Novel Approaches to Venting

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  - Small naturally ventilated enclosure
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Introduction

- Venting can serve one of two purposes:
  - To relieve pressure build up in the case of a deflagration; or
  - To disperse the release of a flammable or toxic gas
- Pressure relief venting is usually achieved by having panels that are being displaced at a set design pressure
  - However, this is not the topic of this presentation so will not be covered further
- Are there any alternatives to venting?
  - Not having releases of flammable gas—aspirational but not realistic
  - Inerting with say nitrogen
    - Likely to be an expensive solution
    - Retrofitting an inerting system into an existing plant might be difficult
    - Potential reliability issues
- The rest of this talk will be concentrating on natural ventilation

Types of Ventilation—1(3)

- Three different types of ventilation:
  - Natural ventilation
  - Mechanical ventilation
  - Combination of natural and mechanical ventilation

What are the differences between these types?

Which type should is most appropriate?

Types of Ventilation—2(3)

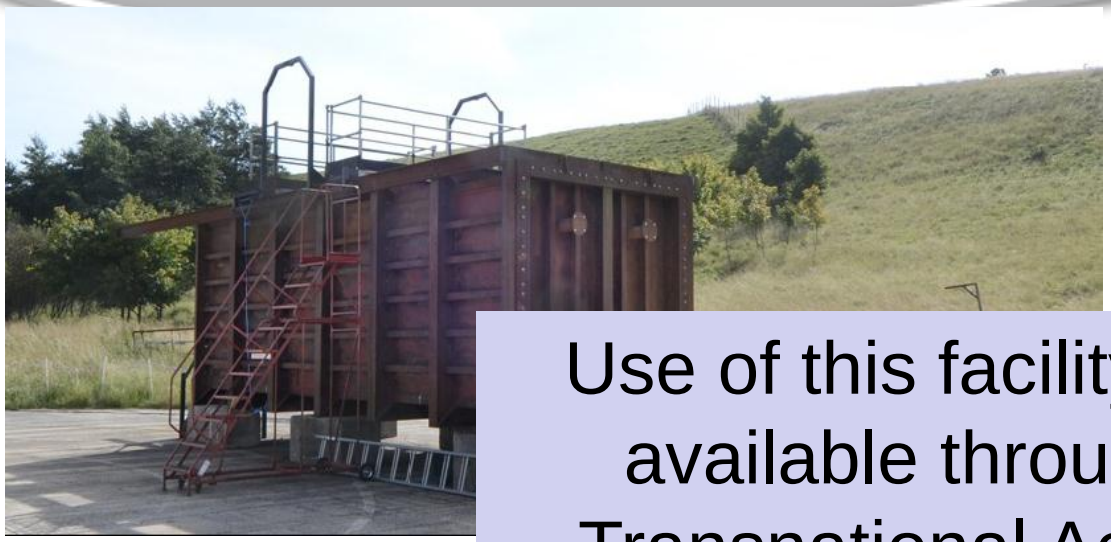
- Natural ventilation
  - Reliant on buoyancy and momentum effects
- What are some of the pros and cons with natural ventilation
  - Pros
    - No fans or other mechanical equipment required
    - No intervention by humans or control systems are required
    - Always on?
    - Energy efficient?
  - Cons
    - Ensuring that the natural ventilation is adequate
    - May be affected by the ambient atmospheric conditions
    - Not well-controlled flow rate

Types of Ventilation—3(3)

- Mechanical ventilation
  - Fans sucking air out of or blowing air into the enclosure
  - Intermittent or continuous operation
- What are some of the pros and cons with mechanical ventilation?
  - Pros:
    - Well-controlled vent flow rate
    - Adjustable vent flow rate
    - (Usually) not significantly affected by ambient conditions
  - Cons:
    - Additional equipment (fans) required
    - Maintenance of the fans
    - Some control system is required
    - May require human intervention (depending on the design)
    - Uses more energy than a natural ventilation system

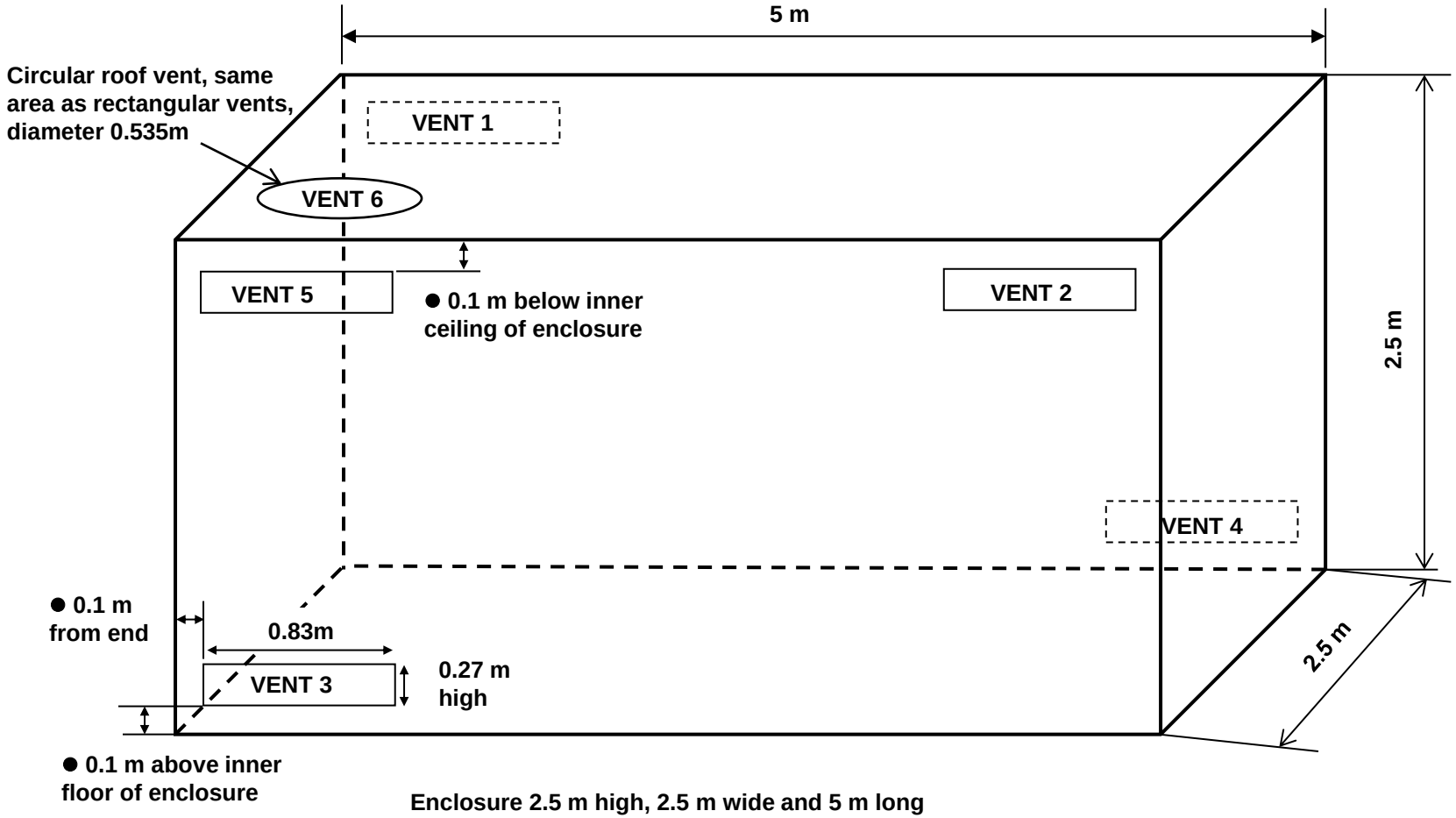
Natural Ventilation in a Small Enclosure HyIndoor

Enclosure - HyIndoor



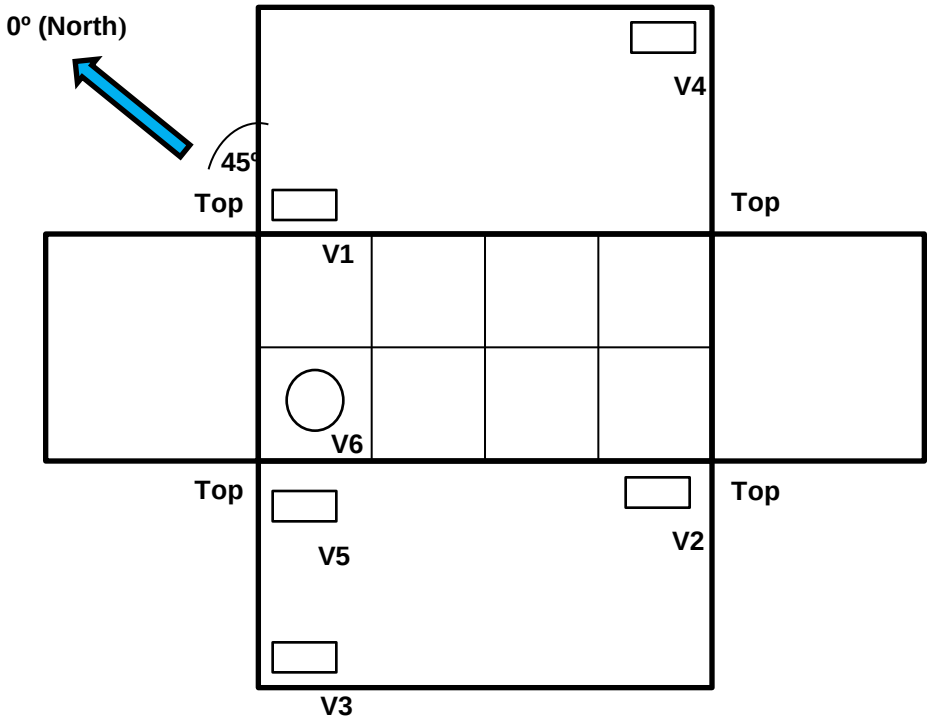
Use of this facility is also available through the Transnational Access in H_2FC

Vent Positions



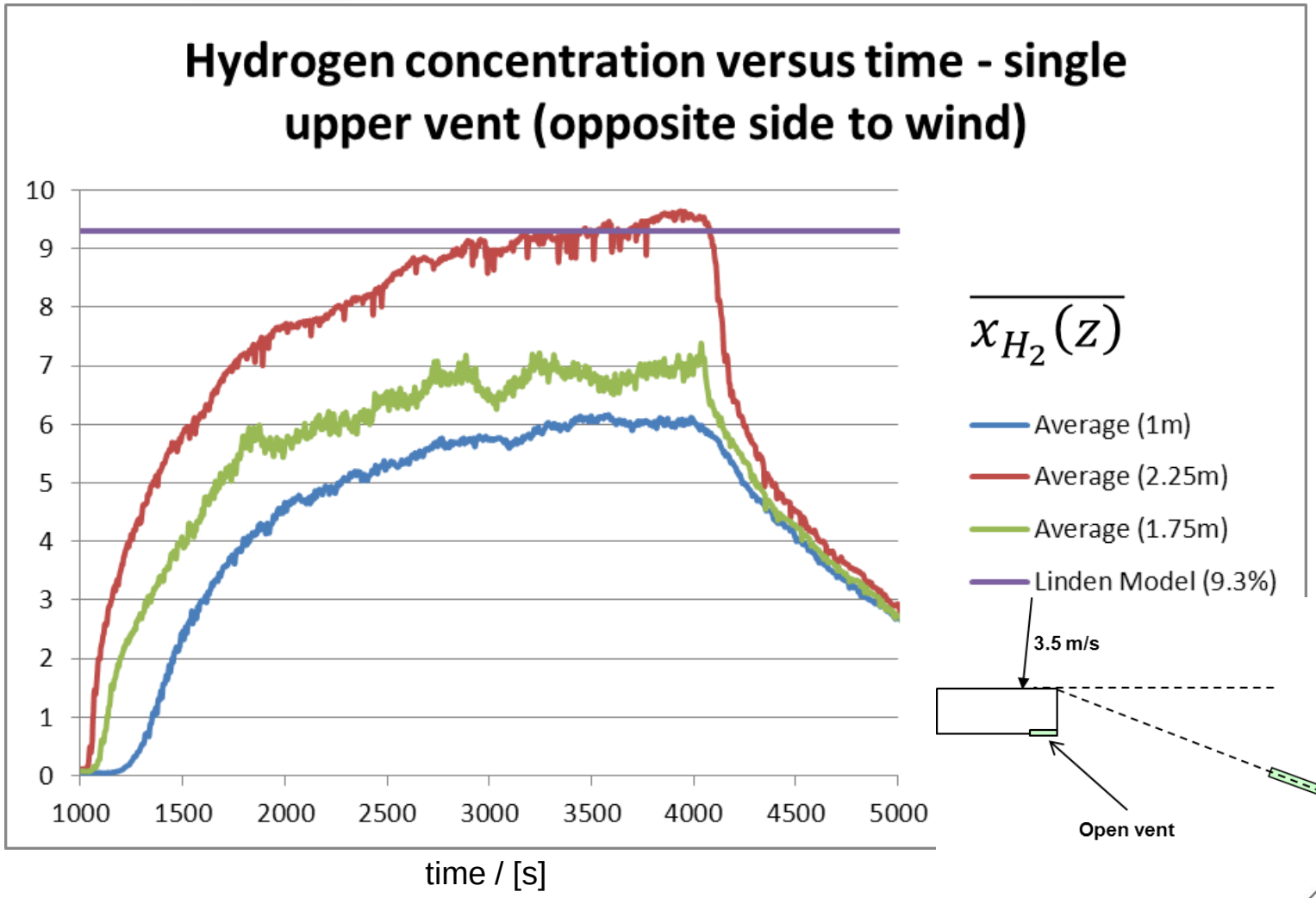
Vent Combinations

- 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



Roof vent

Single Upper Vent – Wind not Incident to Vent



Single Upper Vent – Wind Incident to Vent

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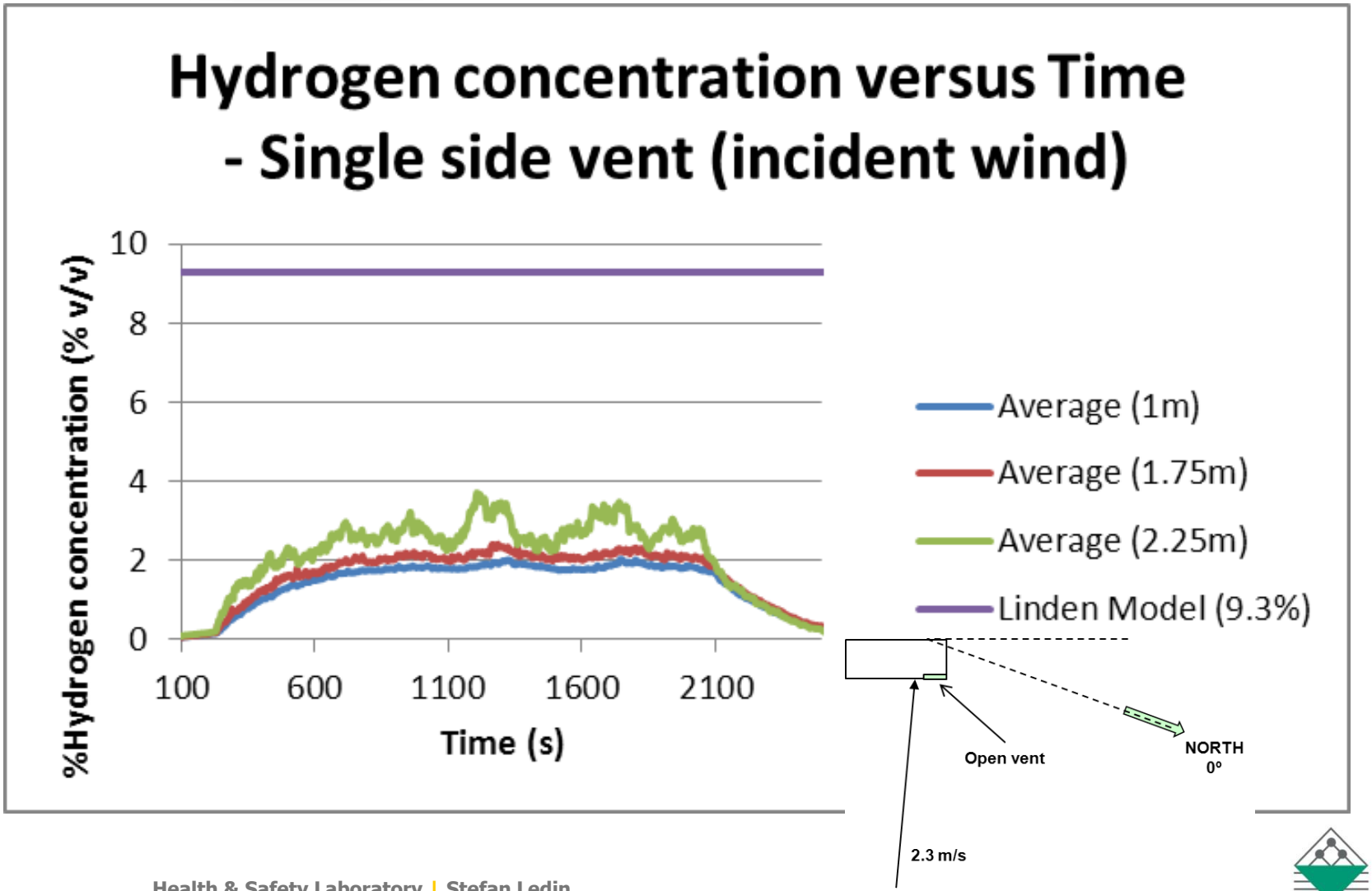

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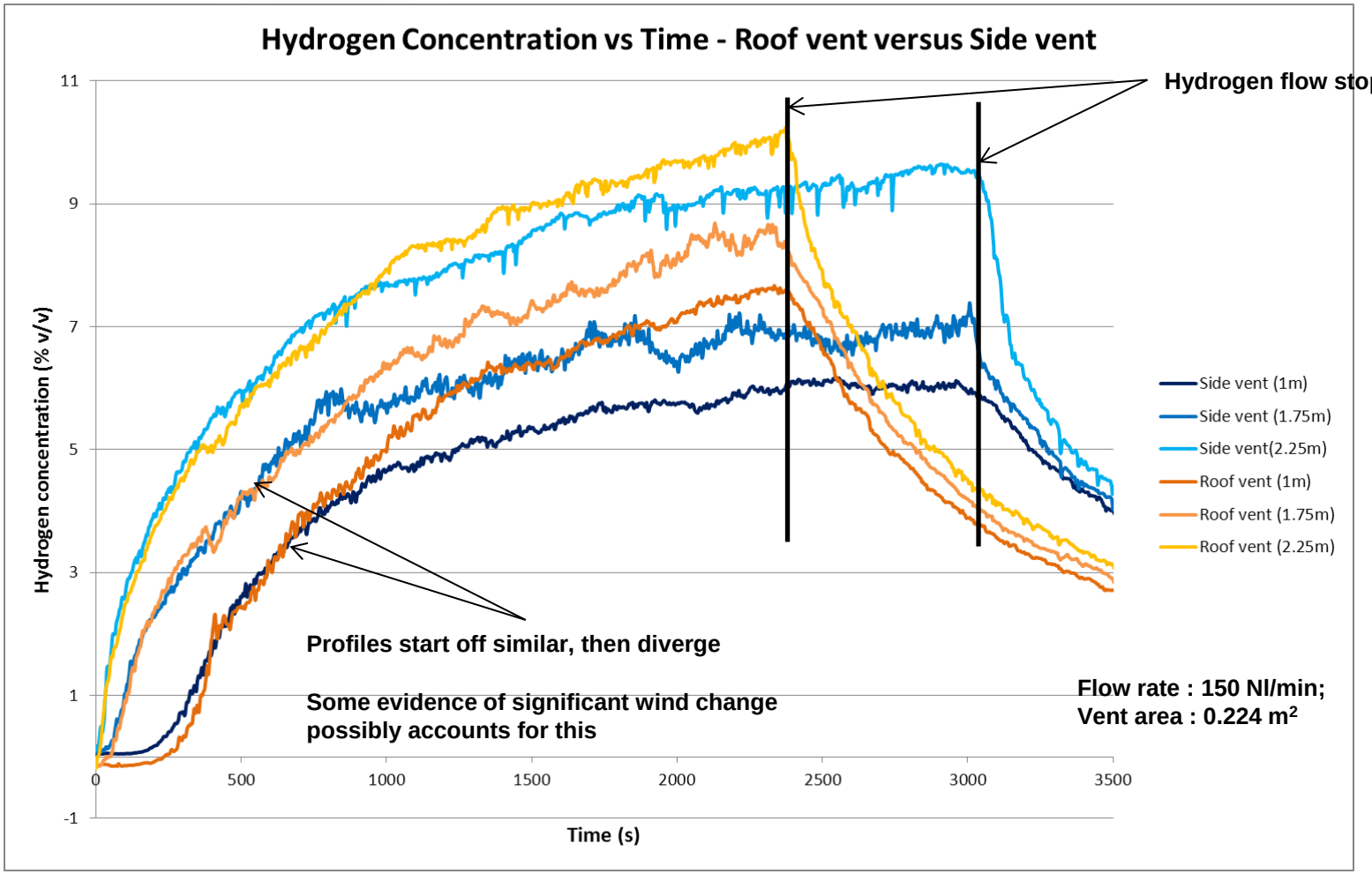
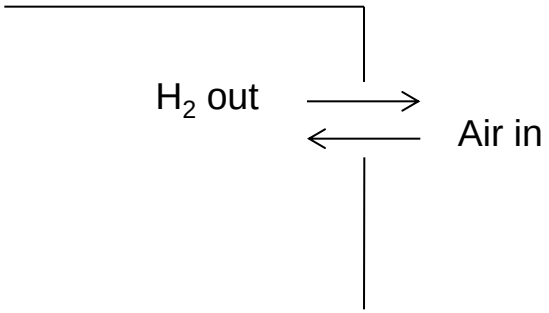
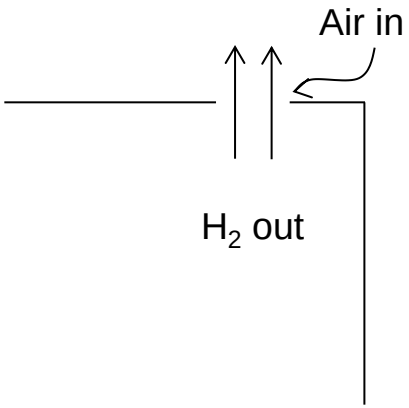
Single Vent – Side Vent v. Roof Vent



Flow through Vent

Close up of a buoyant flow through side and roof vents

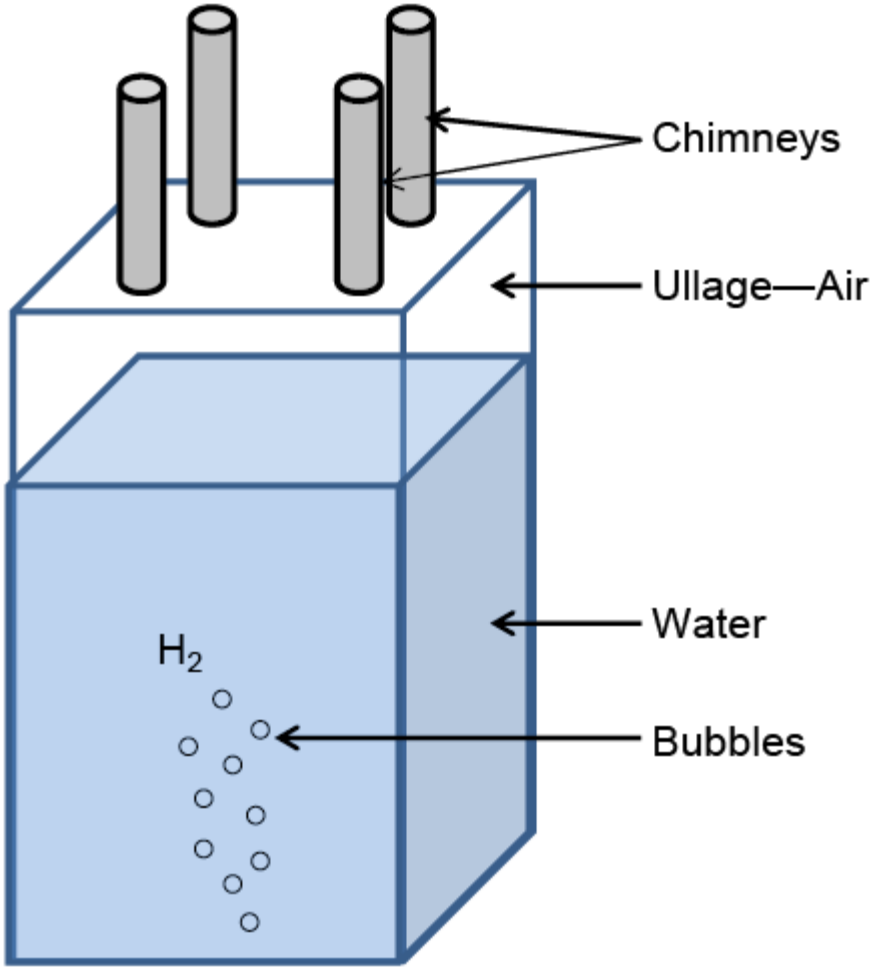




- Side vent
  - Buoyant H_2 leaves through the upper part of the vent
  - Denser air enters through the lower part of the vent
  - More effective venting than a roof vent
- Roof vent
  - Buoyant H_2 exits the enclosure
  - Denser air is hindered from entering the enclosure

Natural Ventilation in a Large Enclosure

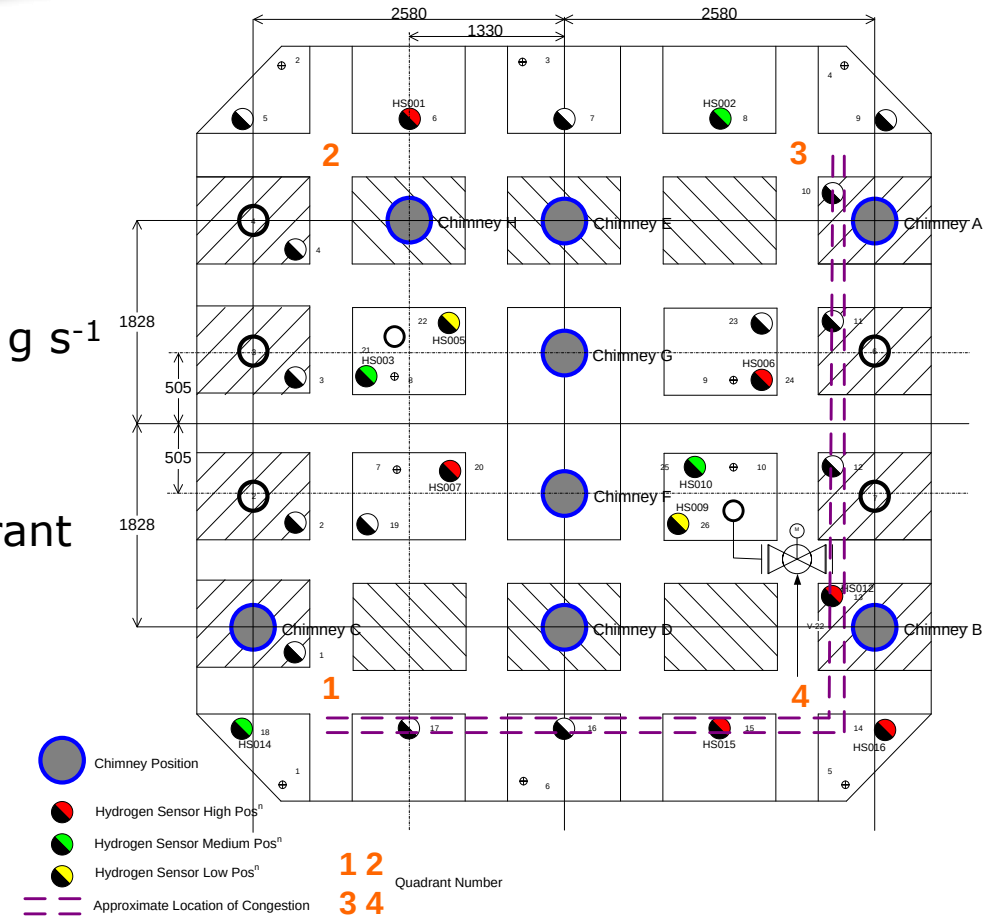
Generic Layout of Rig



- Tall enclosure: ≈ 9 m
- Square base: ≈ 6 m x ≈ 6 m
- Water introduced to a certain level
- Ullage containing
  - Air
  - Some obstructions
- Hydrogen released in bubble form
- Chimneys for passive venting
- Hydrogen concentration measured in the ullage and near the top of the chimneys

Parameters of Interest

- Chimneys
  - Number of chimneys
  - Chimney arrangement
- Hydrogen release rate
  - 0.56-2.25 $m^3\ h^{-1}$ or ● 0.1-0.5 $g\ s^{-1}$
- Hydrogen release point
  - Release across whole base
  - Release in an individual quadrant
- Ullage height
  - 0.9 m or 3 m
- Chimney diameter
  - 0.15 m or 0.3 m
- Ambient conditions
  - Wind direction
  - Wind speed



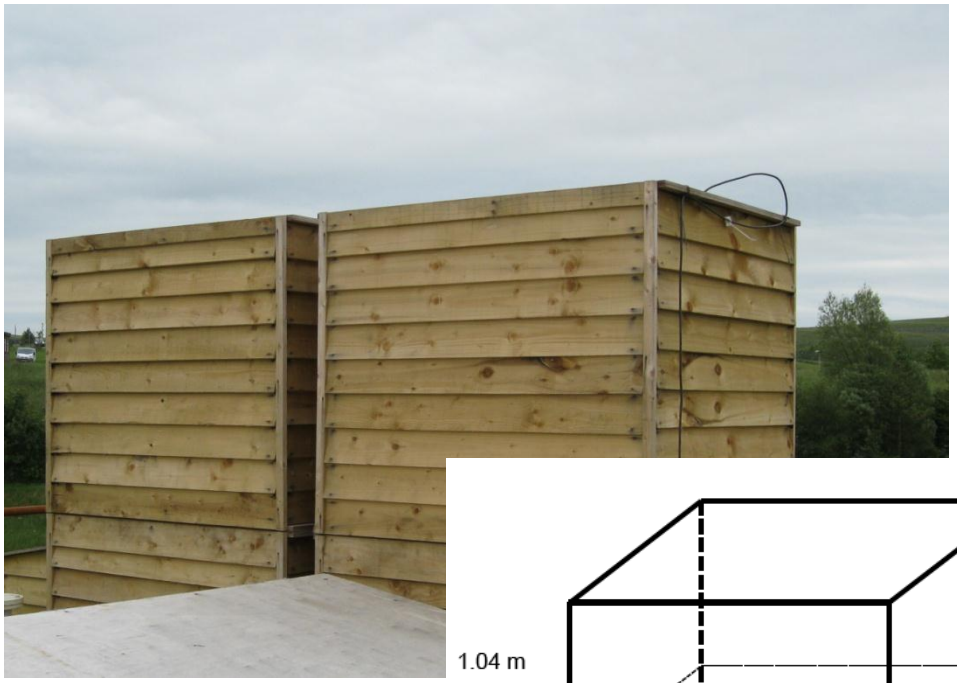
Plan view of top of the tank

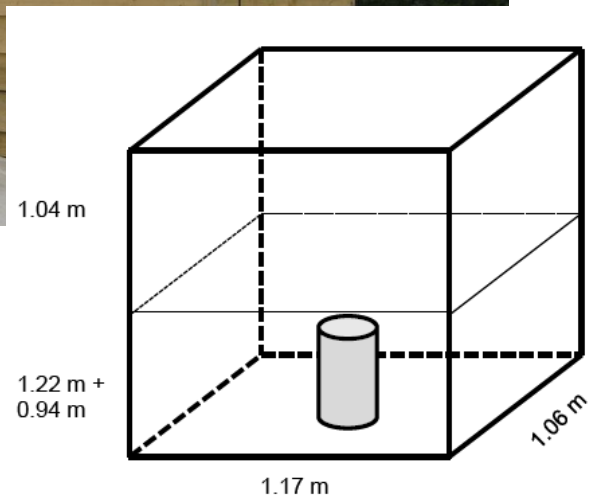
Chimney Setup

Chimney with a 0.3 mm diameter and a height of 1.5 m

Chimney fitted with hydrogen sensor, manometer and shield block

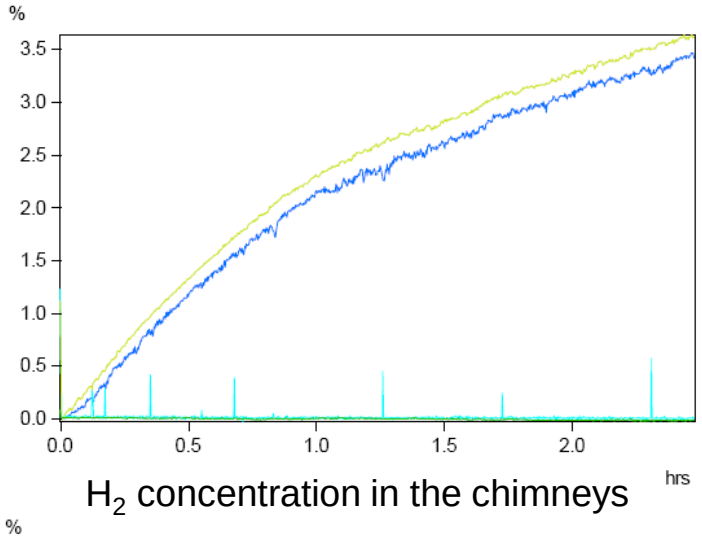
Chimney and Shed Arrangement



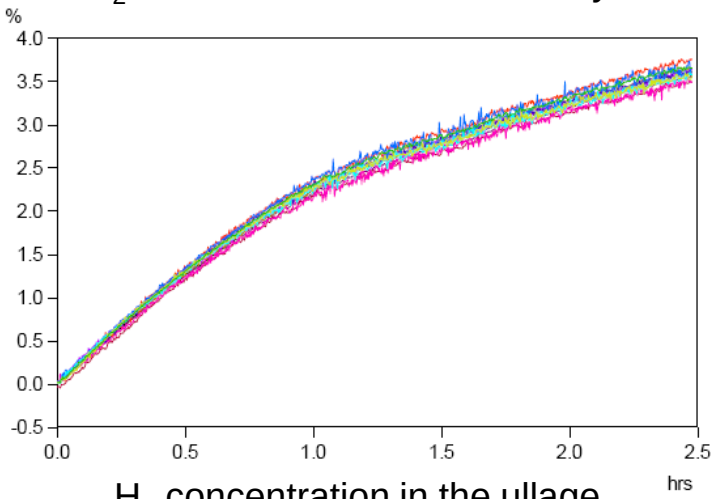


- Introduction of "sheds" to try to reduce the influence of ambient wind conditions on the vent behaviour.
- A pitched roof was placed on top of the shed. However, this led to a build-up of hydrogen reaching unacceptable levels and was therefore subsequently removed

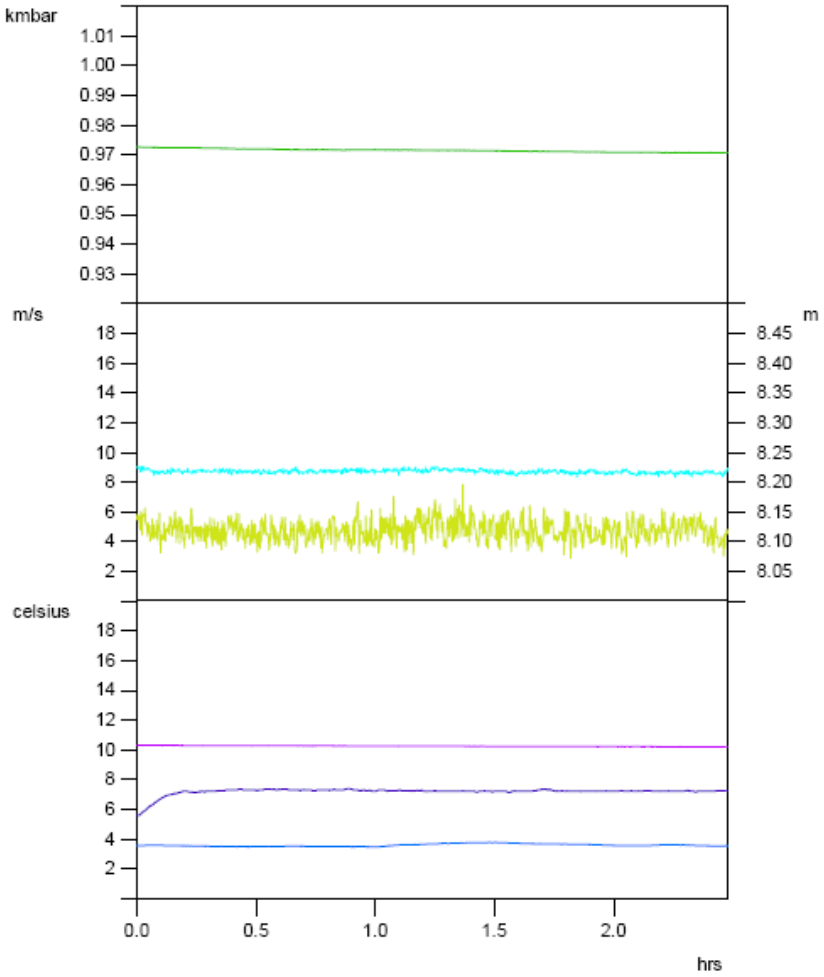
Chimney: ∅=150 mm, 18.75 l min^{-1} H_2



H_2 concentration in the chimneys



H_2 concentration in the ullage



Chimney: ∅=300 mm, 18.75 l min^{-1} H_2—1(2)

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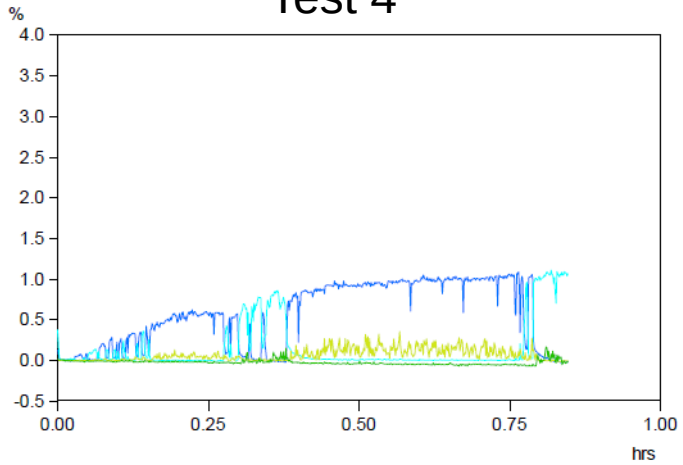
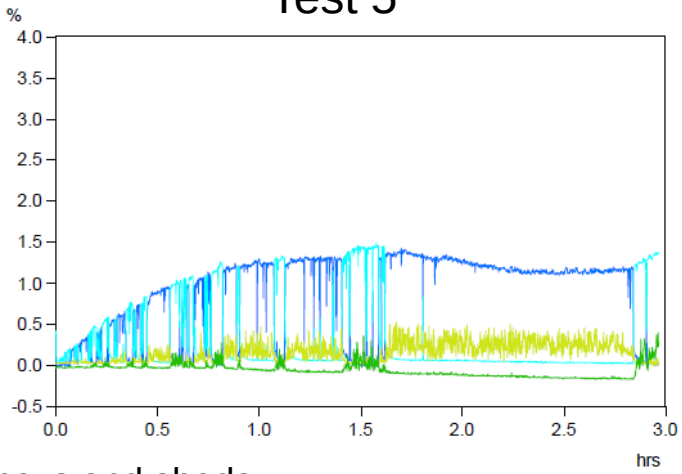
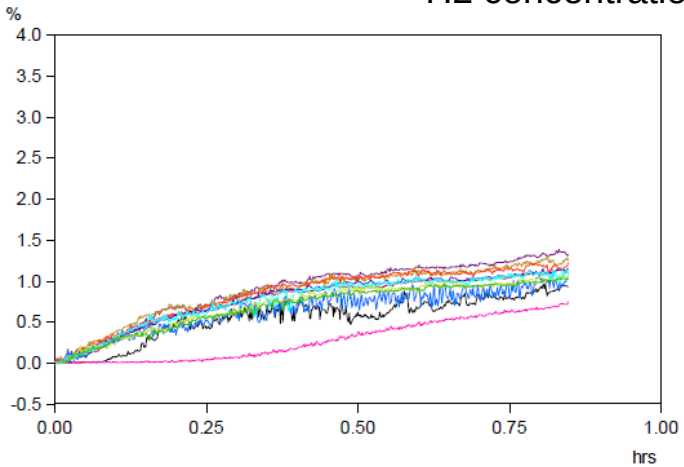
Test 4

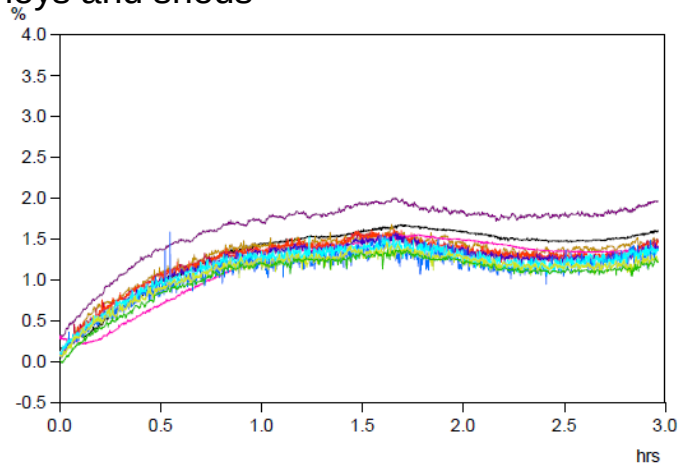


Test 5



H2 concentration in the chimneys and sheds





H2 concentration in the ullage

Chimney: ∅=300 mm, 18.75 l min^{-1} H_2—2(2)

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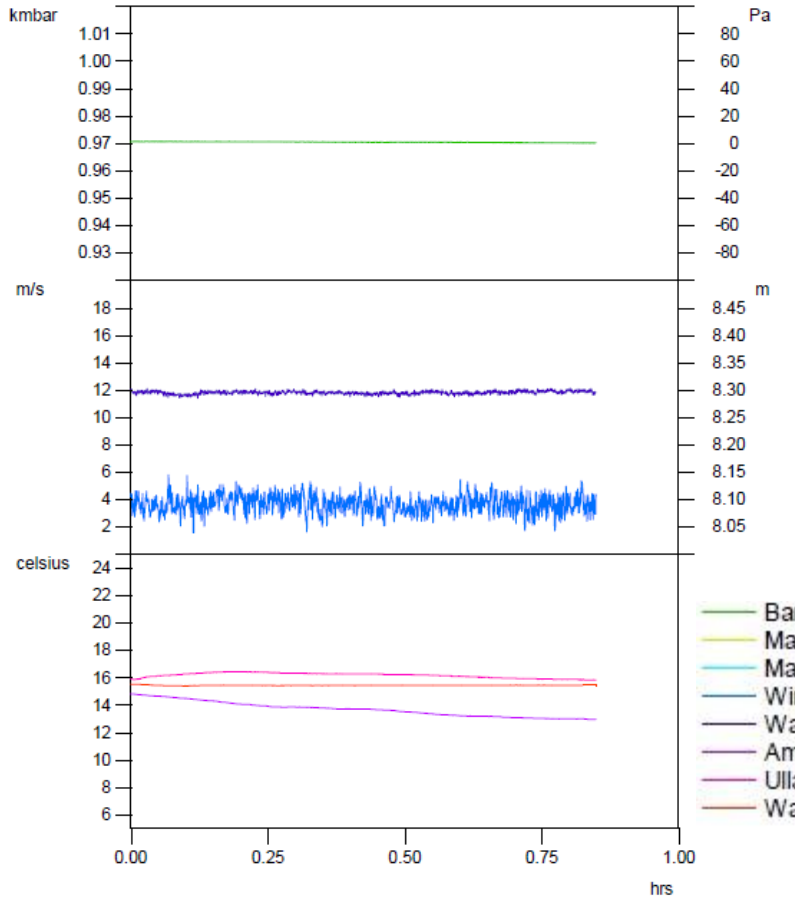
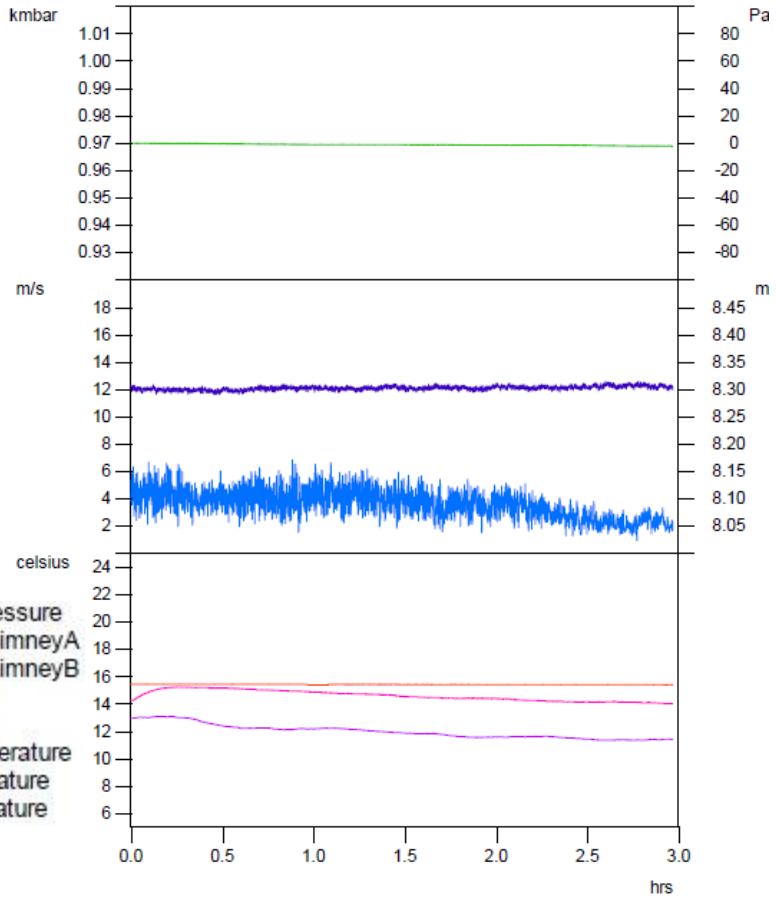
Test 4



Test 5



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Revised Chimney Designs

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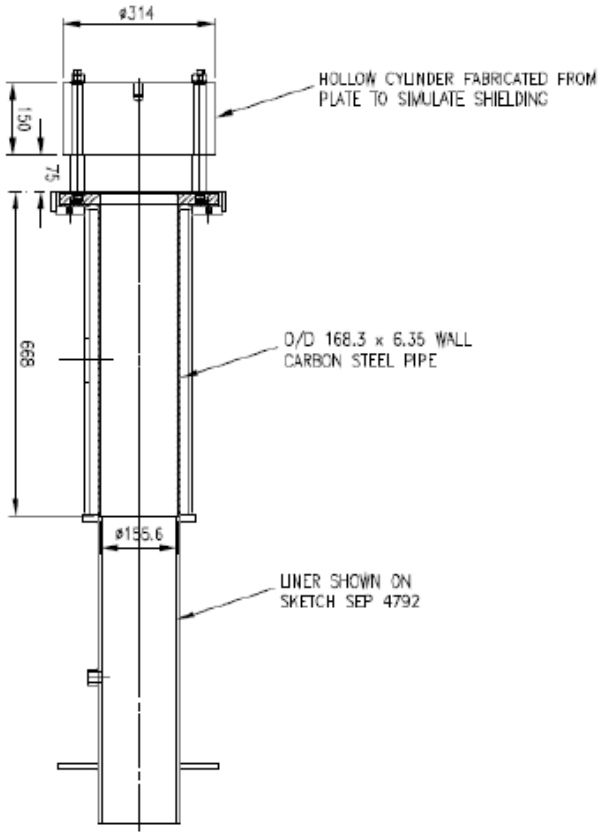
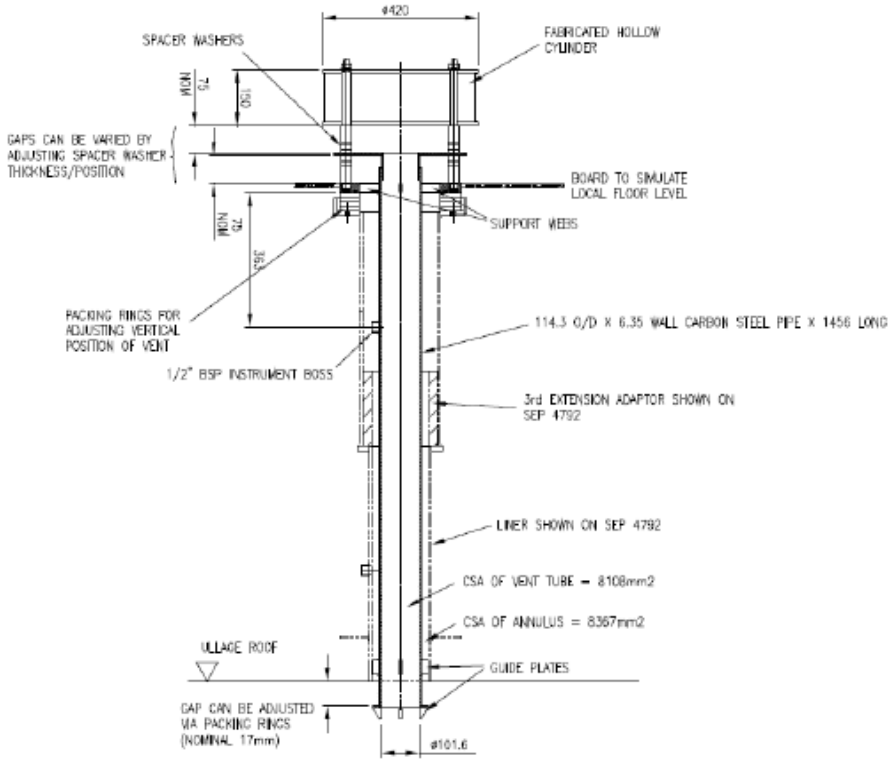


Basic chimney



Coaxial chimney

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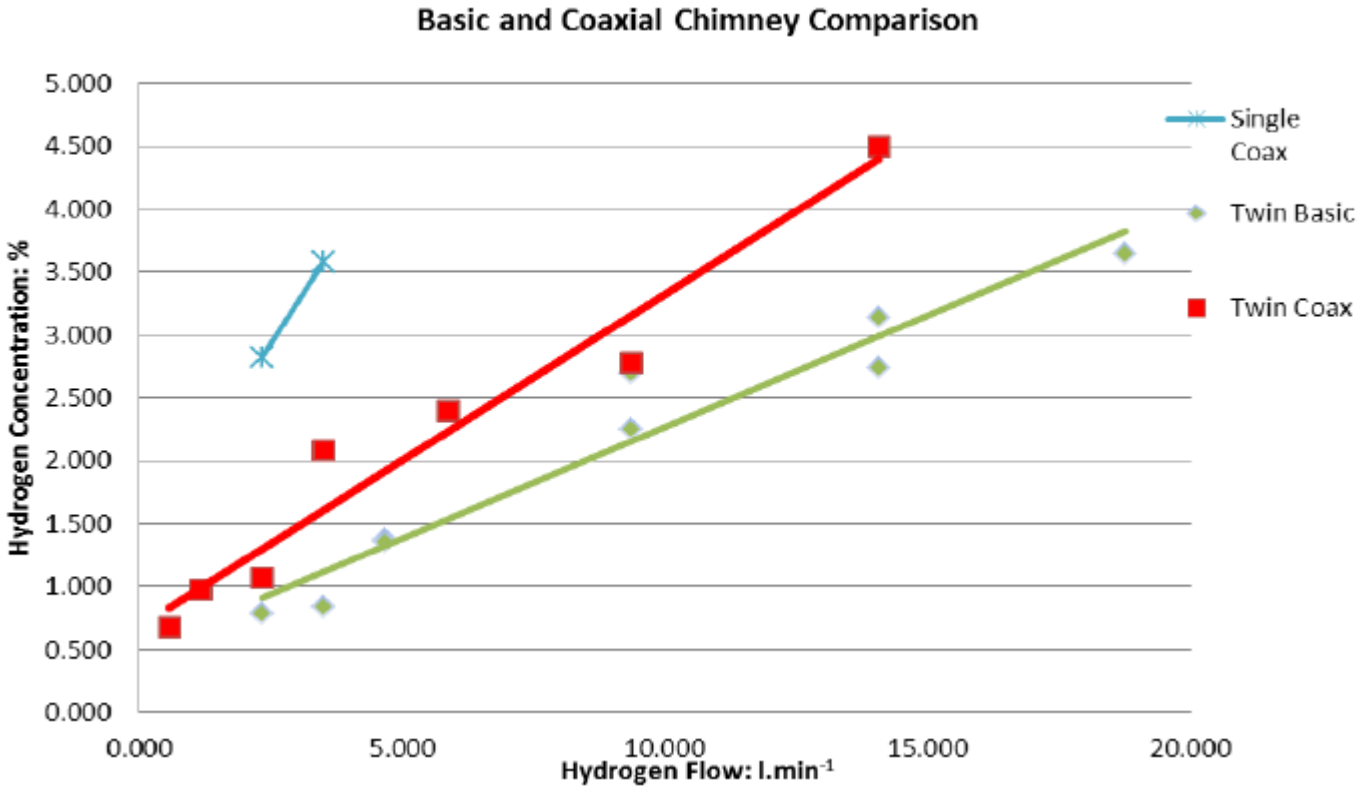
Revised Chimney Design—Preliminary Results



A single basic chimney is ineffective in venting the hydrogen; twin coaxial chimneys perform best

Conclusions

- Three types of ventilations
  - Natural/passive, mechanical or a combination of the two
  - Pros and cons with each of the types
- Appropriate choice of ventilation type is problem specific
- Side vents are more effective than roof vents for buoyant gases
- Ambient wind conditions can help or hinder efficient venting
- Interesting interactions between chimneys observed in the large enclosure

Acknowledgements

H2FC European Infrastructure

Colleagues at HSL
Partners in EU projects
Fuel Cell & Hydrogen / Joint Undertaking
European Commission

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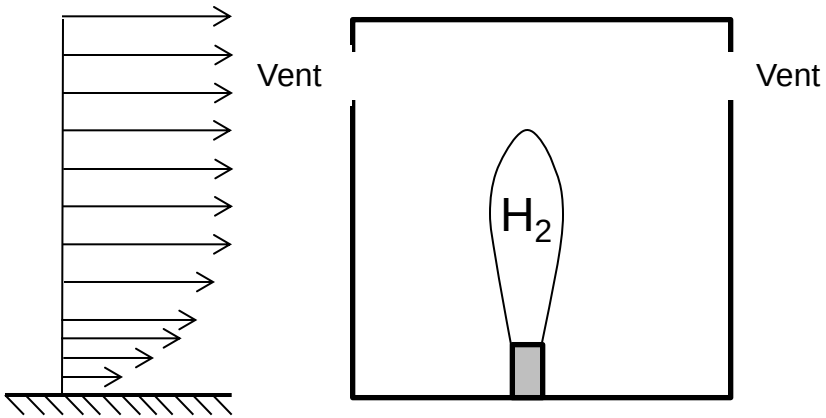
Thank You for Your Attention!

Any Questions?

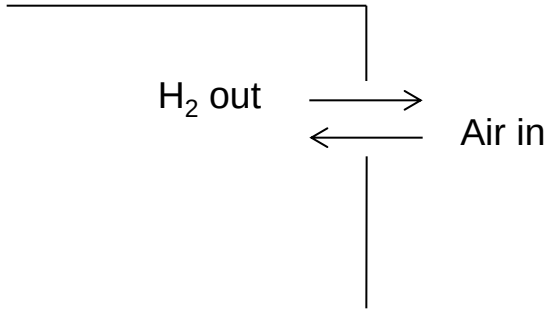
Supplementary Slides

Interaction with the Ambient Wind Field

Ambient wind field



Close up of the flow through a vent



- The wind can aid or hinder the outflow from the enclosure in the open
  - One could envisage situations with unfavourable wind conditions
  - Vents on more than two sides of the enclosure might reduce the risk of ambient wind blocking the vents?