



Pre normative research
on the indoor use of fuel cells and hydrogen systems

Final Dissemination Workshop, Paris, 11th December 2014

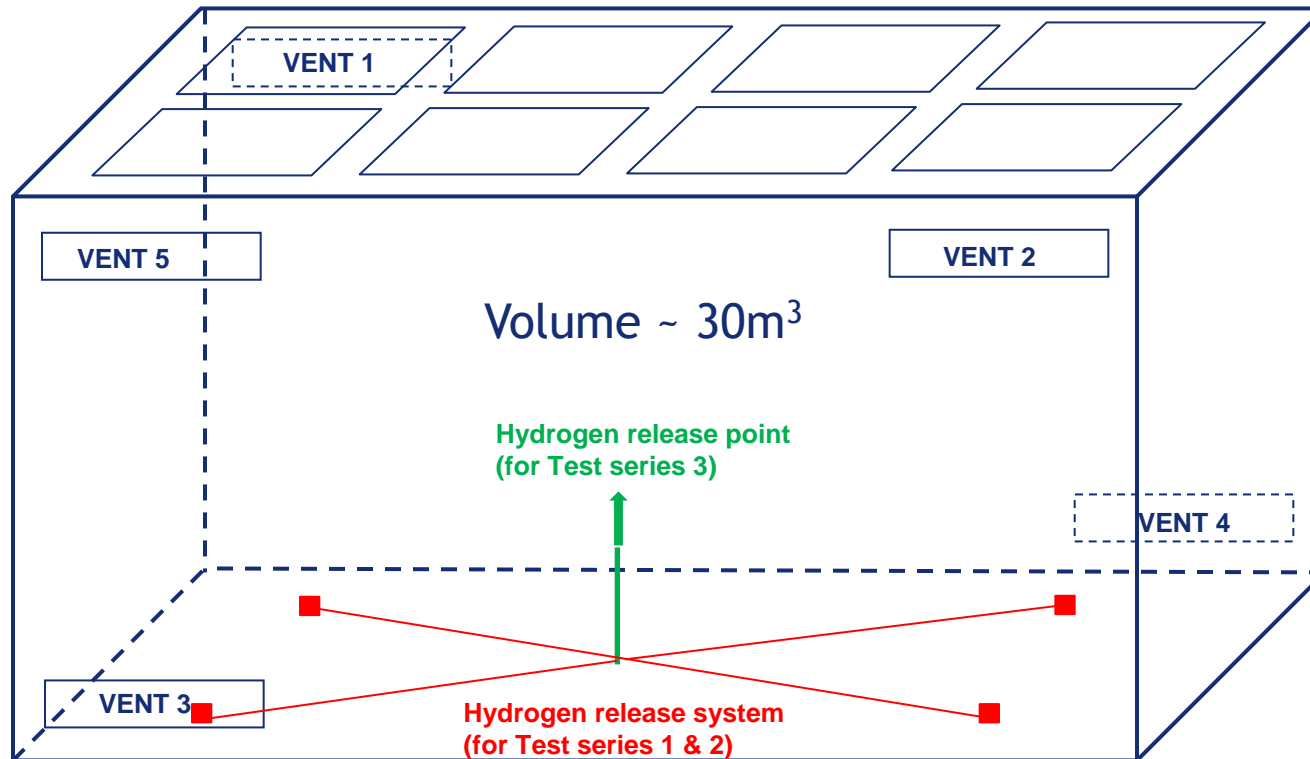
Overview of findings from vented deflagration experiments at HSL
Phil Hooker (HSL)

Objectives of the experiments at HSL

- Gather data from vented deflagrations of lean hydrogen / air mixtures in a large scale (30m³) facility, in the open air, with maximum internal pressure ca. 100mbar (18 experiments)
 - Hydrogen concentration
 - Internal and external pressure
 - IR video of external vented gases
- Test Series 1 : Study homogeneous, quiescent mixtures with explosion relief in enclosure roof
- Test Series 2 : Study homogeneous, quiescent mixtures with explosion relief via passive vents in side wall
- Test Series 3 : Study non-uniform mixtures with explosion relief via passive vents in side wall
 - Quiescent, gradient mixtures
 - Delayed ignition of jets

Experimental arrangement : Enclosure

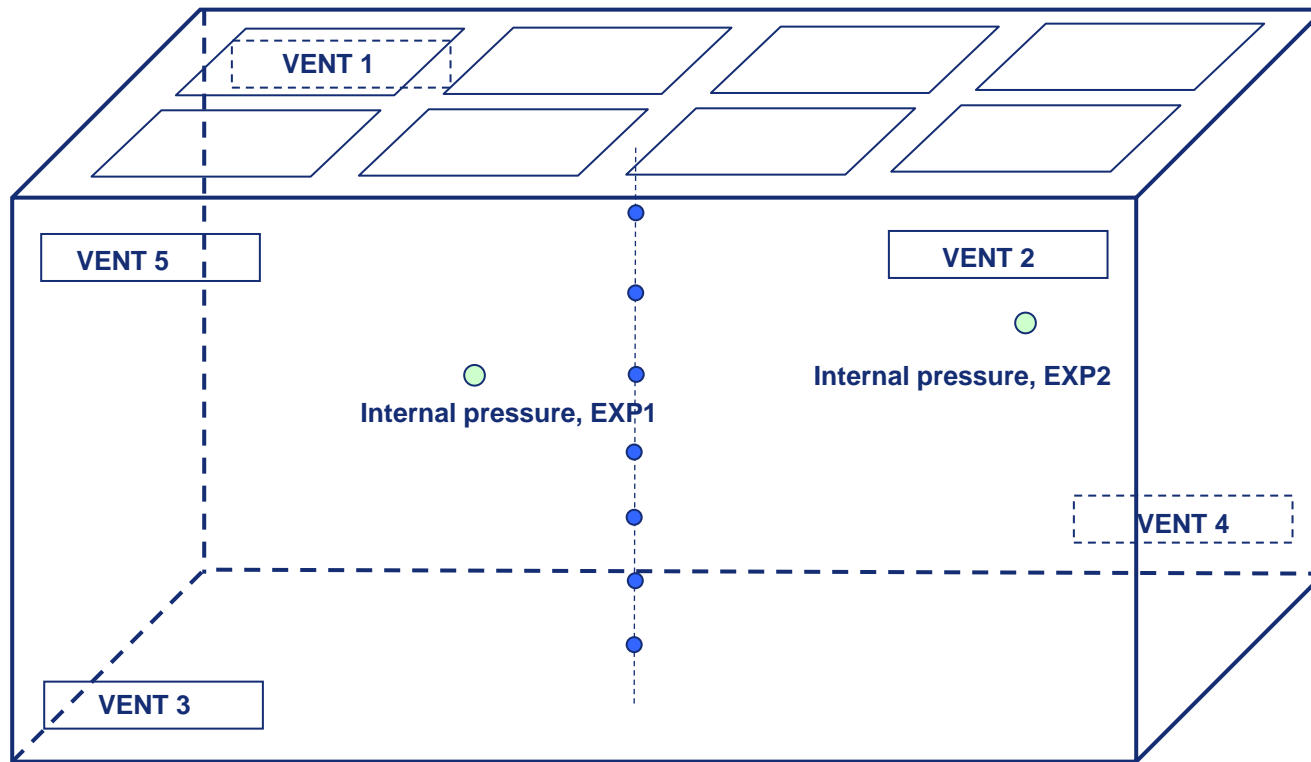
Hydrogen introduction



■ "Air amplifier" (venturi mixer)

Experimental arrangement : Enclosure

Hydrogen concentration and internal pressure measurement

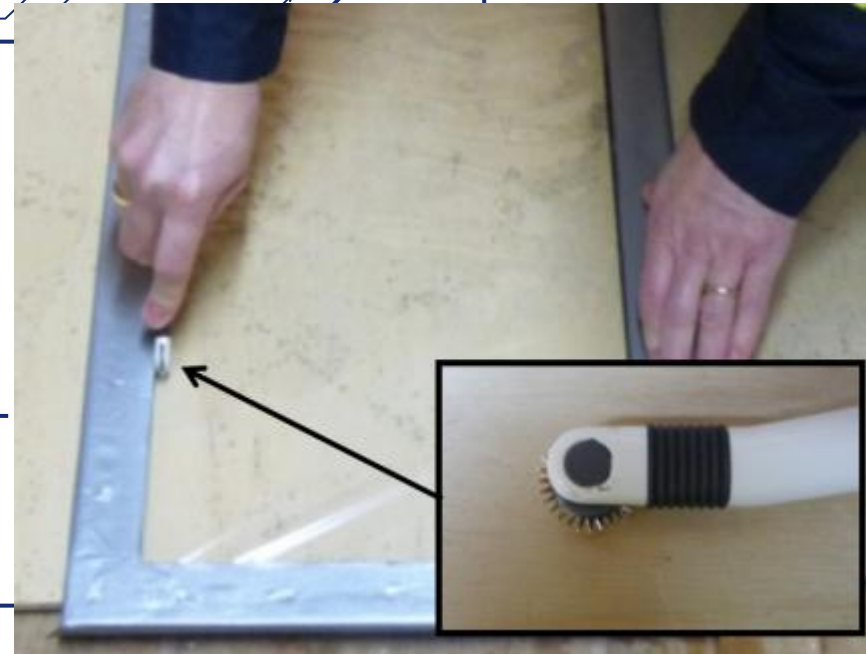
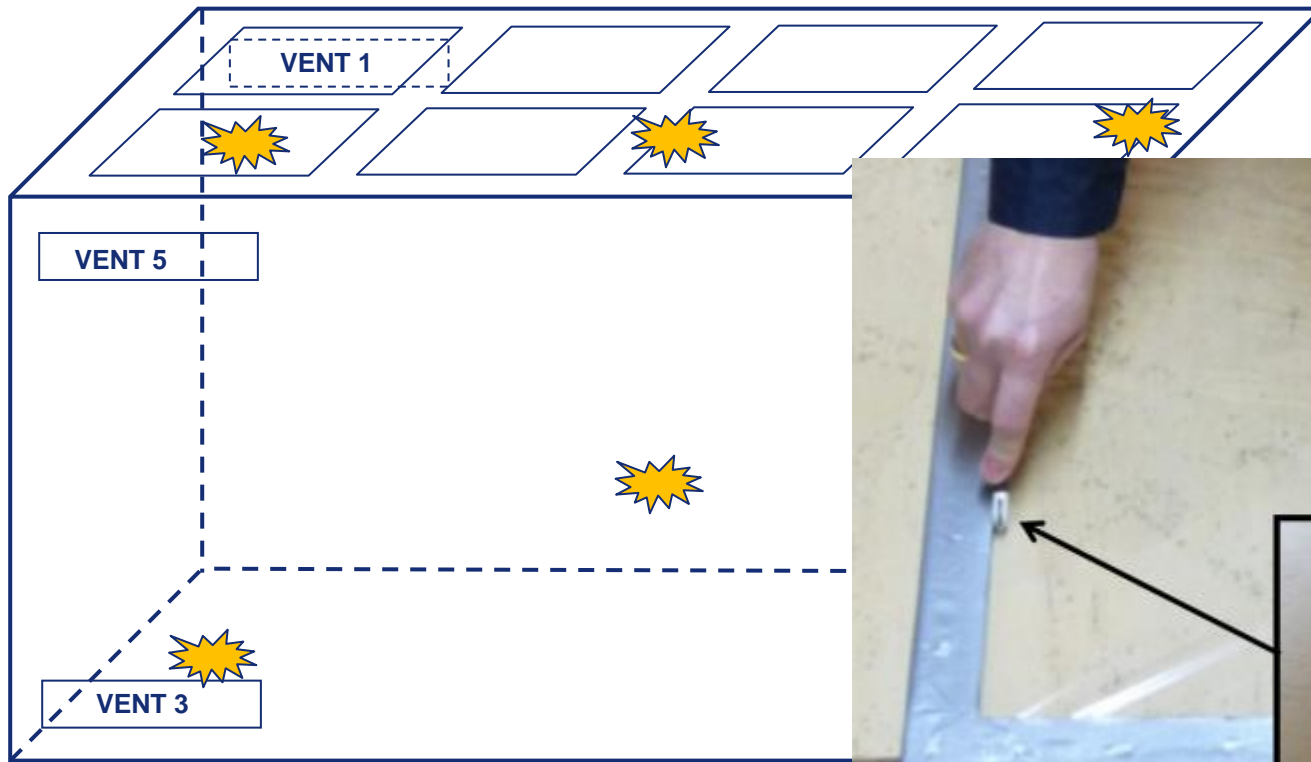


- Internal pressure measured using Kistler pressure transducers, 0 – 2 bar a, mounted flush with side wall of enclosure
- Hydrogen inferred by oxygen depletion, seven electrochemical oxygen sensors spaced at 0.31m intervals



Experimental arrangement : Enclosure

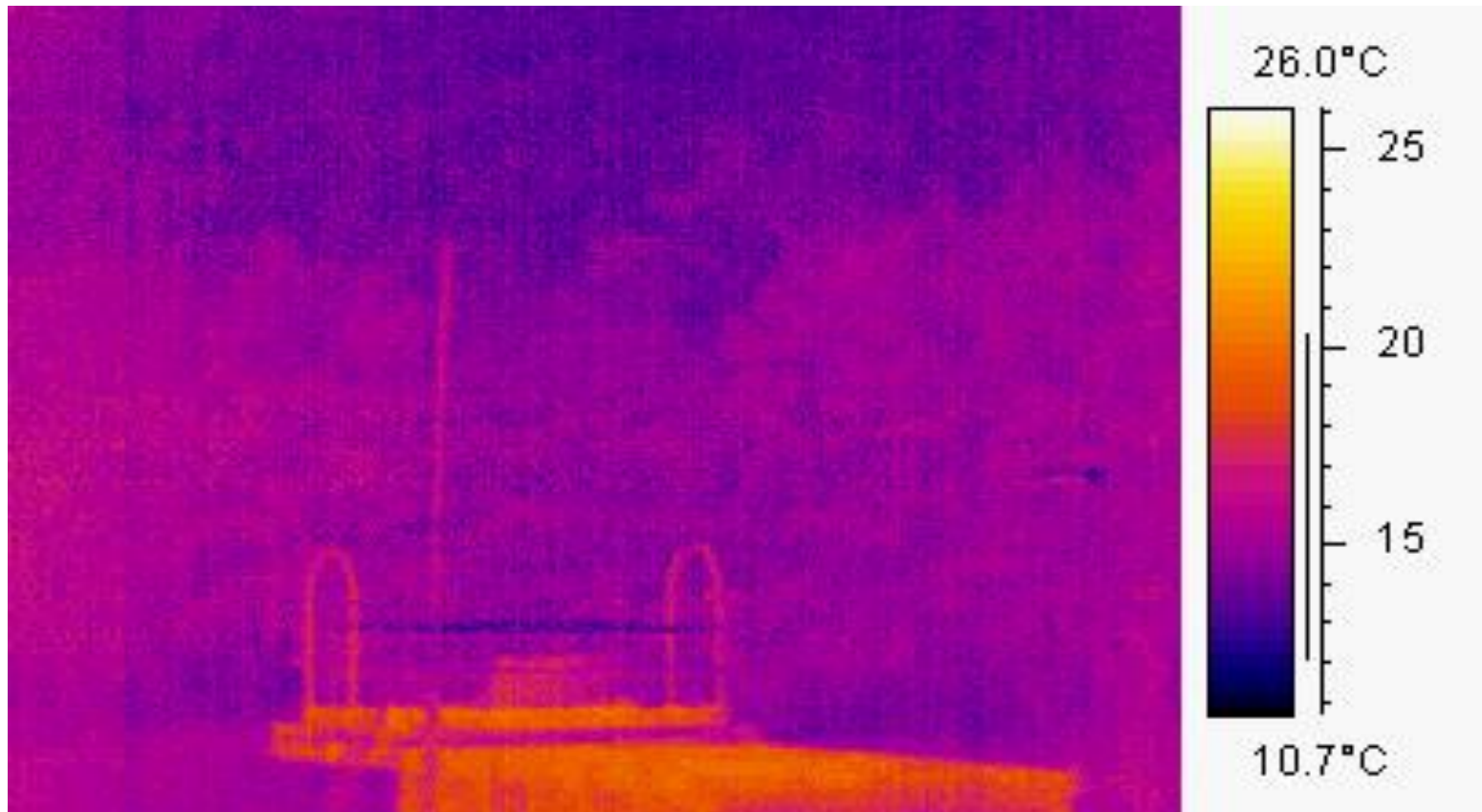
Ignition position varied (depending upon experimental conditions)



Explosion relief via roof or side wall vents (pre-weakened plastic film)

Example IR Video - roof vents

14% v/v well-mixed, 1.6 m², Far, low ignition

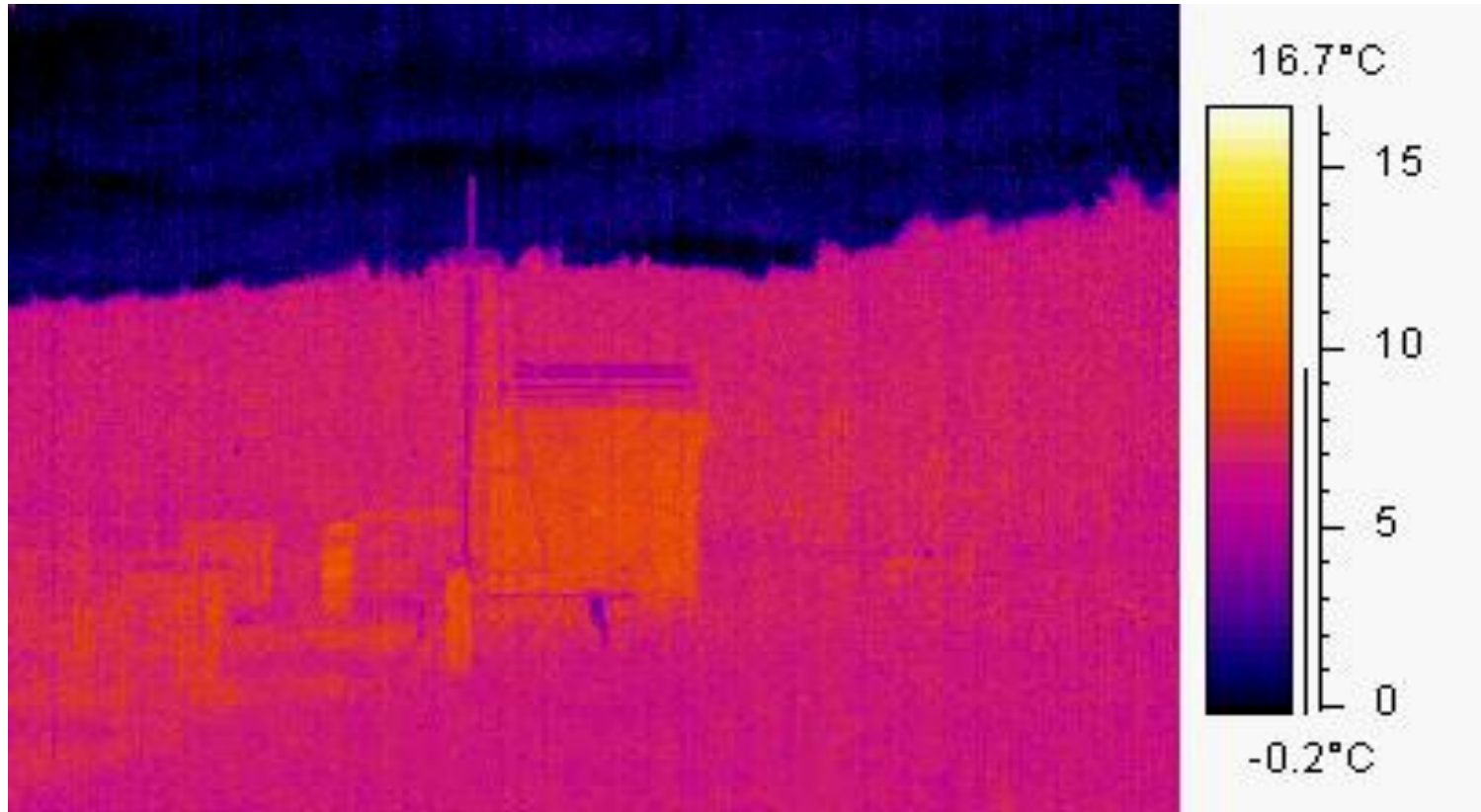


Maximum internal pressure = 64 mbar

Example IR Video - side wall vents



10% v/v well-mixed, 2 passive vents (0.45m²), Far, low ignition



Maximum internal pressure = 118 mbar

Flame emitted from side vents



Distance of flame emitted from passive vents in side wall

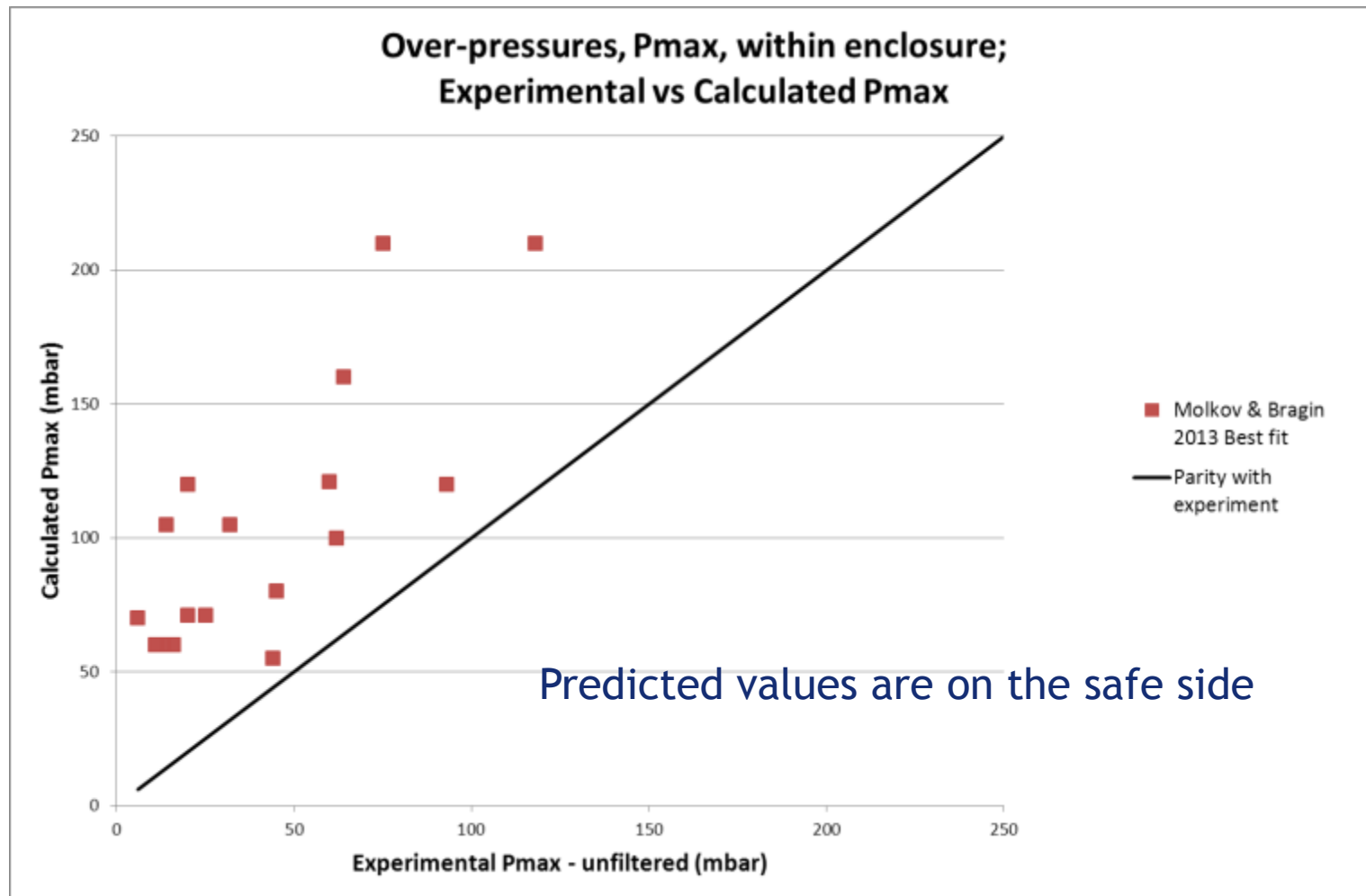


Distance of flame (to 70°C) is less than that calculated using method given in EN14994 (for the conditions tested - up to 10% v/v and internal pressure ~100 mbar)

Typically < 2.5m actual compared to ca. 15m calculated

HSL experiments -summary

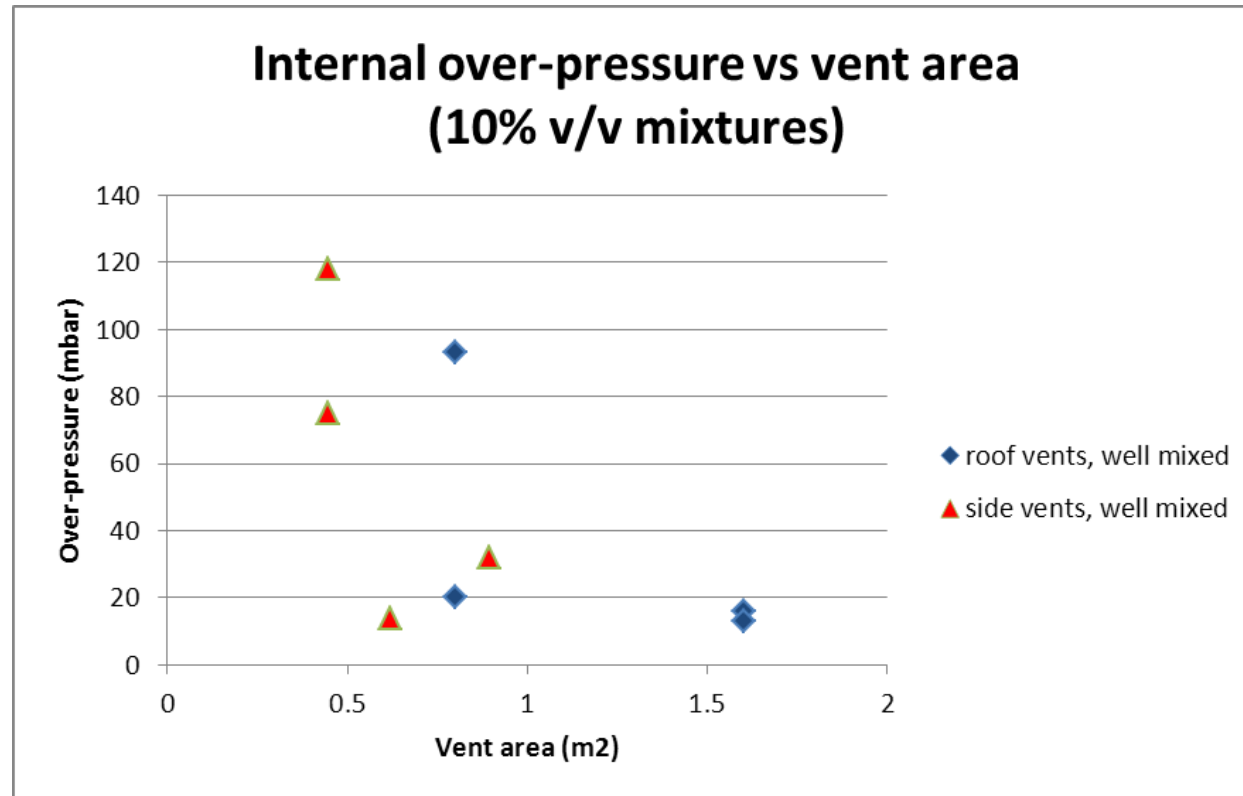
Comparison of experimental data and predicted values (Molkov & Bragin 2013)



HSL experiments -summary



Comparison of roof vents vs side vents (uniform 10% v/v hydrogen mixtures)



Findings from experimental work

- Ignition far away from the explosion relief vent(s) leads to a higher over-pressure than ignition close to the vent
- Explosion relief via side wall vents appears to be as effective as via roof vents (for mixtures of up to 10% v/v)
- Confirmation of result at small scale (KIT) : stratified hydrogen-air mixture leads to higher overpressure than uniform mixture with the same hydrogen inventory

Findings from experimental work

- Ignition of the plume of released hydrogen can generate significant pressures even if the average concentration in the enclosure is low (e.g. ~1% v/v resulted in ca. 20 mbar)
- Molkov & Bragin 2013 approach could be used to predict deflagration over-pressures for lean mixtures (the model is conservative)



Thank you for your attention.



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