

# **Leakage and dispersion of liquid hydrogen in a tank connection space**

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Presented by Wayne Rattigan





## Outline

- Introduction
- Facility and Experiments
- Selected Results
- Summary





- “Enhancing the safety of liquid and vaporised hydrogen transfer technologies in public areas for mobile applications”
- European collaborative research project investigating the safety of liquid hydrogen (LH<sub>2</sub>) transfer technologies
- 3-Year project
- 8 European Partners

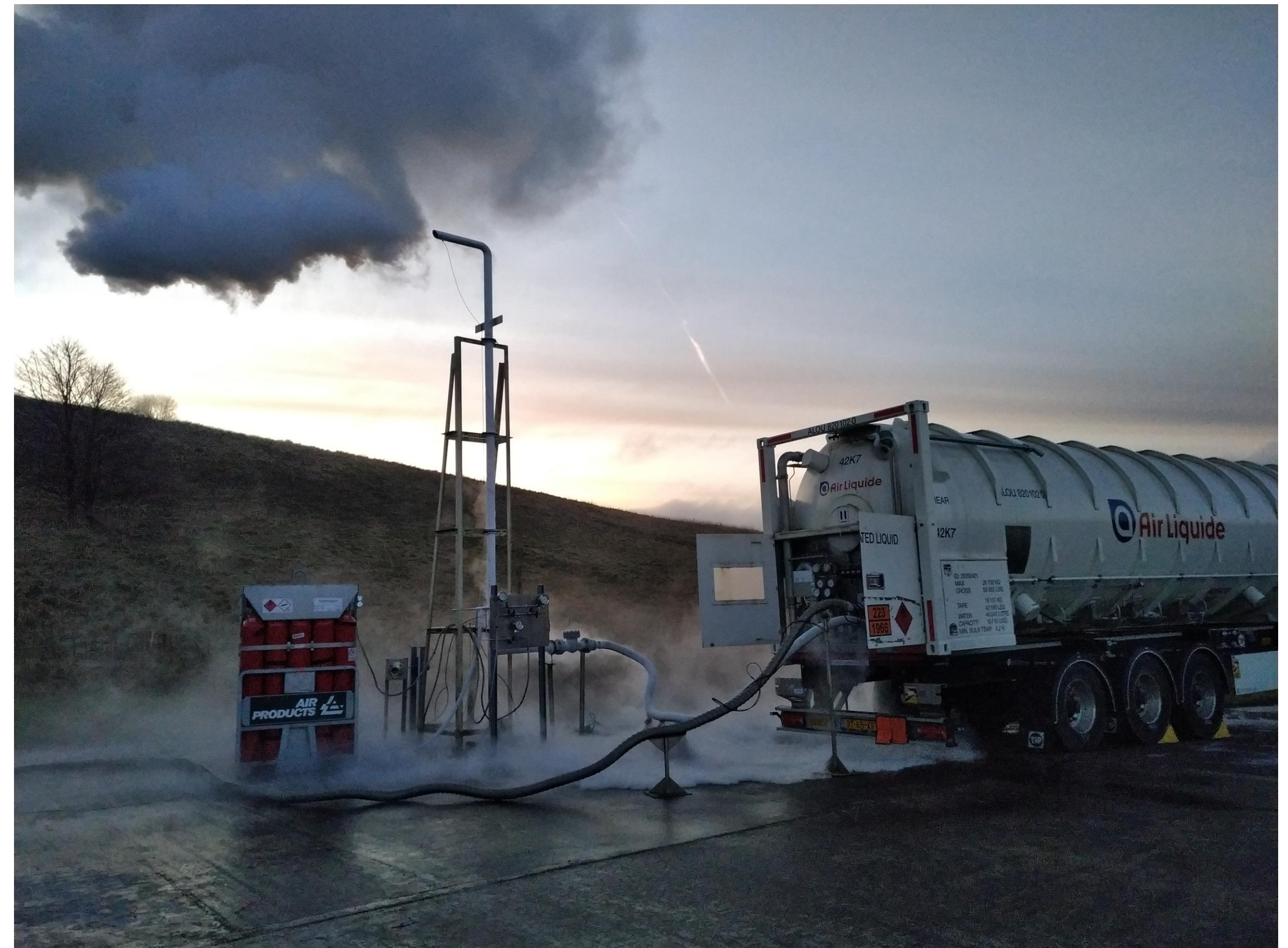


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## **LH2 Release Facility**

- 2.5 tonnes LH2 – ISO tanker
- Pressures up to 12 bar
- 6 m vent stack
- Super insulated vacuum lines (SIVL)
- Up to 1" release diameter

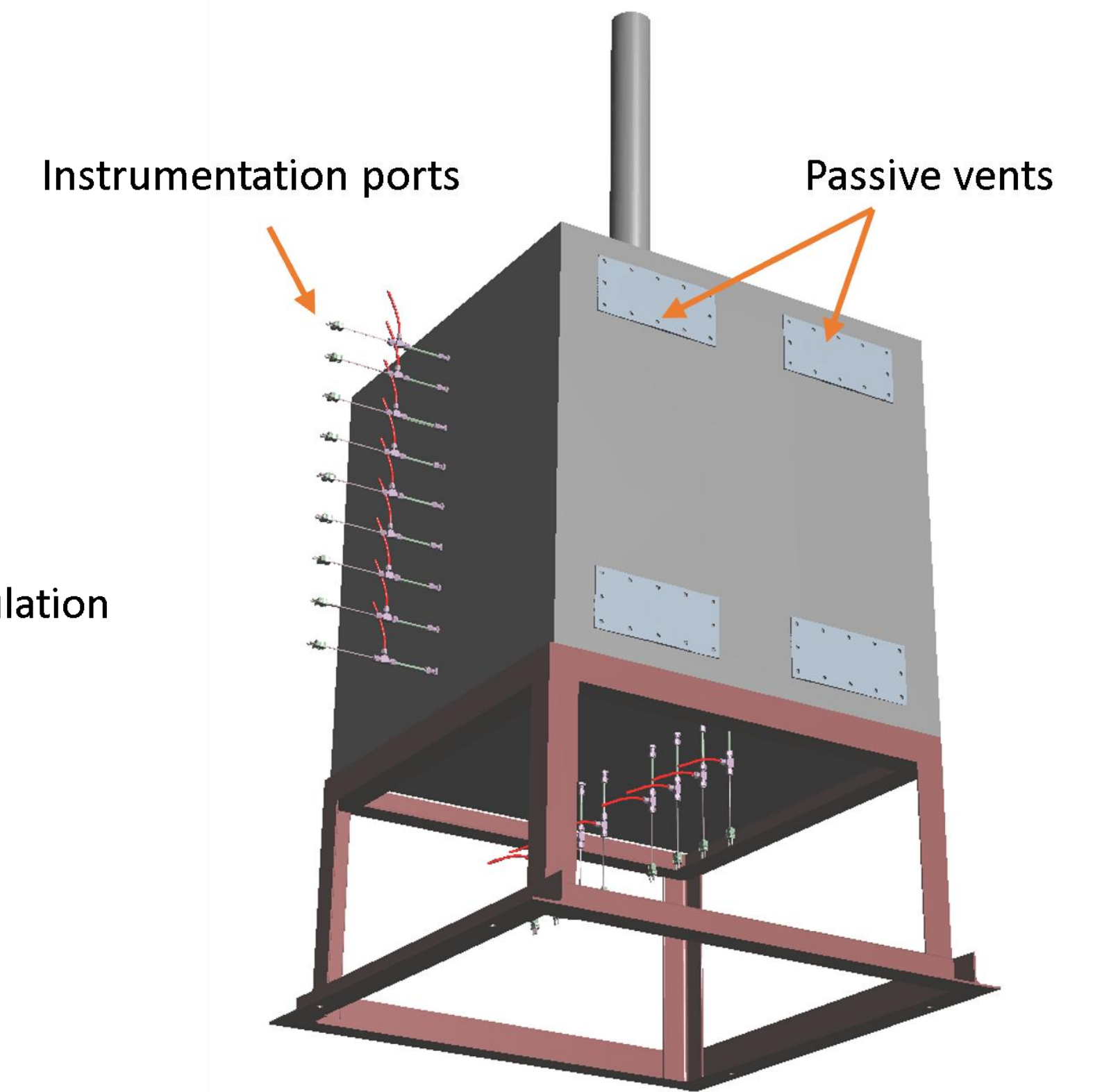
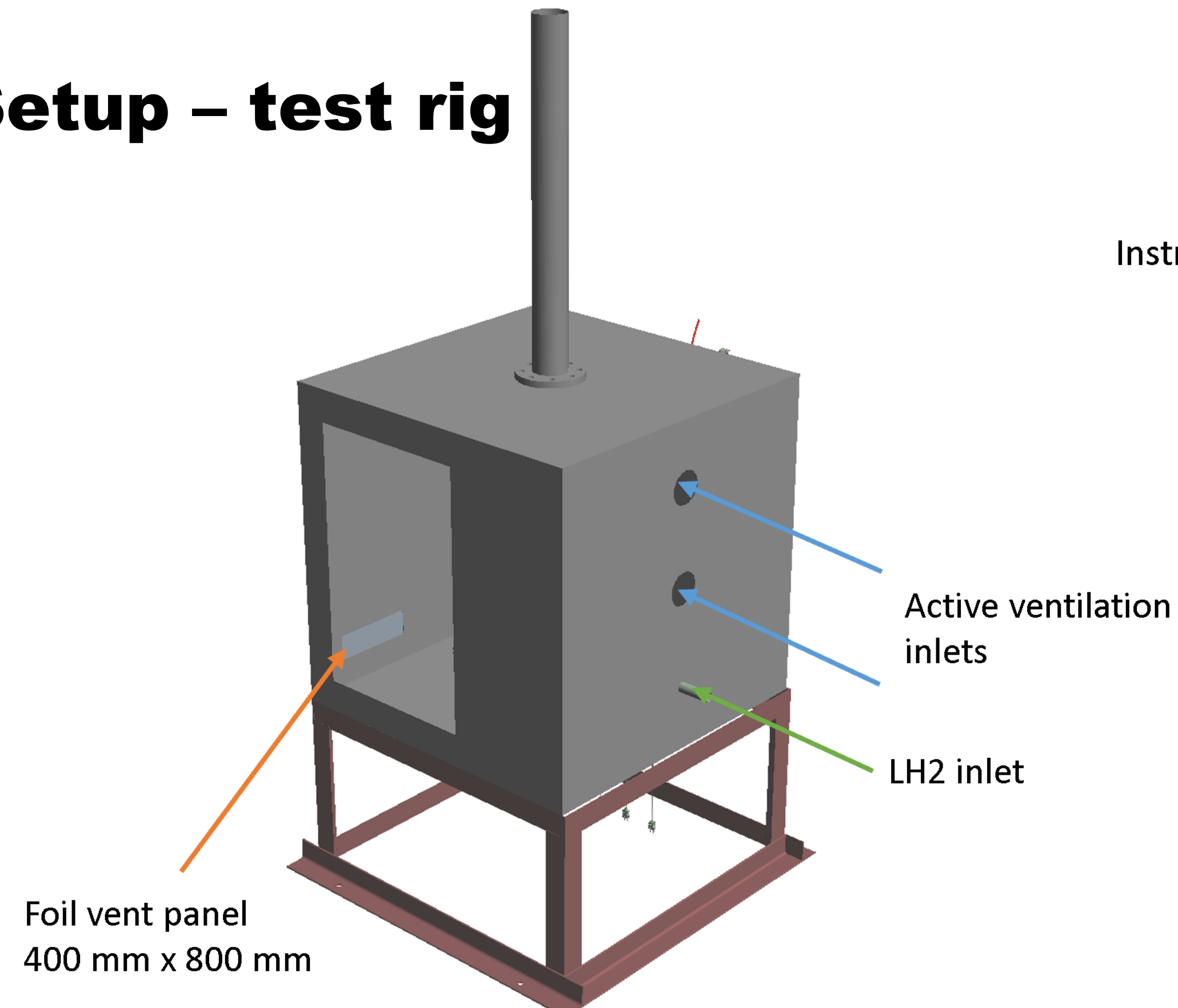




## **Experiments – LH2 dispersion test matrix**

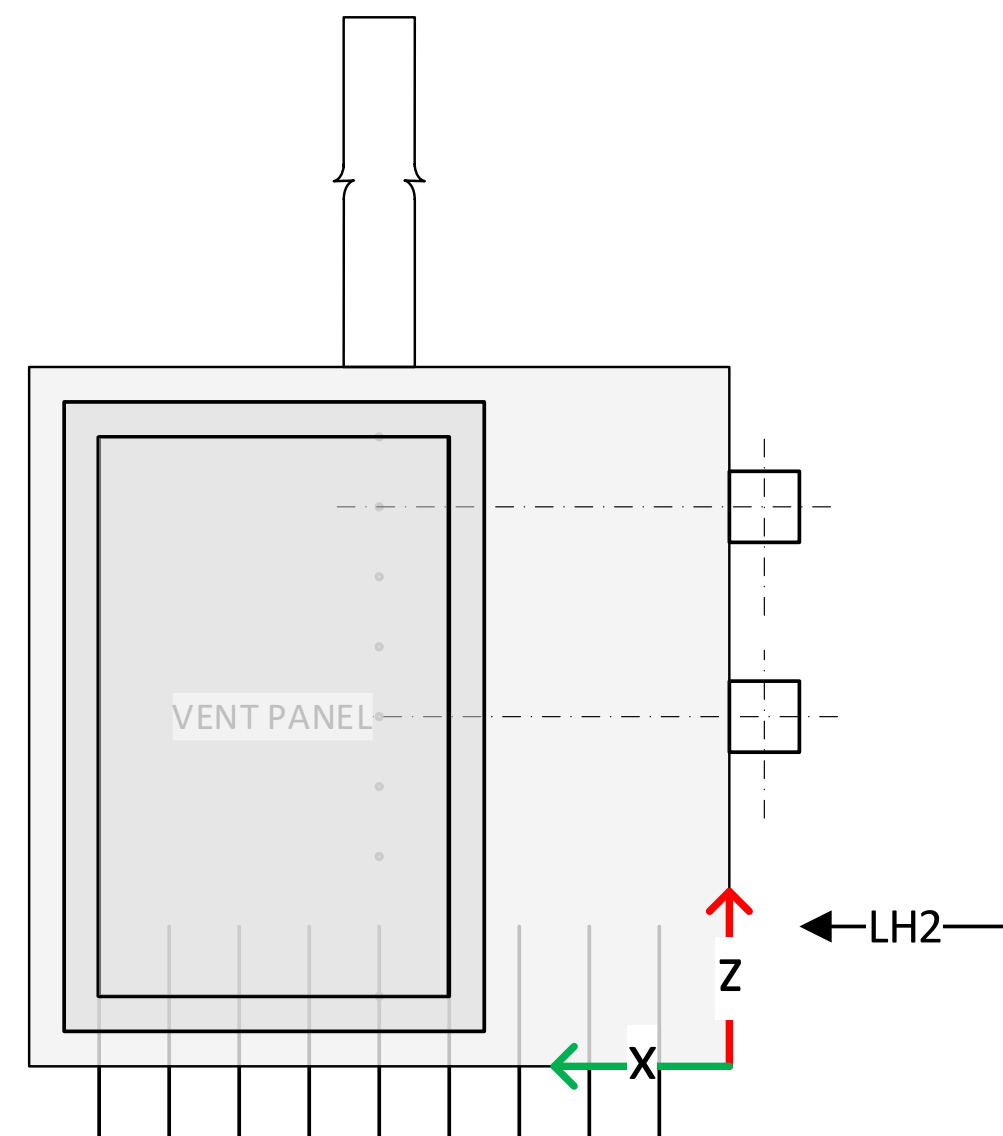
- Undertake releases of LH2 through four nozzle diameters
  - 0.2 mm, 0.5 mm, 1.0 mm and 1.8 mm
- 2 nozzle release pressure
  - 2 barg, 8 barg
- 3 ventilation regimes
  - passive and actively ventilated i.e., 0, 500 l/min and 2000 l/min
- Repeat tests (horizontal) (3)
- Vertical releases for a limited number of conditions, including repeats (6)
- 33 tests in total

## Experimental Setup – test rig

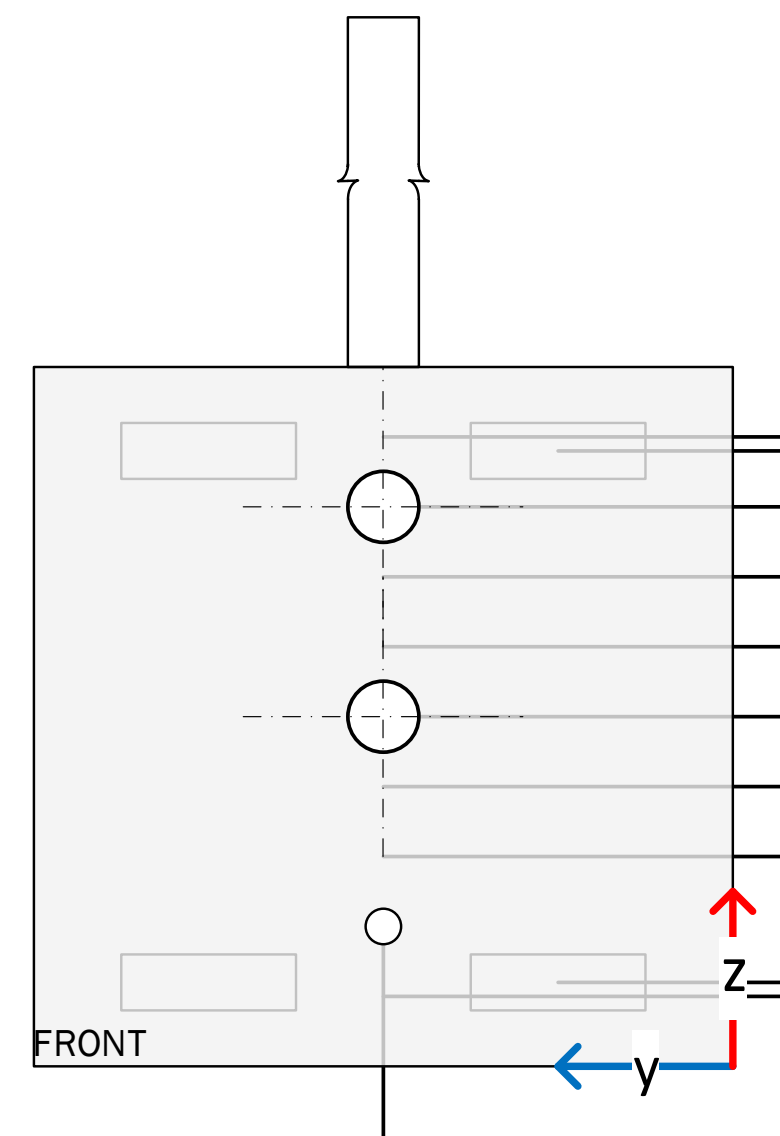


- 1 m<sup>3</sup> stainless steel cube
- LH2 inlet
- 16 x hydrogen gas conc. sensor  
XEN-5320 thermal conductivity  
Measurement range of 0 to
- 100%vol., accuracy of  $\pm 2.0\%$  FS.
- 24 x thermocouples (type T)
- Active ventilation
  - fan – 500 l/min; 2000 l/min
  - Vented via 1 m tall chimney
- Passive ventilation slots  
(0.08 m<sup>2</sup>)
- Weak panel for overpressure protection

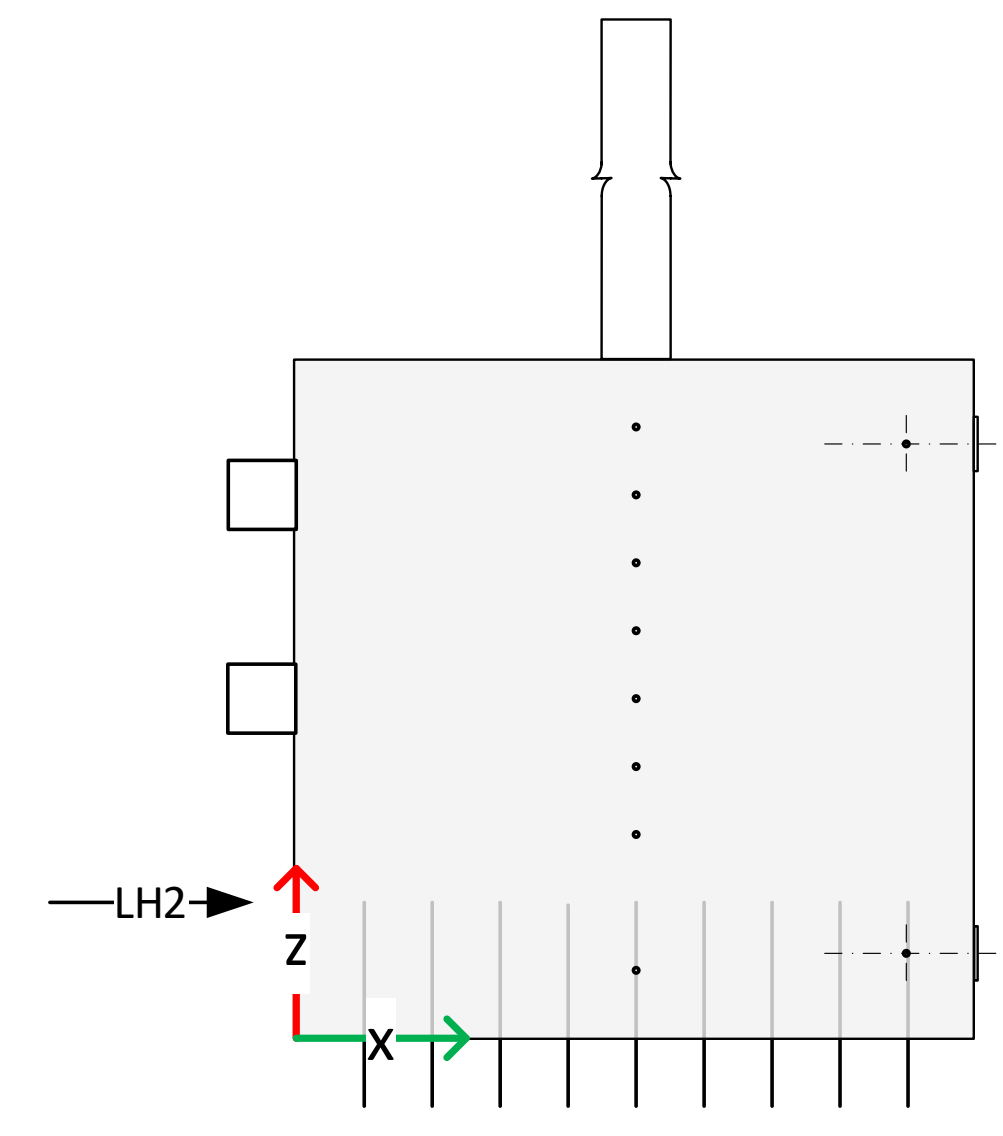
## Experimental Setup



left side



front side

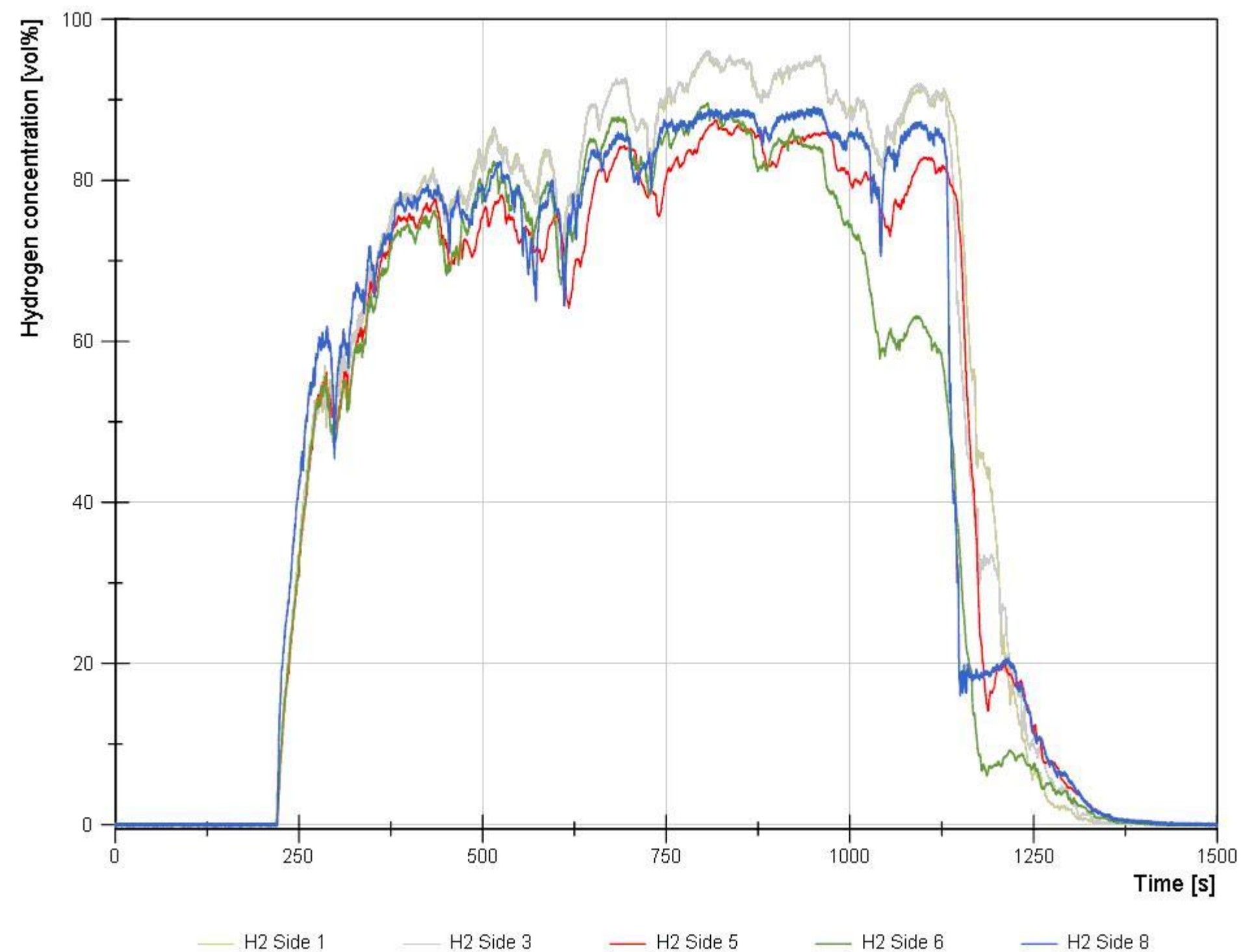


right side

Projected view of thermocouple and hydrogen gas sensor location within the 1 m<sup>3</sup> vessel for the dispersion experiments.



## Results – release duration



immediately  
following opening  
of valve (1 s)



during release  
(577 s),

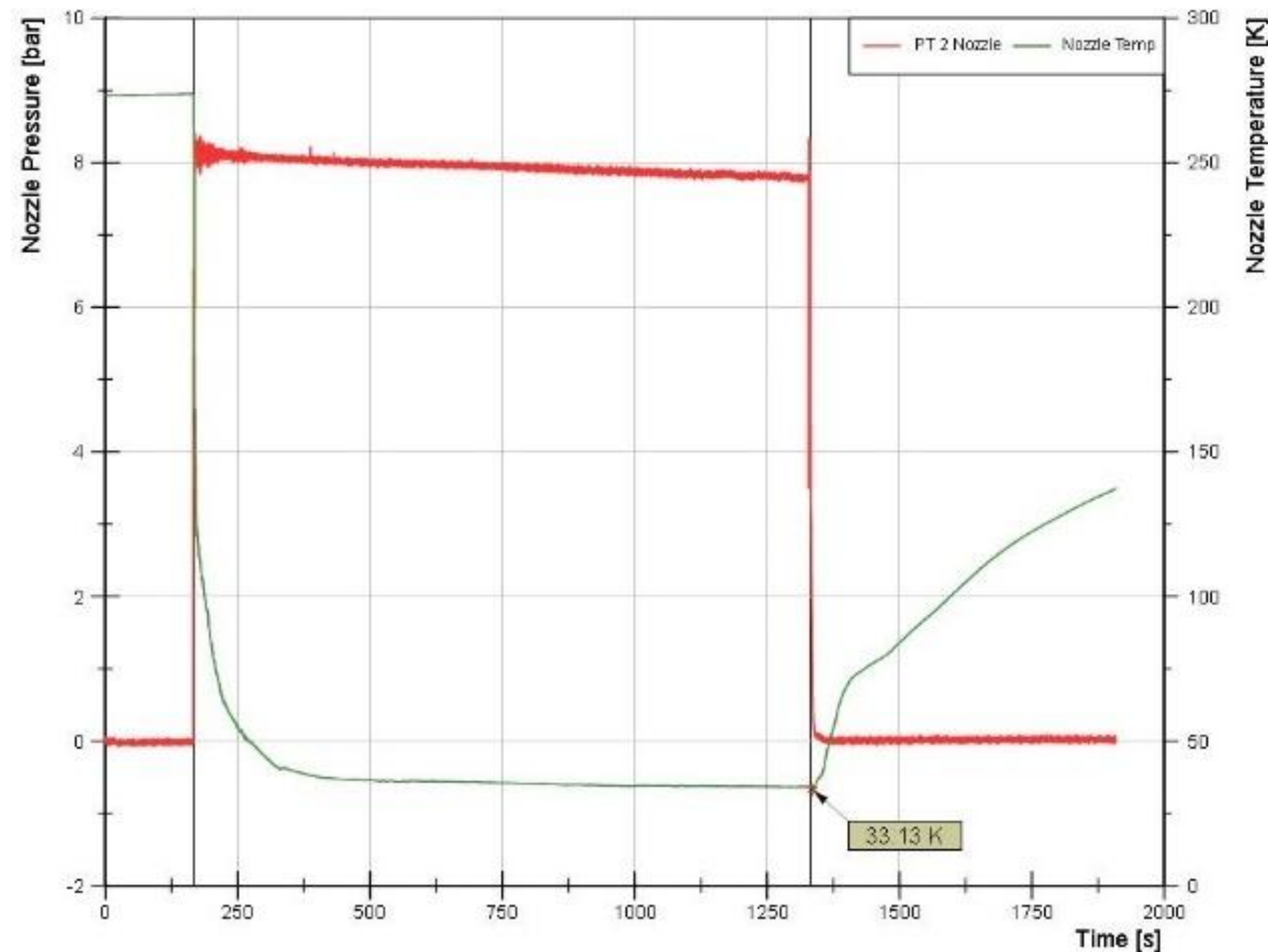


after valve closed  
(915 s), showing  
residual vapour from  
upper passive vent.

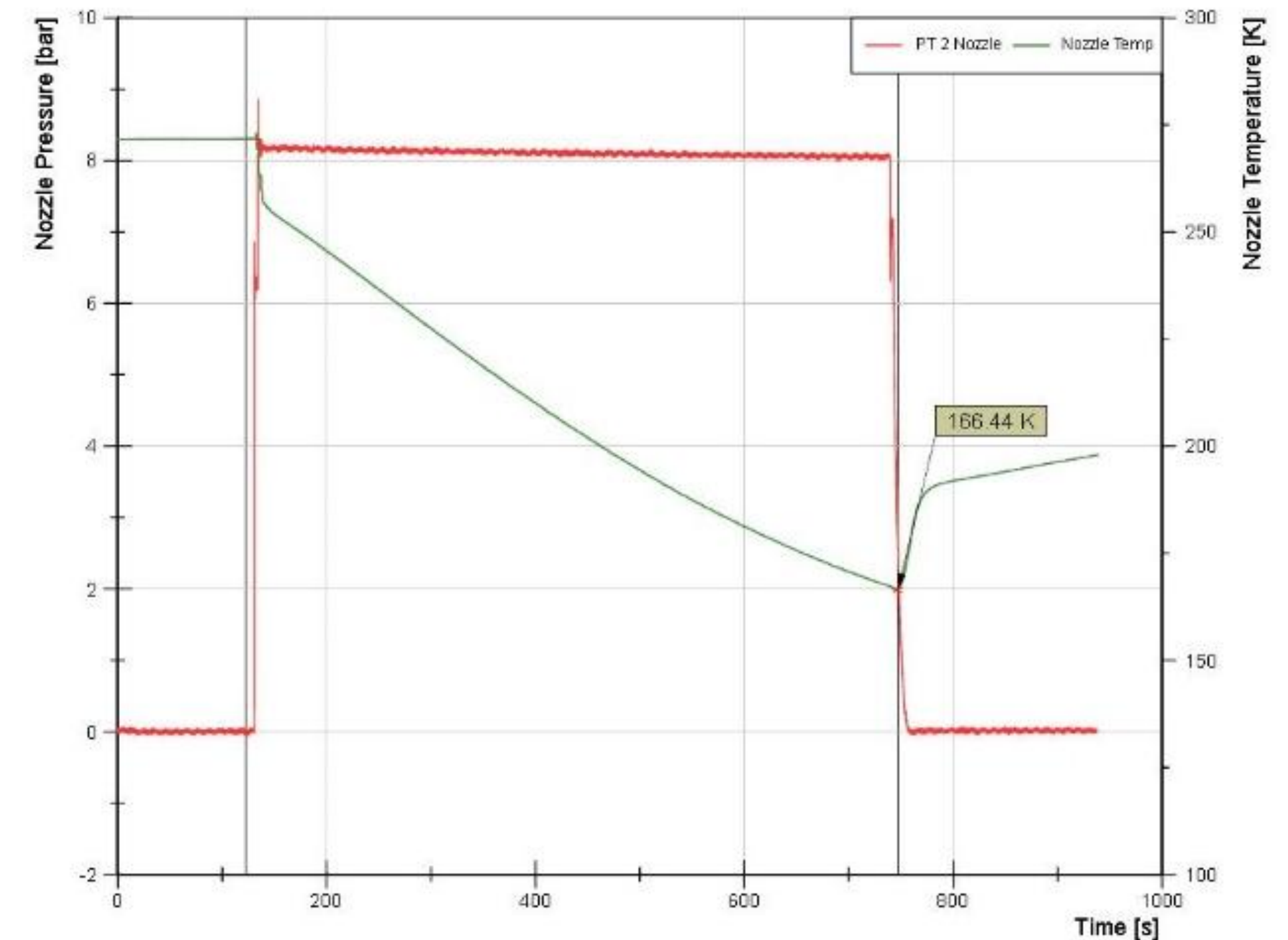
Sequence of video stills from test 21. 8 barg release through a 1.8 mm nozzle under passive ventilation regime



## Results – Source conditions



(a) Minimum nozzle temp 33 K

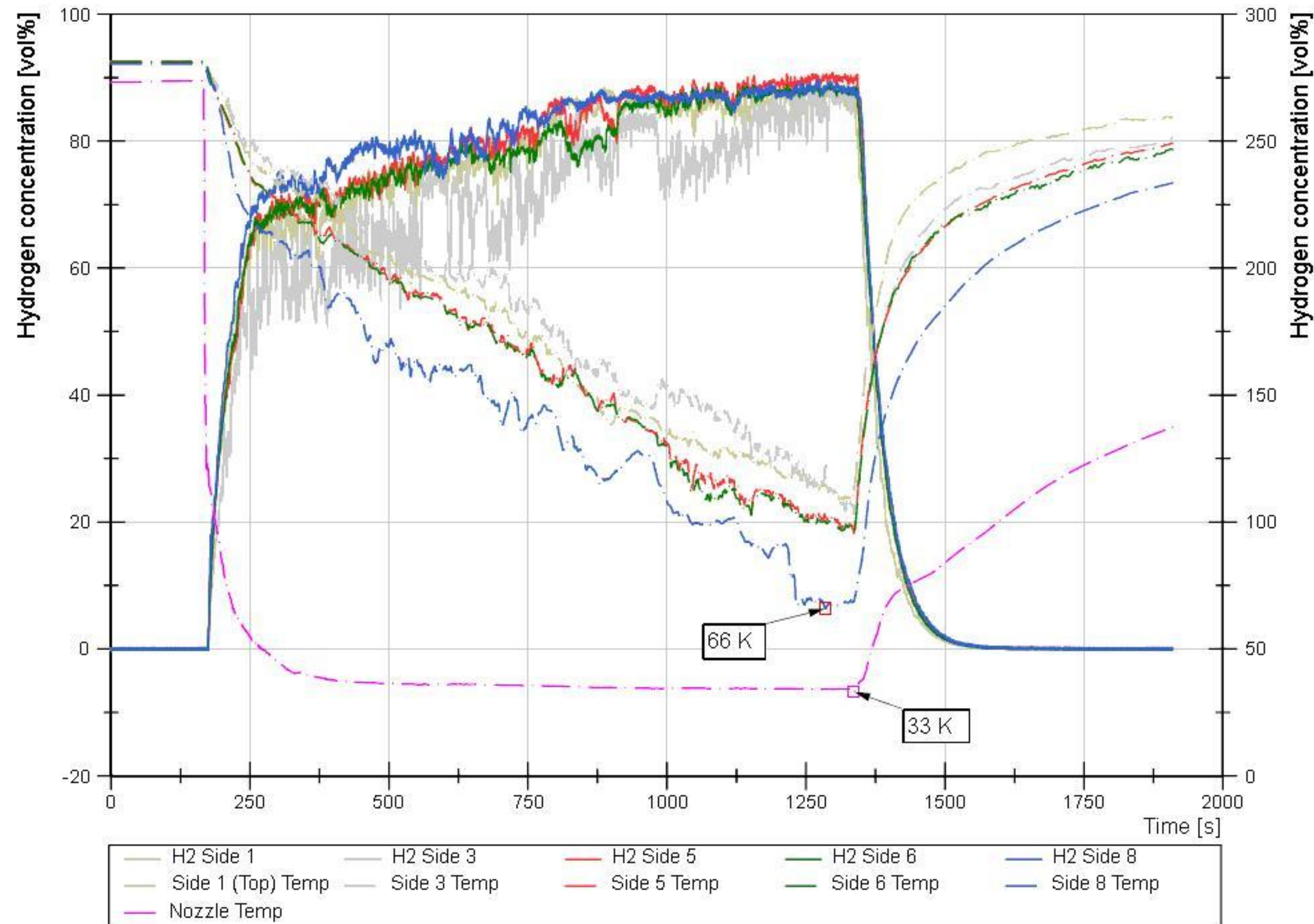


(b) Minimum nozzle temperature 166 K

Nozzle temperature and pressure for a nominal 8 barg release (a) through a 1.8 mm nozzle (Test 17) and (b) through a 0.5 mm nozzle (Test 24).



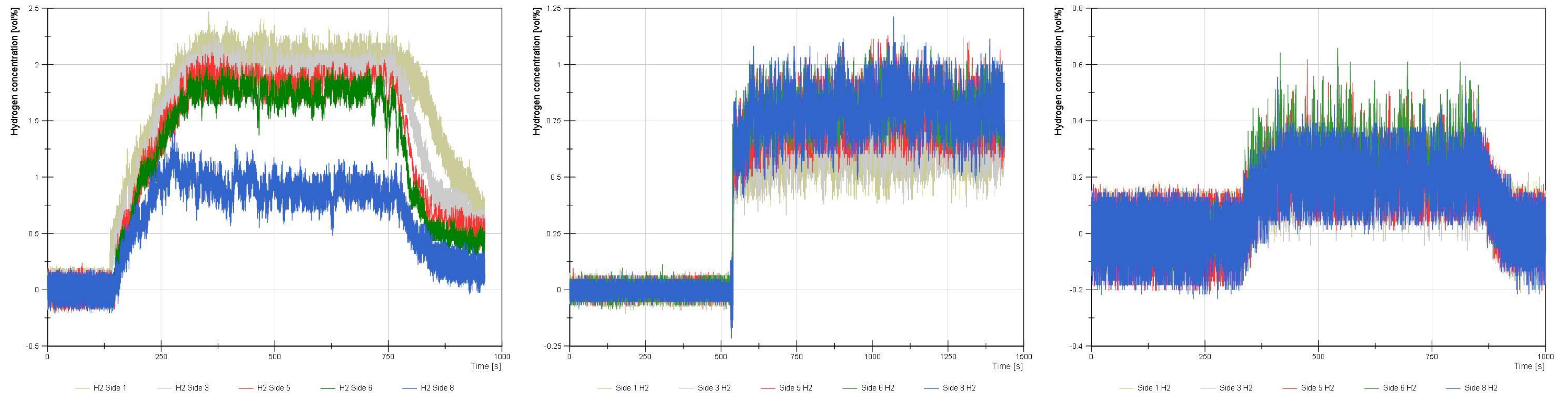
## Results – temperature and concentration



- Test 17. 1.8 mm nozzle, 8 bar nominal release pressure. Active ventilation, 200 l/min
- A plot showing the hydrogen concentrations and temperatures within the box and the fluid temperature at the nozzle



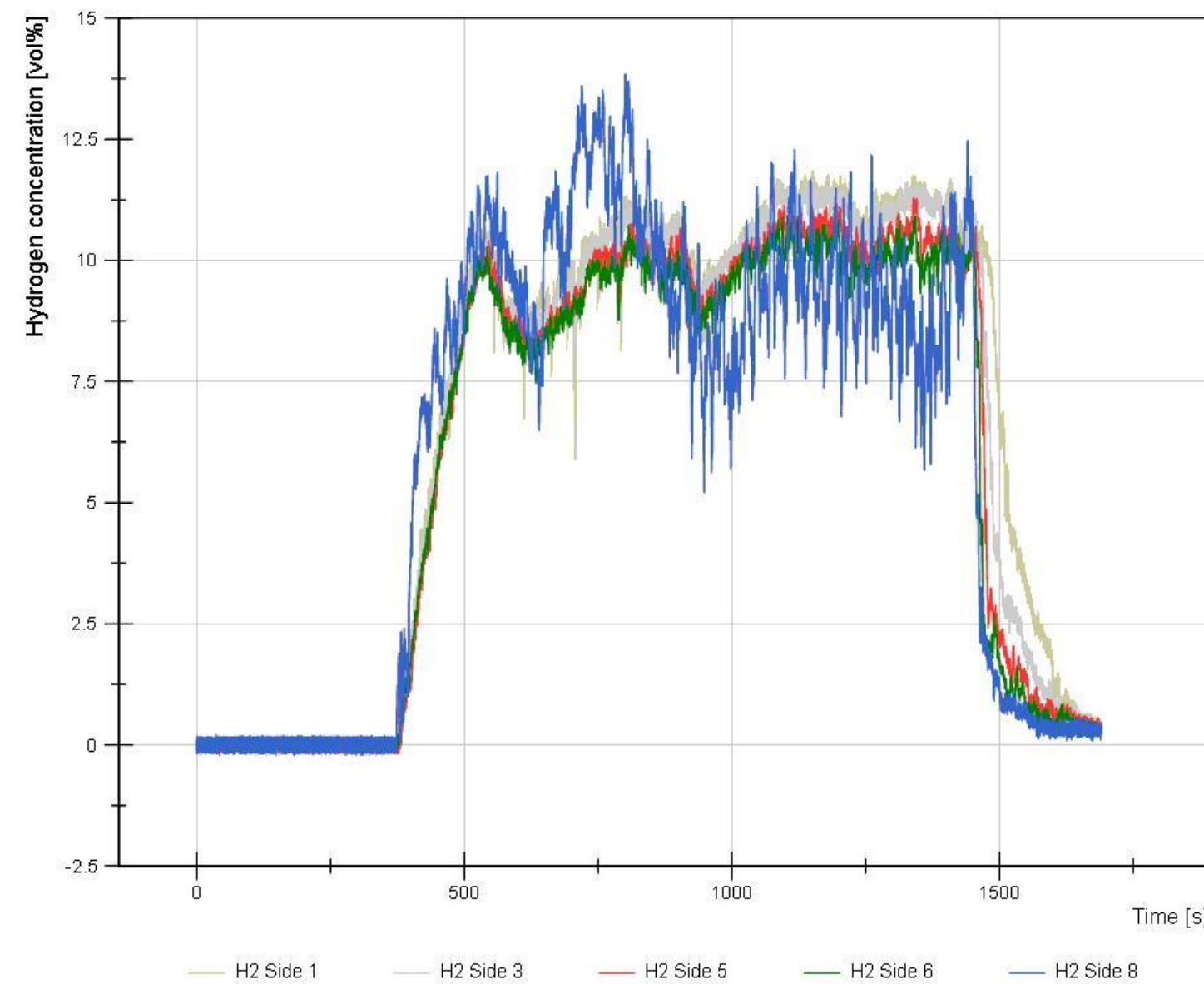
## Results – passive vs active ventilation



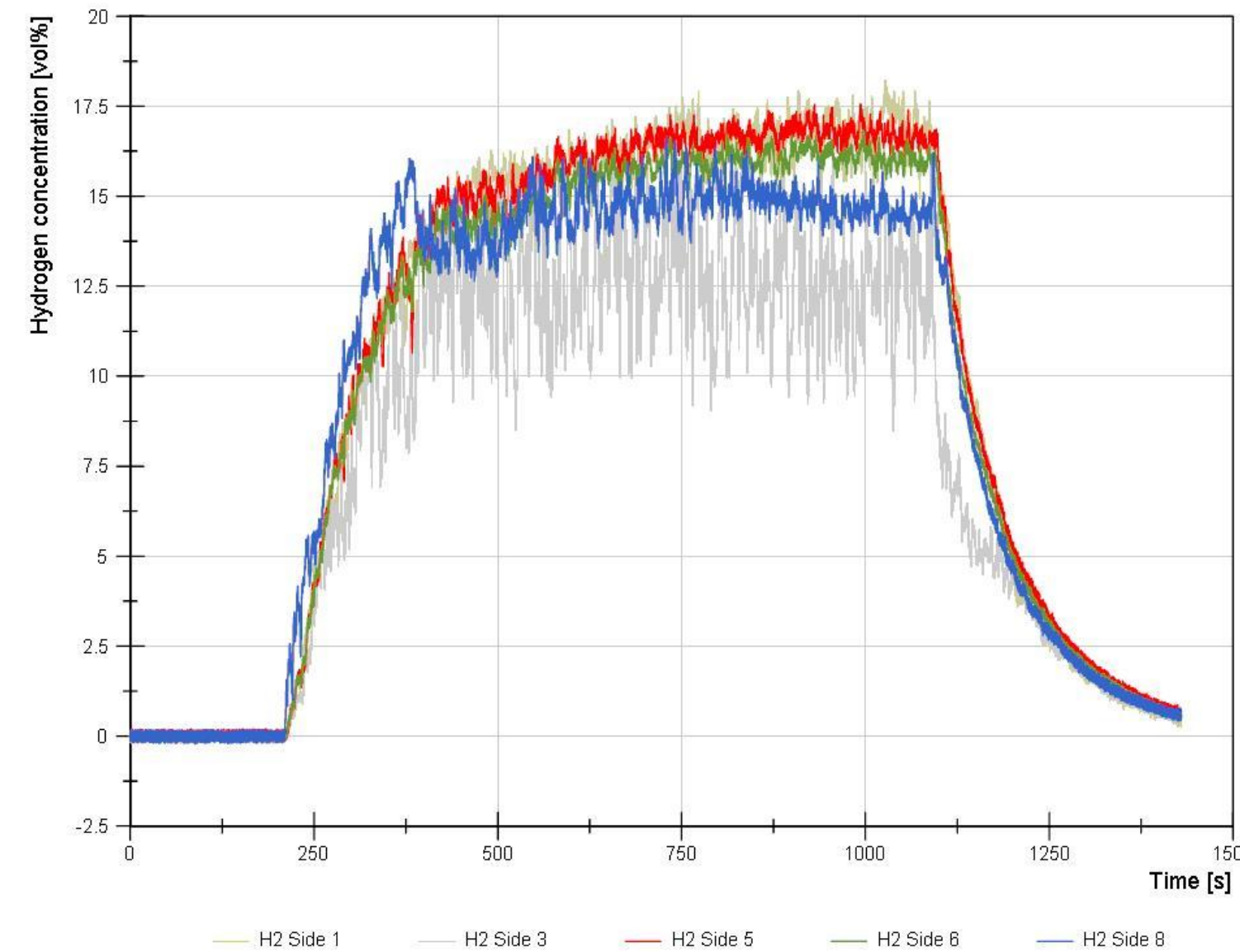
- 0.2 mm nozzle; 2 barg
- Passive ventilation (a), active 500 l/min (b), active 2000 l/min (c)



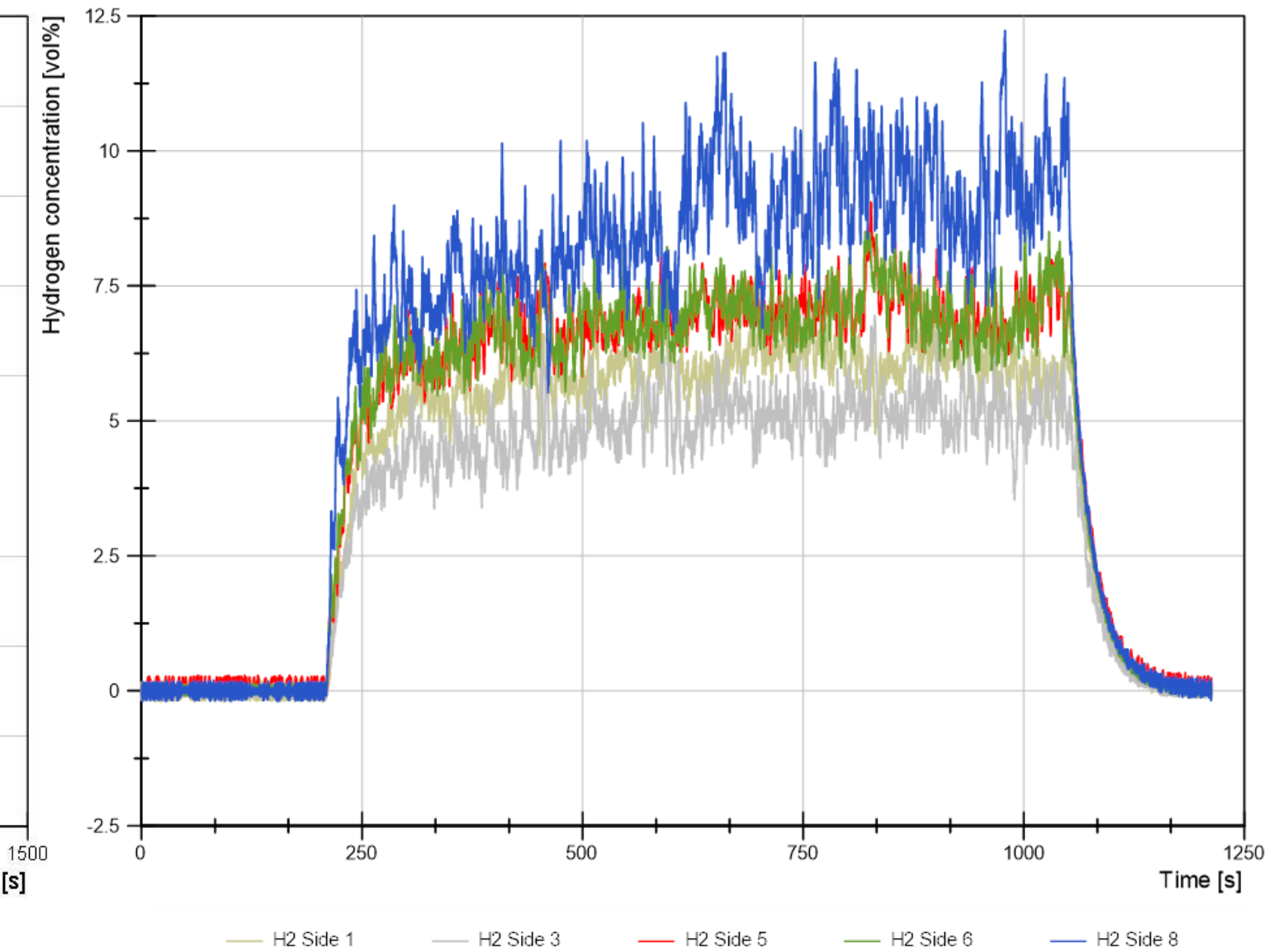
## Results – passive vs active ventilation



(a)



(b)

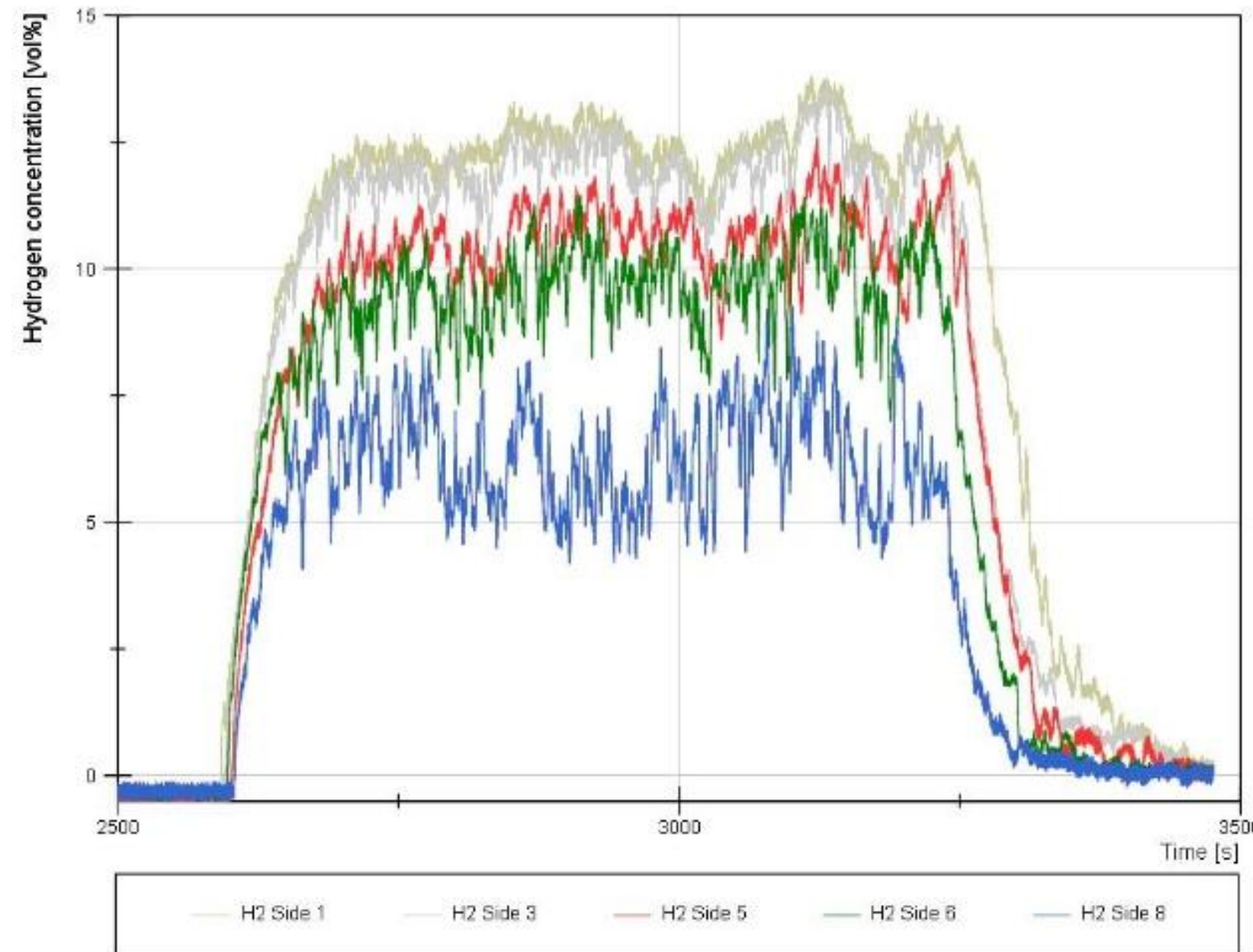


(c)

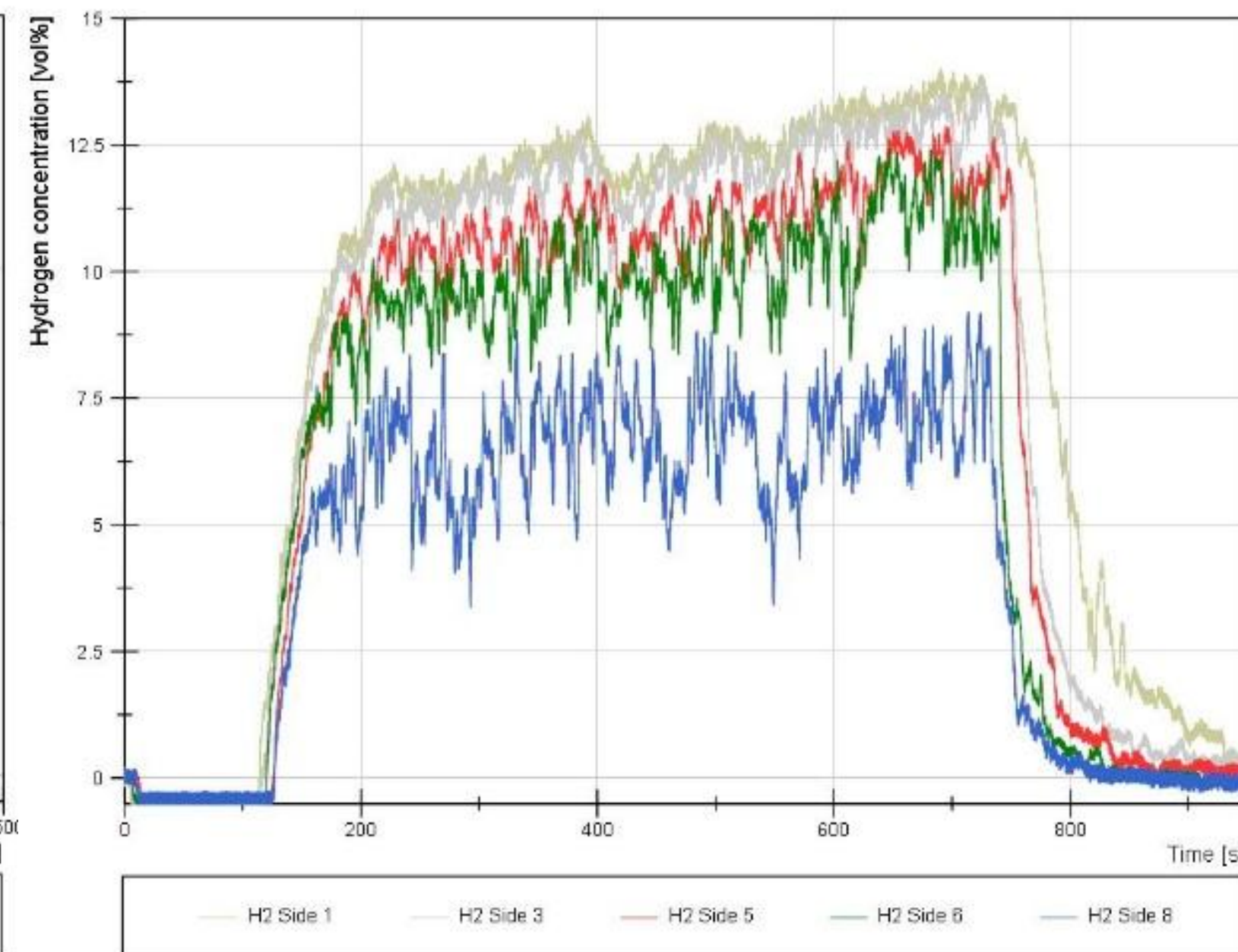
- 1.0 mm nozzle; 2 barg
- Passive ventilation (a), active 500 l/min (b), active 2000 l/min (c)



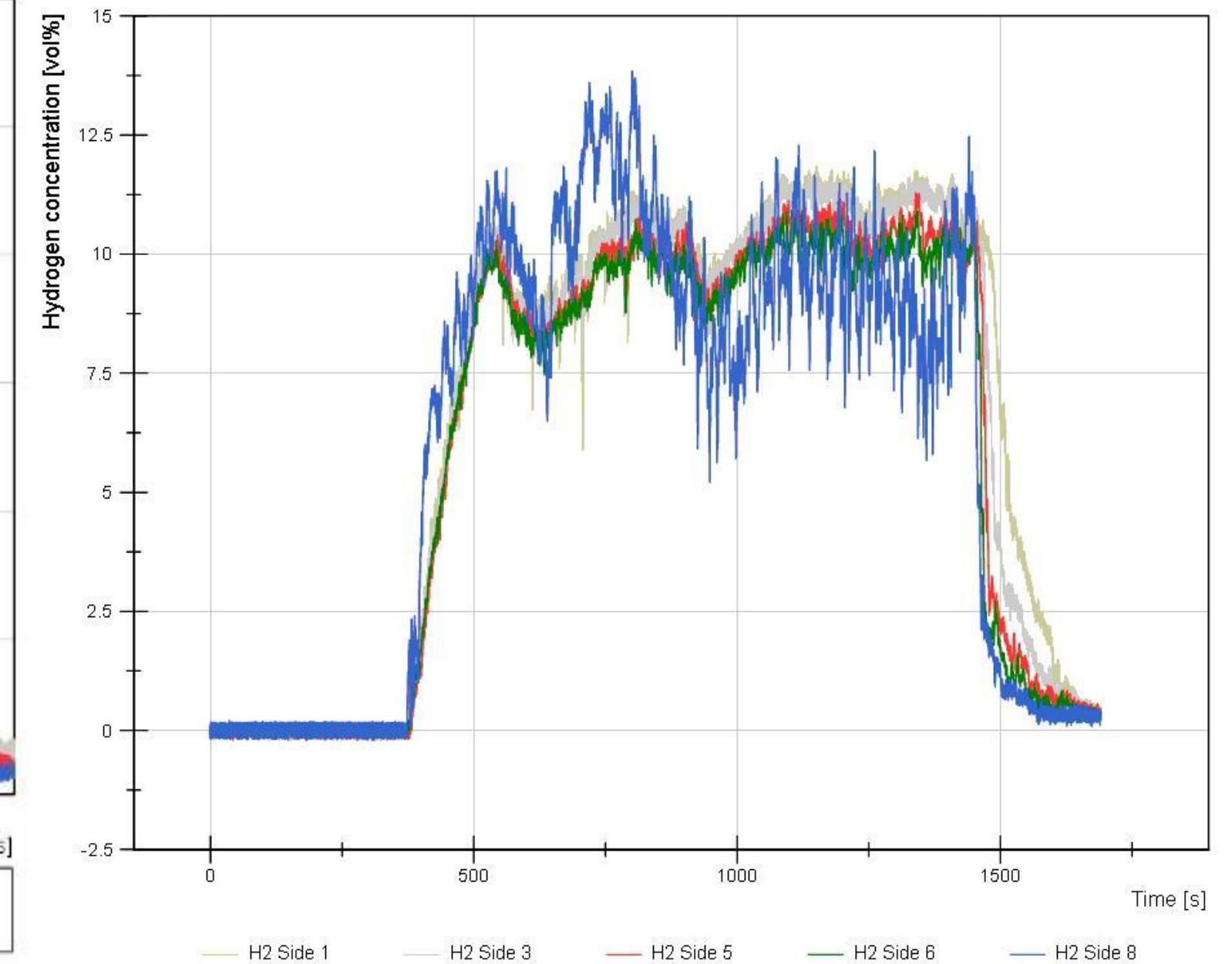
## Results – repeat tests and horizontal vs vertical



(a)



(b)



(c)

Plots of hydrogen concentration over time for tests released through a 1.0 mm nozzle and from a nominal pressure of 2.0 barg, (a) Test 47, (b) Test 48 vertical release, (c) Test 22 horizontal release



## Summary

- 33 LH2 releases into a 1 m<sup>3</sup> steel ventilated box were carried out.
- Repeat tests demonstrated good reproducibility of data for the same release conditions.
- All releases of LH2 through the smallest nozzle size (0.2 mm) resulted in average concentrations within the box that were less than the LEL for hydrogen
- Releases through a 0.5 mm nozzle from a nominal pressure of 2 barg resulted in average peak hydrogen concentrations that were below the LEL for hydrogen (except actively ventilated test (500 L/min), resulted in an average peak hydrogen concentration above the LEL of 4.4%vol hydrogen in air.
- For the nominal 8 barg releases through the same nozzle size the average peak hydrogen concentrations were between 4.3%vol and 9.9%vol hydrogen, above the LEL of hydrogen and close to the limit for downward flame propagation.



## **Summary**

- Releases through a 1.0 mm nozzle from a nominal pressure of 2 barg resulted in average peak hydrogen concentrations inside the box between 10.2% and 18.3%vol hydrogen.
- Releases through a 1.0 mm nozzle from a nominal release pressure of 8 barg resulted in higher average peak hydrogen concentrations inside the box between 26.9%vol and 49.5%vol., which are within the detonable limits of hydrogen (11% to 59%vol.).
- Releases through the same size nozzle but from a nominal release pressure of 8 barg resulted in higher average peak hydrogen concentrations inside the box between 67.9%vol and 99.8%vol., close to or above the UEL of hydrogen.
- The effect of active ventilation on reducing the concentration of hydrogen within the box was not fully demonstrated – design and geometry of active ventilation is critical.



## **Summary**

- Data captured for 24 thermocouples inside experimental rig and up to 16 hydrogen concentration sensors. Comprehensive data sets for all tests undertaken, including detailed descriptions of the facility and release are available at:  
<https://dataverse.no/dataset.xhtml?persistentId=doi:10.18710/JXJP0H>
- These data will be used to validate numerical models, which can be used to evaluate flammability hazards of hydrogen leaks inside tank connection spaces (WP4.5, HSE)



## **Acknowledgements**

- European project partners funded by the European Union
- HSE contribution co-funded by UKRI, Lloyds Research Foundation and

HSE

ELVHYS project No. 101101381 is supported by the Clean Hydrogen Partnership and its members. UK participants in Horizon Europe Project ELVHYS are supported by UKRI grant numbers 10063519 (University of Ulster) and 10070592 (Health and Safety Executive).



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**Thank you.  
Questions?**

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