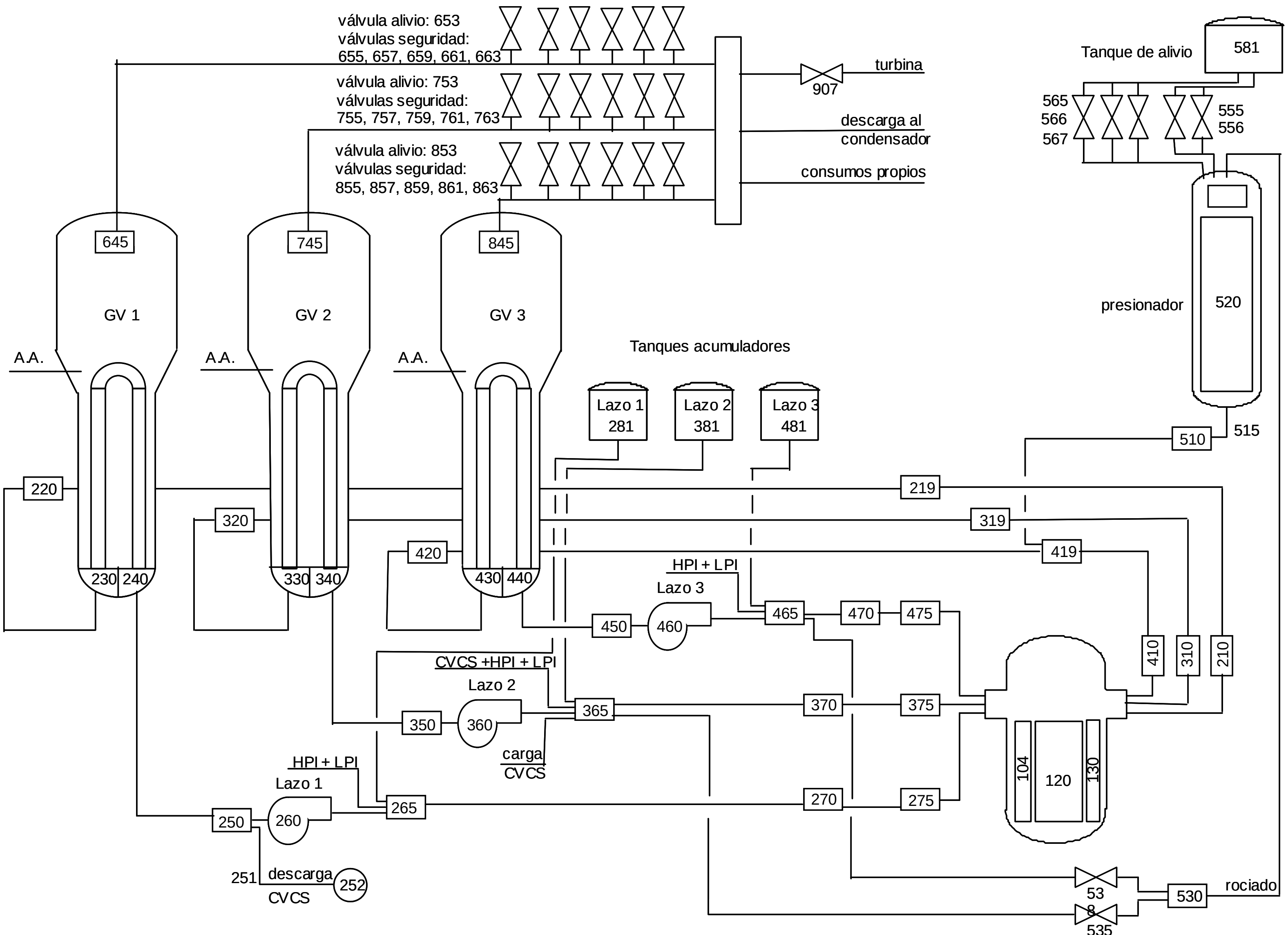
BEMUSE project aims and information:

- to advance in the use of methodologies developed in our country for uncertainty analysis of results obtained in computational simulations
- to compare them in an international framework (OECD)
- to apply them for safety analysis of Spanish NPPs
- ENUSA and CSN
- LBLOCA
- September 2003/End 2007

1.2 Goals of this study

- To perform 1D and 3D analysis of LBLOCA in commercial PWR plant
- To identify phenomena that are predicted with significantly different results
- To identify the parameters representing the above mentioned phenomena
- To quantify eventual gains in safety margins

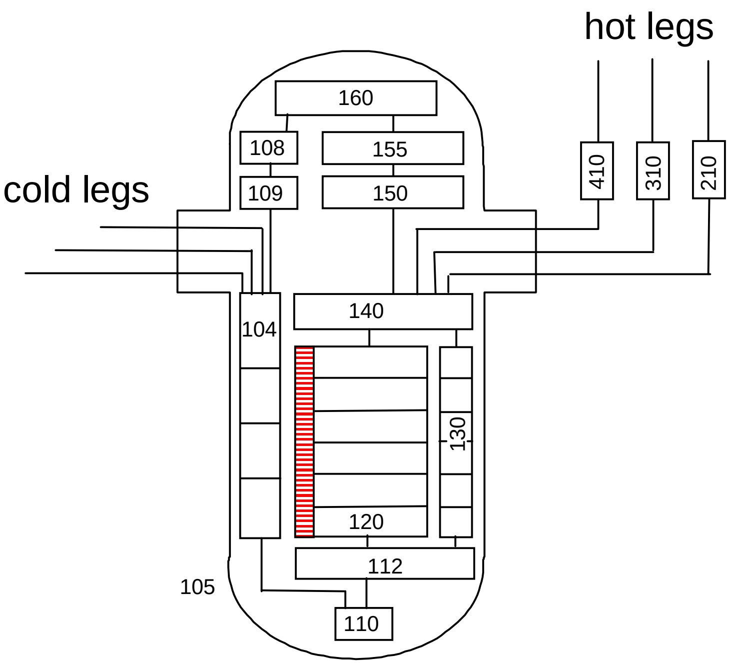
2. 1D and 3D NODALIZATIONS

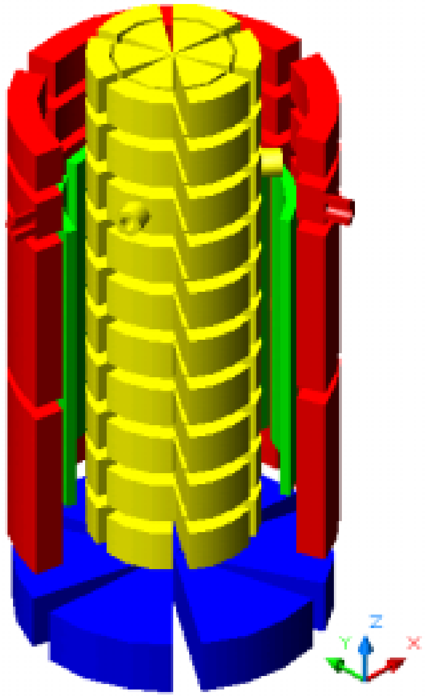


NODALIZACION GENERAL

C.N. VANDELLOS II

1D vessel	3D vessel





Balance of plant identical in both models

1D-input nodalization

The ACTIVE CORE has been modelled with:

- Hydrodynamic component:

  1 pipe (6 nodes)

- Heat structures:

  1 average rod (41447 rods)

  1 hot rod.

3D-input nodalization

HL vessel connection

CL vessel connection

The VESSEL has been modelled with:

- 3D vessel (multi dimensional elements)

The ACTIVE CORE:

- Hydrodinamic component

  multi dimensinonal element (6x6x2 nodes)

- Heat structures

  12 average rods (41444 rods)

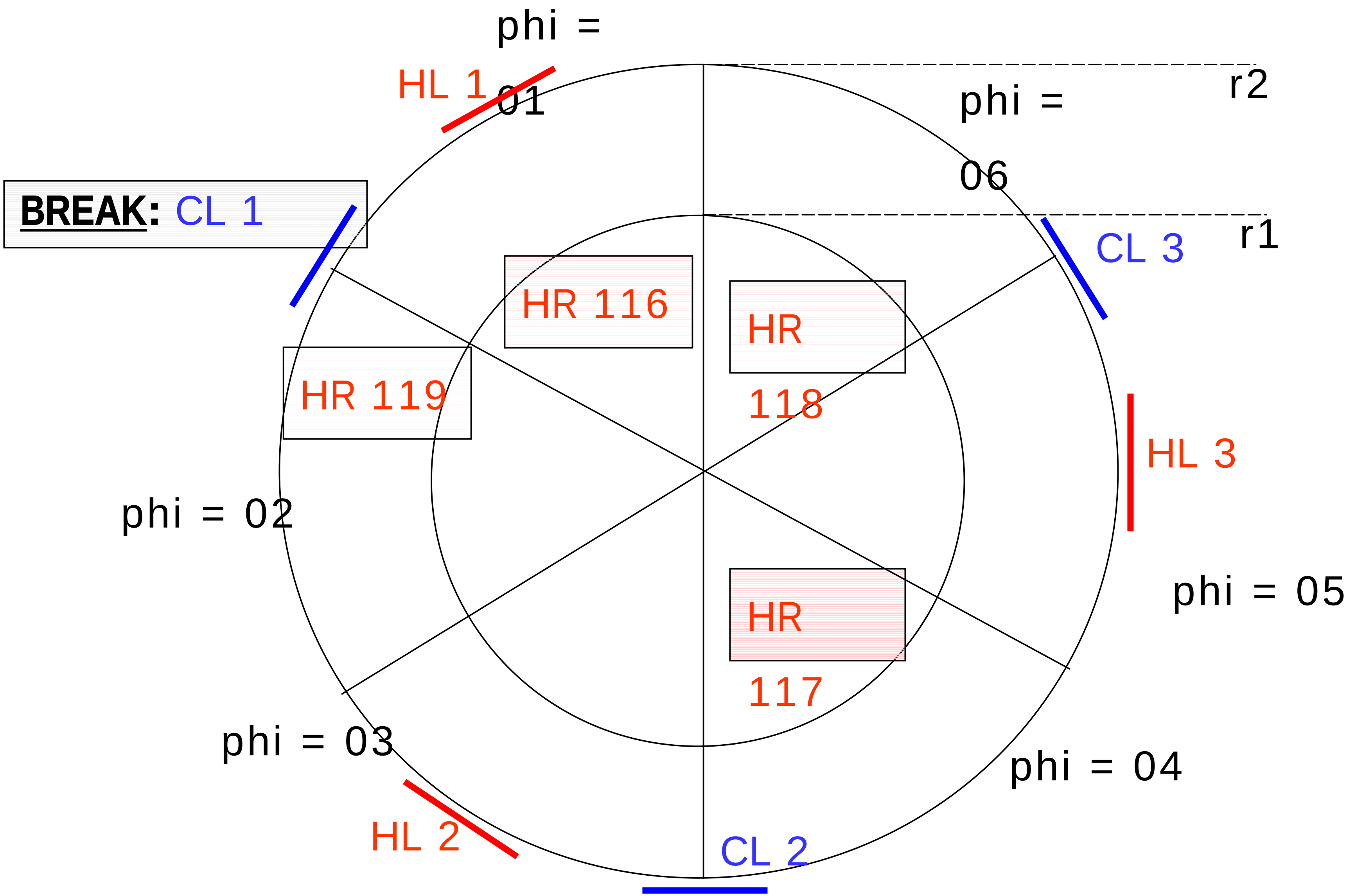
  4 hot rods

3D-input nodalization

The 4 hot rods have:

- the same radial and axial peak factor
- different location in the core

Location choice was made in agreement with the reference NPP core design.


phi = 01
HL 1
r2
phi = 06
BREAK: CL 1
r1
CL 3
HR 116
HR 118
HR 119
HL 3
phi = 02
phi = 05
HR 117
phi = 03
phi = 04
HL 2
CL 2

	1d model	3d model
Power (MW)	2942.9	2942.9
dT core (K)	35.7	35.2
HL temperature (K)	598.8	598.3
dP core (kPa)	312.	291.
Primary pressure (MPa)	15.5	15.5
Primary mass flow (kg/s)	4765.	4842.
RCP velocity (rad/s)	154.8	154.8
Max cladding temperature (K)	626.	626.7

Large Break Cold Leg LOCA

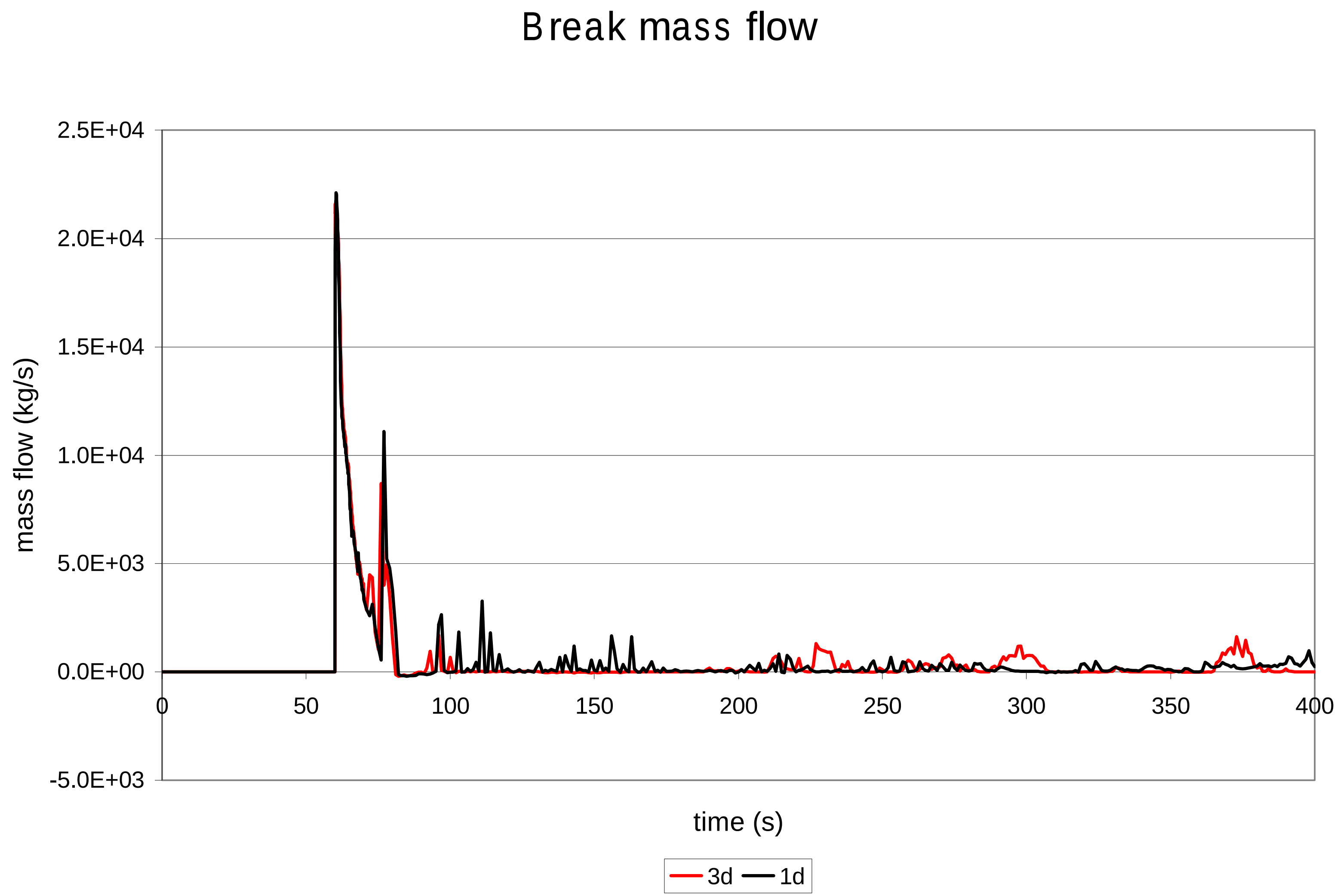
Boundary conditions used in both cases are the same

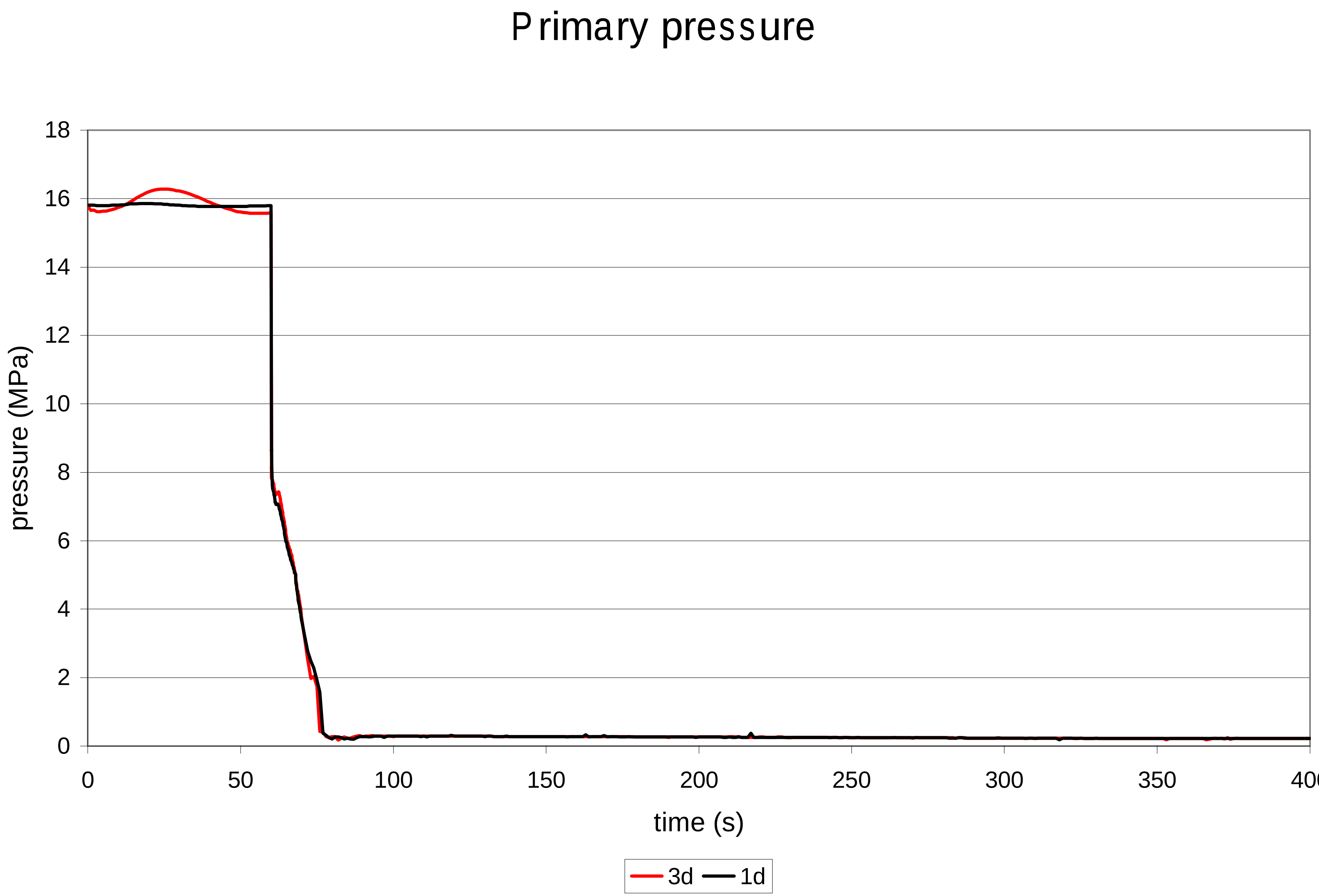
Nodalization features:

The break is modeled with two TRIP VALVES, each of them connected to a time dependent volume simulating the containment

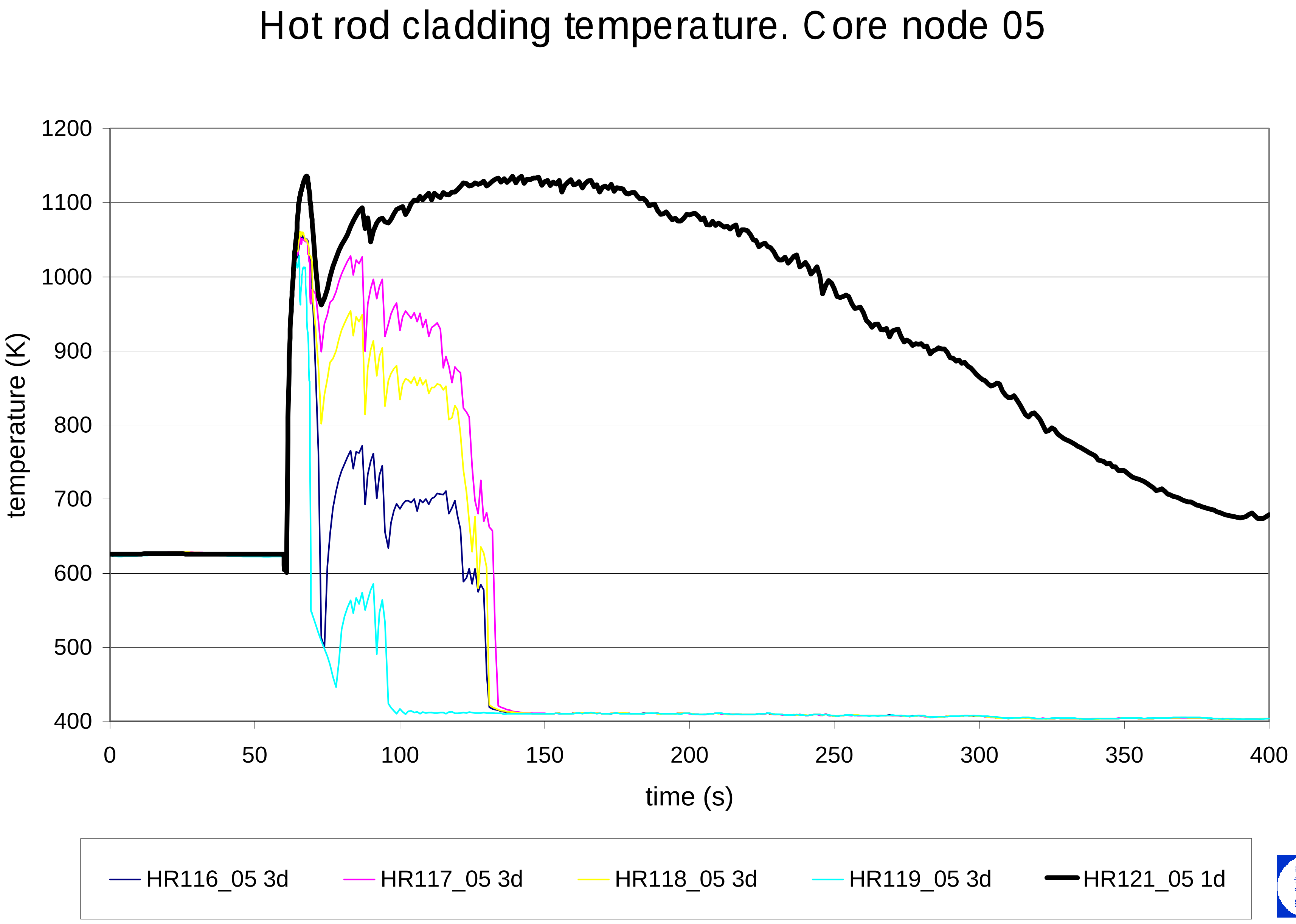
Boundary conditions:

- RCPs stop 50 seconds after break
- The containment pressure follows a standard table


Break mass flow
2.5E+04
2.0E+04
1.5E+04
1.0E+04
5.0E+03
0.0E+00
-5.0E+03
mass flow (kg/s)
0
50
100
150
200
250
300
350
400
time (s)
3d
1d



The predictions made in both cases are reasonably
similar


Hot rod cladding temperature. Core node 05
1200
1100
1000
900
800
700
600
500
400
temperature (K)
0
50
100
150
200
250
300
350
400
time (s)
HR116_05 3d
HR117_05 3d
HR118_05 3d
HR119_05 3d
HR121_05 1d

The main differences between the two calculations regarding the maximum cladding temperature are:

- Blowdown peak height:

  higher in the 1d nodalization case

- Core quenching time:

  much larger in the 1d nodalization case

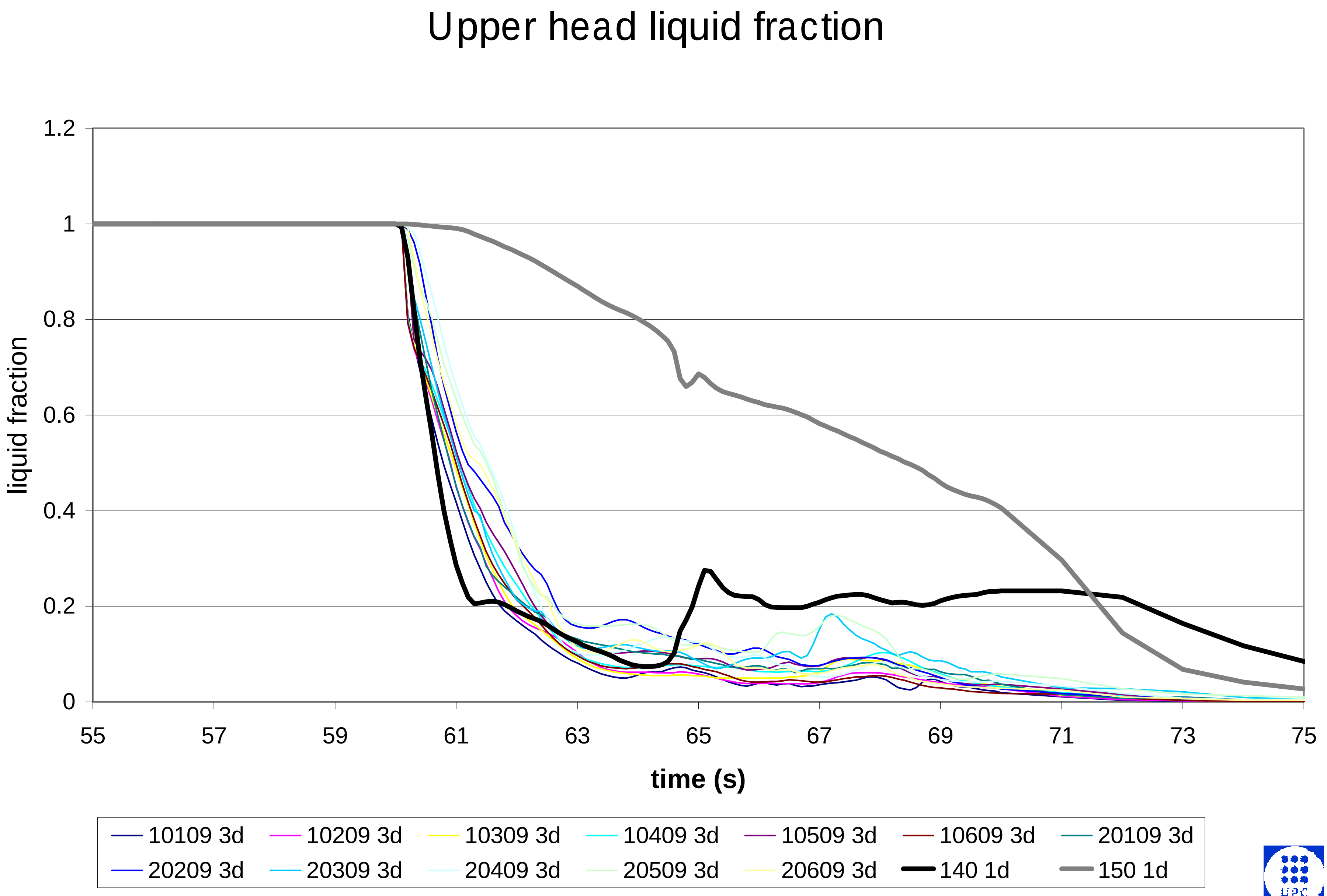
4.1 Blowdown peak

Possible reasons of the differences between the two cases:

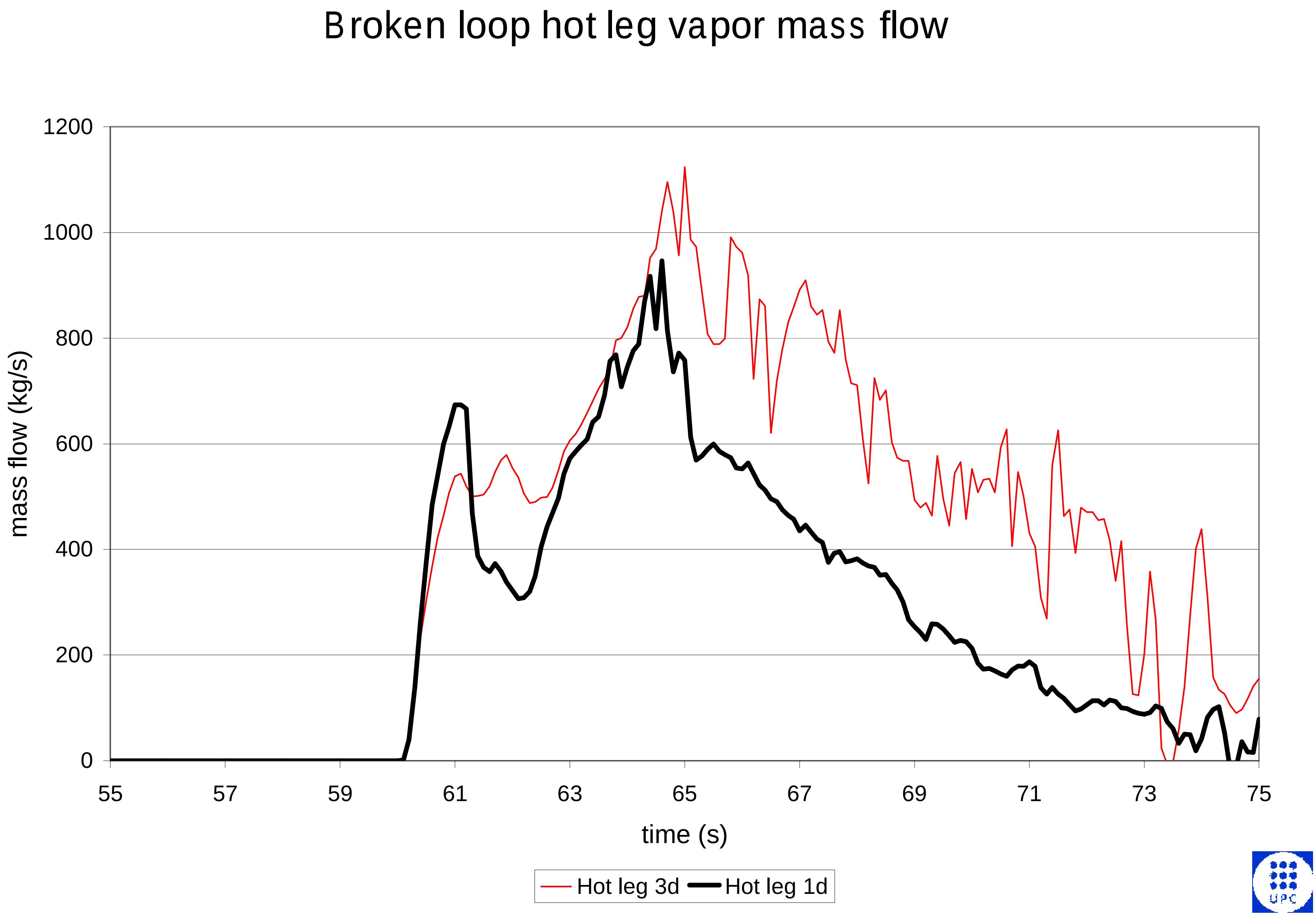
a. Short term core steam evacuation

b. Radial and azimutal coolant velocities in the core

4.1 Blowdown peak



4.1 Blowdown peak



4.1 Blowdown peak

a. Short term core steam evacuation

In the 1D case the liquid fraction in the upper head is greater than in the 3D case for the considered period of time (first 15 sec.). Due to this fact the steam evacuation from the core to the hot legs becomes more difficult than in 3D case.

Only the broken loop hot leg is affected by this phenomenon.

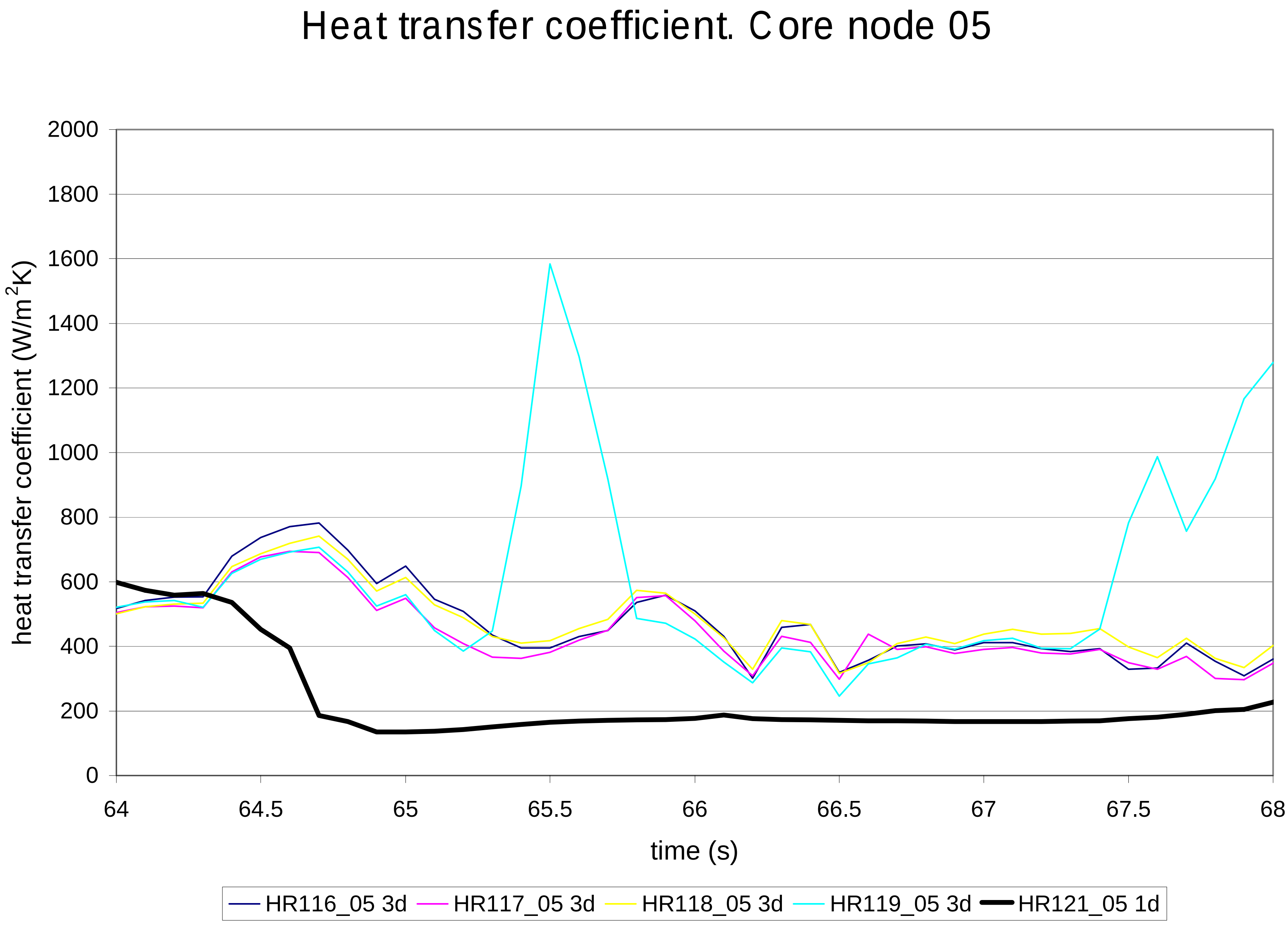
4.1 Blowdown peak

Possible reasons of the differences between the two cases:

a. Short term core steam evacuation.

b. Radial and azimutal coolant velocities in the core.

4.1 Blowdown peak

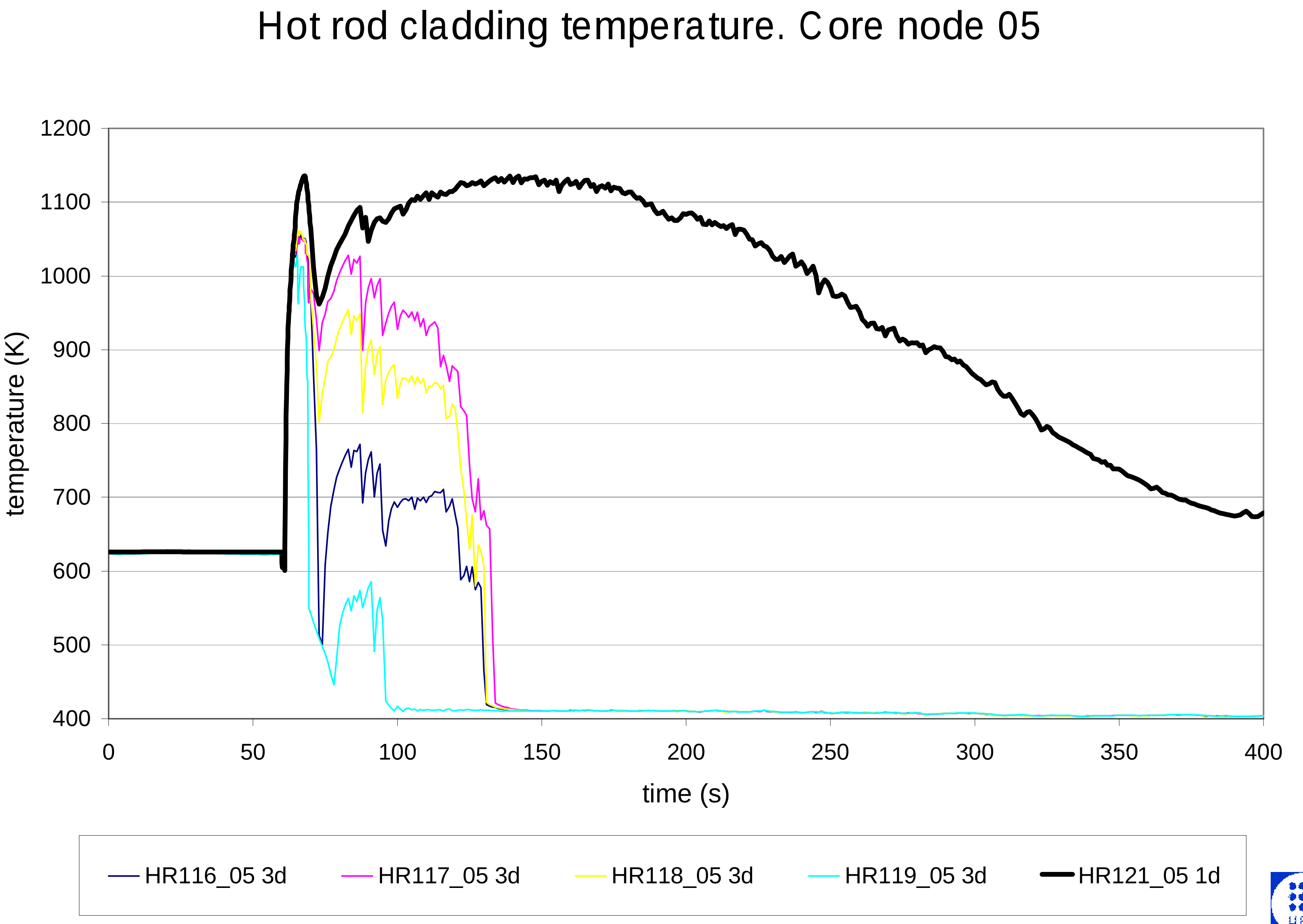


4.1 Blowdown peak

b. Radial and azimutal coolant velocities in the core

The existence of flows in the radial and azimutal direction can only be modelled by the 3D nodalization.

The existence of such flows improve the heat transfer and therefore the core cooling.

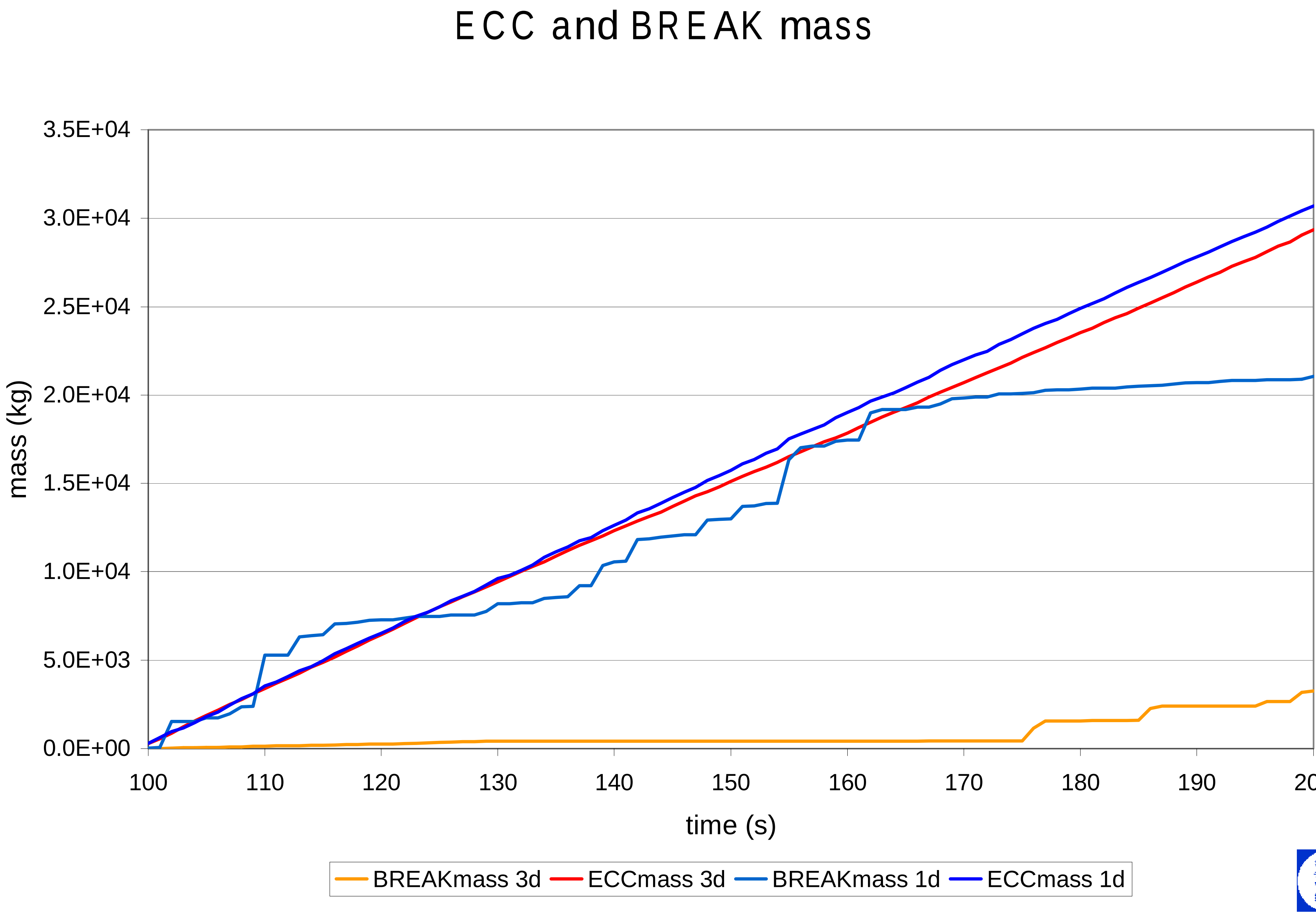

Hot rod cladding temperature. Core node 05
1200
1100
1000
900
800
700
600
500
400
temperature (K)
0
50
100
150
200
250
300
350
400
time (s)
HR116_05 3d
HR117_05 3d
HR118_05 3d
HR119_05 3d
HR121_05 1d

The differences between the two sets of results can be explained by taking into account:

a. Downcomer nodalization

b. Flow pattern in the core

4.2 Core quenching



a. Downcomer nodalization

The 1D downcomer does not permit the ECC injection water to get into the core: the water injection flows quite directly towards the break due to the differencial pressure conditions.

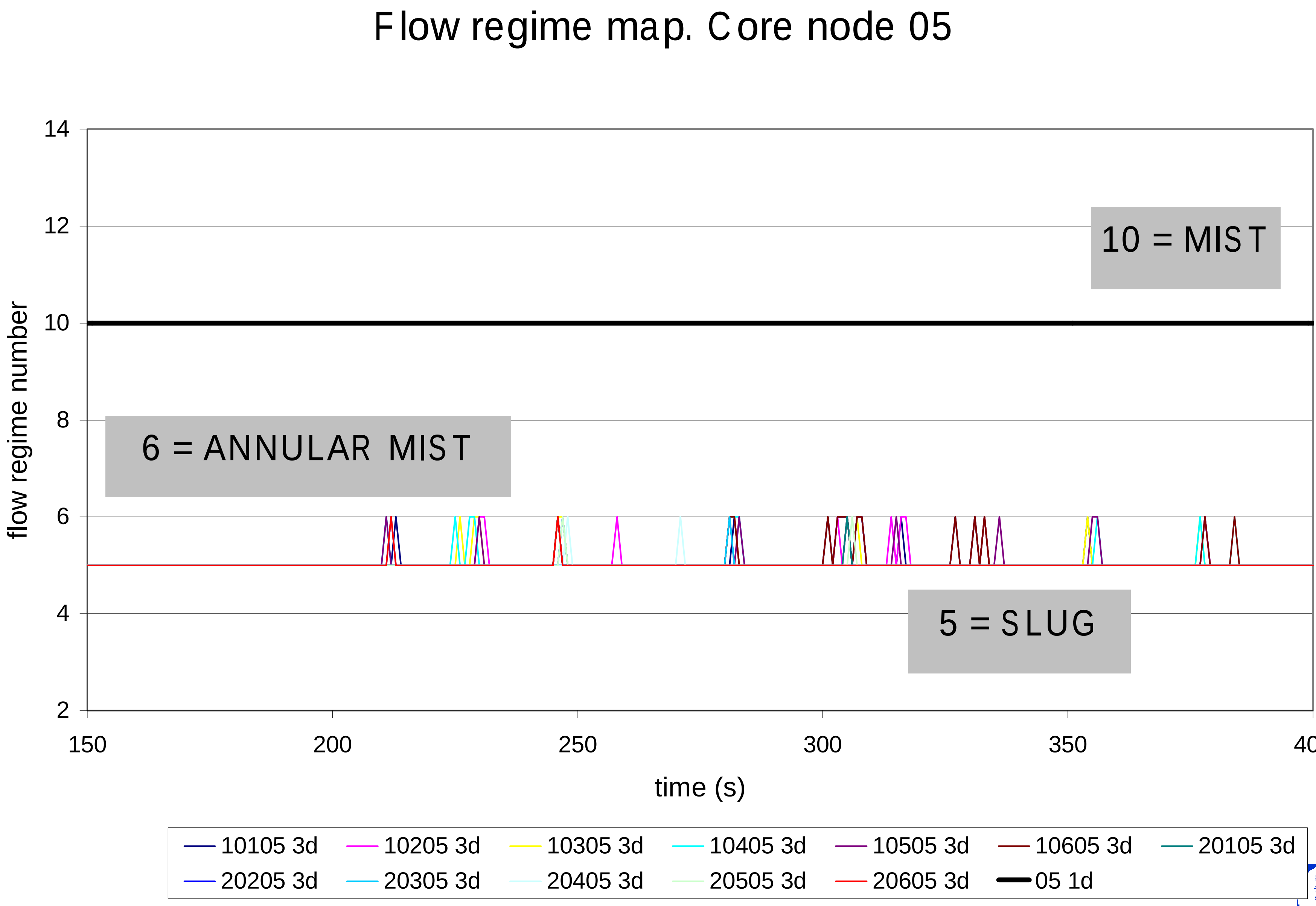
In the 3D case this problem is solved as the downcomer is nodalized with a multi dimensional element which allows the water injected to get into the core.

The differences between the two sets of results can be explained by taking into account:

a. Downcomer nodalization

b. Flow pattern in the core

4.2 Core quenching

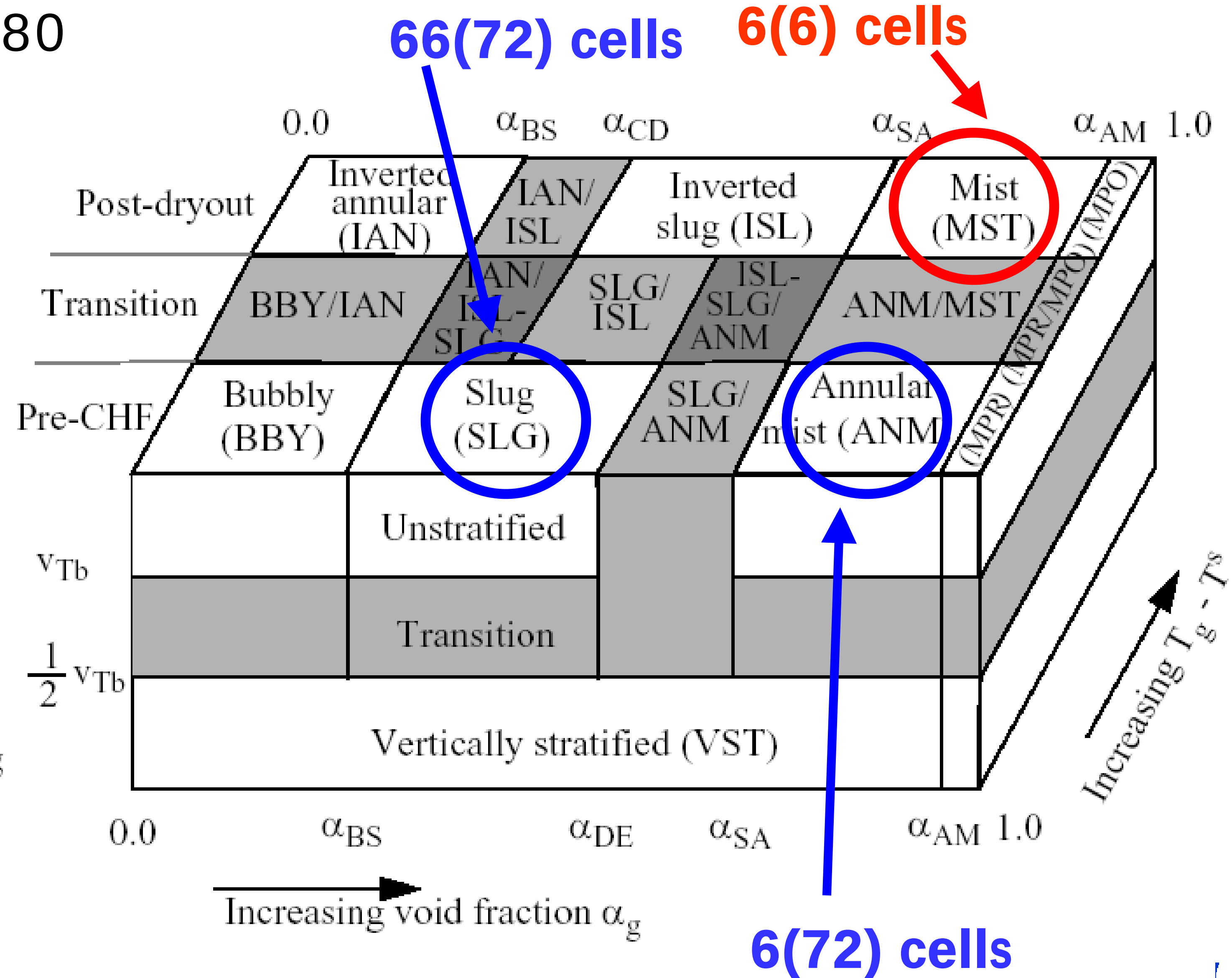


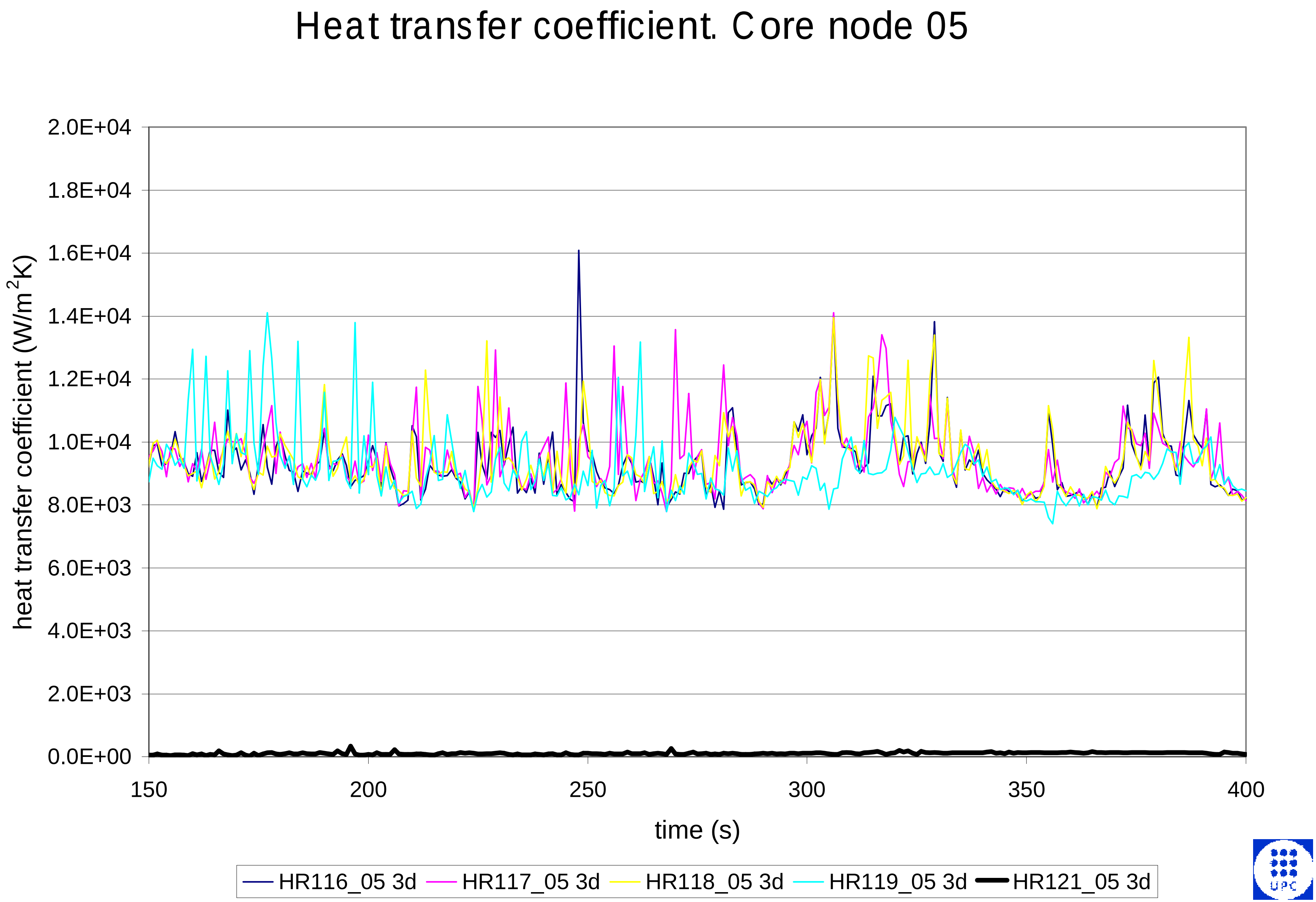
4.2 Core quenching

time = 280 seconds

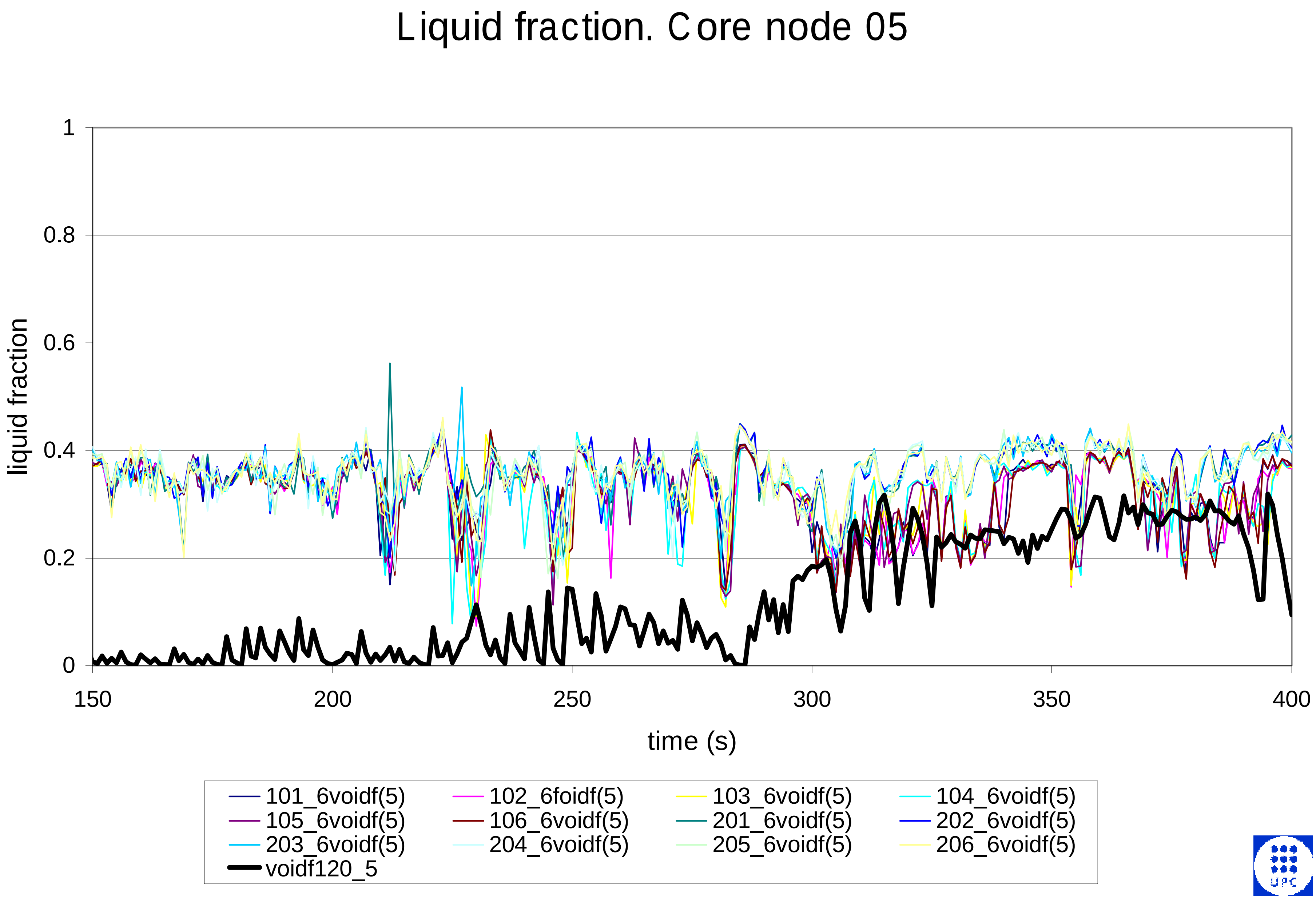
3D

1D




Heat transfer coefficient. Core node 05
heat transfer coefficient (W/m2K)
2.0E+04
1.8E+04
1.6E+04
1.4E+04
1.2E+04
1.0E+04
8.0E+03
6.0E+03
4.0E+03
2.0E+03
0.0E+00
150
200
250
300
350
400
time (s)
HR116_05 3d
HR117_05 3d
HR118_05 3d
HR119_05 3d
HR121_05 3d

4.2 Core quenching



4.2 TRANSIENT: Core quenching

b. Flow pattern

Due to downcomer by-pass, the core region stays in the mist flow pattern in the 1D calculation whereas in 3D other less degradated flow patterns are predicted.

5. CONCLUSIONS

The differences between the results of the 1D and 3D calculations when simulating a LB-LOCA scenario have been identified and analyzed successfully:

-3d nodalization allows the simulation of radial and azimutal flow velocities which are important when predicting the blowdown peak height.

-3d downcomer nodalization appears to be of great rellevance when predicting the core quenching time.

5. CONCLUSIONS

The detail (number of nodes, number and location of hot rods...) of the implemented nodalization is suitable for the discussion of most relevant phenomena.

The 3D calculations point towards a margin recovery regarding peak cladding temperature evaluation in a Large Break LOCA scenario (70º K).

The results of this study are a good starting point for UPC's participation in the last phase of BEMUSE OECD project