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Issues and discrepancies between SNAP visualizations and MELCOR calculations simulating THAI

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SÚRO
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National Radiation Protection Institute

CVŘ Centrum výzkumu Řež

Outlook

- THAI-2
  - Introduction
  - Facility
  - Tests
- Nodalizations
  - 7CV
  - Intersection of several vertical and horizontal planes. 97 CVs with 180 FPs
  - Toroidal. 97 CVs connected with 214 FPs
  - Conical-Toroidal. 119 CVs connected with 351 FPs
  - Inverted Conical-Toroidal
- Tests
  - HD-24
  - HD-18
  - HD27

THAI 2 - Introduction

OECD-THAI project 1 (Thermal-hydraulics, Hydrogen, Aerosols and Iodine)

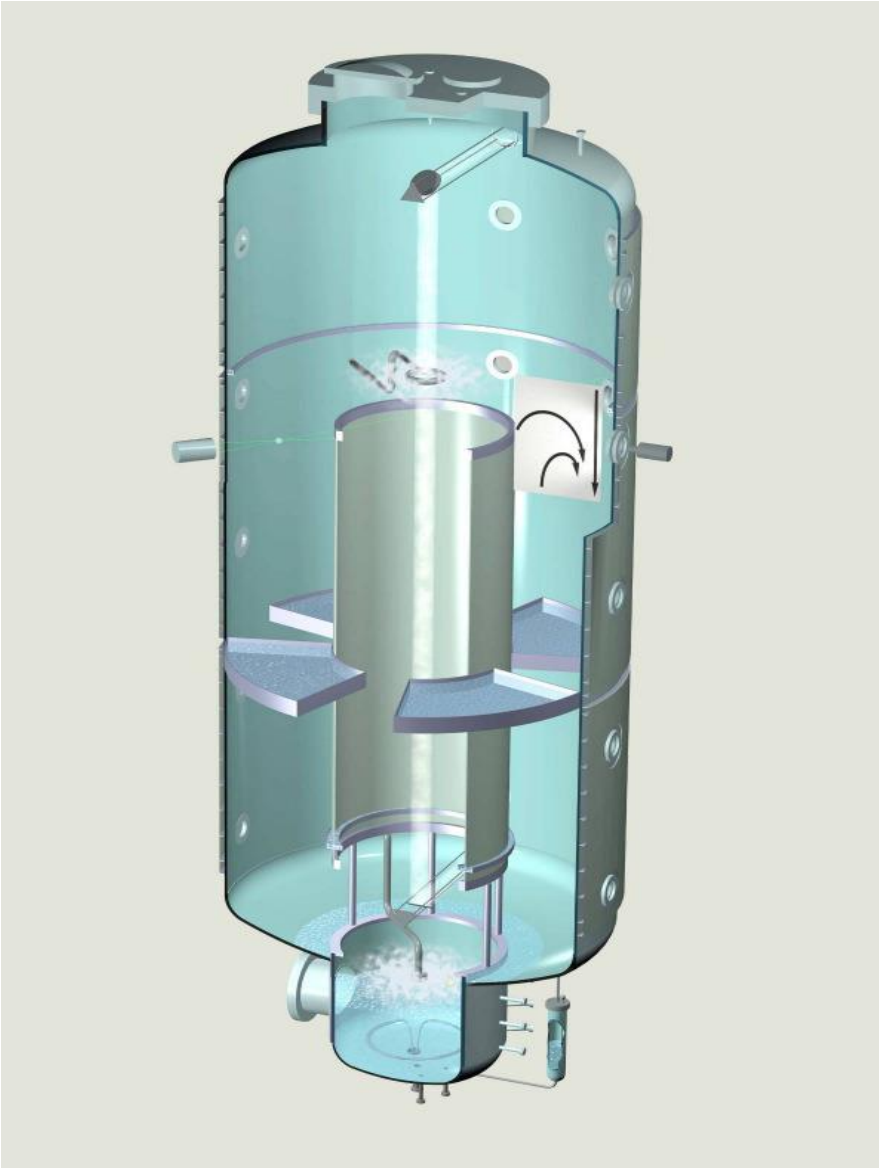
- Program performed by Becker Technologies, in close operation with AREVA
- Used to validate Lumped Parameter and CFD codes
- Develop physical models for different phenomena relevant to severe accidents conditions in NPPs
- Hydrogen behavior
- Iodine and aerosol in the containment of LWR

CVR - Fukushima II project

- MELCOR 2.1 and MELCOR 2.2 validation
- Improve our analysis capability

THAI facility- Tests

- Helium/Hydrogen Material scaling (HM)
- Hydrogen Deflagration (HD)
- Hydrogen Recombiner (HR)
- Interaction of Metal Iodides with Passive Autocatalytic Recombiner
- Passive Autocatalytic Recombiner Poisoning
- Aerosol Wash-Down



Modelling and simulation of 3 Representative experiments

Vertical flame propagation = f (temperature, H_2 & steam content, burn direction)

Variation of fluid and wall temperature & H_2 concentration (pre-mixed)

Po = 1 bar, 25°C, no steam		6 % H_2: HD-4		7.5 % H_2, 1.14 bar: HD-5				
Po = 1.5 bar, no steam								
t = 25 °C	upwards	6 % H_2: HD-1R	7 % H_2: HD-6	8 % H_2: HD-2R, HD-12	9 % H_2: HD-3	10 % H_2: HD-7		
t = 25 °C	downwards			ignition limit: HD-13/-14	9 % H_2: HD-11	10 % H_2: HD-8	11 % H_2: HD-9	12 % H_2: HD-10
t = 140 °C	upwards	6 % H_2: HD-20				10 % H_2: HD-17		
t = 140 °C	downwards				9 % H_2: HD-21	10 % H_2: HD-18		12 % H_2: HD-19

11 + 8 tests

Variation of steam concentration (pre-mixed)

Po = 1.5 bar, t = 90°C

upwards	10 % H_2	no steam: HD-15	25 % steam: HD-22 (74°C dewpoint) P_{steam}= 0.375 bar	47 % steam: HD-24 (saturation) P_{steam}= 0.7 bar
downwards	12 % H_2	no steam: HD-16	25 % steam: HD-23 (74°C dewpoint) P_{steam}= 0.375 bar	

5 tests

Vertical flame propagation in a stratified atmosphere

Po = 1.5 bar top 90°C / saturation (47 % steam)
bottom 30°C / saturation (3 % steam)

upwards	top 10 % H_2 bottom 10% H_2 HD-26	top 12 % H_2 bottom 6% H_2 HD-27	top 6 % H_2 bottom 12 % H_2 HD-28
downwards	top 12 % H_2 * bottom 10% H_2 HD-25	top 12 % H_2 bottom 6% H_2 HD-29	

5 tests

* = originally specified to be 10 % H_2; this mixture, however, turned out too lean for downward combustion.
Tests labelled blue: supplementary tests, not included in the contracted test matrix

HD 24. 10% H_2 - 47% steam P_{steam}=0.7 bar T=90°C

Vertical flame propagation = f (temperature, H_2 & steam content, burn direction)

Variation of fluid and wall temperature & H_2 concentration (pre-mixed)

Po = 1 bar, 25°C, no steam		6 % H_2: HD-4		7.5 % H_2, 1.14 bar: HD-5				
Po = 1.5 bar, no steam								
t = 25 °C	upwards	6 % H_2: HD-1R	7 % H_2: HD-6	8 % H_2: HD-2R, HD-12	9 % H_2: HD-3	10 % H_2: HD-7		
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t = 140 °C	upwards	6 % H_2: HD-20				10 % H_2: HD-17		
t = 140 °C	downwards				9 % H_2: HD-21	10 % H_2: HD-18		12 % H_2: HD-19

11 + 8 tests

Variation of steam concentration (pre-mixed)

Po = 1.5 bar, t = 90°C

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downwards	12 % H_2	no steam: HD-16	25 % steam: HD-23 (74°C dewpoint) P_{steam}= 0.375 bar	

5 tests

Vertical flame propagation in a stratified atmosphere

Po = 1.5 bar top 90°C / saturation (47 % steam)
bottom 30°C / saturation (3 % steam)

upwards	top 10 % H_2 bottom 10% H_2 HD-26	top 12 % H_2 bottom 6% H_2 HD-27	top 6 % H_2 bottom 12 % H_2 HD-28
downwards	top 12 % H_2 * bottom 10% H_2 HD-25	top 12 % H_2 bottom 6% H_2 HD-29	

5 tests

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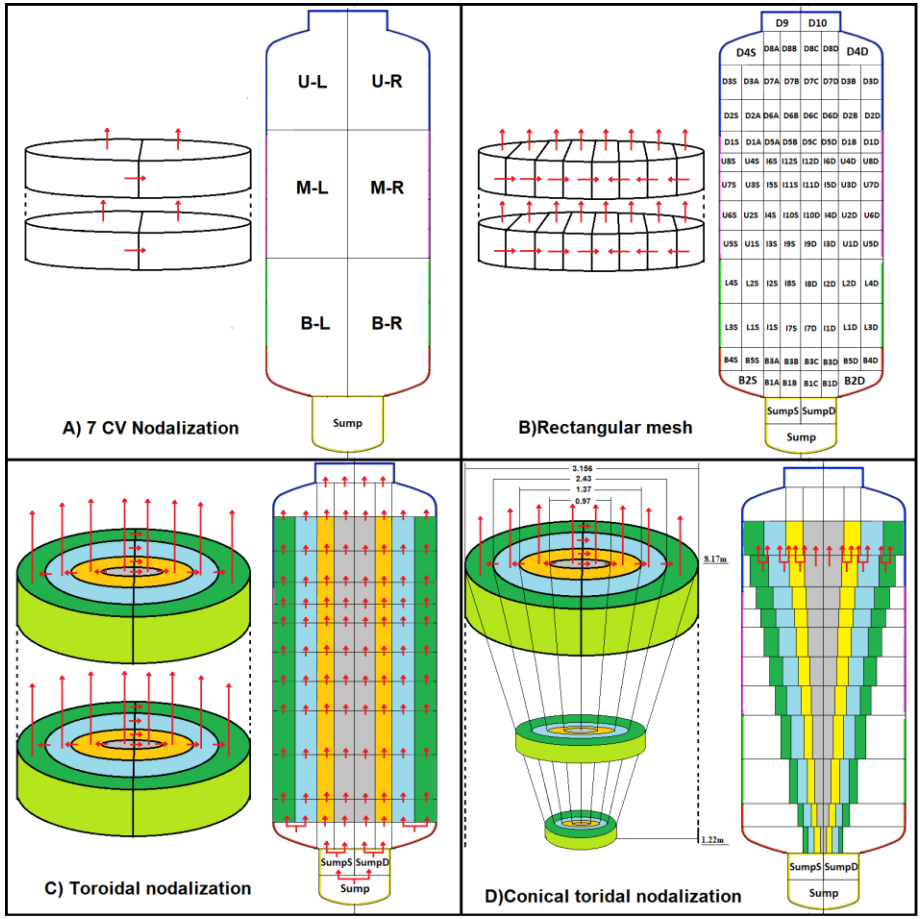
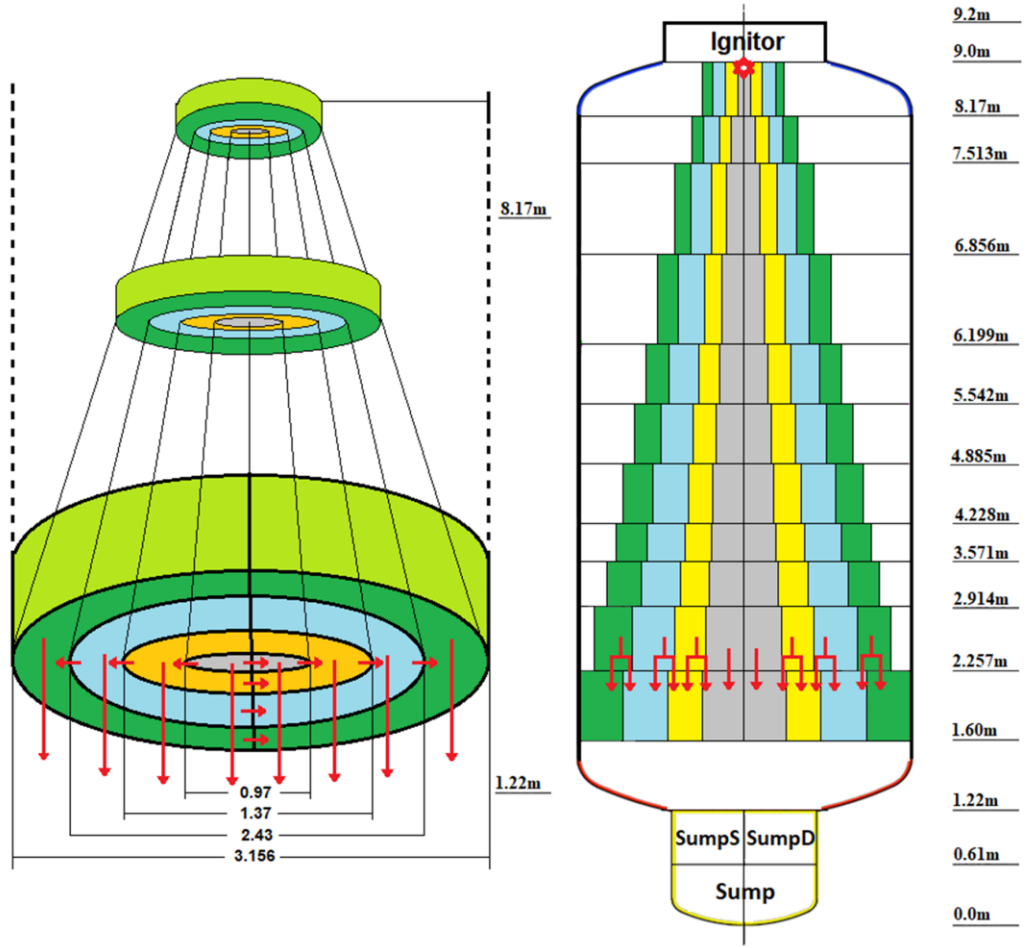
Tests labelled blue: supplementary tests, not included in the contracted test matrix

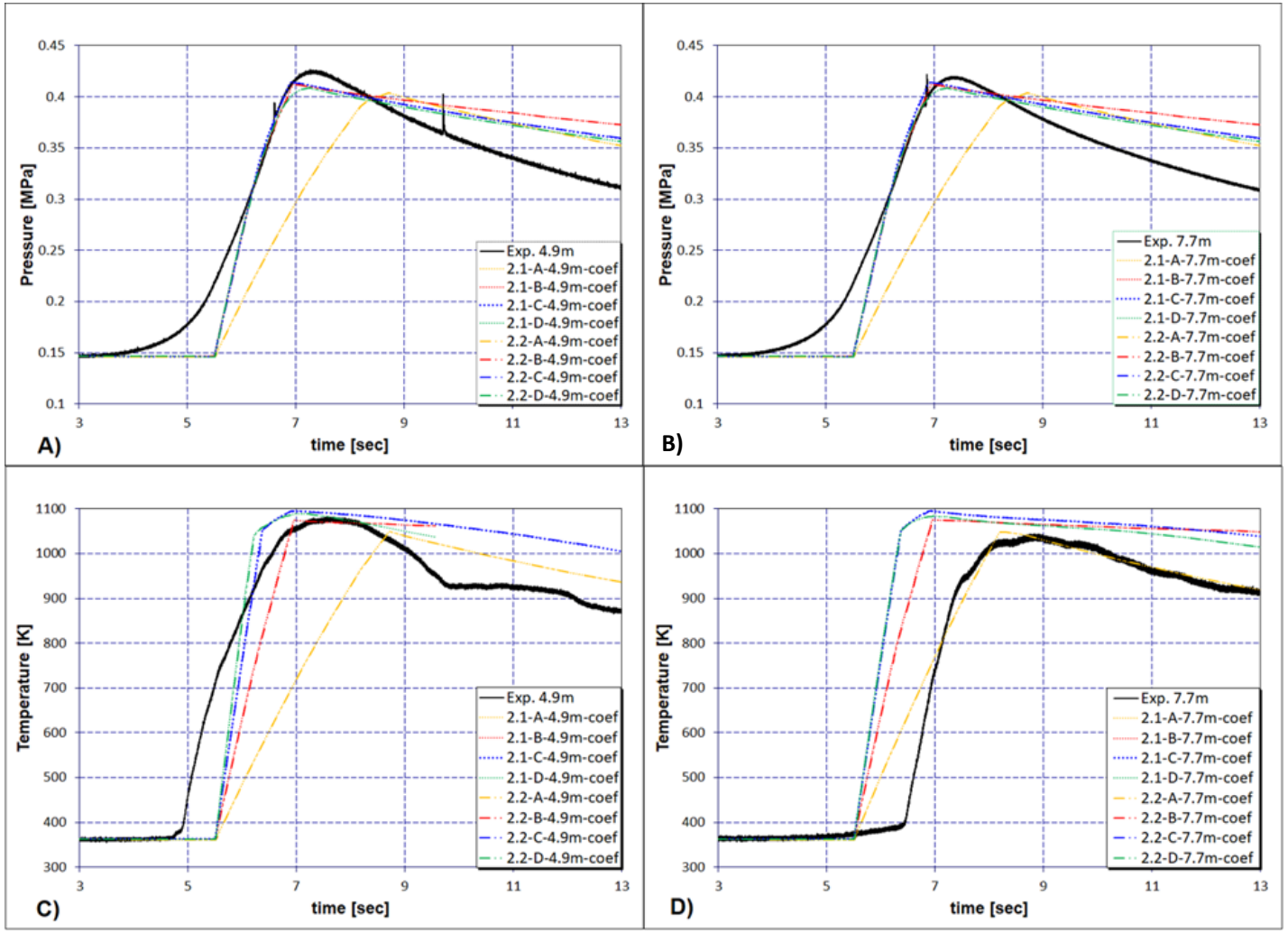
Nodalizations





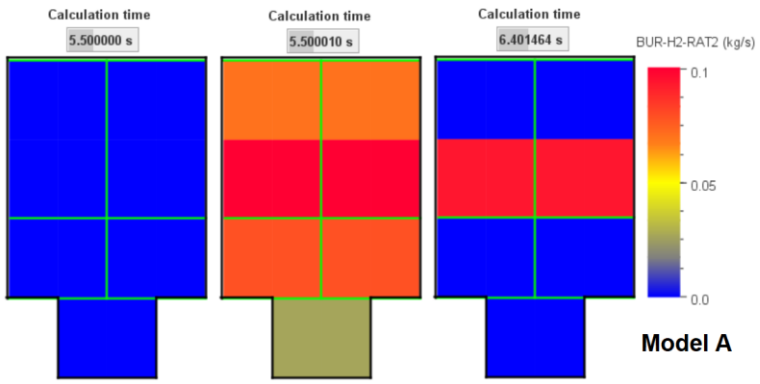
E)

HD-24. Pressure and Temperature for different nodalizations

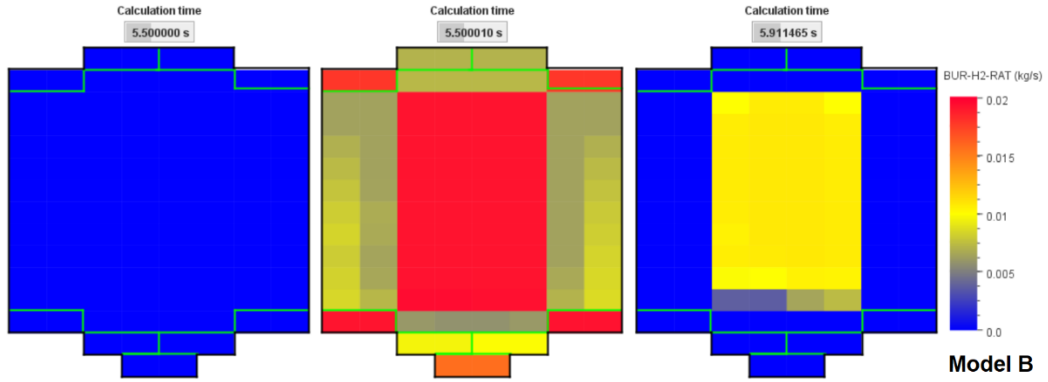


MELCOR 2.1

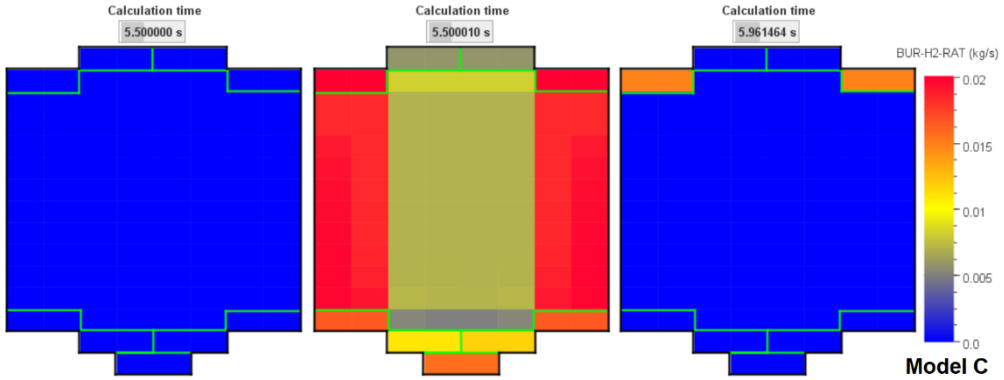
A)



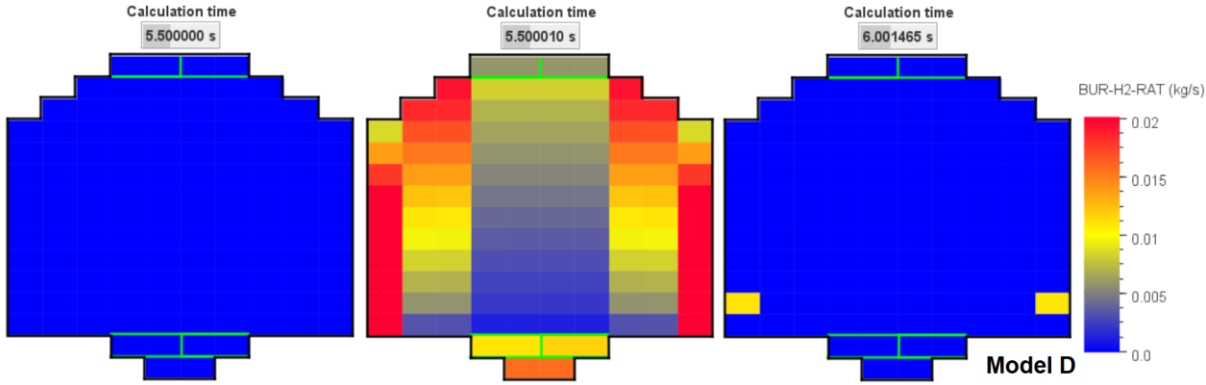
B)



C)

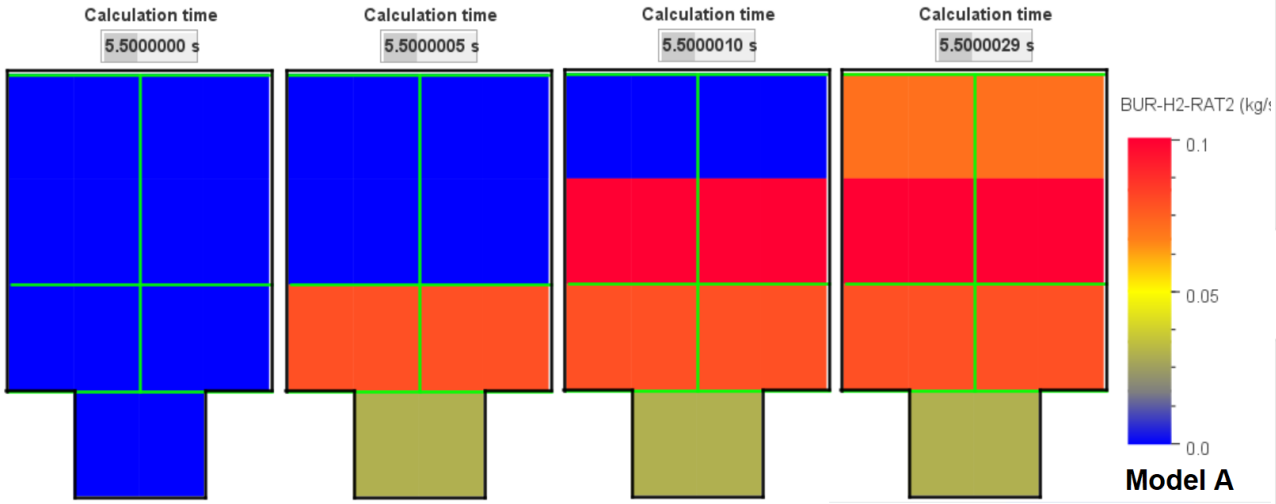


D)



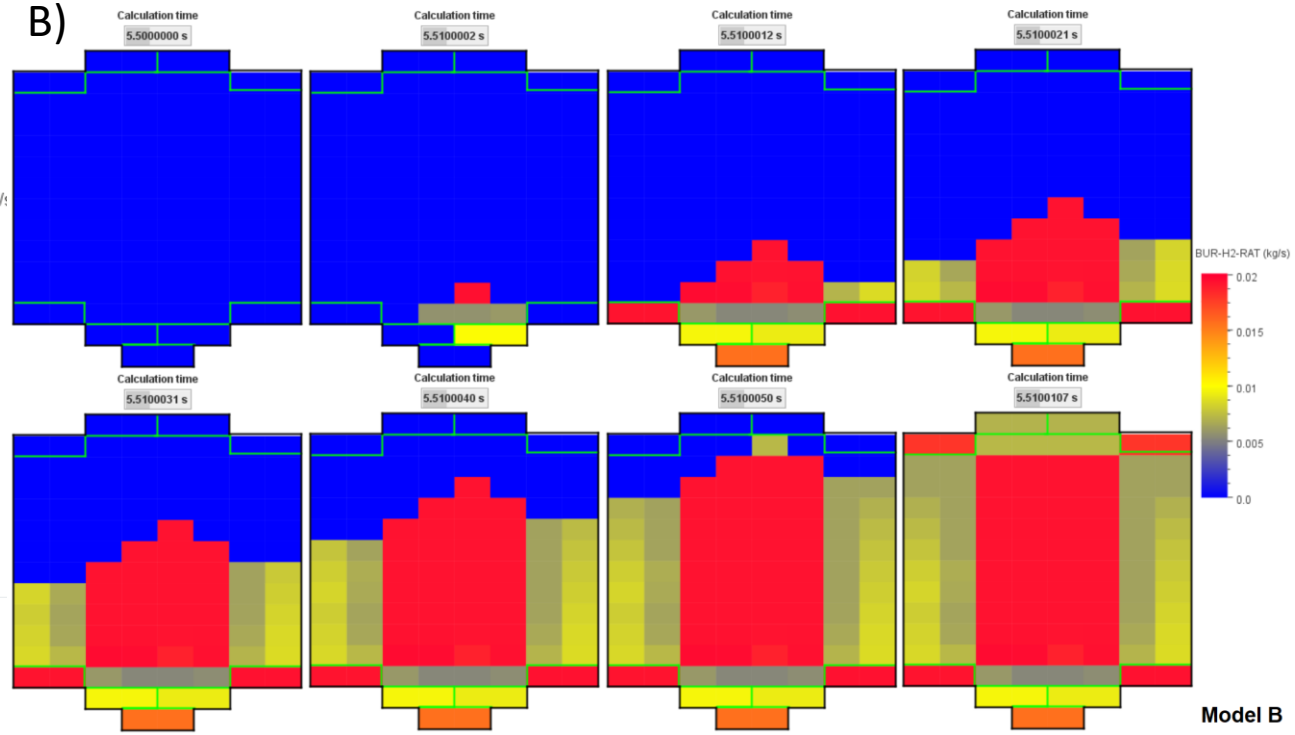
MELCOR 2.2

A)



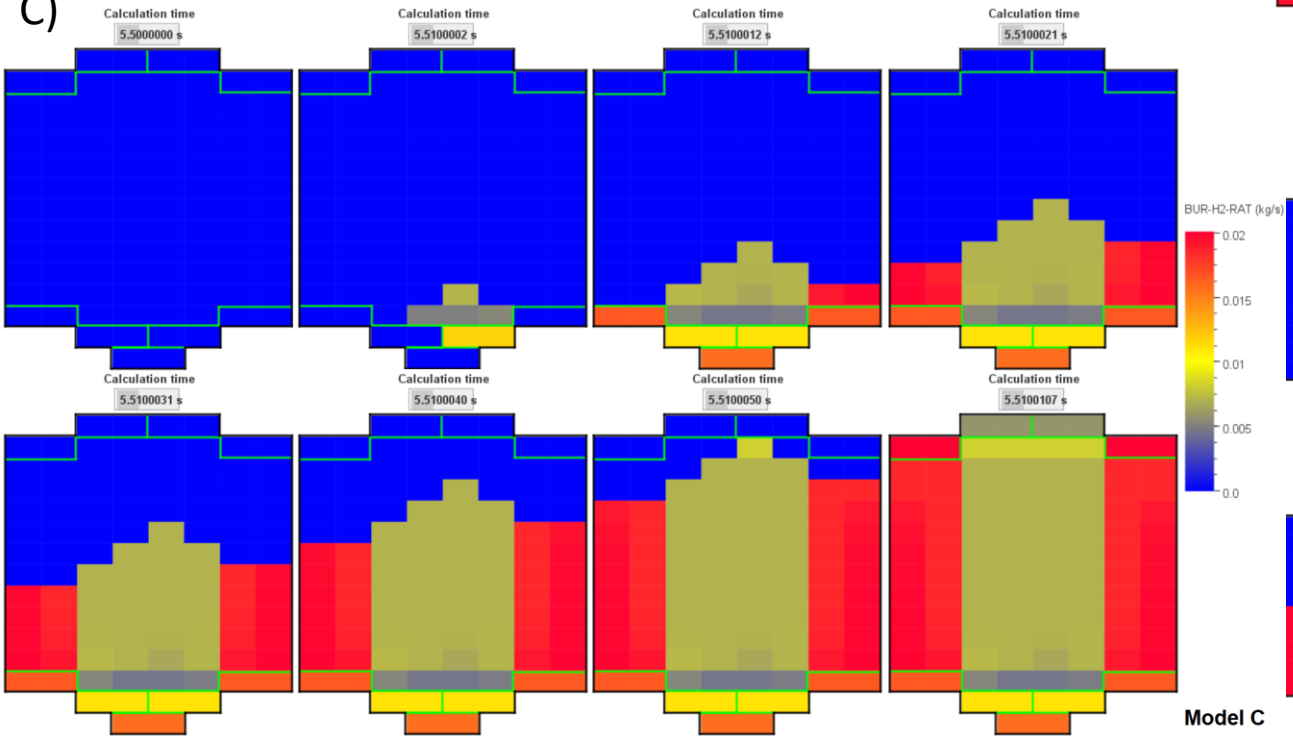
Model A

B)



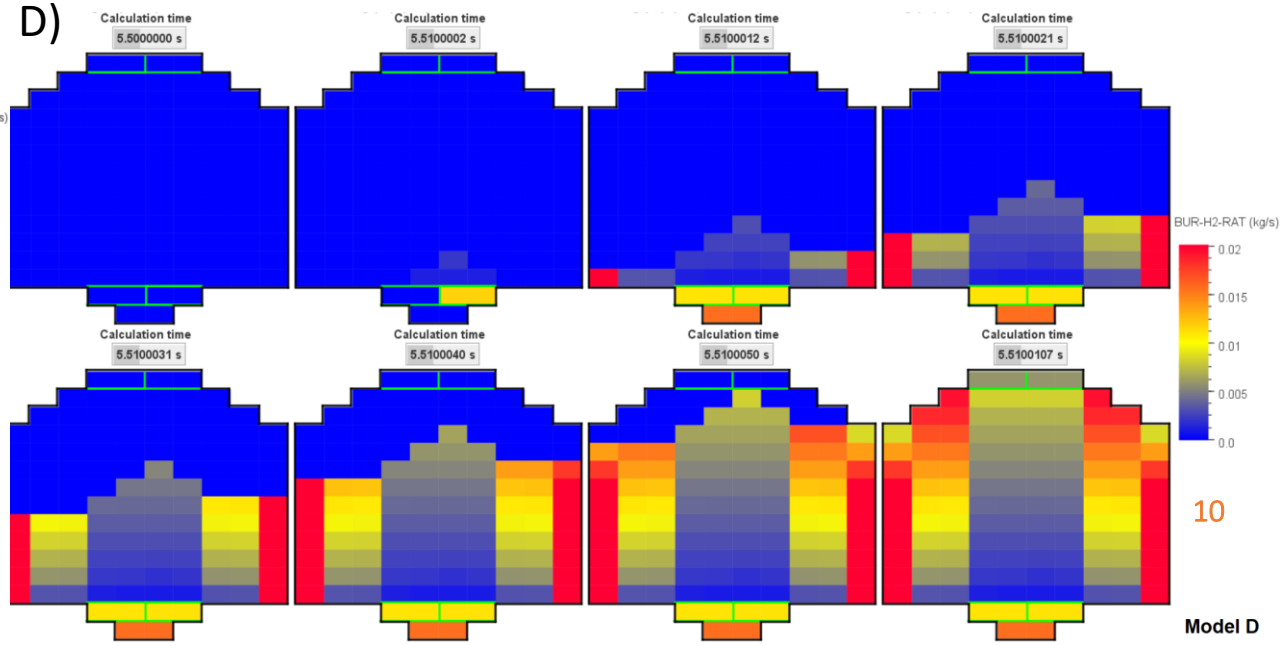
Model B

C)



Model C

D)



Model D

Modelling and simulation of 3 Representative experiments

Vertical flame propagation = f (temperature, H_2 & steam content, burn direction)

Variation of fluid and wall temperature & H_2 concentration (pre-mixed)

Po = 1 bar, 25°C, no steam		6 % H_2: HD-4	7.5 % H_2, 1.14 bar: HD-5					11 + 8 tests
Po = 1.5 bar, no steam								
t = 25 °C	upwards	6 % H_2: HD-1R	7 % H_2: HD-6	8 % H_2: HD-2R, HD-12	9 % H_2: HD-3	10 % H_2: HD-7		
t = 25 °C	downwards			ignition limit: HD-13/-14	9 % H_2: HD-11	10 % H_2: HD-8	11 % H_2: HD-9	12 % H_2: HD-10
t = 140 °C	upwards	6 % H_2: HD-20				10 % H_2: HD-17		
t = 140 °C	downwards				9 % H_2: HD-21	10 % H_2: HD-18		12 % H_2: HD-19

Variation of steam concentration (pre-mixed)

Po = 1.5 bar, t = 90°C

upwards	10 % H_2	no steam: HD-15	25 % steam: HD-22 (74°C dewpoint) P_{steam}= 0.375 bar	47 % steam: HD-24 (saturation) P_{steam}= 0.7 bar	5 tests
downwards	12 % H_2	no steam: HD-16	25 % steam: HD-23 (74°C dewpoint) P_{steam}= 0.375 bar		

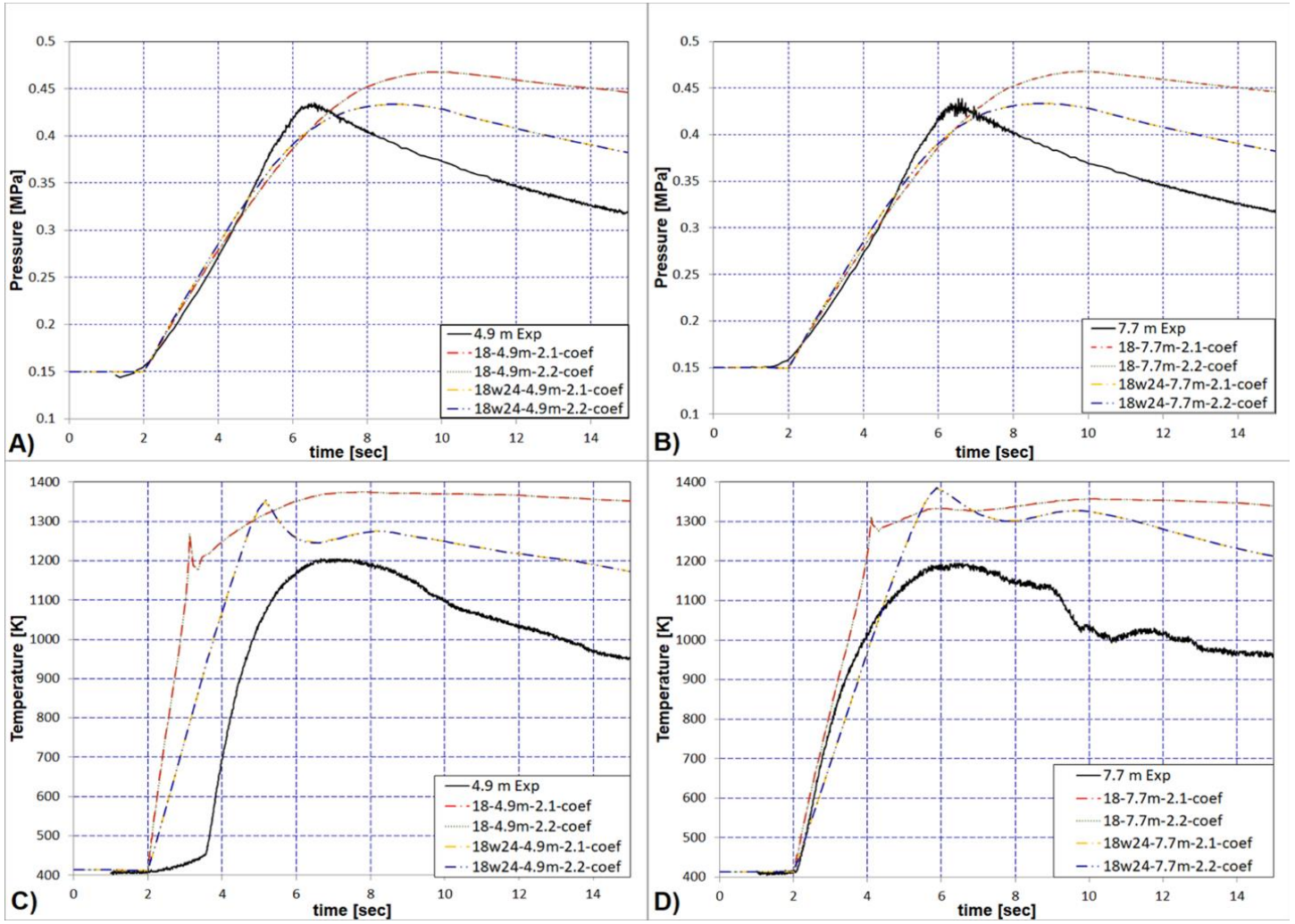
Vertical flame propagation in a stratified atmosphere

Po = 1.5 bar top 90°C / saturation (47 % steam)
bottom 30°C / saturation (3 % steam)

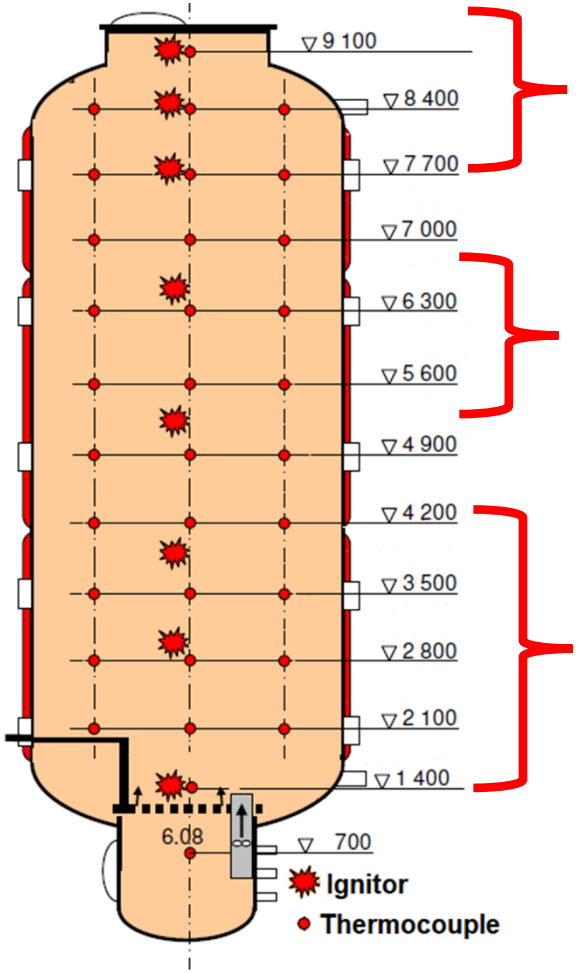
upwards	top 10 % H_2 bottom 10% H_2 HD-26	top 12 % H_2 bottom 6% H_2 HD-27	top 6 % H_2 bottom 12 % H_2 HD-28	5 tests
downwards	top 12 % H_2 * bottom 10% H_2 HD-25	top 12 % H_2 bottom 6% H_2 HD-29		

* = originally specified to be 10 % H_2; this mixture, however, turned out too lean for downward combustion.
Tests labelled blue: supplementary tests, not included in the contracted test matrix

HD-18. Pressure and Temperature.



Sensitivity analyses on HD-18 different ignitor localizations



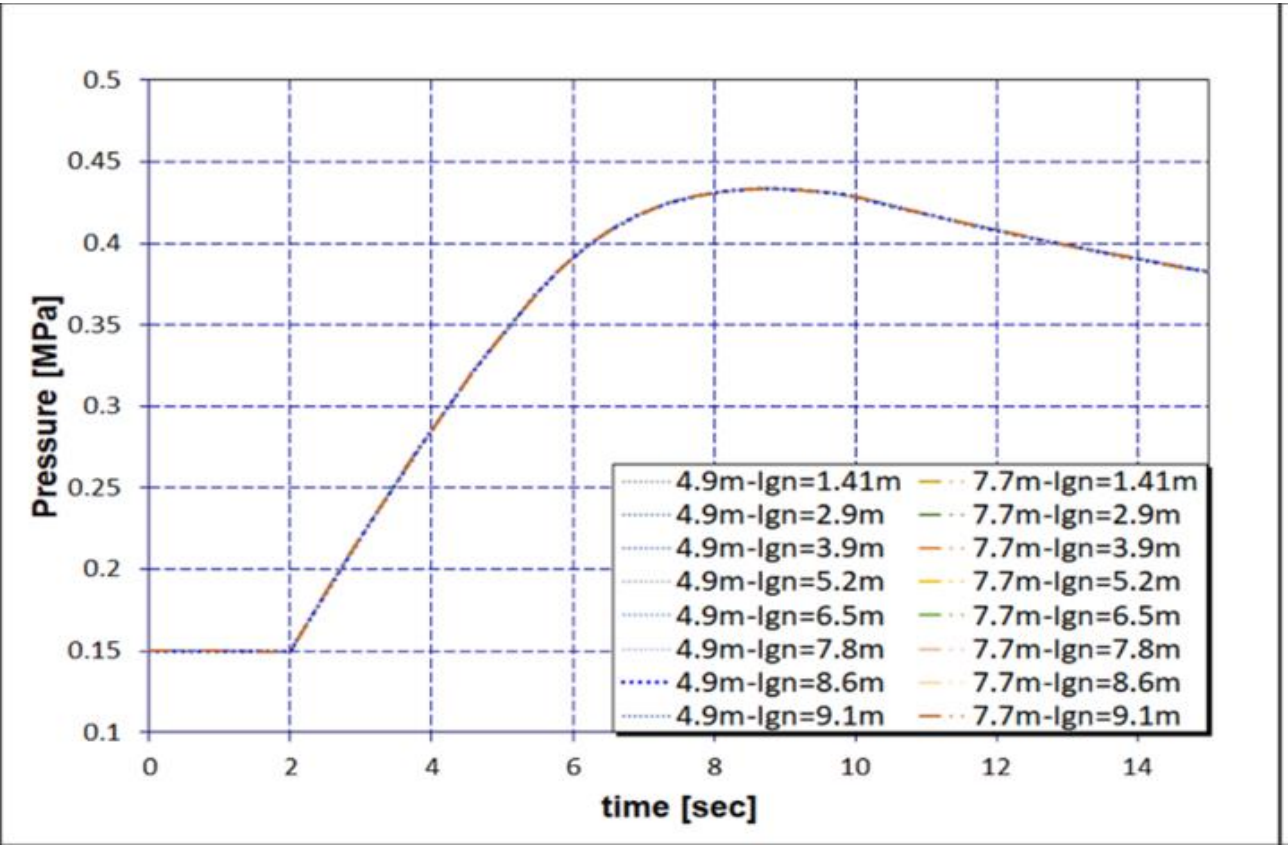
Ignitors position:

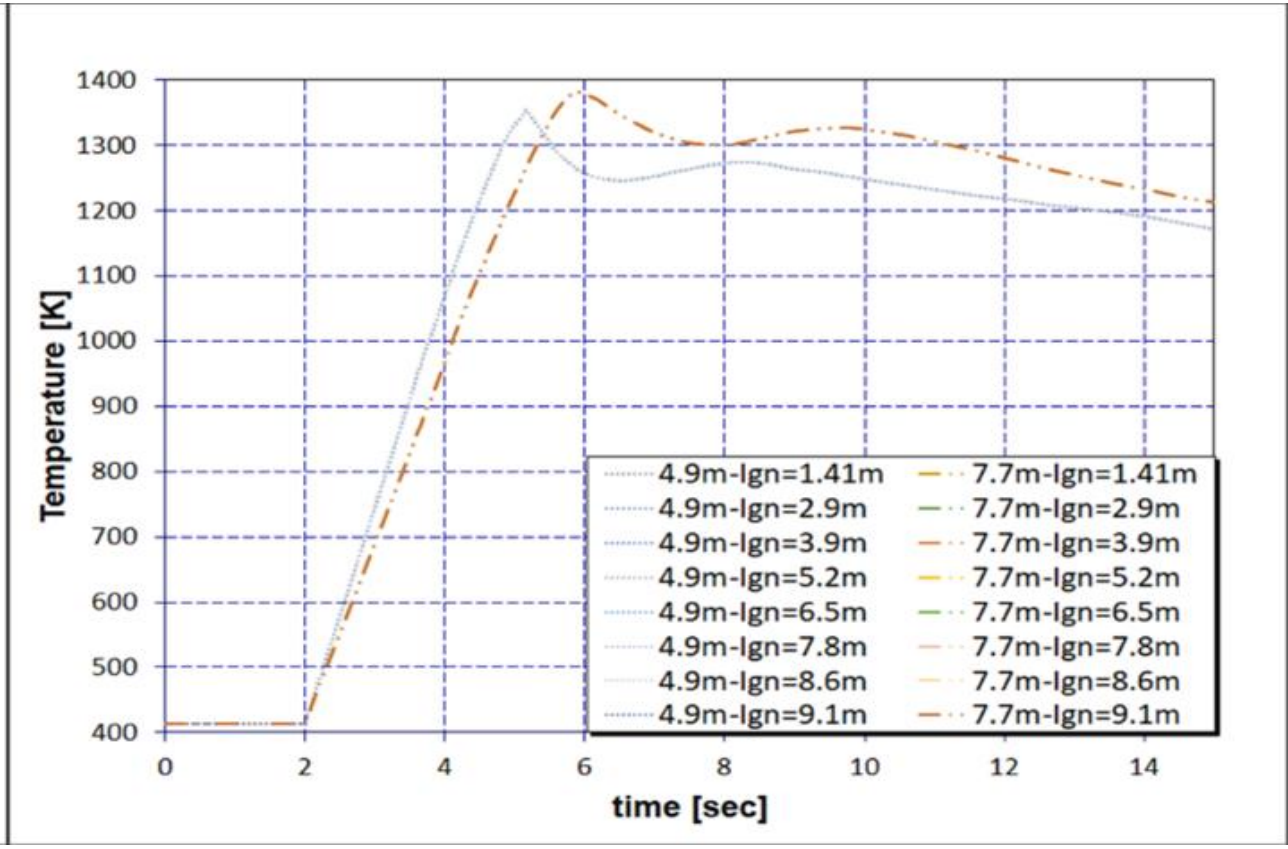
Top (Original experiment position 9.1 m)

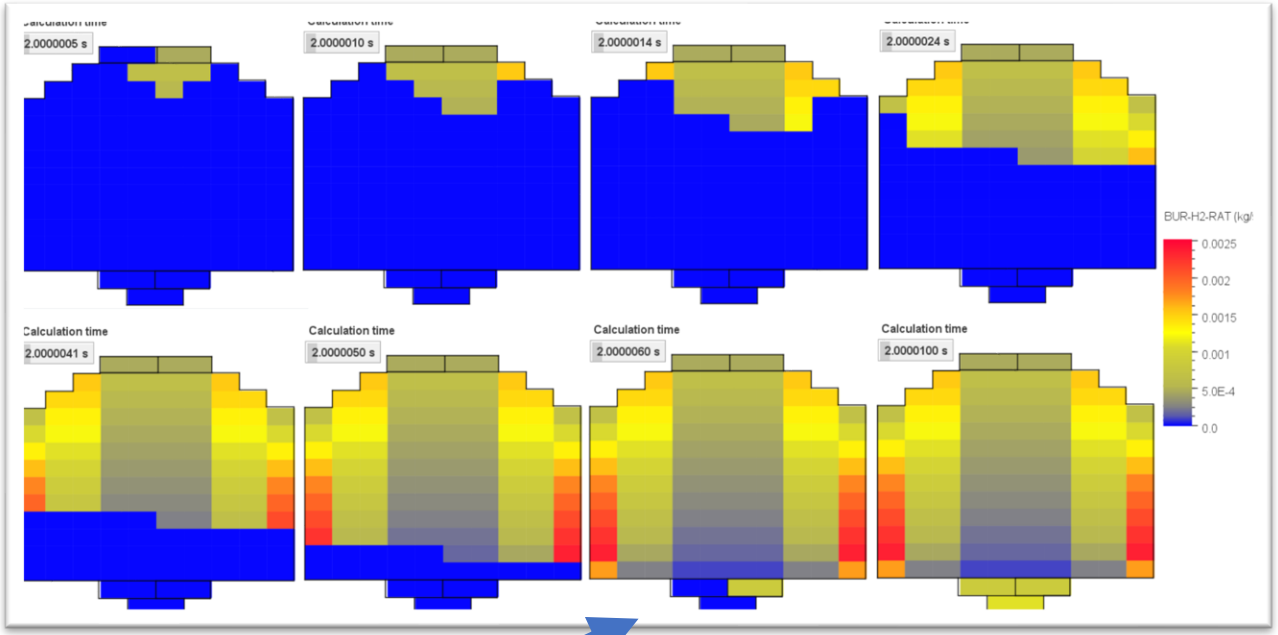
Centre

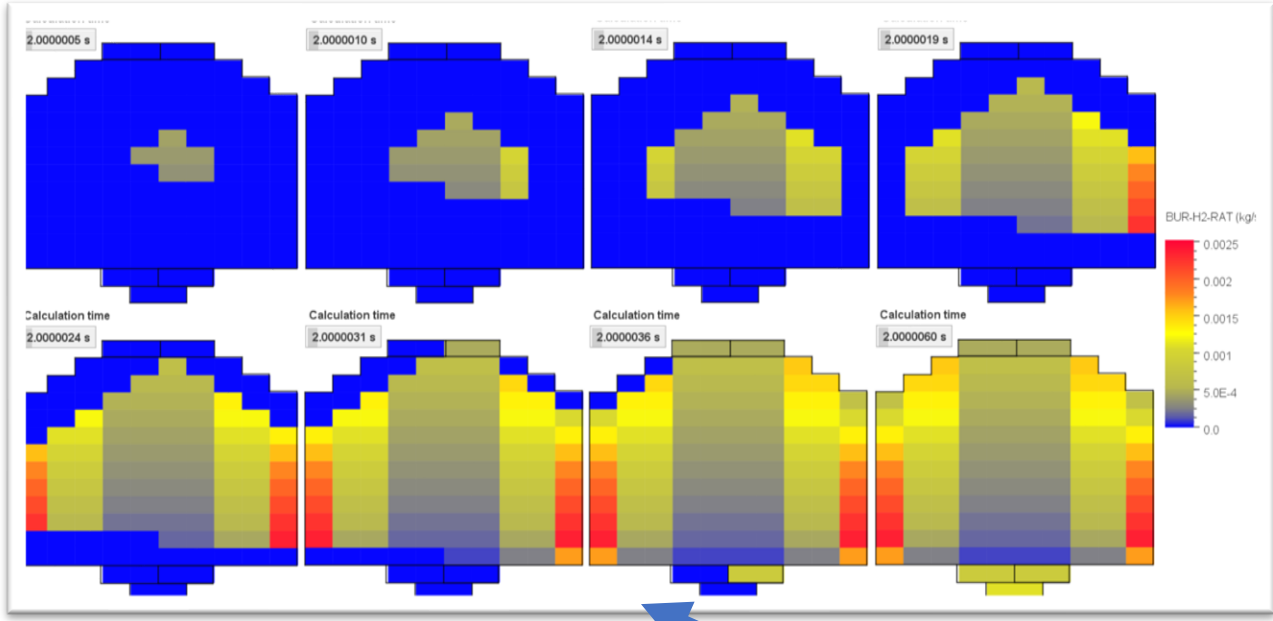
Bottom

Pressure and Temperature results.



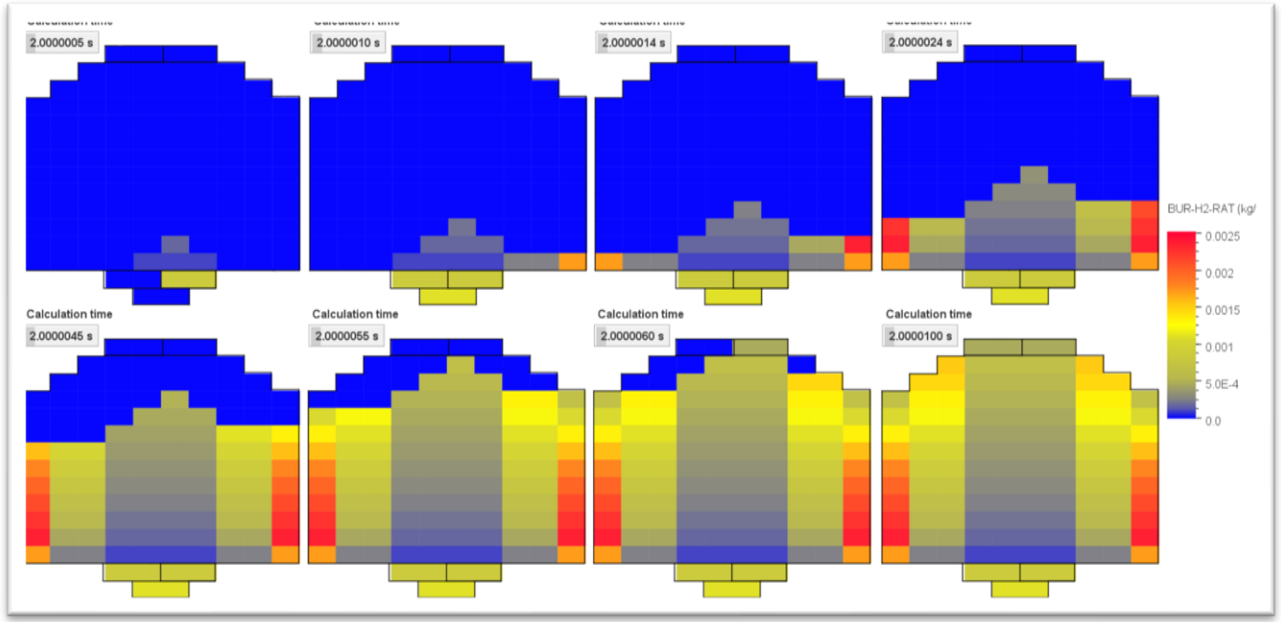






- Ignitor on top of vessel

- Ignitor on bottom of vessel



- Ignitor on middle part of vessel

Modelling and simulation of 3 Representative experiments

Vertical flame propagation = f (temperature, H_2 & steam content, burn direction)

Variation of fluid and wall temperature & H_2 concentration (pre-mixed)

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Po = 1.5 bar, no steam								
t = 25 °C	upwards	6 % H_2: HD-1R	7 % H_2: HD-6	8 % H_2: HD-2R, HD-12	9 % H_2: HD-3	10 % H_2: HD-7		
t = 25 °C	downwards			ignition limit: HD-13/-14	9 % H_2: HD-11	10 % H_2: HD-8	11 % H_2: HD-9	12 % H_2: HD-10
t = 140 °C	upwards	6 % H_2: HD-20				10 % H_2: HD-17		
t = 140 °C	downwards				9 % H_2: HD-21	10 % H_2: HD-18		12 % H_2: HD-19

11 + 8 tests

Variation of steam concentration (pre-mixed)

Po = 1.5 bar, t = 90°C

upwards	10 % H_2	no steam: HD-15	25 % steam: HD-22 (74°C dewpoint) P_{steam}= 0.375 bar	47 % steam: HD-24 (saturation) P_{steam}= 0.7 bar
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5 tests

Vertical flame propagation in a stratified atmosphere

Po = 1.5 bar top 90°C / saturation (47 % steam)
bottom 30°C / saturation (3 % steam)

upwards	top 10 % H_2 bottom 10% H_2	top 12 % H_2 bottom 6% H_2 HD-27	top 6 % H_2 bottom 12 % H_2 HD-28
downwards	top 12 % H_2 * bottom 10% H_2 HD-25	top 12 % H_2 bottom 6% H_2 HD-29	

5 tests

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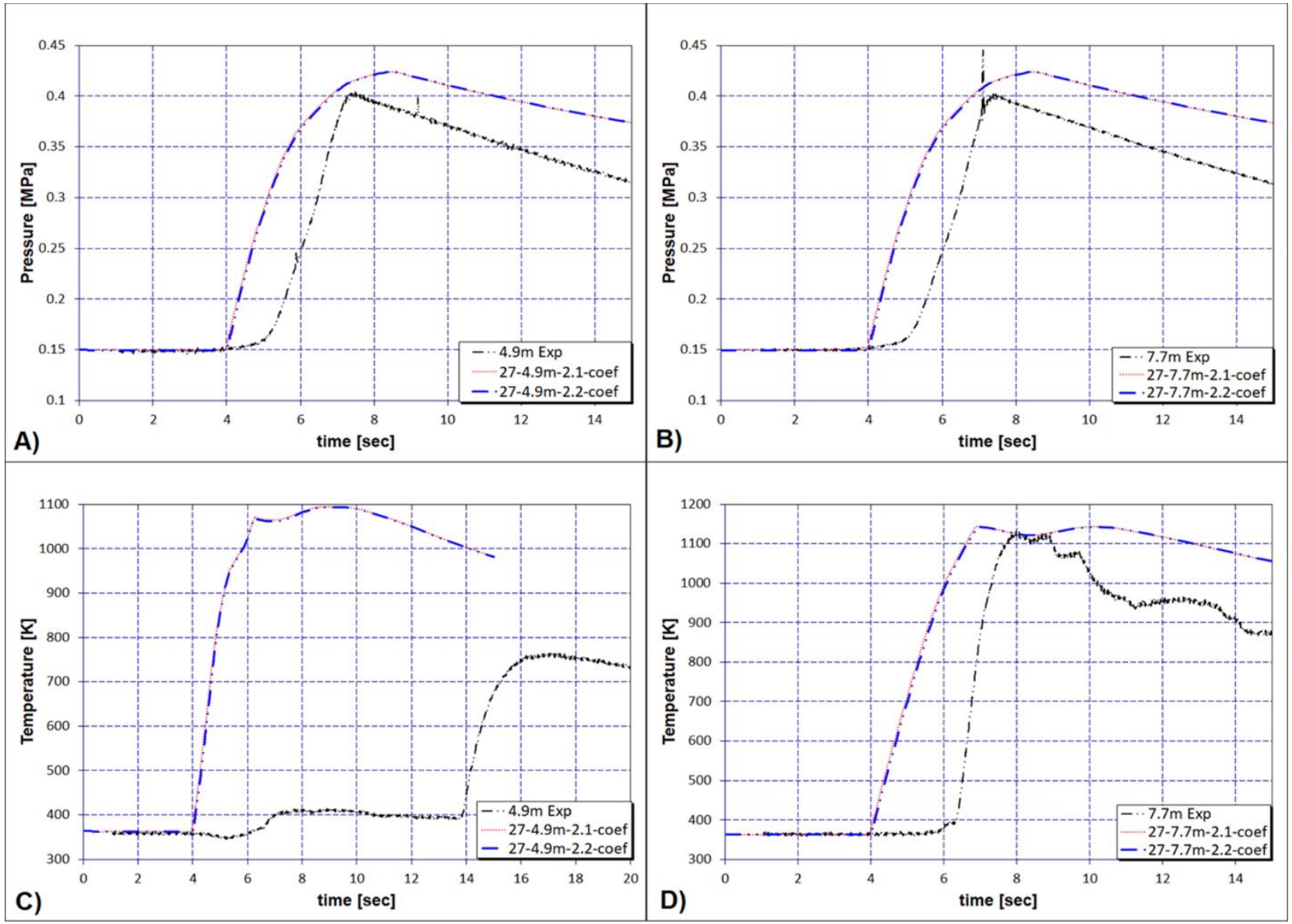
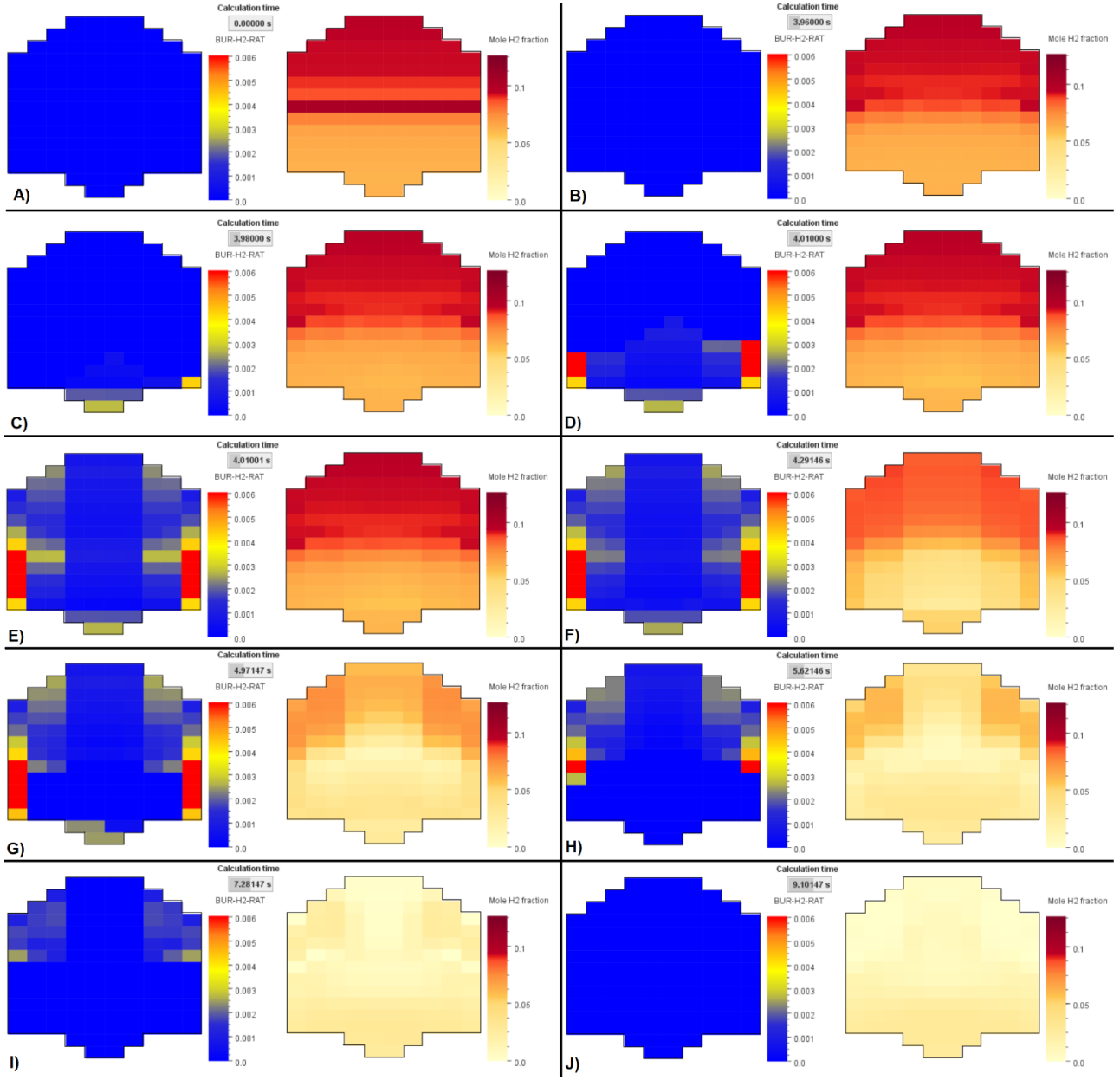
Tests labelled blue: supplementary tests, not included in the contracted test matrix

HD-27 Top: 90°C 12%H_2-Steam 47%. Bottom: 30°C 6%H_2-Steam 3%



HD-27. Burn H_2 rate and H_2 mole fraction



Conclusions and Questions (1/2)

- MELCOR 2.1 and 2.2 show same results (from APT plot) for:
  - *pressure*
  - *temperature*
  - *the H_2 burn rate*
- **but** in the MELCOR 2.2 SNAP visualization shows a “kind” of flame front propagation.
- For experiment 18, 3 locations of the ignitor were selected **(to check the ignitors influence on flame propagation)** :
  - *Top*
  - *Centre*
  - *Bottom*

Conclusions and Questions (2/2)

- It was detected a “kind of propagation” of the flame rate:
  - *Top*: with origin in the ignitor and extended downwards.
  - *Centre*: with a radial propagation and down directions.
  - *Bottom*: with propagation upwards.

- That propagation **does not represent** the flame front propagation.

- Rather just the CVs **activation** (when is **allowed** the burning).
- The **“user effect”** can play an important role in the results **customizing the CV and FL pattern**.