CURRENT APPLICATION OF MELCOR 2.1 CODE AT BEL V

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  - Feedback
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INTRODUCTION

- MELCOR: reference code selected by Bel V for severe accident analysis
- Acquisition of the MELCOR code: end 2012
- MELCOR code mainly used in the framework of Bel V R&D program
- Objectives of the presentation
  - Exchange experience and information about model development efforts (plant safety studies)
    - Key messages from model development
    - Focus on modeling activities, some sample results

Accident progression analysis

PROGRESS IN MELCOR MODELING

PWR 3-LOOPS 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
  - PWR 3-loops plant model ~ 1000 MWe

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

- Main assumptions for the development of the plant input deck:
  - Existing MELCOR input deck 'adapted' to the selected plant:
    - same subdivision of the input deck in separated files
    - similar 'noding' of the components
    - similar structure of the CFs
  - The behavior of several systems currently modeled, then flags added in CF for activation (or not)
- Main modeling effort
  - COR package: plant data converted into the plant input deck
  - Steady state analysis: stabilization at full-power

PWR 3-LOOPS PLANT MODEL

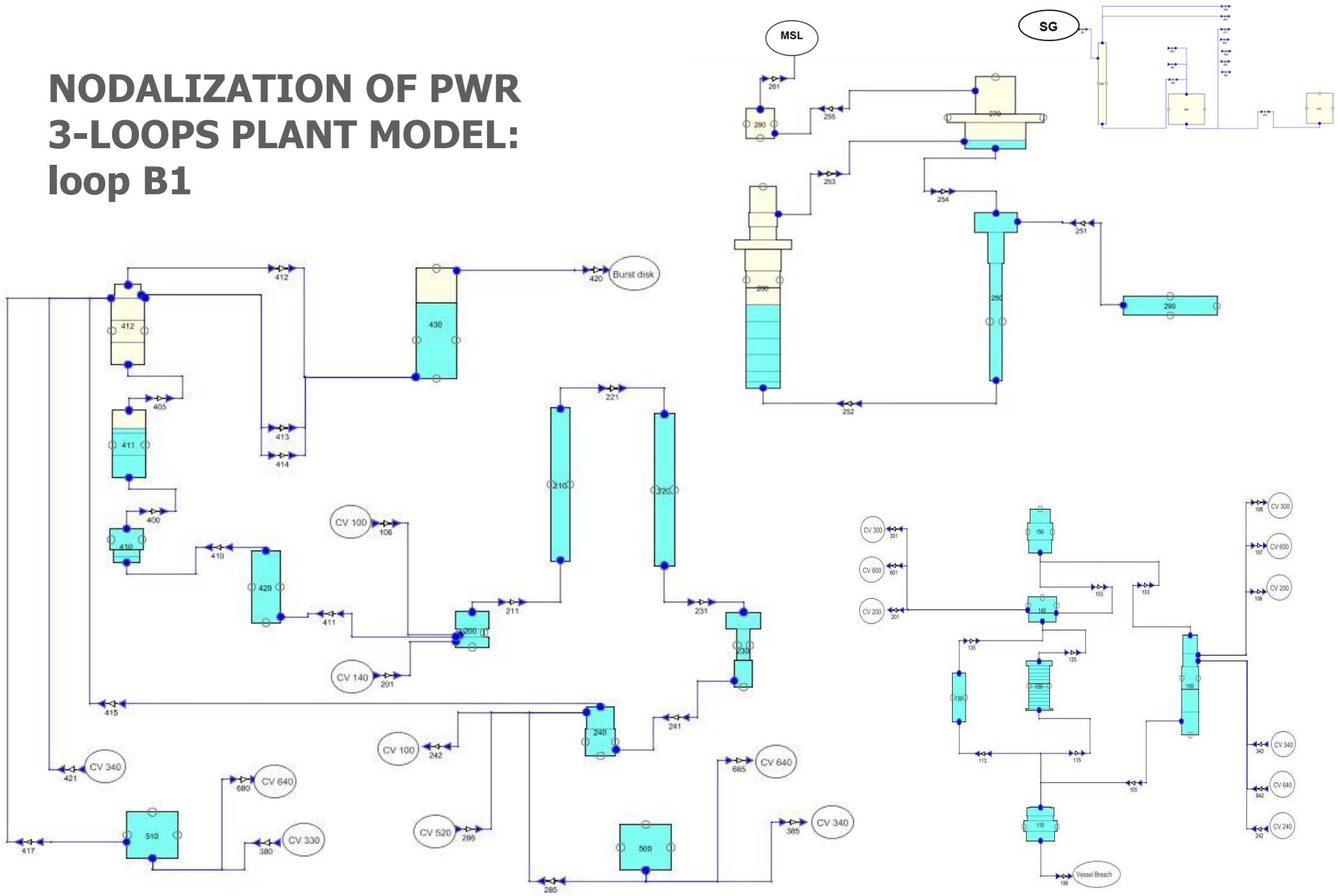
- Initial development with MELCOR 1.8.6
- MELCOR 1.8.6 input deck converted to MELCOR 2.1 by means of SNAP
  - correction of conversion errors and refinements (i.e. SH)
- Ongoing
  - DCH/RN improved with results of ORIGEN: conversion 1.8.6-2.1
  - Containment: developed for MELCOR 2.1
- Availability of input model(s) from different codes:
  - other codes: e.g. TH-system codes like CATHARE or RELAP, facilitates the MELCOR plant model development of CVH/FL/HS
  - MELCOR code (possibly the same version used, e.g. 1.8.6 and/or 2.1): facilitates the development of a new plant model!

Plant and Cycle specific ORIGEN results kindly provided by the Utility

PWR 3-LOOPS PLANT MODEL

- Included in the current MELCOR 1.8.6 (and 2.1) plant model:
  - Primary hydraulic circuits and MCPs (*each loop individually*)
  - Reactor pressure vessel hydraulic circuit
  - Core and LH
  - PRZ, SVs, PORVs, relief tank and burst disk
  - PRZ pressure regulation system, with heaters and sprays
  - CVCS, including function of PRZ level regulation
  - SGs
  - FW/AFW
  - MS line, MSIVs, SVs, RVs, collector, turbine and steam dump
  - Accumulators
  - HPSI/LPSI (*injection and recirculation*)
  - Containment **ONGOING**

NODALIZATION OF PWR 3-LOOPS PLANT MODEL: loop B1



Exchange experience and information about model development efforts

MELCOR 1.8.6-2.1 MODELING

Partially presented at CSARP 2015

CONVERSION MELCOR 1.8.6-2.1

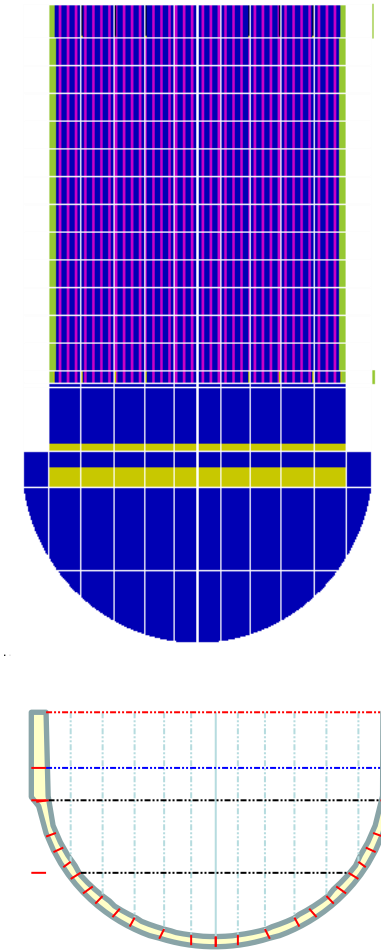
- Conversion from MELCOR 1.8.6 input to 2.1 has been done by means of SNAP (thanks to the MELCOR Users' Workshop 2014)
  - MELGEN/MELCOR 1.8.6 input deck imported in SNAP
  - Code flavors changed to 2.1 (in '*model options*' AND in '*cases/MELCOR/edit case/model options*')
  - Besides some minor modifications, both MELGEN and MELCOR run without problem
    - *'WARNING FROM CF Package: Control Function **AAA** uses CF-VALU('**BBB**') as an argument The OLD value of CF-VALU('**BBB**') will be used because its definition appeared AFTER that of **AAA** in input'* → *reorganization of CFs: needed?*
- SH added to COR package → *see next slides*

SH MODELING STRATEGY

- Core SHroud component added in COR package (IA 6÷19 IR 5)
  - **COR_KSH**: PWR Core Shroud Component Masses
  - **COR_SSA**: PWR Shroud and Former Surface Area Record
  - **COR_SDR**: PWR Shroud and Former Equivalent Diameter Record
  - **COR_PCT**: Initial PWR Component Temperatures
  - **COR_SHS**: PWR Core Baffle (Shroud) Support Options (FIXED)
- Formers have not been added in the current revision
- Bypass (*region outside the core shroud*) included in **COR_RBV ICVHB** input in (IA 6÷19 IR 5)
  - *Diagnostics COR package:' WARNING: ALTITUDES IN CVH VOLUME ALTITUDE TABLES DO NOT MATCH COR CELL ELEVATIONS'*
  - this required re-adjusting the volume/altitude table for the bypass volume so as to match the elevations in the COR package

SH MODELING STRATEGY

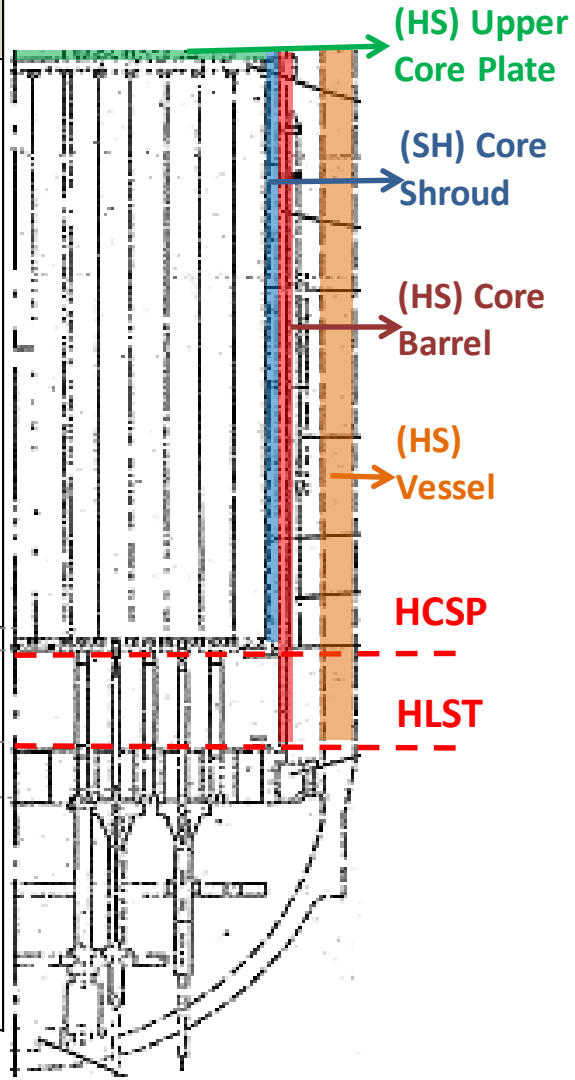
- Core SHroud HSs removed
- Core barrel HSs redefined as the radial boundary for the COR package using **COR_ZP IHSA** records
  - HSs subdivided so as to have a separate segment for each elevation in the core
  - Barrel HSs ABOVE **HLST** (elevation of bottom plate)
  - **HS_LBF** DTDZ records added to specify a dT/dz boundary fluid temperature option for the inner surfaces
  - **HS_DG** record not added



HS representation in SNAP might be very helpful to verify nodalization

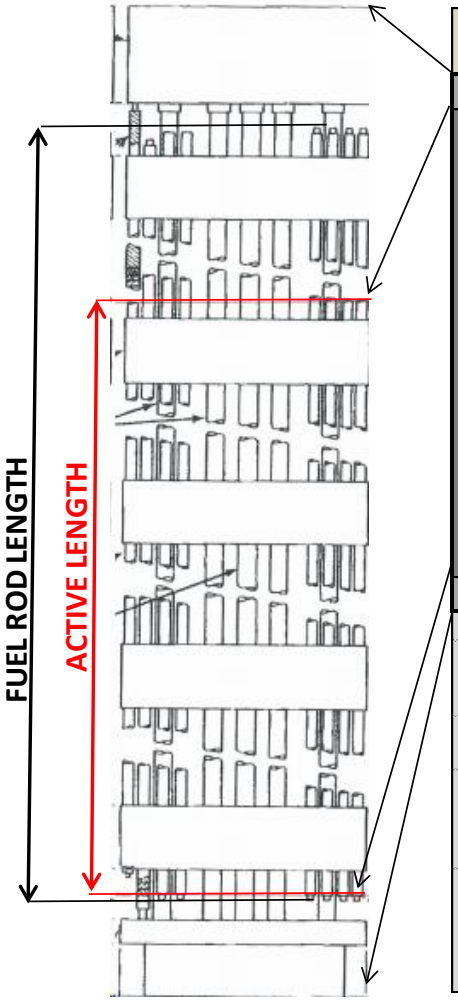
SUMMARY COR MODELING

IA	IR		IR	COR_KSH / XMSHSS	IHSA	CV
19	1÷5	Top nozzle + upper internals	5	SH	Barrel_15	CV120/CV130
18	1÷5	heated fuel 12	5	SH	Barrel_14	
17	1÷5	heated fuel 11	5	SH	Barrel_13	
16	1÷5	heated fuel 10	5	SH	Barrel_12	
15	1÷5	heated fuel 9	5	SH	Barrel_11	
14	1÷5	heated fuel 8	5	SH	Barrel_10	
13	1÷5	heated fuel 7	5	SH	Barrel_9	
12	1÷5	heated fuel 6	5	SH	Barrel_8	
11	1÷5	heated fuel 5	5	SH	Barrel_7	
10	1÷5	heated fuel 4	5	SH	Barrel_6	
9	1÷5	heated fuel 3	5	SH	Barrel_5	
8	1÷5	heated fuel 2	5	SH	Barrel_4	
7	1÷5	heated fuel 1	5	SH	Barrel_3	
6	1÷5	Lower nozzle + debris gris	5	SH	Barrel_2	
5	1÷5	Lower core plate	5	-	Barrel_1	
4	1÷5	Core support internals	5	-	Barrel_0	CV110
3	1÷5	Core support plate	5	-	NO	
2	1÷5	Lower plenum internals	5	-	NO	
1	1÷5	Lower plenum internals	5	-	NO	



** Inspired by Fig. 3 of SAND2010-8249*

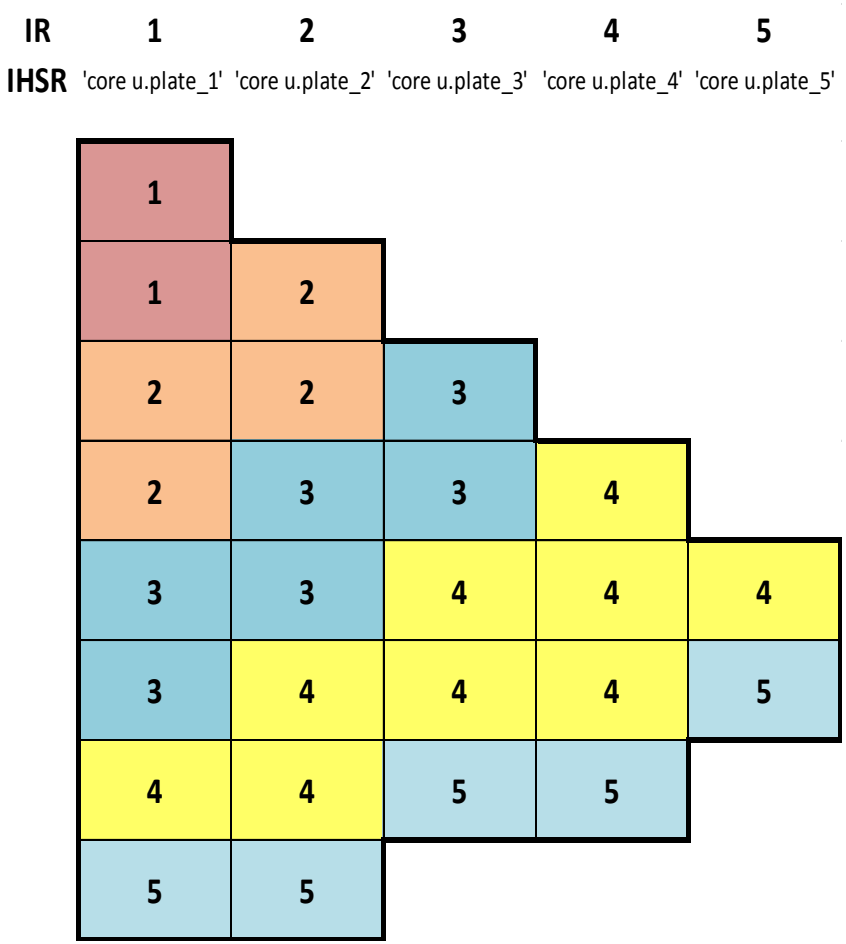
SUMMARY COR MODELING



IA	IR	COR_KFU	COR_KCL		COR_KSS	COR_KNS	
		XMFUUO	XMCLZR	XMCLIN	XMSSSS	XMNSSS	XMNSZR
19	1÷5	-	Cladding	Grid spacers	Top nozzle	CR cladding	CRGT / IT
18	1÷5	UO_2	Cladding	Grid spacers	-	CR cladding	CRGT / IT
17	1÷5	UO_2	Cladding	Grid spacers	-	CR cladding	CRGT / IT
16	1÷5	UO_2	Cladding	Grid spacers	-	CR cladding	CRGT / IT
15	1÷5	UO_2	Cladding	Grid spacers	-	CR cladding	CRGT / IT
14	1÷5	UO_2	Cladding	Grid spacers	-	CR cladding	CRGT / IT
13	1÷5	UO_2	Cladding	Grid spacers	-	CR cladding	CRGT / IT
12	1÷5	UO_2	Cladding	Grid spacers	-	CR cladding	CRGT / IT
11	1÷5	UO_2	Cladding	Grid spacers	-	CR cladding	CRGT / IT
10	1÷5	UO_2	Cladding	Grid spacers	-	CR cladding	CRGT / IT
9	1÷5	UO_2	Cladding	Grid spacers	-	CR cladding	CRGT / IT
8	1÷5	UO_2	Cladding	Grid spacers	-	CR cladding	CRGT / IT
7	1÷5	UO_2	Cladding	Grid spacers	-	CR cladding	CRGT / IT
6	1÷5	-	Cladding	-	Lower nozzle, debris grid	CR cladding	CRGT / IT
5	1÷5	-	-	-	Lower core plate	-	-
4	1÷5	-	-	-	Core support internals	-	-
3	1÷5	-	-	-	Core support plate	-	-
2	1÷5	-	-	-	-	LP internals	-
1	1÷5	-	-	-	-	LP internals	-

** Inspired by Fig. 3 of SAND2010-8249*

SUMMARY COR MODELING



** Similar to Fig. 4-3 of NUREG/CR-7110 vol.2*

- 5 radial rings (IR1÷5)
- 1 additional ring for downcomer (IR6)

STEADY STATE RESULTS

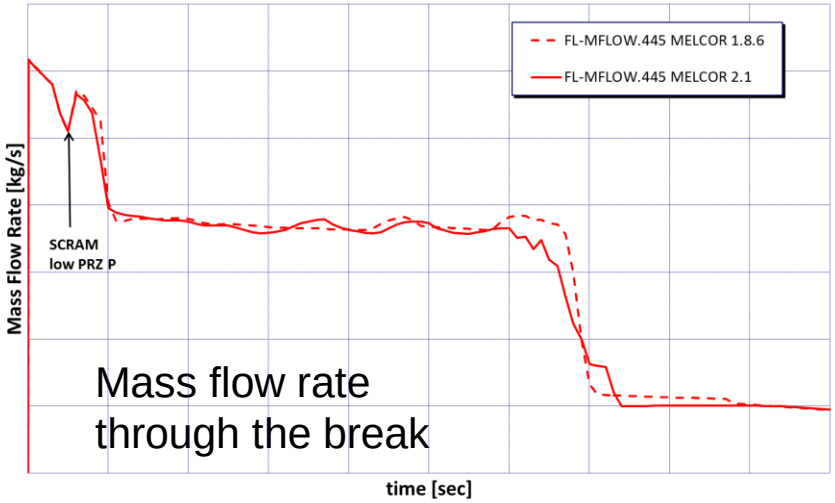
- The difference % respect to the plant nominal operating value is calculated as the ratio: |reference value – calculated value| / |reference value|
- Check of the steadiness of the steady state (qualitatively, from figures)
- Other quantities are checked and compared with plant data and the results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

Comparison also with results of CATHARE and RELAP

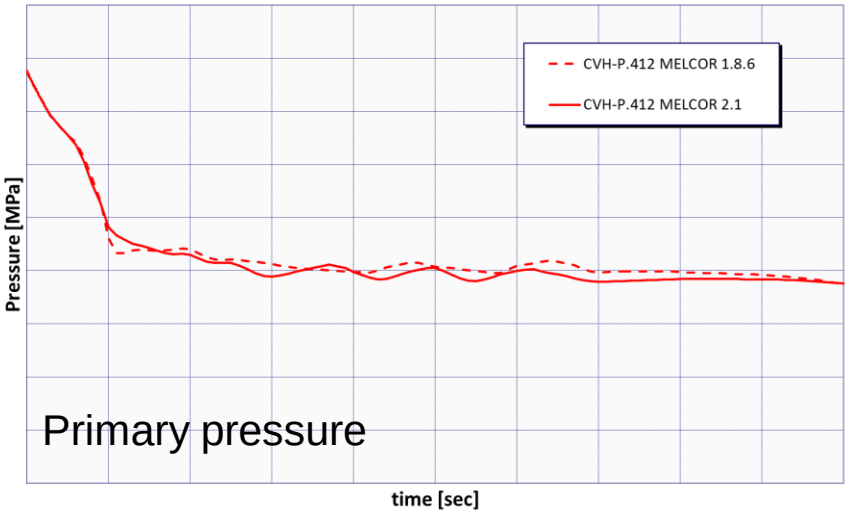
Parameter	Difference %
Primary System	
Core power	*Imposed*
Primary pressure (PRZ)	*<1*
PRZ level	*<1*
Temperature Cold-Leg	*<1*
Temperature Hot-Leg	*<1*
Temperature average	*<1*
ΔT HL-CL	*<5*
Mass flow rate (loops)	*<1*
Bypass core	*<1*
Secondary System	
Temperature FW	*Imposed*
SG level	*<5*
SG pressure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

No noticeable differences MELCOR 1.8.6–MELCOR 2.1

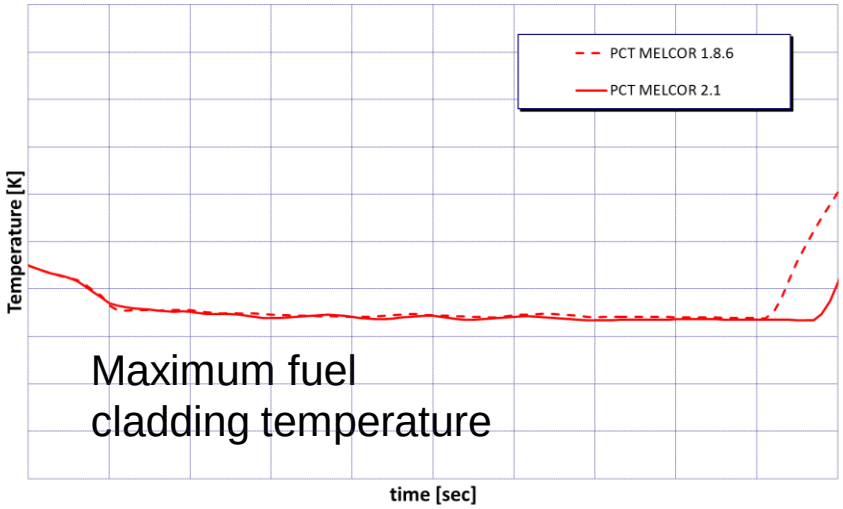
TRANSIENT RESULTS: IB-LOCA



Mass flow rate through the break



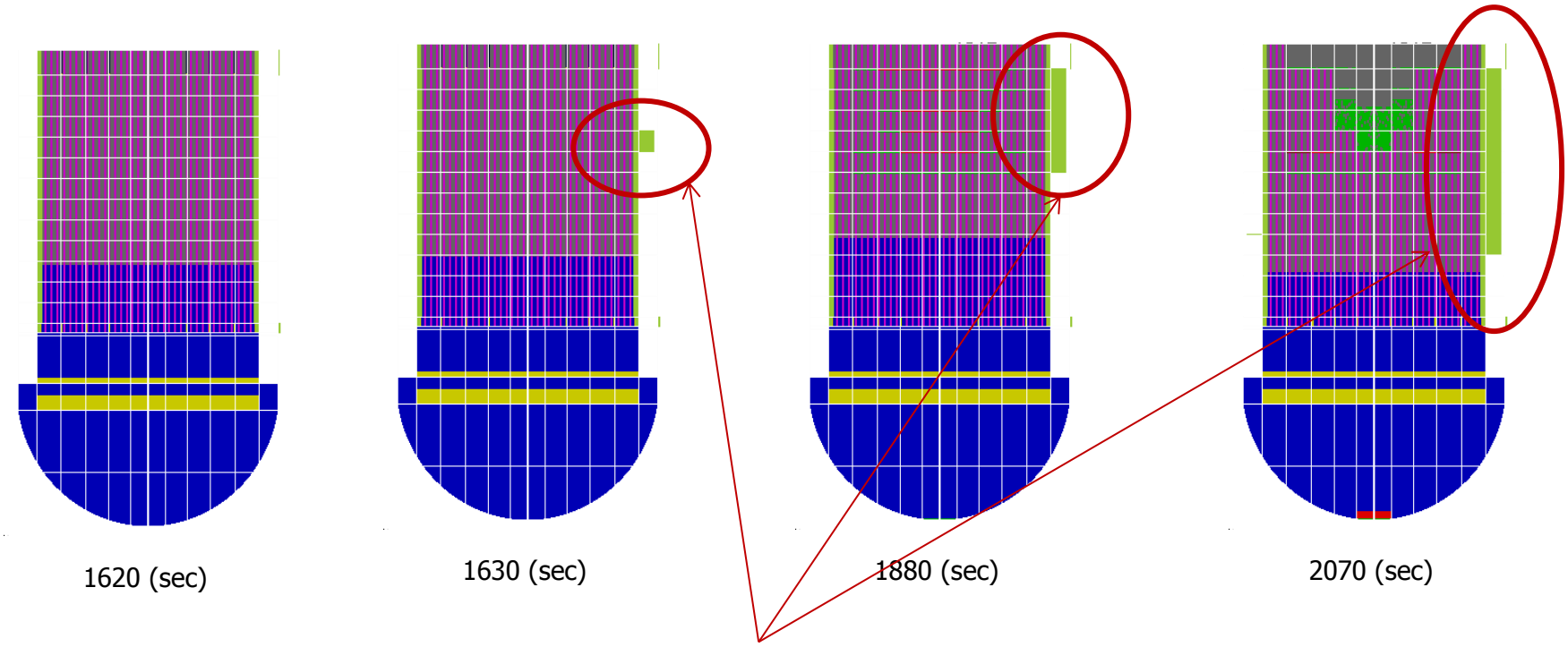
Primary pressure



Maximum fuel cladding temperature

- IB-LOCA HL loop with PRZ
- Break equivalent diameter: 7.5 cm
- Break opening time: t=0s
- 3 accumulators, 1 for each CL
- HPSI and LPSI fail
- FW and MCP stop at SCRAM
- AFW not available

TRANSIENT RESULTS: IB-LOCA



- What appeared with the modeling of the SH in COR package
  - MELCOR 2.1 results, PTFread version 1.8.6
  - IR6: additional ring for downcomer

SH

DCH MODELING AND CONVERSION

- Plant and Cycle specific ORIGEN results kindly provided by the Utility
  - (by means of) MELCOR 1.8.6 input deck
    - Initial mass and decay heat (per unit mass) as function of time
    - Axial and radial power profiles
- Conversion 1.8.6-2.1 by means of SNAP
  - Only DCH input replaced after conversion (*conversion errors already corrected for the other parts of the input deck*)
  - No error messages in the output after conversion for the selected part

DCH MODELING AND CONVERSION

MELCOR 2.1

- DCH
  - …
  - **DCH_EL** Element Name and Time, Decay Heat Data
  - Table *decay heat:* not needed

- COR
  - Table *prompt power:* needed
  - Radial (COR_RP frpow) and axial (COR_ZP fzpow) power profiles are optional
  - ***Where to input radial and axial power profiles, to reproduce reactor data?***

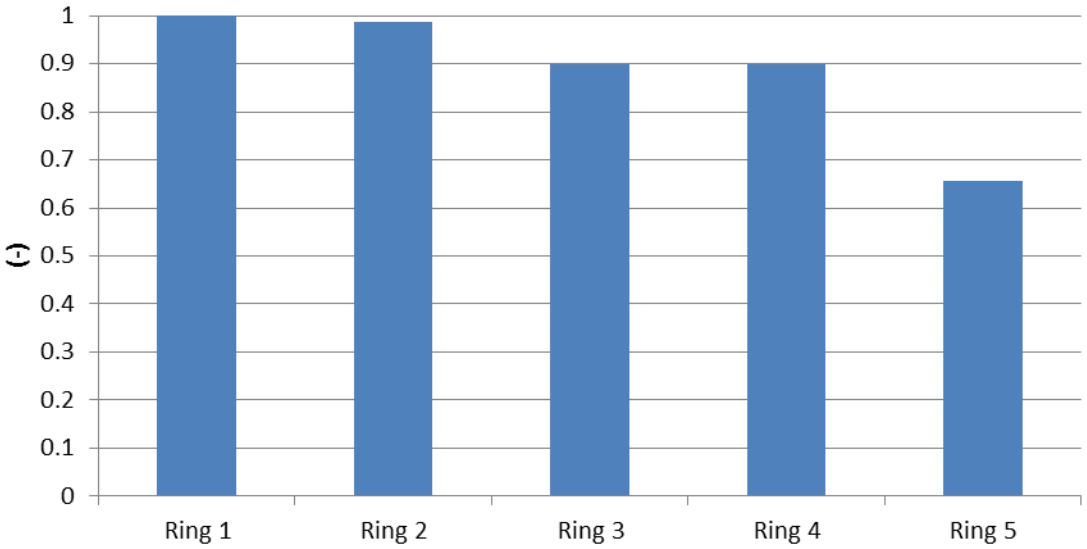
RN MODELING

- RN input
  - Axial and radial fractions to match the expected axial and radial power profiles
  - **RN1_FPN** Initial Core Fuel and Cavity Radionuclide Inventories
    - **RINP1**: axial node multiplier
    - **RINP2**: radial node multiplier

- ***How to verify that the quantities introduced in the input file are correctly implemented?***

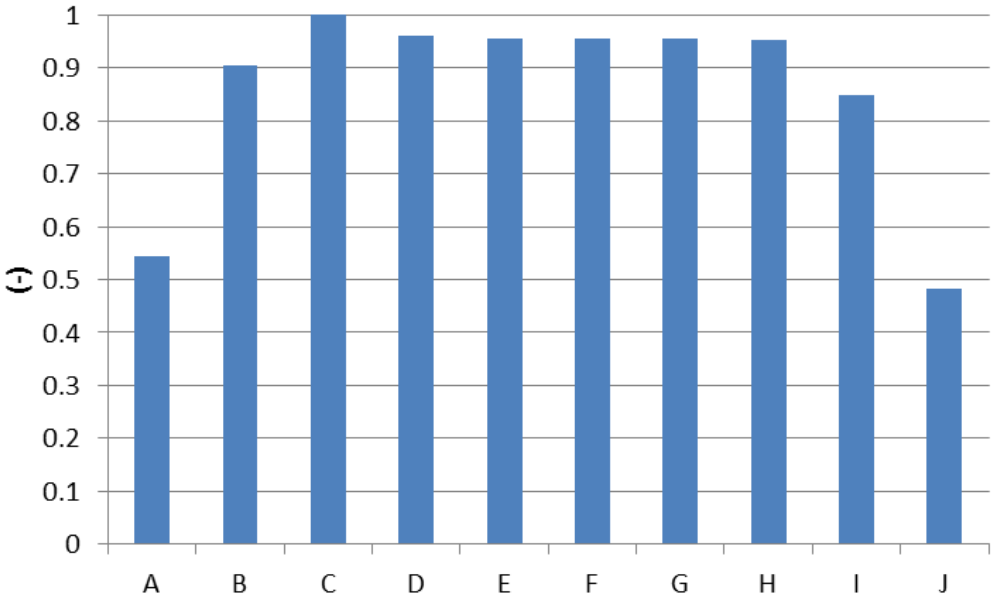
VERIFICATION

- Radial power / FA
  - From output file & Microsoft Excel



VERIFICATION

- Axial power / ring
  - From output file & Microsoft Excel



FEEDBACK

- Main issues after conversion
  - ALL THE COMMENTS disappear
  - Subdivision of the input deck in separated files is kept BUT input records REORGANIZED
  - NAME-approach e.g. CF/FL…, in place of numbers
- MELCOR 1.8.6 input deck used for
  - COMMENTS (still to be transferred)
  - NAME-approach (not much attention for development of input deck 1.8.6, more familiar with the numbers)
- SNAP is really useful and user friendly tool for the conversion
- Verification of input deck after conversion is needed!

FEEDBACK

- No noticeable differences MELCOR 1.8.6-2.1 steady state results
- Differences in transient results might be due to the differences in the input decks (*the input decks are not identical*)
  - improvements/corrections only in MELCOR 2.1 input deck version
  - limited number of comparisons
- '*Diagnostics and Error Messages*' sections in UG very helpful
- Further training/guides on SNAP post processing might be useful
- Further model development (and analysis) will only continue with MELCOR 2.1
  - too complex to keep two input decks updated
  - not too complex to make modifications, as 1.8.6 version was developed on Microsoft Excel spreadsheets

Current application of MELCOR 2.1 code at Bel V

CONCLUSIVE REMARKS

CONCLUSIVE REMARKS

- 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 3-loops PWR has been developed for MELCOR 1.8.6 and converted in MELCOR 2.1
  - The model is suitable for steady-state and transients calculations
    - Comparisons against plant nominal conditions and code-to-code are performed for steady-state results (when available, mainly with results of CATHARE)
    - Transient analyses are ongoing on selected transients (including comparisons against CATHARE results, when available)
  - Verification of input deck after conversion is needed!
- Further model development will only continue with MELCOR 2.1 code version

THANKS FOR YOUR ATTENTION!

QUESTIONS?