MELCOR MODELING ACTIVITIES AT BEL V AND APPLICATION TO BELGIAN NPP

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OBJECTIVES

- Exchange experience and information about model development efforts (plant safety studies)
  - Key messages from model development
  - Focus on modeling activities, some sample results
- Feedback on the use of MELCOR and SNAP

Progress in MELCOR plant model development

MODELING ACTIVITIES INSIDE BEL V

MODELING OF EXISTING PLANT

- MELCOR: reference code selected by Bel V for severe accident analysis
- Acquisition of the MELCOR code: end 2012
- Requested external expertise to GRS
  - to support Bel V in the plant-model development
  - to transfer knowledge in the use of the severe accident codes and best practice
- MELCOR code mainly used in the framework of Bel V R&D program

TIHANGE 2 PLANT MODEL

PLANT DATA

- Framatome PWR (1982)
- 3064 MWth
- 1055 MWe (gross)
- 3 cooling loops
- Power uprate (1992)
- SG replacement (2001)
- 157 17X17 UO2 FA
- *Status: temporally shutdown*

MELCOR MODEL

- Cooling loops: B1, R2, G2
- RPV, core and LH
- PRZ with heaters and sprays
- Accumulators
- SG secondary side, FW system, Turbine, Environment, etc.
- *Code version: 1.8.6*

TIHANGE 2 PLANT MODEL

- *Creation of plant model*: interactive procedure including selection of a nodalization scheme, preparation of the code input deck, and documentation of these activities

Objective: unique interpretation, and the full traceability and reproducibility of the code input deck; *includes Excel spreadsheets*

- Main assumptions for the development of the CNT2 input deck:
  - Existing MELCOR input deck 'adapted' to CNT2 plant:
    - same subdivision of the input deck in separated files
    - similar 'noding' of the components
    - similar structure of the CFs
  - Only the behavior of some safety systems currently modeled
  - DCH/RN still to be improved with results of ORIGEN
  - Containment CVH/FL/HS models to be adapted to CNT2

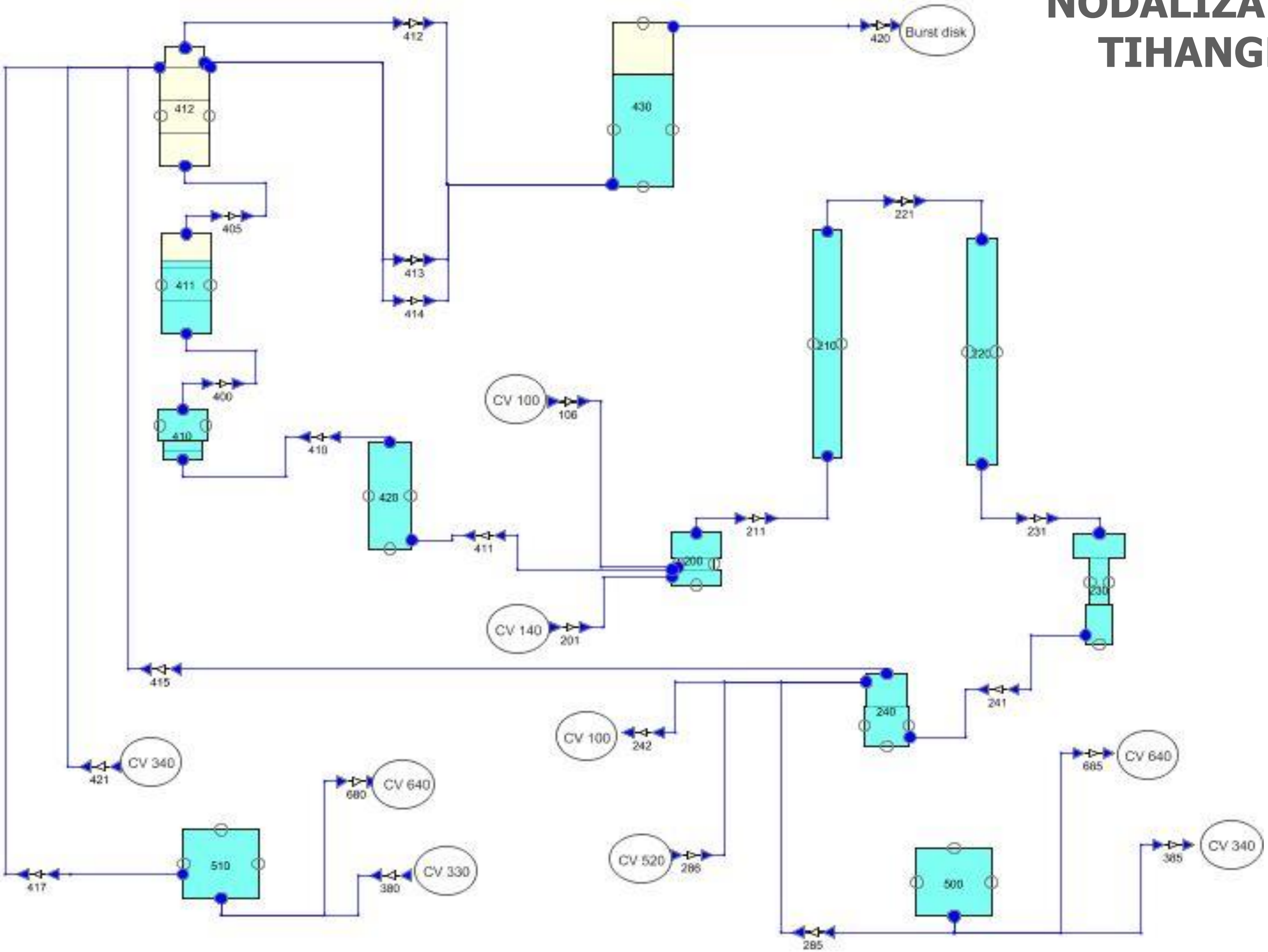
Plant and Cycle specific ORIGEN results will be kindly provided by the Utility

CVH NUMBERING THROUGHOUT THE TIHANGE 2 MODEL

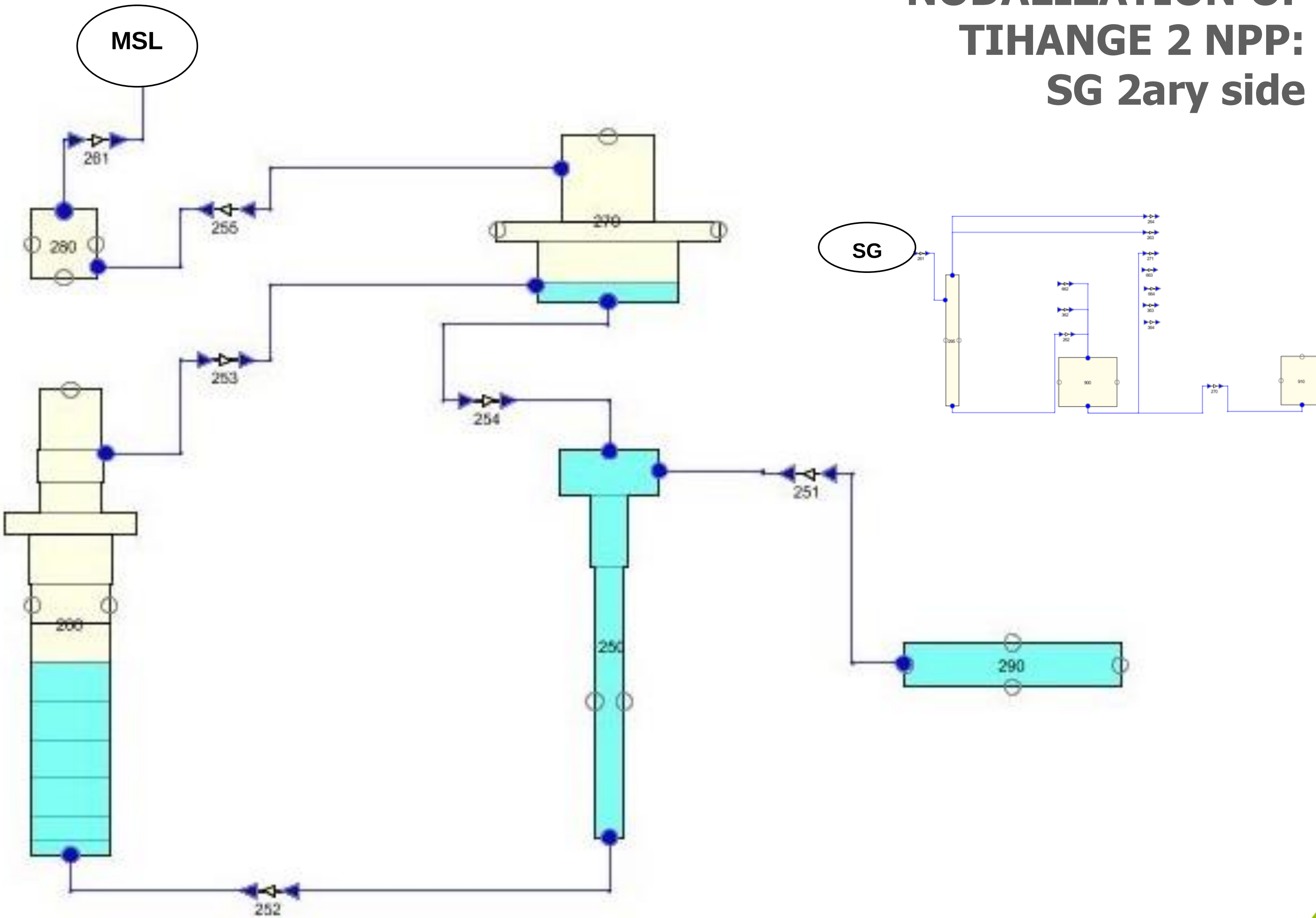
CVH#	Part of the model	Note
100 to 150	Reactor pressure vessel	-
200 to 240	Cooling loop B1	-
300 to 340	Cooling loop R2	-
600 to 640	Cooling loop G3	
410 to 430	Pressurizer	Connected to cooling loop B1
250 to 295	Steam generator B1	-
350 to 395	Steam generator R2	-
650 to 695	Steam generator G3	
500, 510	CVCS	-

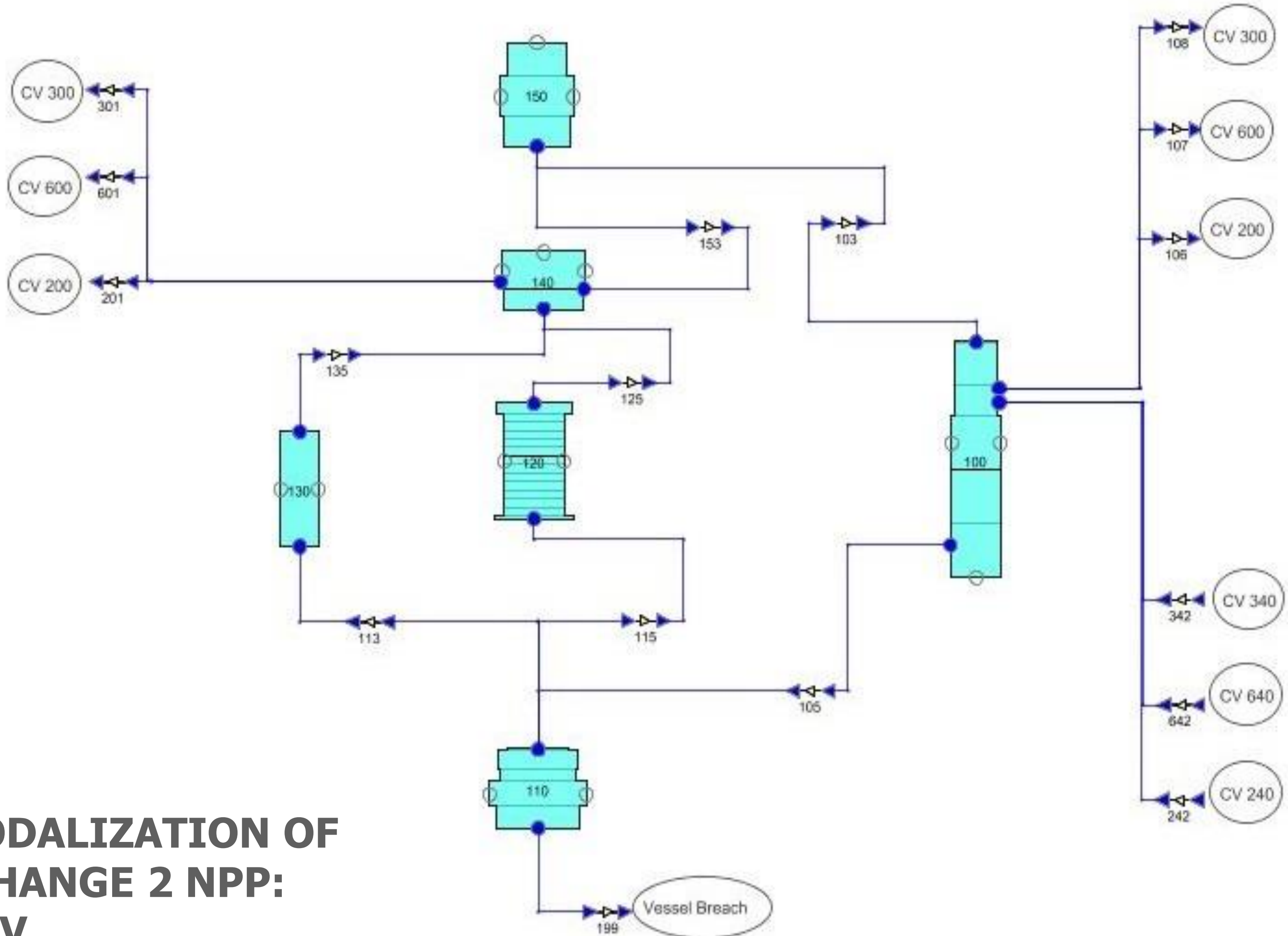
CNT2 = Centrale nucléaire de Tihange unité 2

NODALIZATION OF TIHANGE 2 NPP: loop B1



NODALIZATION OF TIHANGE 2 NPP: SG 2ary side





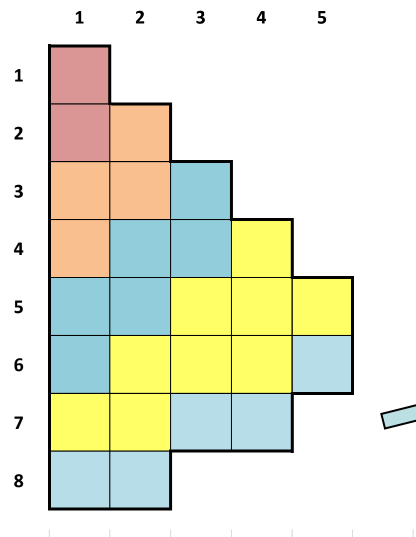
NODALIZATION OF TIHANGE 2 NPP: RPV

CORE RADIAL RINGS

- 17x17 Core structure
- 157 Fuel assembly

⇩

- 5 radial rings
- 1 additional ring for downcomer



	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1							5	5	5						
2					5	5	4	4	4	5	5				
3				5	4	4	4	3	4	4	4	5			
4			5	4	4	4	3	3	3	4	4	4	5		
5		5	4	4	4	3	3	2	3	3	4	4	4	5	
6		5	4	4	3	3	2	2	2	3	3	4	4	5	
7	5	4	4	3	3	2	2	1	2	2	3	3	4	4	5
8	5	4	3	3	2	2	1	1	1	2	2	3	3	4	5
9	5	4	4	3	3	2	2	1	2	2	3	3	4	4	5
10		5	4	4	3	3	2	2	2	3	3	4	4	5	
11		5	4	4	4	3	3	2	3	3	4	4	4	5	
12			5	4	4	4	3	3	3	4	4	4	5		
13				5	4	4	4	3	4	4	4	5			
14					5	5	4	4	4	5	5				
15							5	5	5						

- MELCOR COR radial rings correspond to **Fig. 4-3 of NUREG/CR-7110 vol.2**
- Tihange 2 MELCOR model is developed using plant-specific data

CORE AXIAL LEVELS AND LOWER HEAD

Single Tihange 2 fuel assembly stand alone testing

- *19 Levels in axial direction*
- *5 Levels in Lower Plenum*
- 12 Levels active fuel

THEN

Extrapolation to plant model:

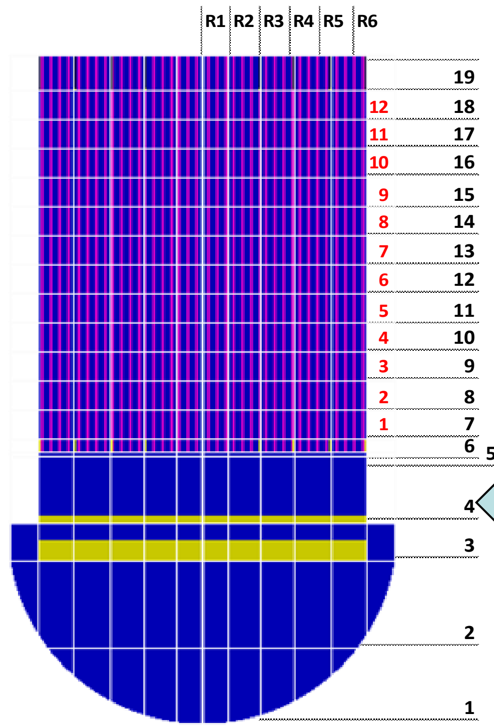
- Masses
- Equivalent diameters
- Flow areas
- Surface areas
- Failure mechanisms,
- etc.

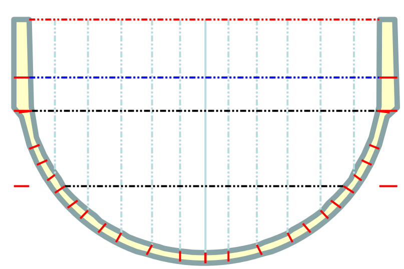
Axial Level		Core cell	HS	CV	
19	Top nozzle + upper internals	COR119	11513		
18	heated fuel 12	COR118	11515		
17	heated fuel 11	COR117	11514		
16	heated fuel 10	COR116	11512		
15	heated fuel 9	COR115	11511		
14	heated fuel 8	COR114	11510		
13	heated fuel 7	COR113	11509	CV120	CV130
12	heated fuel 6	COR112	11508		
11	heated fuel 5	COR111	11507		
10	heated fuel 4	COR110	11506		
9	heated fuel 3	COR109	11505		
8	heated fuel 2	COR108	11504		
7	heated fuel 1	COR107	11503		
6	Lower nozzle + debris gris	COR106	11502		
5	Core lower plate	COR105	11501		
4	Core support internals	COR104	0		
3	Core support plate	COR103	0	CV110	
2	Lower plenum	COR102	0		
1	Lower plenum	COR101	0		

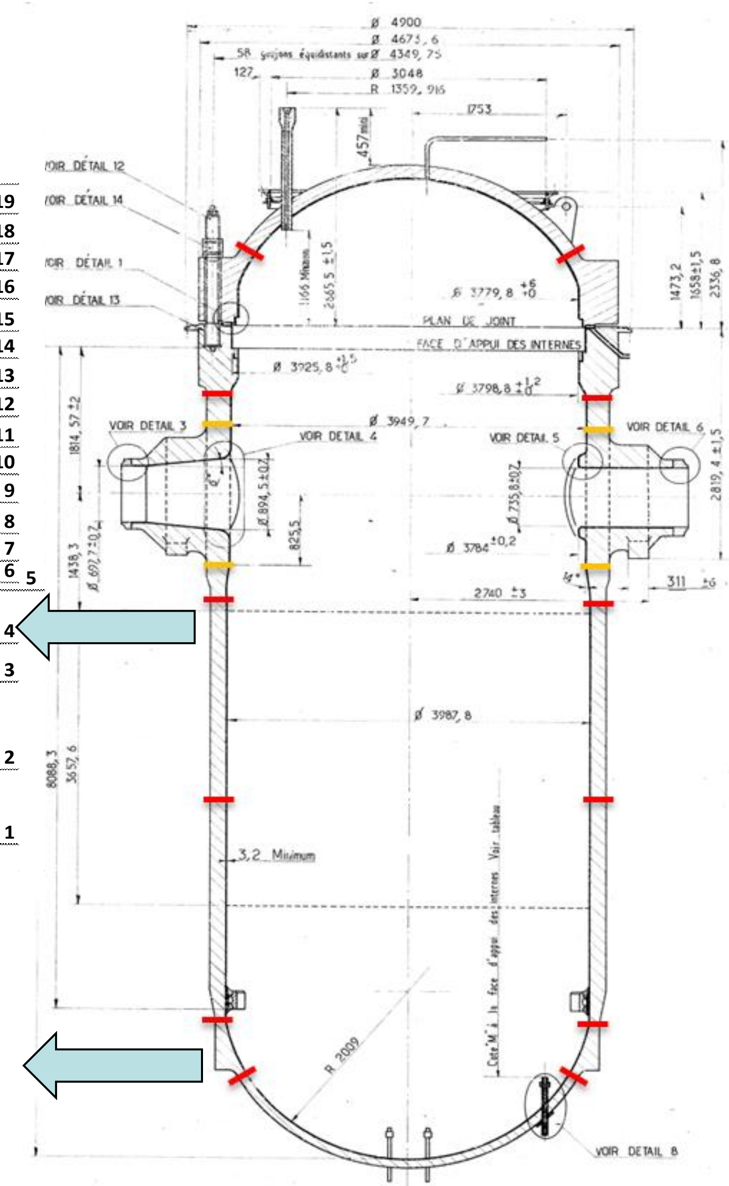
- MELCOR COR FA nodalization is similar to **Fig. 3 of SAND2010-8249** (SFP-FA)
- **SAND2010-8249** contains very useful details of how the FA data has been converted into the MELCOR input deck
- Tihange 2 MELCOR model is developed using plant-specific data (*not reported*)

CORE AXIAL LEVELS AND LOWER HEAD

- Failure criteria analyzed in detail
  - Supporting and non-supporting structures
  - Fuel rod failure
- LH failure
  - overpressure
  - creep-rupture
  - LH penetration: failure not modeled as mechanism for vessel failure (NUREG/CR-7008)







BEL V

Steady state and transient analyses

SAMPLE RESULTS

STEADY STATE ANALYSIS

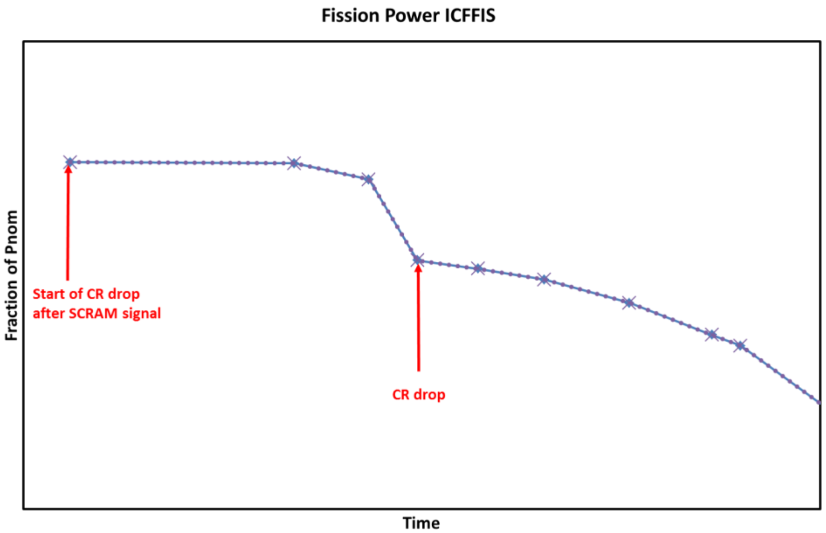
- The difference % respect to the plant nominal operating value is calculated as the ratio: |reference value – calculated value| / |reference value|
- The dimensional error is the numerator in the above expression
- Check of the steadiness of the steady state (qualitatively, from figures)
- Other quantities are checked and compared with plant data and the results of other calculations (notably CATHARE and RELAP) e.g. pressure drops

Comparison also with results of CATHARE and RELAP

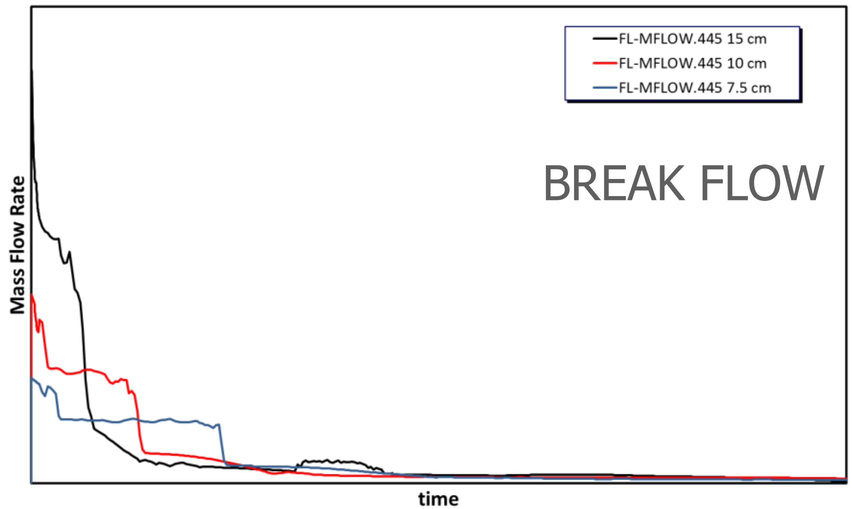
Parameter	Differfernce %
Primary System	
Core power	*Imposed*
Primary pressure (PRZ)	*<1*
PRZ level	*<1*
Temperature Cold-Leg	*<1*
Temperature Hot-Leg	*<1*
Temperature average	*<1*
ΔT HL-CL	*<5*
Mass flow rate (loops)	*<1*
Bypass core	*<1*
Secondary System	
Temperature FW	*Imposed*
SG level	*<5*
SG pressure	*<5*
SG power	*<1*
SG total mass	*<5*
Recirculation ratio	*>15*

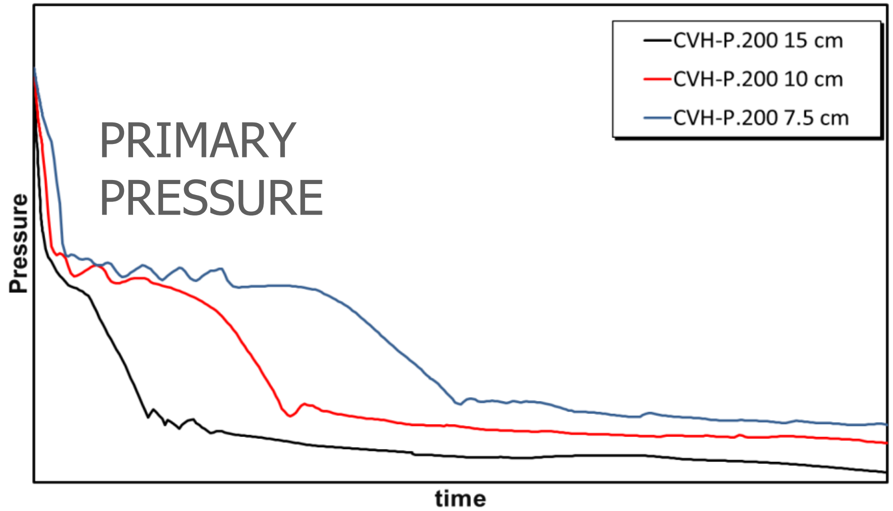
TRANSIENT ANALYSIS

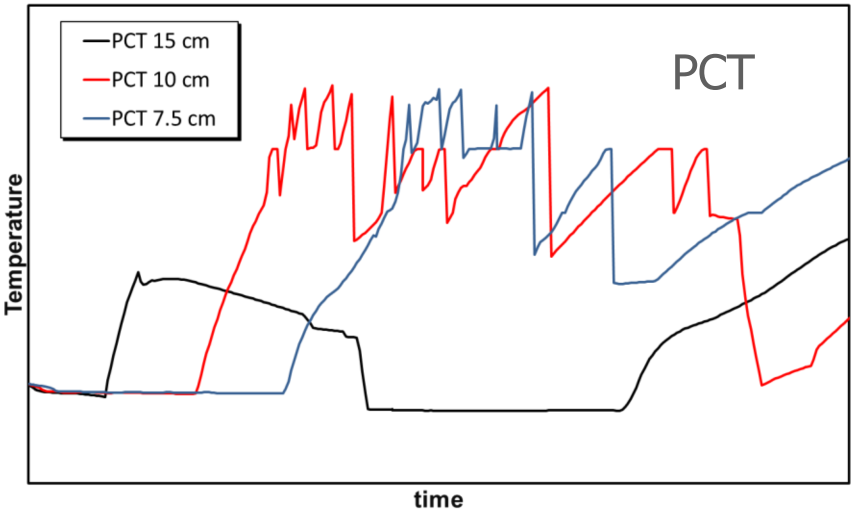
- IB-LOCA HL loop with PRZ (CV200 bottom, FL445)
- Break equivalent diameter:
  - 7.5 cm
  - 10 cm
  - 15 cm
- Break opening time: t=0s
- 3 accumulators, 1 for each CL
- HPSI and LPSI fail
- FW stops at SCRAM
- AFW/EFW not available

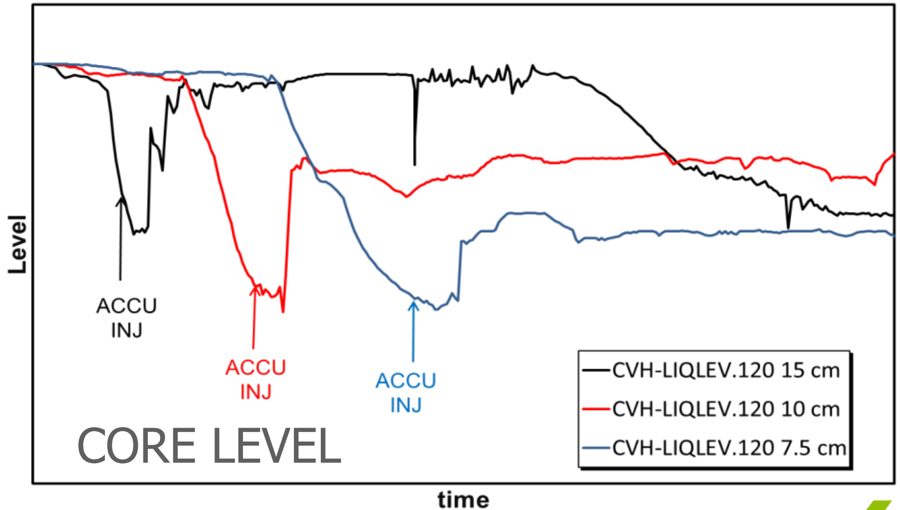


SAMPLE RESULTS









Sharing information

FEEDBACK ON THE USE OF MELCOR AND SNAP

FEEDBACK ON THE USE OF SNAP

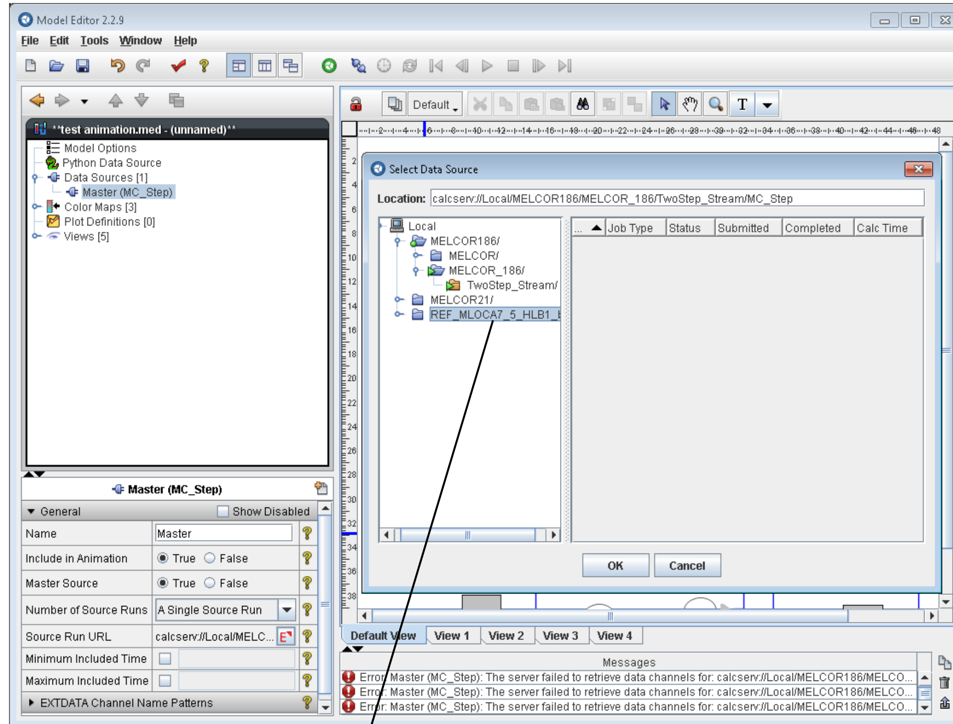
- Input running with exe, does not necessarily run using SNAP

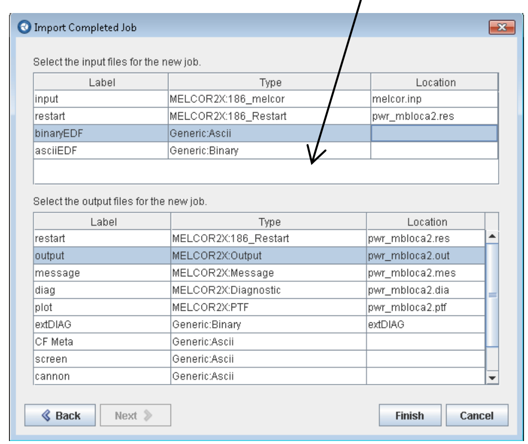
  → *errors can be solved by checking the diagnostic file*

- ONLY if input run using SNAP, its results can be "connected" to the animation tool

  → *not possible to connect a data source run in batch*

  → *Intermediate steps missing?*





- Mount folder
- Import completed job
- MELCOR 1.8.6

FEEDBACK ON THE USE OF MELCOR

- CVH/FL/HS: availability of input model(s) of other codes (e.g. TH-system codes like CATHARE or RELAP) facilitates the MELCOR NPP model development
- Main modeling effort:
  - COR package: plant data converted into the plant input deck
  - steady state analysis: stabilization at full-power

The availability of a complete and best practice input model facilitates the development of a new plant model!

MELCOR modeling activities at Bel V and application to Belgian NPP

CONCLUSIVE REMARKS

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- MELCOR: reference code selected by Bel V for severe accident analysis
- MELCOR code mainly used in the framework of Bel V R&D program
- A MELCOR model for CNT2 NPP has been developed
  - The model is suitable for steady-state and transients calculations (= it is able to calculate the accident sequences)
  - Comparisons against plant data and code-to-code are performed for steady-state results (when available, mainly with results of CATHARE), transient analysis ongoing on selected transients
- The availability of a complete and best practice input model facilitates the development of a new plant model

CONCLUSIVE REMARKS

- Further plan:
  - continuation of transient analysis
  - consideration of conversion to MELCOR 2.1 (thanks to the Workshop 2014)
  - completion of the model (i.e. DCH/RN and containment)
  - validation activities
    - steady state analysis: comparisons against plant data and code-to-code
    - transient analysis: comparison with results of CATHARE and Safety Report Tihange 2 (DBA)

THANKS FOR YOUR ATTENTION!

QUESTIONS?