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Interaction of hydrogen jets with walls and barriers

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INTRODUCTION

- It is thought that separation or safety distances for pressurised hydrogen can be reduced by inclusion of walls and barriers
- Various NFPA codes suggest the use of 60° inclined barrier in preference to vertical one
- The work complemented a jet barrier interaction modelling and experimental work programme undertaken by Sandia National Laboratories

INTRODUCTION

- Work primarily focused on compressed hydrogen storage for stationary fuel cell systems – Hyper project
- All releases were made from storage at 200 bar
- Series of experiments to compare the performance of 60° barrier against 90° barrier
- Different sized orifices were used to simulate leaks
- Thermal radiation and blast overpressure were measured along with the thermal radiation and overpressures reflected back to the source (effect of barrier)

AIM OF WORK

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- **Investigate the effectiveness of barriers at preventing physical fire spread, radiative heat flux and blast overpressure**

WORK PLAN

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- Perform hydrogen jet releases at 200 bar horizontally towards the barrier
- Tests against a 60° barrier with three different size orifices
- Tests against a 90° barrier with three different size orifices
- A test without a barrier for comparison purposes
- Used 3.2, 6.4 and 9.5mm orifices in pipe-work (peak flows 120, 300 and 490g/s).

Simplified schematic of release system

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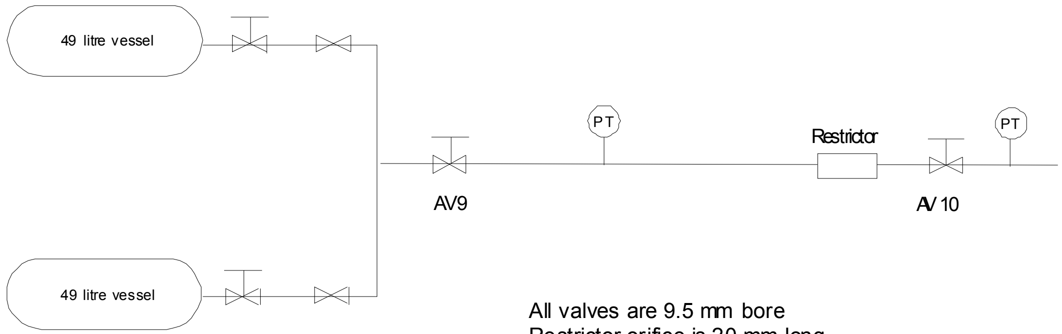

All valves are 9.5 mm bore
Restrictor orifice is 20 mm long
Tubing internal diameter is 11.9 mm

Test set up and barrier construction

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- Ignition position 2 m from release point and at a height of 1.2 m – 800ms delay after release
- Jet stand off - 2.6 m and impacted at centre of barrier

- Barriers were constructed of 1.6mm steel sheet supported on a frame - dimensions were 3.0 m wide X 2.4 m high
- Anchored using a 1 tonne concrete block

Photo of 60° barrier

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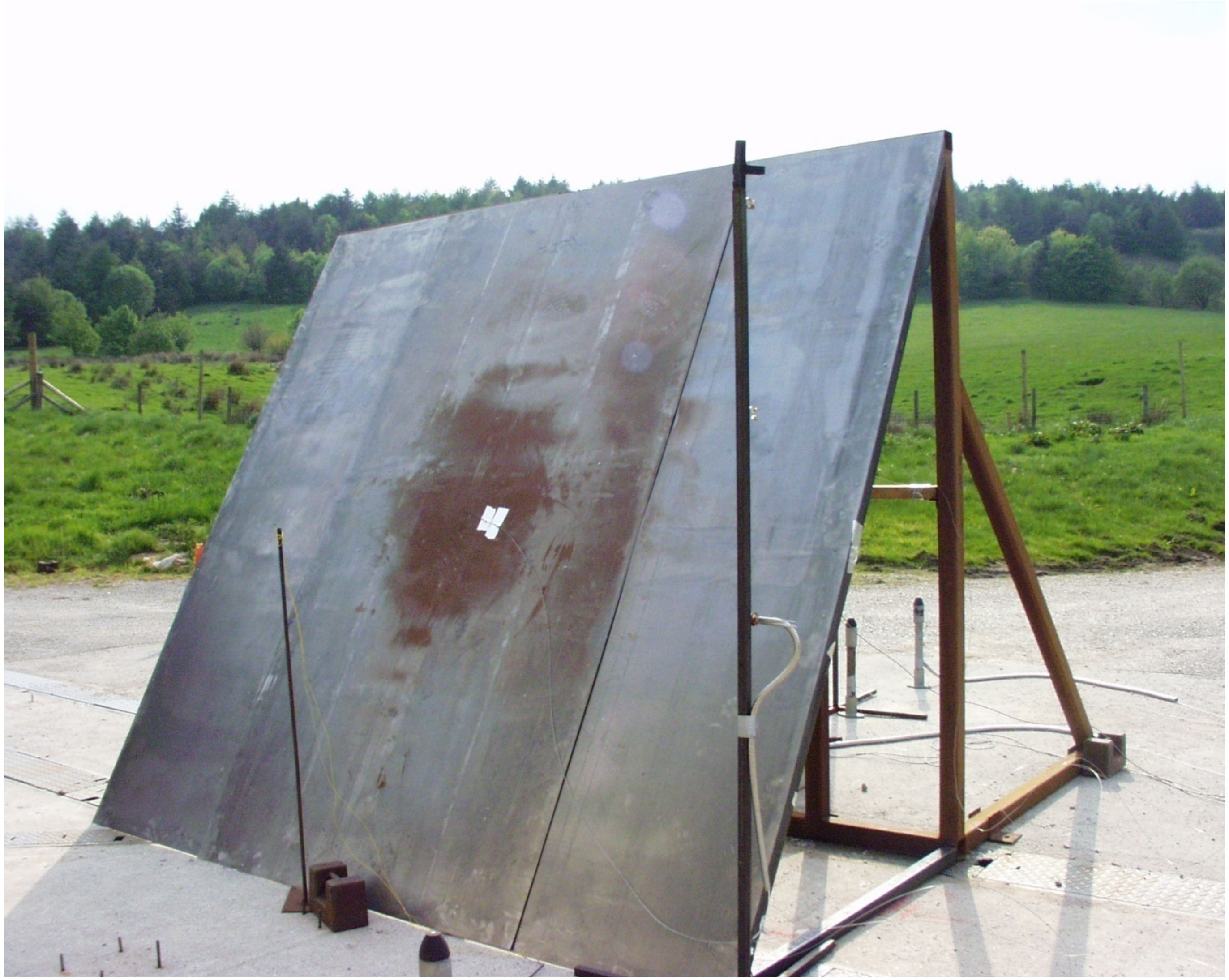

Photo of 90° barrier

Instrumentation and locations

- Pressure sensors 150kHz piezo resistive types with shielded diaphragms used to measure overpressure
- Located in front, behind and directly opposite the barriers at a height of 500 mm.
- Fast response elipsoidal radiometers used to measure heat flux
- Located to the side, top and behind barriers

Sensor positions - 60° barrier

Pressure sensors in front of 60 ° barrier and relative to wall

Radiometer at side of barrier

Sensor positions - 60° barrier

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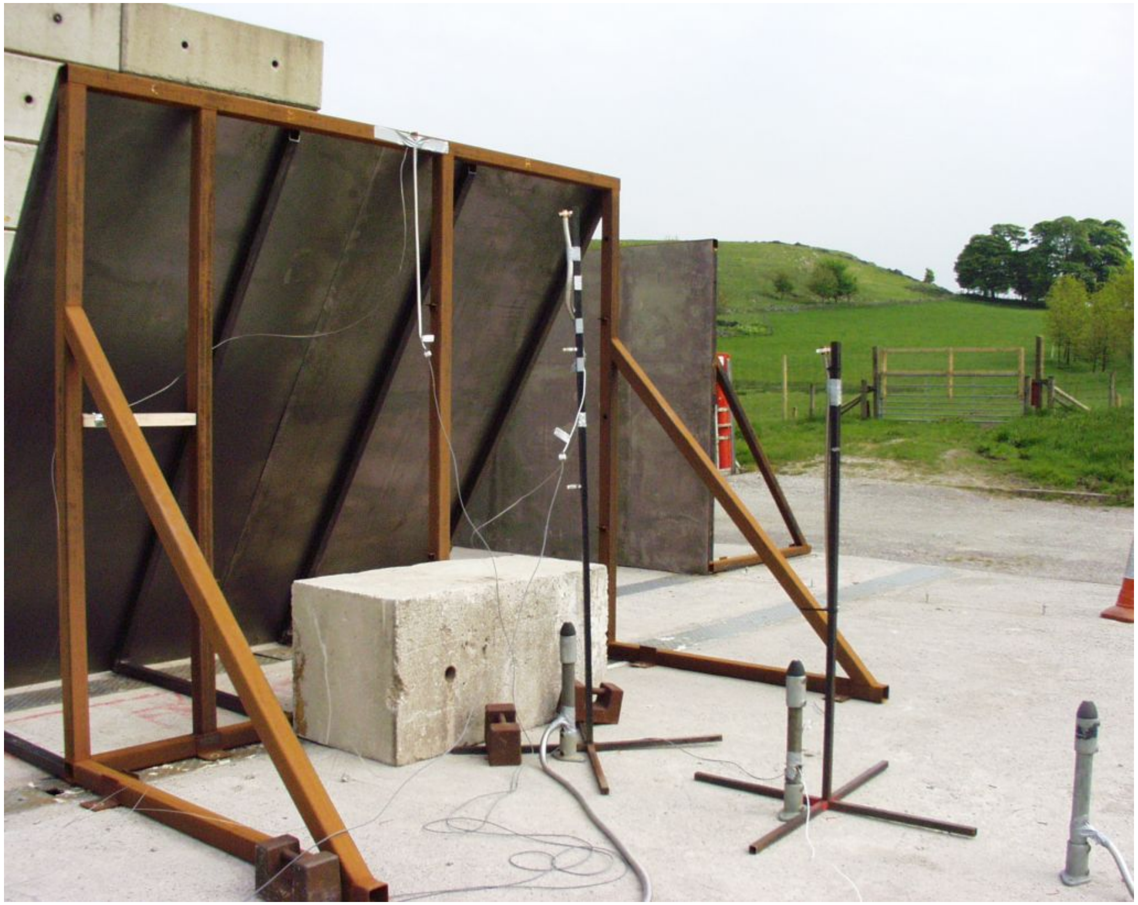

Pressure sensors at back of barrier

Radiometers at top and behind barrier

Sensor positions - 90° barrier

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Pressure sensor and radiometer locations relative to 90° barrier and wall

Free jet sensor positions

- Overpressure and heat flux measurements were made on a free jet for comparison purposes
- Same locations as with barrier for overpressures
- Two heat flux sensors deployed - One at 2.6m and one at 5.2m from release point and 1.5m from jet centre line (equivalent positions to barrier set up)

RESULTS

- Just look at results from 9.5mm orifice (peak flow rate 490g/s)
- Pressure in bar
- Heat flux in kW/m^2

Comparison of maximum overpressures - between barriers

	90° barrier	60° barrier	Without barrier
Wall	0.422	0.572	0.165
Ground	0.224	0.288	0.239

Max overpressure was recorded in the wall with 60 °barrier
Pressure readings on the ground were all very similar

Comparison of maximum overpressures - front and behind barrier

	60° barrier	90° barrier	Without barrier
Front	0.288	0.222	0.239*
Behind	0.094	0.089	0.239*

*No barrier present but equivalent location of sensor

Overpressures in front and behind were very similar for both barriers

Heat flux comparison between barriers (kW/m²)

Heat flux sensor	Free Jet	60° barrier	90° barrier
HF1 (1m behind barrier 2m high)	65.8	27.8	9.05
HF2(Centre right of barrier level with impact point)		60.1	125.7
HF3 (top centre of barrier)	68.5	84.9	32.3
HF4 (2m behind barrier 1.5 m high)		11.6	5.4

Reduction in heat flux behind both barriers when compared to free jet

The 90° barrier deflects more heat sideways – the 60° barrier deflects more over the top

Comparison between 60° and 90° barriers

- 60° barrier results in more heat flux being transmitted behind and around the barrier than the 90 ° barrier (up to 3 times more)
- A 60° barrier results in less heat flux reflected back to the leak source than the 90° barrier
- 90° barrier results in more heat flux in front of barrier - twice the magnitude of that for the 60° barrier
- Overpressures measured for the 60° and the 90 ° barrier were comparable

Effect of barriers

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- Barriers can create turbulence which results in higher overpressure in front of the barrier
- Immediately behind the barrier overpressures were significantly reduced
- The highest overpressure recorded was on the wall as a result of the reflected blast wave from the barrier
- Both 60° and 90° barriers give a significant reduction in heat flux at similar distances from the release point when compared with a free jet.
- Barriers prevent physical transport of fire

CONCLUSIONS

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- **Barriers are effective in preventing physical fire spread, reducing thermal radiation and overpressures behind the barrier**
- **Barriers do however increase the reflected overpressures in front of the barrier when compared to a free jet**
- **Barriers could result in more thermal radiation being deflected back to the source leak**
- **A 60° barrier would seem to offer few advantages over a 90° barrier in terms of reducing safety distances**

60° barrier video 3.2 mm orifice

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60° barrier video 9.5mm orifice

90° barrier video 3.2 mm orifice

90° barrier video 9.5mm orifice