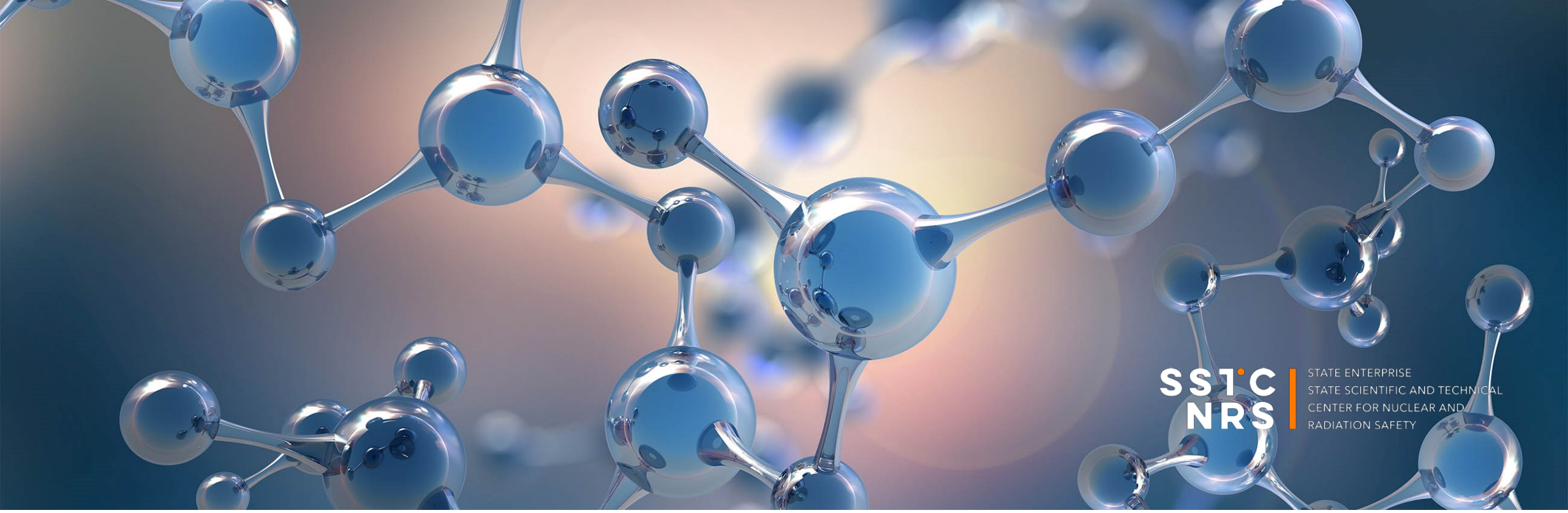

Use of MELCOR code for IVMR analysis. Code assessment and other issues

14th Meeting of the European MELCOR and MACCS User Group (EMUG)

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EMUG Meeting
Slovenia, April 12- 14, 2023

Contents

MELCOR application to IVMR of VVER-1000 (ver 21402)

SSTC NRS | STATE ENTERPRISE STATE SCIENTIFIC AND TECHNICAL CENTER FOR NUCLEAR AND RADIATION SAFETY

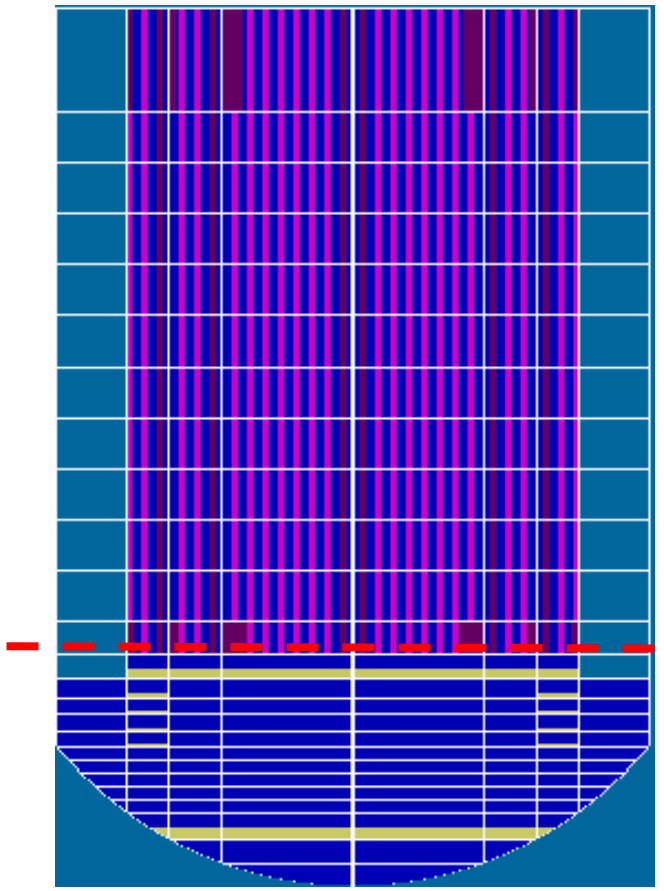
Issue 1. VVER-1000 IVMR. Not enough space in LP to accommodate all the melt

Description

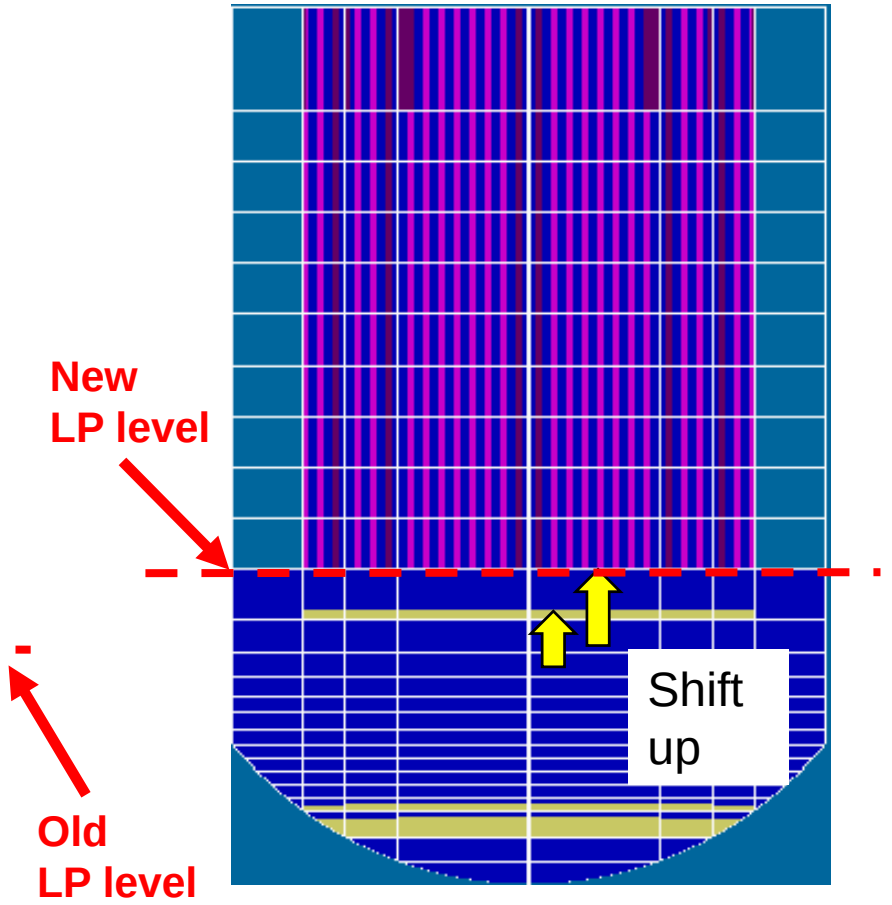
- Shallow LP for VVER-1000
- Large steel mass
- MP2 melt partially stays in core

Resolution

- Change of COR nodalization
- LP area shifted up
- Part of downcomer included in LP
- Fuel in the core is shifted up
- Core support plate up



Reactor nodalization before



Reactor nodalization after

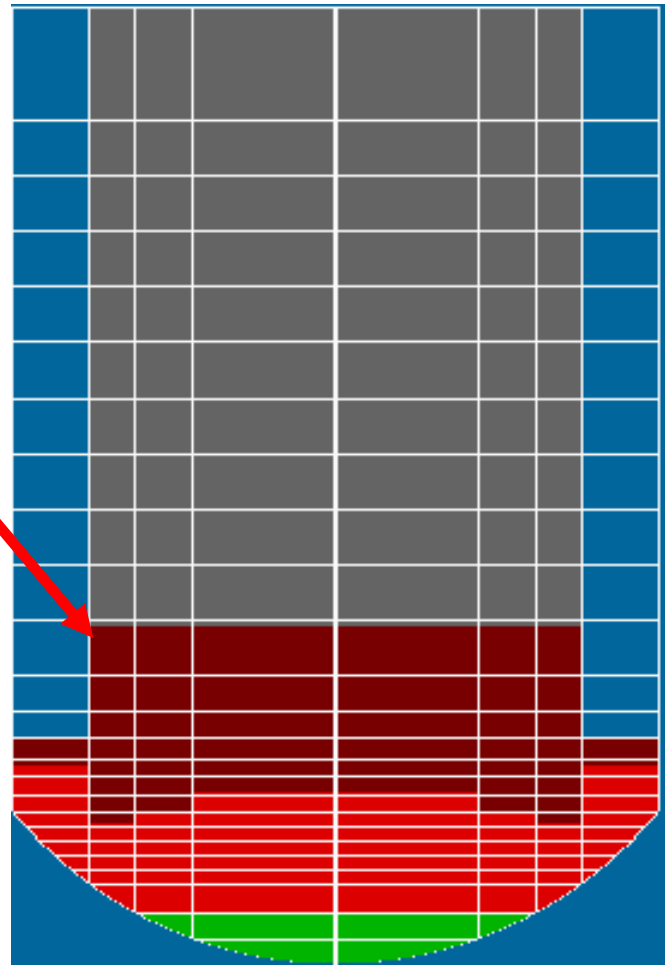
Issue 2. VVER-1000 IVMR. Not enough space in LP to accommodate all the melt

Results before

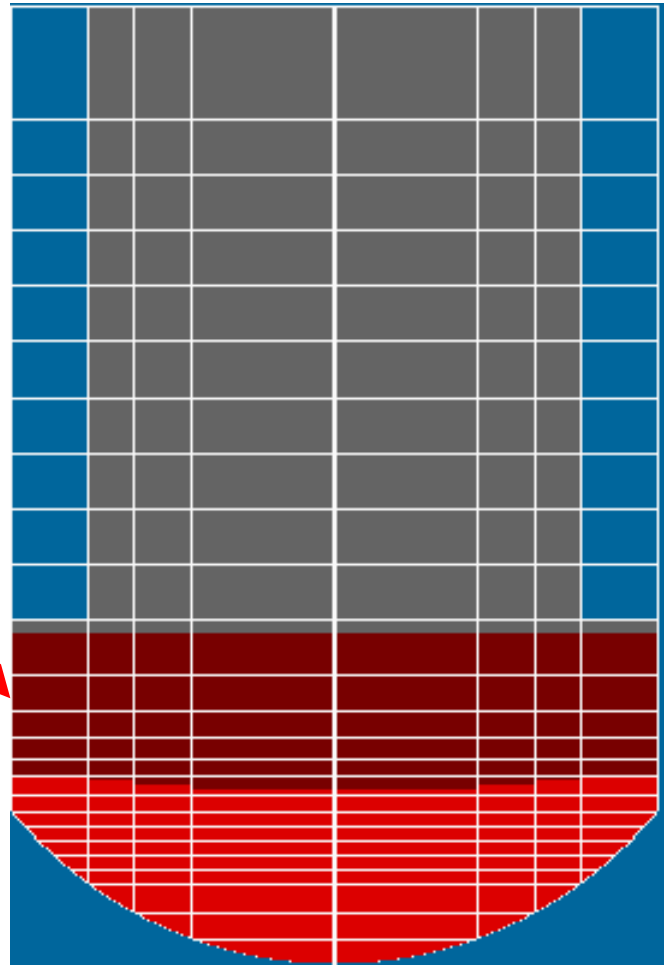
- MP2 in core overheating
- MP2 not contacting with vessel (partially)

Results after

- All MP1 and MP2 in LP area
- MP2 normally contacting vessel wall
- Thermal radiation is calculated OK



Reactor nodalization before



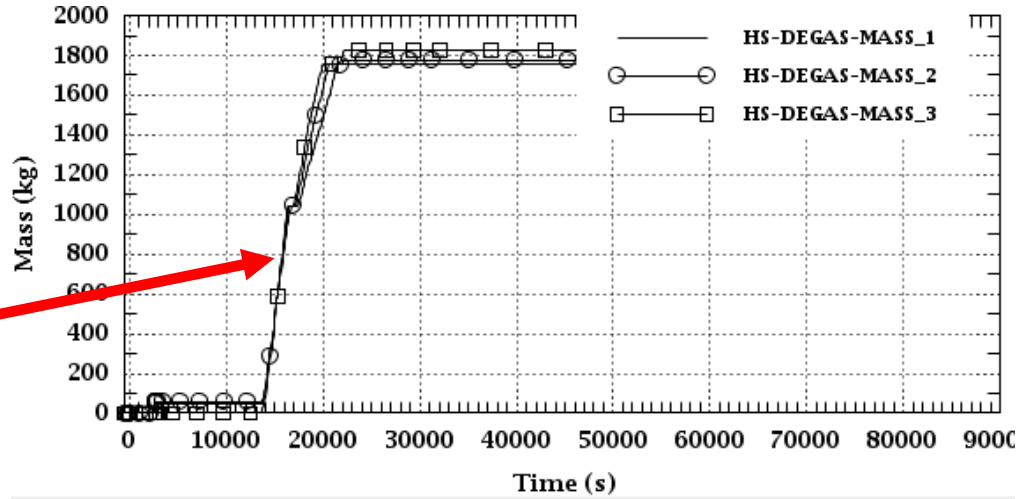
Reactor nodalization after

Issue 2. VVER-1000 IVMR. COR HS degassing influence on LP melt

Description

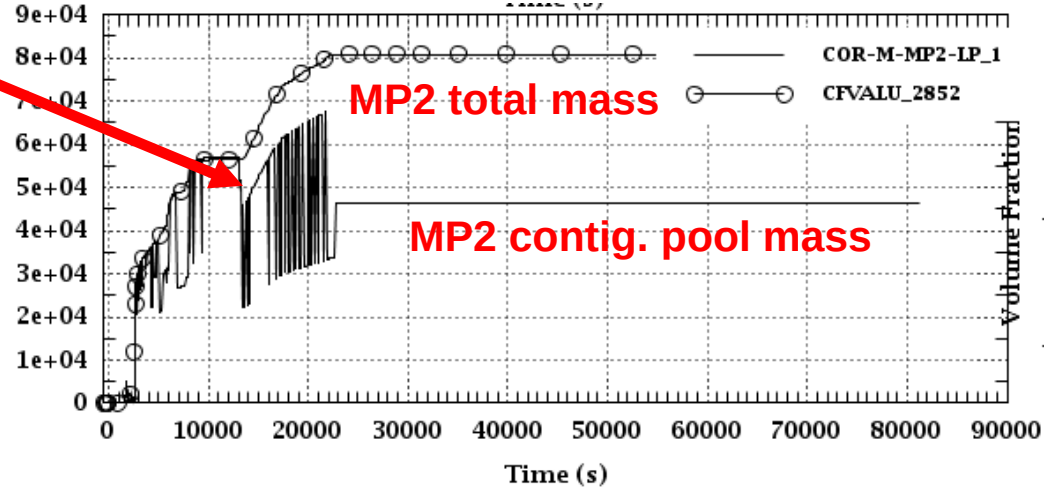
- Appears when HS degassing with MP2 in LP
- After HS degassing the MP2 contiguous pool in LP is **LESS** than total melted metal mass in LP!!!
- This excludes part of LP MP2 pool from convection and makes **WRONG** heat exchange to reactor vessel !!!

Degassing in process



Degassing mass

MP2 contiguous pool mass changed

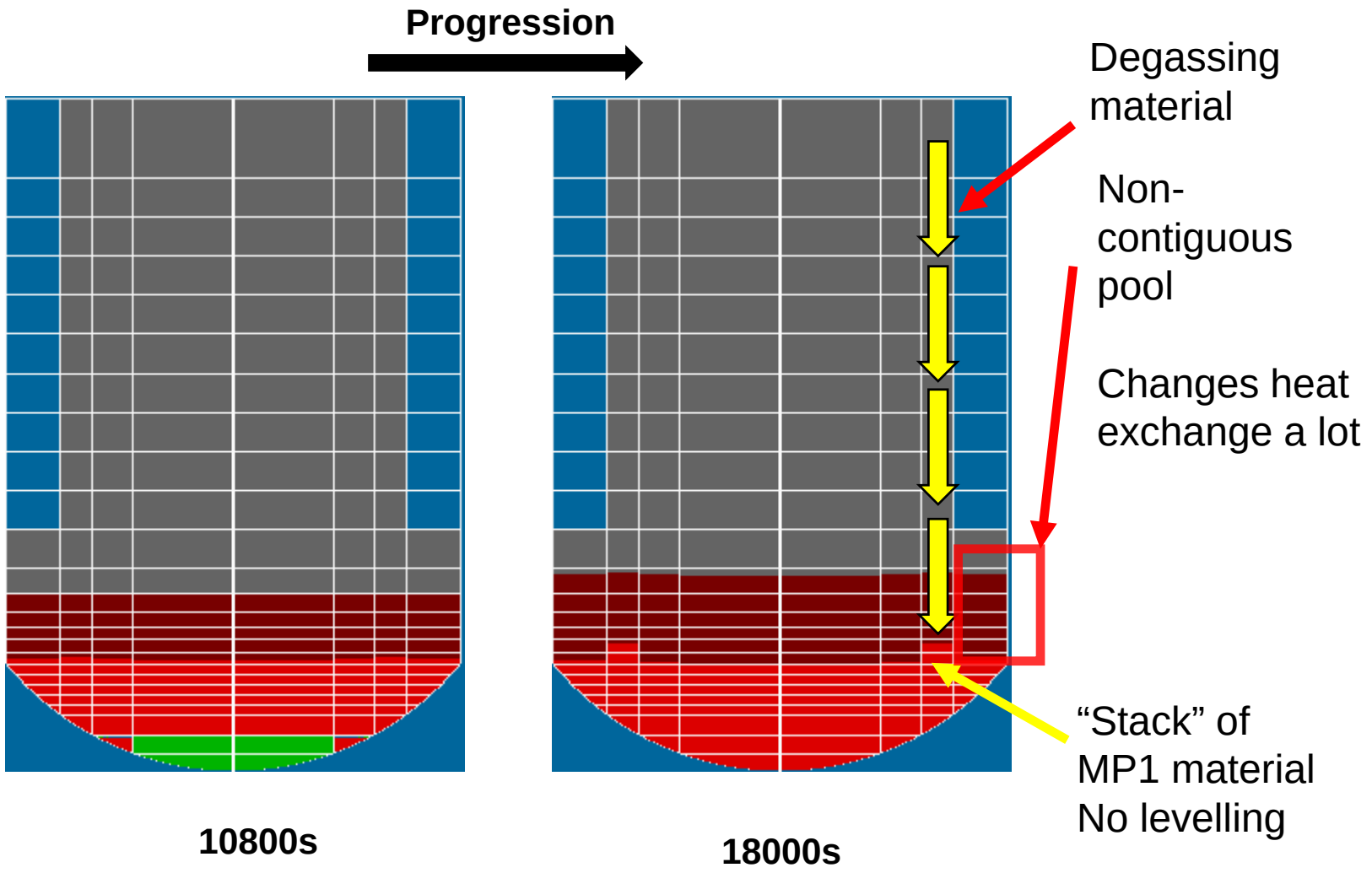


Mass of melted metal and MP2 contig. pool in LP

Issue 2. VVER-1000 IVMR. COR HS degassing influence on LP melt

Description

- HS degassing material falls to MP2 pool
- Part of oxides from degassing is “stacked” in MP1 without leveling
- Periferal MP2 pool is switched to “non-contiguos” and excluded from convection
- Possible code deficiency in MP1 leveling and MP2 contiguous pool mass definition

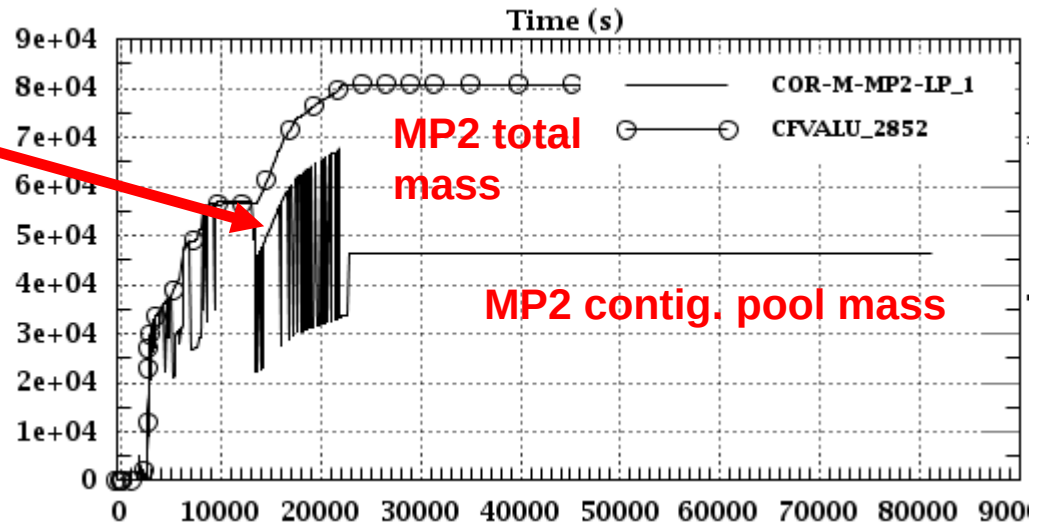


Issue 2. VVER-1000 IVMR. COR HS degassing influence on LP melt

Resolution

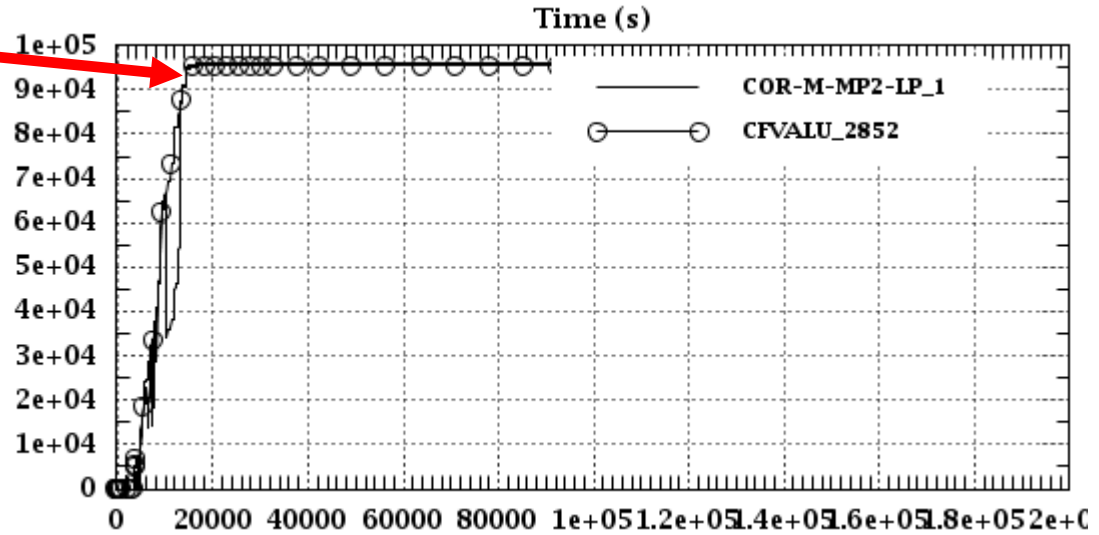
- Turn OFF HS degassing
- Extra metal as non-support structures in LP
- NO “falling” material from core to LP after LP molten pools formation!!!
- The MP2 contiguous pool mass **should be EQUAL** to calculated moltet metal mass!!!

With HS degassing (**Not good**)



Mass of melted metal and MP2 contig. pool in LP

No HS degassing (**good**)



Mass of melted metal and MP2 contig. pool in LP

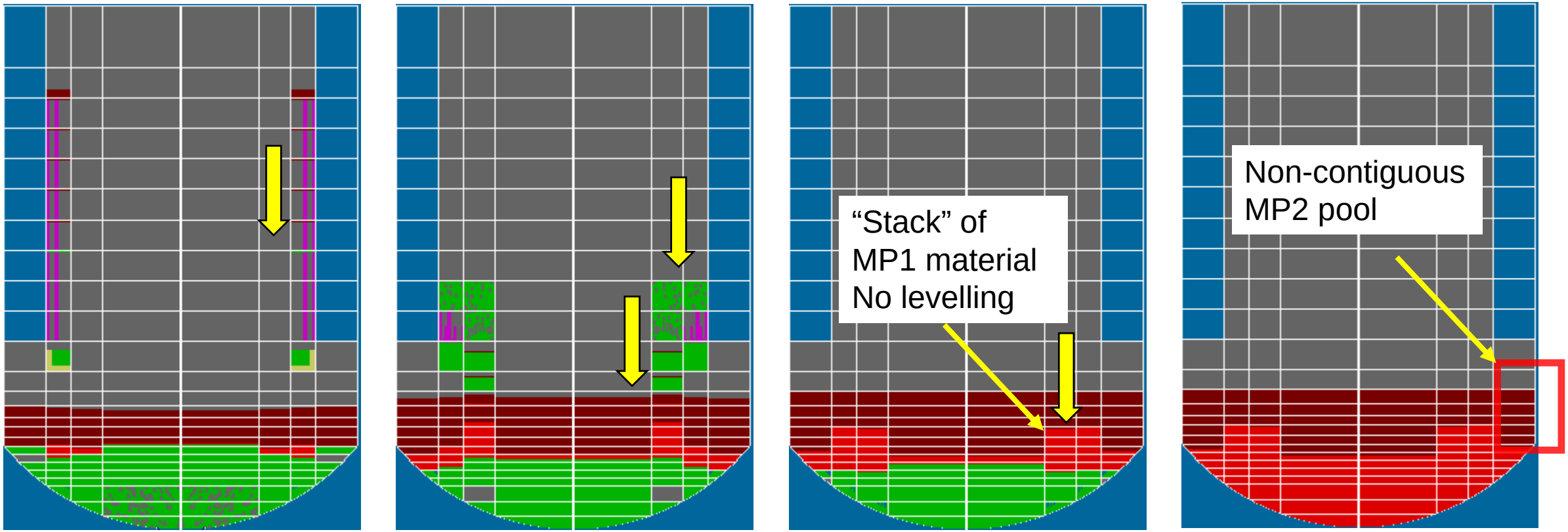
Issue 3. VVER-1000 IVMR. Late material slumping from core to LP melt

Description

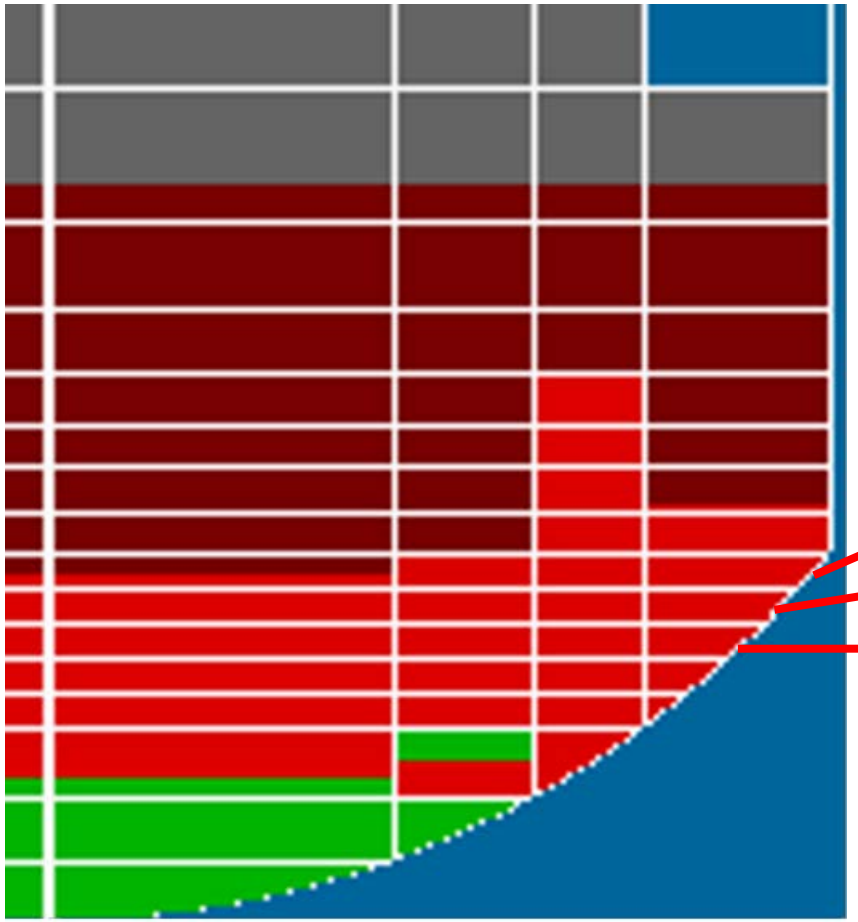
- Similar to HS degassing material fall to MP2 pool
- Core materials late fall

Resolution

- Avoid late debris falling)))



Issue 4. VVER-1000 IVMR. MP1 and MP2 contact with LH issue



Description

Boundary LH temperature is very different when contacting with MP1 at levels 6, 7, 8
This gives VERY different heat flux

IA, Rad	CELL AV. TEMP., K	COR LH TEMP 1st mesh, K	TEMP. P-DEB, K	TEMP. MP-OXI, K	TEMP MP-MET , K	Q flux, ext., MWt/m2
8,4	2984.45	1578.81	0.0	2984.4	0.0	0.24
7,4	2984.45	2271.45	0.0	2984.4	0.0	1.25
6,4	2984.45	1339.11	0.0	2984.4	0.0	0.29

HTC=500Wt/m2K is the same for all levels
Similar issue can happen sometimes with MP2

What is wrong?

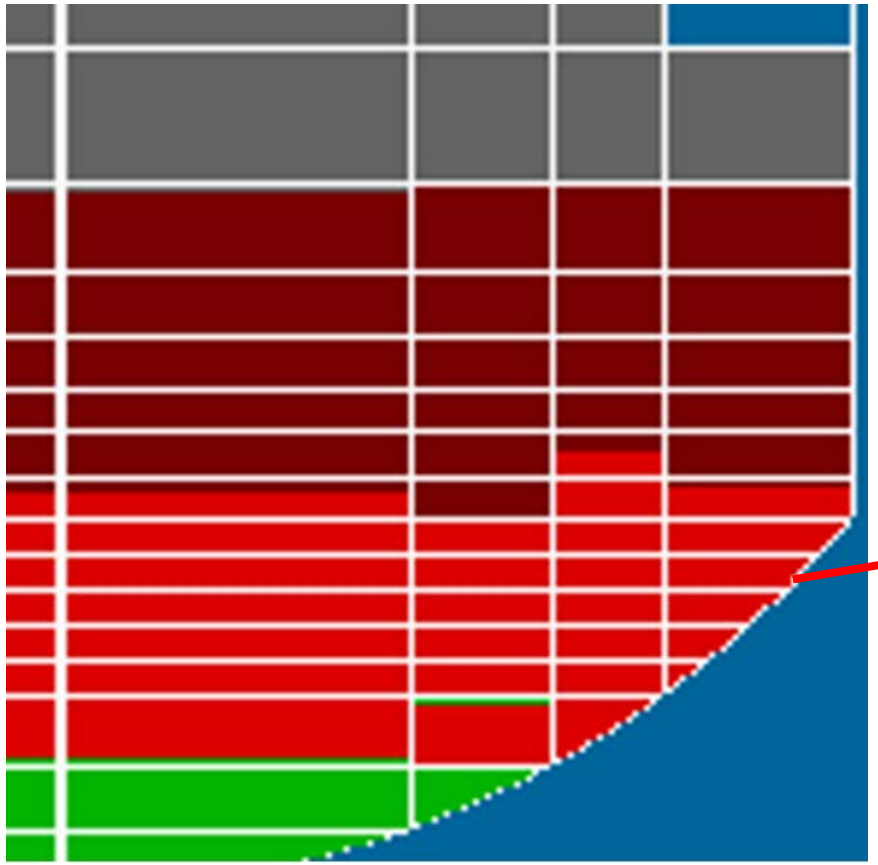
Issue 4. VVER-1000 IVMR. MP1 and MP2 contact with LH issue

Resolution

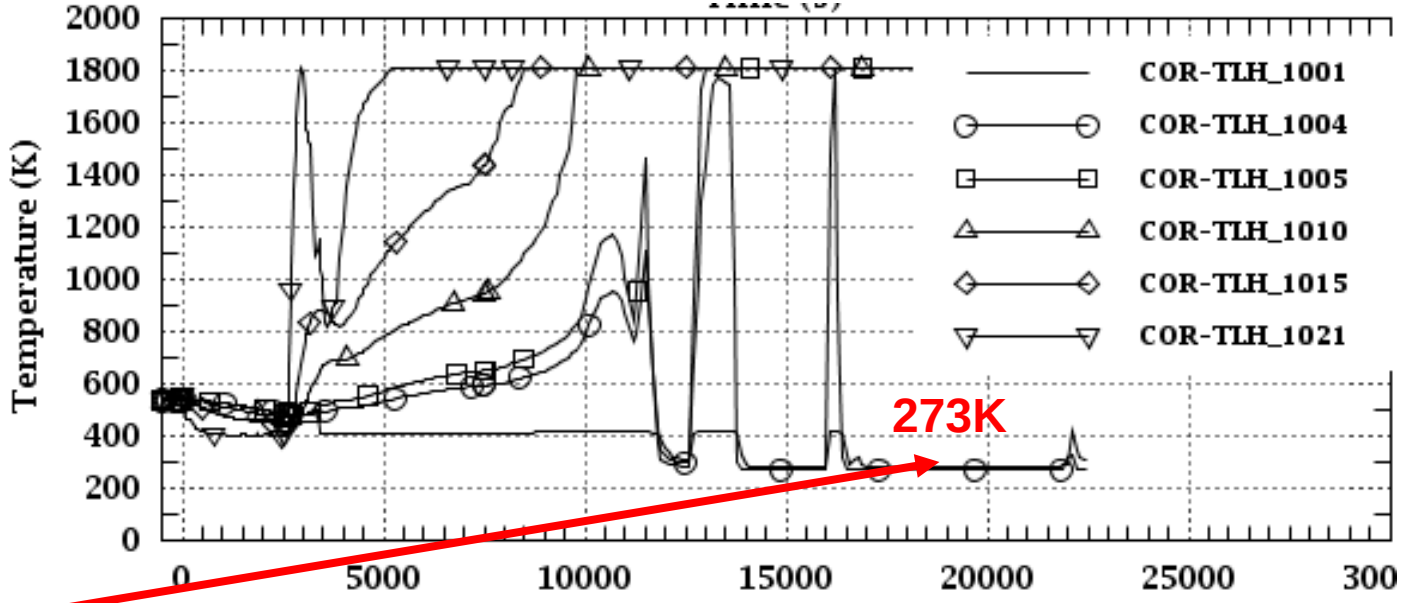
- A lot of changes and approaches are checked
- Problem resolution with existing LH model **is not possible**
- **Needs code check!**
- Resolved: See later approach to NEW LH and LP modeling with HSs

Issue 5. VVER-1000 IVMR. LH mesh temperatures issue when melting ON (LHM ON)

LP materials, time 18000s, LHM ON



Description



LH meshs temperature, Segment 10 (IA=7, IR=4)

LH mesh 4 temperature of Segment 10 is equal to 273K. Similar thing for segments 6, 13, 14,…
The reason is **NOT KNOWN**

Issue 5. VVER-1000 IVMR. LH mesh temperatures issue when melting ON (LHM ON)

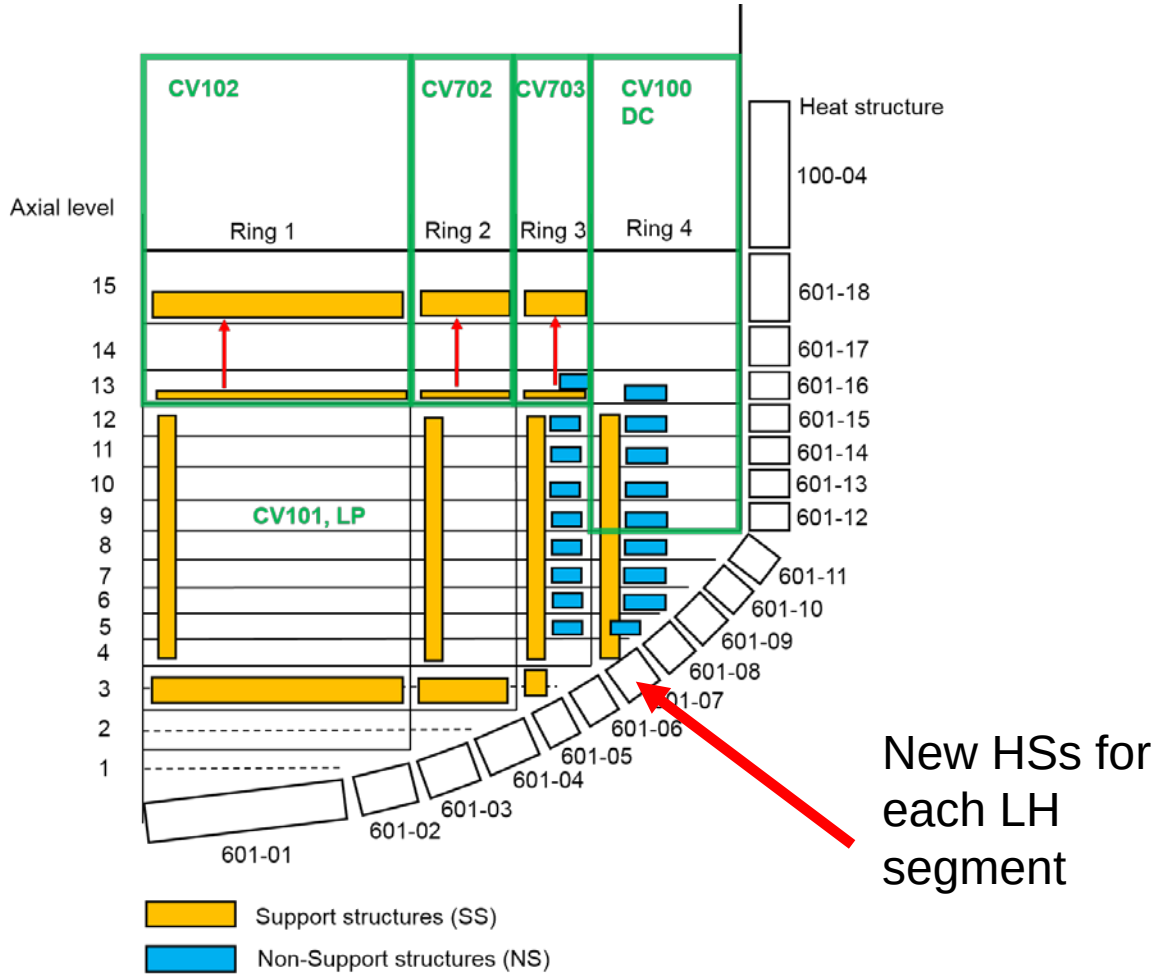
Resolution

- A lot of changes and approaches are checked
- Problem resolution with existing LHM ON model **is not possible**
- Resolved: LHM OFF, no problem without melting
- **Needs code check!**

VVER-1000 IVMR. Hybrid LH and LP modeling

Approach

- MELCOR “dummy” LH is made thin, adiabatic and unbrokable
- New LH flat heat structures modeled imitating segments of LH (contact with ext water)
- Nu correlation is used to model heat transfer from MP1, MP2 and PD to HSs
- The heat sources and sinks are applied to PD, MP1, MP2 and HSs
- HTC is axially profiled in MP1 pool, crust is accounted in HTC
- Thermal radiation from upper MP2 surface is described by CFs
- Molten pools behavior is left to MELCOR code

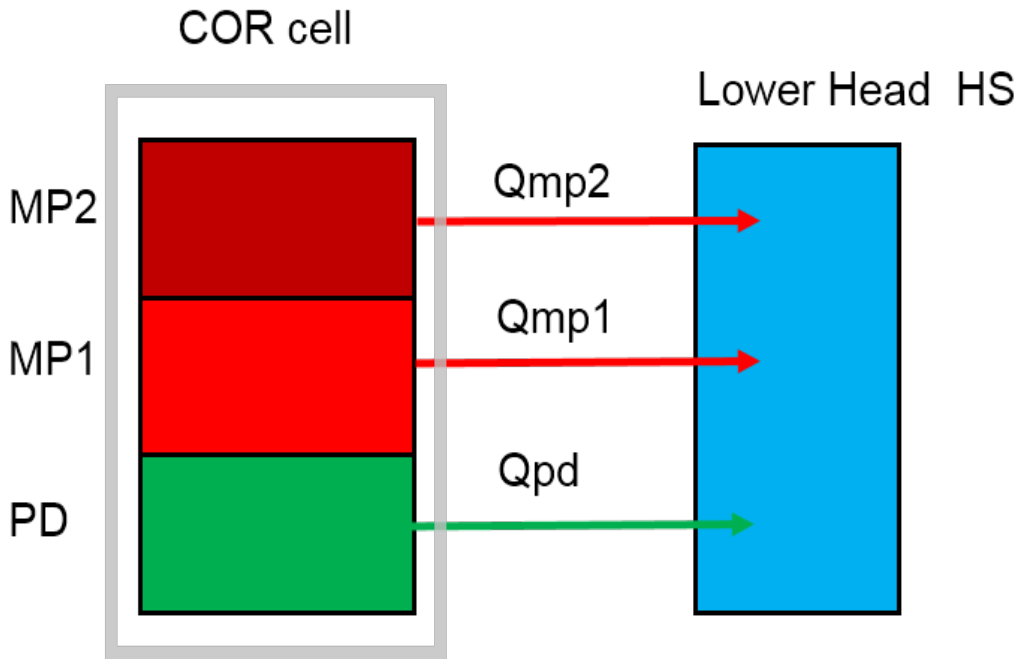


LP nodalization and materials

VVER-1000 IVMR. Hybrid LH and LP modeling

Approach (cont.)

- If HS node melting temperature achieved the conductivity increased
- Heat balance checked OK
- Dummy LH MELCOR model capacity and influence is small, OK
- The decay heat concentration in MP1 ratio to MP2 as 9:1



MP1, MP2 and PD heat source to surrounding LH HSs

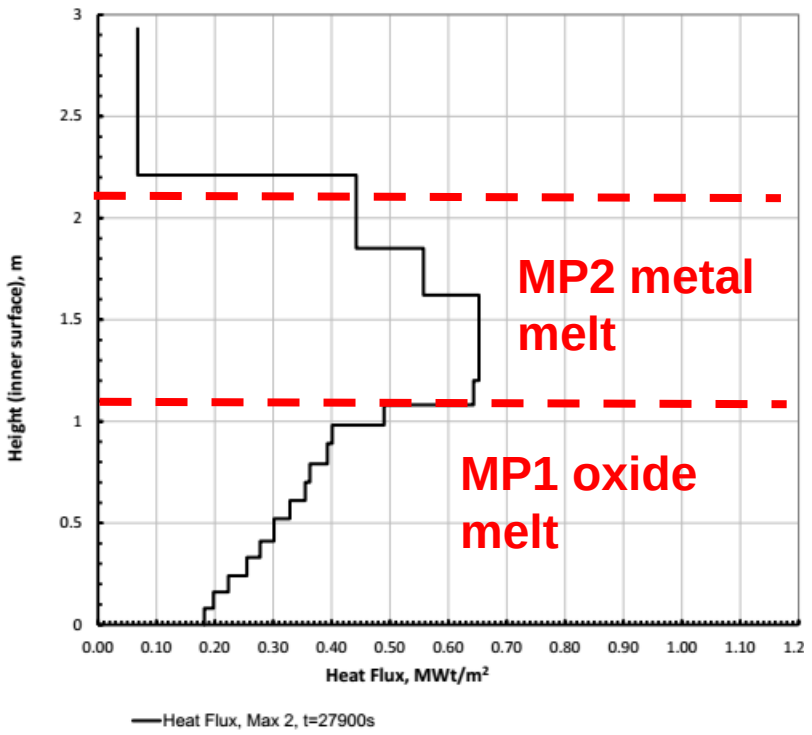
VVER-1000 IVMR. Hybrid LH and LP modeling

Event+assumption

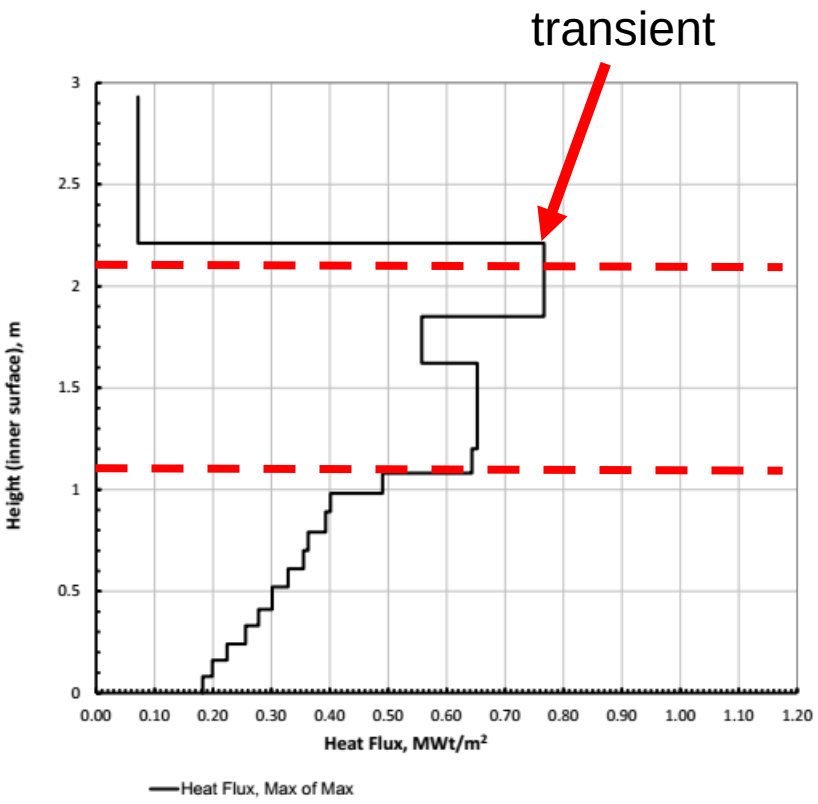
- 300 CL break+ blackout
- IVMR started at 2400s of the accident
- **Large metal** case

Results

- Focusing effect OK, in metal layer
- MP1 / MP2 height is 1.1m/1.0m
- Max stable wall flux **0.65 MWt/m2**
- MP1 pool heat distribution side/up is 40% to 60%
- MP2 below heat flux 0.82MWt/m2



LH external heat flux at maximal value (t=27900s)



LH external heat flux (max of max)

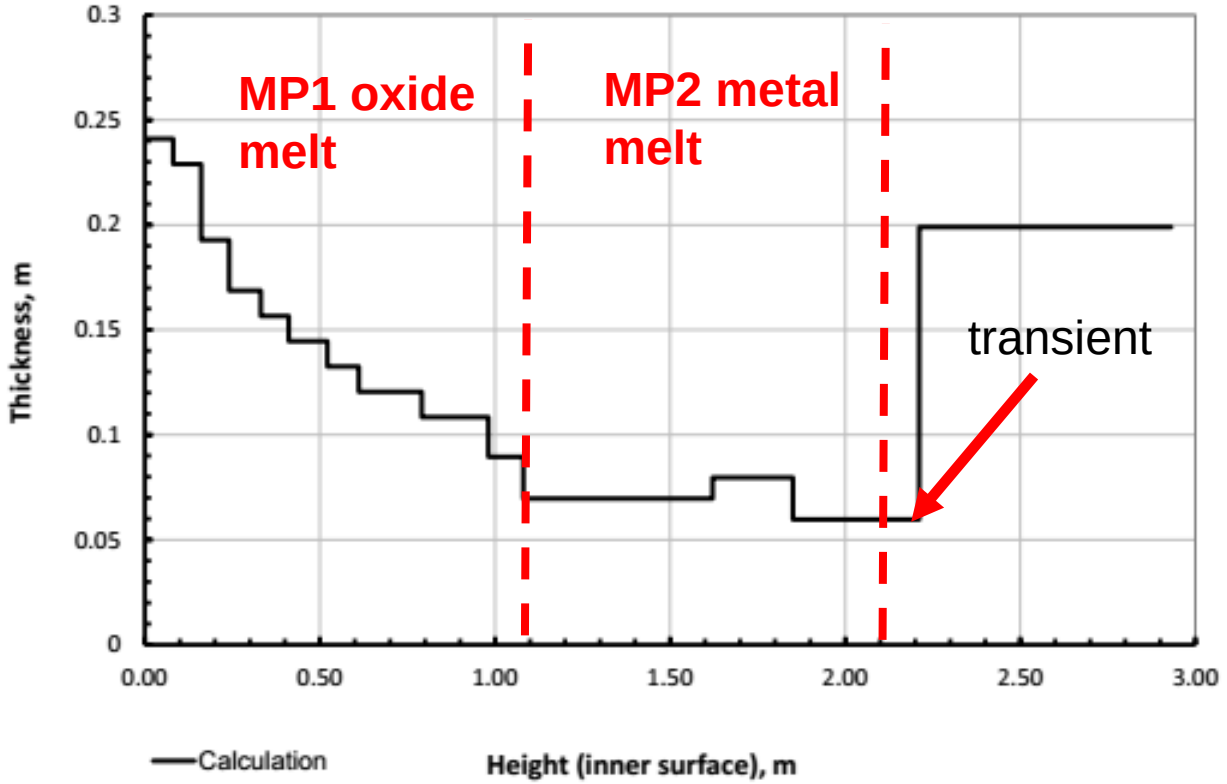
VVER-1000 IVMR. Hybrid LH and LP modeling

Event+assumption

- 300 CL break+ blackout
- IVMR started at 2400s of the accident
- **Large metal** case

Results

- Residual LH thickness 0.06-0.07m



LH residual thickness

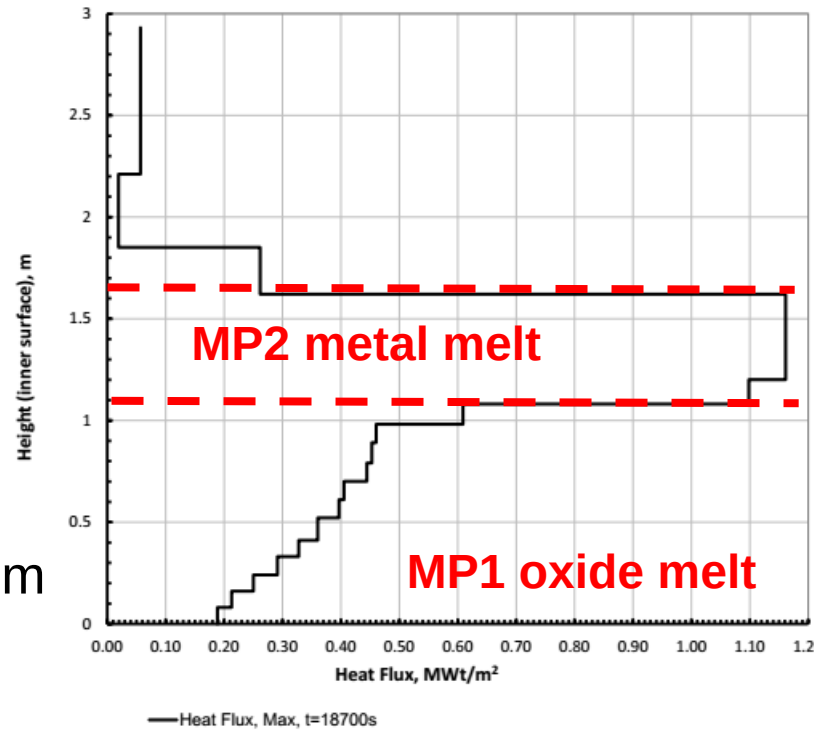
VVER-1000 IVMR. Hybrid LH and LP modeling

Event+assumption

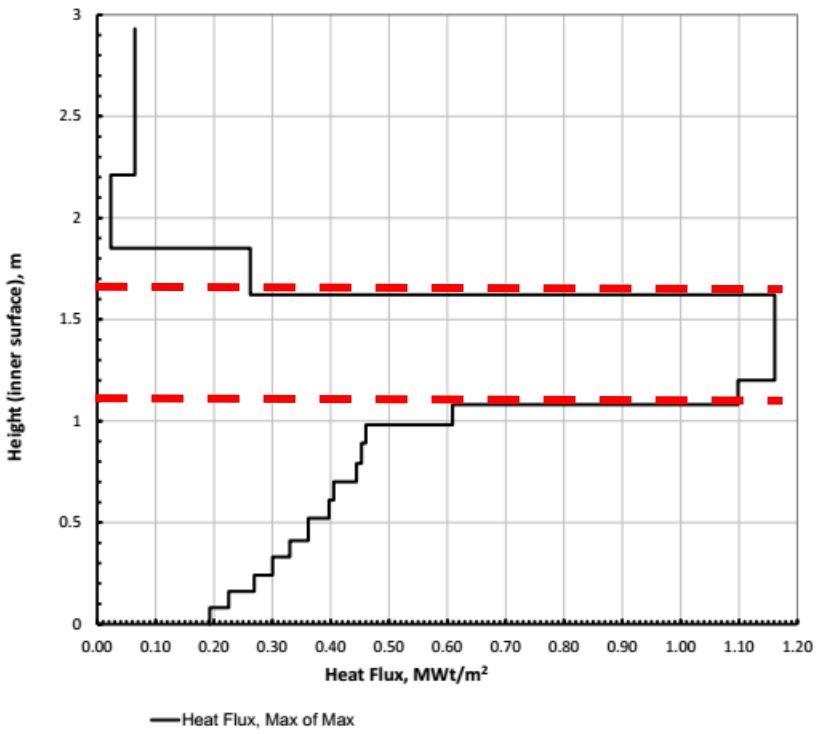
- 300 CL break+ blackout
- IVMR started at 2400s of the accident
- **Low metal** case (No baffle melting)

Results

- Focusing effect OK, in metal layer
- MP1 / MP2 height is 1.1m/0.5m
- Max stable wall flux **1.16 MWt/m2**
- MP1 pool heat distribution side/up is 40% to 60%
- MP2 below heat flux 0.89MWt/m2



LH external heat flux at maximal value (t=18700s)



LH external heat flux (max of max)

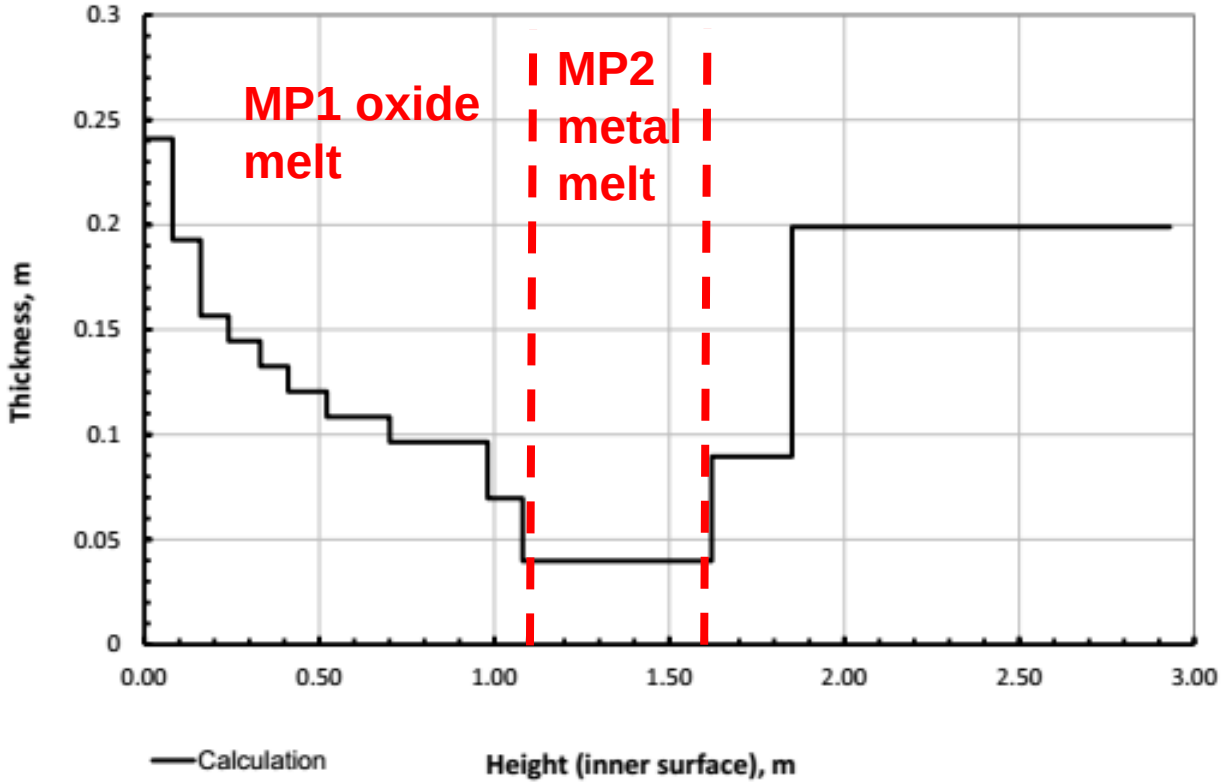
VVER-1000 IVMR. Hybrid LH and LP modeling

Event+assumption

- 300 CL break+ blackout
- IVMR started at 2400s of the accident
- **Low metal** case

Results

- Residual LH thickness 0.04m



LH residual thickness

VVER-1000 IVMR. MELCOR modeling. Conclusions

MELCOR applied to IVMR

- Possible code deficiency in MP1 leveling and MP2 contiguous pool mass definition in LP is found
- Issues found in MP1, MP2 contact heat transfer to LH
- LH model with melting option has some issues with mesh low temperatures
- Hybrid MELCOR LH modeling proposed for LP melt behavior
- Simple hybrid MELCOR modeling shows good phenomenological / predictable behavior
- More flexibility and control is needed for LP melt modeling in MELCOR

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