HEALTH & SAFETY LABORATORY

Accumulation of Hydrogen Released into a Vented Enclosure – Experimental Results

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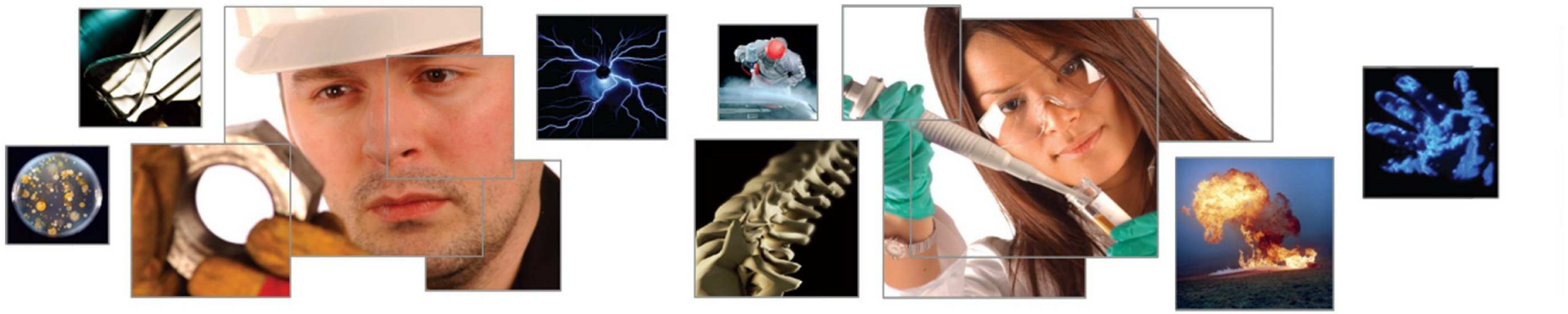


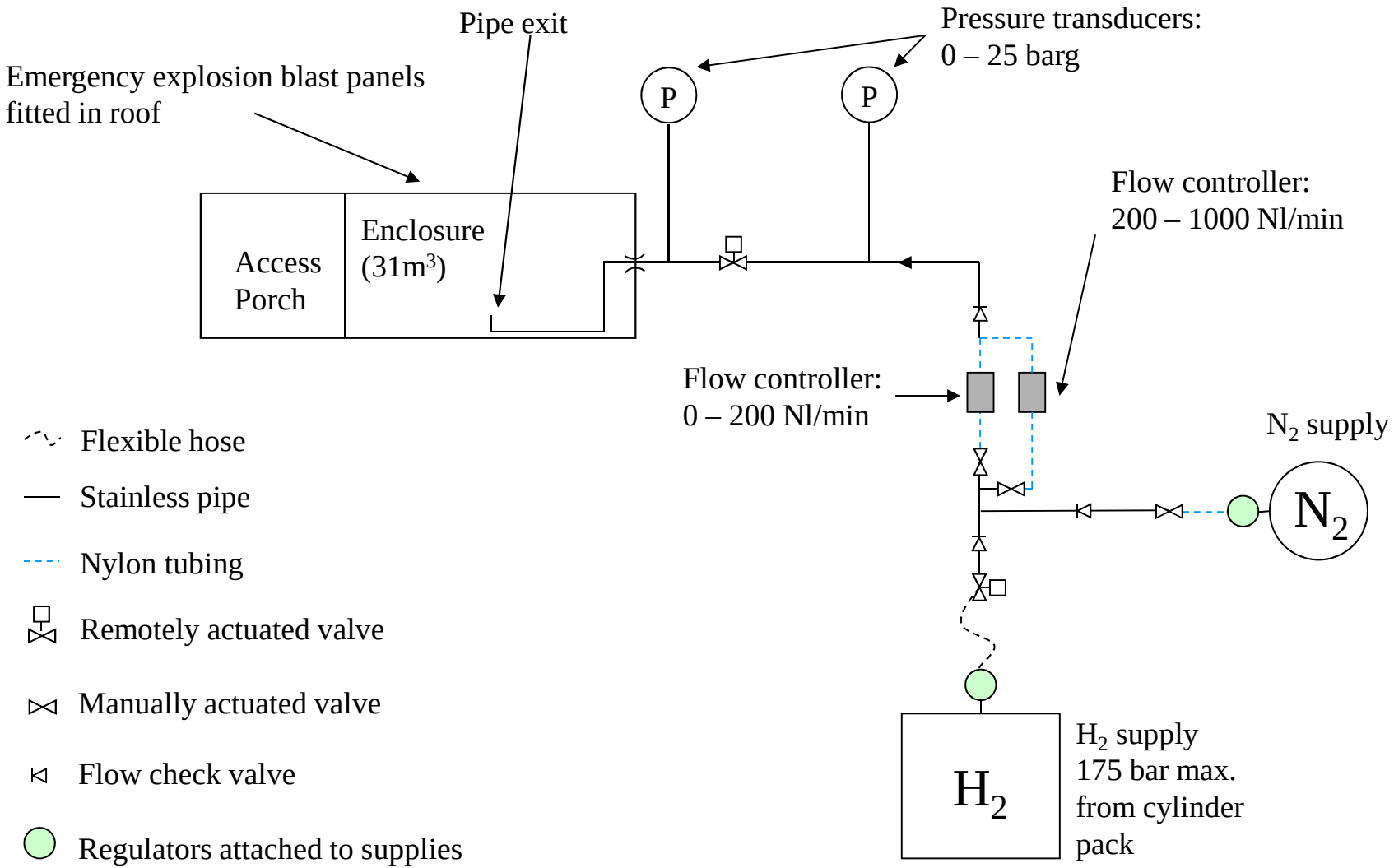
Contents

- Objectives
- Experimental arrangement
- Initial experimental results
- Comparison of results with some simple models
- Follow-on work

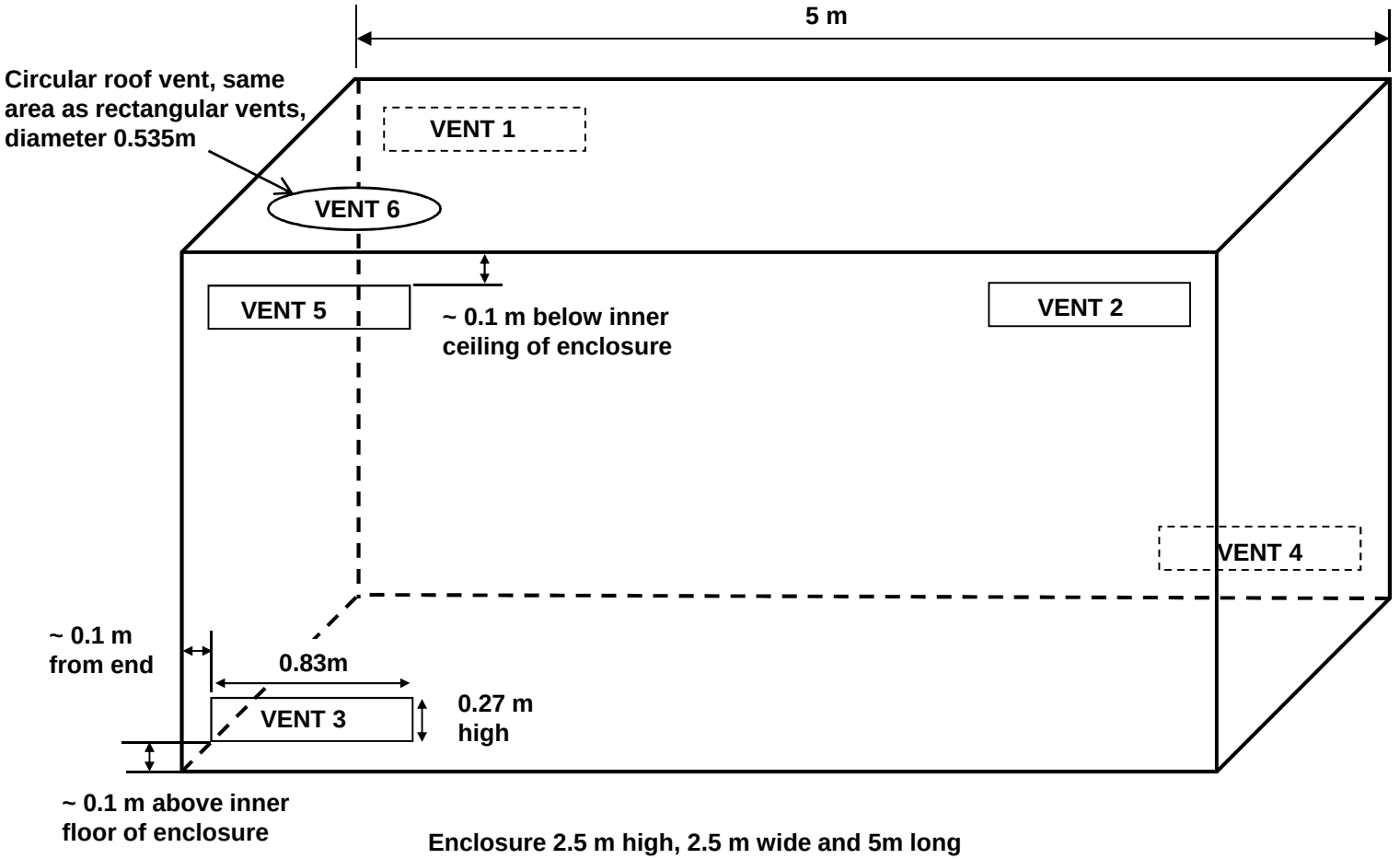
Objectives

- Part of the EU Hyindoor Project
  - Address knowledge gaps for hazards of hydrogen in confined spaces (e.g. enclosures, containers, warehouses etc)
  - See Paper ID 128 for more details of overall project
  - http://www.hyindoor.eu/
- Work Package 2 (WP2)
  - dispersion and accumulation of hydrogen
- WP2 HSL experiments
  - study dispersion and accumulation
    - At large scale (31m^3 enclosure)
    - Subject to real wind conditions (enclosure sited outdoors)
    - Using a range of passive vent arrangements

Experimental Arrangement



Experimental Arrangement

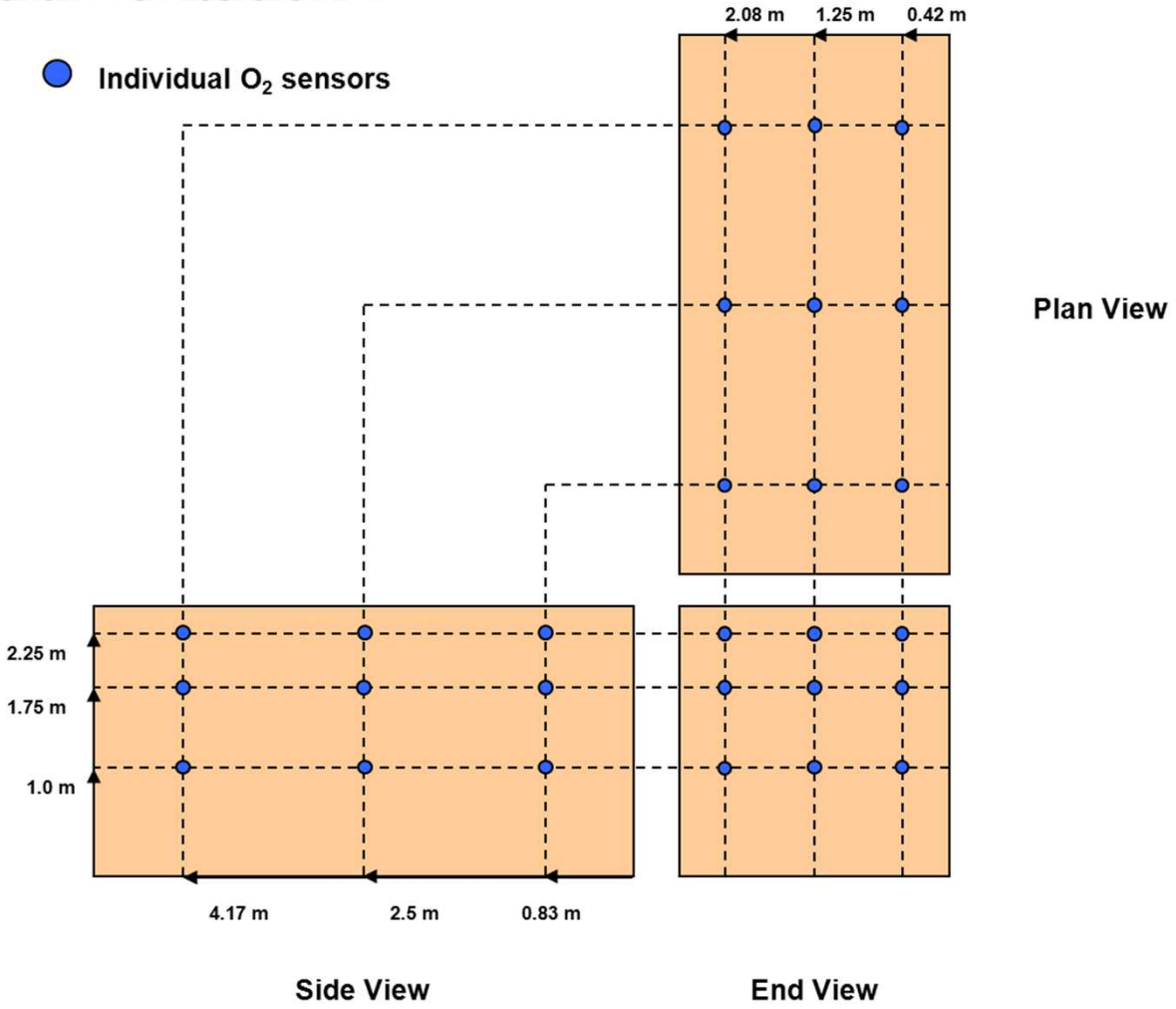


Experimental Arrangement

Experimental Arrangement

Instrumentation :

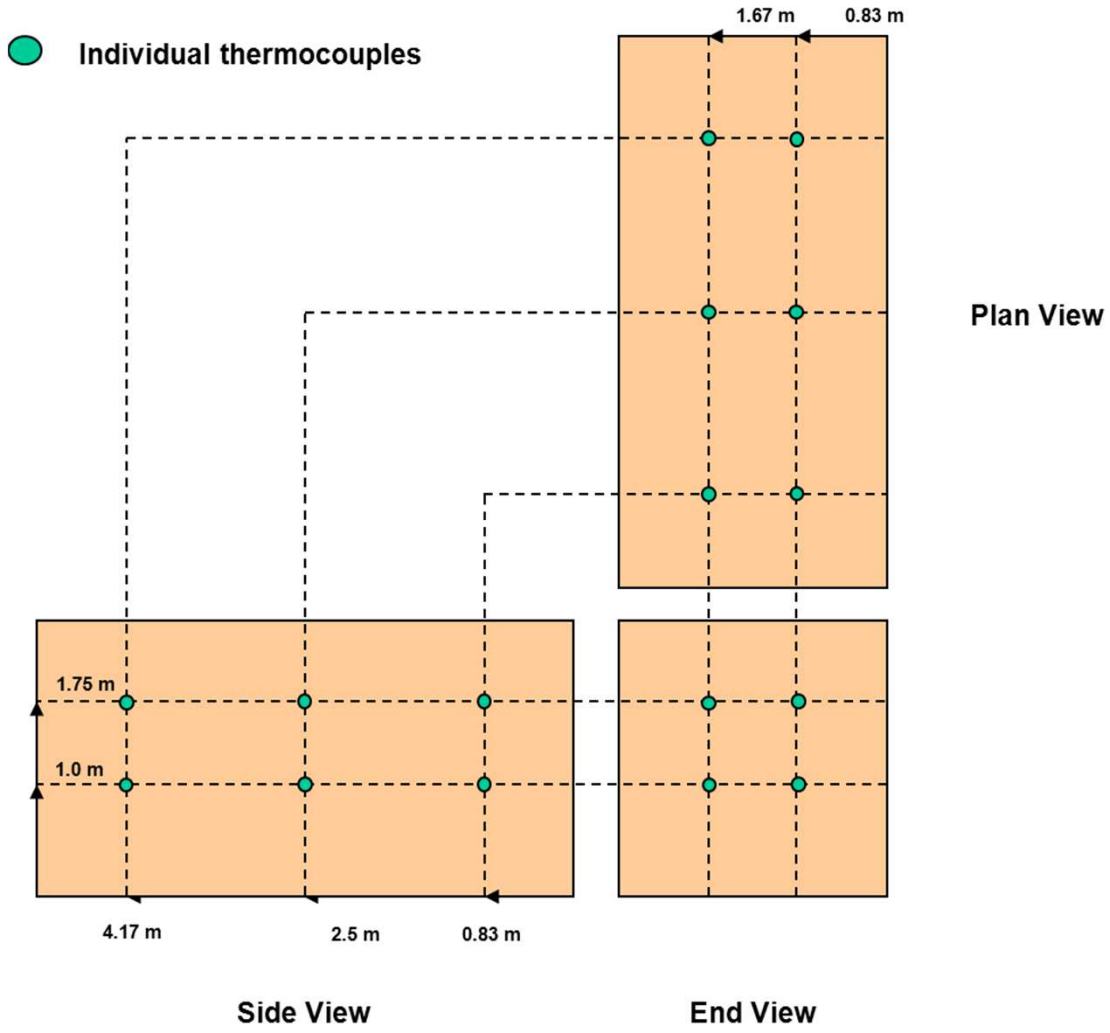
- 27 electrochemical cell oxygen sensors
  - Mounted on suspending wires
  - In “layers” at 1 m, 1.75 m and 2.25 m from floor
- Additional oxygen sensors placed within the open vents as required
- Hydrogen concentration calculated from oxygen depletion detected by each sensor.



Experimental Arrangement

Instrumentation :

- 14 thermocouples (Type K)
  - Mounted on suspending wires
- Additional thermocouples peened into the centre of each of the 6 walls of the enclosure (i.e. the four walls, the ceiling and the floor)
- Additional thermocouple placed within each open vent as required.



Experimental Arrangement

Instrumentation :

- Pressure transmitters were installed on the hydrogen supply pipeline.
- Bidirectional probes connected to differential pressure transmitters (+/- 19.6 Pa) were installed for some of the later runs in an attempt to detect flow through the open vents.
- Weather conditions close to the enclosure were monitored (i.e. wind speed, wind direction, temperature and humidity).

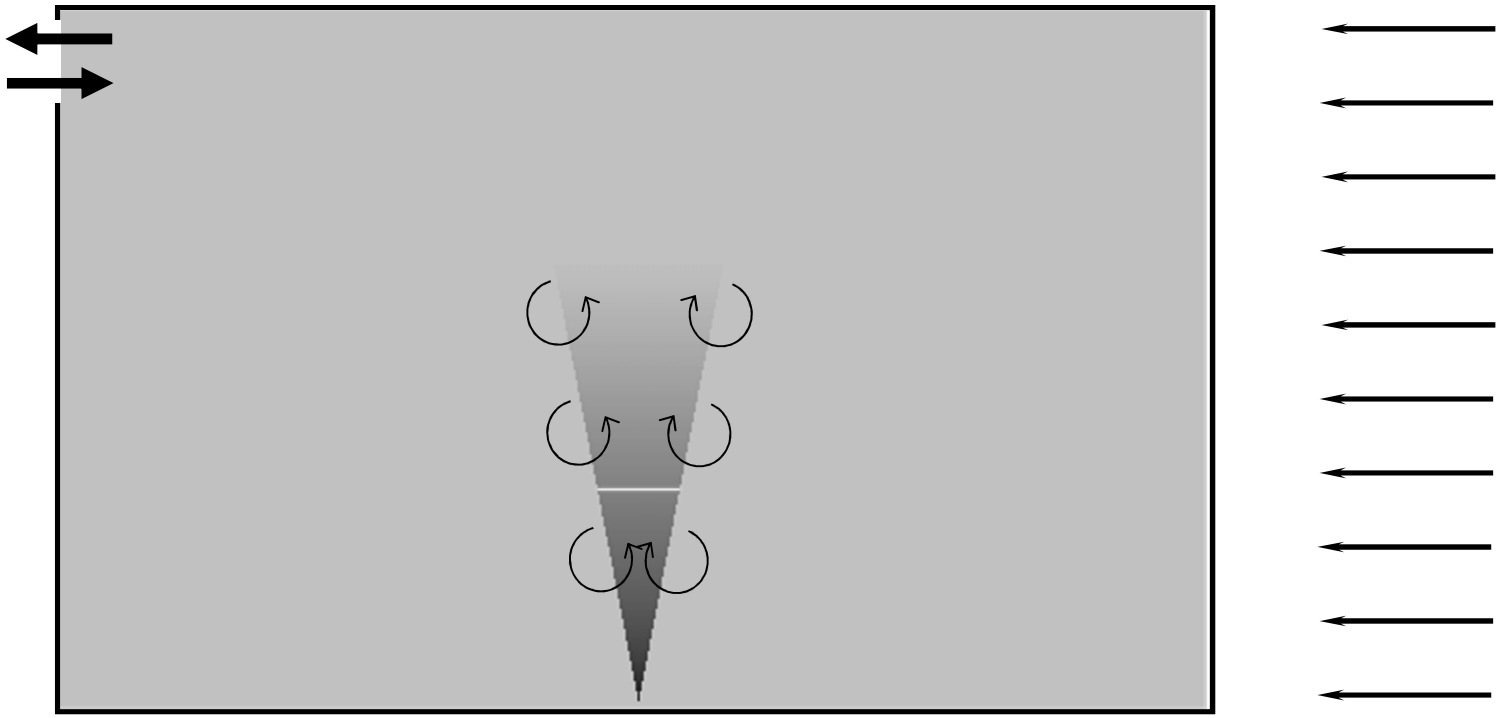
Experimental Arrangement

- Experiments with single vent
  - Upper vent in side wall
    - Wind incident on vent / Wind on opposite side to vent
  - Roof vent

- Experiments with more than one upper vent
  - On opposite sides
- Experiments with one lower vent and one upper vent
  - On opposite sides

Initial results

- Experiments with single upper vent with wind “not incident on vent” :



Initial results

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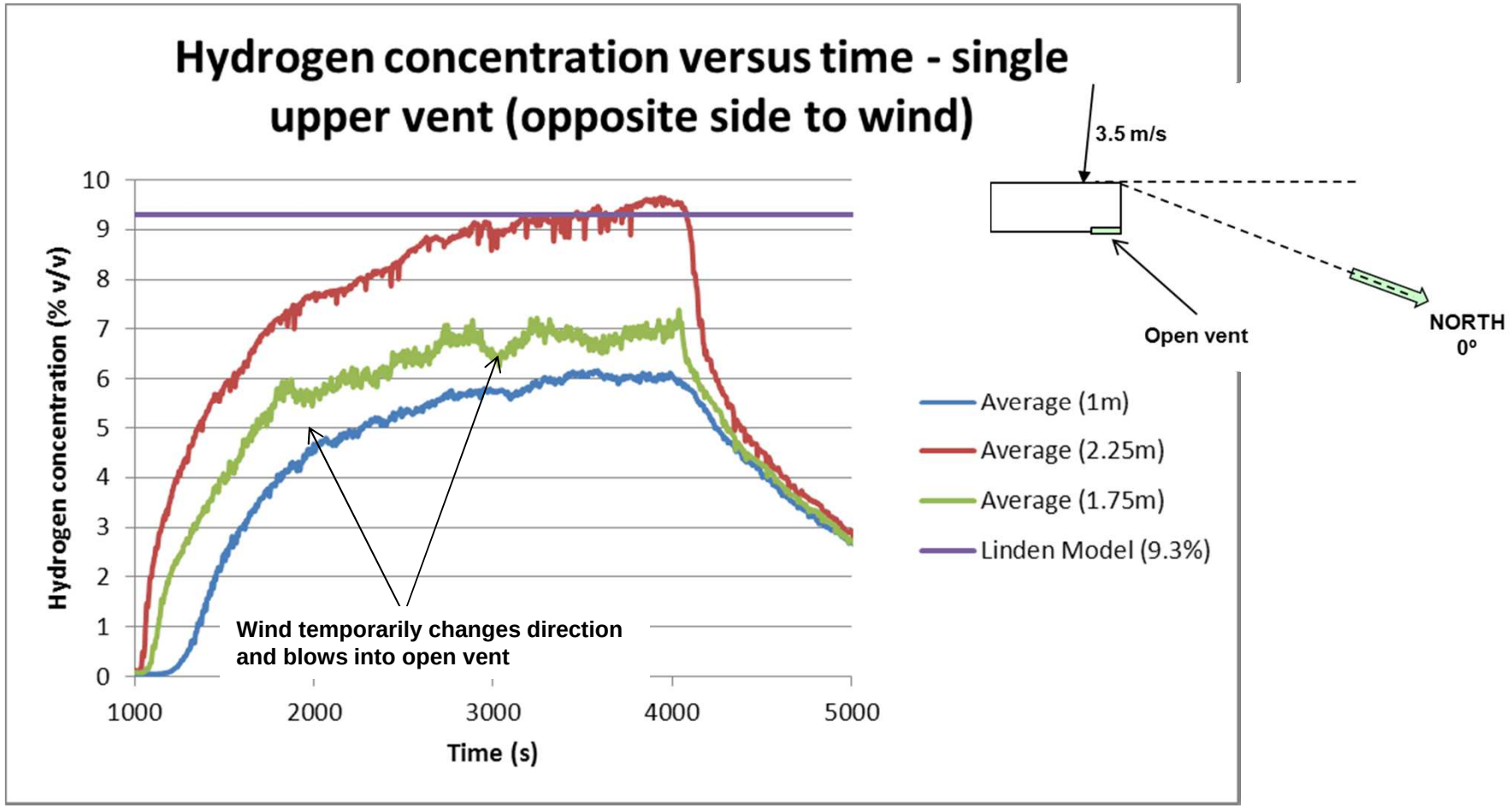
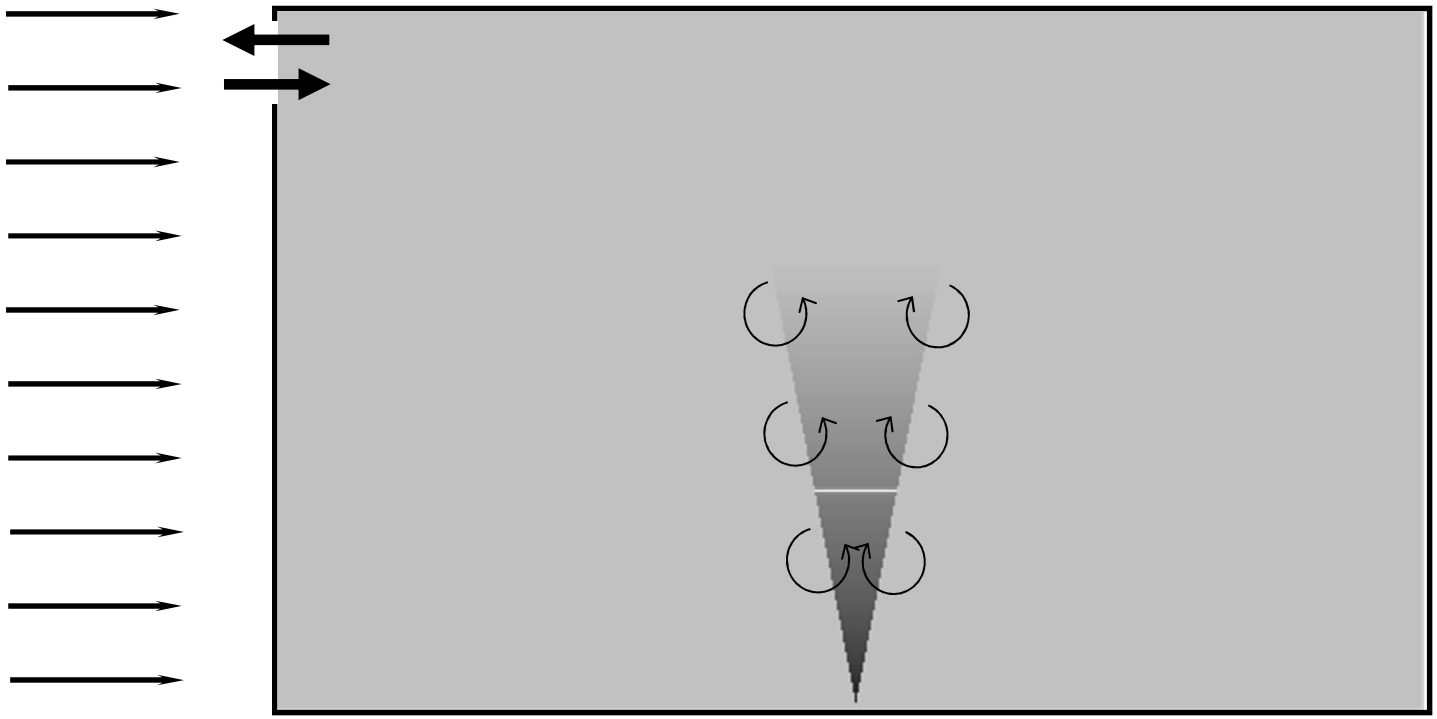


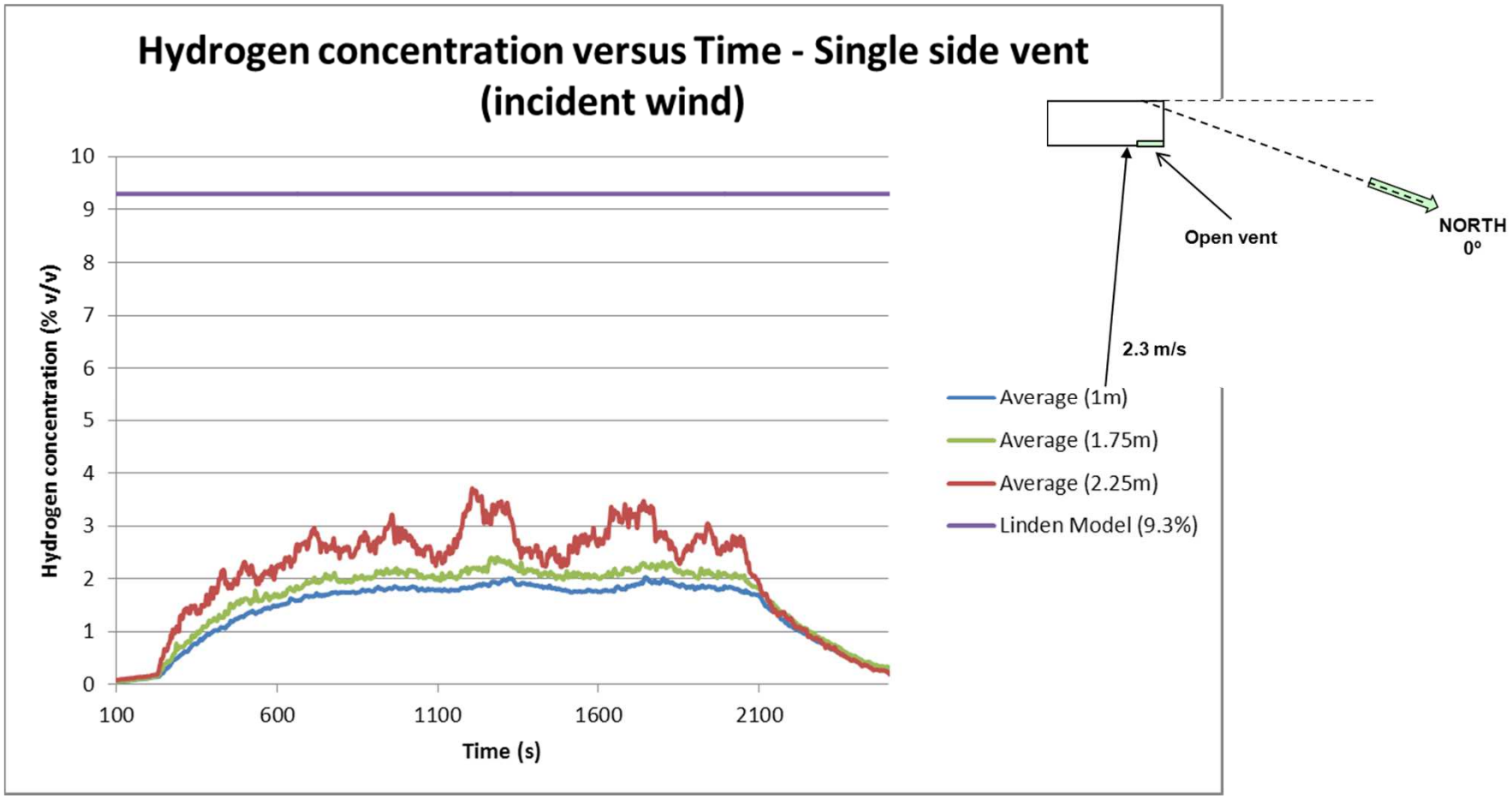
Initial results

- Experiment with single upper vent with wind incident on vent :



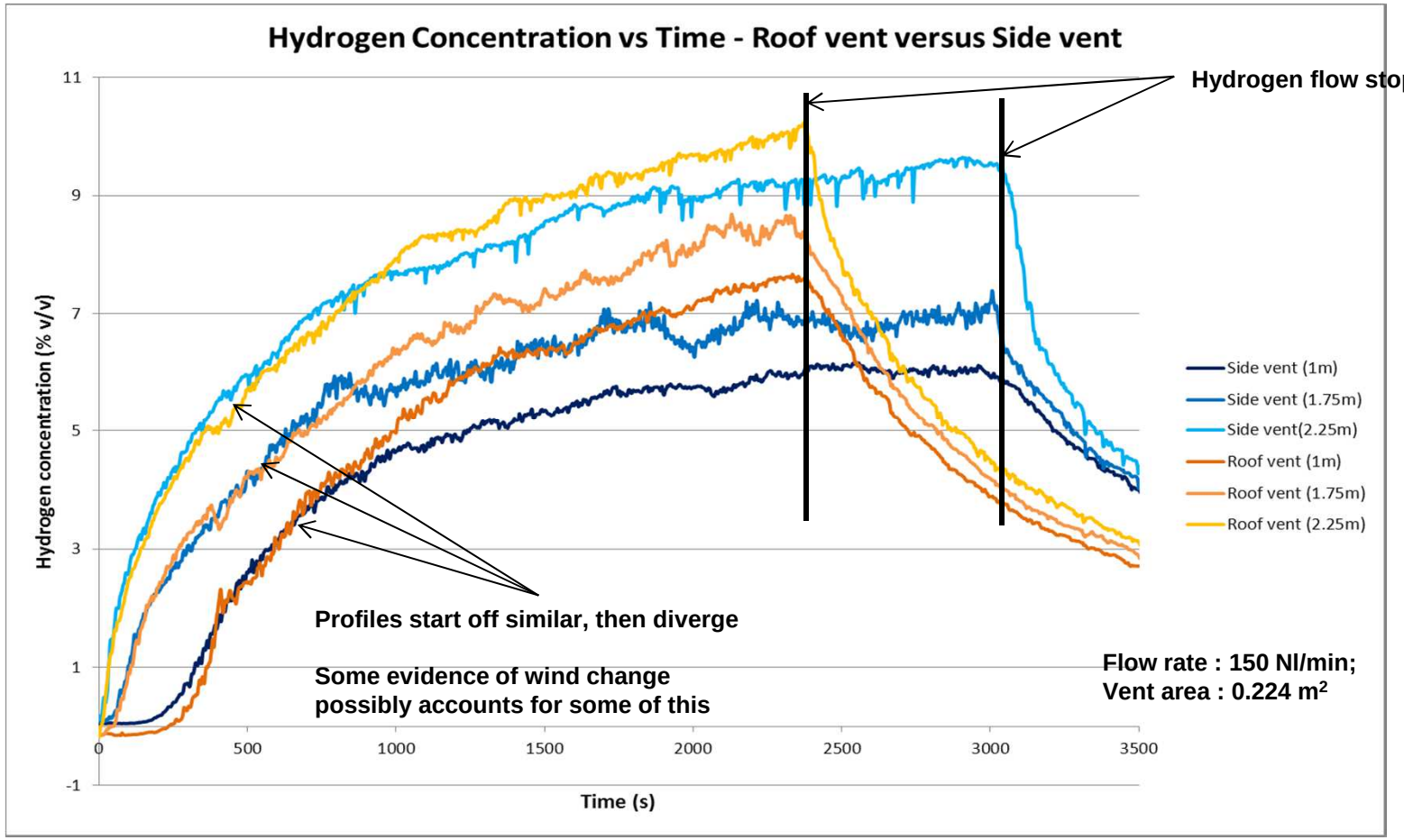
Initial results

- Experiment with single upper vent with wind incident on vent :



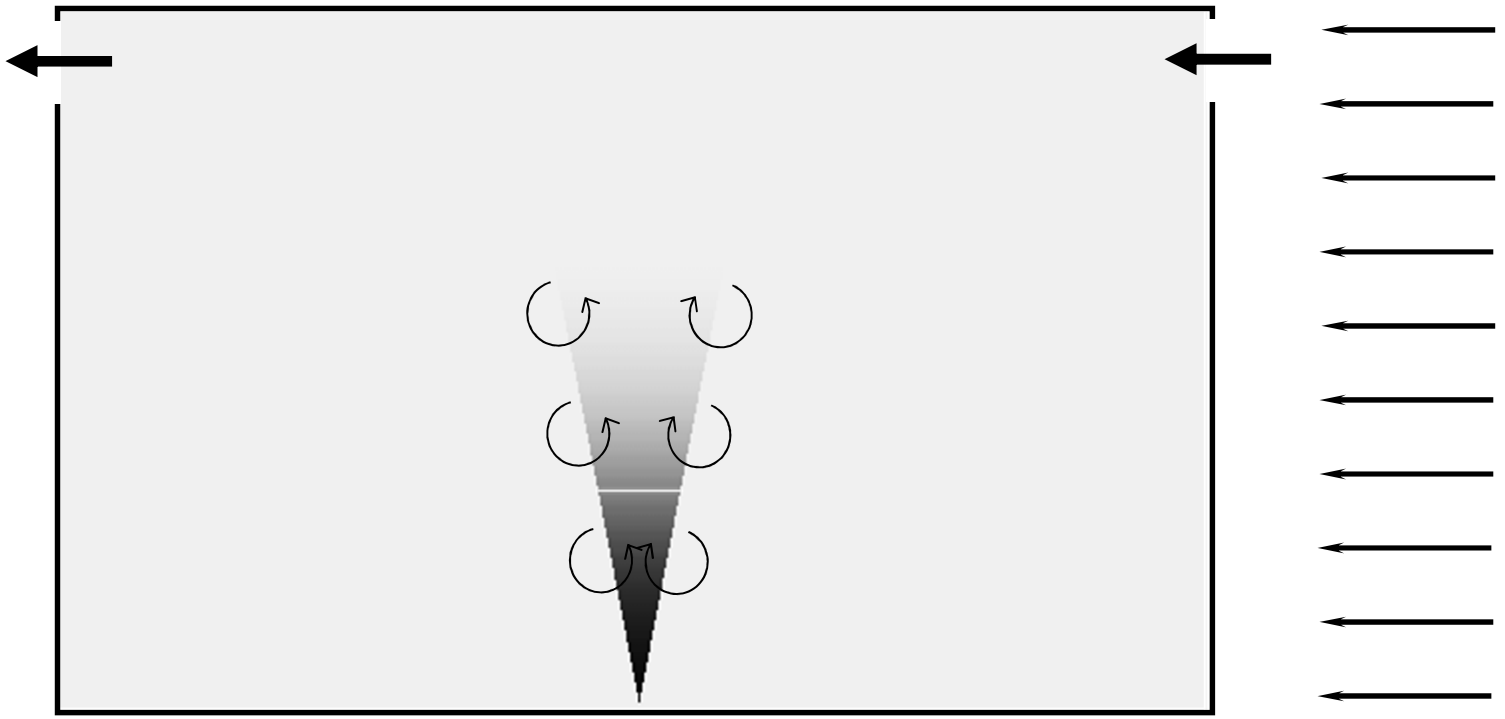
Initial results

- Experiments with single vent – side vent versus roof vent:



Initial results

- Experiments with multiple vents at high level (vents at opposite sides of the enclosure):



Initial results

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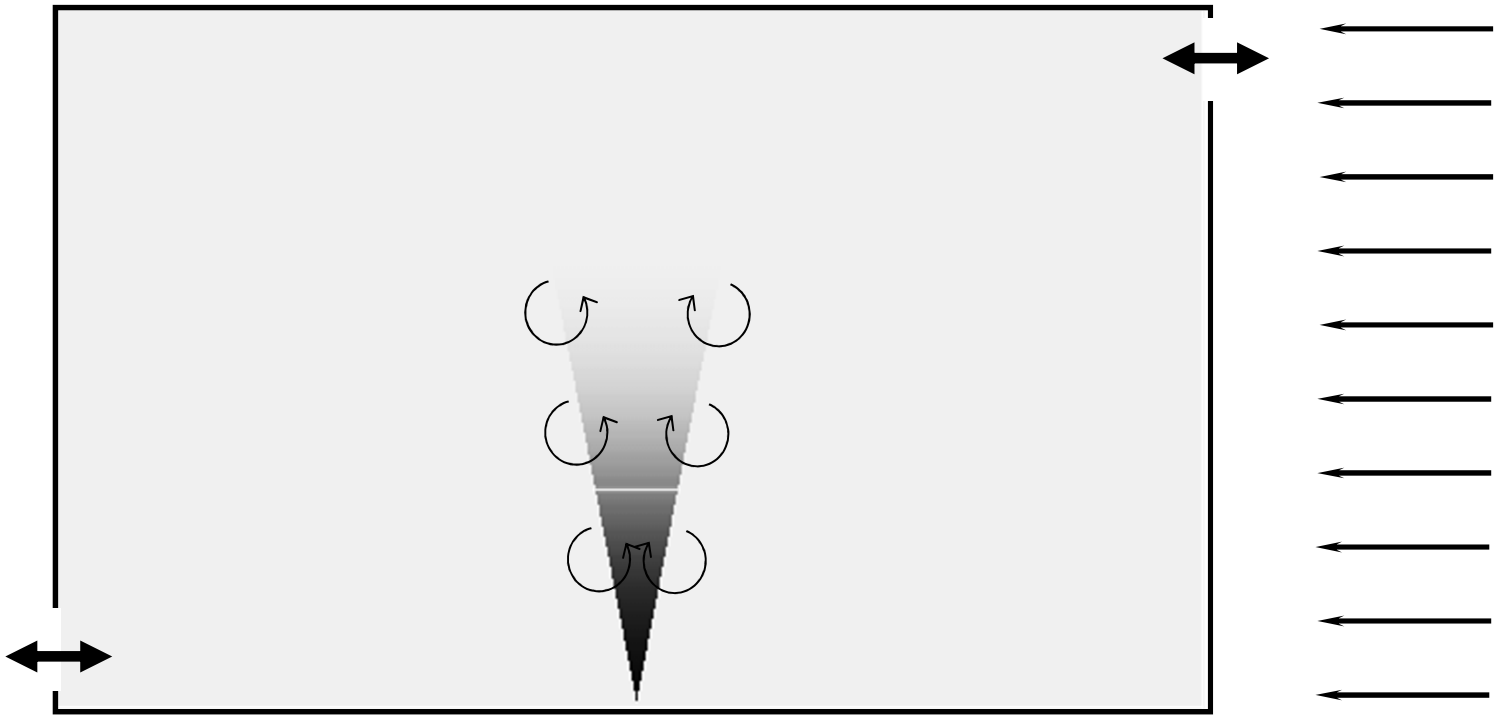
- Experiments with multiple vents at high level (vents at opposite sides of the enclosure):
  - Concentrations far lower than predicted by buoyancy-based model (i.e. Linden)
  - Wind driven ventilation model (Quadvent) *generally* gives better agreement (providing there *is* wind into vent !)

Hydrogen flow rate (Nl/min)	Average wind speed (m/s)	Actual Volume average H2 concentration (% v/v)	Linden Volume average H2 concentration (% v/v)	Quadvent Volume average H2 concentration (% v/v)
300	3.1	2.2	9.3	100*
150	2.4	0.7	5.9	1.1
300	2.5	1.6	9.3	2.0
600	2.5	2.4	14.8	3.7

*** Model not applicable; wind parallel to vent – treated as equal pressures on each side => no flow into enclosure**

Initial results

- Experiments with one upper side vent and one lower side vent (vents at opposite sides of the enclosure ; wind into upper vent):



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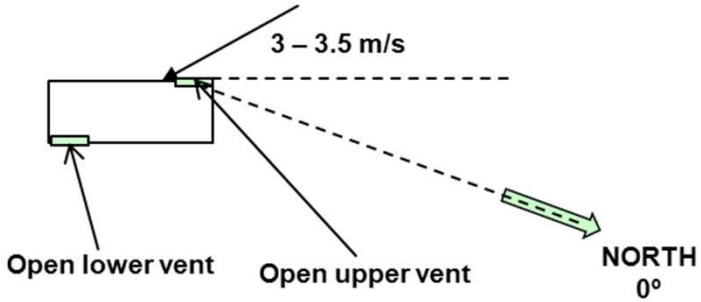
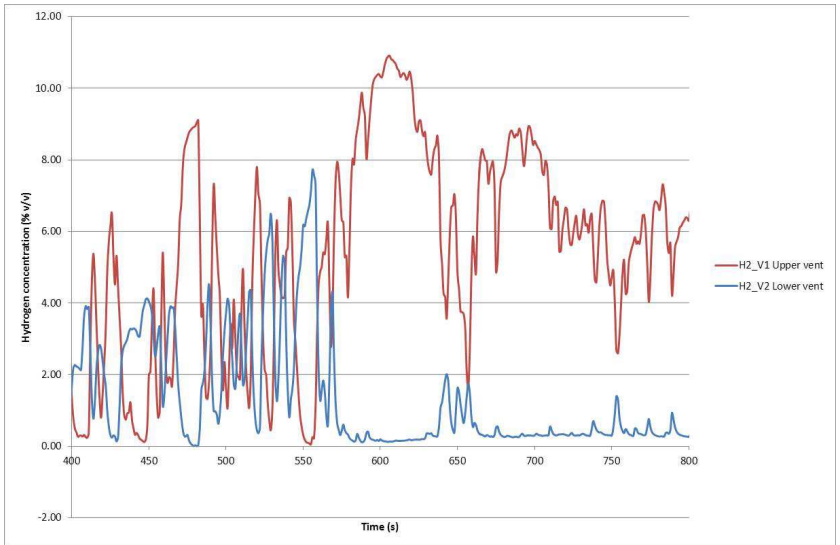


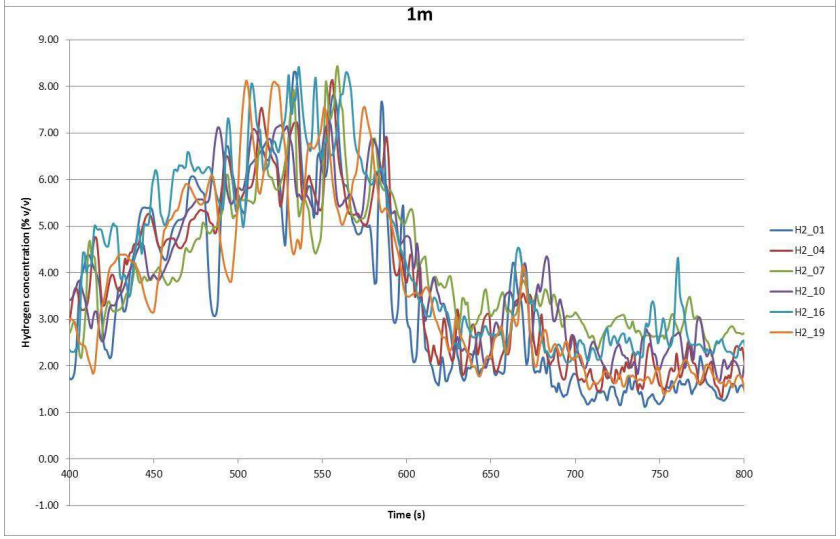
Hydrogen flow rate (Nl/min)	Average wind speed (m/s)	Actual H2 concentration Average / Maximum (% v/v)	Linden Volume H2 concentration in layer (% v/v)	Quadvent Volume average H2 concentration (% v/v)
800	3.3	3.2 / 4.8	10.6	4.0
1000	3.3	4.1 / 6.5	12.3	4.9
1200	3.3	4.9 / 7.9	13.9	5.9

Initial results

- Interesting influence of wind ?



1m



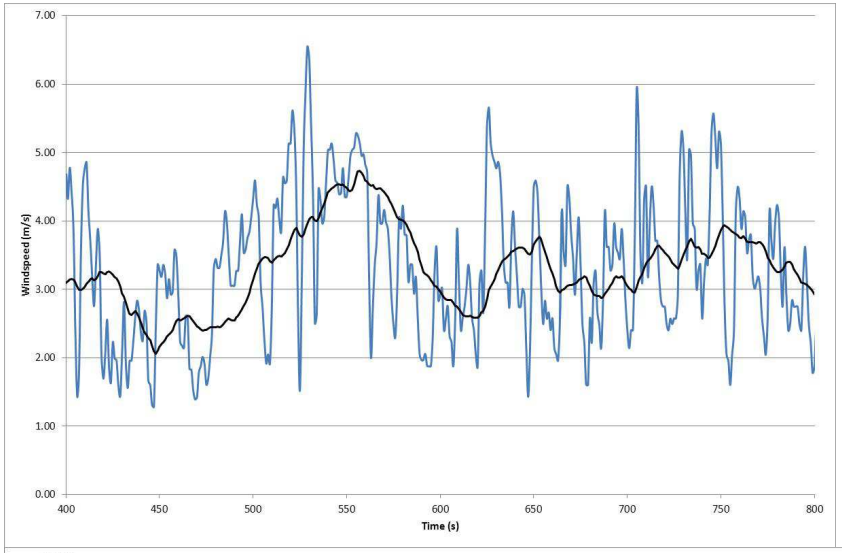
Initial results

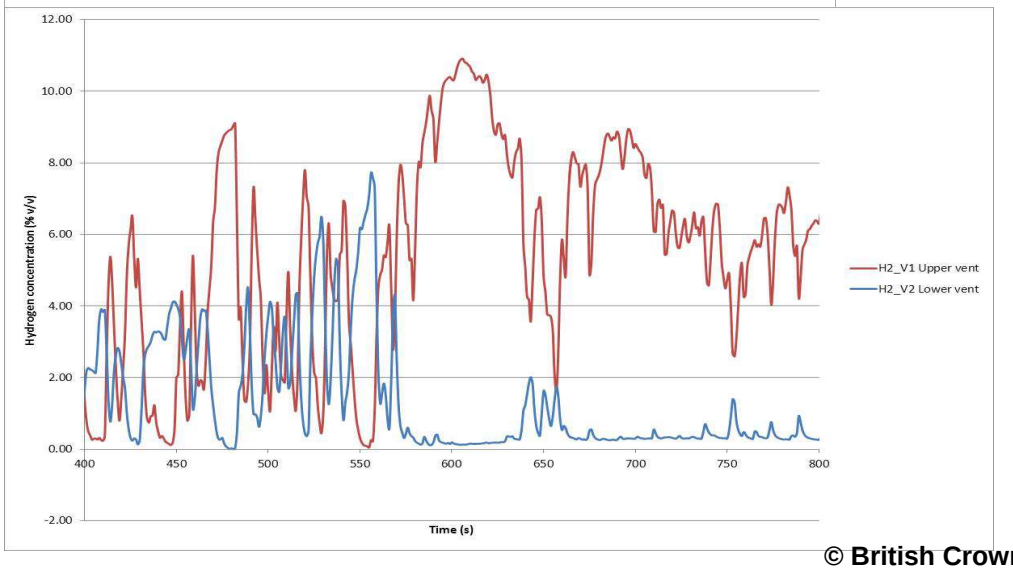
- Interesting influence of wind ?

Flow “flips” when velocity ~ 3m/s

Angle ~19º

Vector into vent ~ 1m/s





Conclusions (so far…..)

- For single vents “free” of wind effects, buoyancy model seems to broadly agree with experimental findings
- For multiple vents with wind effects concentrations appear to be more in line with wind-driven model and lower than buoyancy only model
- Wind into upper vents can overcome buoyancy and reverse the flow in two-vent systems

Further Work

- Further experiments to compare choked and sub-sonic releases
  - Completed
- Further experiments measuring concentrations below the 1 m level
  - Complete
- Further analysis of data from all tests
  - ongoing

Acknowledgements

- EU JU
- HSE
- All Hyindoor partners

References

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