EXPERIMENTAL CHARACTERIZATION OF THE OPERATIONAL BEHAVIOR OF A CATALYTIC RECOMBINER FOR HYDROGEN MITIGATION

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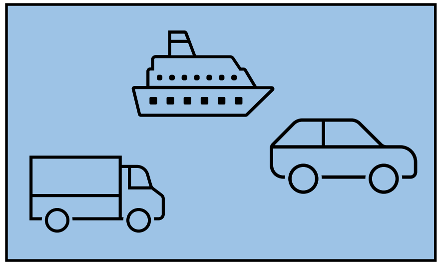
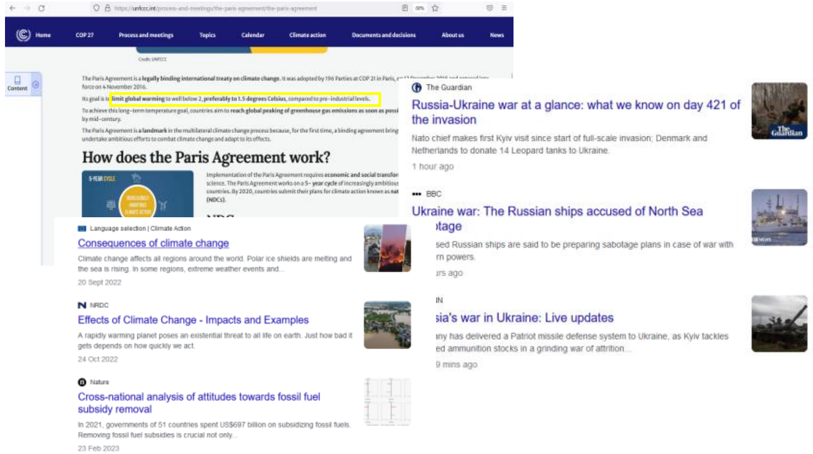
Introduction

Electrolyzer

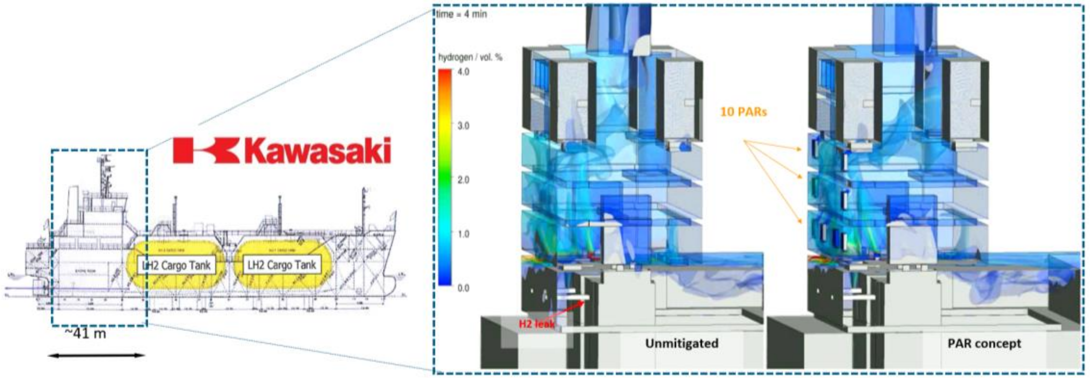




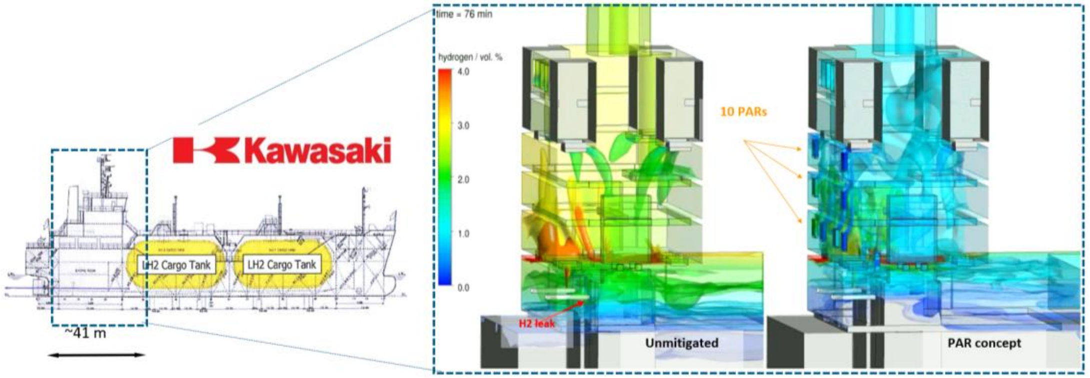
- Gaseous hydrogen
- Liquid hydrogen
- Novel hydrogen carriers

Introduction: Hydrogen Risk

- Flammability Range: 4 to 75 vol%
- Density: 0.084 kg/m³
- Risk
    - Limited in outdoor/open spaces
    - Greater in enclosed spaces
- Risk Mitigation
    - Forced/Natural ventilation
    - Ventilation + Recombiners
    - Recombiners



Kelm et al., Simulation of H2 mixing and PAR operation during accidental release in an LH2 carrier engine room, ICHS, 2021



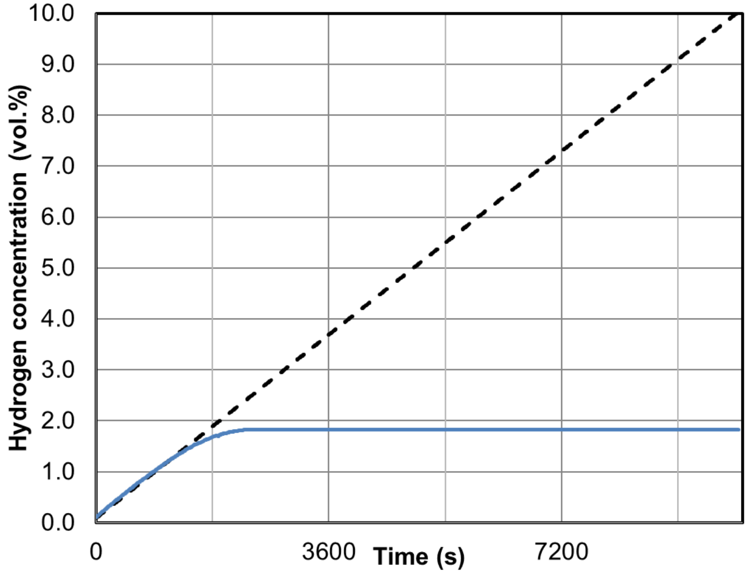
Kelm et al., Simulation of H2 mixing and PAR operation during accidental release in an LH2 carrier engine room, ICHS, 2021

Passive Auto-Catalytic Recombiners

- Chemically convert hydrogen into water

$$H_{2\,(g)} + \frac{1}{2} O_{2\,(g)} \xrightarrow{Pt\backslash Pd} H_2O_{(g)} + 240\ \frac{kJ}{mole}$$

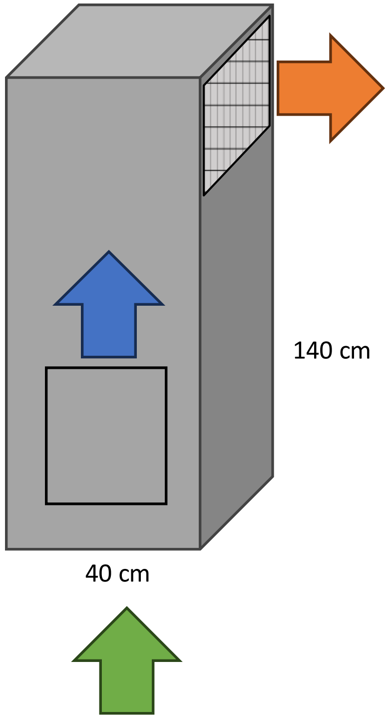
- Reduce hydrogen accumulation



PAR from Nuclear Power Plant

Enersys-Hawker Hydrogen Eliminator

Passive Auto-Catalytic Recombiners



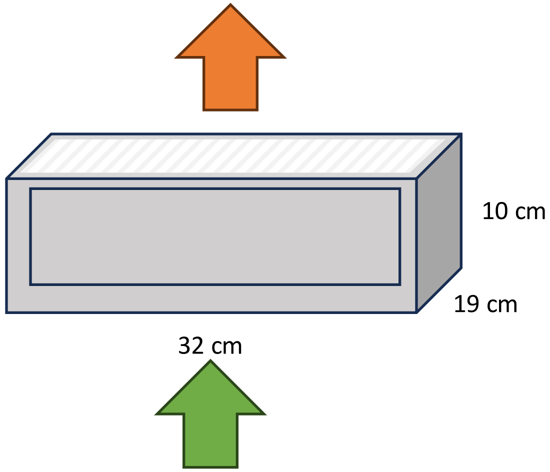
Outlet

Chimney

Catalyst Section

$$H_{2\,(g)} + \frac{1}{2} O_{2\,(g)} \rightarrow H_2O_{(g)} + 240\ \frac{kJ}{mole}$$

Inlet



PAR from Nuclear Power Plant

Enersys-Hawker Hydrogen Eliminator

Objective: Study the operational behavior of the Hawker Eliminator

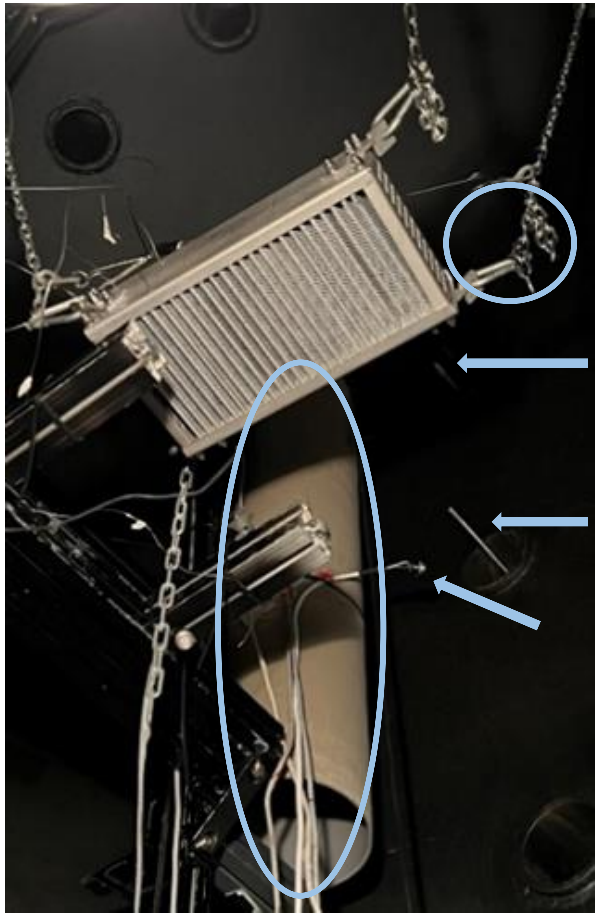
Agenda

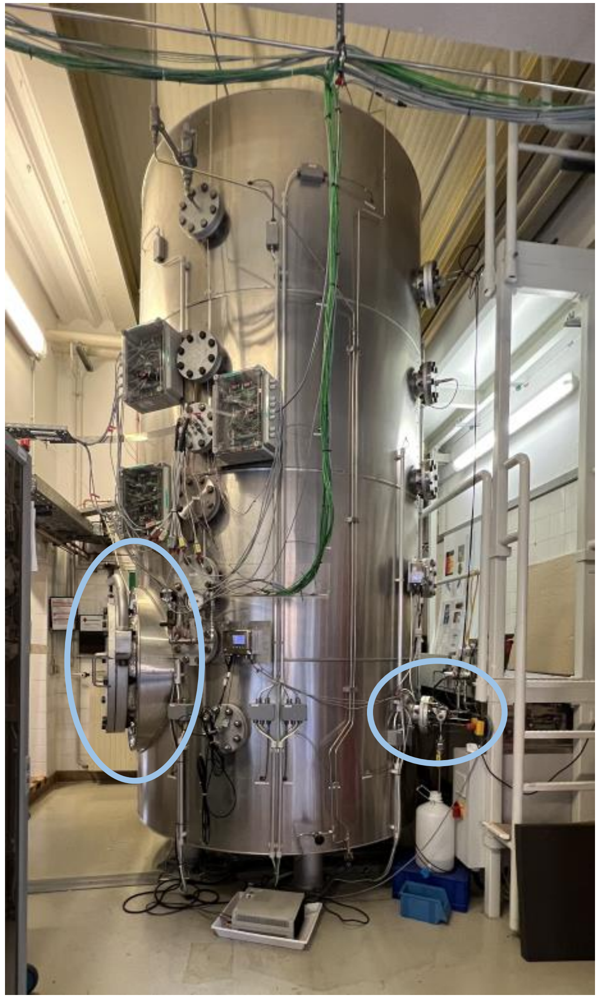
- Introduction
- Passive Auto-Catalytic Recombiners
- Experimental Setup
- Test Procedure
- Results
- Conclusion
- Acknowledgements

Experimental Setup: Instrumentation

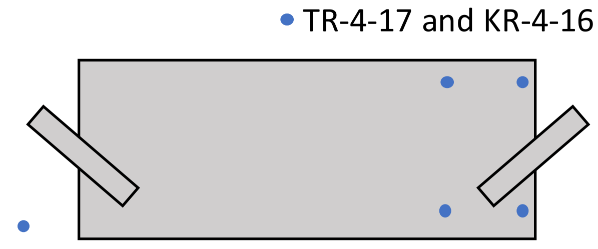
Measurement Devices

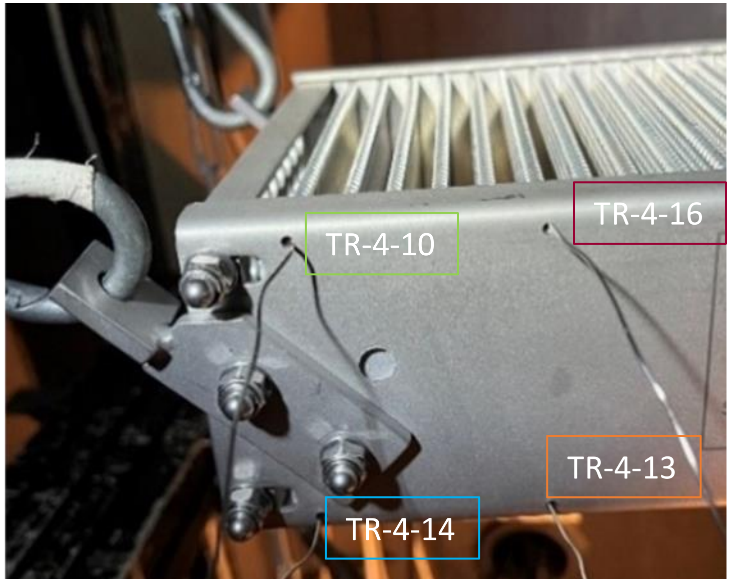
- Pressure sensor
- Thermal conductivity sensor
- Oxygen sensor
- Humidity sensor
- Thermocouple

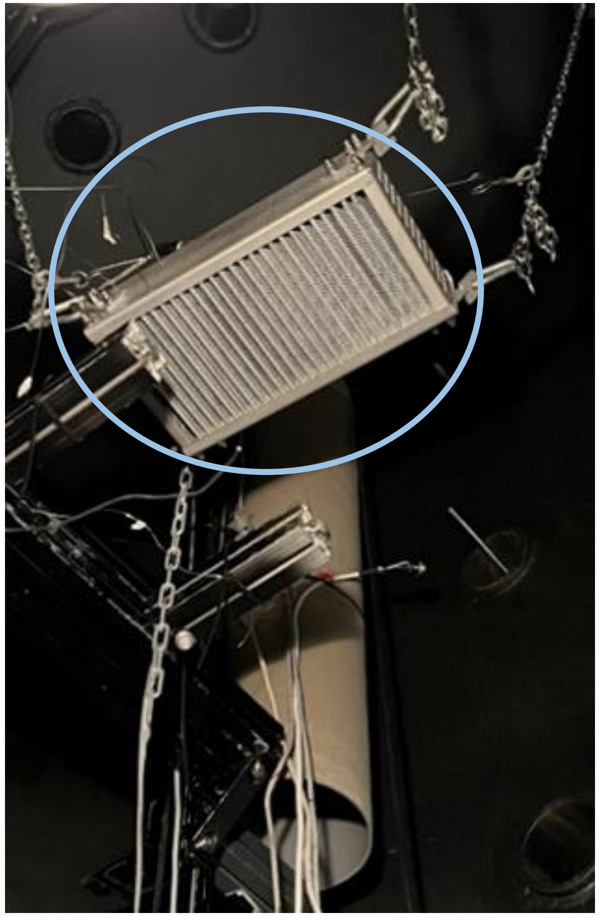




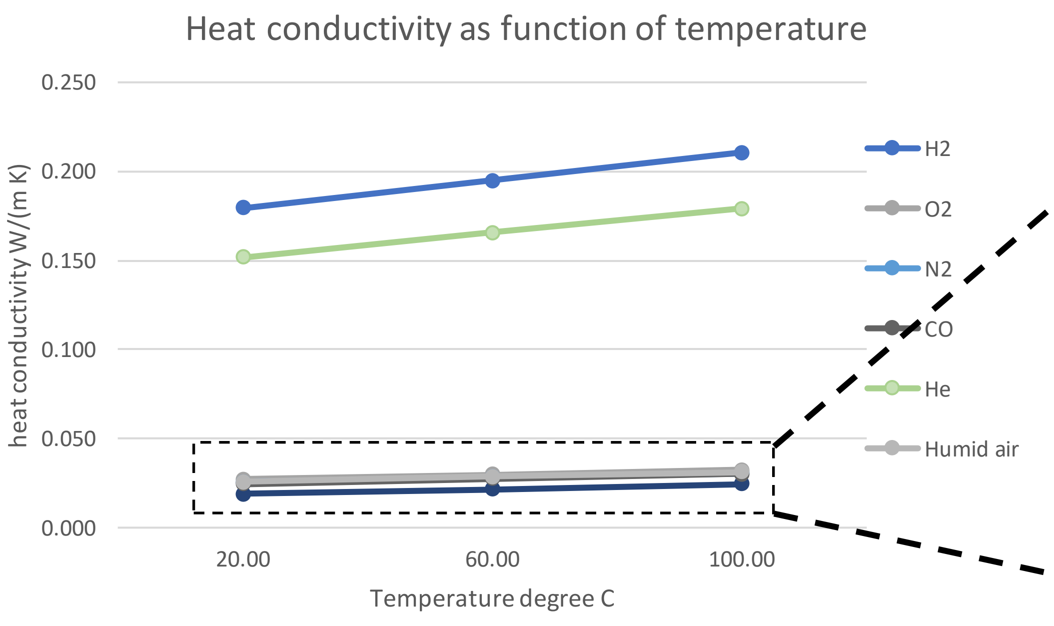
Experimental Setup: Instrumentation

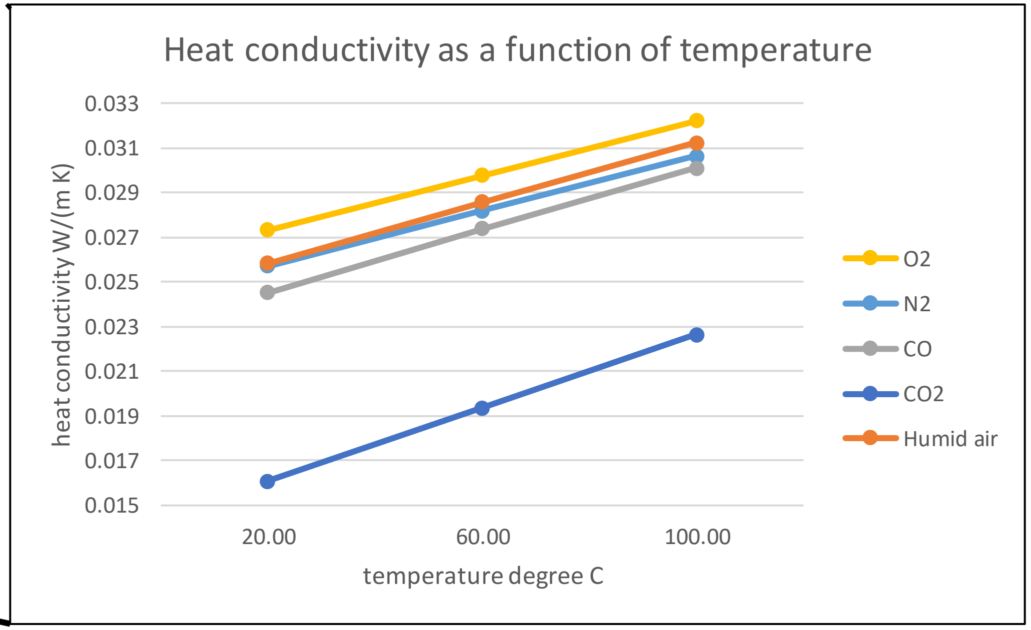




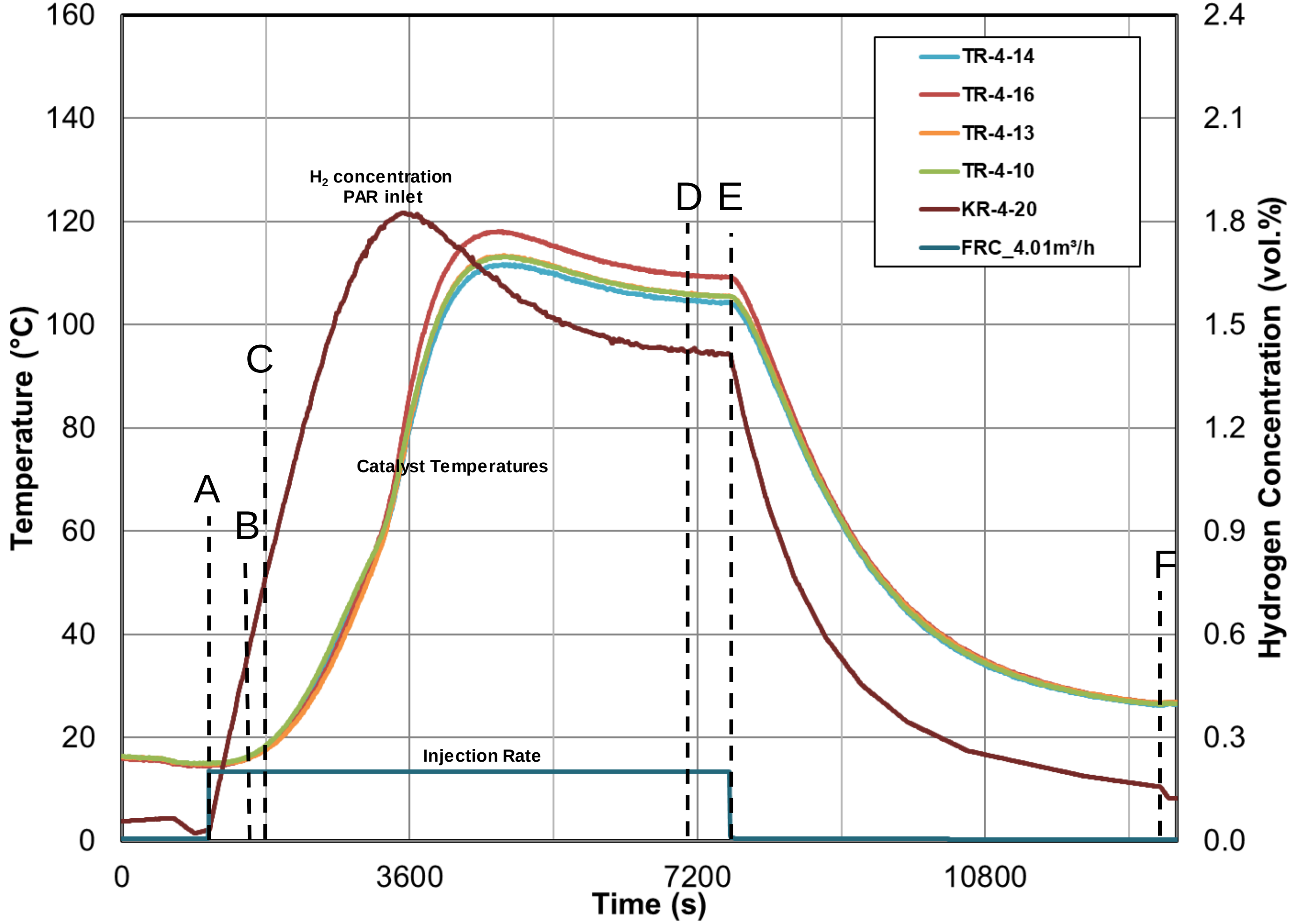


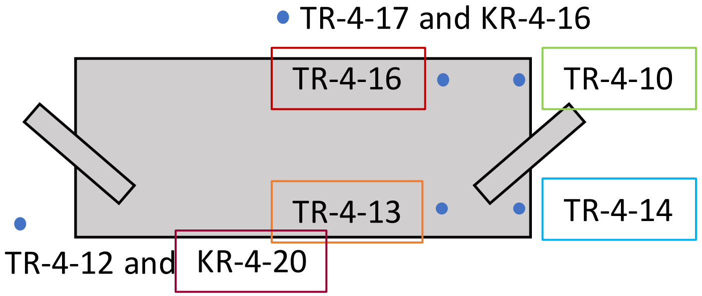
Experimental Setup: Instrumentation





Test Procedure





A: Start of Hydrogen Injection

B: Start of Reaction

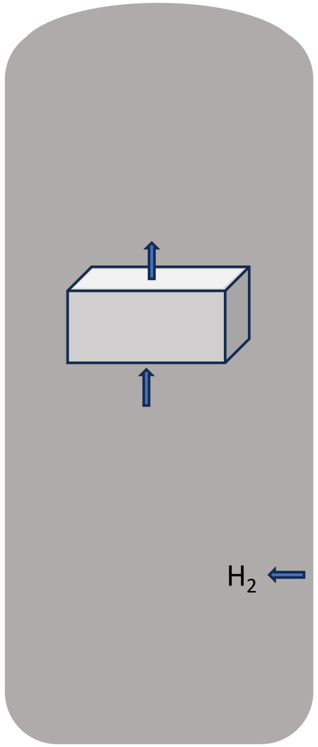
C: Catalyst Light-off

D: Start of quasi–Steady State phase

E: End of quasi-Steady State, Injection Stopped, and Start of Dynamic phase

F: End of Dynamic and Start of Purging

Test Procedure



$$\frac{dn}{dt} = \dot{n}_{in} - \overset{?}{\dot{r}}$$

Steady State $\frac{dn}{dt} = 0$

$$\Downarrow$$

$$\dot{r} = \dot{n}_{in}$$

Test #	Injection Rate 1 (n-m³/h)	Injection Rate 2 (n-m³/h)	Injection Rate 3 (n-m³/h)	Injection Rate 4 (n-m³/h)
1	0.10	0.15	0.20	0.25
2	0.10	0.15	-	-
3	0.25	0.20	0.15	0.10
4	0.20	-	-	-
5	0.25	0.20	0.15	0.10
6	0.15	-	-	-

Results: Start-up

$$H_{2\,(g)} + \frac{1}{2} O_{2\,(g)} \rightarrow H_2O_{(g)} + 240\ \frac{kJ}{mole}$$

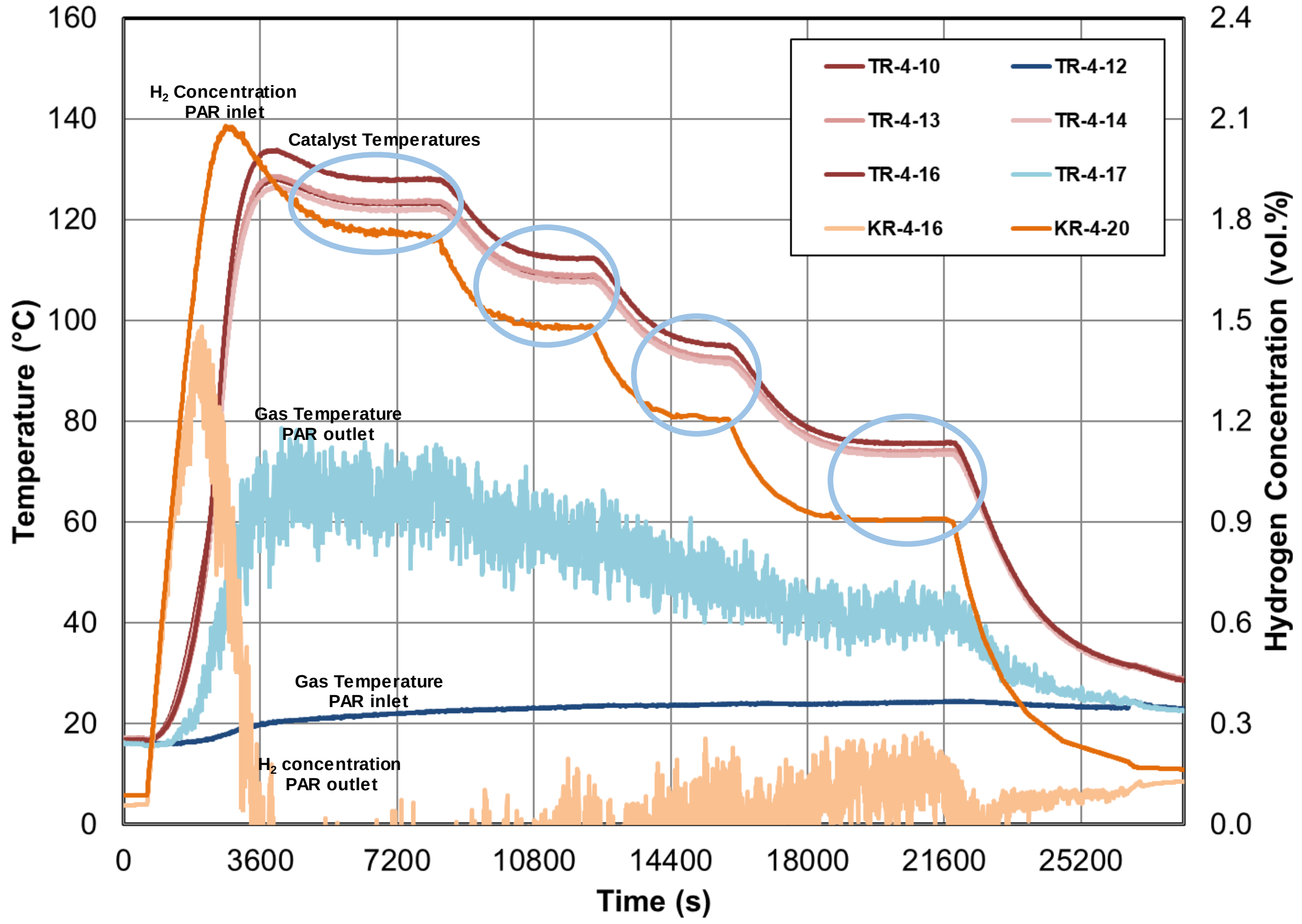
Hydrogen concentration and average catalyst temperature at the initial reaction start.

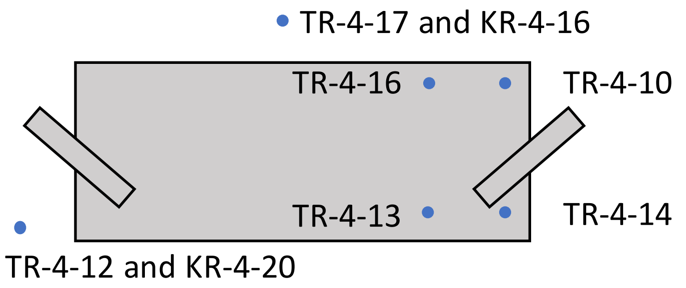
Test #	Hydrogen Concentration (vol.%)	Average Catalyst Temperature (°C)	Time (min)
1	0.25	19.0	8.1
2	0.16	20.7	5.6
3	0.23	21.3	3.1
4	0.54	16.2	8.1
5	0.51	18.1	6
6	0.42	20.1	7.8

Average catalyst light off temperature and hydrogen concentration

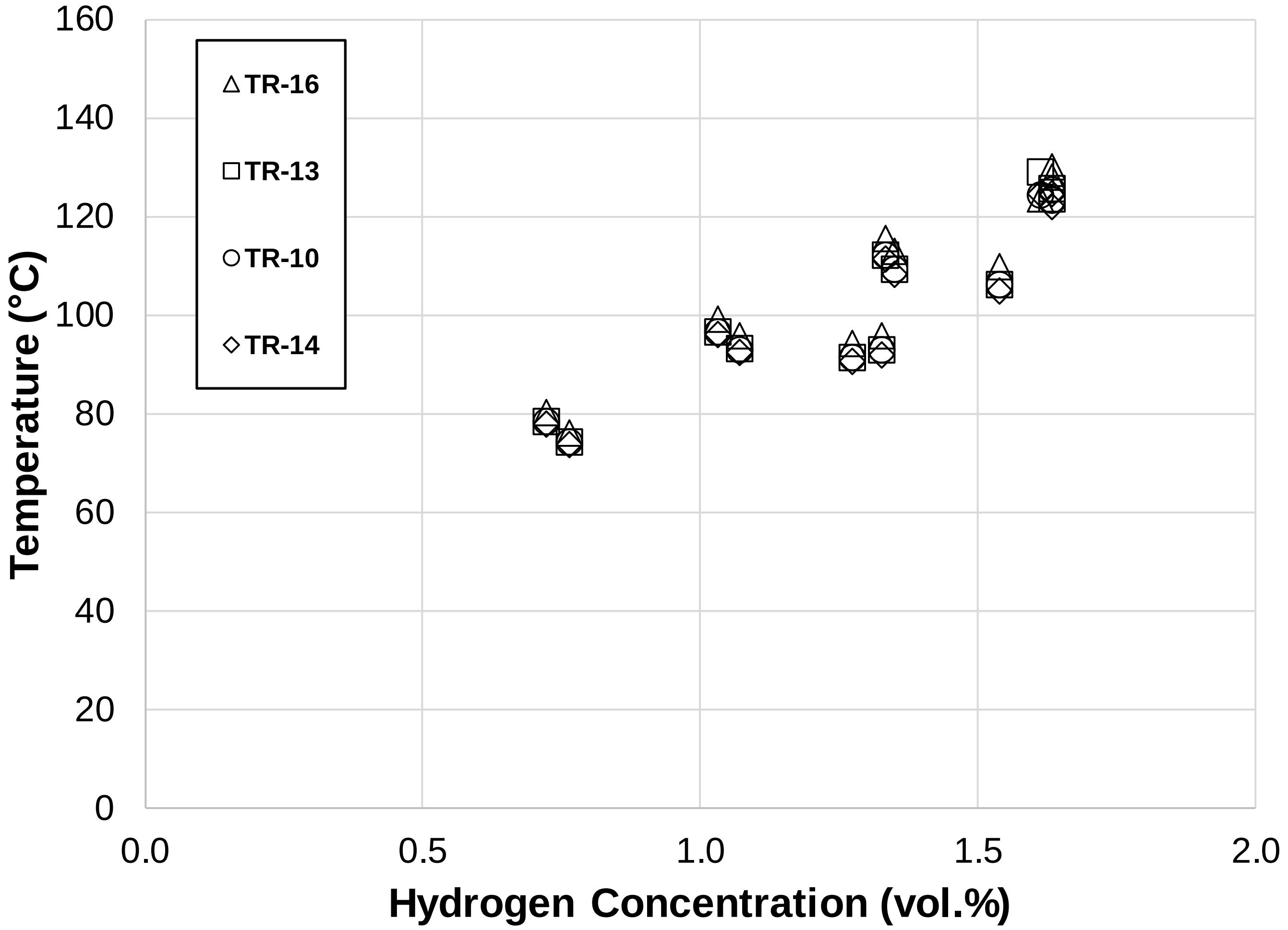
Test #	Average Catalyst Temperature (°C)	Hydrogen Concentration (vol.%)	Time (min)
1	22.7	0.53	17.4
2	33.6	0.45	22.7
3	34.5	0.81	11.2
4	17.4	0.71	10.8
5	20.9	0.82	10.1
6	21.4	0.59	11.4

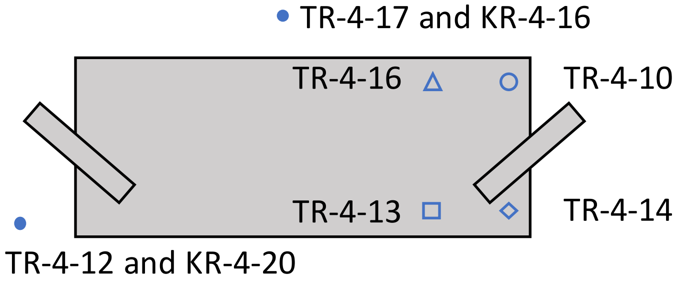
Results: Steady-states



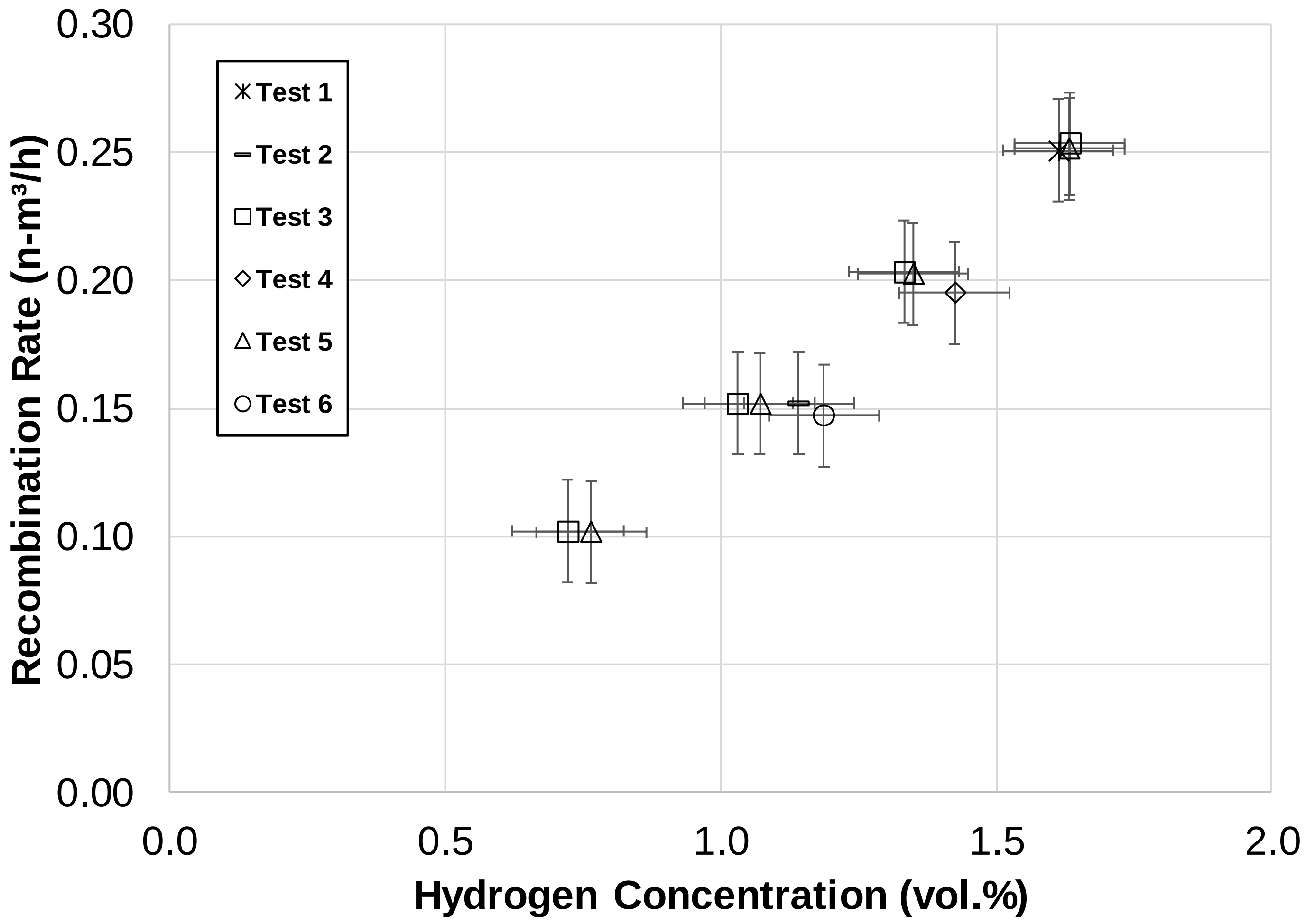


Results: Temperature Profile





Results: Recombination Rates



Conclusion

Characterized:

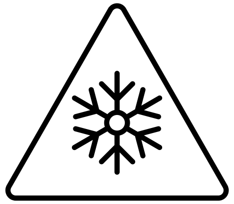
- Recombination rates

Key Characteristics:

- Fast start up
- Prolonged use

Observation:

- Opposite temperature profile than convectional recombiners
    - Possible Explanations:
        - Lower flow velocities
        - Not as well-developed boundary layers



Future work:

- Numerical model
- Lower temperatures
- Higher Injection Rates

Acknowledgments

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Thank you!

Questions?

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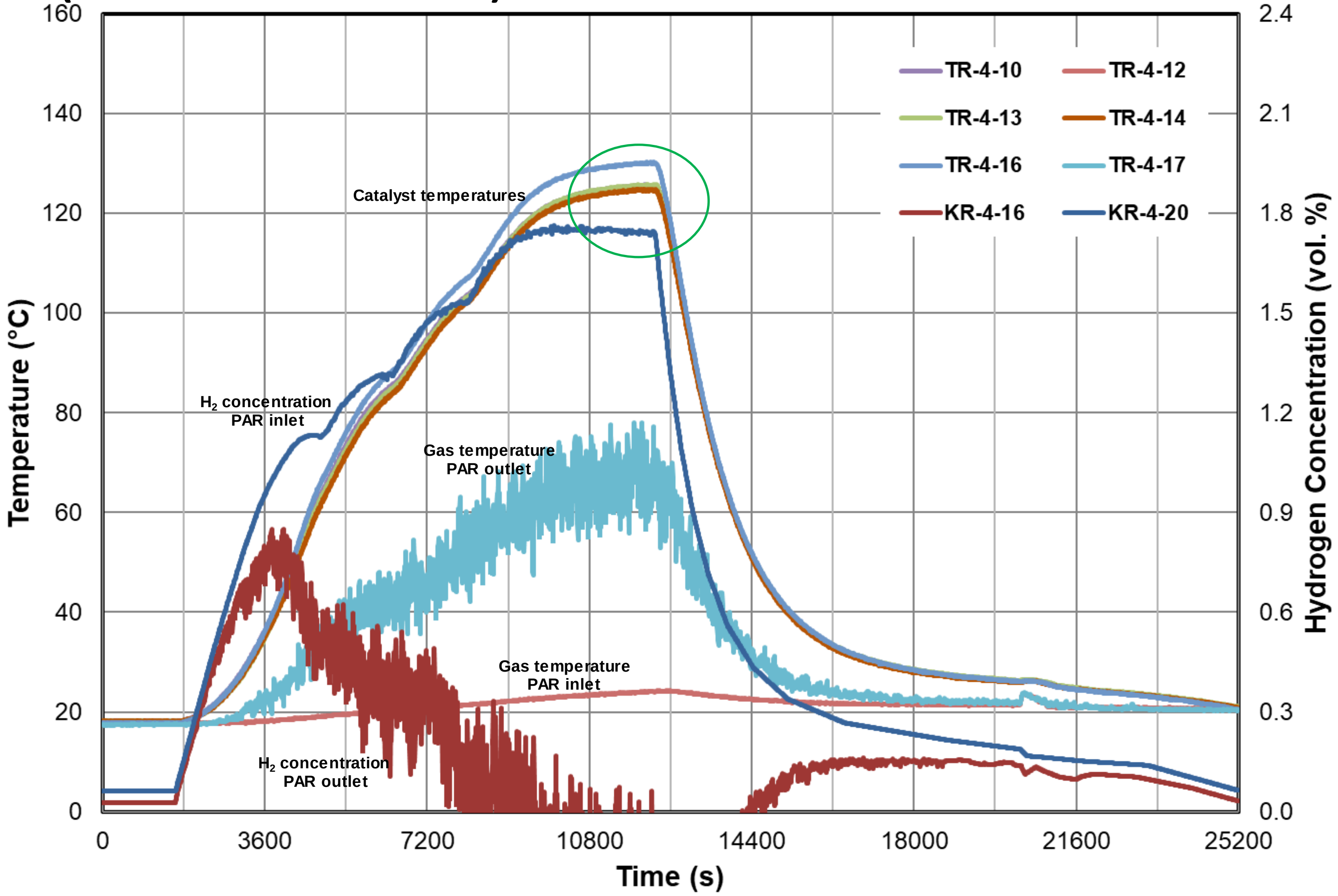
www.stacy-project.eu/en

Results (continued)



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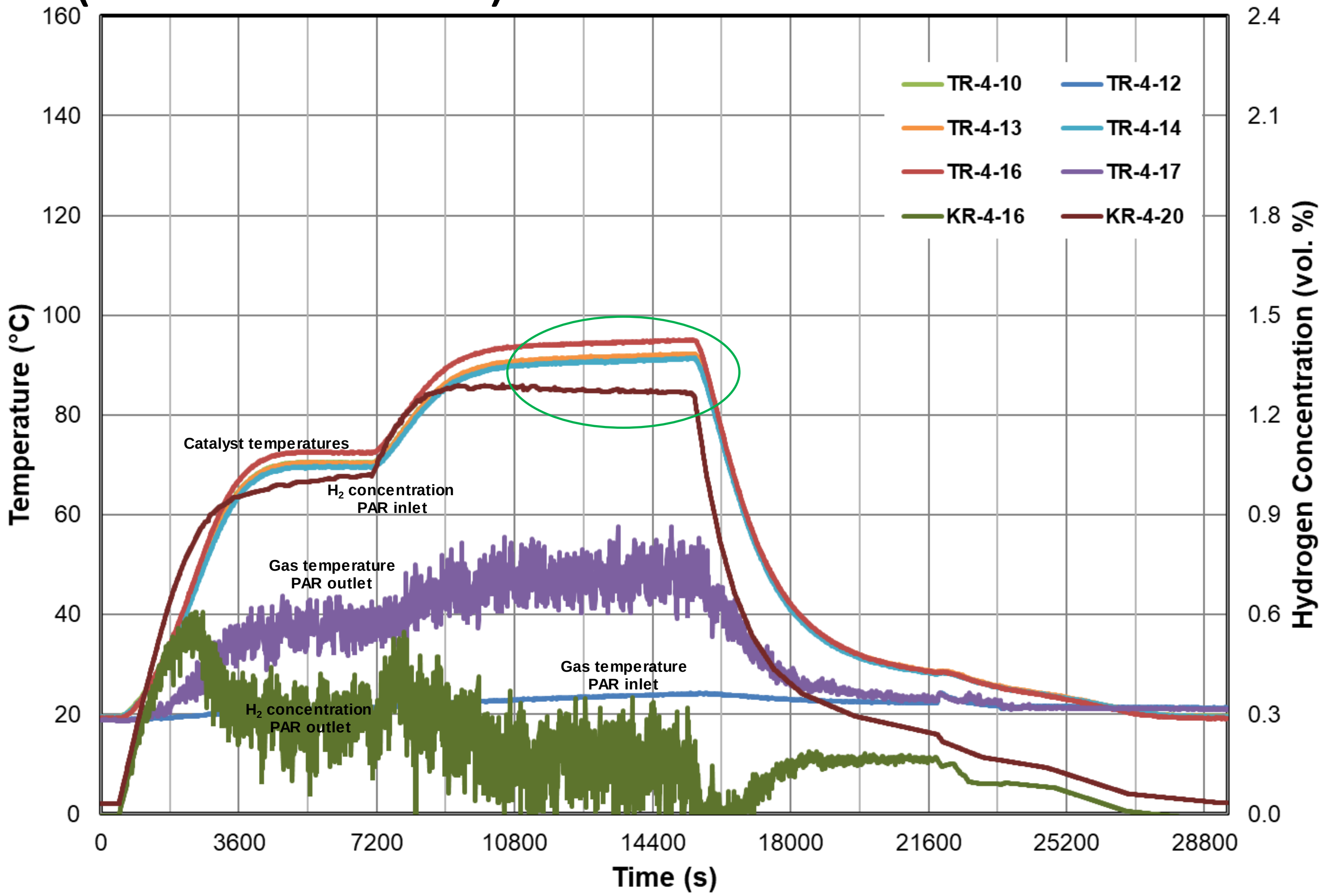
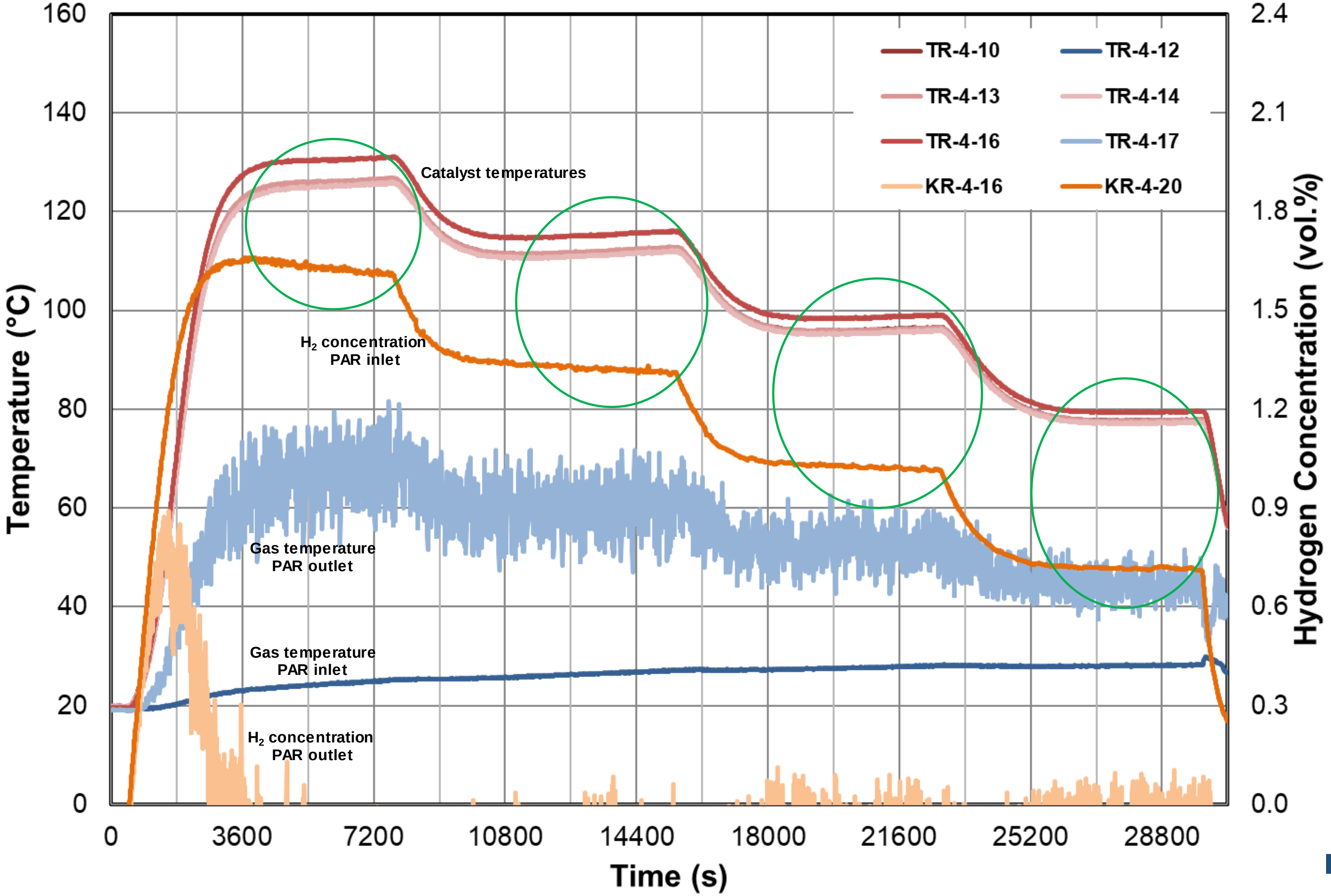


Results (continued)



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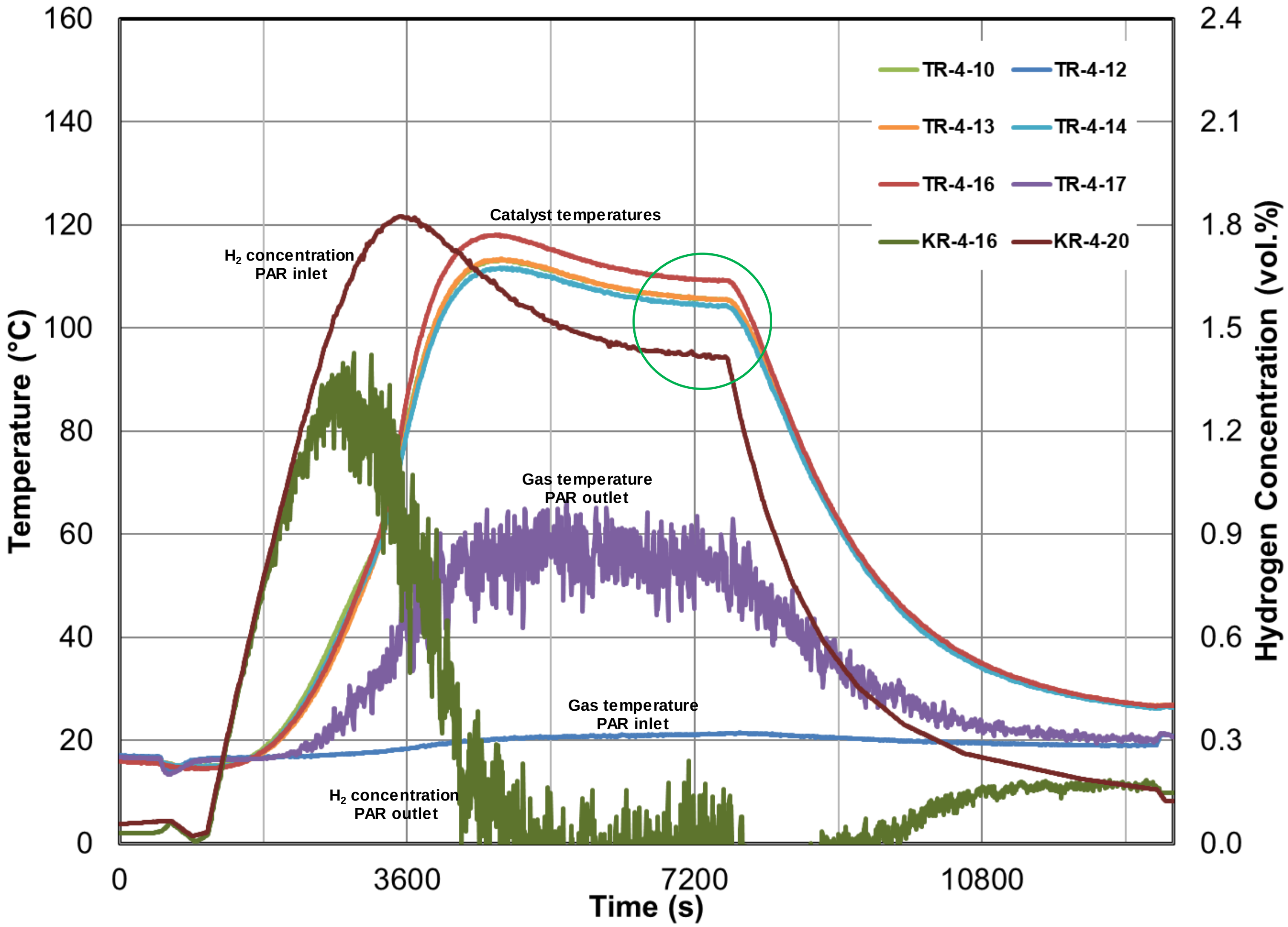

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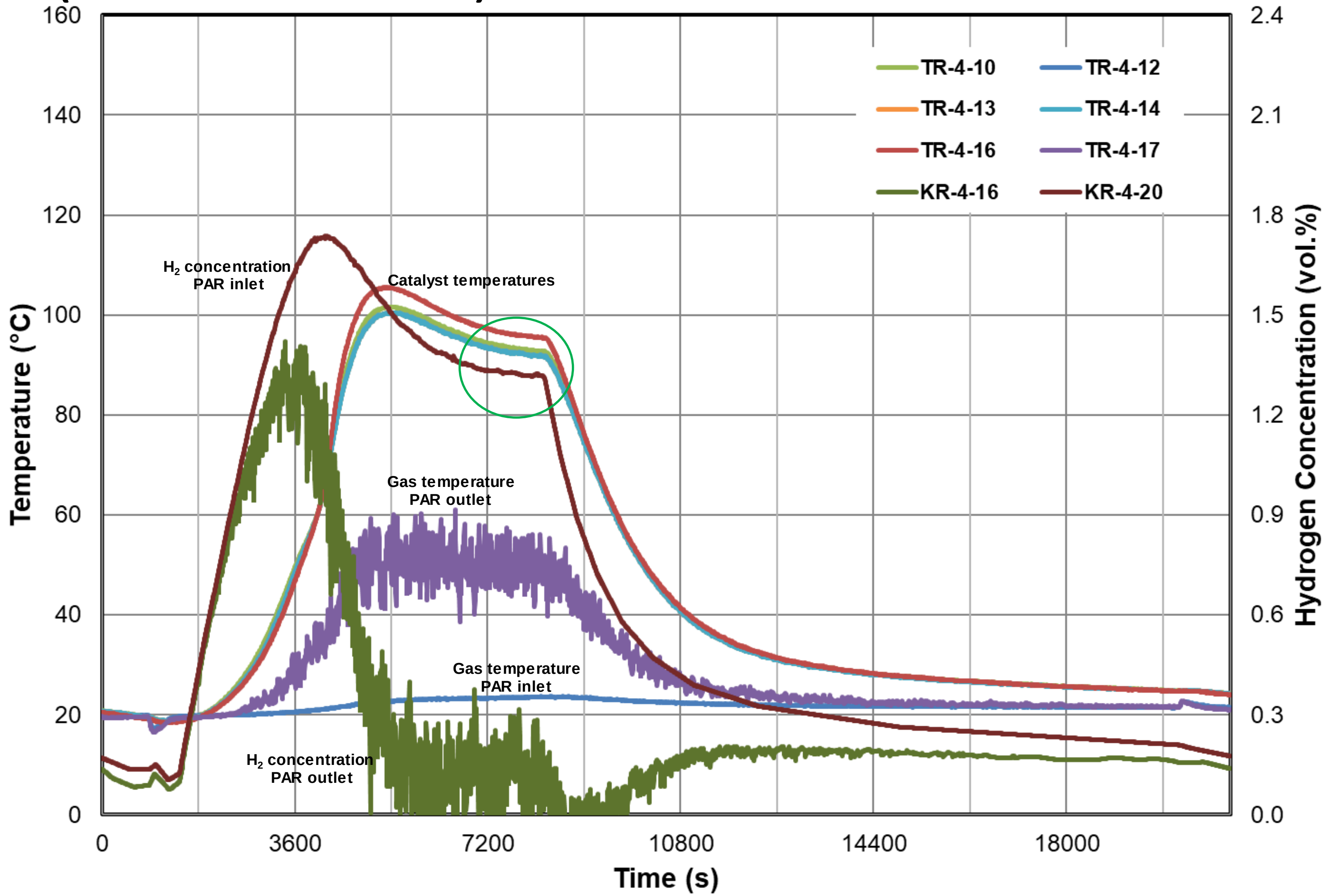

Passive Auto-Catalytic Recombiners