PAUL SCHERRER INSTITUT

PSI

Wir schaffen Wissen – heute für morgen

Air ingress experiments Q-10 and Q-16 analysis with MELCOR 1.8.6

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Outline

Nuclear Energy and Safety
Laboratory for Thermal Hydraulics
Severe Accident Research Group, SACRE

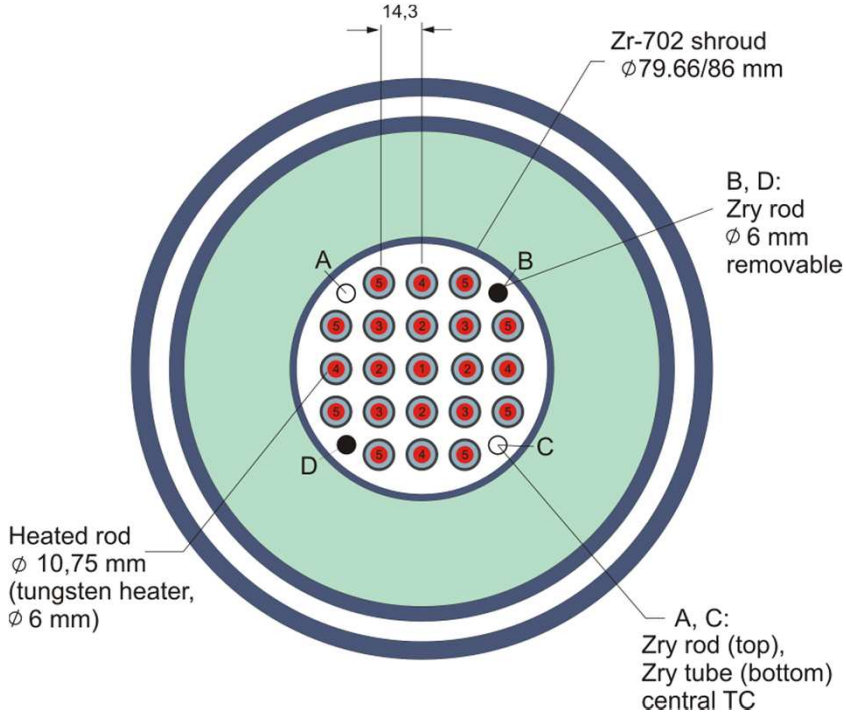
- QUENCH facility
- Q-16
  - Preoxidation
    - Difference between code versions MELCOR 1.8.6 YR and YT
  - Air Ingress phase
    - Nodalization influence
    - Oxidation kinetics
    - Oxygen consumption
  - Reflood
- Q-10
  - Preoxidation
  - Air Ingress phase
  - Reflood
- Conclusions

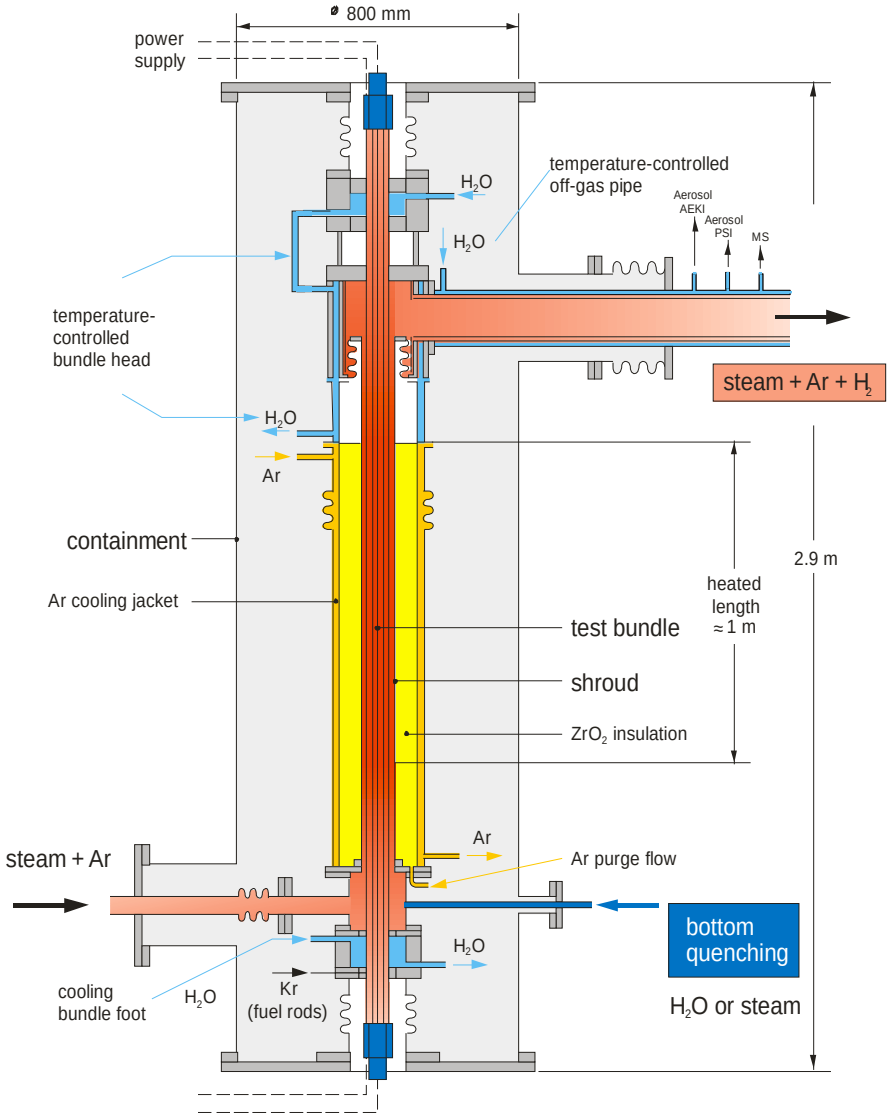
QUENCH Facility

QUENCH facility: electrically heated fuel rod simulator assembly

Operated by Karlsruhe Institute of Technology

ZrO2 pellets; Zry-4 cladding





QUENCH-16

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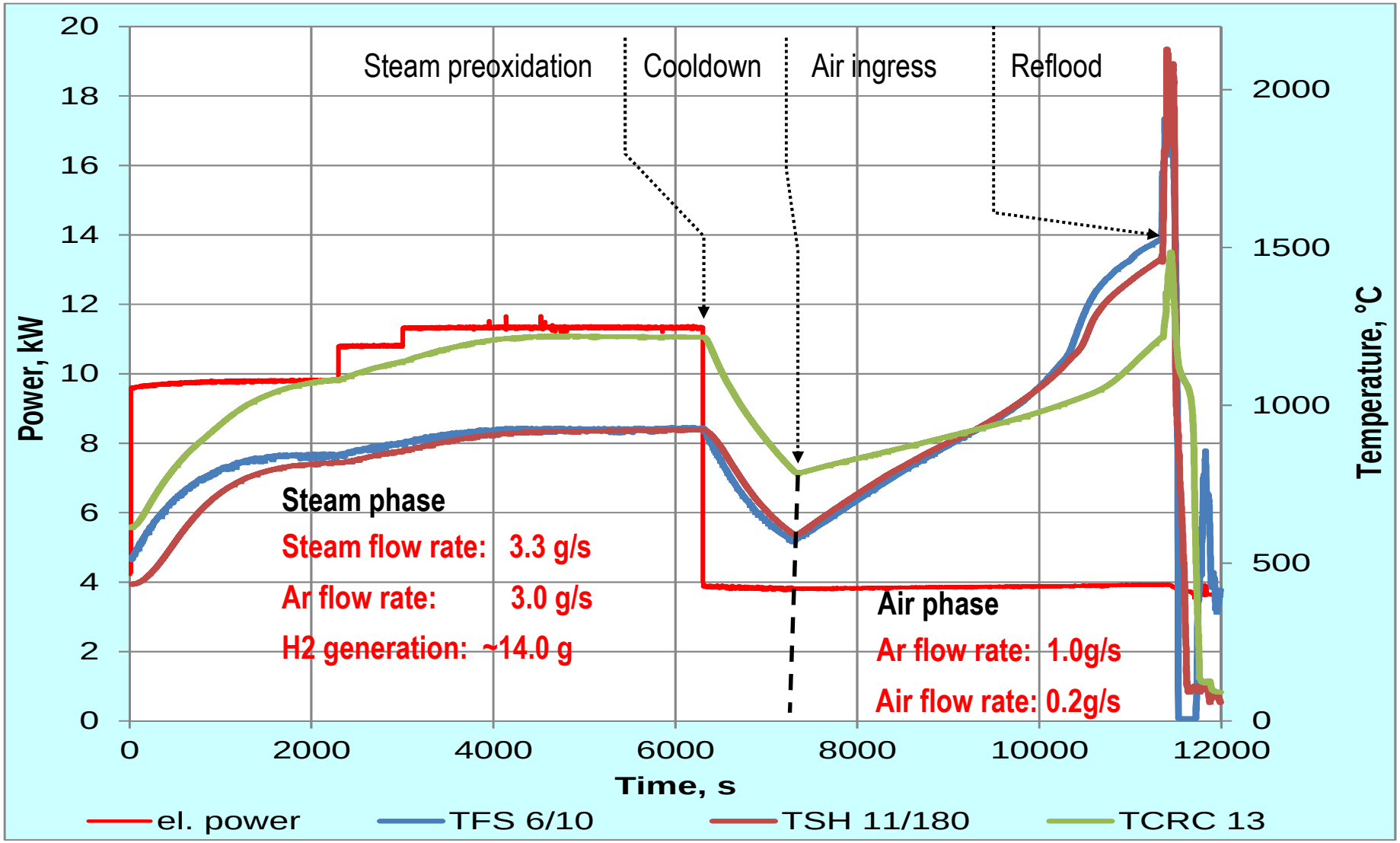

Difference between YT and YR versions

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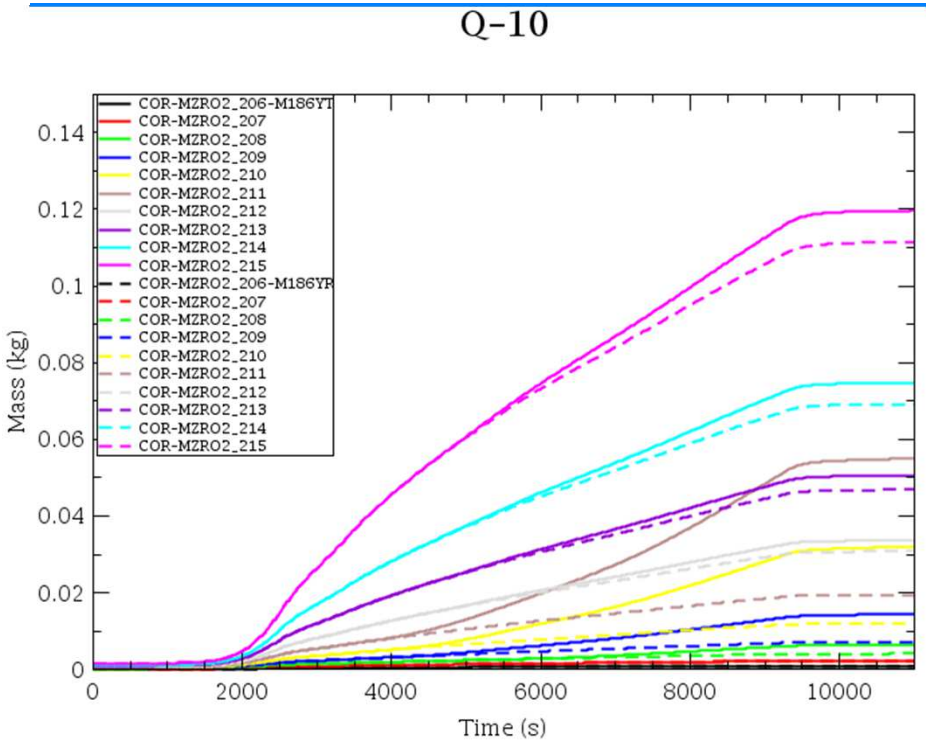
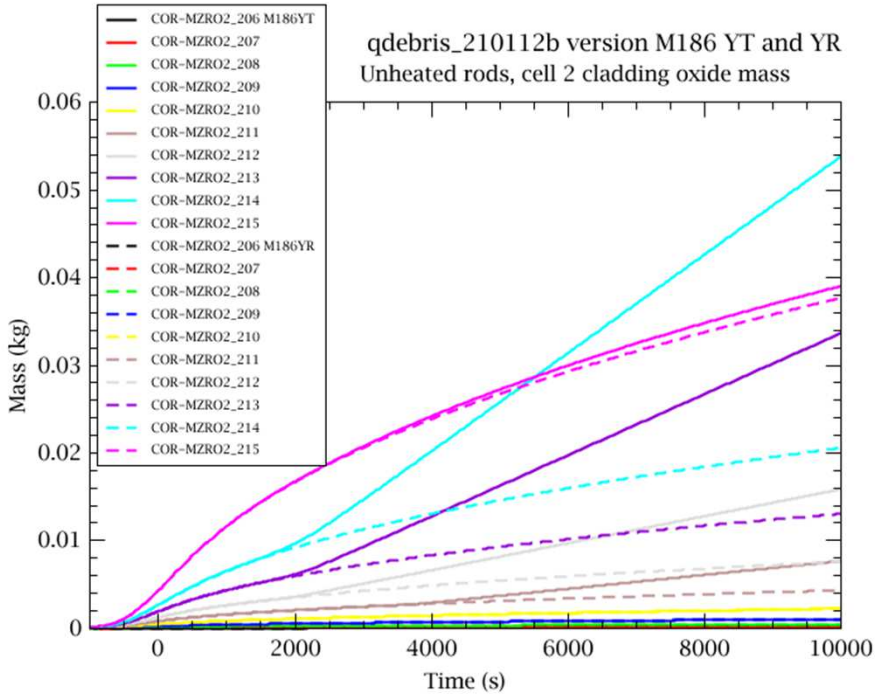
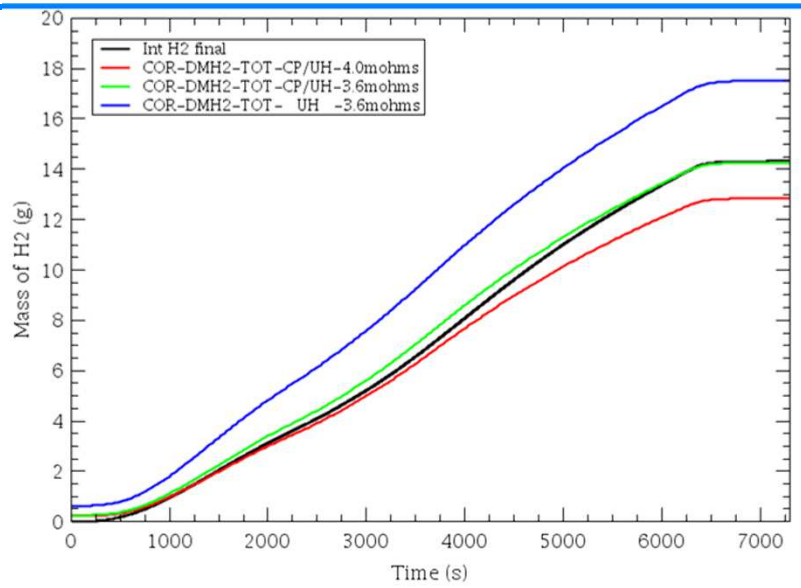
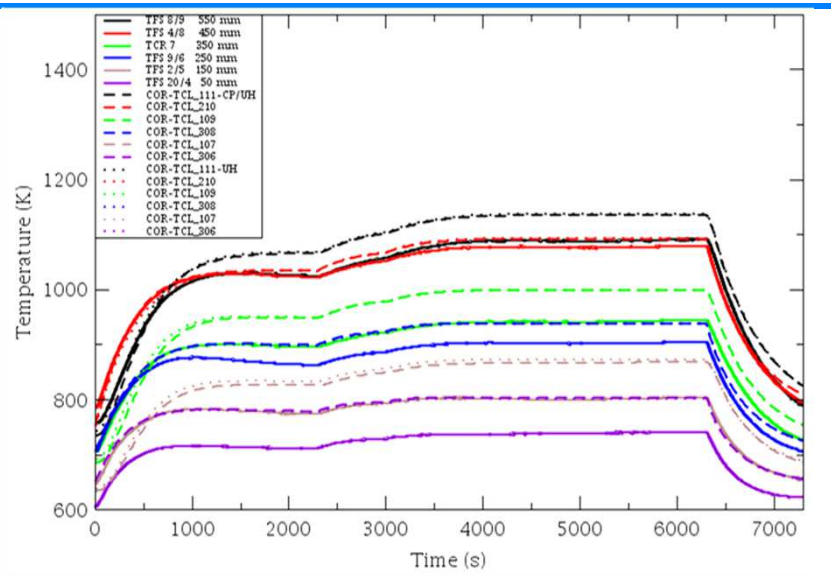




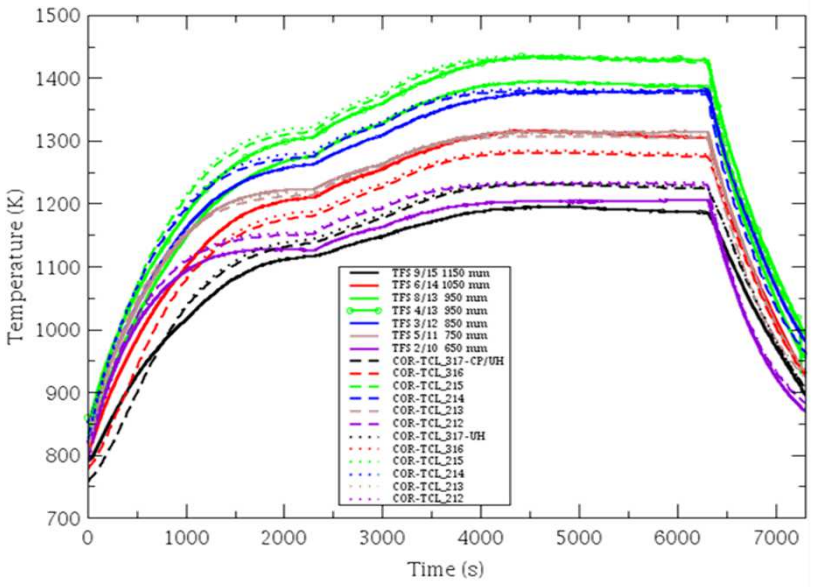
- The YT version gives different oxidation behavior than the YR version:
  - First we believed that breakaway was activated regardless the option is selected in card COROXB.
  - But looking closer to the fortran it was realised bkwy model is only applied in air. Nevertheless it gives a perfect breakaway behavior in steam.
  - We believe that it must be a bugg in the YT version
  - This seem to be corrected for the YV version. It gives very similar results to YR
- For the rest of the calculation the MELCOR 1.8.6 YR version was used.

QUENCH-16 preoxidation



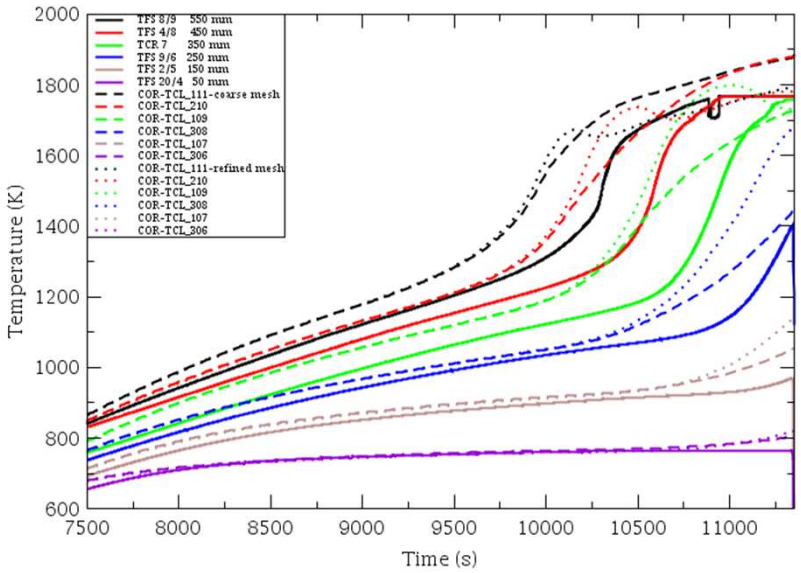


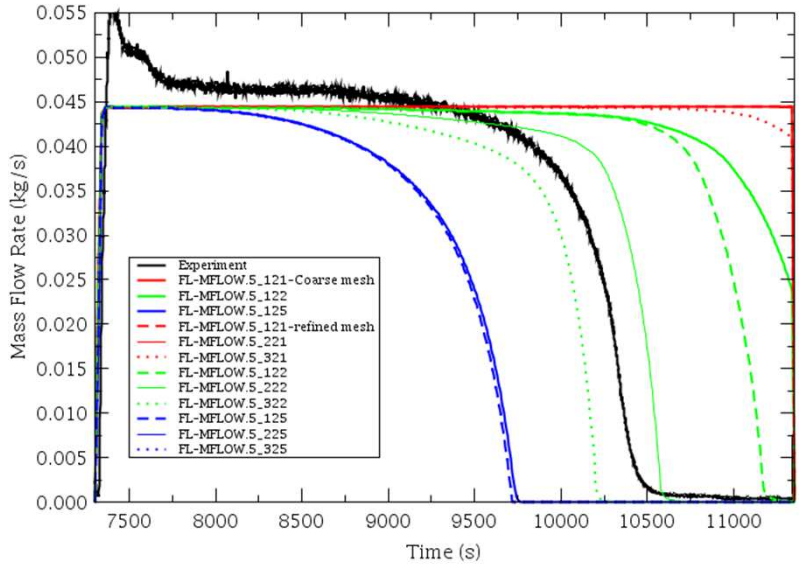
- The best agreement was obtained with CP/UH and R = 3.6 mohms.
- The axial calculated Temperature profile is in good agreement with the experimental results



Nodalization influence

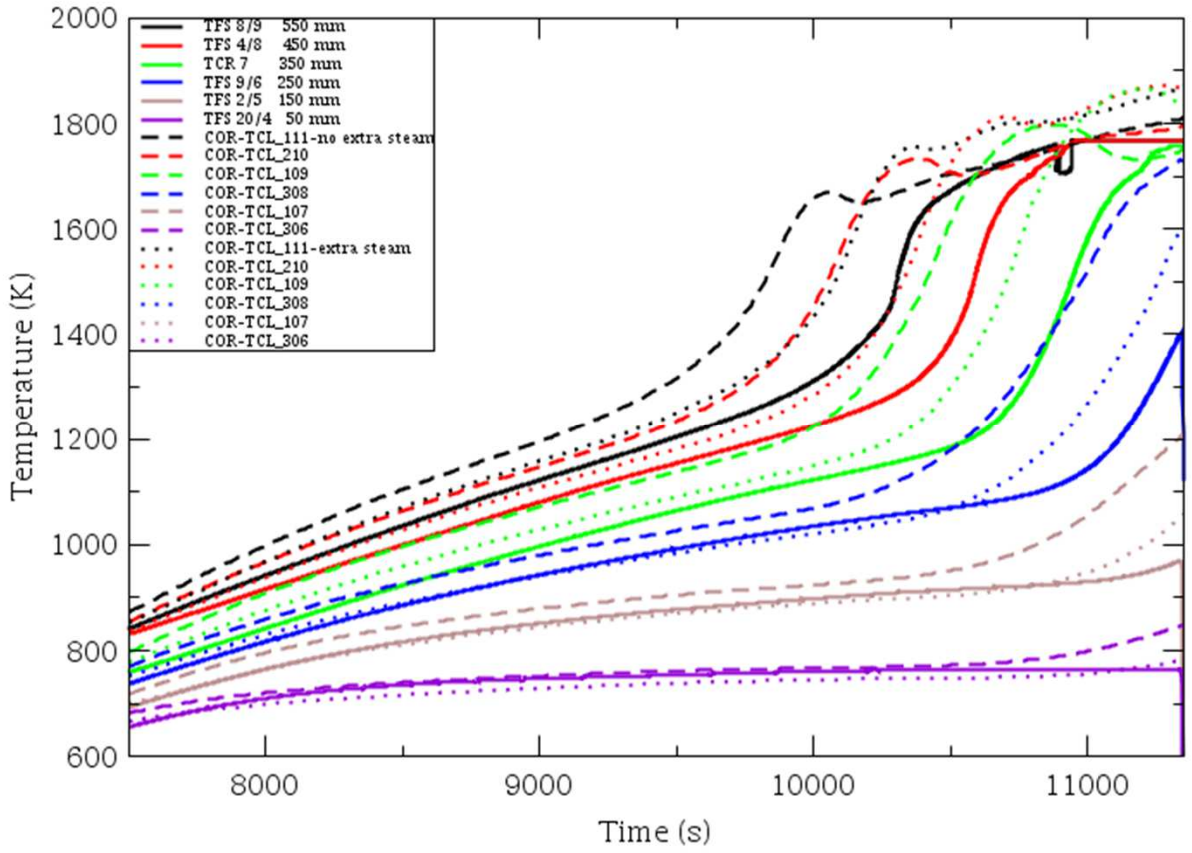
coarse mesh	refined mesh
150	150
130	130
126	226
	126
125	325
	225
	125
124	224
	124
123	223
	123
122	322
	222
	122
121	321
	221
	121
120	320
	220
	120
119	119
50	50





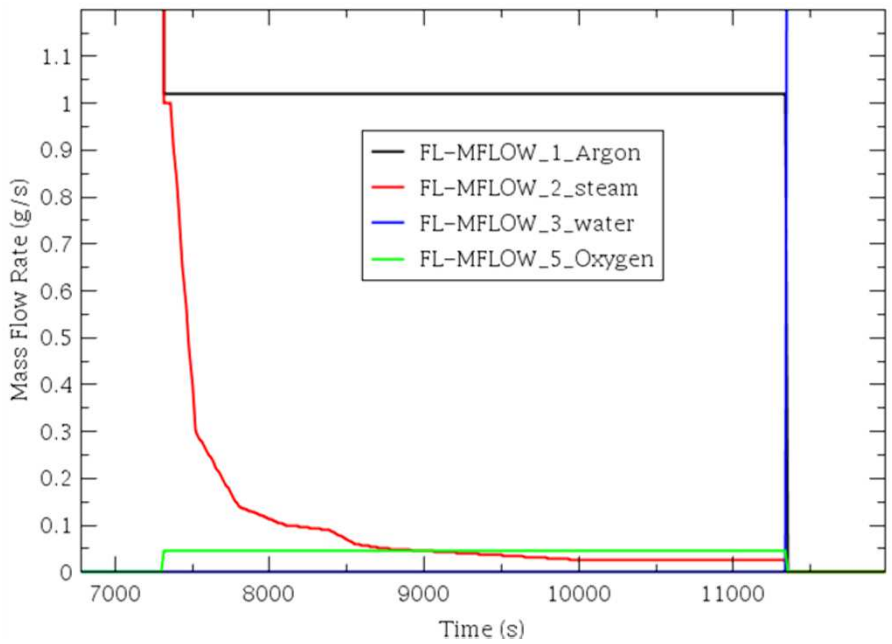
- No significant difference during the steam phase.
- Big influence during the air phase due to the fast oxygen consumption
- The refined mesh was used for the rest of the analysis

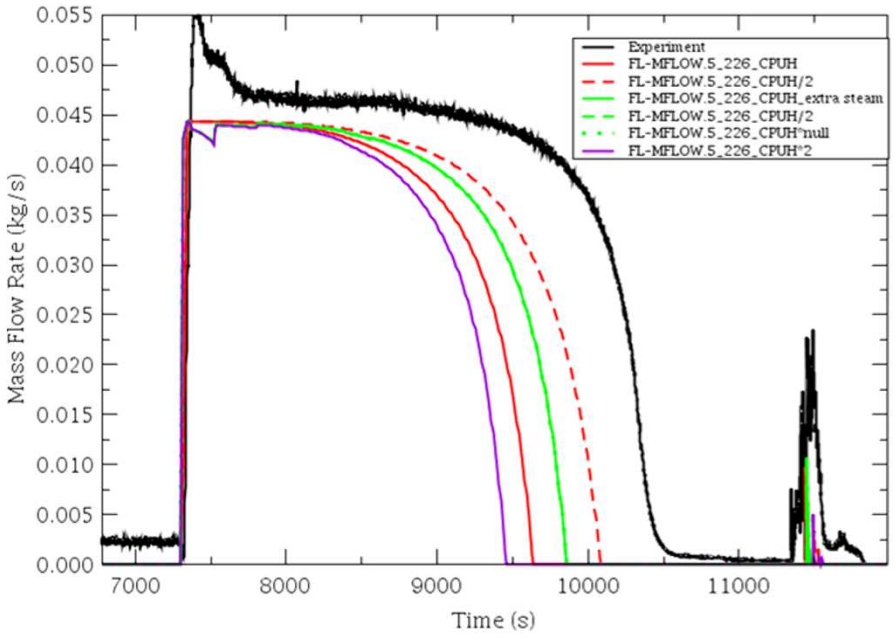
QUENCH-16 air phase



- Increase in slope marks onset of rapid oxidation
- The extra steam acted as a coolant as long as there is still oxygen available (including after starvation onset)

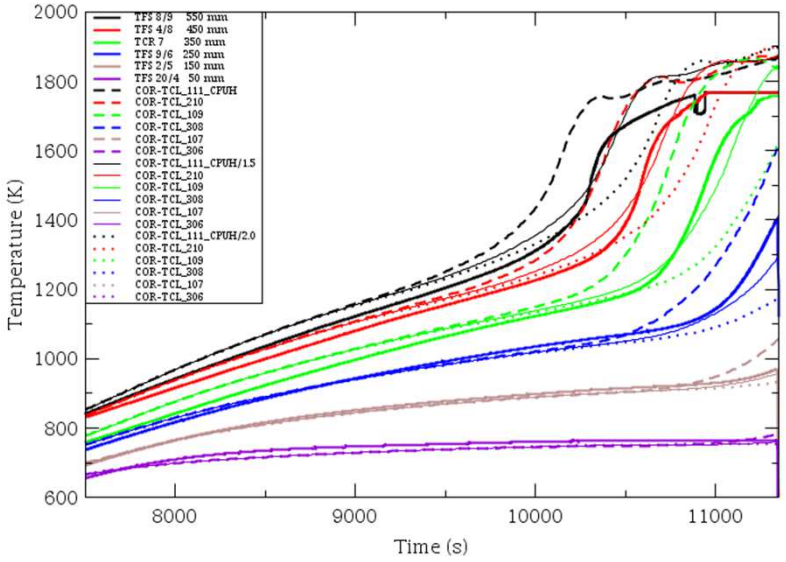
Q-16 oxygen consumption

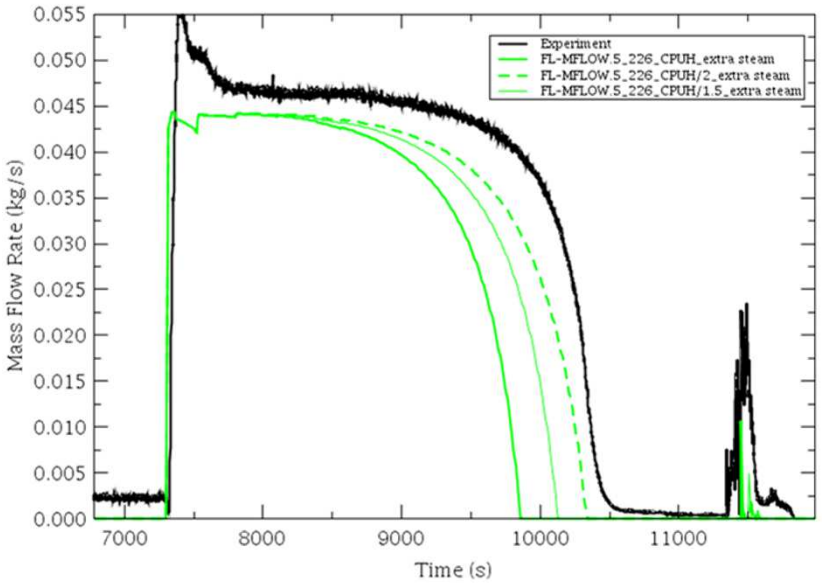


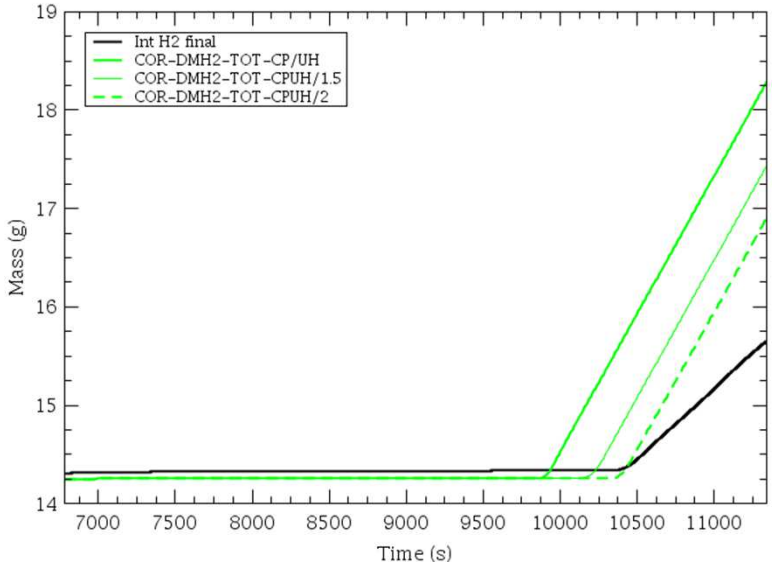


- The oxygen starvation predicted by MELCOR was earlier than in the experiment
- The air kinetics has a lower limit when steam is present (steam kinetics)
- There is a fortran line **DXMDT = MAX (DXMDTS, DXMDTO)** that forces the code to use the maximum between steam and air kinetics. Why?

QUENCH-16 air phase adjusted Kinetics

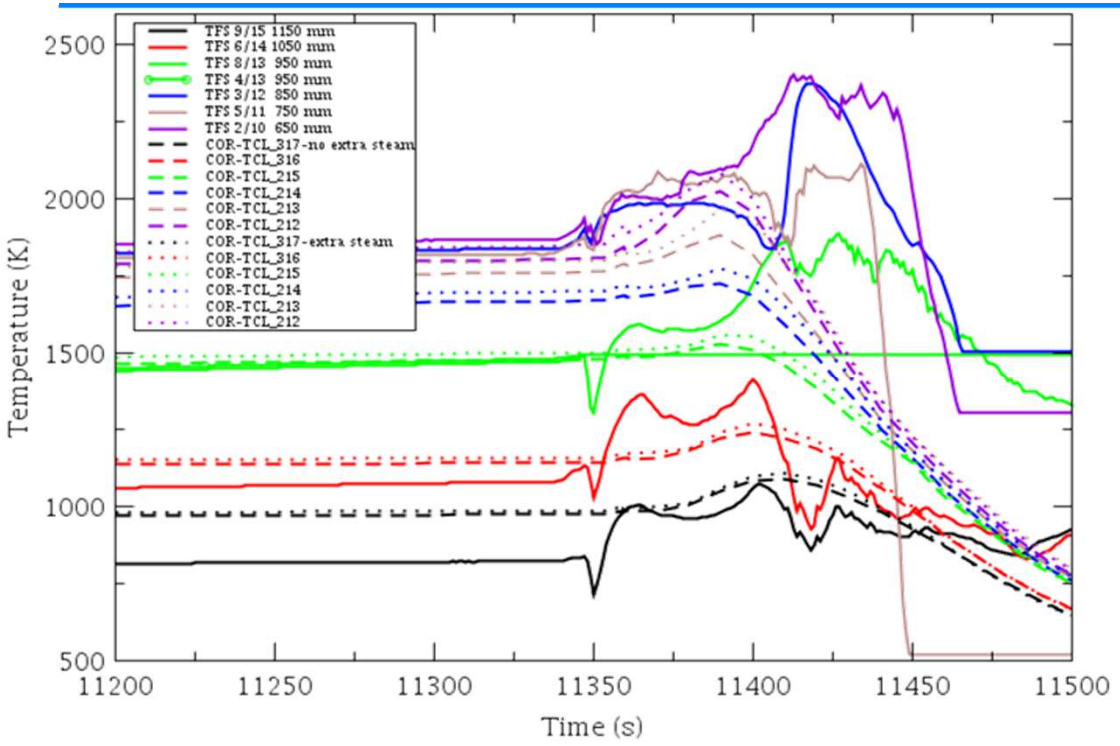






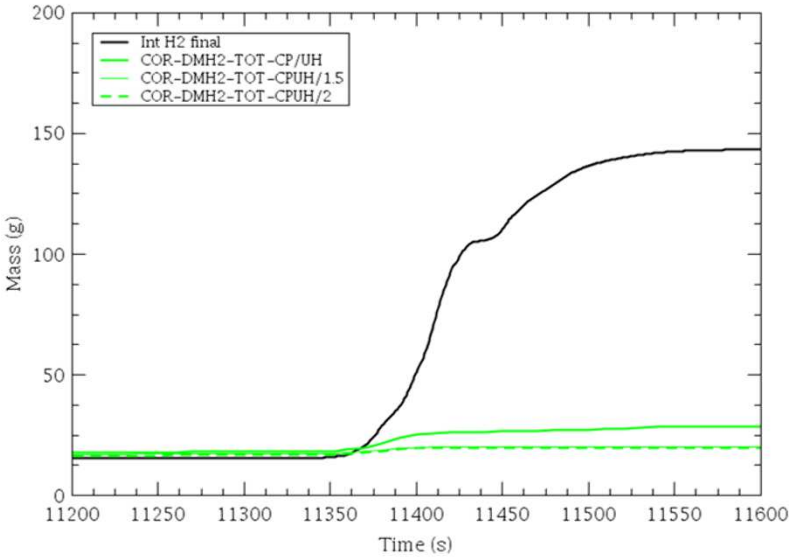
- Slower kinetics were calculated for oxygen (setting lower kinetics for both: steam and oxygen)
- The closest agreement with the onset of starvation is found when CPUH/2 is used
- The best temperature agreement was obtained when CPUH/1.5 was used

QUENCH-16 reflood



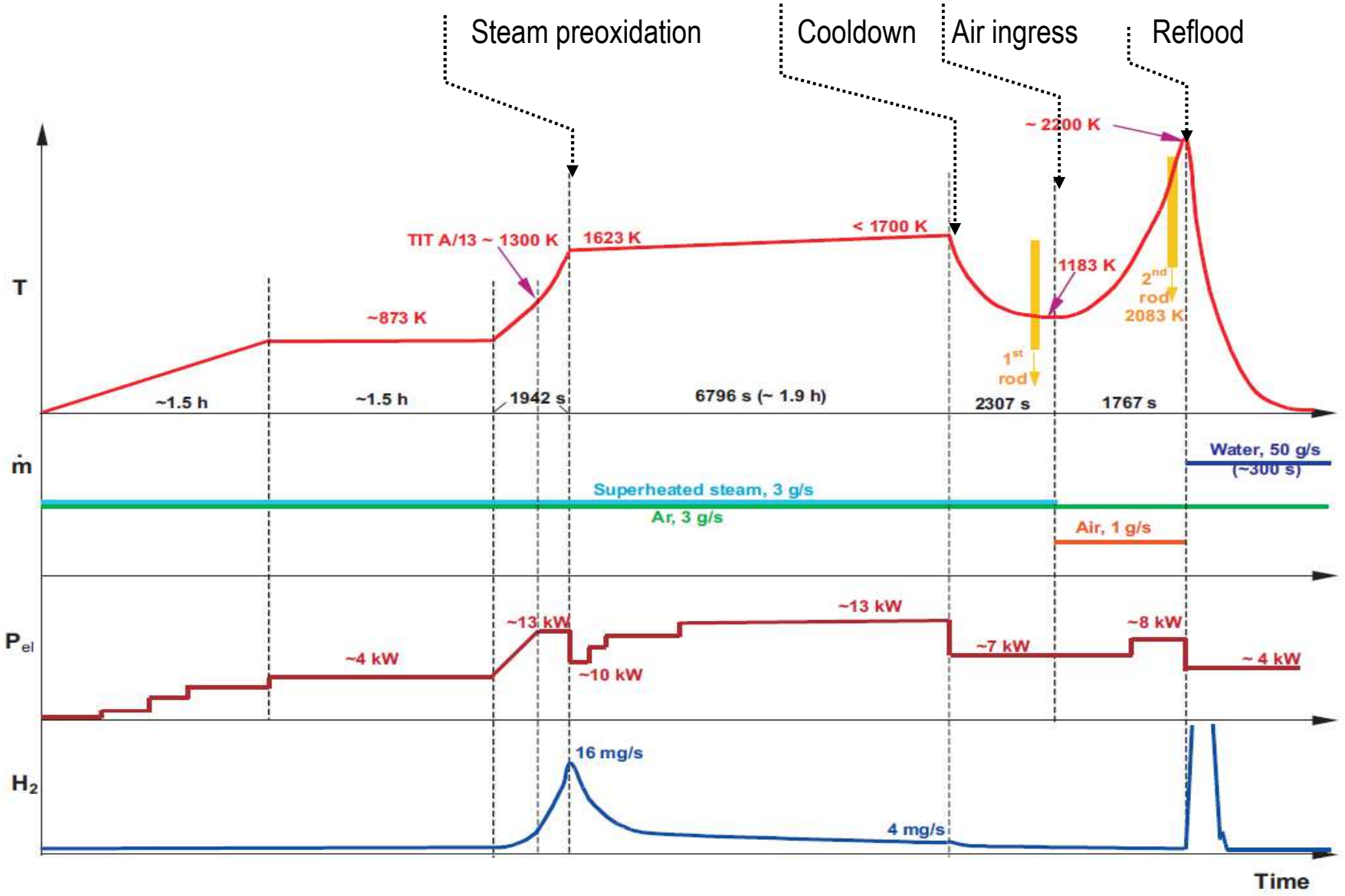
The temperature excursion was underestimate by MELCOR

The H2 excursion was no near to the experimental observation

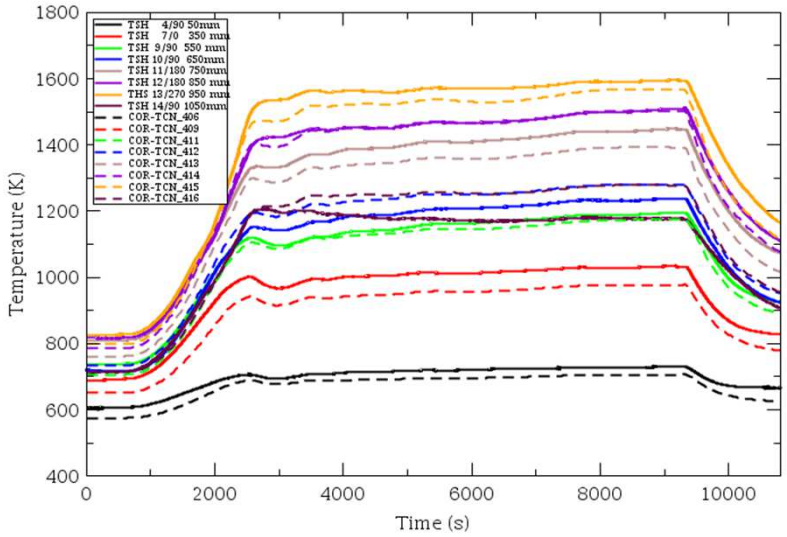


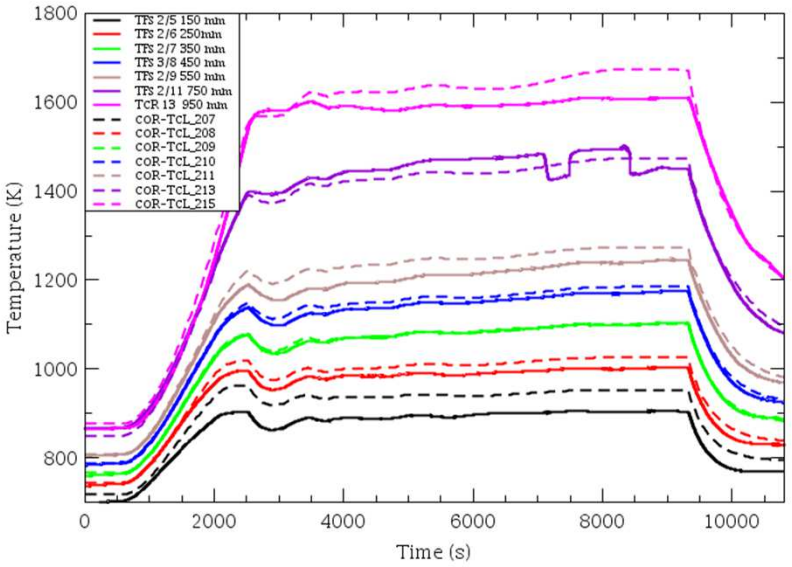
Causes of excursion:

- Oxide layer was weakened by:
  - Long period of oxygen starvation (reduced oxide layer)
  - Nitrogen attack during the starvation
- Nitrade reaction during reflood
- Evidence of molten material (post-test examination)

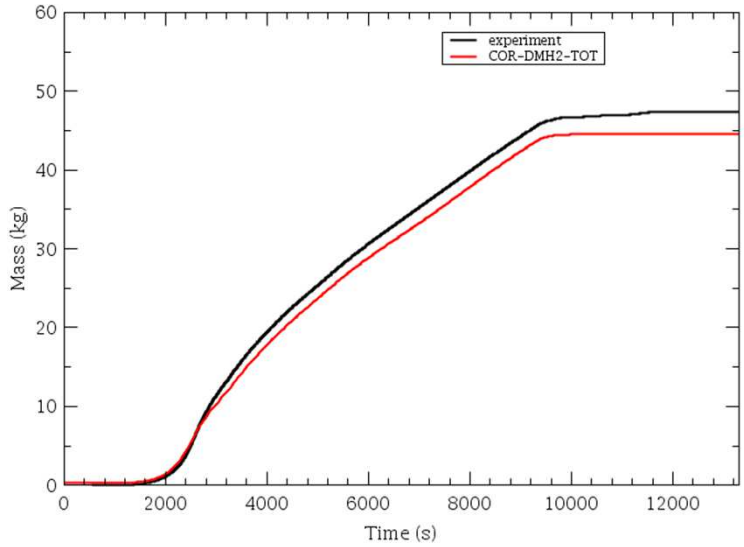

Steam preoxidation
Cooldown
Air ingress
Reflood
T
~ 2200 K
TIT A/13 ~ 1300 K
1623 K
< 1700 K
1183 K
2nd rod
2083 K
1st rod
~873 K
~1.5 h
~1.5 h
1942 s
6796 s (~ 1.9 h)
2307 s
1767 s
ṁ
Water, 50 g/s
(~300 s)
Superheated steam, 3 g/s
Ar, 3 g/s
Air, 1 g/s
Pel
~13 kW
~13 kW
~8 kW
~4 kW
~7 kW
~10 kW
~ 4 kW
H2
16 mg/s
4 mg/s
Time

QUENCH-10 preoxidation

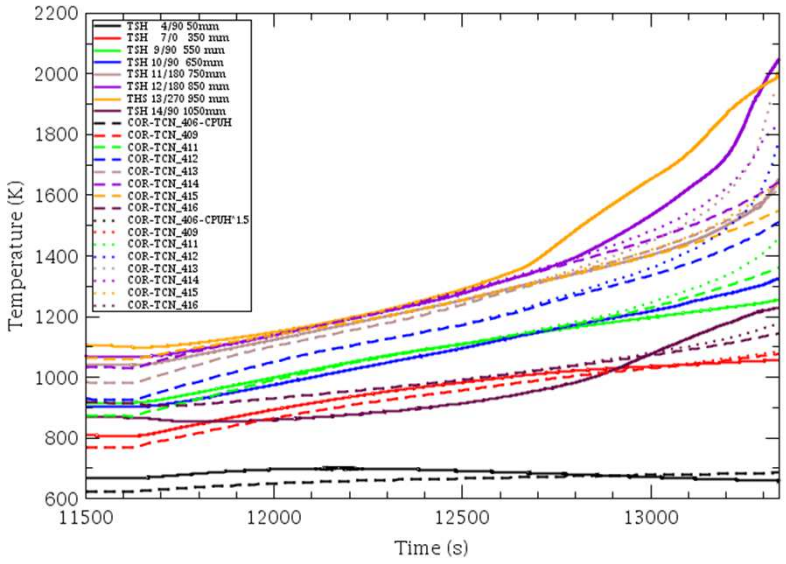


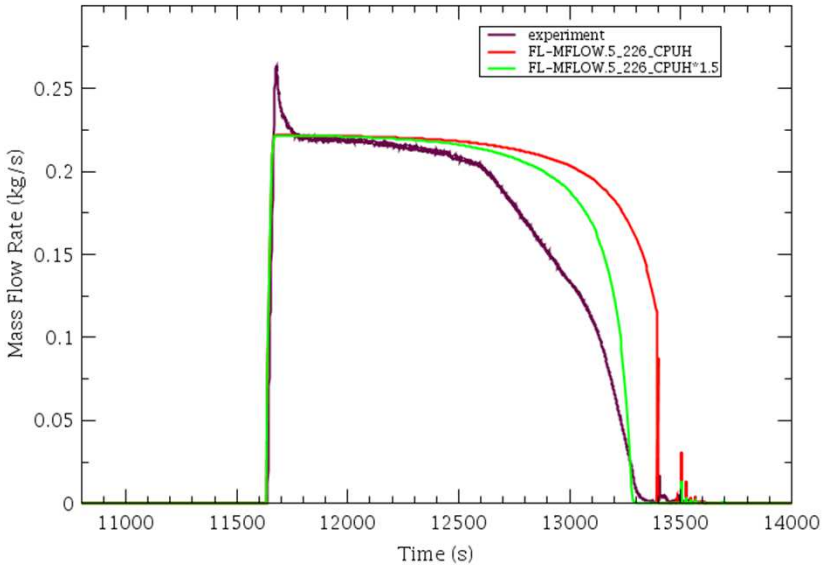


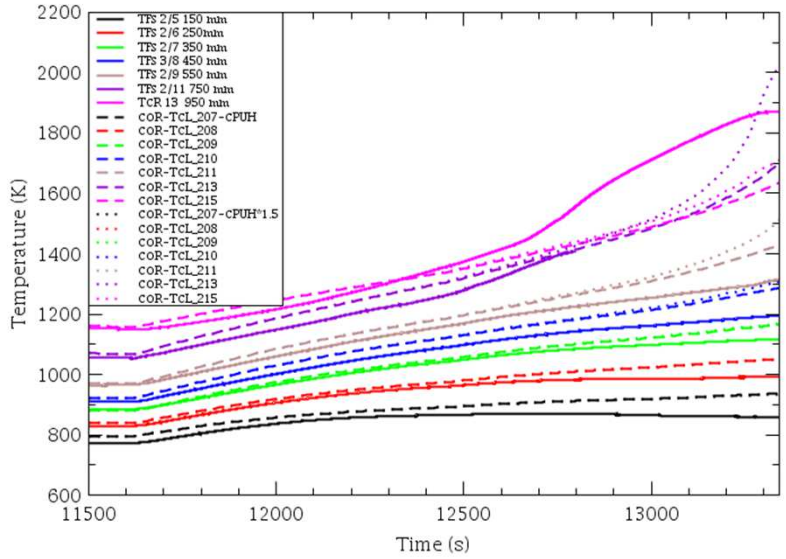
- The input used for Q-10 was the same as the one using for Q-16 by just changing the boundary conditions.
- Aim at assessing models under 2 different conditions.
- The temperatures during the pre-oxidation phase as well as the hydrogen generation where in fair agreement with the experimental results.



QUENCH-10 air phase

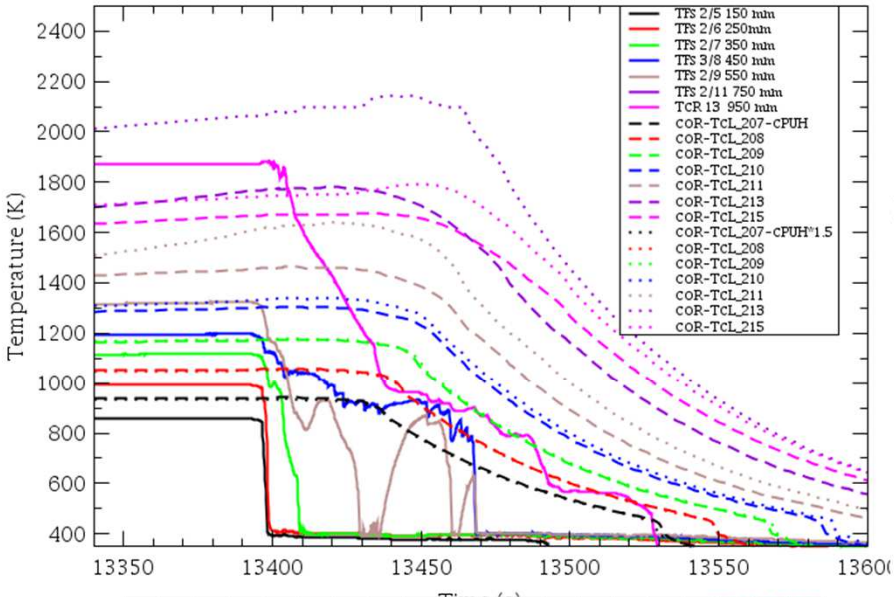


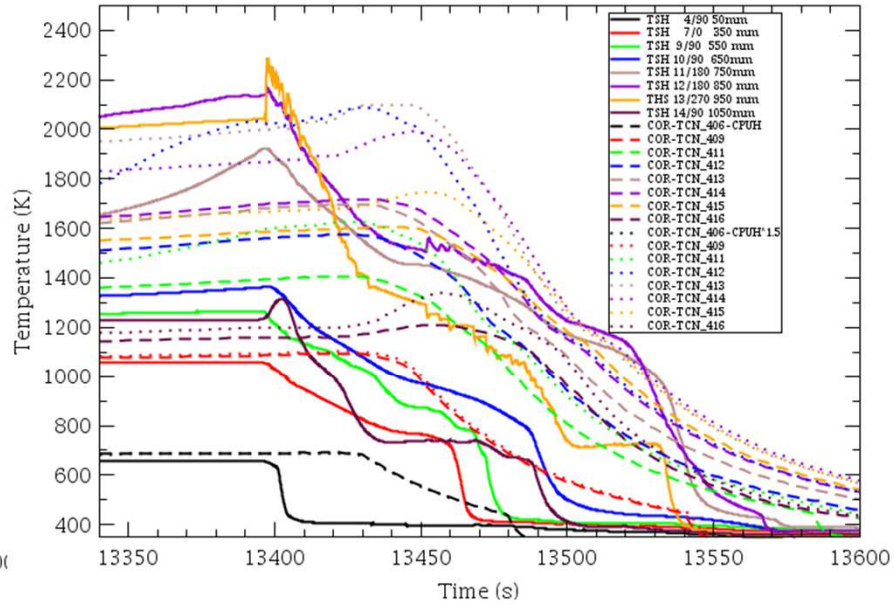


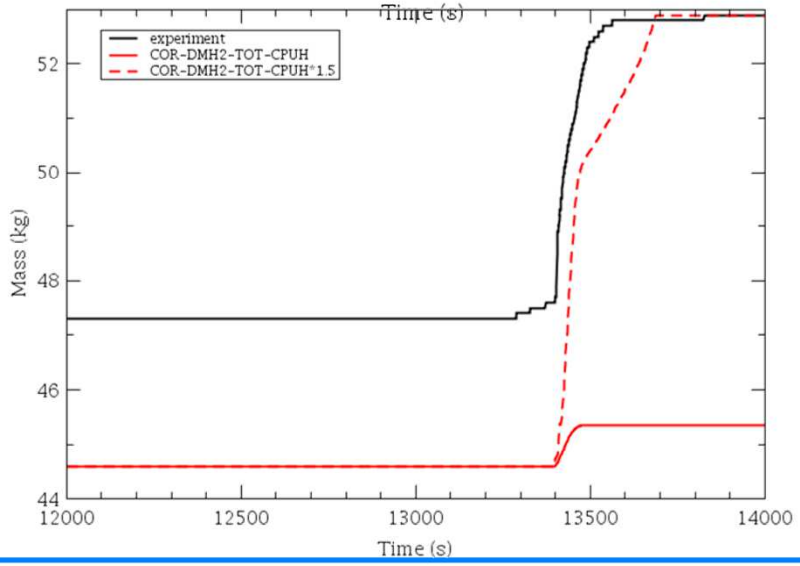


- Melcor calculated a later oxygen consumption
- The oxidation correlation was adjusted (CPUH*1.5) to adjust the time of fully consumption.
- An acceleration in the calculated temperatures is observed.
- The shroud temperatures show that the transition from regular to accelerated kinetics was not captured.

QUENCH-10 reflood







- Most of the rod thermocouples failed during reflood.
- The amount of H2 generated was about right when the CPUH*1.5 was used

Conclusions

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- The pre-oxidation phase was very well reproduced by MELCOR using the same input deck for both experiments, showing consistency.

- The oxygen consumption was understimated for the QUENCH-10 and overstimated with QUENCH-16.
  - One explanation is that the oxygen concentration might have played a role.
  - There maybe other reasons

- The excursion observed in Q-16 was understimated
  - Causes of excursion are not fully resolved
- The influence of the nodalization during the air phase was shown

Buggs:

- The YT version has a bugg for the oxidation kinetics
- When steam and air are present MELCOR assumes that the fastest correlation has to be used
  - DXMDT = MAX (DXMDTS, DXMDTO)

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Thank you for your attention

Experience with SNAP

Nuclear Energy and Safety
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- SNAP has proved very useful in conveying the results and helps interpretation
- No major complications to import the QUENCH input to SNAP
- The fuel material of ZIRCONIUM-OXIDE was not recognized by SNAP. One has to use the ZRO2-int instead
- When being asked to overite a file not posible
- **Example: Q-16 with SNAP**