First REKO-4 experiments on the start-up behaviour of passive auto-catalytic recombiners under counter flow conditions with variation of the chimney geometry

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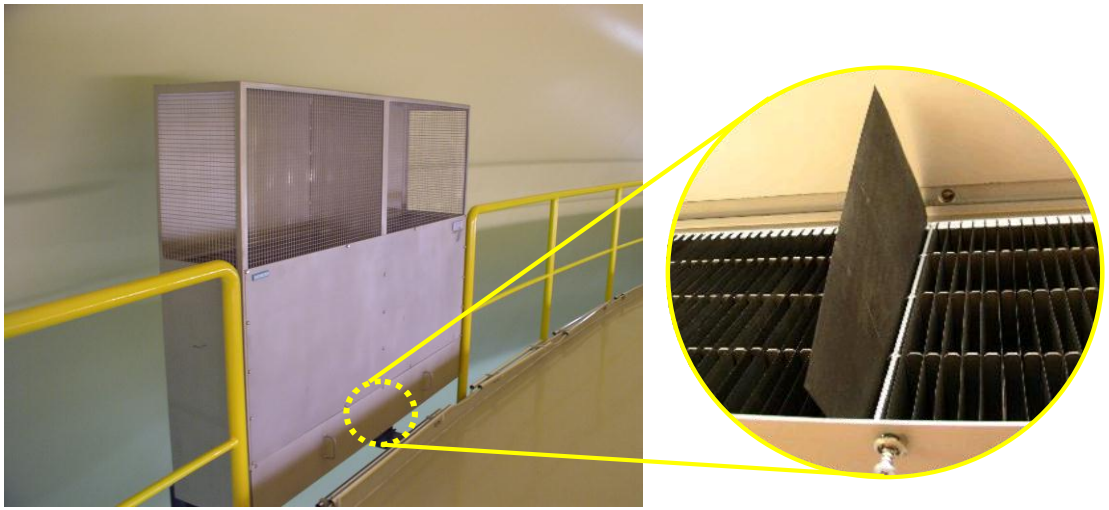
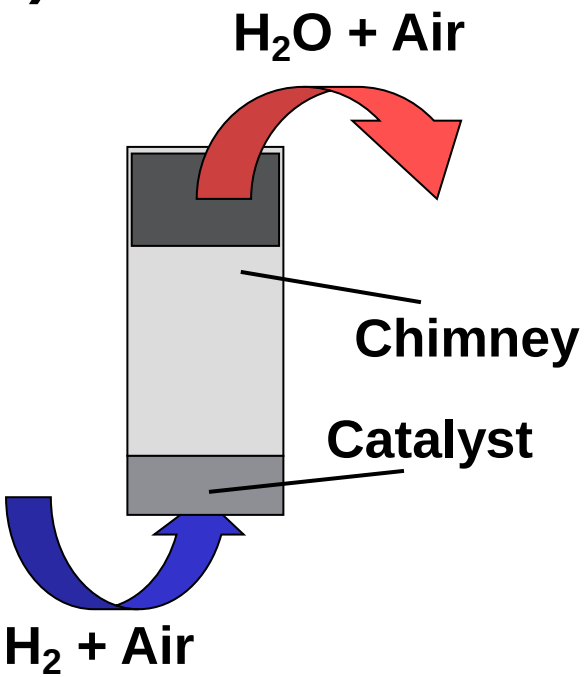
Contents

- Background
- Experimental set-up
- Experimental results
- Outlook

Passive auto-catalytic Recombiners (PAR)

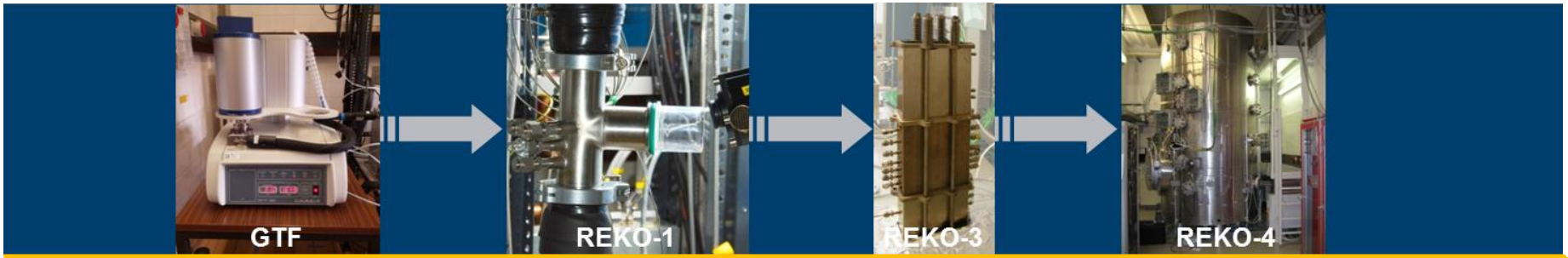




Key element in hydrogen mitigation strategy

- Passive operation
- Hydrogen removal already at low hydrogen concentrations (below ignition limits)
- Comprehensive qualification programme
  (conversion rates, earth quake resistance, catalyst poisoning)

PAR research at JÜLICH and RWTH



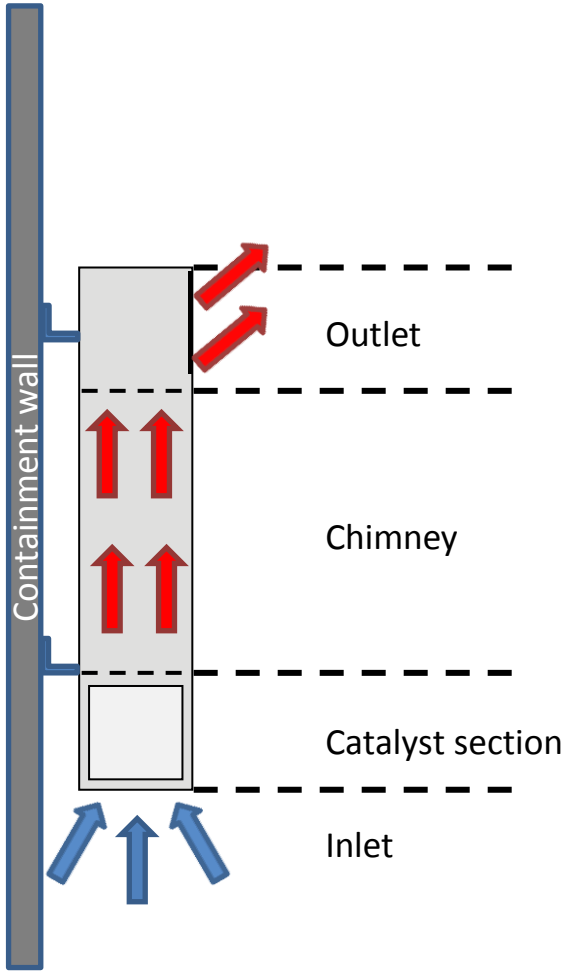
Model development (REKO-DIREKT/JÜLICH, SPARK/IRSN)

Open modelling issues

- Start-up behaviour (delay under certain conditions)
- Interaction with CO (Poisoning ←→ Recombination)
- Ignition (hot catalyst elements)
- Adverse flow conditions (PAR-atmosphere interaction)

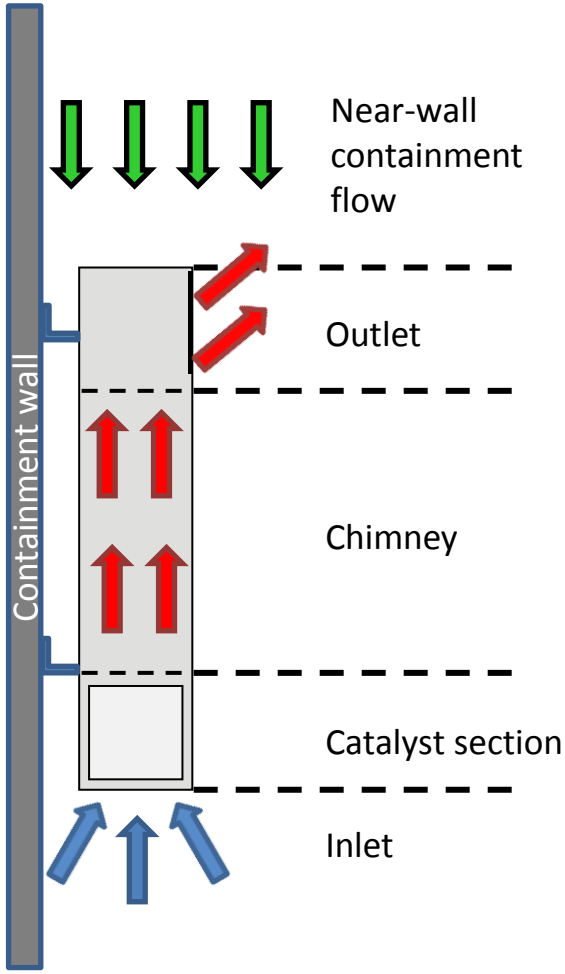
Background

- Chimney effect: gas heat-up due to exothermal reaction reduces gas density inside PAR box
- Overall hydrogen conversion rate: (catalytic efficiency) X (flow velocity)
- Typical flow velocities: ~ 0.6 – 1.2 m/s



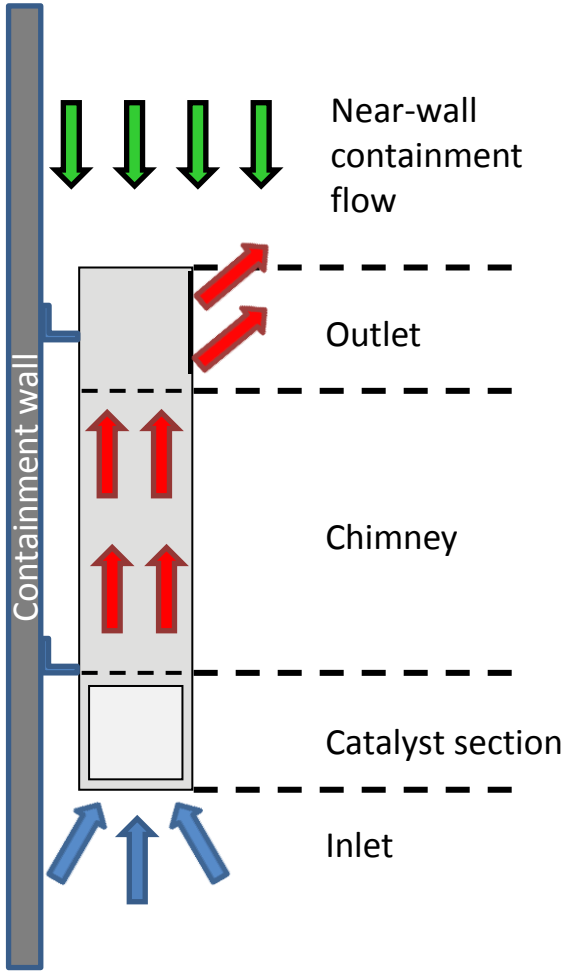
Background

- Chimney effect: gas heat-up due to exothermal reaction reduces gas density inside PAR box
- Overall hydrogen conversion rate: (catalytic efficiency) X (flow velocity)
- Typical flow velocities: ~ 0.6 – 1.2 m/s
- Downward near-wall containment flow due to gas-cooling and wall condensation
- Expected flow velocities: ~ 0.5 m/s



Goal of present study

- Investigate the impact of vertically downward-directed flow on PAR start-up
  - Variation of PAR chimney
- First assessment of relevant parameters and processes
- Provide data for model development (later)



REKO-4 facility

- 5.5 m³ vessel
  - Diameter 1.4 m
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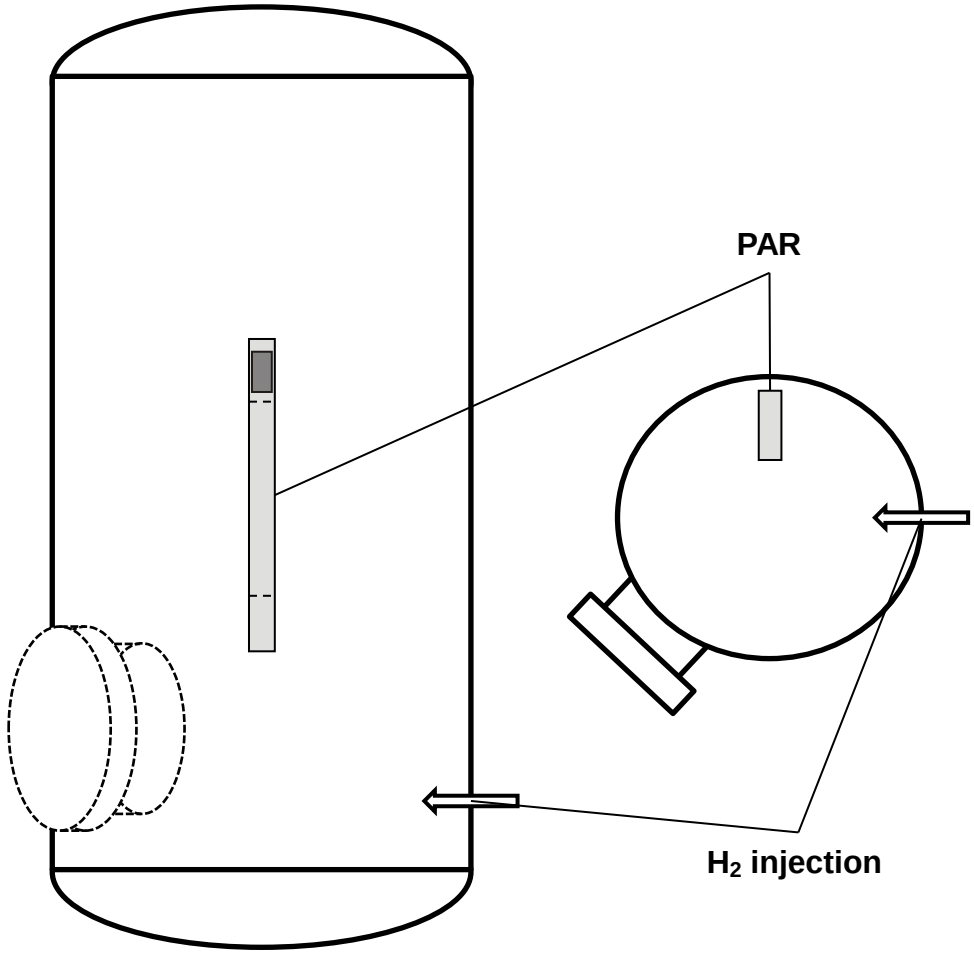

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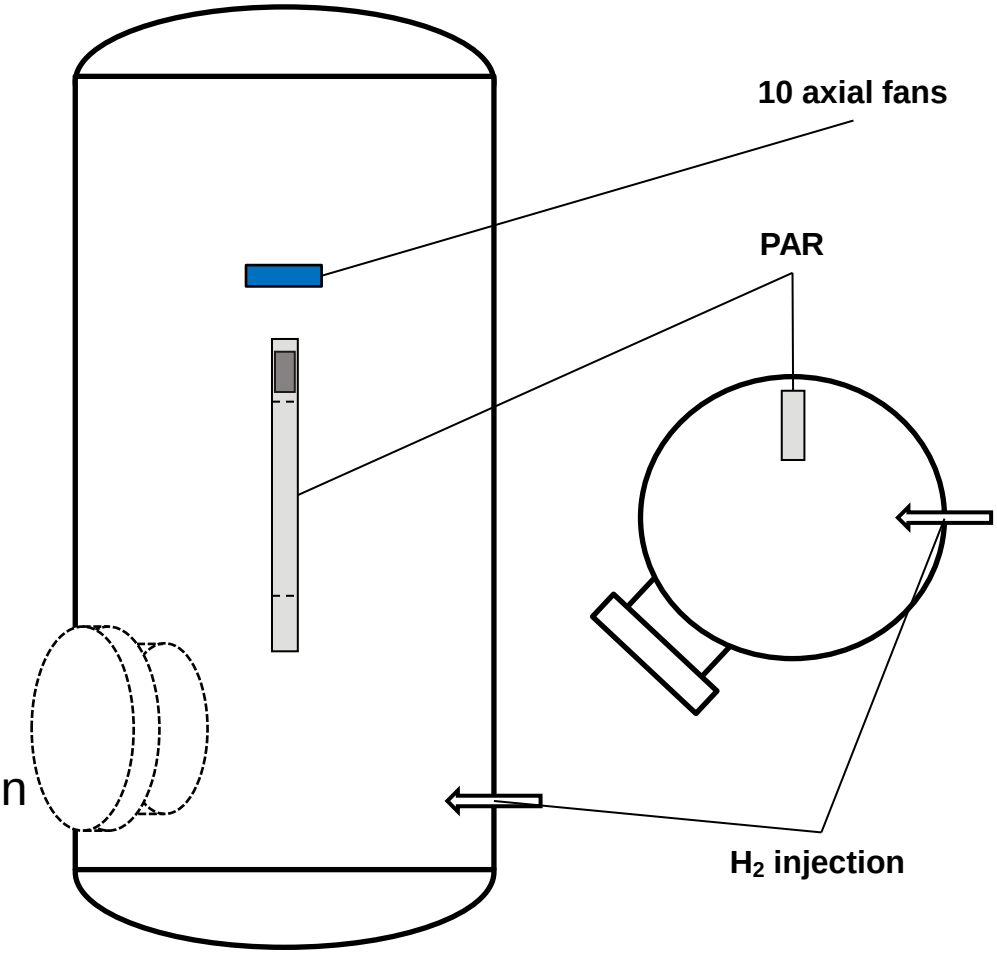
- Hydrogen injection: 10 mm line
- Horizontal set of 10 axial fans
  - Rotational speed: 1000-2300 1/min
  - PIV quantification



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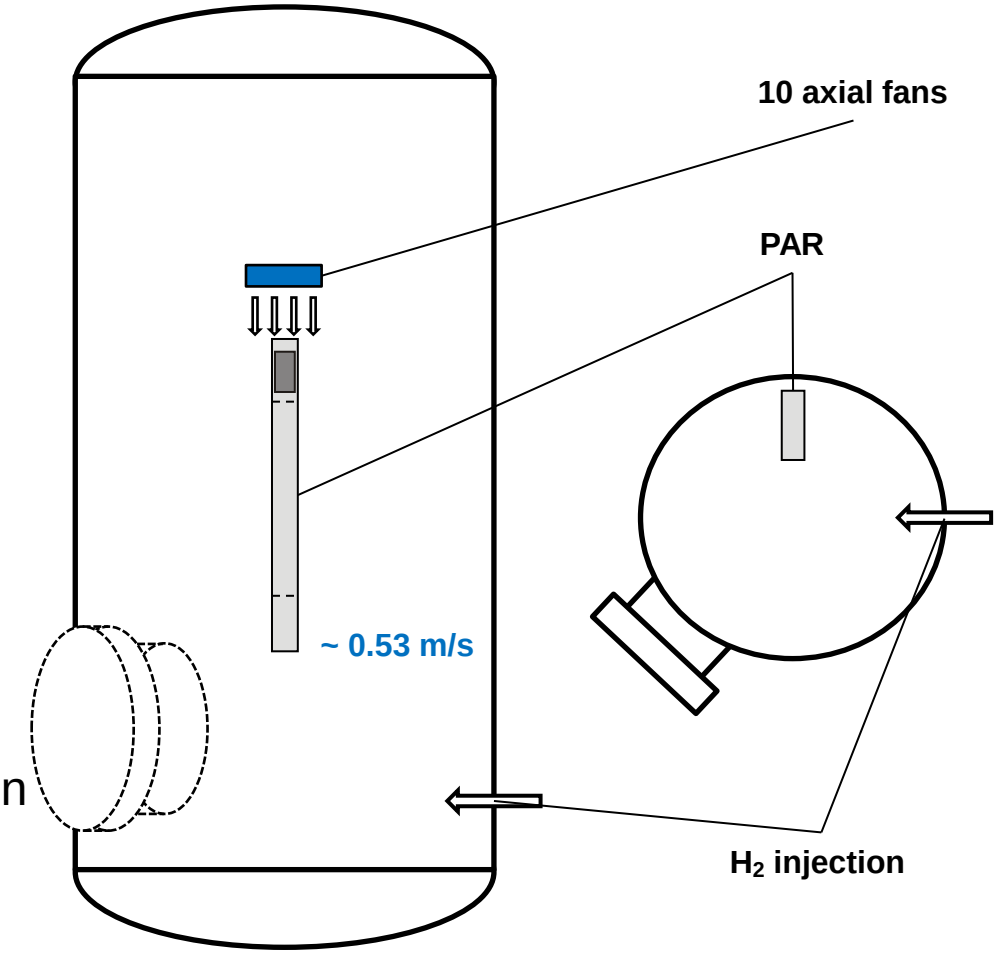

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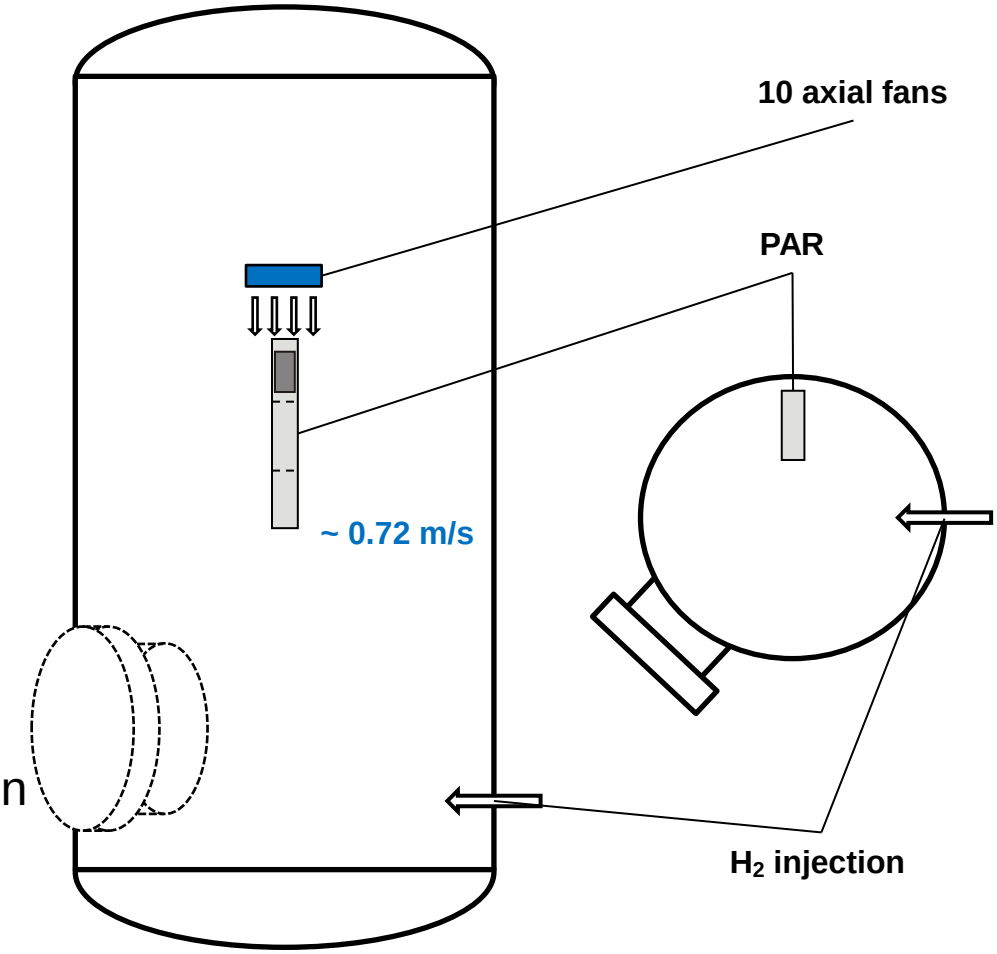
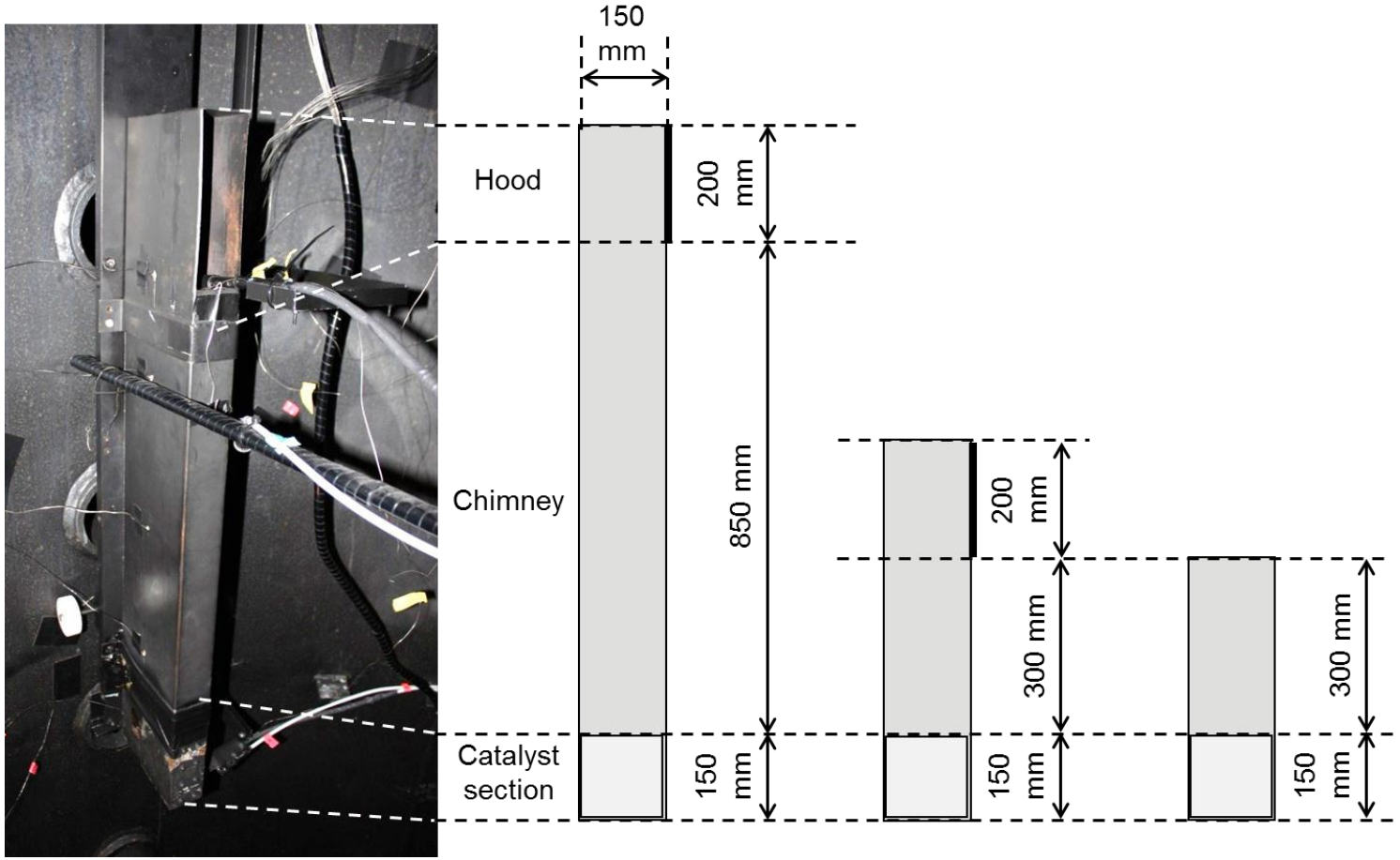
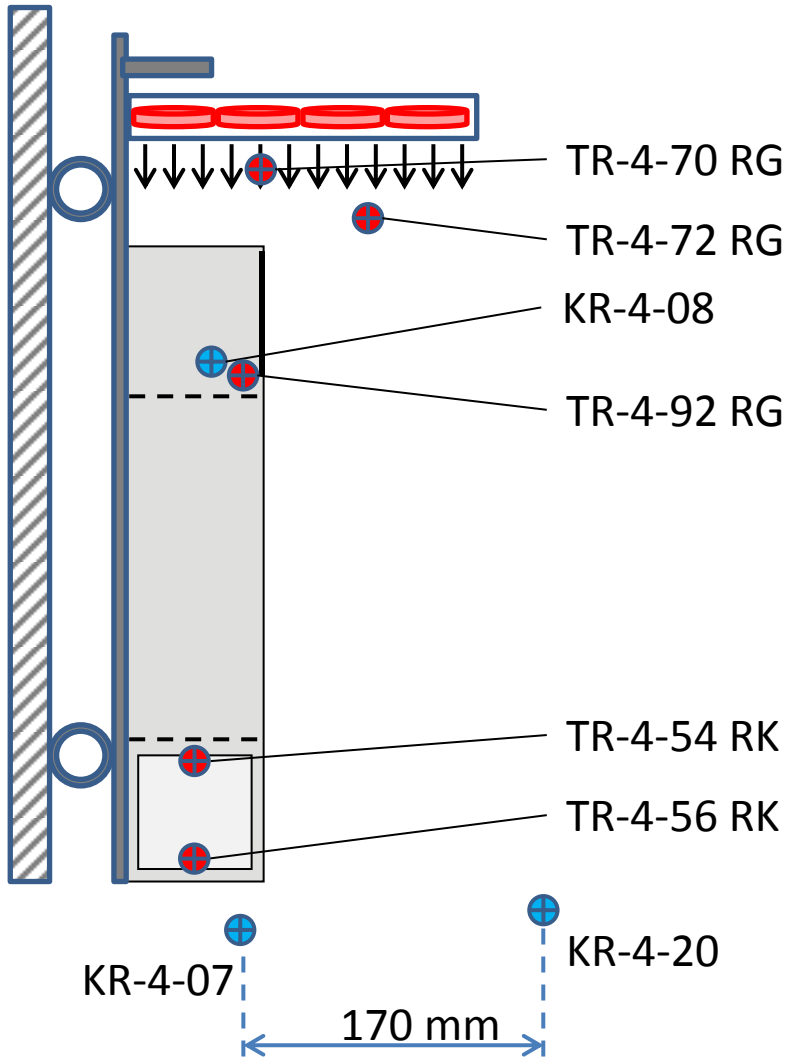


PARs installed



Instrumentation

- Thermocouples (TR)
  - Vessel: ~30
  - PAR: ~30 (20 @ catalyst)
- Hydrogen sensors (RK)
  - Vessel: ~15
  - PAR: 3



Test matrix

Test number	Chimney height (mm)	Flow velocity at PAR inlet (m/s)	Initial atmosphere
R4-P-05/06/07	850	0.53	Counter flow
R4-P-08/09	850	0.00	Quiescent
R4-P-11/12/13	300	0.72	Counter flow
R4-P-14/15/16	300	0.00	Quiescent
R4-P-18/19/20	300 (w/o hood)	0.72	Counter flow
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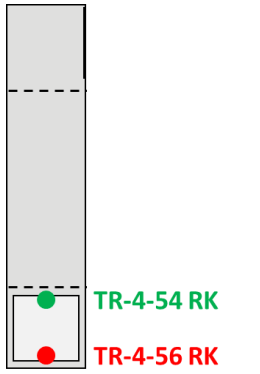
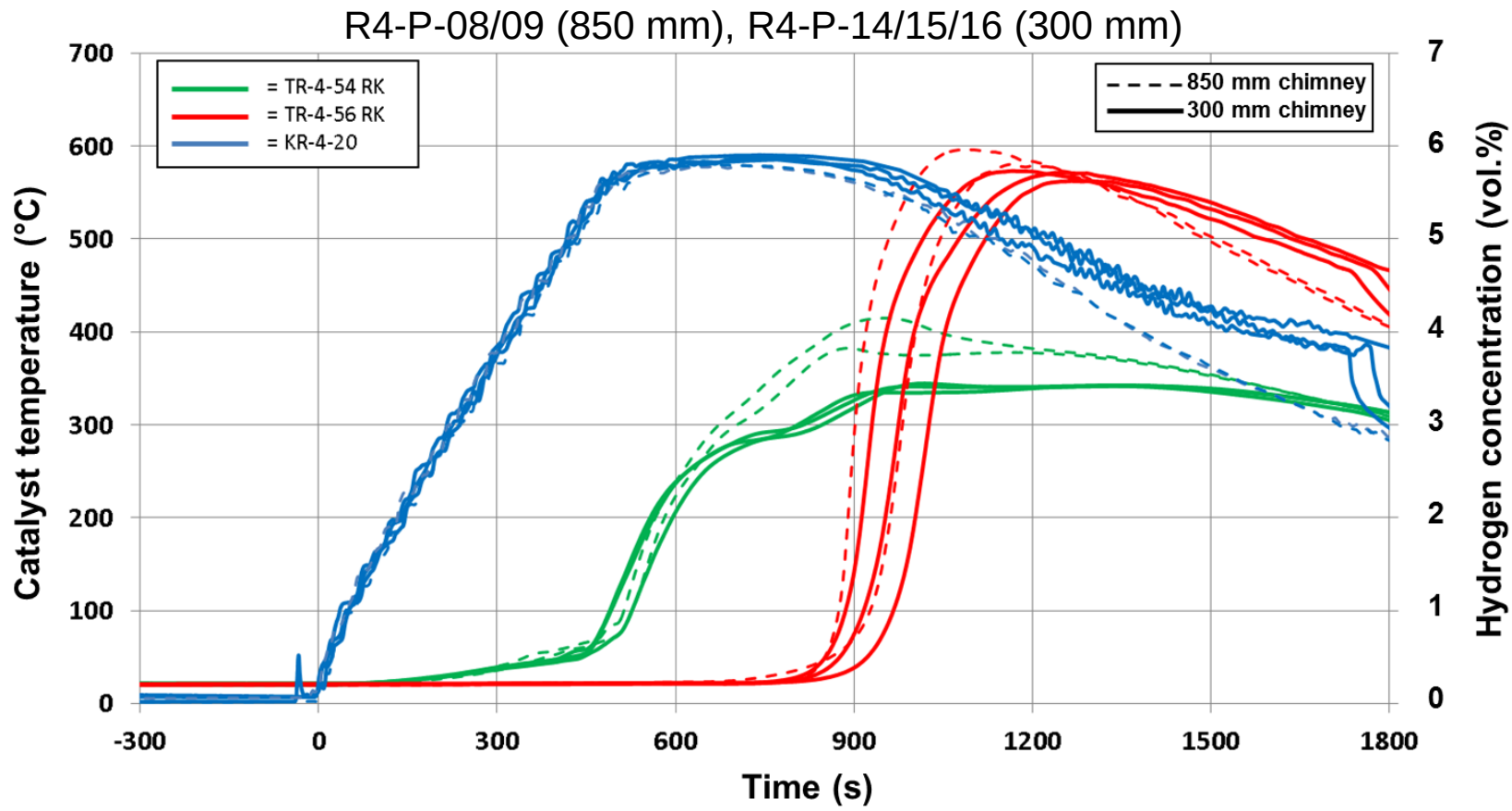
Start-up in quiescent atmosphere





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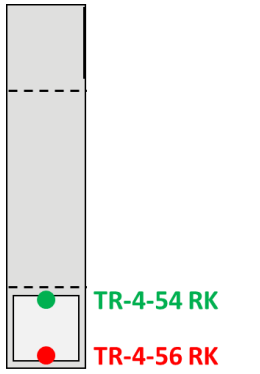
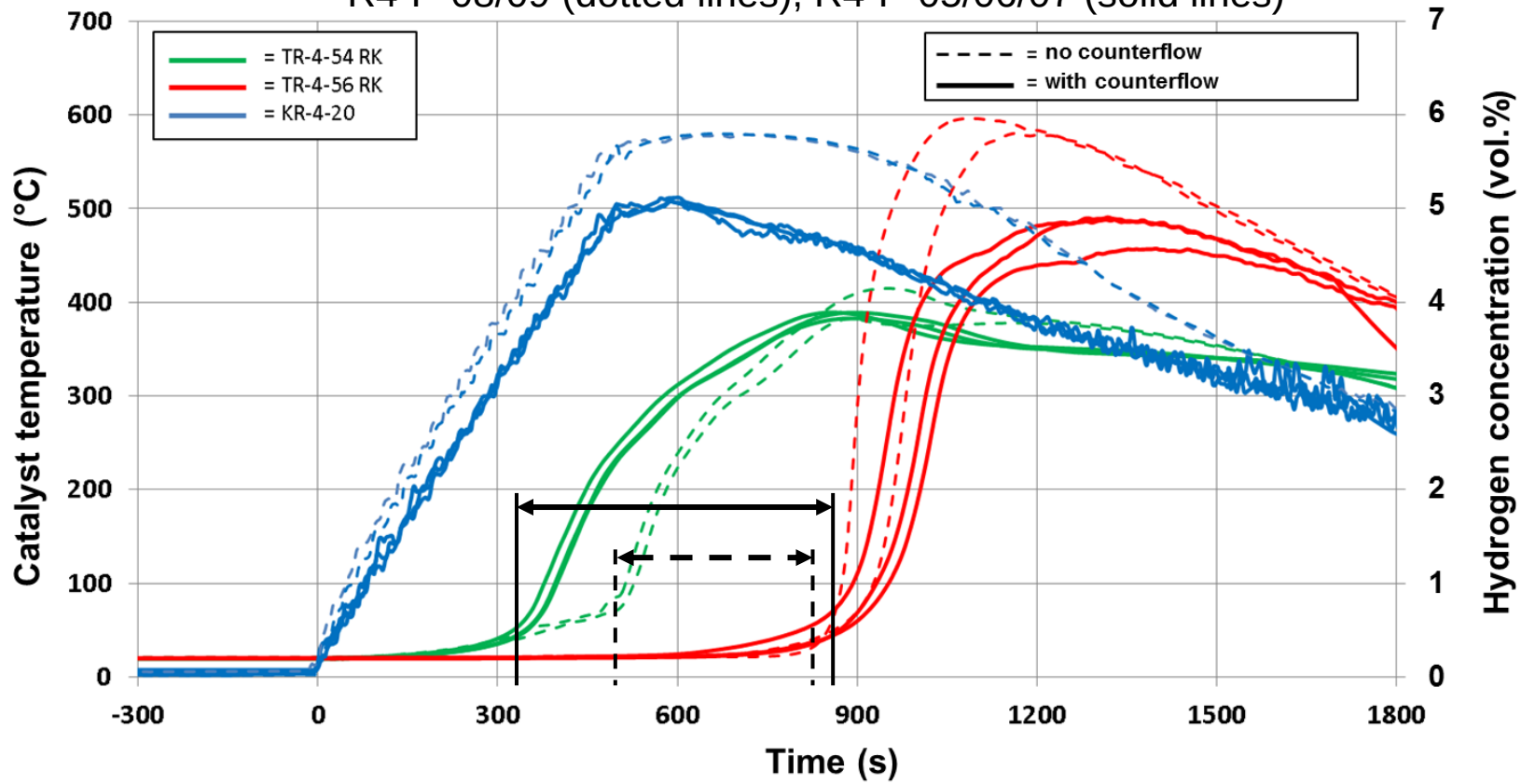
Start-up under counter flow conditions (850 mm chimney)



R4-P-08/09 (dotted lines), R4-P-05/06/07 (solid lines)



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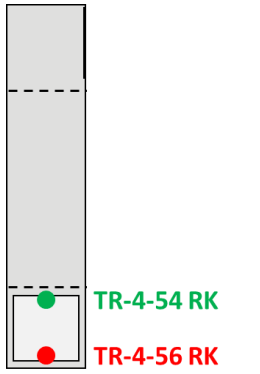
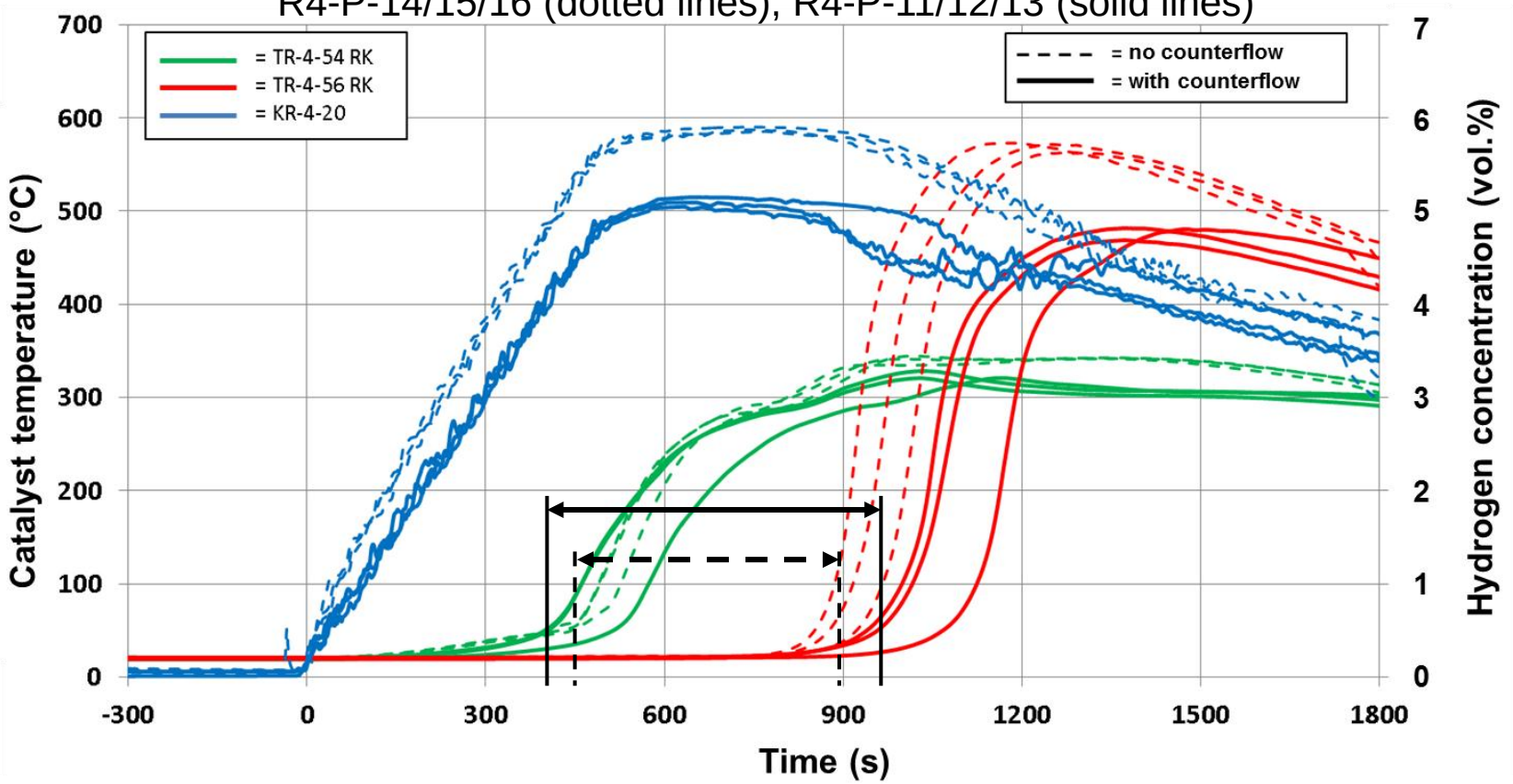
Start-up under counter flow conditions (300 mm chimney)



R4-P-14/15/16 (dotted lines), R4-P-11/12/13 (solid lines)



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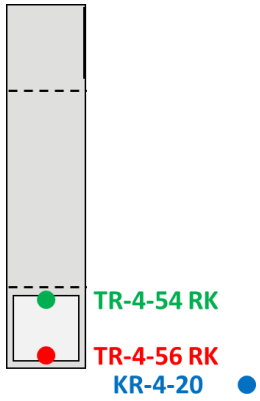
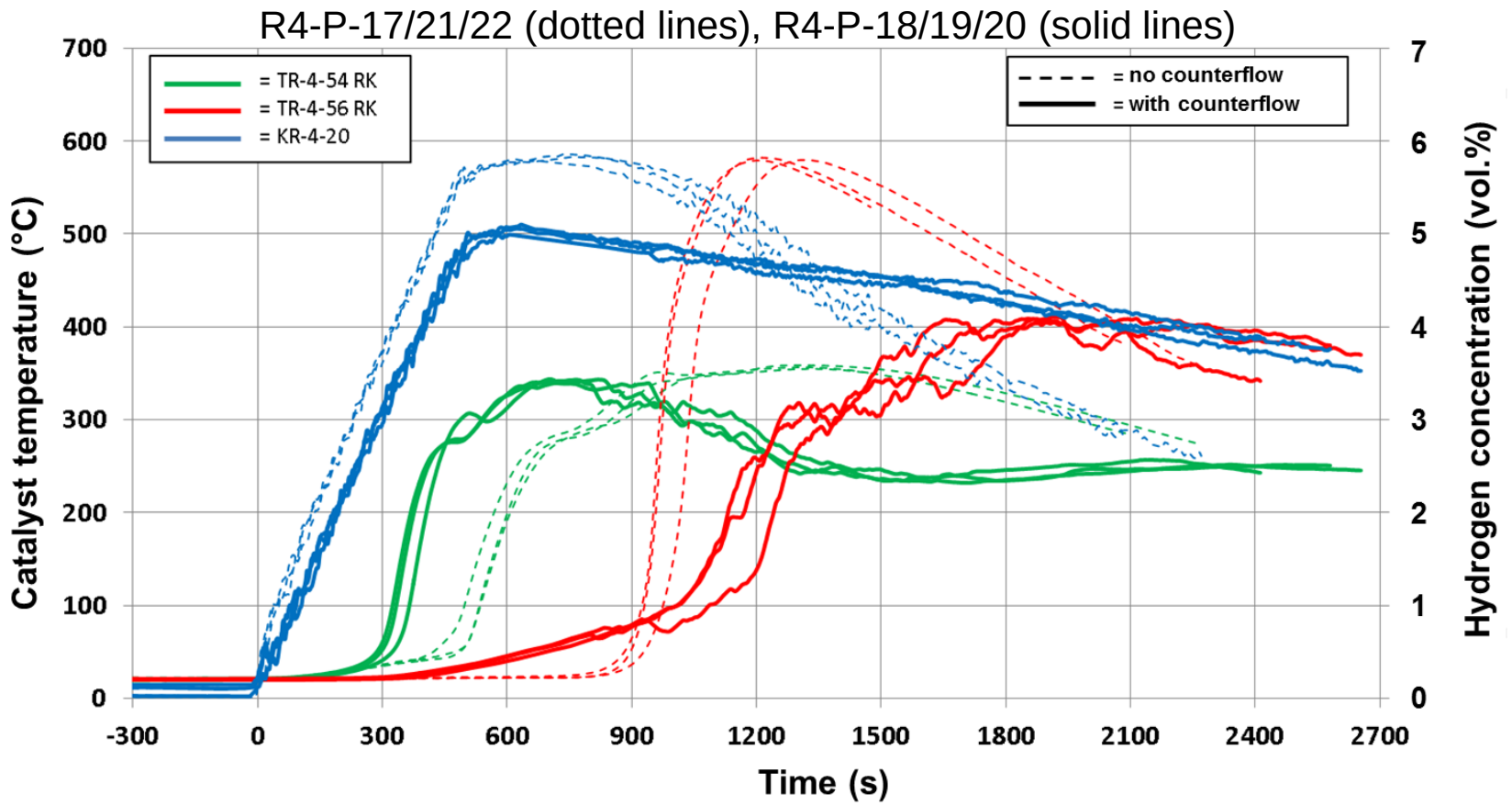
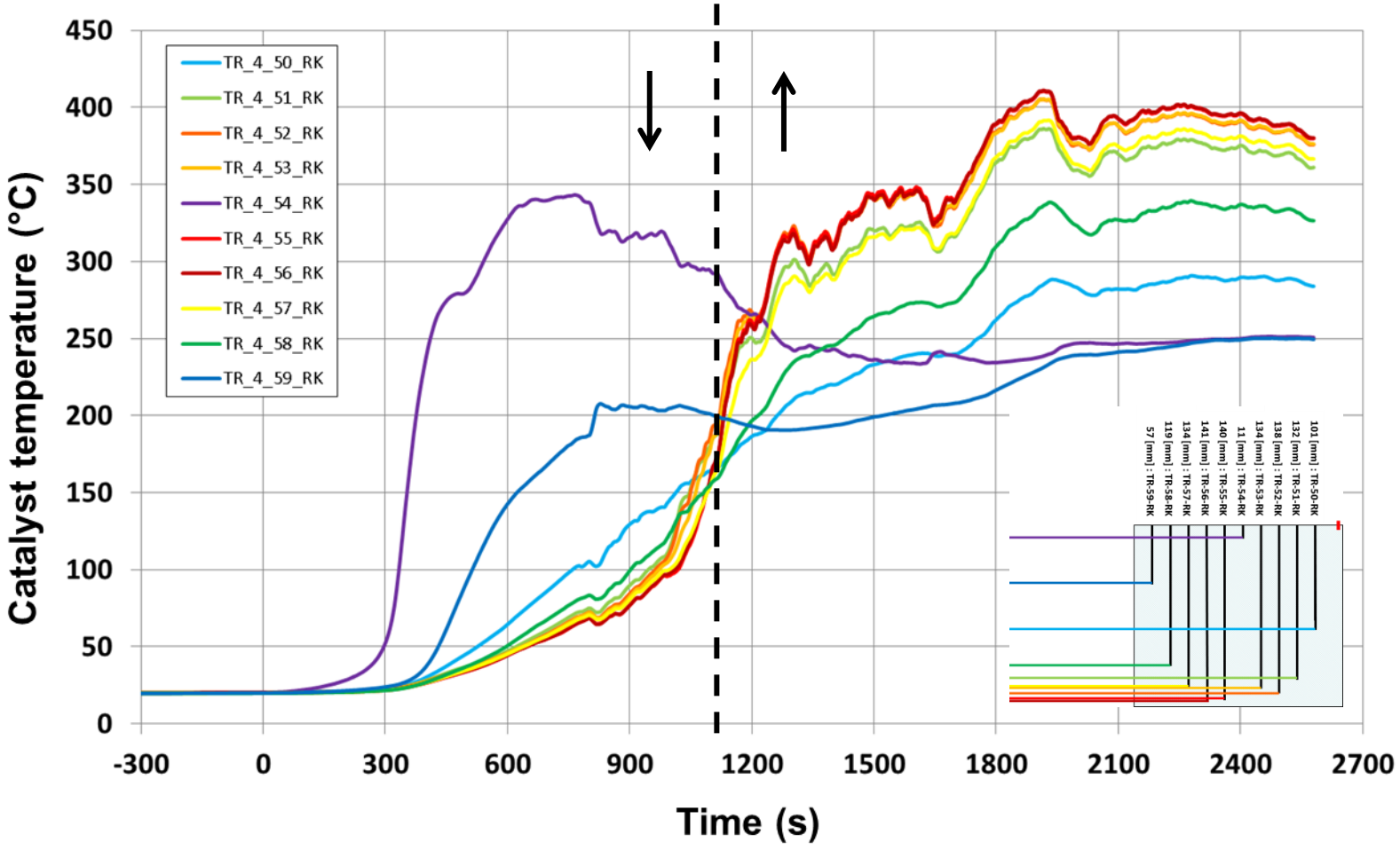
Start-up under counter flow conditions (300 mm, w/o hood)

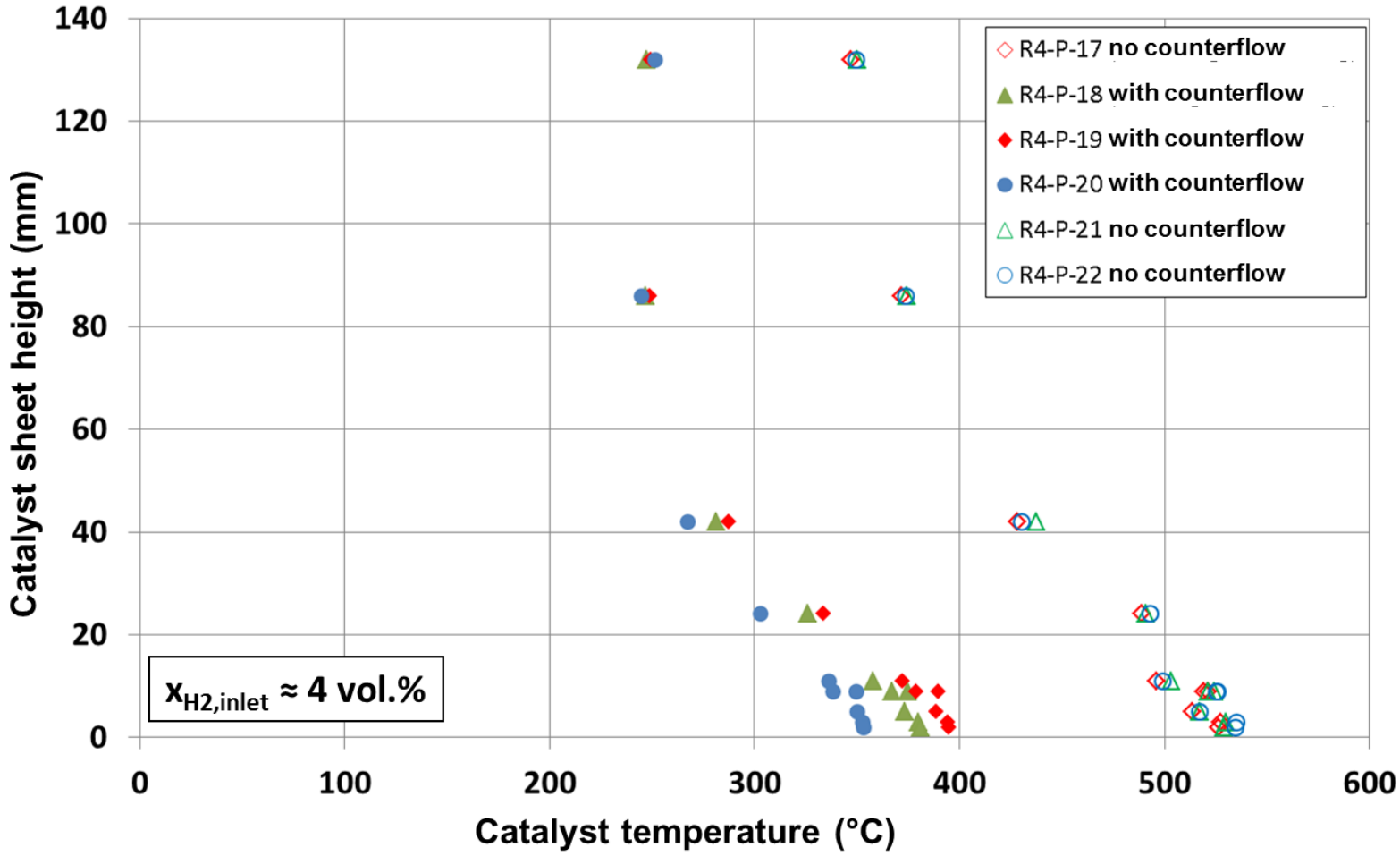




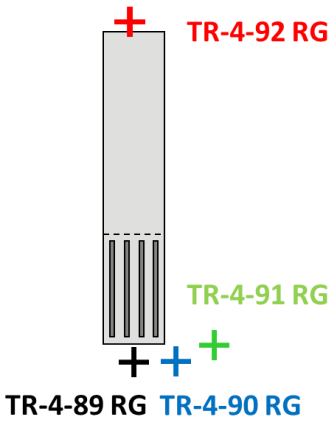
Catalyst temperature development (300 mm, w/o hood)

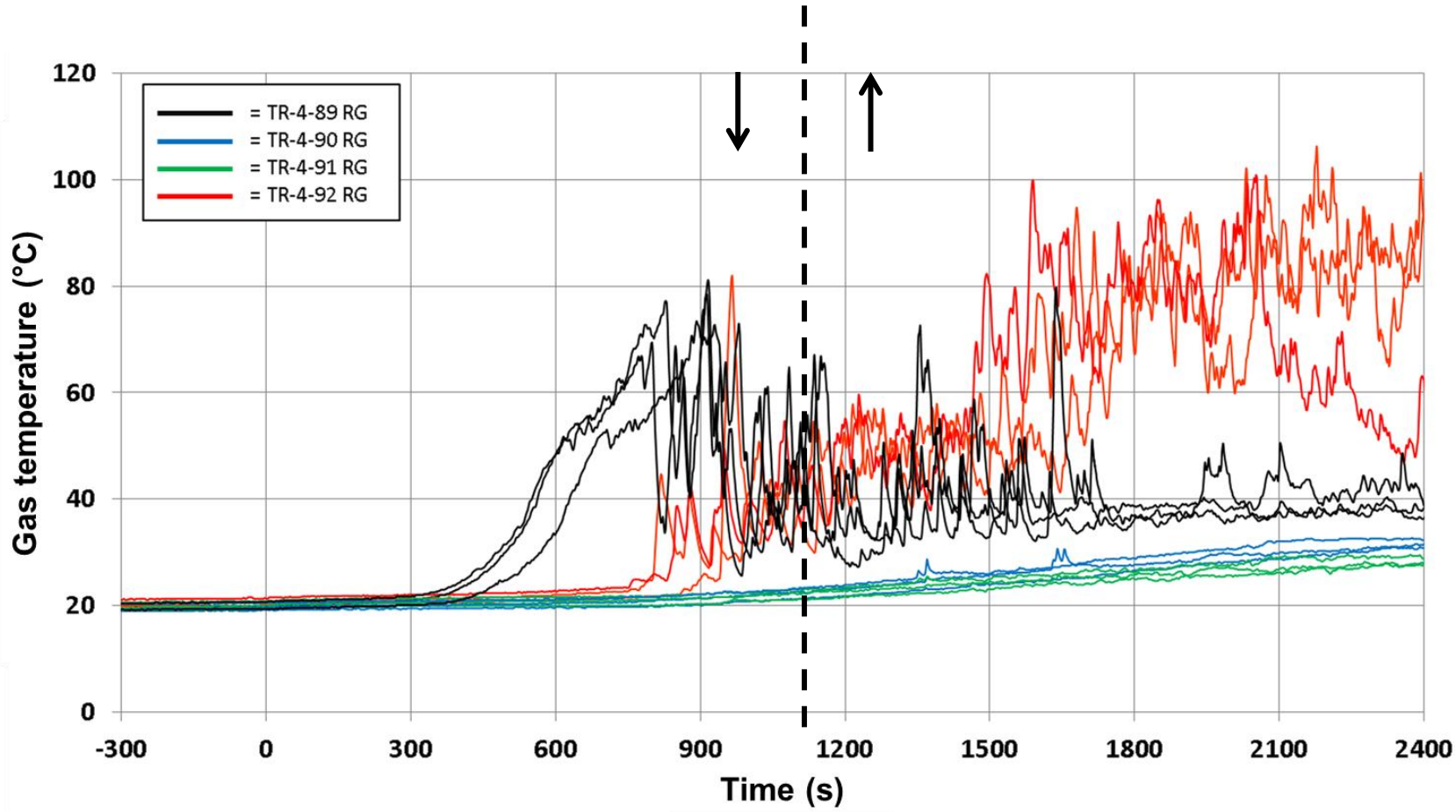


Catalyst temperature profile (300 mm, w/o hood)



Gas temperatures (300 mm, w/o hood)





Summary and conclusions (1/2)

- The influence of a downward directed flow on the PAR start-up behaviour is investigated.
- A test series using three chimney configurations was performed in the REKO-4 facility as first assessment.
- The reference tests started in quiescent atmosphere. In the remaining tests, a downward flow was realised with a set of axial fans. All tests had the same boundary conditions and showed mostly a remarkable good reproducibility.

Summary and conclusions (2/2)

- Counterflow results vs. reference: chimneys with hood
  - Earlier local start-up of the catalytic reaction @ upper edge of catalyst
  - Establishment of full PAR operation requires more time
  - Full PAR performance (after chimney flow inside PAR has established)
- Counterflow results vs. reference: chimney without hood
  - Earlier local start-up of the catalytic reaction @ upper edge of catalyst
  - Downward flow dominates first phase
  - Significantly lower hydrogen conversion rate (after chimney flow inside PAR has established)

Outlook (lessons learned)

- Reference tests in homogenised atmosphere
- Hydrogen injection at lower rates
- Confirmation of the flow phenomena by means of PIV
- Systematic data for code and model development.
  - Variation of counterflow rate
  - Variation of hydrogen concentration

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