MELCOR 2.1 model for VVER 1000 (V320) spent fuel pool – issues identified

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The 7th Meeting of "European MELCOR User Group"

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Reliability, Safety and Management
Engineering and Software Development Services

OUTLINE

o   Objectives of the presentation

o   SFP of VVER-1000 (V320) – layout

o   MELCOR 2.1 model of SFP for VVER-1000 (V320)

o   Initial conditions for the SFP

o   Scenario considered and boundary conditions

o   Results

o   MELCOR limitations

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Objectives of the presentation

The current presentation has the following purposes:

o To summarize the most important results for a scenario (TBO in combination with LOCA from the SFP (TG21B02) bottom) with late SFP coolant injection

o To discuss some limitations in MELCOR 2.1 and to present recommendations for future code versions

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SFP of VVER-1000 (V320) – layout (part 1)

Reactor Pit

Revision Shafts
Pool TG21B05
Pool TG21B06

Transportation cask pit
Pool TG21B04

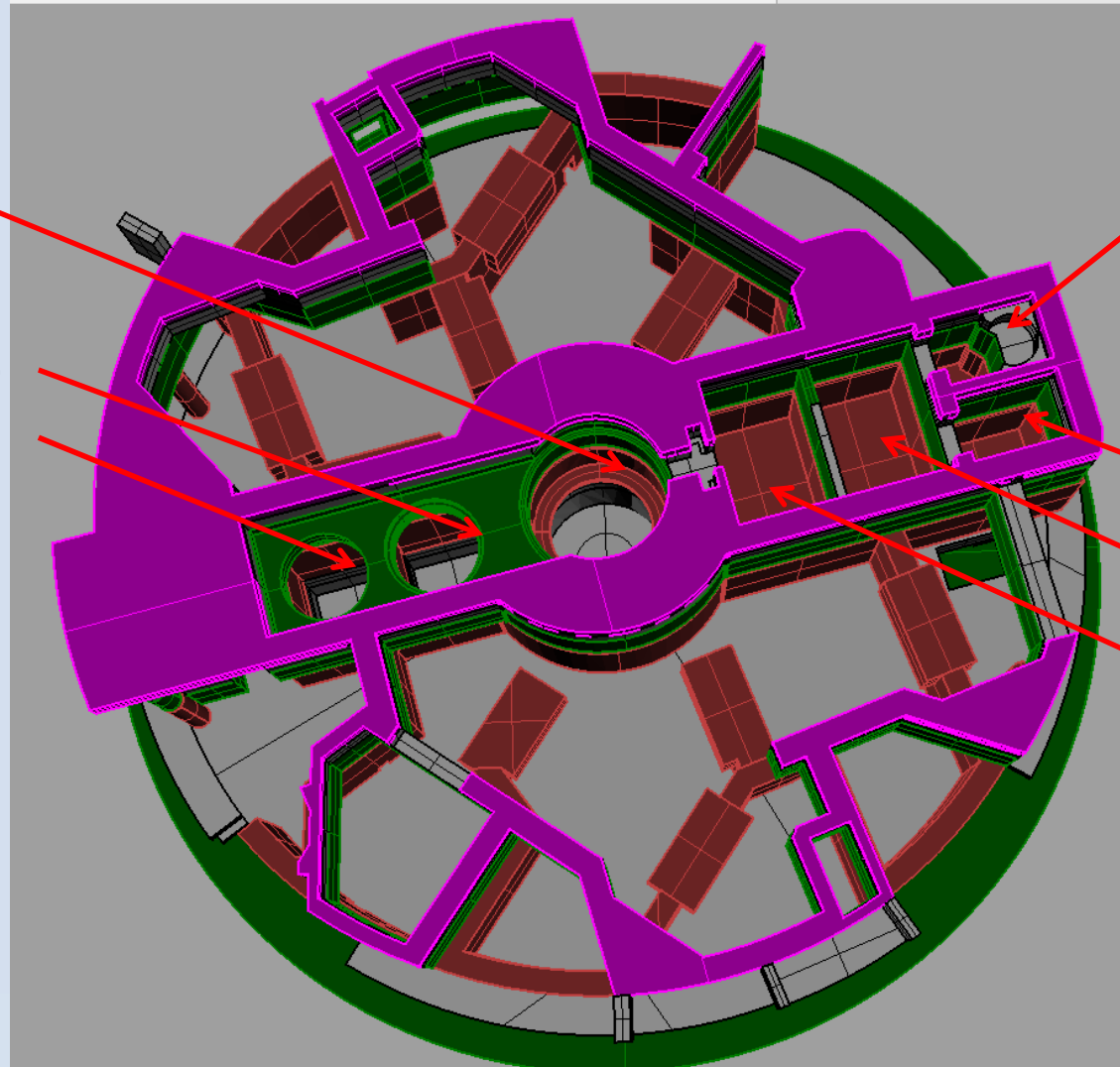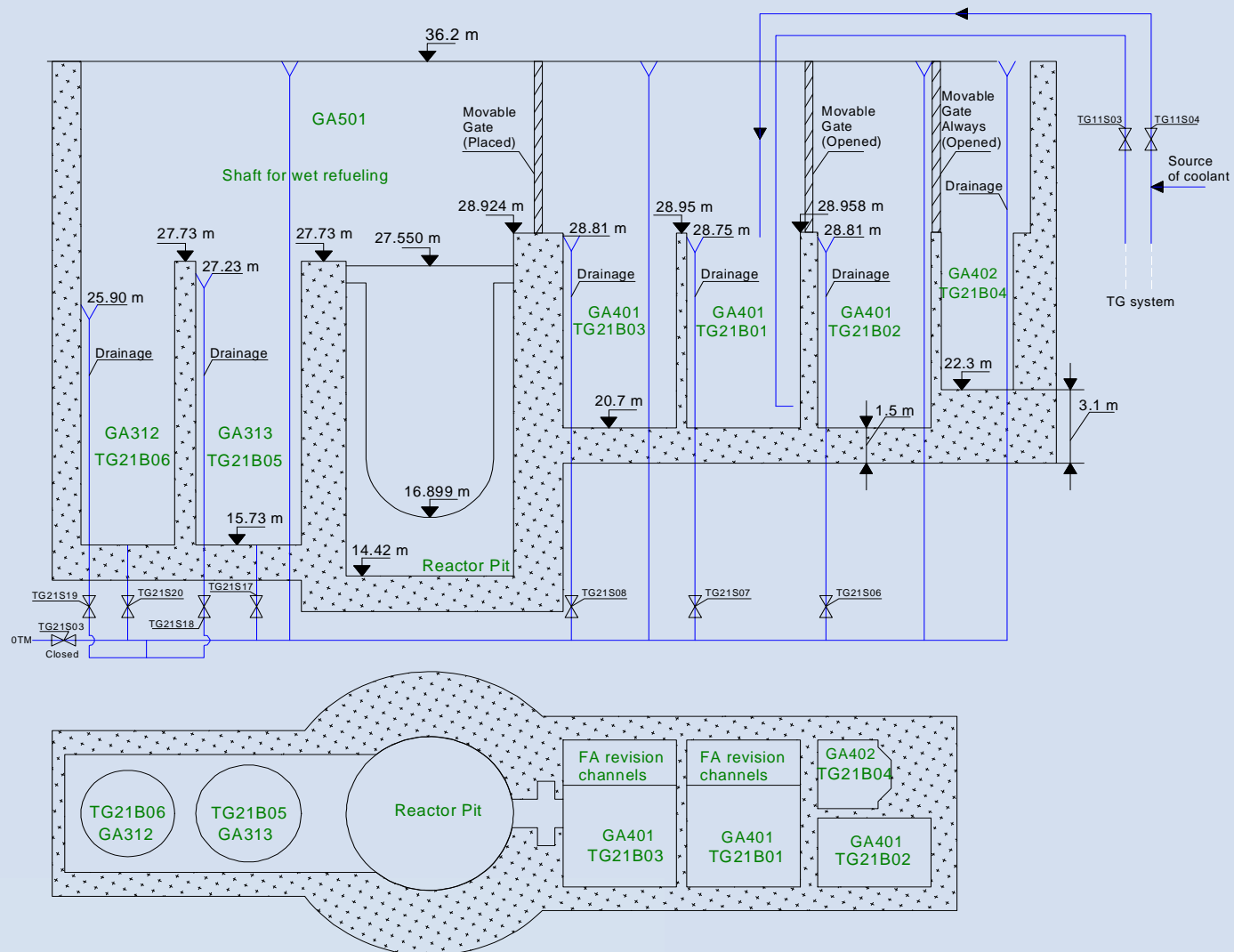Spent fuel pools

Pool TG21B02

Pool TG21B01

Pool TG21B03

SFP positioning in the containment

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SFP of VVER-1000 (V320) – layout (part 2)

SFP views and elevations

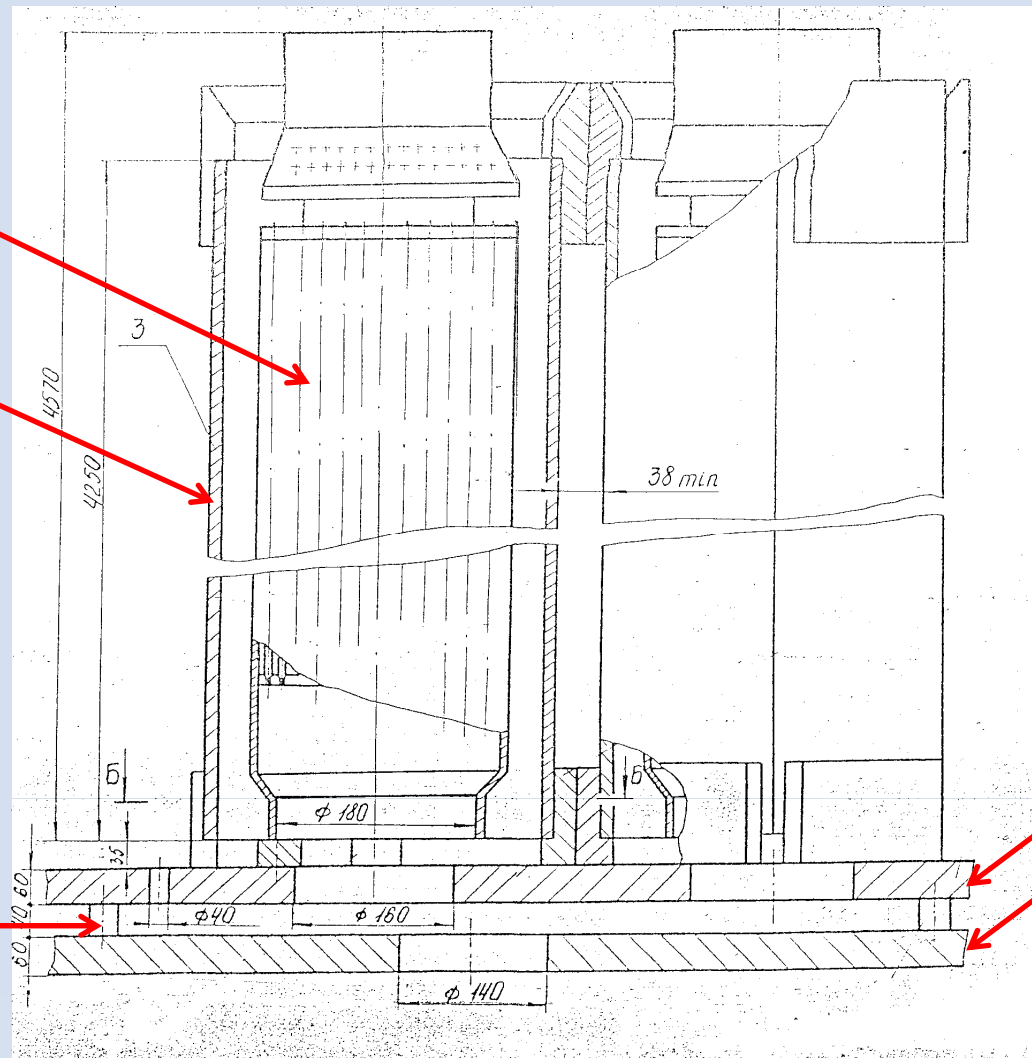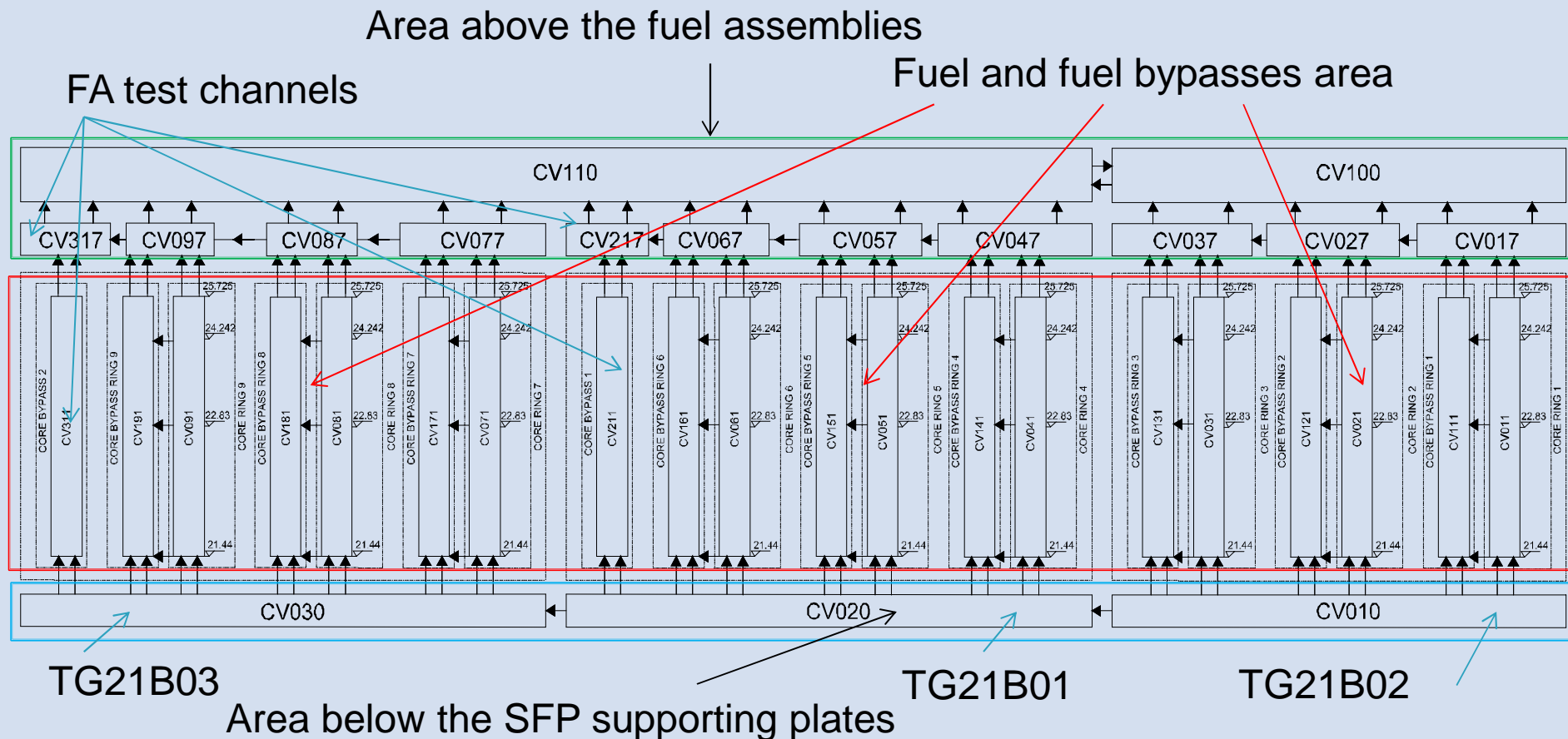# SFP of VVER-1000 (V320) – layout (part 3)

Fuel Assembly

SFP Rack

Supports

Upper supporting plate

Lower supporting plate

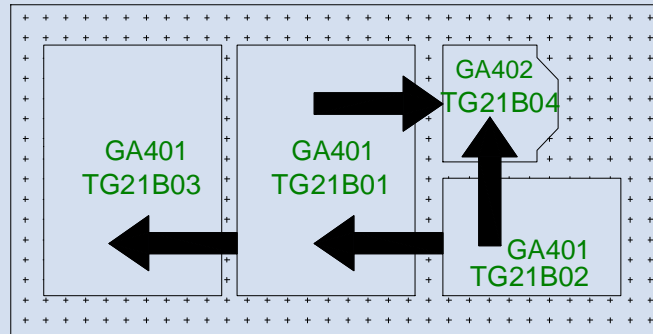SFP Rack for VVER-1000 (V320)

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MELCOR 2.1 model of SFP for VVER-1000 (V320) – part 1

Area above the fuel assemblies

FA test channels

Fuel and fuel bypasses area

TG21B03

TG21B01

TG21B02

Area below the SFP supporting plates

VVER 1000 (V320) spent fuel pools (three pools with FA are separately modeled) – **9** radial rings for the COR package, **36 CV**

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MELCOR 2.1 model of SFP for VVER-1000 (V320) – part 2

GA402
TG21B04

GA401
TG21B03

GA401
TG21B01

GA401
TG21B02

GA401
TG21B03

TG21B01

GA401
TG21B02

GA402
TG21B04

Cavity 40

Cavity 30

Cavity 10

Cavity 20

22.3 m

20.7 m

1.5 m

3.1 m

19.2 m

Possible ways for
corium transport

Cavity 50

GA310

GA302

GA308

TF (tubes)
penetrations

13.4 m

10.5 m

Cavity 60

A337

6.6 m

Possible drainage of corium between
TG21B01-TG21B02 and between
TG21B03-TG21B01 and between
TG21B04 to TG21B02 is considered
in artificial way. When conditions for these
drainages are met then it is assumed that the
drained corium is transferred directly to Cavity 50.
This is due to the fact that the transfer of corium in
MELCOR 2.1 can be modeled only in one direction
and the real transfer between for example
TG21B01-TG21B02 cannot be modeled in MELCOR 2.1
if the initial transfer direction in CAV package is defined in
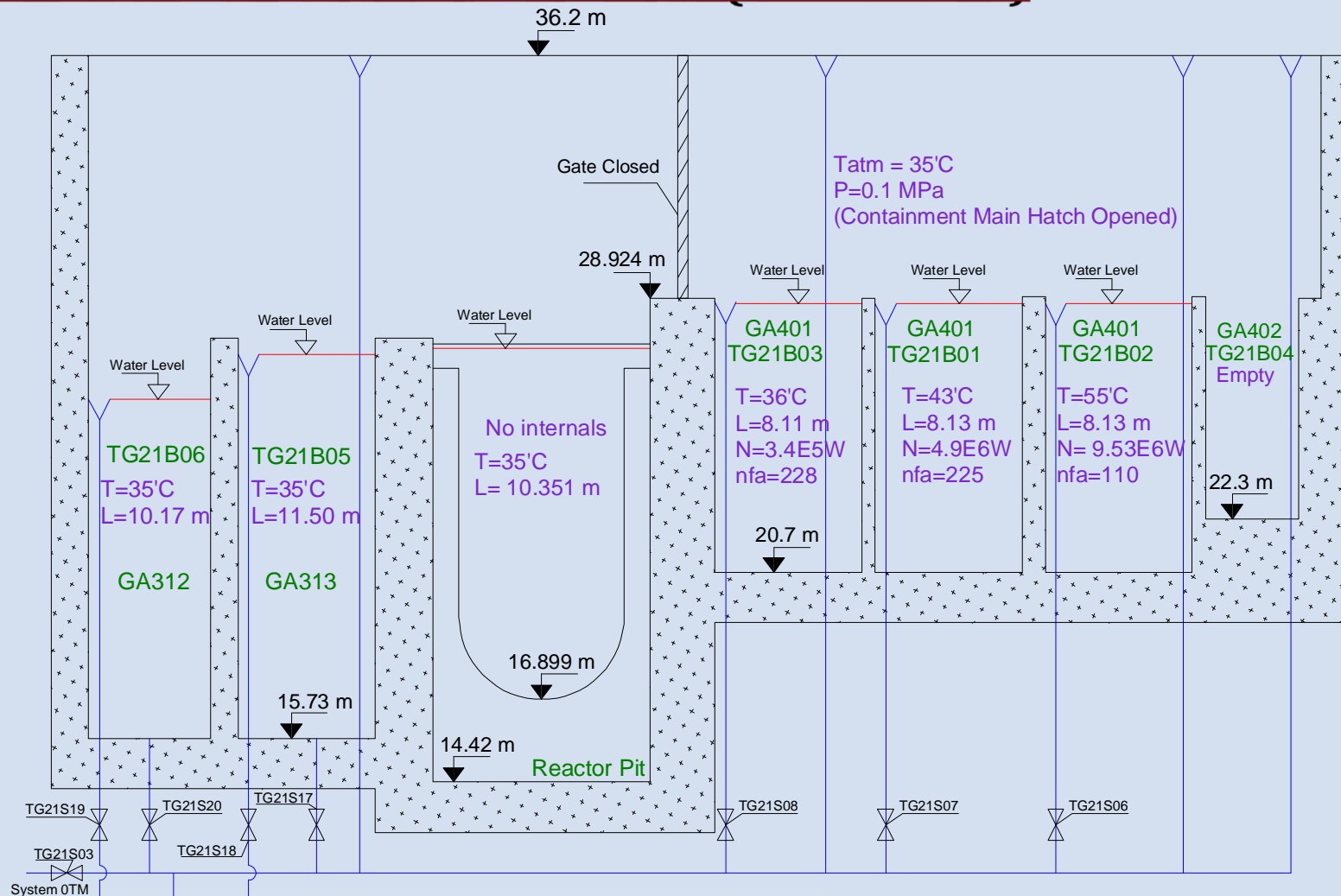the opposite direction

Fukushima parametric model
for corium spreading is used (modified for VVER-1000 SFP)
(coded by MELCOR 2.1 control functions)
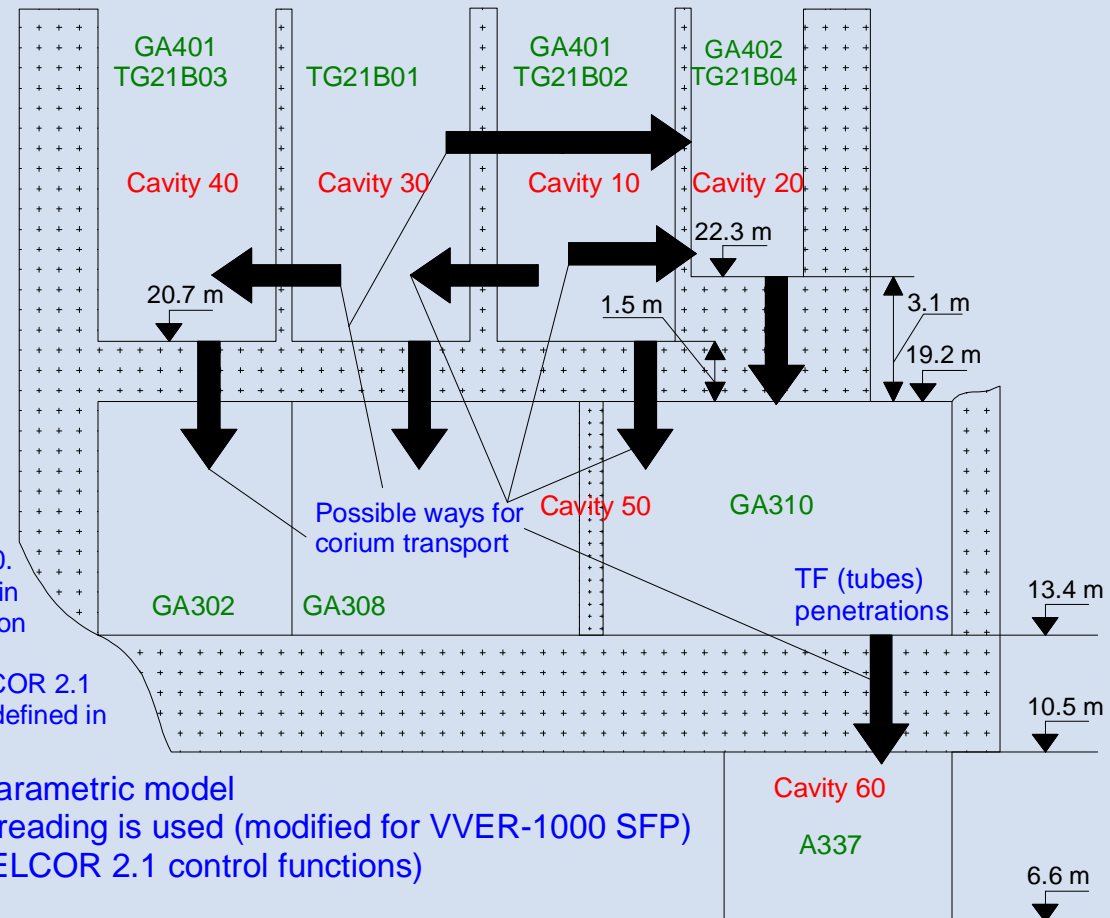
CAV package nodalization (**6 cavities modeled – all
possible ways for corium transfer are considered**)

Scenario considered and boundary conditions

Scenario	TBO	LOCA from TG21B02 (5 m³/h)	CONT isolation (2h after 70'C in SFP)	CONT venting system	SFP Injection	SFP Injection onset (late injection)	SFP injection mass flow rate, m³/h	SFP injection sequence
Scenario 4	Yes	Yes	Manual	No	Yes	at MCCI onset	45	TG discharge -> TG21B01 -> TG21B02

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Results – Summary information

Scenario	TBO	LOCA from B02 (5 m³/h)	Containment pressure, MPa Acceptance Criterion: 0.49	Containment temperature, degC Acceptance Criterion: 150	H2 max vol. conc. % Acceptance Criterion: H2/O2/Steam =4/5/55	CONT Failure	SFP inj. success	H2/CO total mass, kg	Time for containment failure, h
Scenario 4	Yes	Yes	0.182	94	3.22/13/29	YES	NO	563/7397	19:14

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Results – Corium transport scheme
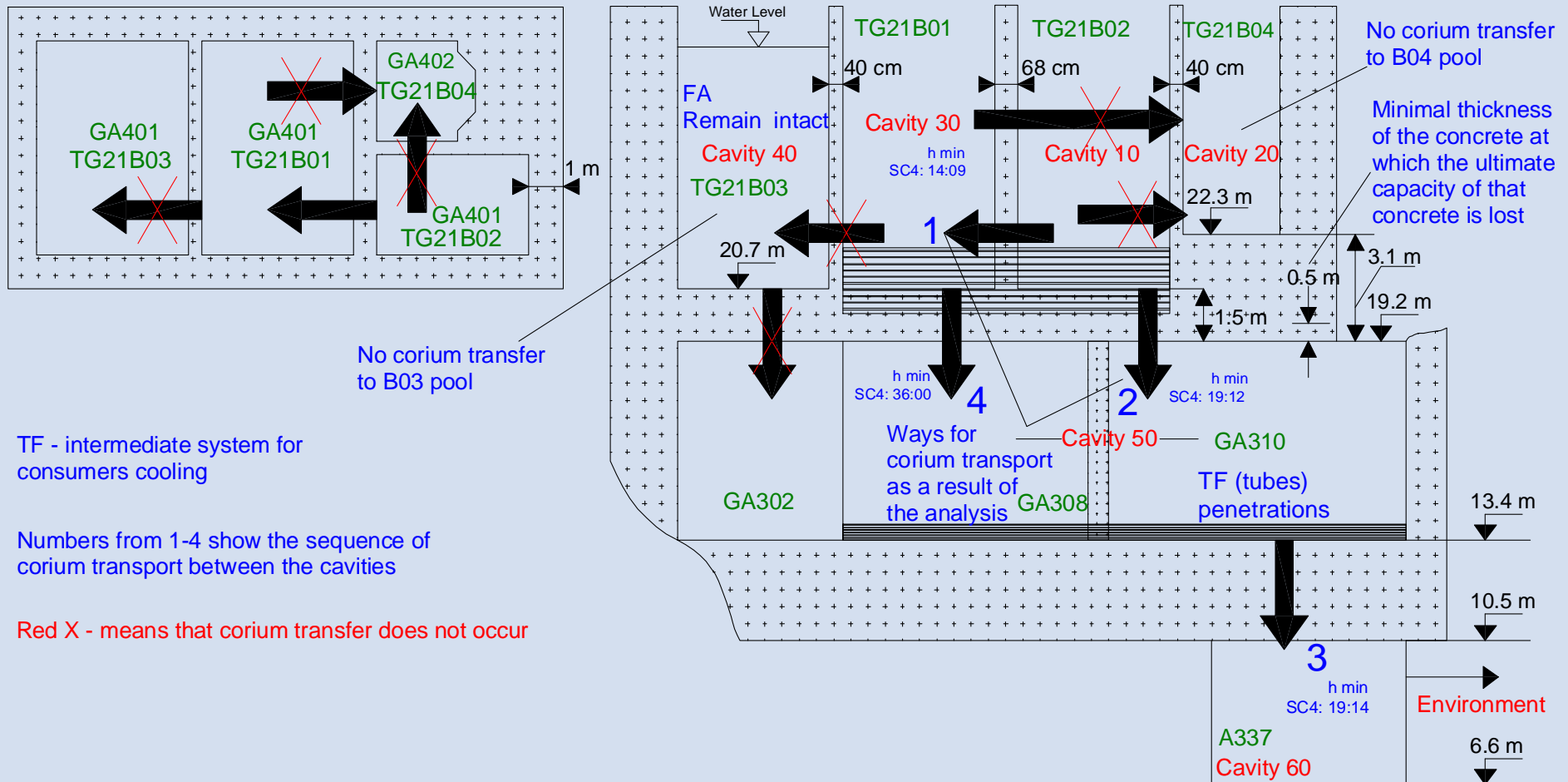
Corium transport sequences for Scenario 4: SFP injection at MCCI onset (not successful)

TF - intermediate system for consumers cooling

Numbers from 1-4 show the sequence of corium transport between the cavities

Red X - means that corium transfer does not occur

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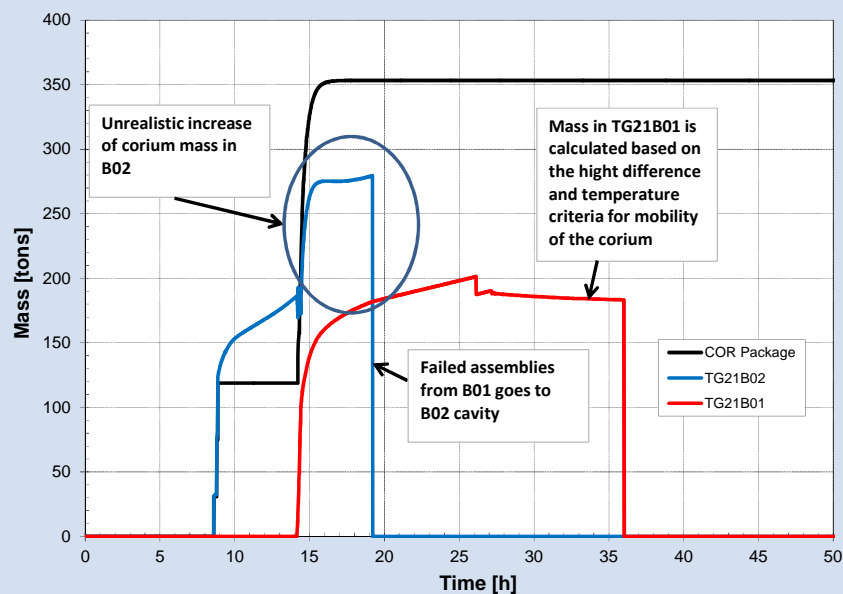*Brussels, Belgium, March 17-18, 2015*

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MELCOR limitations

o Use of SC1020 for radial relocation model switch off up to the moment of inner SFP walls failure - when the walls between SFP pools are not damaged, this coefficient have to be switch off. In this way the corium relocation between border core rings will not occur (wall between B02 and B01 – rings 3 and 4). It has to be switched on when the wall is ablated

o Why CHANNEL-BOX model is not permitted for SFP-BWR rack failure?

o Inability of the code to connect more than one cavity models to COR package – leads to unphysical corium behavior (thickness) in case of VVER type of SFP models

o Drainage of the corium from one to another cavity - one direction of corium spreading limits the corium relocation between SFP pools

o Lack of water ingression model – leads to high uncertainty in corium temperature prediction. The issue is still unresolved in subversion 6616 R2

In the last MELCOR 2.1 subversion WATINGR and ERUPT keywords are given only in the User Guide (NUREG/CR-6119, Vol. 1, Rev 3179), but they are not implemented in executable files. Code cannot initializes when these keywords are included in CAV_U record.
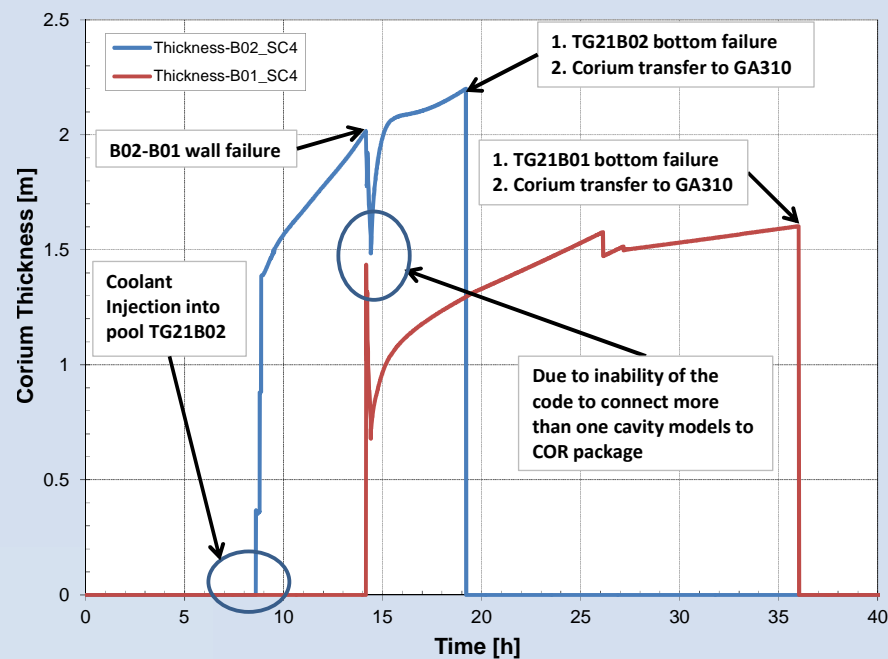
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MELCOR limitations (Cont'd)

The corium thickness increases rapidly and injected water in pool TG21B02 cannot cool down the corium even if water column above the corium is significant (corium cracks and water ingression modeling is not implemented in subversion 6616 R2)
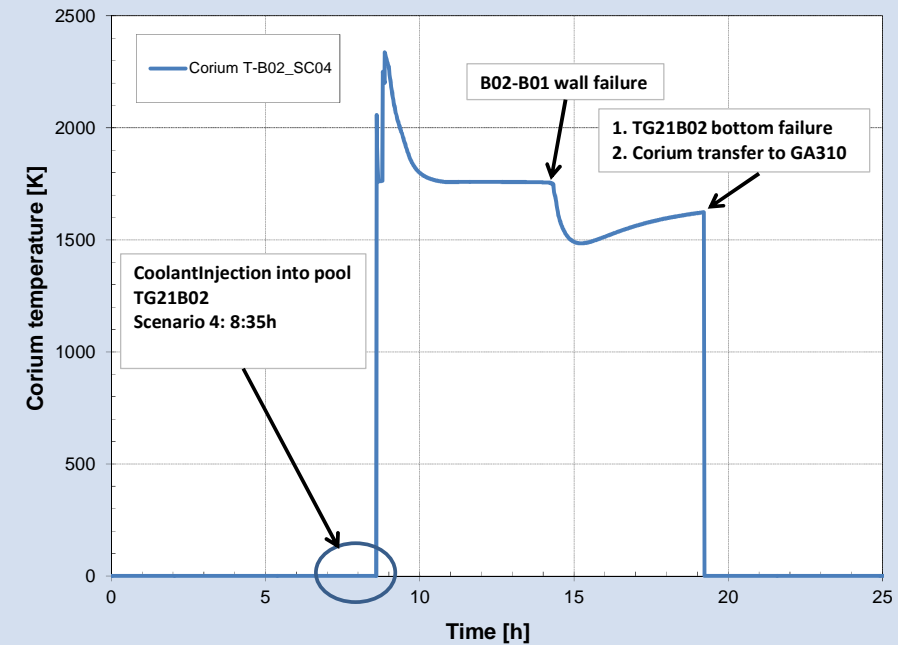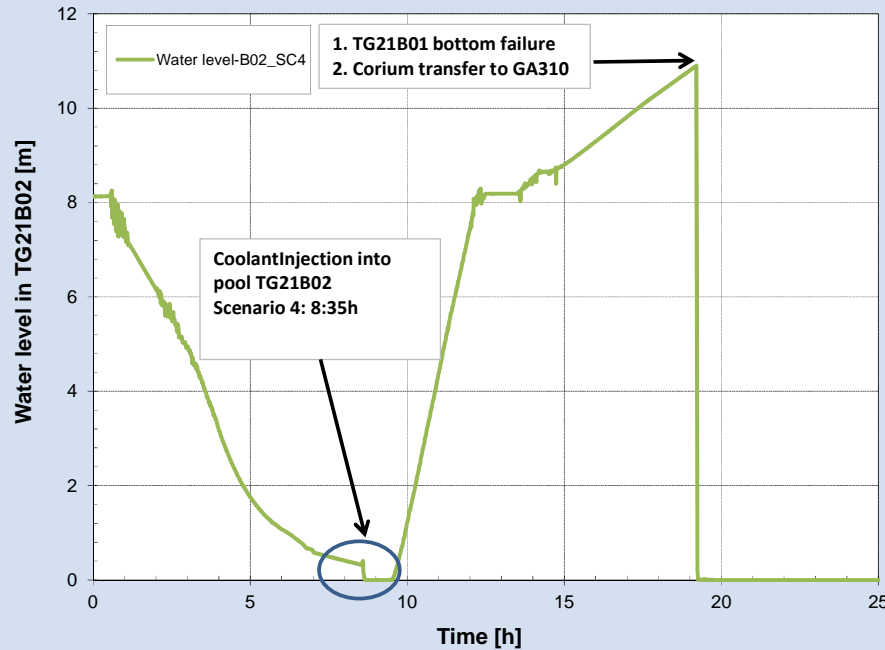
The behavior of corium masses is related to inability of simulate a two-way corium relocation in radial direction between pools B02 and B01. This leads to unrealistic corium mass distribution.

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MELCOR limitations (Cont'd)

The increase of injected water level and corium temperature in pool TG21B02 is also related to inability to use water ingression model. So corium cooling can only be done via heat transfer between corium and the available water above the corium

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MELCOR limitations (Cont'd)

When CALC option (corium layers mixing and separation rates from correlations) in CAV_U record is used then at the moment of cavity opening "Executive detected abort signal" is generated (Bug 1261 from Bugzilla). This issue is not resolved yet (at least CALC option does not work for our particular cases).

From the message file (subversion 6616 r1)

CAVITY SFP B02 WAKING UP

Listing written TIME= 3.08744E+04 CYCLE=   510709

Restart written   TIME =   3.087441E+04 CYCLE=   510709

Listing written TIME= 3.08986E+04 CYCLE=   511032

Restart written   TIME =   3.089861E+04 CYCLE=   511032

Calculation terminated by: Executive detected abort signal - see above for reason

TIME= 3.08986E+04 CYCLE= 511032 CPU = 8.29246E+04

From the external diagnostic file (subversion 6616 r1)

Warning message for cavity

 * * * CCHLAY * * *, AXIAL CONVERGENCE FAILURE. L,KOUNT,LOOPL,LOOPT = 4 51 26 26

 ********** POSSIBLE ERROR, EXECUTION CONTINUES

<Diagnostic Message> Time= 3.0899E+04 Dt= 1.0000E-12 Cycle= 511032 (CAV) L,C= 2,1266532

 Warning message for cavity

 * * * CCHLAY * * *, AXIAL SOLID CORE/LIQUID SURFACE WITH L,TS,TB,TL,TT = 1 2309.30850 2393.09171 1920.73626 4999.99848

 ********** POSSIBLE ERROR, EXECUTION CONTINUES

<Diagnostic Message> Time= 3.0899E+04 Dt= 1.0000E-12 Cycle= 511032 (CAV) L,C= 2,1266533

 Warning message for cavity

 * * * CCINTP * * *, CONVERGENCE FAILURE

 ********** POSSIBLE ERROR, EXECUTION CONTINUES

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