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Air Liquide

Experimental study on the dispersion of LH2 from small scale leaks in a tank connection space



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UK Research
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Outline

- Introduction
- Facility & Experiments
- Results & Discussion
- Summary & Conclusions



- Consequence analysis, hazardous area classification and safety/separation distance setting all rely on a fundamental understanding of how likely failure modes translate into a loss of containment and to the hazard extent of any release. This work presents experiments considering realistic foreseeable releases/leaks from LH2 transfer equipment, hoses, couplings and pipework inside a tank connection space.
- The aim of this research was to provide experimental data to help refine both hazardous zone sizes and safety distances for LH2 transfer equipment by performing releases through small diameter holes.
- This work complements previous experimentation performed for the Norwegian Defence Research Establishment (FFI)[1] by considering smaller scale releases more akin to transport types below ship scale.

LH2 Release Facility

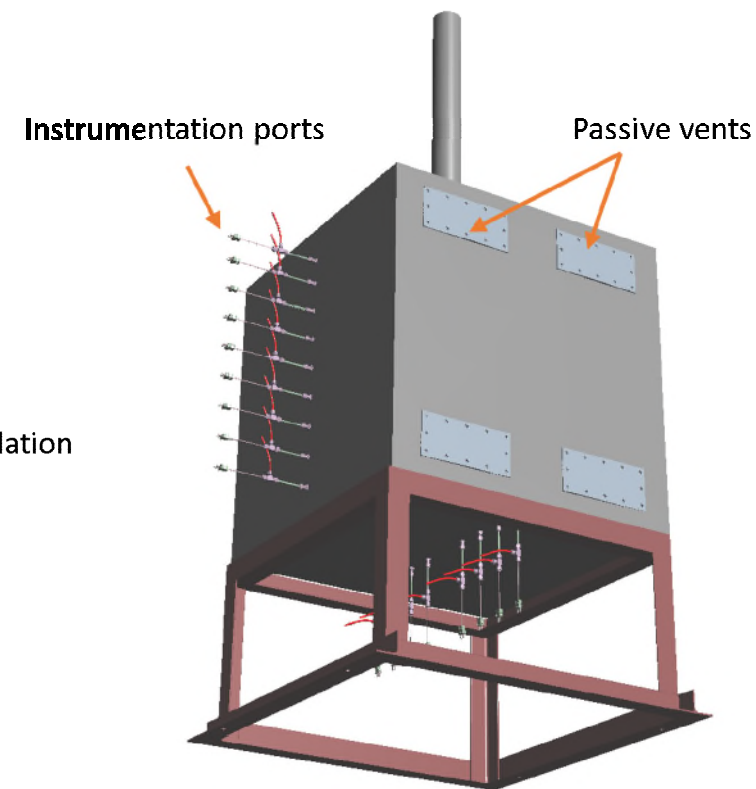
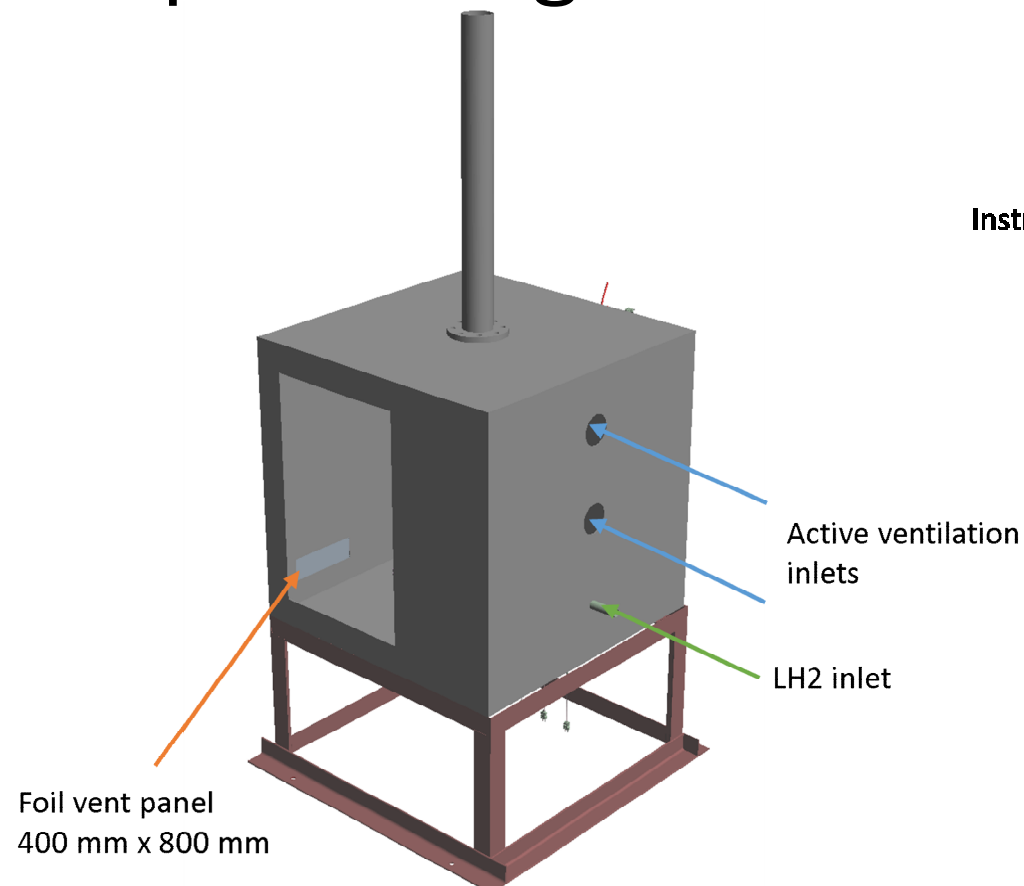
- 2.5 tonnes LH2 – ISO tanker
- Pressures up to 12 bar
- 6 m vent stack
- Super insulated vacuum lines (SIVL)
- Up to 1" release diameter



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 (30 and 120 ACH respectively)
- Repeat tests (horizontal) (3)
- Vertical releases for a limited number of conditions, including repeats (6)
- 33 tests in total

Experimental Setup – test rig

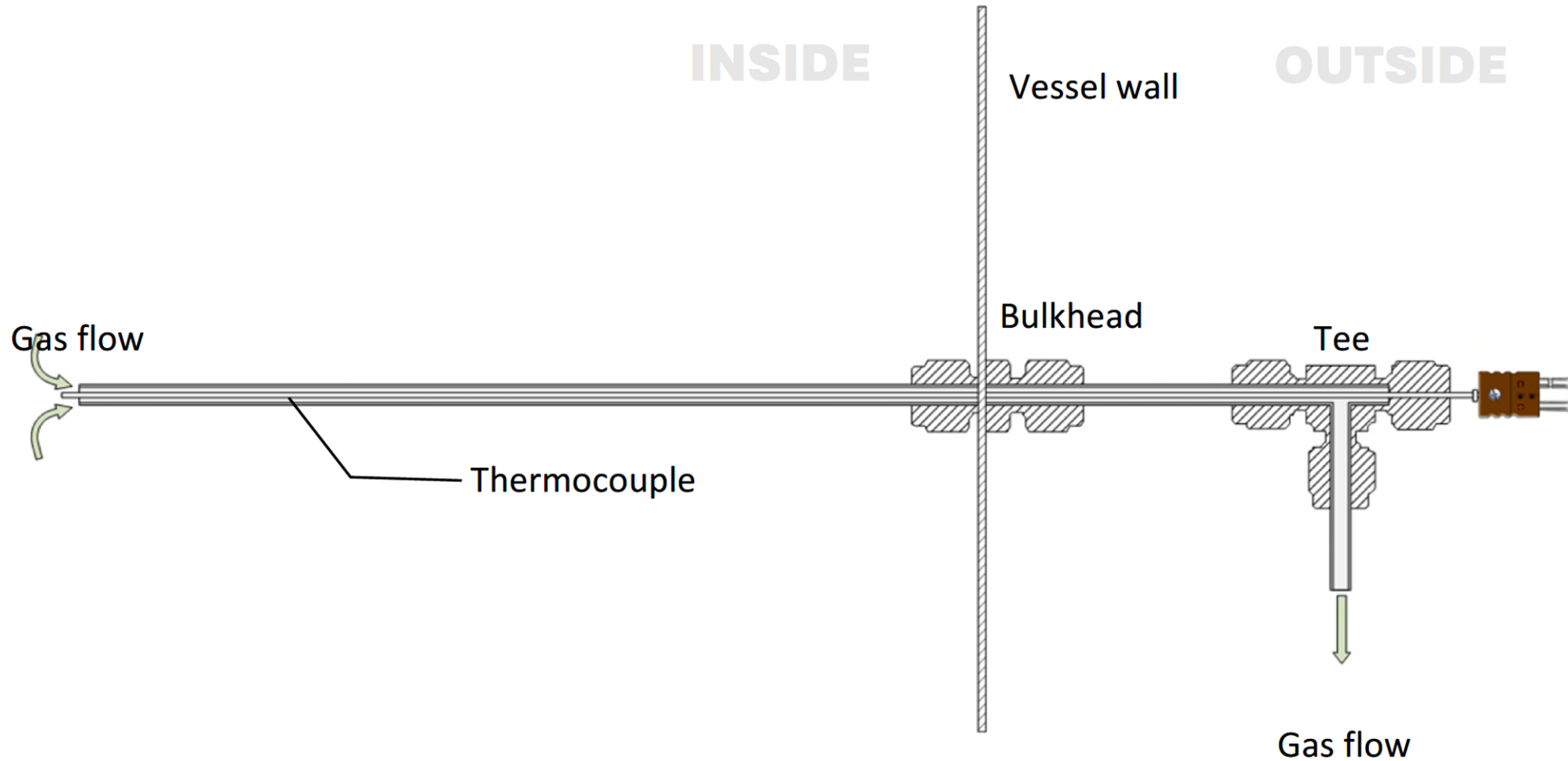


- 1 m³ stainless steel cube
- LH2 inlet
- 16 x hydrogen gas conc. sensor
- XEN-5320 thermal conductivity Measurement range of 0 to

- 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

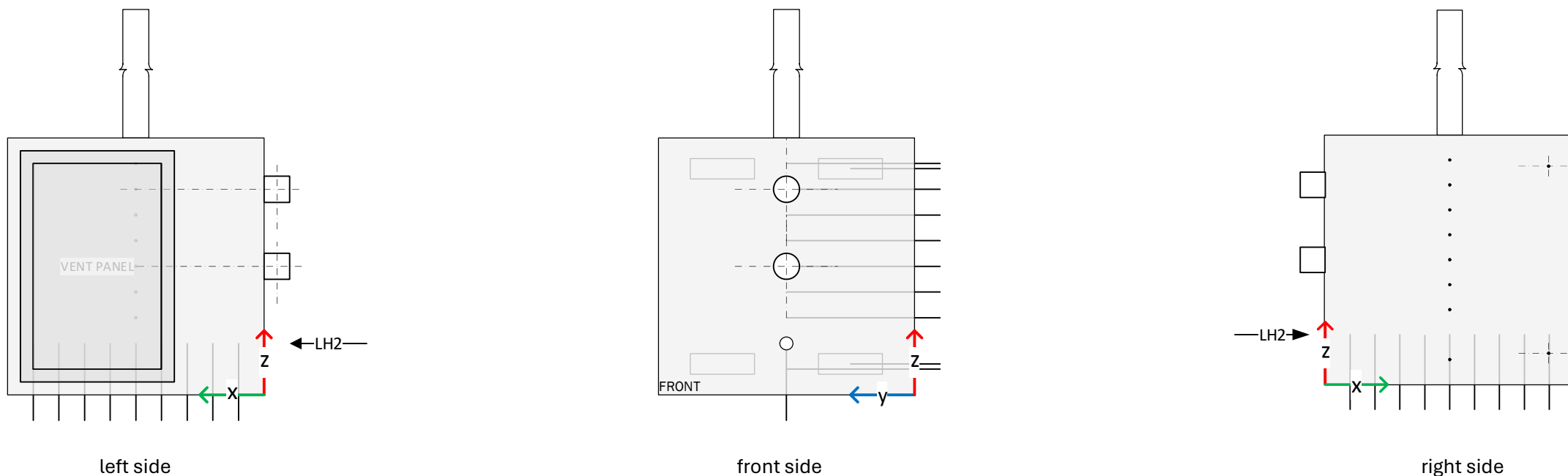
- Passive ventilation slots (0.08 m²)
- Weak panel for overpressure protection

Experimental Setup



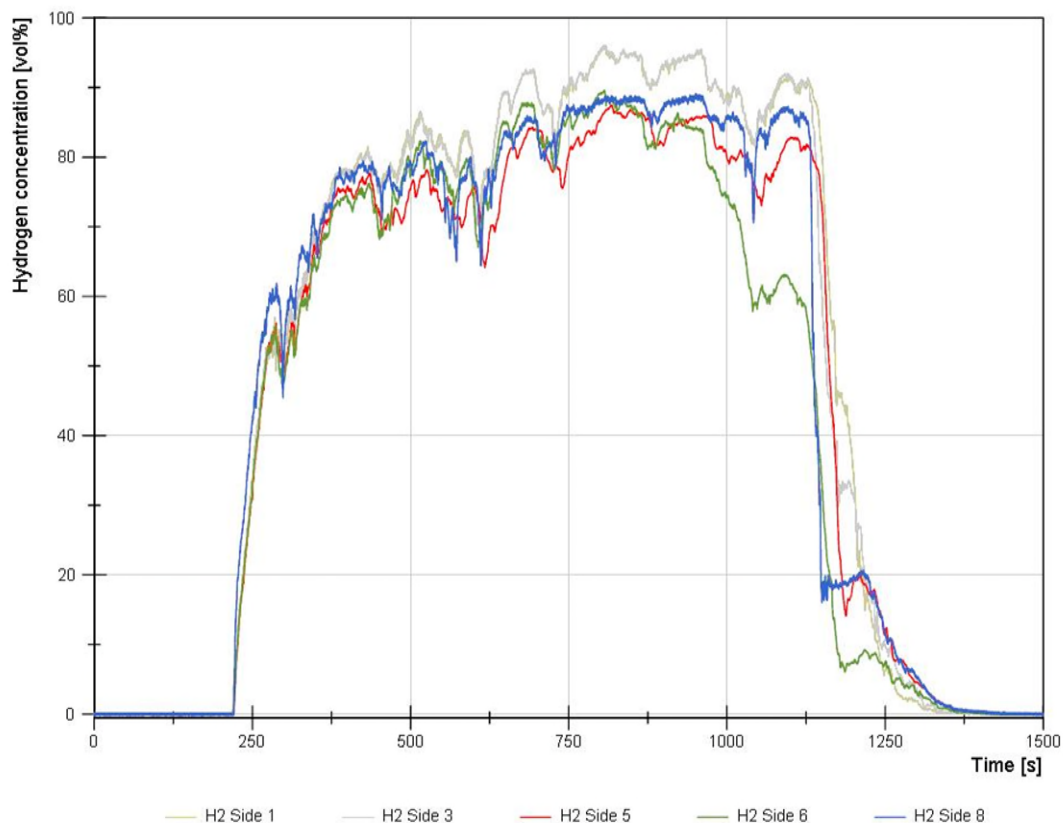
Sketch of thermocouple and gas sensing assembly.

Experimental Setup



Projected view of thermocouple and hydrogen gas sensor location within the 1 m³ vessel for the dispersion experiments. Sensors spaced at 100 mm intervals.

Results – release duration



immediately following opening of valve (1 s)



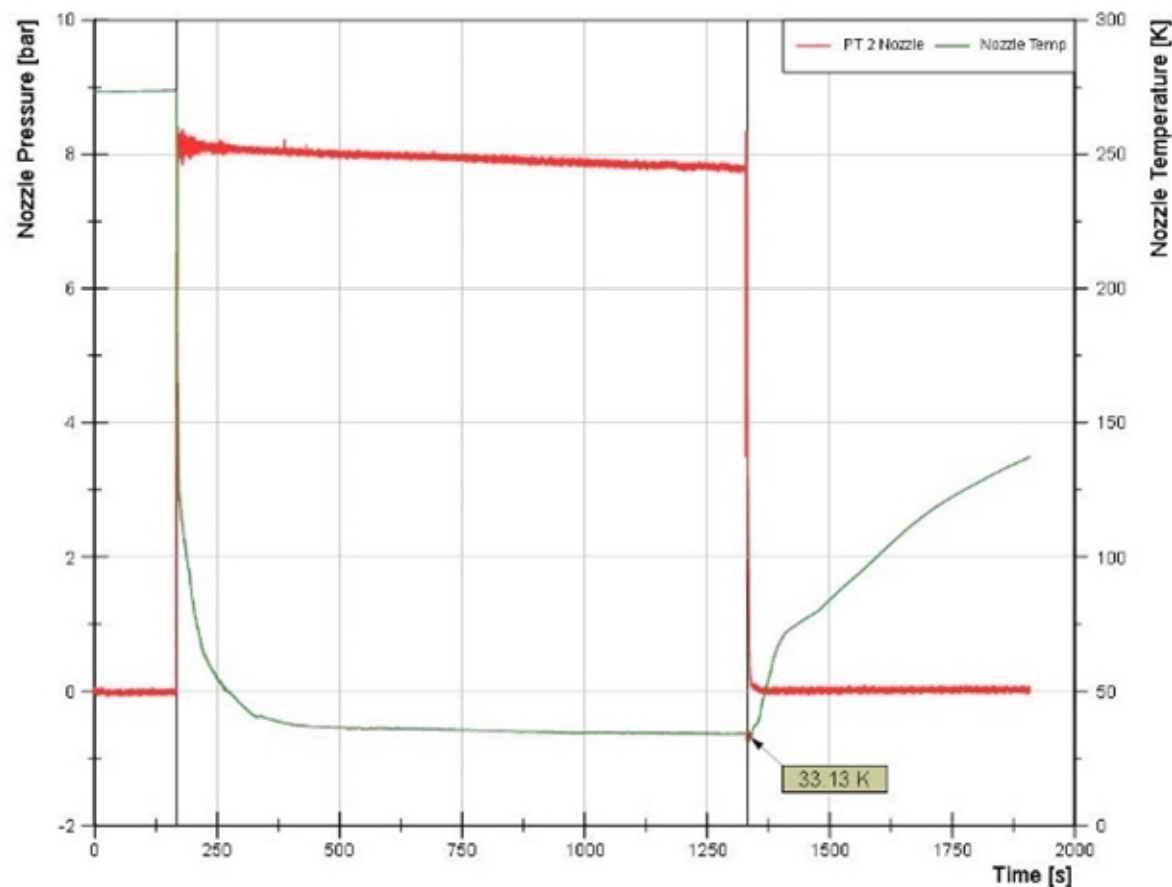
during release (577 s),



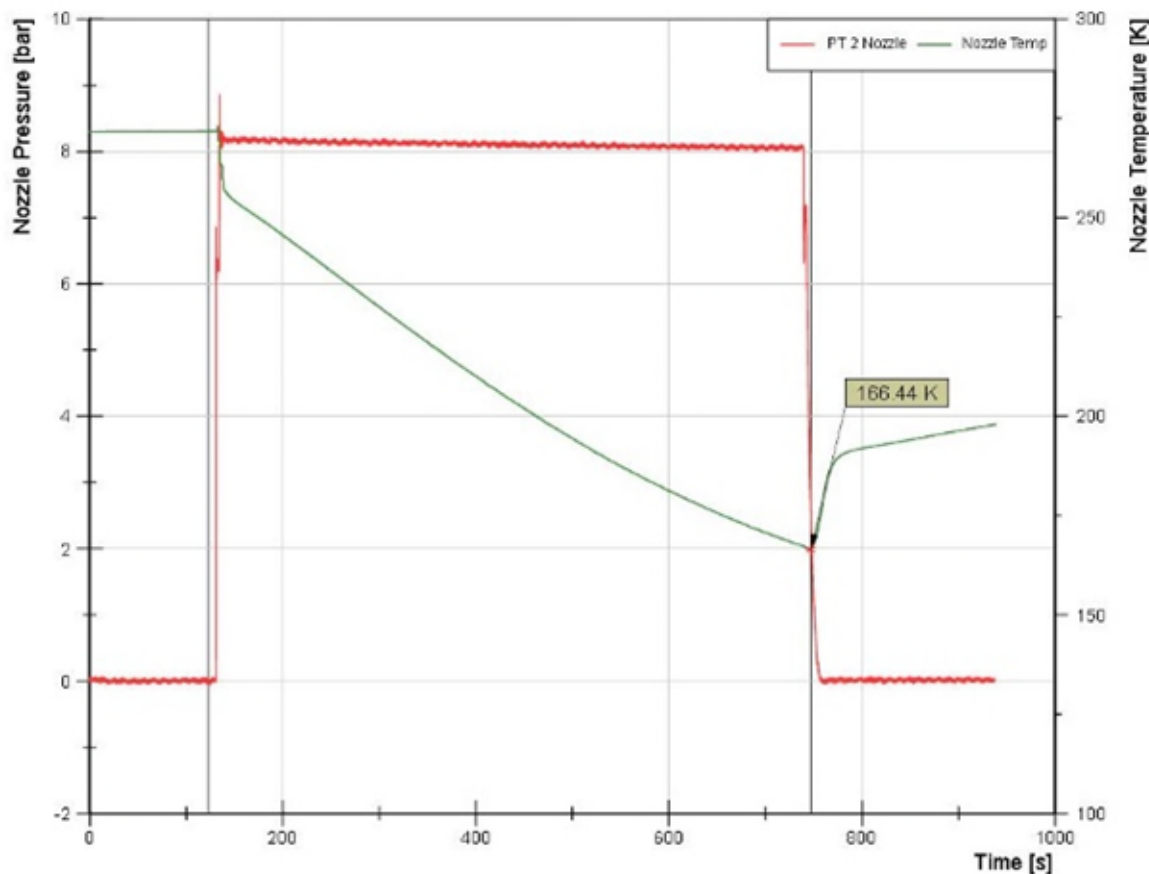
after valve closed (915 s), showing residual vapour from upper passive vent.

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

Results – Source conditions



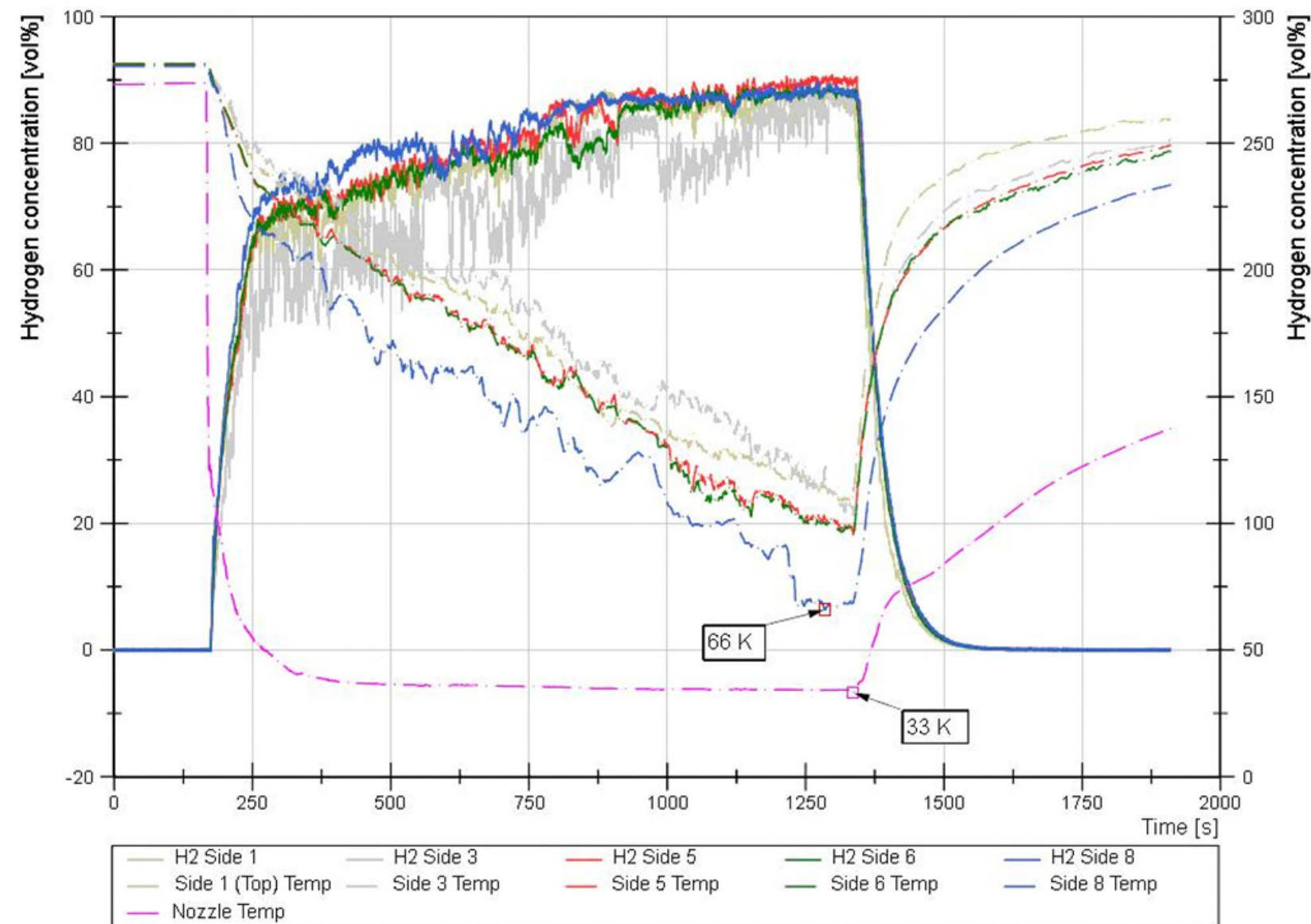
(a) Minimum nozzle temp 33 K



(b) Minimum nozzle temperature 166 K

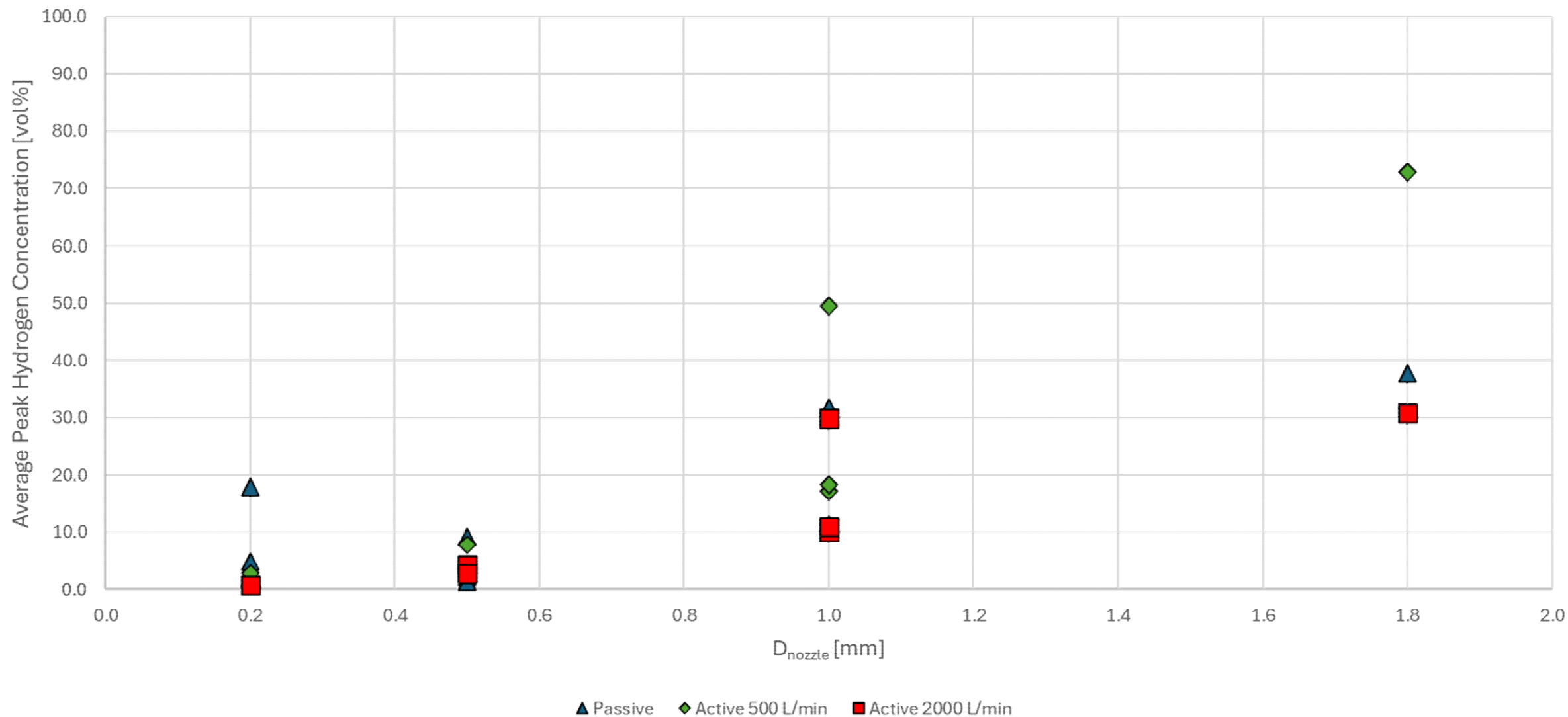
Nozzle temperature and pressure for a nominal 8 barg release (a) through a 1.8 mm nozzle (Test 17) and (b) through a 0.5 mm nozzle (Test 24).

Results – temperature and concentration

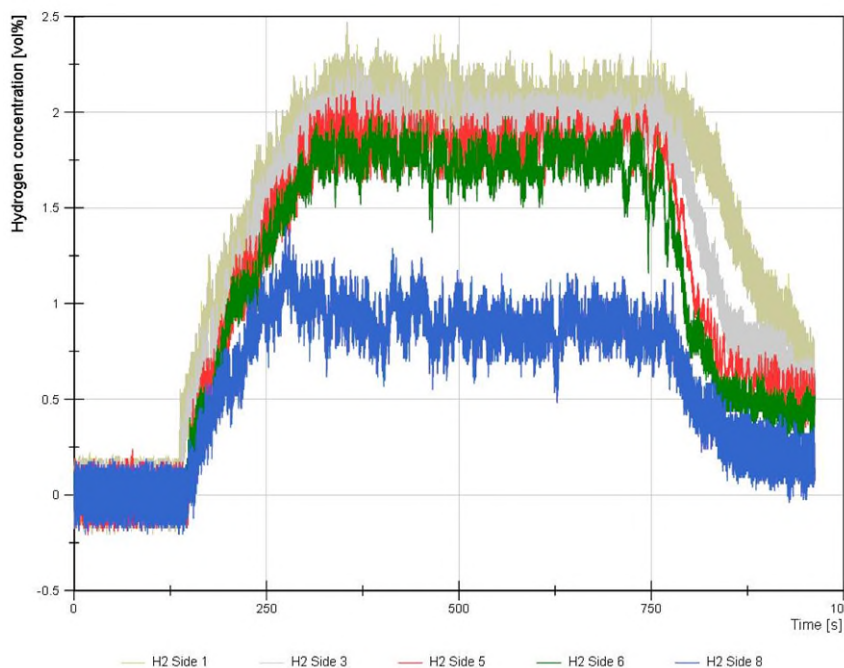


- Test 17. 1.8 mm nozzle, 8 bar nominal release pressure. Active ventilation, 500 l/min
- A plot showing the hydrogen concentrations and temperatures within the box and the fluid temperature at the nozzle

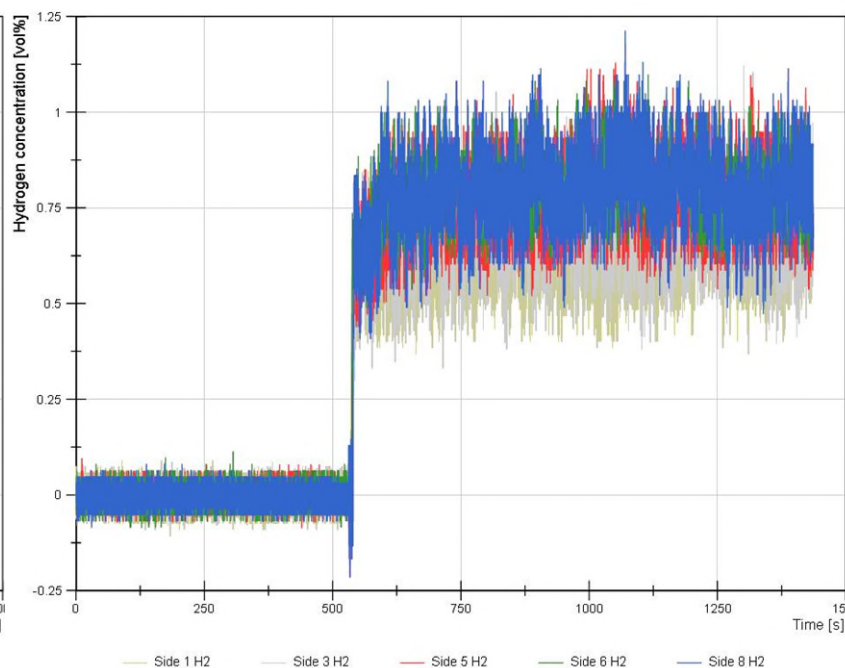
Results – Horizontal releases



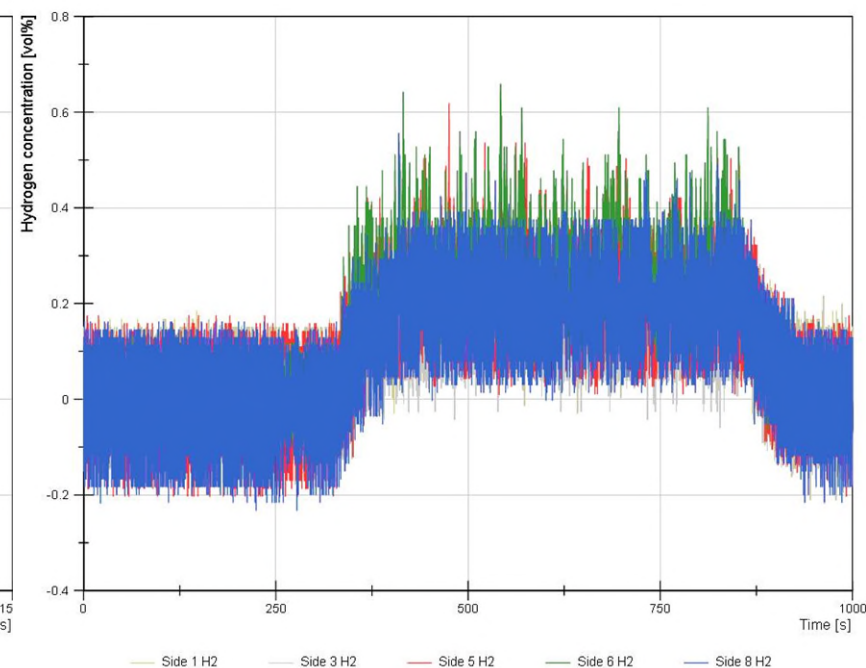
Results – passive vs active ventilation



(a)



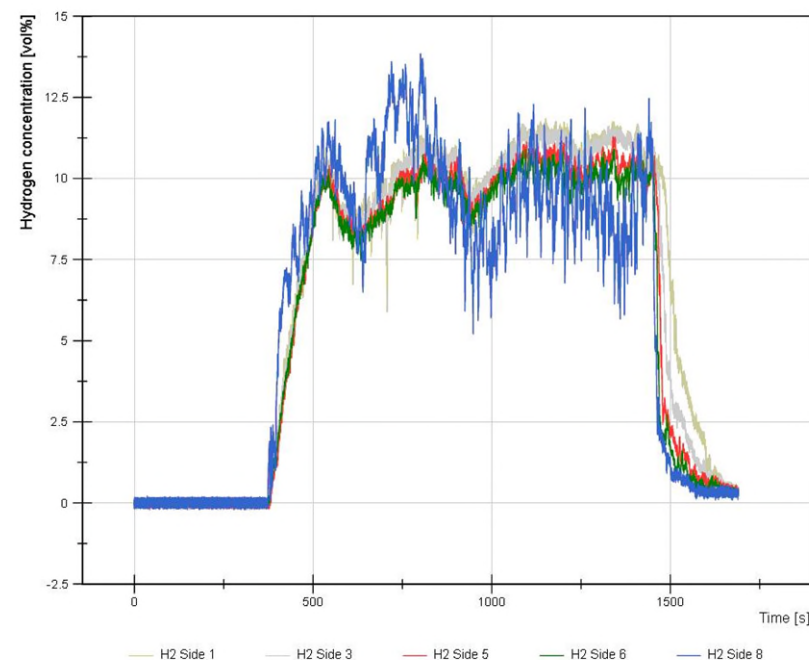
(b)



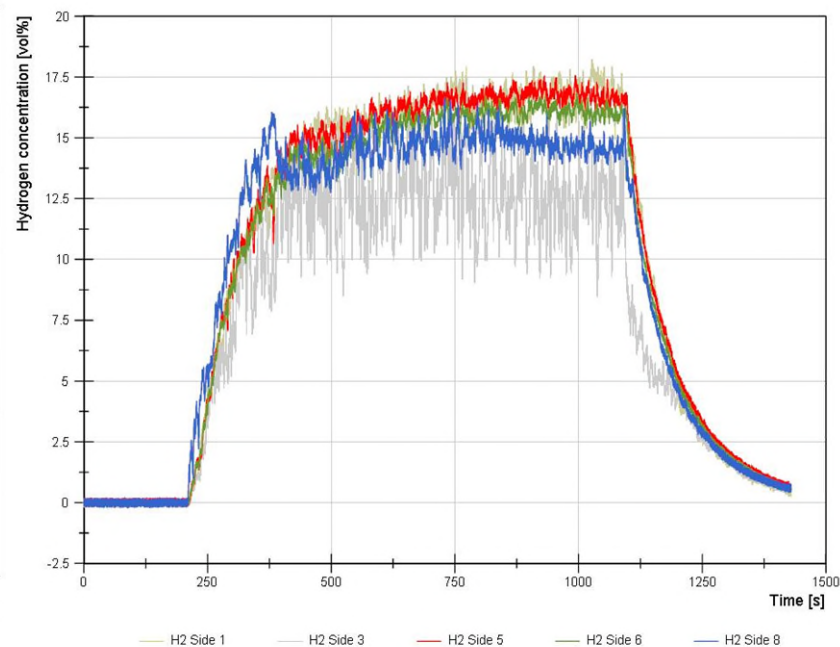
(c)

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

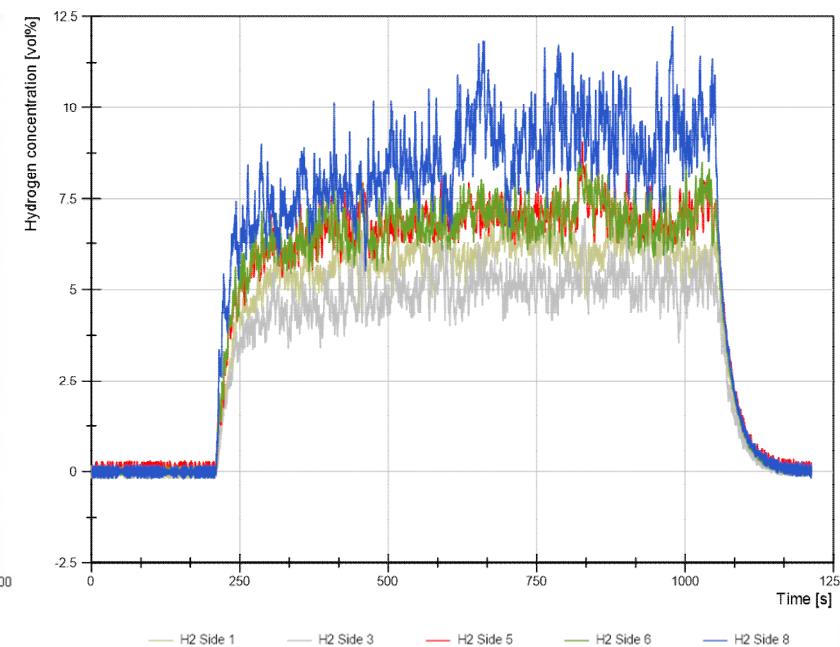
Results – passive vs active ventilation



(a)



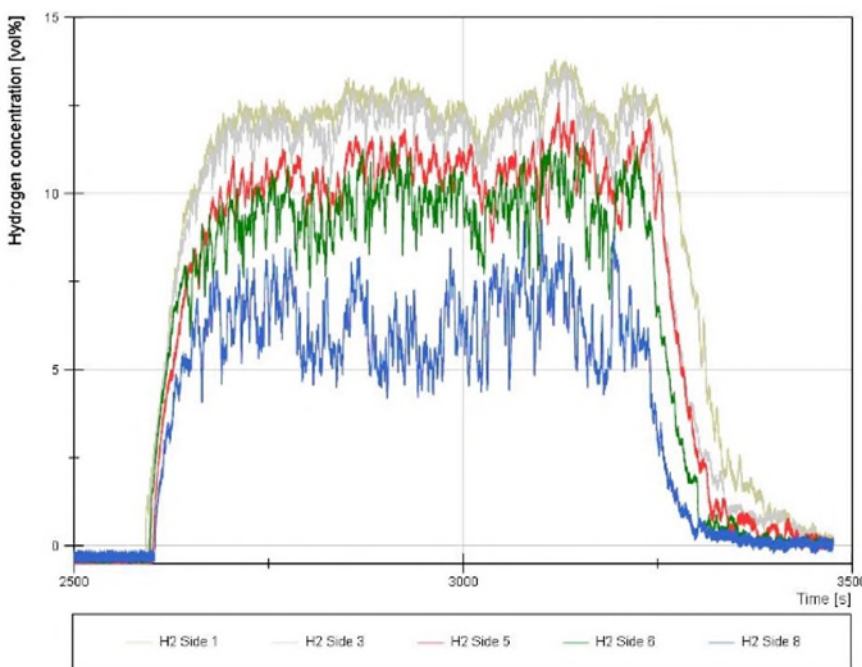
(b)



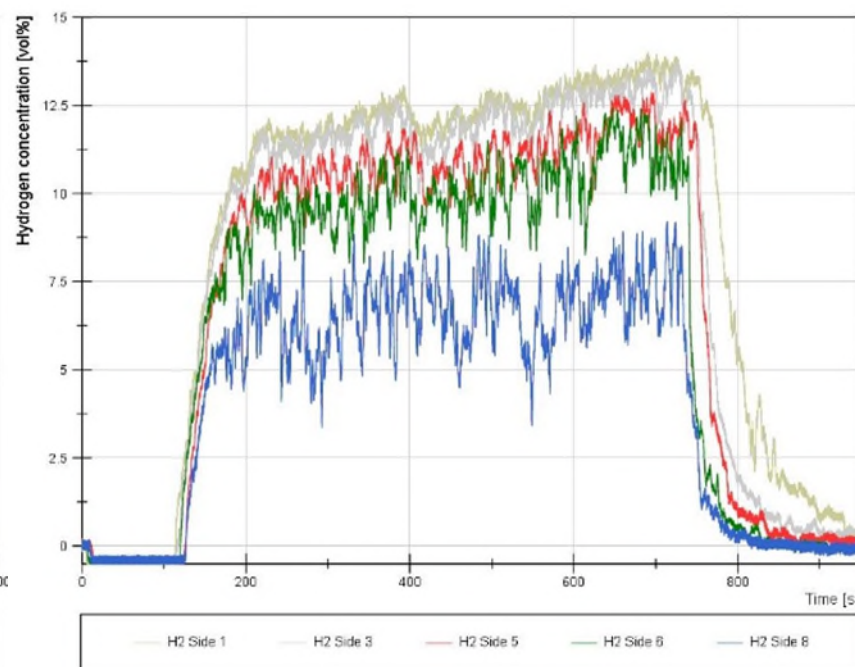
(c)

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

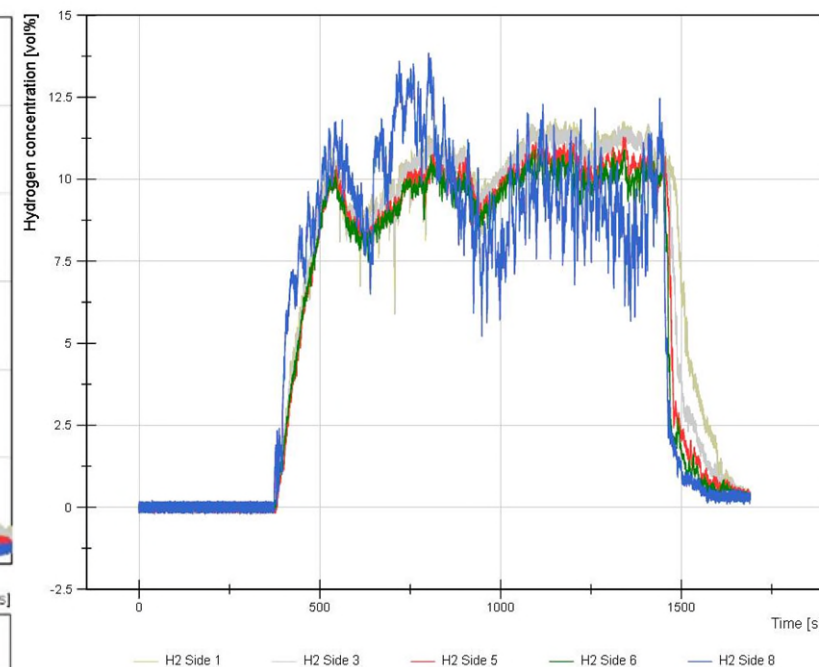
Results – repeat tests and horizontal vs vertical



(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

Conclusions

- 33 LH2 releases into a 1 m³ 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.

Conclusions

- 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.
 - For releases through this size of nozzle, it became apparent that the active ventilation did not give the expected reduction in hydrogen concentration inside the box. The highest average peak concentration (18.3%vol) was attained during the release with an active ventilation regime and a nominal flow rate of 500 L/min, which is significantly higher than the value for the passively ventilated case (11.5%vol).
 - The lowest concentrations were seen for the releases under an active ventilation regime and a nominal flow rate of 2000 L/min, 10.2% and 11.1%vol respectively, but these were barely any lower than the passively ventilated regime.
- 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 26.9%vol and 49.5%vol., which are within the detonable limits of hydrogen (11% to 59%vol.).

Conclusions

- 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.
- 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)



Thank you for your attention

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