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Passive Recombiner model in MELCOR 2.1 and its validation against THAI HR-1 test experimental data

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Joint R&D Project

- Joint international R&D Project "*Examination and improvement of mitigation capabilities and strategies of operating PWRs and an APR series PWR against Design Extension Conditions (DEC)*" was launched in January 2021.
- Partners from Czech Republic and Republic of Korea
  - CZE Partners: TES, BUT
  - KOR Partners: FNC Technology, KHNP, KINGS
- Project is co-financed from TACR (Technology Agency of the Czech Republic) in frame of DELTA 2 funding program for applied research, experimental development and innovation

Passive Recombiner (PAR)

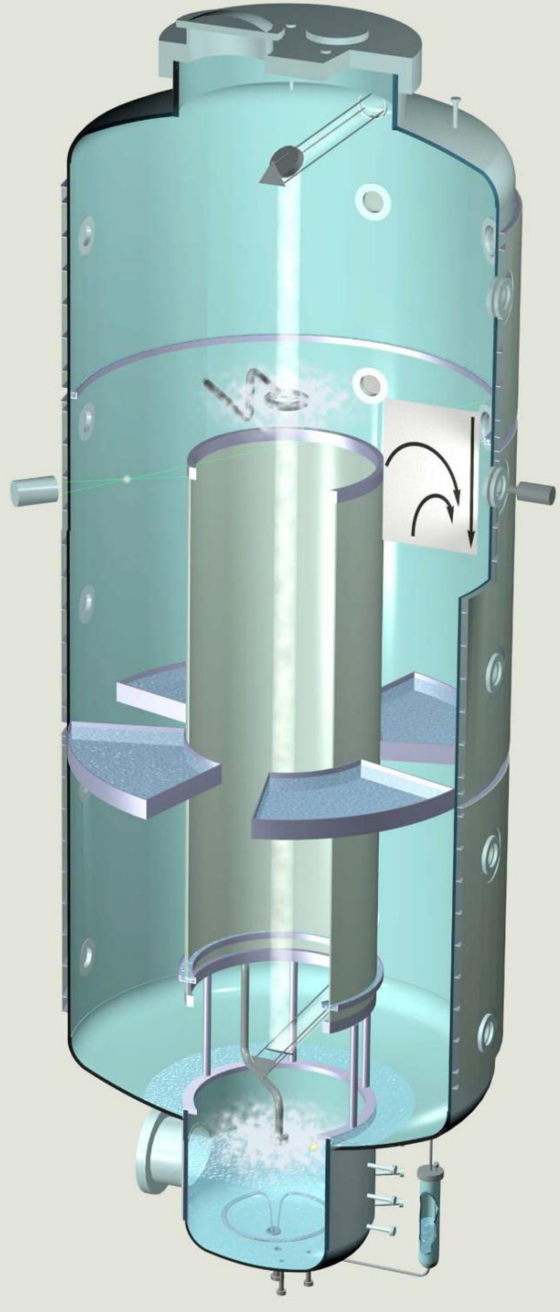
- Passive safety elements for Hydrogen (H_2) removal
- Vercital body contains plates covered with catalyst
- Platinum (Pt) or Palladium (Pd) are usually used as a catalyst

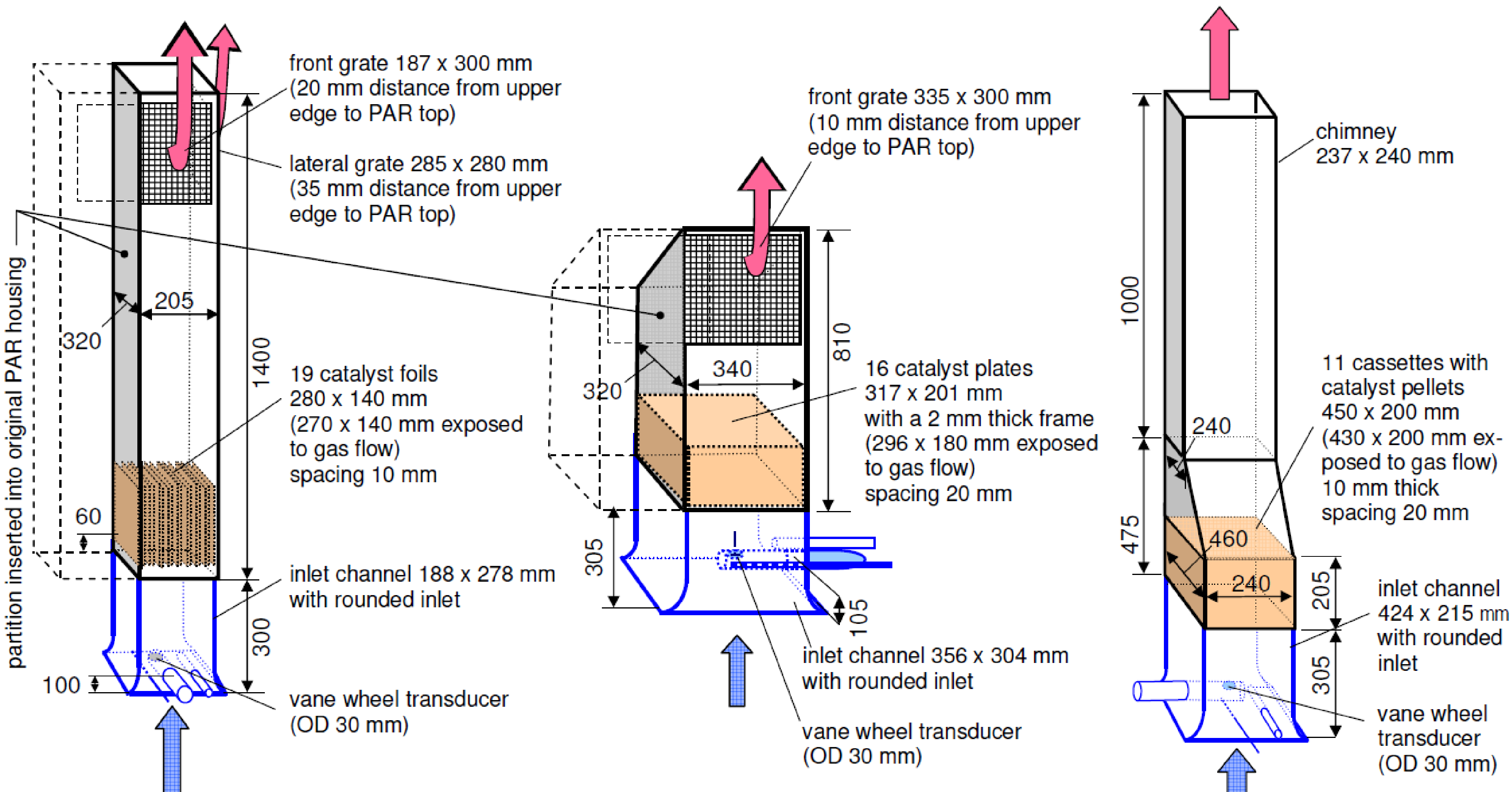
$$2H_2 + O_2 \rightarrow 2H_2O + heat$$

- Hydrogen is removed, vapor and heat are generated

THAI Facility Description

- Operated by Becker Technologies GmbH, Eschborn, Germany
- 60 m^3 test vessel, 9.2 m high, 3.2 m diameter
- Maximum overpressure 1.4 MPa at 180 °C





Areva (Siemens)
0.5 * FR-380 size

AECL
0.52 * standard size

NIS
1/8 module

HR-1 Test Description

- Initial conditions:
  - Pressure 0.1002 MPa
  - Temperature 24.6 °C
  - 21 vol% O_2, no steam, no H_2
- Phase 1: t = 0 – 24.7 min
  - Low rate (0.15 g/s) H_2 injection
  - Automatic onset of recombination (t = 17 min)
  - Switch to full rate (0.30 g/s) H_2 injection

HR-1 Test Description

- Phase 2: t = 24.7 – 84.7 min
  - Interrupt H_2 injection when inlet H_2 concentration reaches approx. 6.1 vol%
- Phase 3: t = 84.7 – 104.7 min
  - Full H_2 injection when inlet H_2 concentration falls to 0.6 vol%
  - Injection continues until H_2 inlet concentration reaches 6.8 vol%

HR-1 Test Description

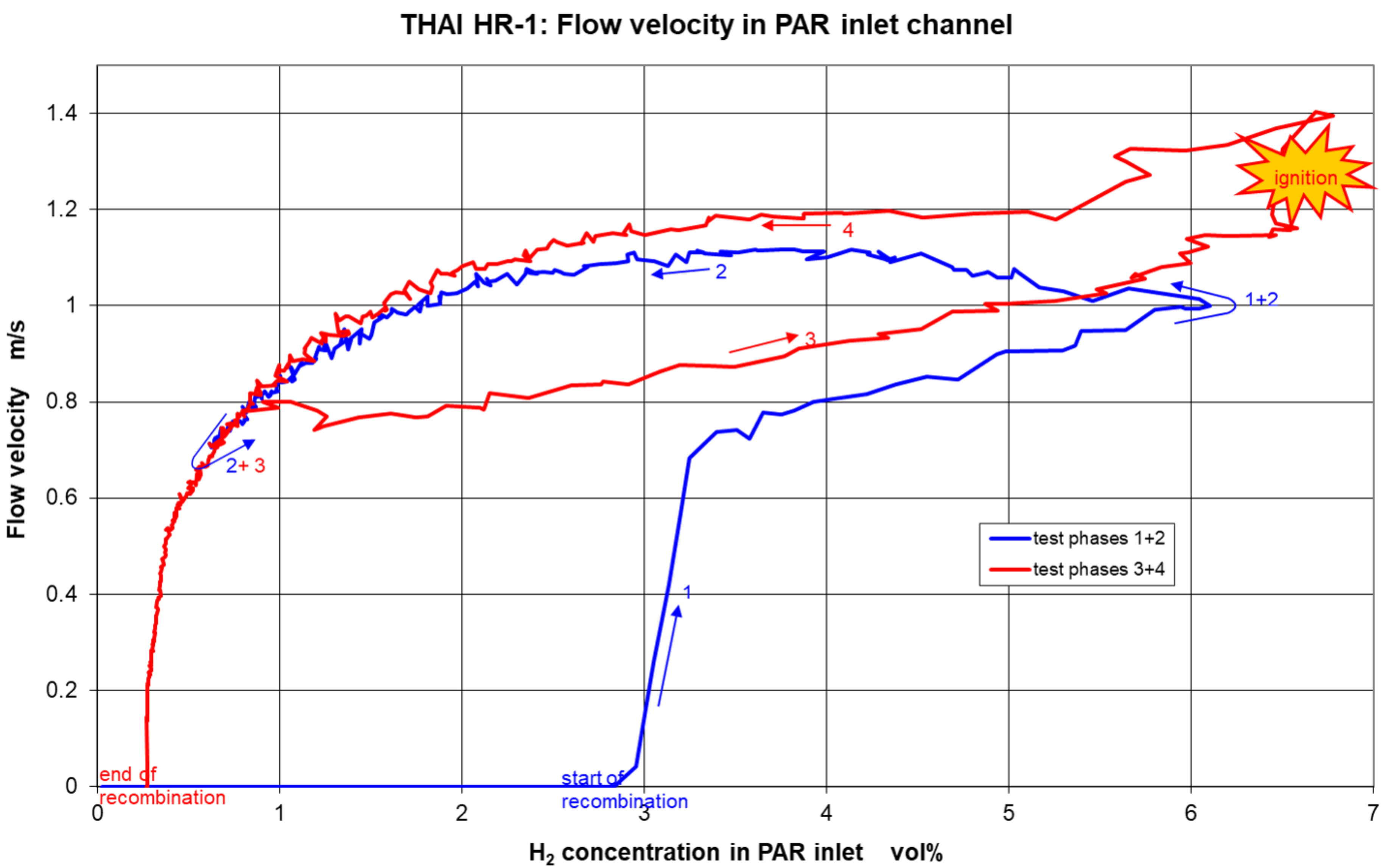
- Phase 4: t = 104.7 – 210.7 min
  - At 6.8 vol% H_2 inlet concentration ignition at PAR outlet occurrs
  - No more H_2 injection
  - H_2 concentration falls to 0.27 vol%

PAR model in MELCOR

- Engineering Safety Features (ESF) Package
  - PAR subpackage
- Fischer model

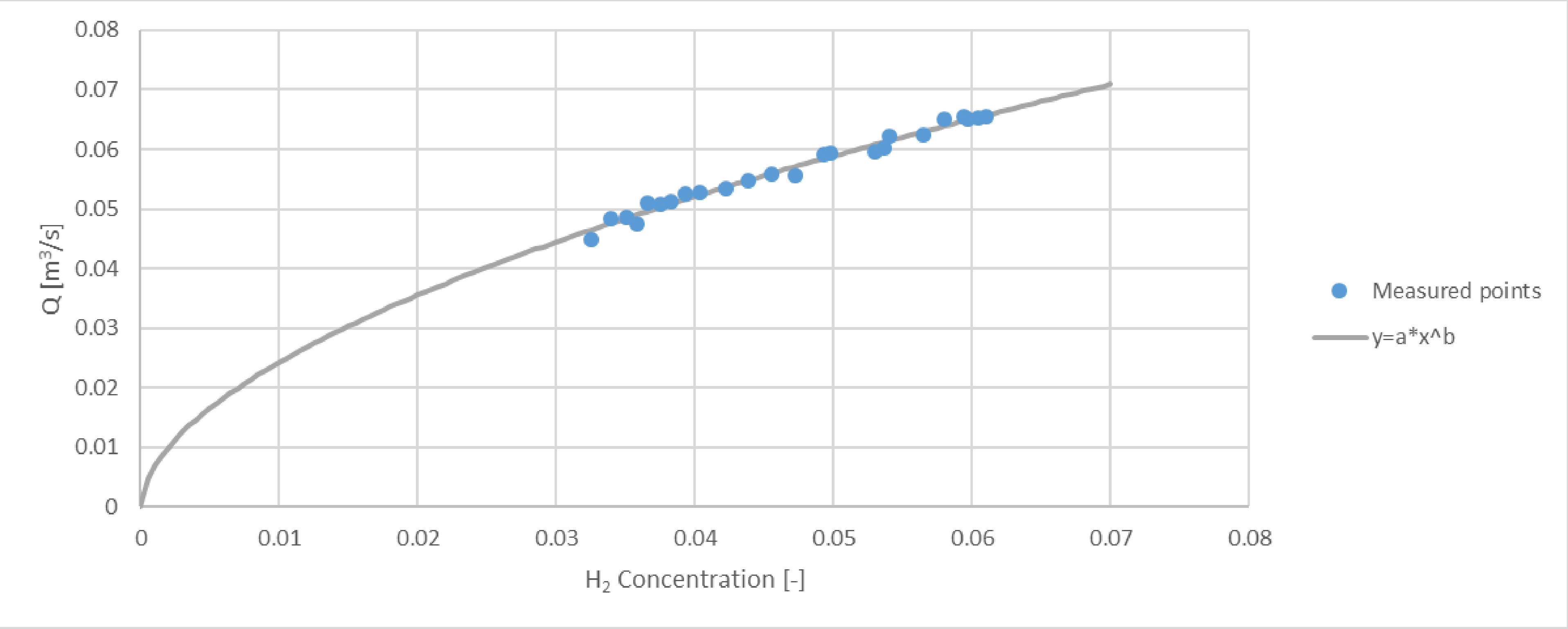
$$Q = aC_H^b$$

  - Q … volumetric flow rate through a PAR unit $[m^3/s]$
  - C_H … molar concentration of Hydrogen [-]
  - a, b … constants specific for a PAR unit
- PAR Package determines the changes in Hydrogen, Oxygen and Vapor masses
- Changes are passed to CVH Package



THAI HR-1: Flow velocity in PAR inlet channel
Flow velocity m/s
H_2 concentration in PAR inlet vol%
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
7
ignition
4
2
1+2
3
2+ 3
1
test phases 1+2
test phases 3+4
end of
recombination
start of
recombination

When data available



When data unavailable

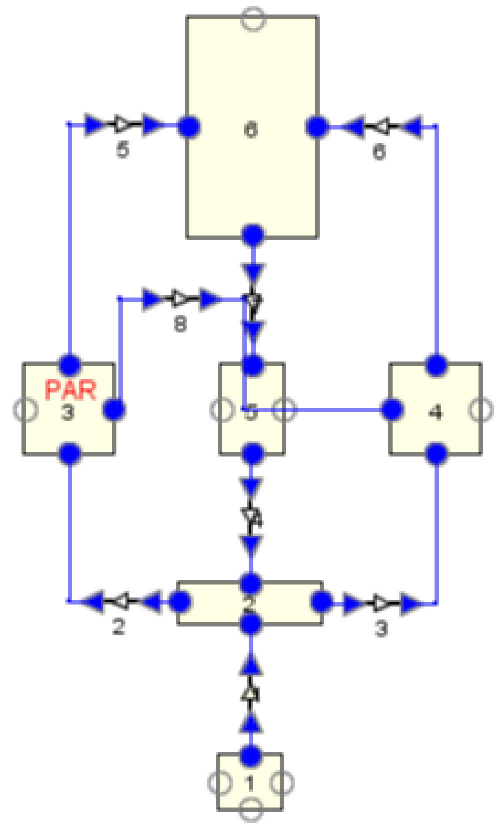
- Only single measured point was provided by the manufacturer/operator
- It is not clear in which „phase“ the point was measured
- Therefore a Methodology was developed
  - Pressure drop evaluation is used
  - Heat loss is taken into account
  - Simplified dependence of Q on C_H is determined
  - The constants a, b are calculated
  - A conservative coefficient 0.85 is used

The MELTHA model

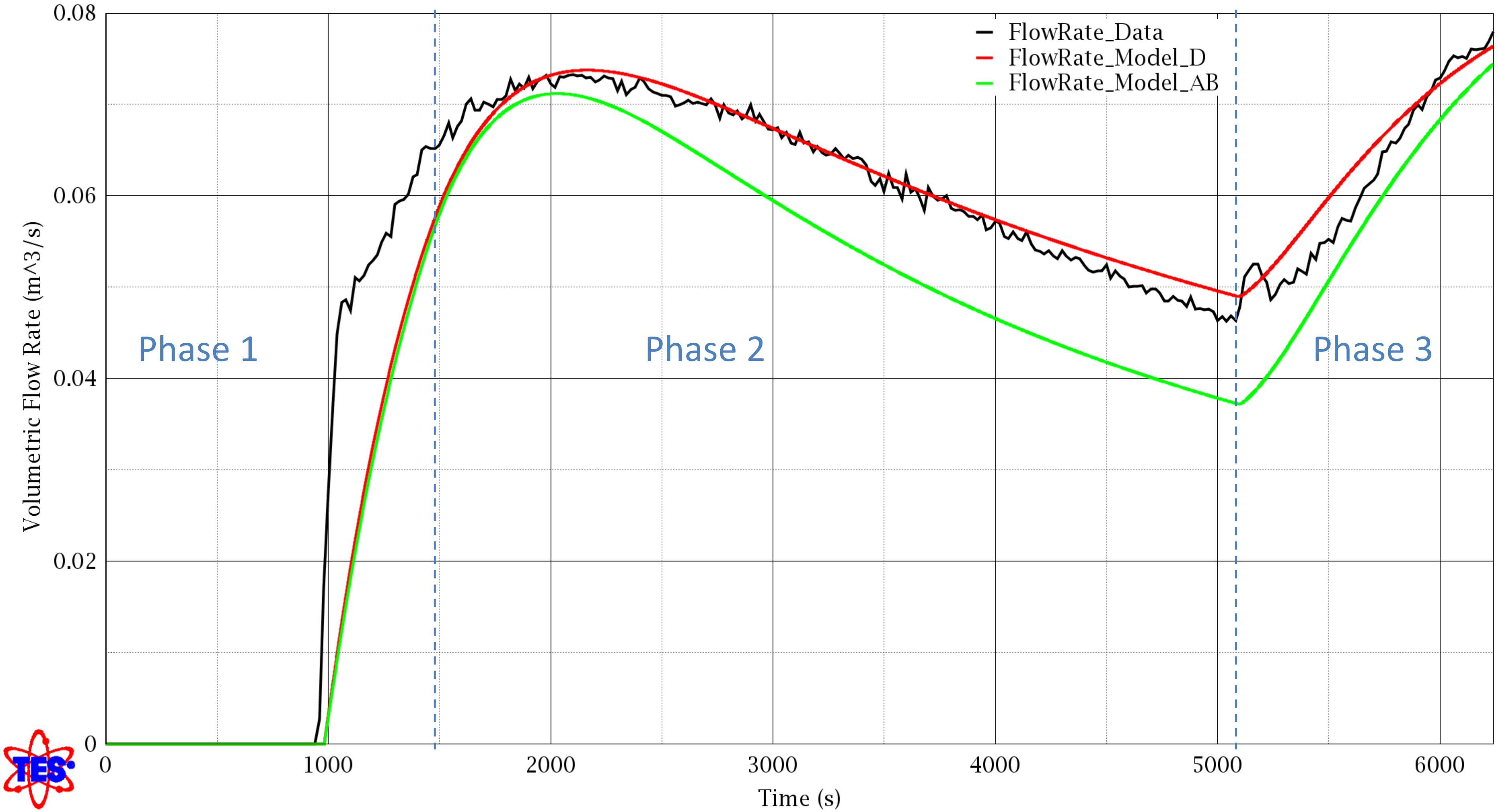
- Two different PAR models:
- Model_D
  - Koefficients based on the full experimental data (Phase 2)
- Model_AB
  - Only one data point was used (from Phase 2)
  - A methodology for a, b constants determination was used
- Phases 1, 2, and 3 were simulated in MELCOR

MELTHA nodalization

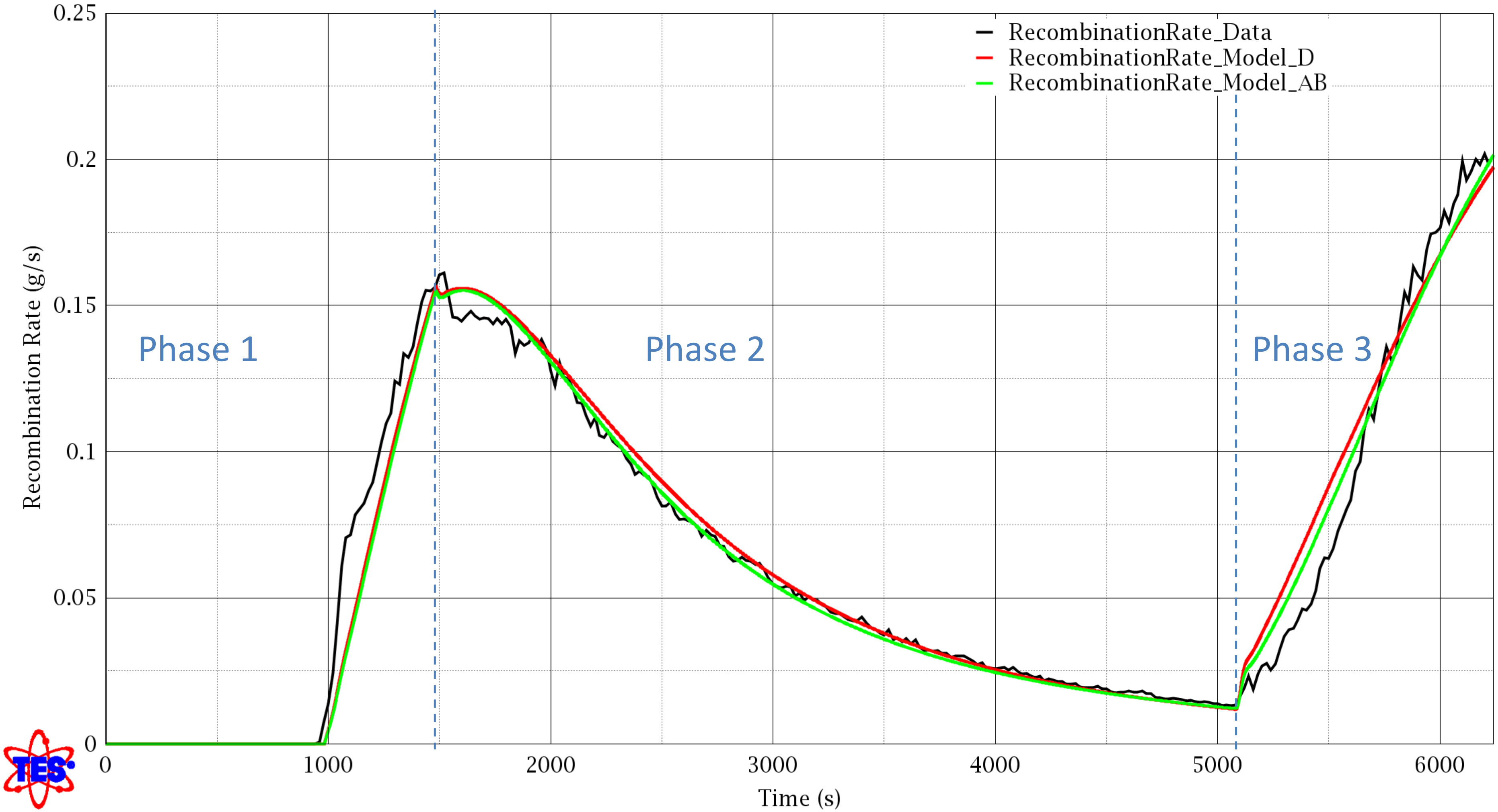
- 6 control volumes for vessel
- 1 CV for gass bottle
- 1 CV for surrounding environment
  - For heat losses by external cooling



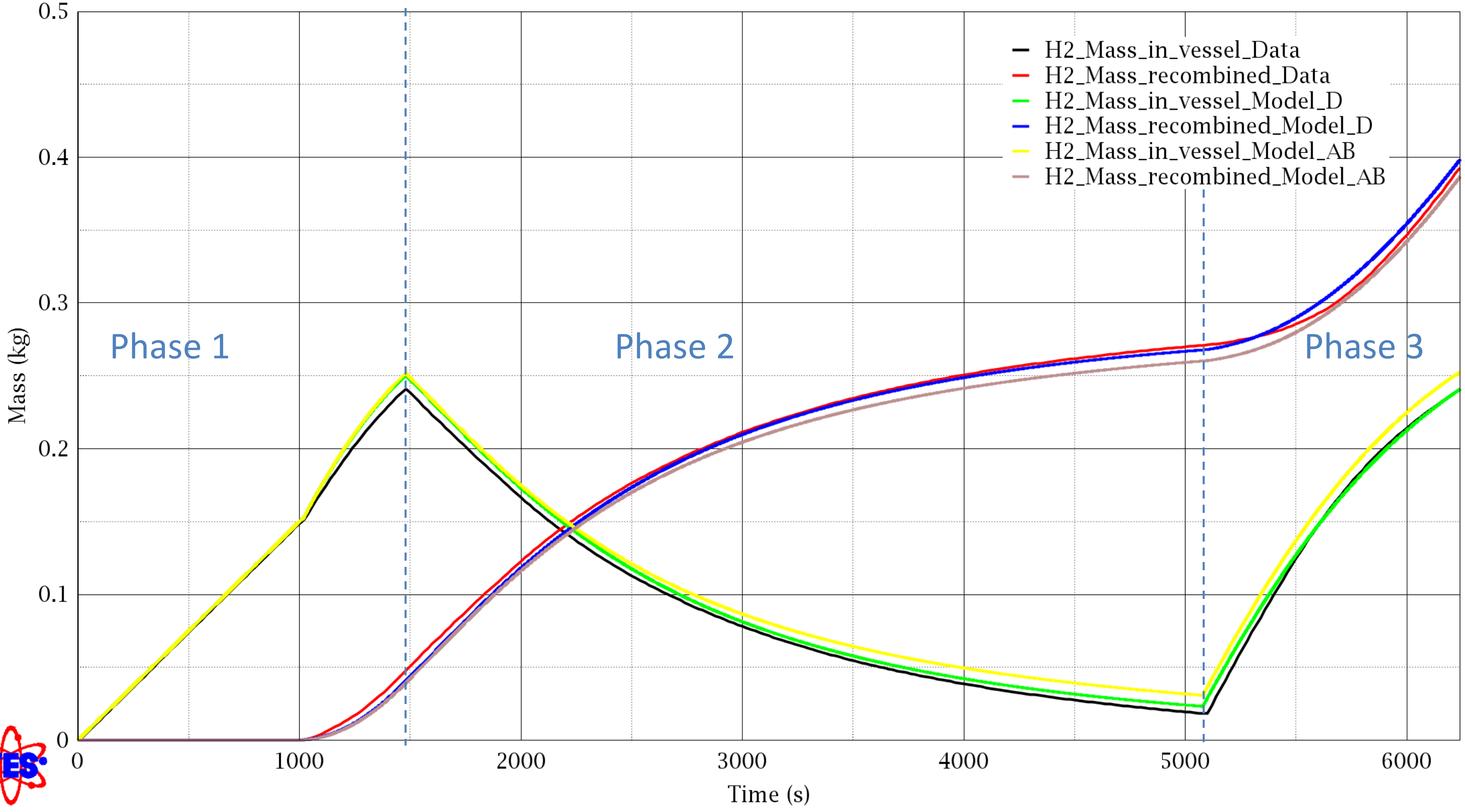
Results – volumetric fow rate



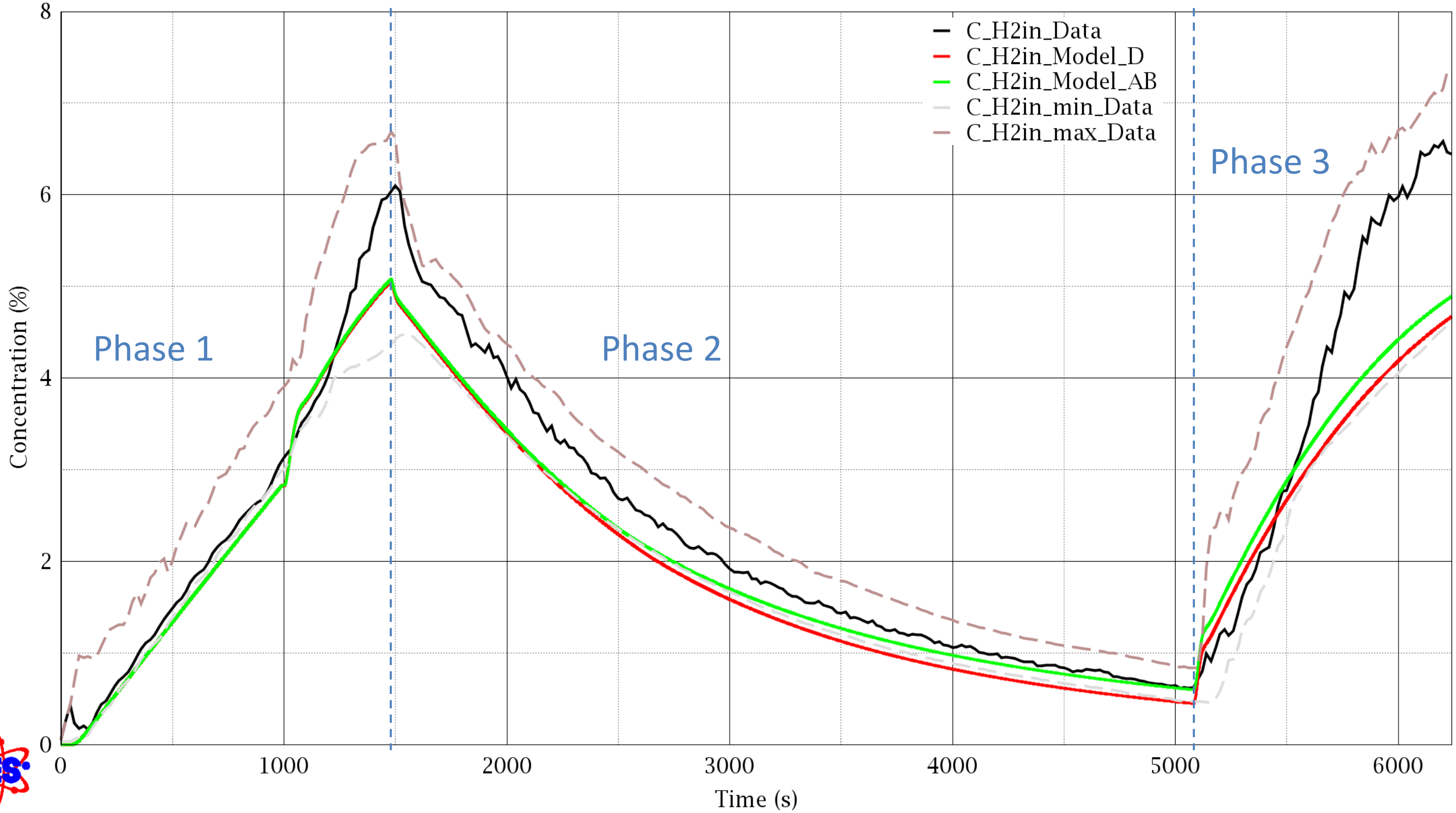
Results – recombination rate



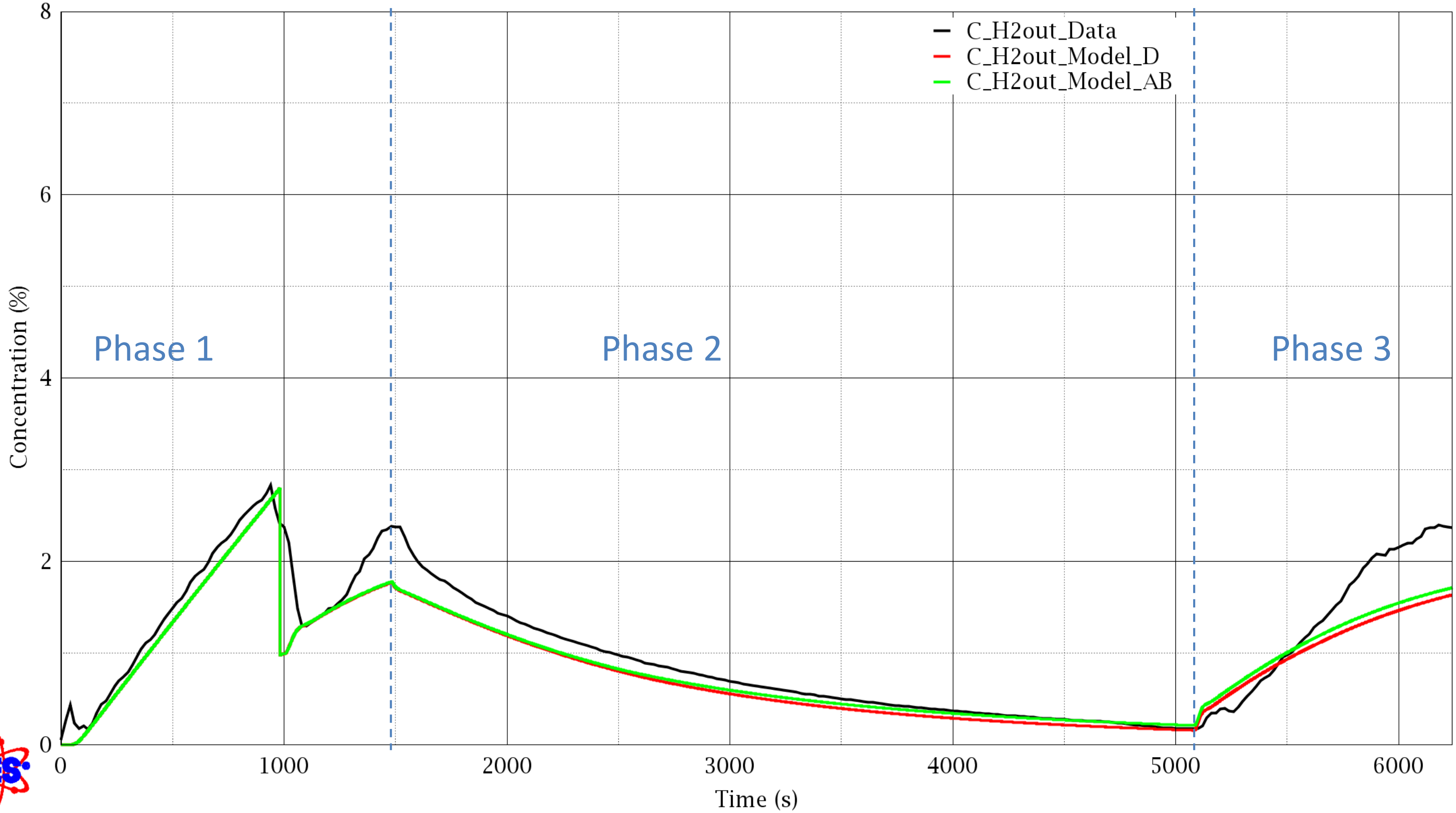
Results – Hydrogen masses



Results – H_2 concentrations



Results – H_2 concentrations



Quantitative assessment

- ACAP software was used (part of SNAP)

Metric name	Abbreviation	Value
D‘Aurie Fast Fourier Transformation	FFT	0.35
Mean Error Magnitude	MDM	0.35
Size-Independent (Pred - Perf) Norm	SI-PMPN	0.13
Degree of Randomness	DOR	0.13

Quantitative assessment

Identification	FOM – Model_D	FOM – Model_AB
PAR volumetric flow rate	0.897	0.868
Recombination rate	0.919	0.922
PAR inlet Hydrogen concentration	0.866	0.877
PAR outlet Hydrogen concentration	0.824	0.829

- If FOM ≥ 0.77, the prediction is very good
- Conclusion: Very good prediction by both models

Summary

- MELCOR PAR model is suitable for real recombiners
- Model_D gives good prediction of flow rate through a PAR
- Methodology for calculating a, b from one reference point was developed
- Model_AB gives conservative prediction of flow rate through a PAR
- QA: Very good prediction by both models

References

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Thank you for your attention

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