Generic Containment Benchmark

Comparing results starting from an identical problem description

Marco Sangiorgi - ENEA

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Introduction

- The following results are extracted form a SARNET project
- SARNET: A Network Of Excellence Federating European Research On Core Meltdown Reactor Accidents
- The SARNET network has been set up under the aegis of the Framework Programmes (FP) of the European Commission on research. Two projects have been defined, both coordinated by IRSN (France), in the FP6 (2004-08) and FP7 (2009-13)

Purpose

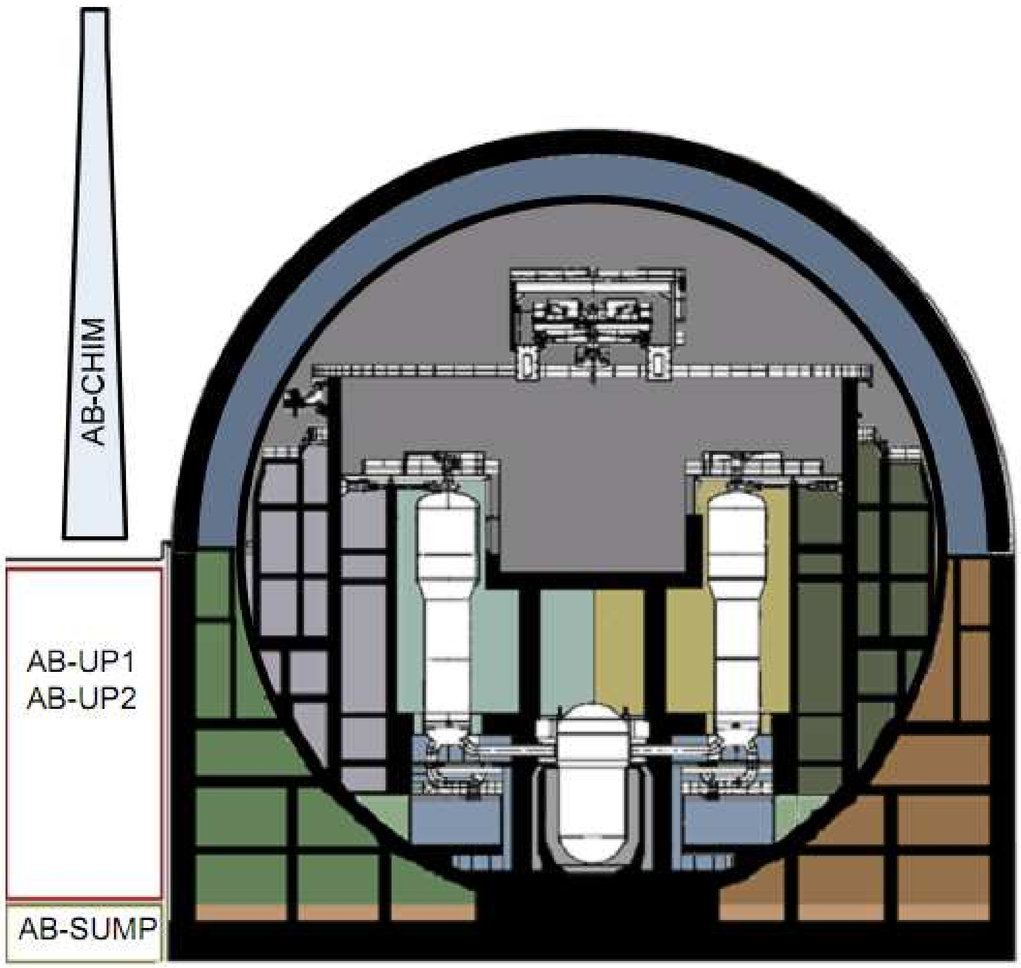
- One outcome of the ISP-47 activity was the recommendation to elaborate a generic containment including all important components.
- A generic containment description was created to help rating analyses being performed with different lumped parameter models
- MELCOR was one of the codes used in the benchmark

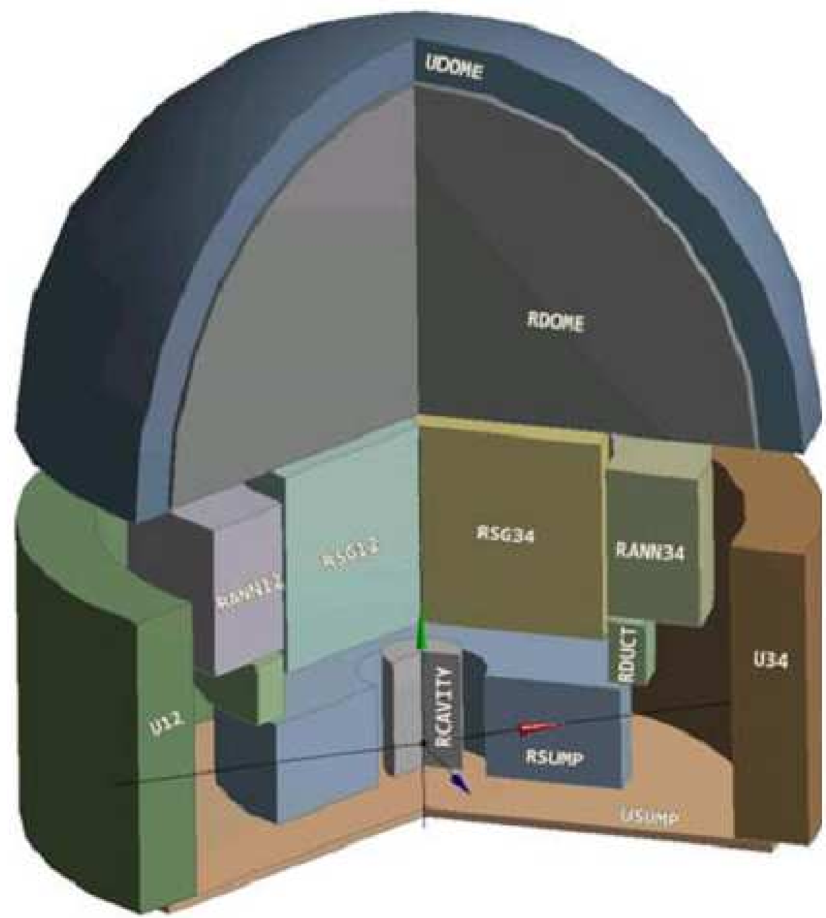
Participants

- Codes used in the benchmark are: MELCOR, GOTHIC, GASFLOW, ASTEC, COCOSYS, CONTAIN, ECART, APROS
- MELCOR users are: Pisa University (IT), RSE (IT), NRG (NL), VUJE (SK), UJV (CZ), ENEA (IT)
- MELCOR versions are 1.8.6 and 2.1

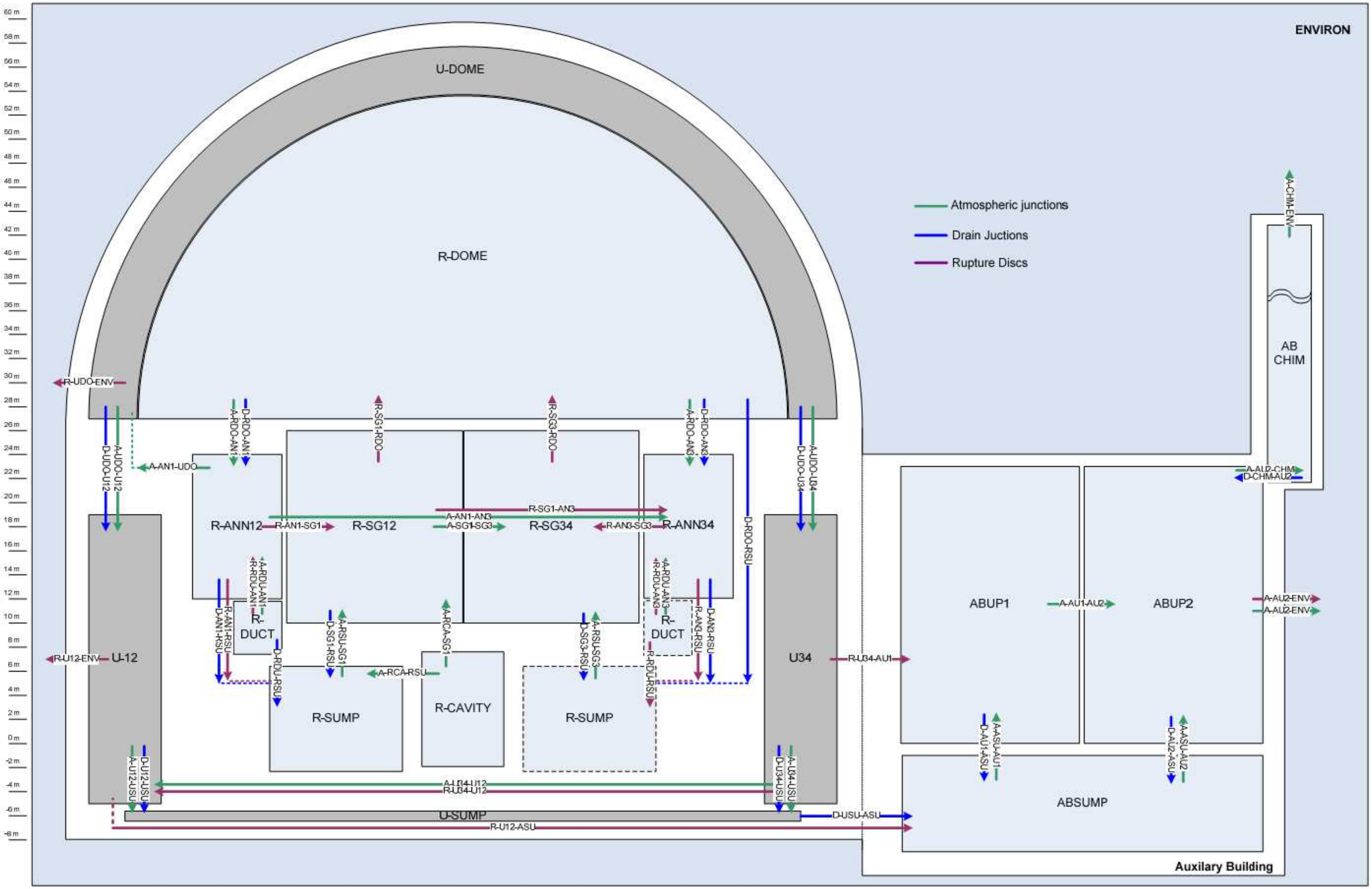
Specifications

The general specification and nodalization has been built on the basis of a German PWR with 1300 MW_{el}





Nodalization

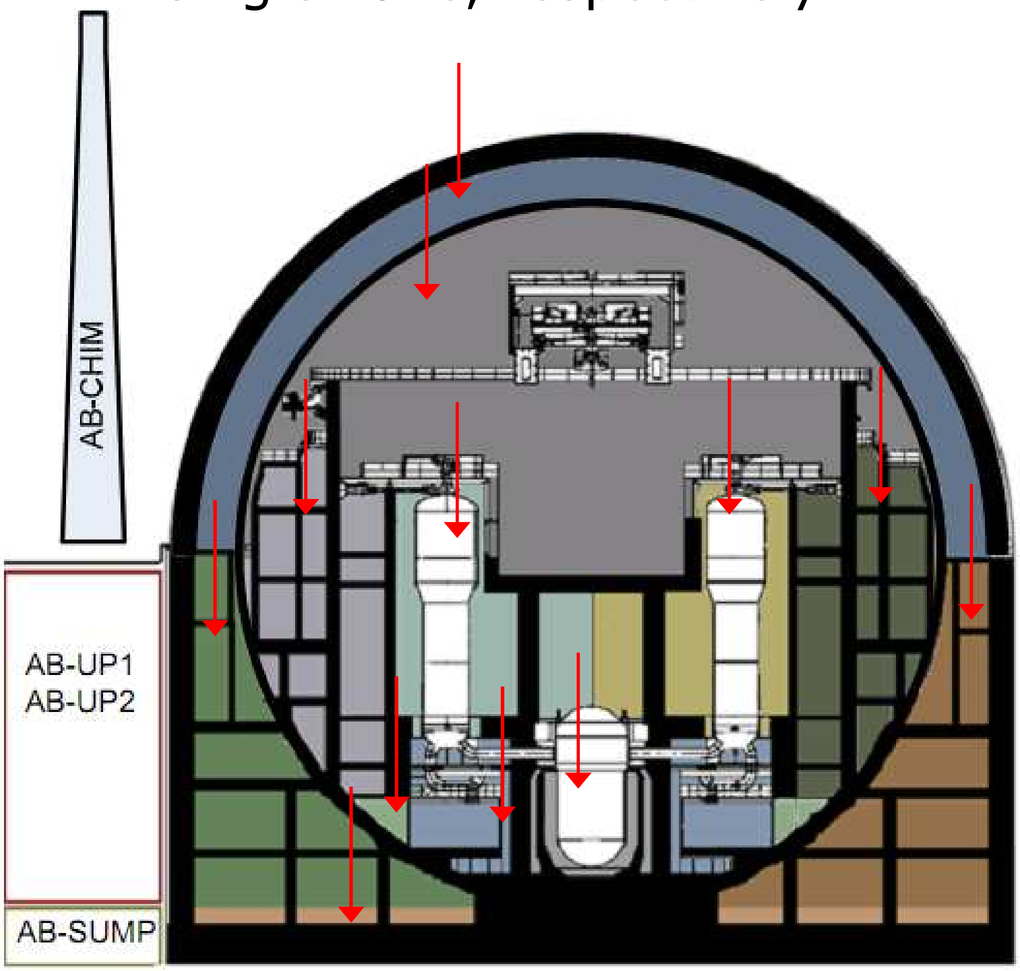


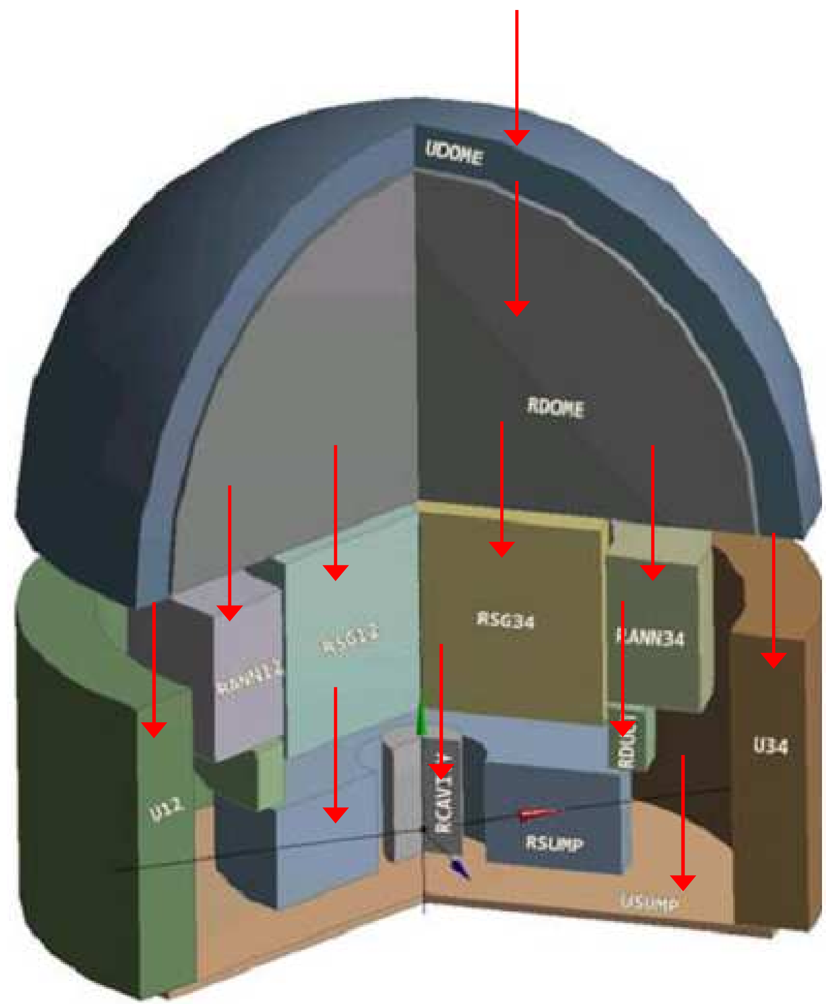
Nodalization

- 16 control volumes
- 2 steam generators zones
- 2 annular inside-the-shield compartments
- 2 annular safeguards compartments
- common dome and sump zones inside-the-shield
- common dome and sump zones in the safeguards
- reactor cavity and pipe ducts represented by means of a single zone, respectively
- there is a connection to the lower nuclear auxiliary building sump
- Gas can distribute within two auxiliary compartments, leak or be vented by the exhaust chimney

Nodalization

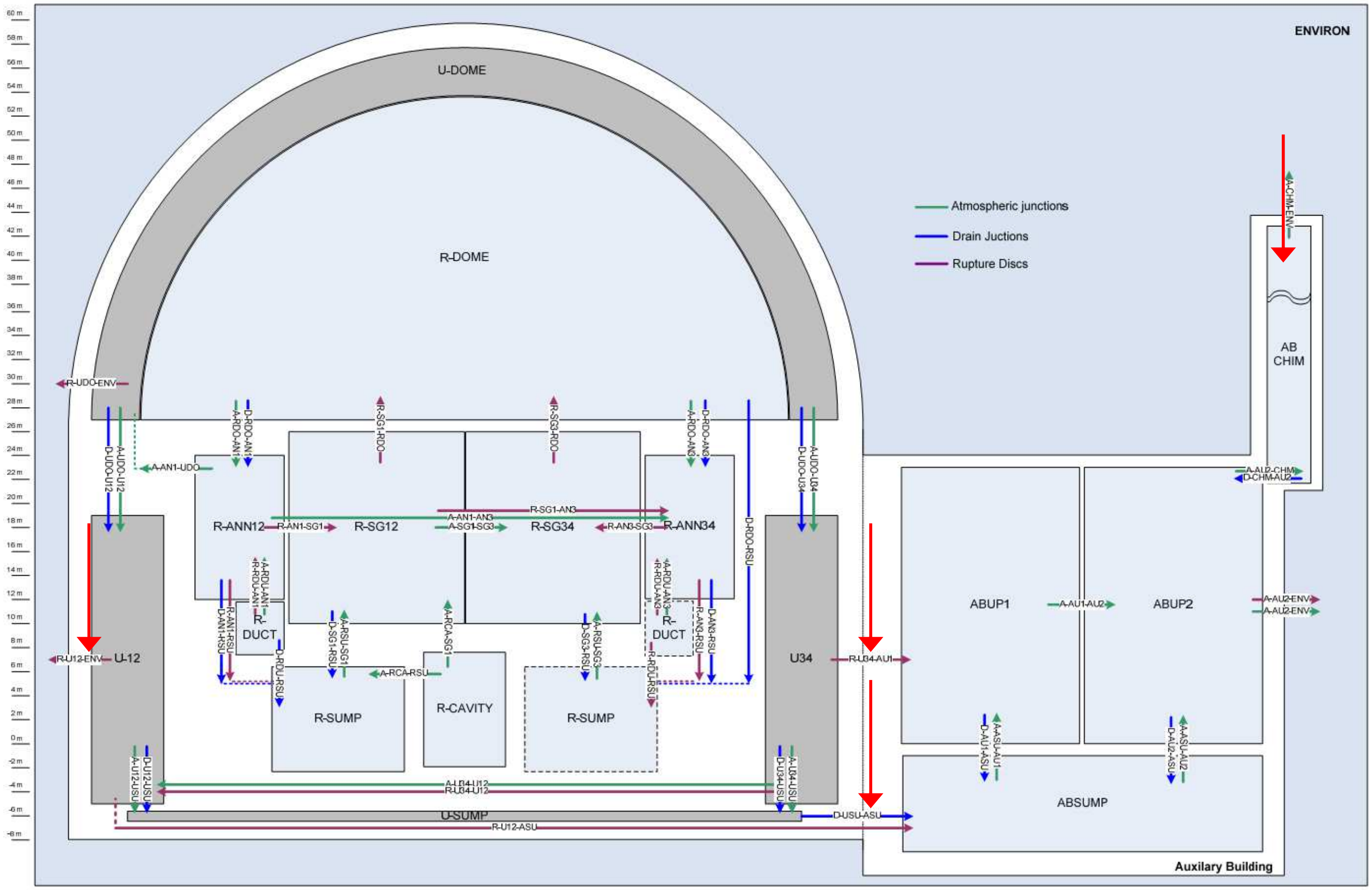
- [illegible] ns of a single zone, respectively





Nodalization

- Gas can distribute within the two auxiliary compartments, leak or be vented by the exhaust chimney
- there is a connection to the lower nuclear auxiliary building sump



Flow Paths

Generic containment zones are connected by means of:

- single atmospheric paths (only vapor and non-condensible gases)
- and drains (only fluid)
- rupture discs and pressure relief flaps have been merged

Anyway MELCOR can handle vapor/gases and water in the same flow path

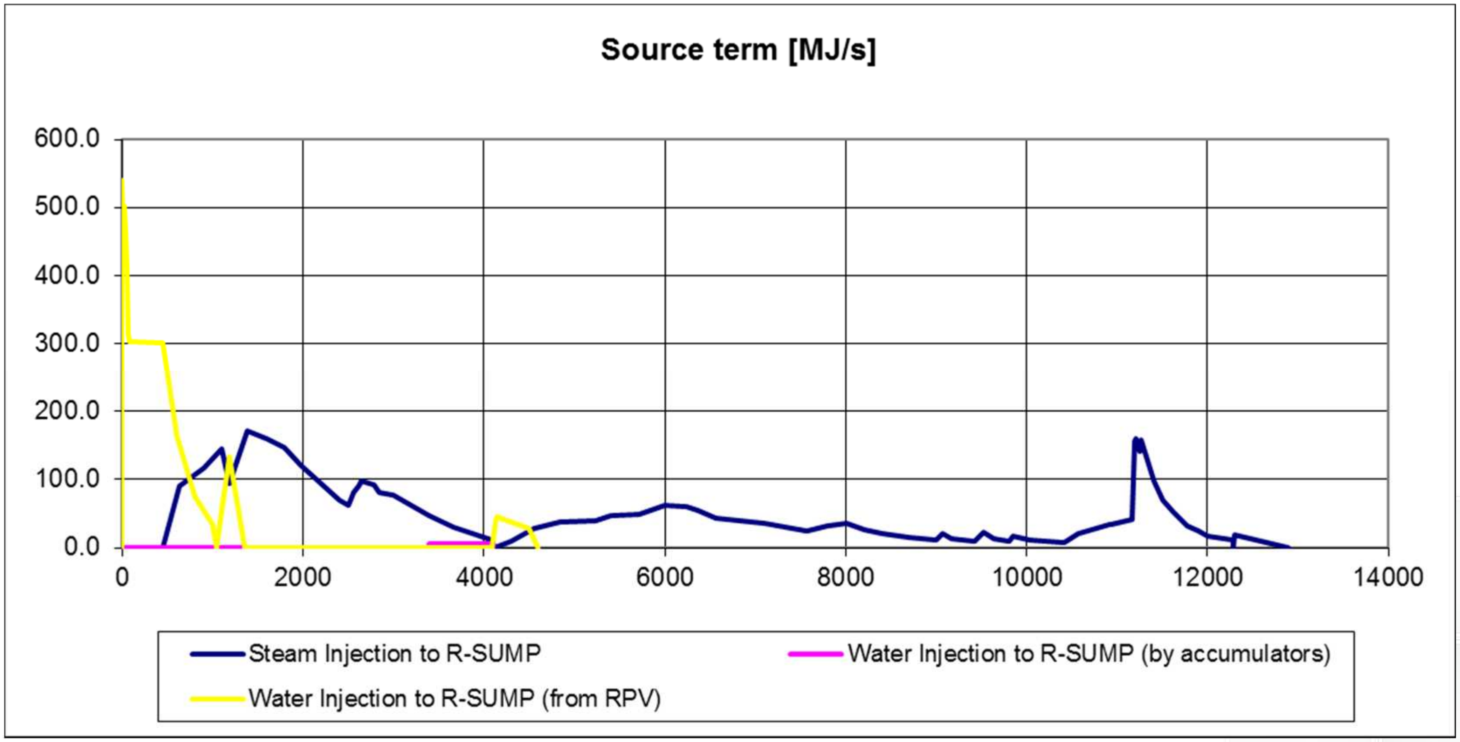
Heat Structures

- Total heat capacity and heat transfer areas have been preserved
- Zone contains both steel and concrete heat structures
- Most heat structures are located within a single control volume
- Heat transfer is considered only from the inner containment to the safeguard building and from there to the environment
- Only walls and floors structures are considered
- Structures are simply considered as rectangular solids

Properties	c_p [J/kgK]	λ [W/mK]	ρ [kg/m³]	ε [-]
CONCRETE	879	2,1	2225	0,9
STEEL	480	35	7850	0,9

Accident Scenario

- The analyzed scenario is the early phase of a SB-LOCA with loss of secondary heat sink and without core damage.
- Only the containment thermal hydraulics have been modeled
- The primary circuit behavior is considered by means of source terms (mass and enthalpy rates) for steam and water

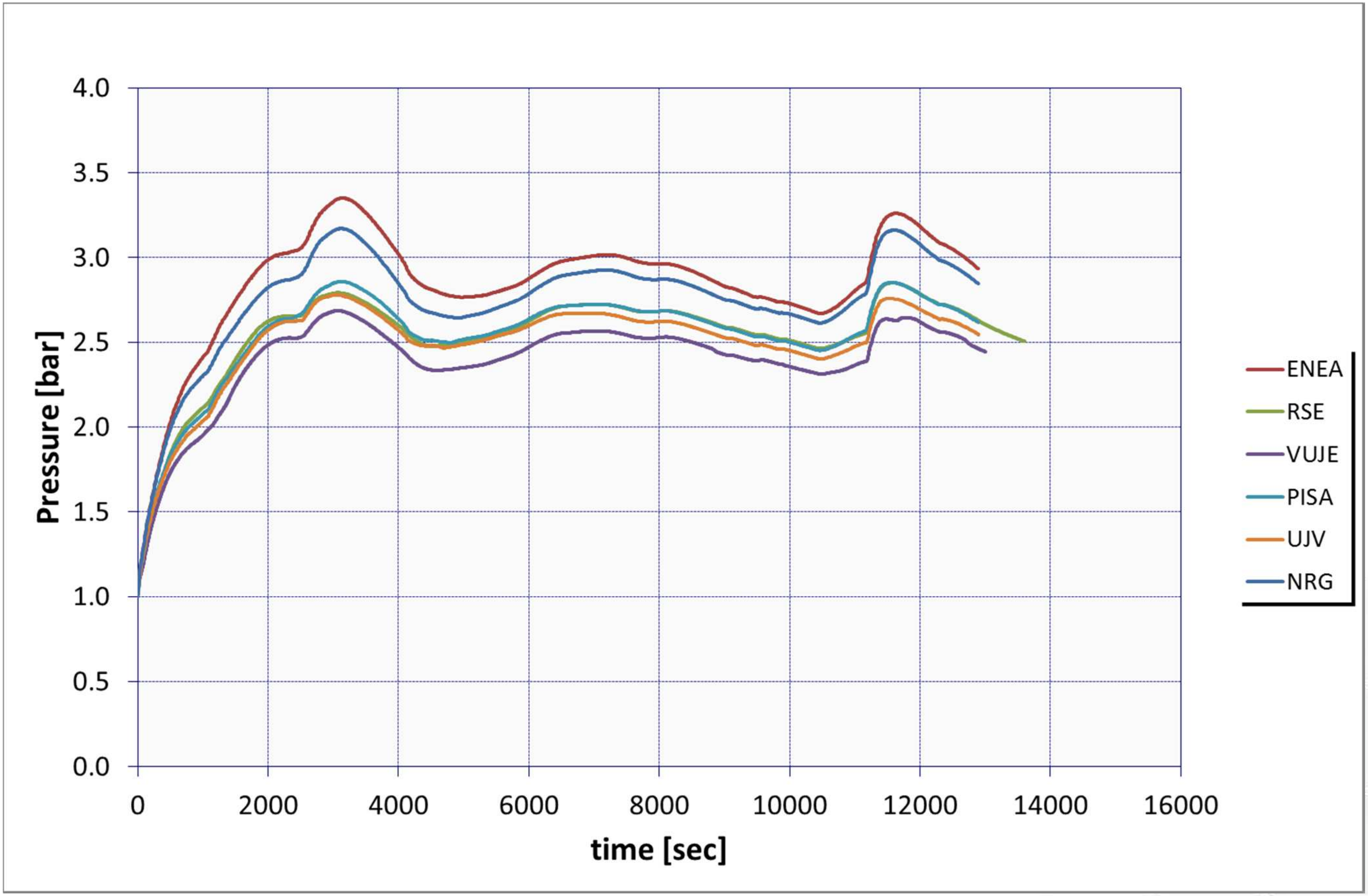


Expected Data

- Global pressure history
- Pressure differences between leakage zone (R-SUMP) and neighbor zones
- Temperatures in all zones
- Relative humidity in all zones
- Inner Surface Temperature (the steel surface of the containment)
- Qualitative flow description

Same problem, same nodalization, same results… isn't it?

Results: Global Pressure



well……

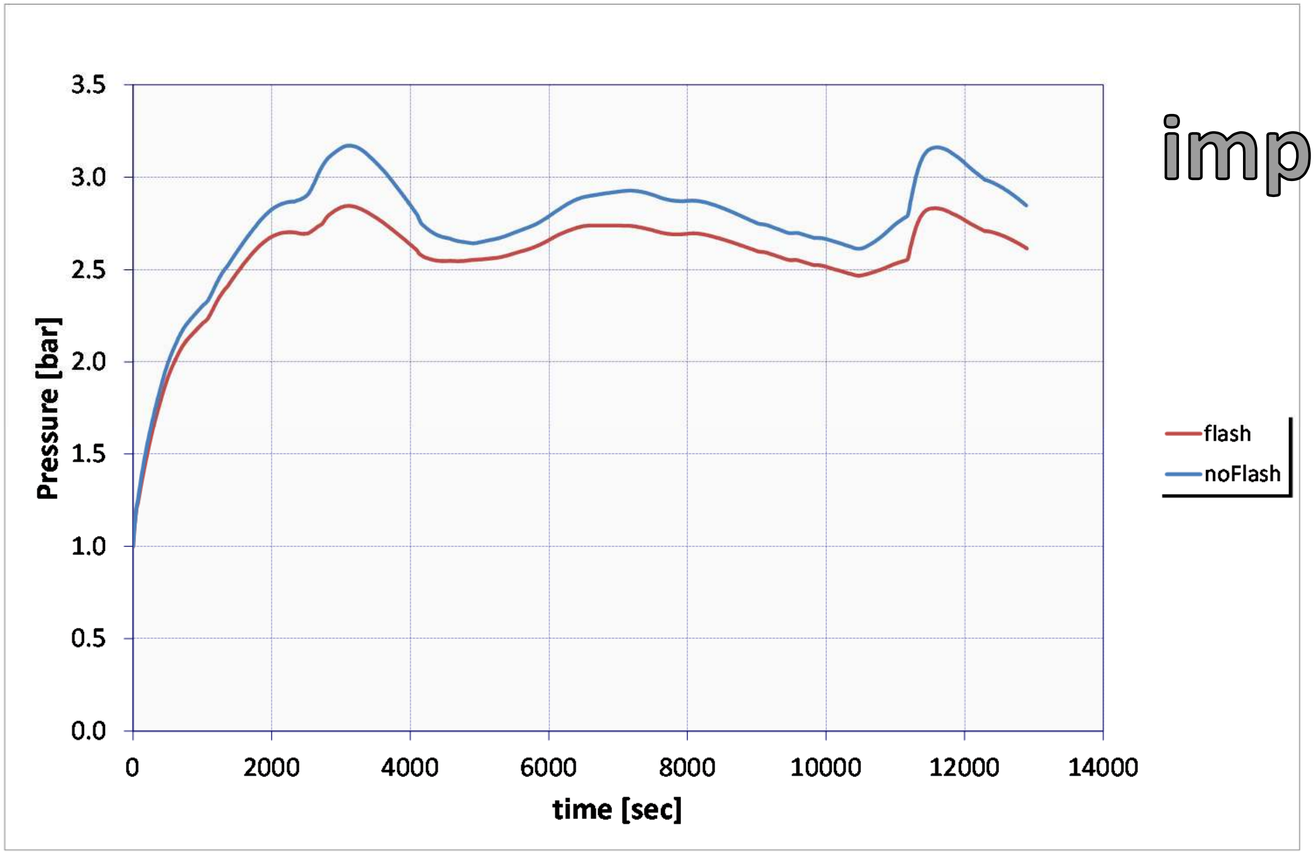
Why different results?

- User effect?
- Different code effect?
- Sensitivity coefficients effect?
- Mistakes?

Difference I

- Water source treated in a different way
- Flashing of Superheated Water Sources

Flashing of Superheated Water Sources					
ENEA	RSE	UNIPI	UJV	VUJE	NRG
Yes	No	Yes	Yes	No	No



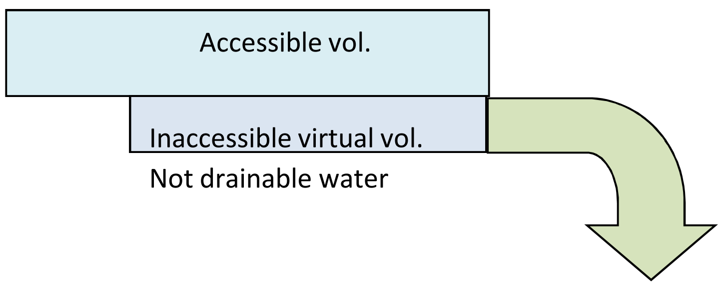
important

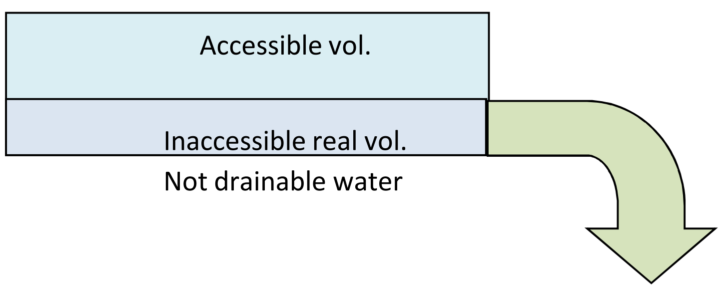
Difference II

- Minimum drainable water
- Very small importance

Not drainable water					
ENEA	RSE	UNIPI	UJV	VUJE	NRG
Yes	Yes	Yes	Yes	No	No

not important

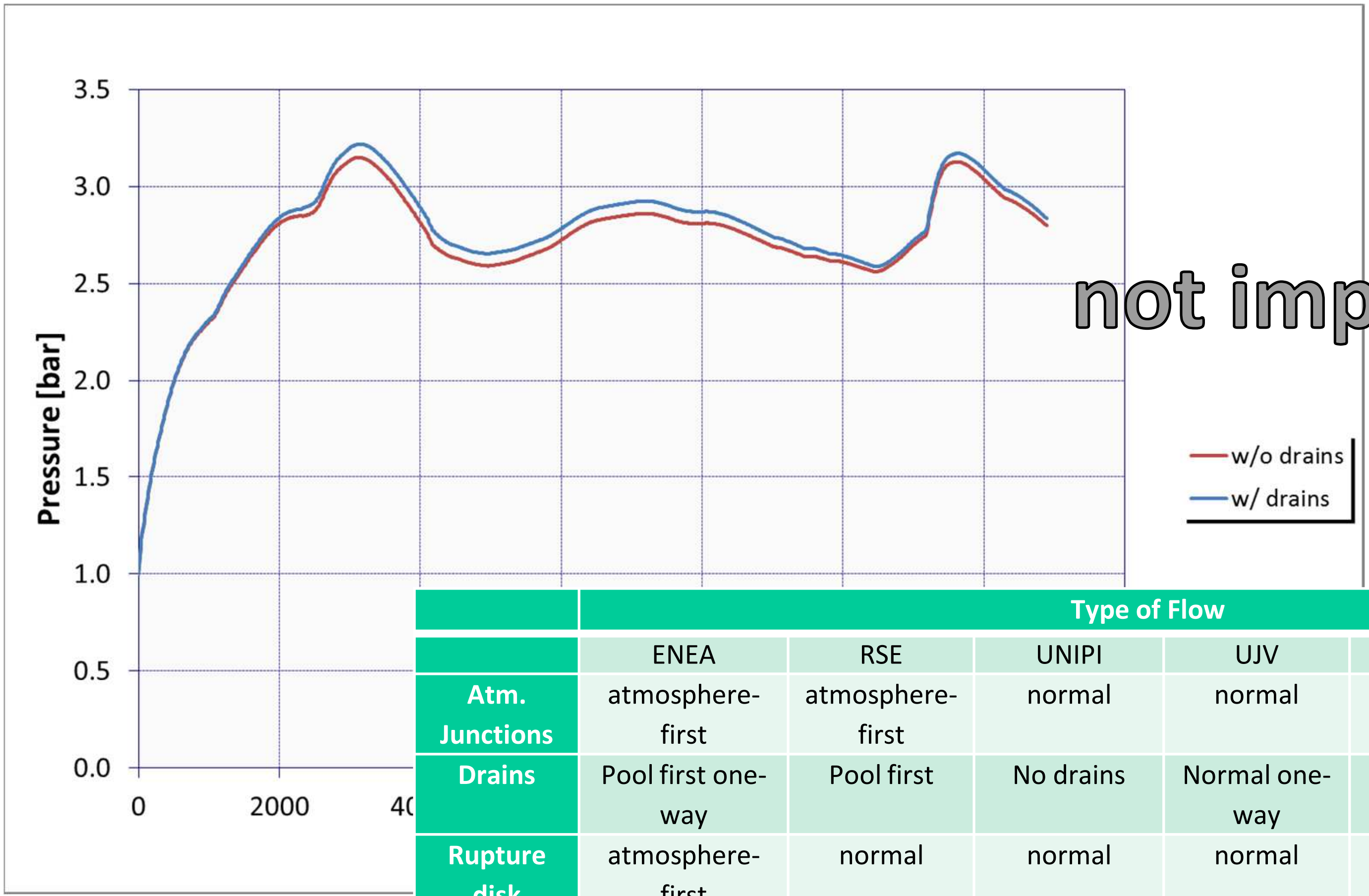




	$[m^3]$	$[m^3]$	
AB-UP1	2.194	24000	0.0091%
AB-UP2	2.194	24000	0.0091%
AB-CHIM	0.097	13250	0.0007%
R-DOME	1.64	43000	0.0038%
R-DUCT	0.286	1950	0.0147%
R-SG12	0.581	5360	0.0108%
R-SG34	0.644	5360	0.0120%
R-ANN34	0.904	5250	0.0172%
R-ANN12	0.828	5250	0.0158%
U-DOME	1.212	14850	0.0082%
U-34	1.554	12450	0.0125%
U-12	1.537	12450	0.0123%
U-SUMP	0.25	2000	0.0125%

Difference III

- MELCOR is able to treat **water** and **vapor/gases** in the same flow path
- Small importance, more fluent calculation w/o drains



not important

	Type of Flow					
	ENEA	RSE	UNIPI	UJV	VUJE	NRG
Atm. Junctions	atmosphere-first	atmosphere-first	normal	normal	normal	normal
Drains	Pool first one-way	Pool first	No drains	Normal one-way	No drains	Pool first
Rupture disk	atmosphere-first	normal	normal	normal	normal	normal

Difference IV

- No calculation influence
- Trips or logical comparisons

Rupture disks modeling					
ENEA	RSE	UNIPI	UJV	VUJE	NRG
ADD (ΔP) L-GT (ΔP>x) L-A-IFTE (open)	ADD (ΔP) L-GT (ΔP>x) L-A-IFTE (open)	ADD (ΔP) L-GT (ΔP>x) L-A-IFTE (open)	ADD (ΔP) T-R-O-F EQUALS	ADD (ΔP) USETRIP	ADD (ΔP) L-GT (ΔP>x) L-A-IFTE (open)

Difference V

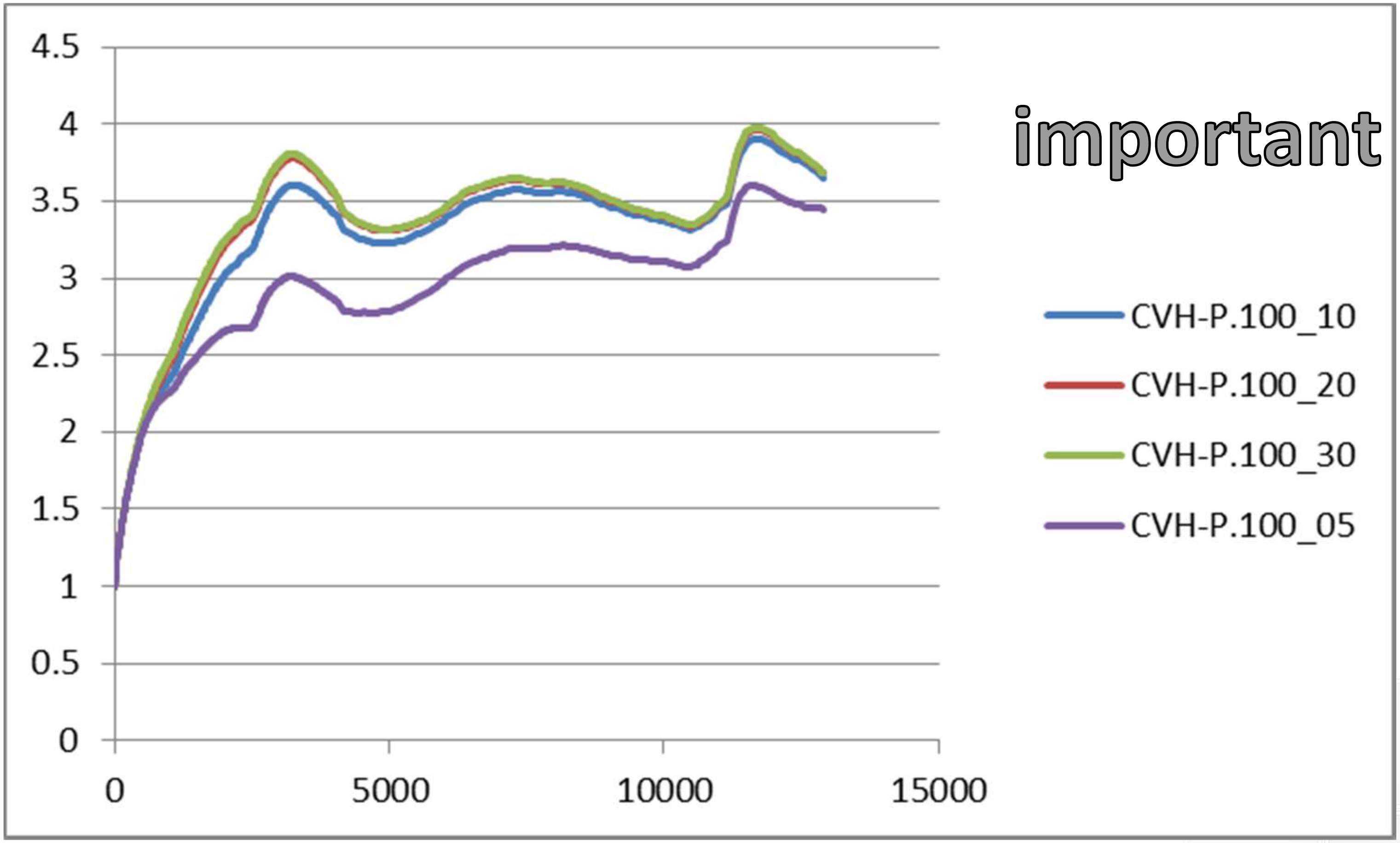
- Nodes number very important
- Radiative heat transfer important
- Characteristic length important

Heat structures

	Heat Structures					
	ENEA	RSE	UNIPI	UJV	VUJE	NRG
Nodes in concrete	Every 1 cm	21 / 51 environ.	40	Every 1 cm	Every 5-10 cm	21 / 51 environ.
Geometry	Rectangular	Rectangular	Rectangular	Rectangular	Rectangular	Rectangular
Floor orientation	Right-up	Left-up	Left-up	Left-up	Left-up	Left-up
Meshing	Uniform	Uniform	Uniform	Uniform	Finer on the surface	Uniform
Internal Heat Structures	2 heat exchanging surfaces	1 heat exchanging surface, 1 adiabatic surface	1 heat exchanging surface, 1 adiabatic surface	1 heat exchanging surface, 1 adiabatic surface	1 heat exchanging surface, 1 adiabatic surface	1 heat exchanging surface, 1 adiabatic surface
emissivity, radiation length	Only for the basement	0.90 GRAY-GAS-A 1.0E6	NO	0.9 equiv-band 1.000	0.9 EQUIV-BAND 3.0	0.90 gray-gas-a 1.0E6
char.length walls floors	1.0 1.0	height c_width	c_height c_width	height c_width		height c_width
Axial length Walls Floors	Height Width	1.0 1.0	Height Width	Height C_Width	Height C_width	1.0 1.0

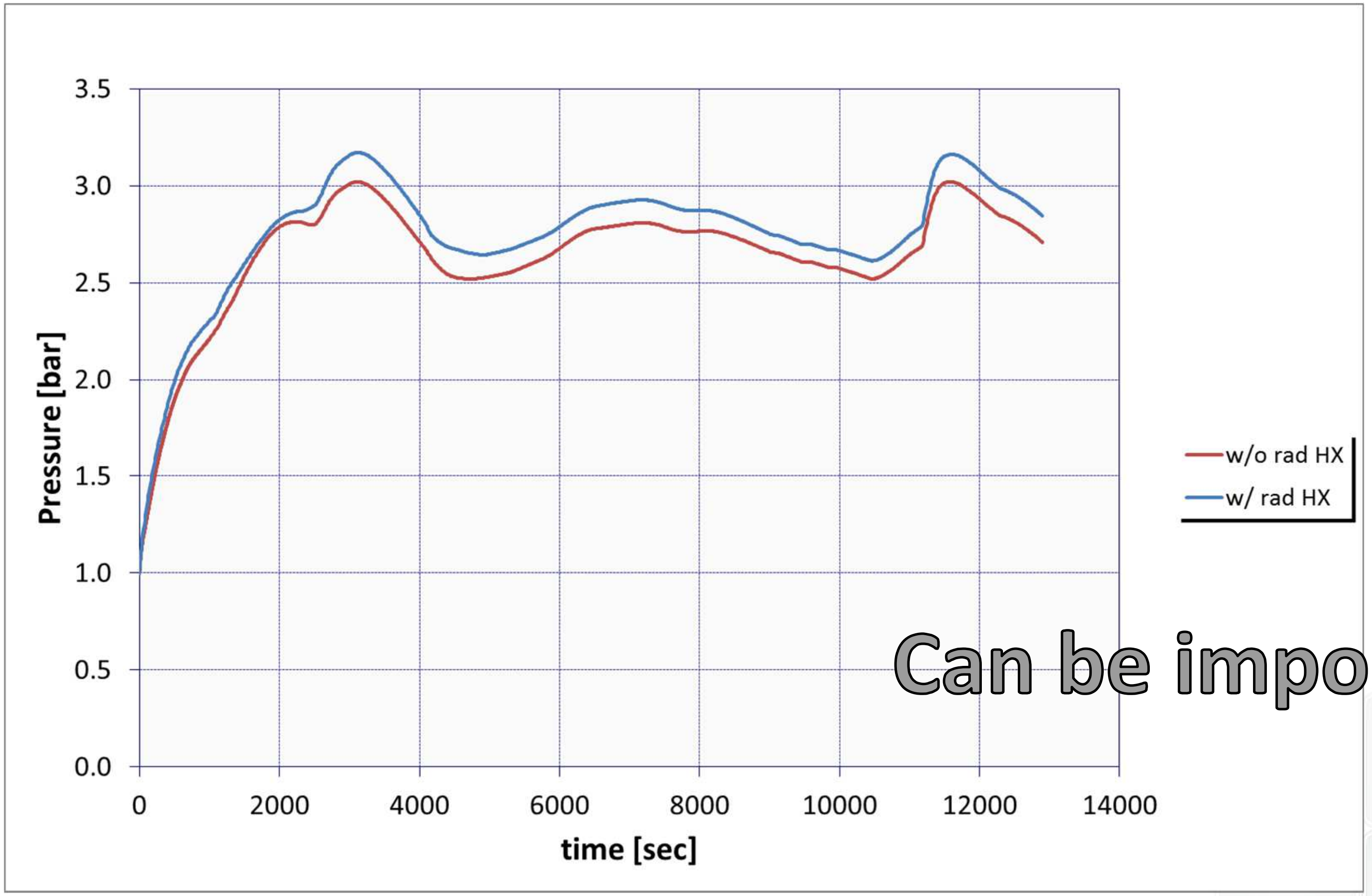
Difference V (HS nodes)

- Higher number of temperature nodes converge to same results



Difference V (HS rad. HX)

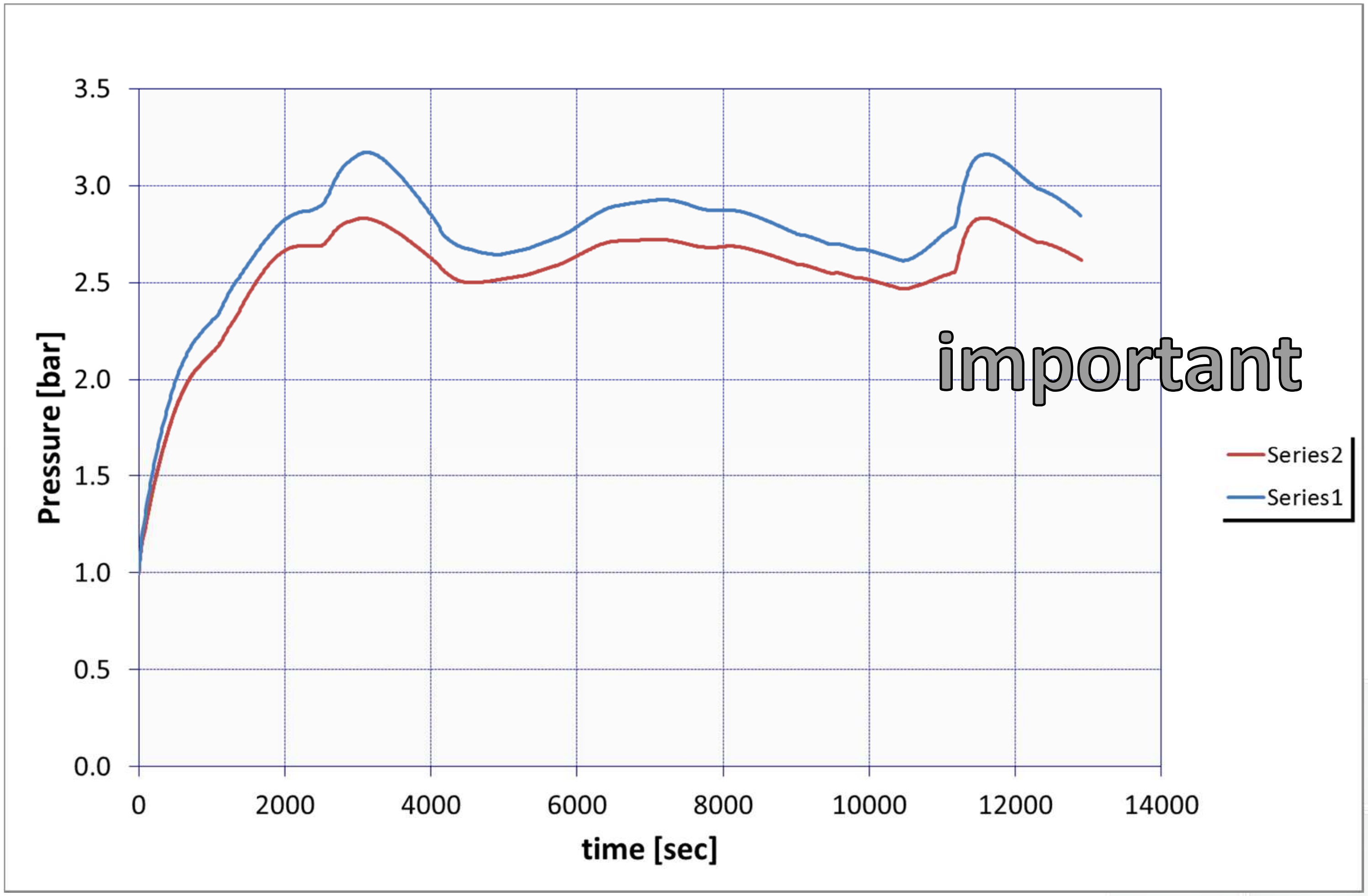
- Results are different if radiative heat transfer is taken into account



Can be important

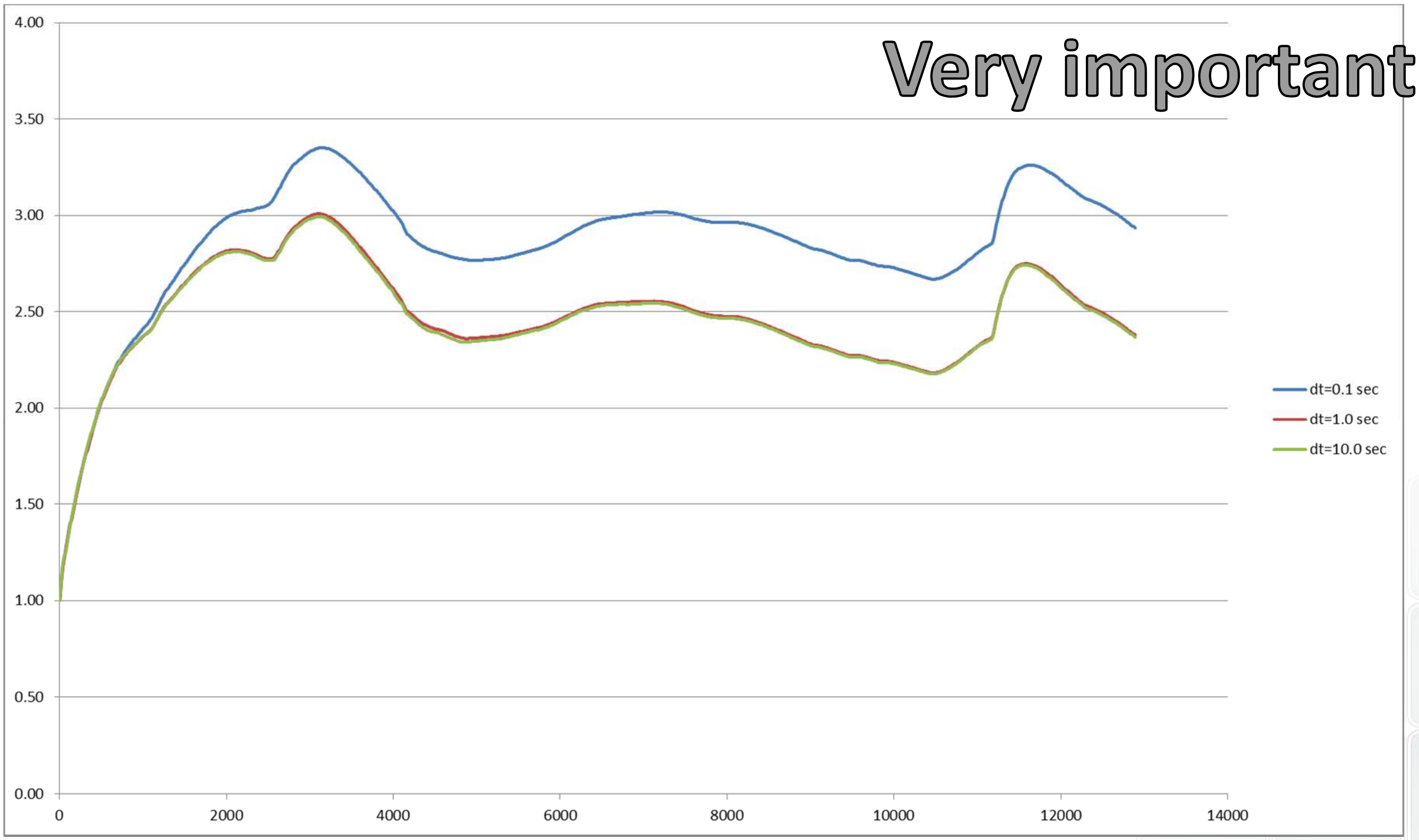
Difference V (HS char. lenghth)

- Results are different if the characteristic lenghths are different



Difference VI

- Time step very sensitive



Difference VII

- MELCOR 1.8.6 vs 2.1

Conclusions

- There are a lot of user effects
- In the MELCOR user manual there should be more practical hints on nodalization
- Surprising difference in 1.86 and 2.1 (hopefully just a user mistake)

Grazie