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# RISE Fire Research

**Invitation to blind-prediction benchmark exercise on jet fires**



## Task 2.1 – Hydrogen jet fire tests

- Nov/Dec 2018 – Preliminary tests
- April 2019 – Prepare details of test setup for blind prediction study of enclosed jet fire tests
- Oct 2019 – Receive results from blind prediction study
- Oct/Nov 2019 – Jet fire tests in enclosure

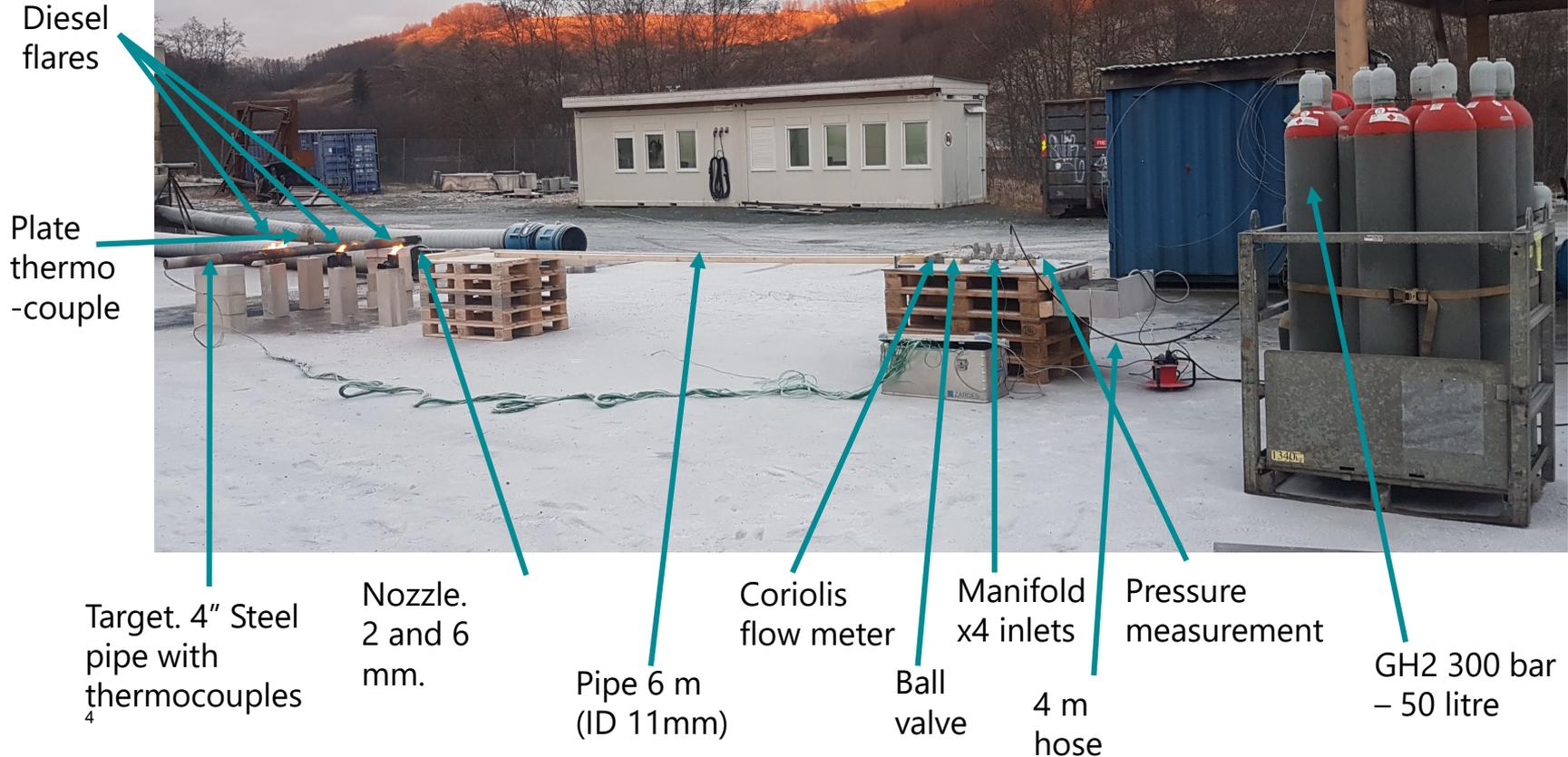


# Preliminary tests

- Open jet fire tests
- Steel pipe impinged by jet
- 300 bar bottles.
- 50 liter
- 1 – 24 bottles at the same time
- Transient release pressure

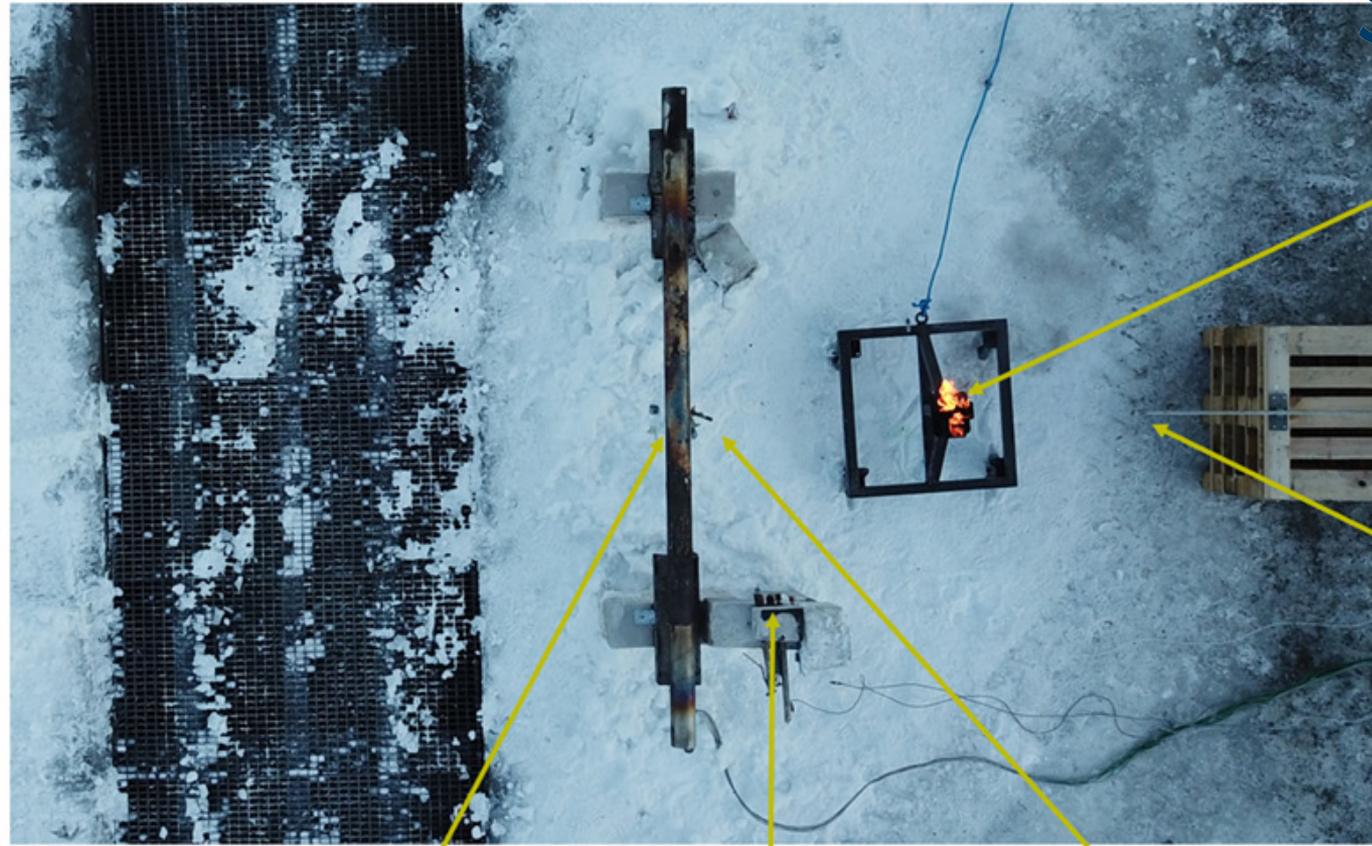


# Test setup – Preliminary tests



4m 3m 2m 1m

3m 2m 1m



Removeable diesel flare

Nozzle. 2 and 6 mm.

Target. 4" Steel pipe with thermocouples

Radiometers and total heat flux meters

Gas temperature measurement

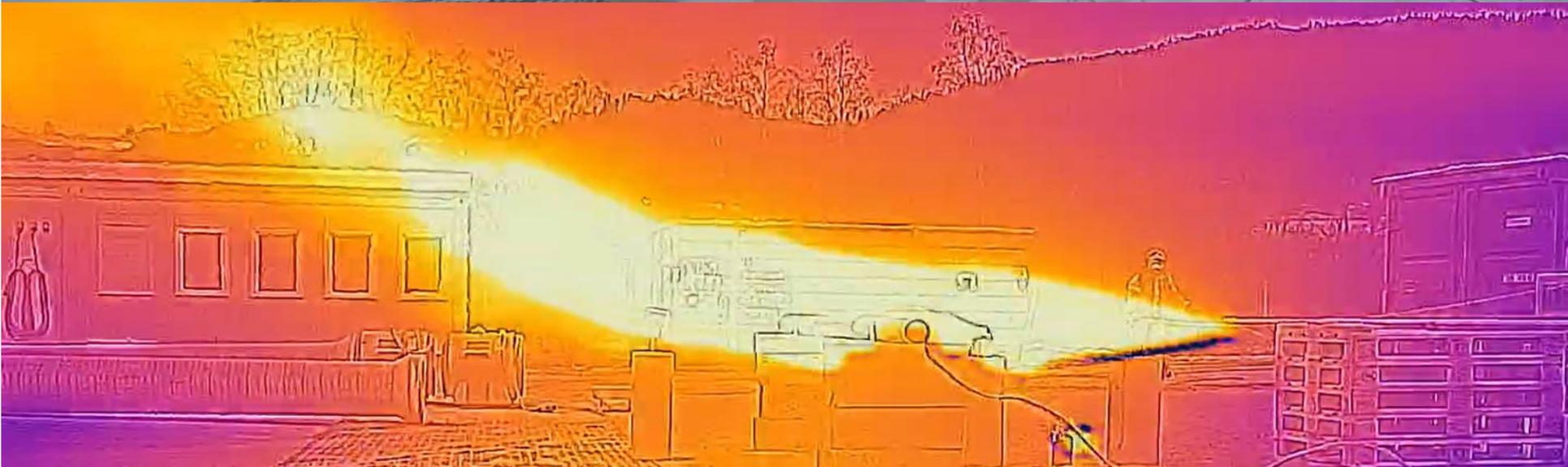
Test #	T1	T2	T3	T4	T5	T6	T7	T8
Date	22.11. 2018	22.11. 2018	22.11. 2018	22.11. 2018	13.12. 2018	13.12. 2018	13.12. 2018	13.12. 2018
H <sub>2</sub> reservoir	Manifold	1 x 50 l	Manifold	1 x 50 l	2 x 50 l	2 x 50 l	2 x 12 x 50 l	4 x 50 l
Initial pressure - bar	245	244	238	261	252	253	269	254
Ø Nozzle - mm	2	2	6	6	6	2	2	6
Ambient temp - °C	-2	-2	-1	-2	-13	-12	-12	-11
Relative humidity -%	98	98	98	98	83	83	83	83
Wind - m/s / heading	Low / S	Low / S	Low / S	Low / S	1.7 / WSW	1.7 / W	1.7 / WSW	1.7 / WSW

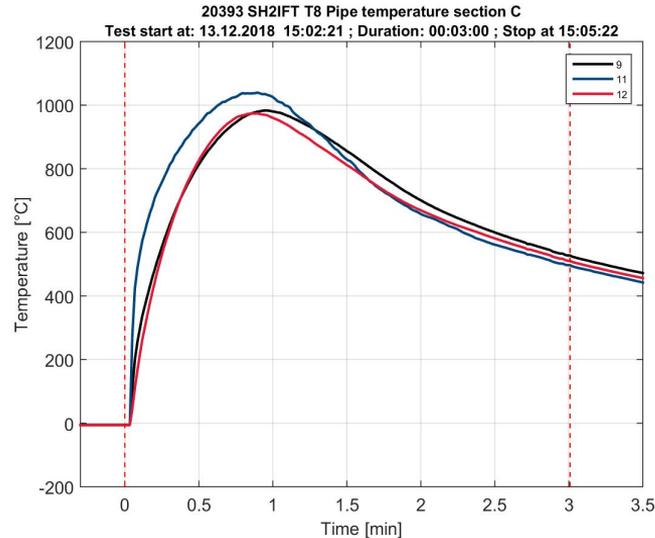
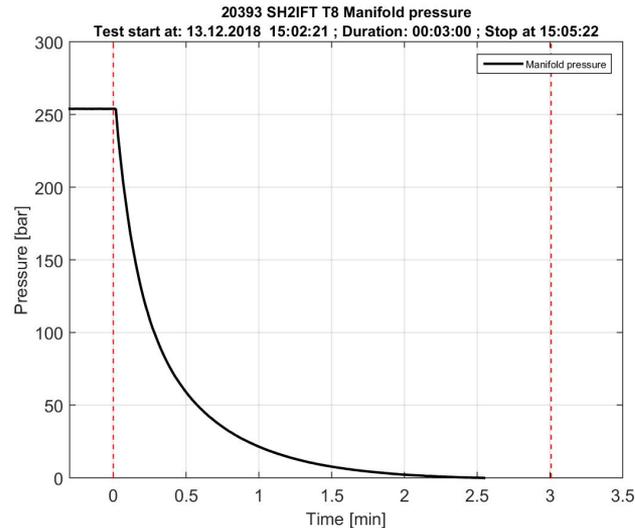
Test #	T2	T4	T5	T6	T7	T8
Maximum flow – kg/min	2.1	4.1	6.9	2.8	3.2	8.7
Accumulated flow measured - kg	0.97	1.27	1.92	2.21	26.4	4.38
Accumulated flow in 2 minutes - kg	0.96	1.27	1.92	1.92	5.20	4.31
Time to pressure < 50% of initial - seconds	11	1	4	22	288	12
Maximum measured target pipe temperature - °C	666	784	1004	1030	>1370*	>1039 *
Flame length maximum - m	Ca 6	Ca 8	Ca 8	Ca 7	Ca 8	>8 **

\* Target pipe thermocouple destroyed during test 7.

\*\* Flame reached outside IR image range

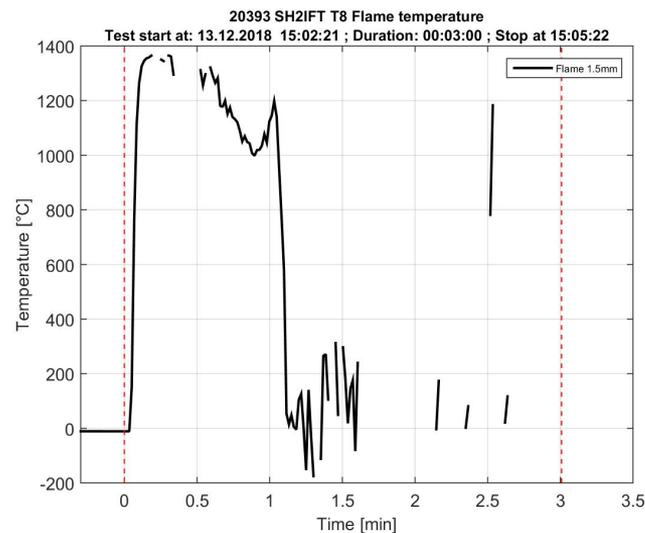
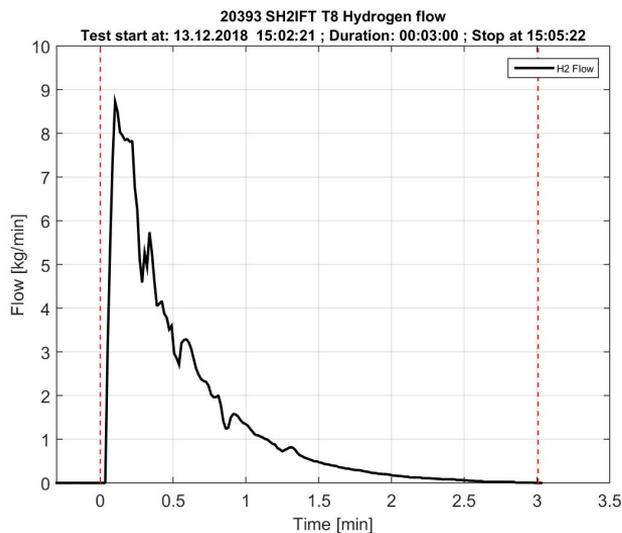
## Test 2 – Optical and infrared image





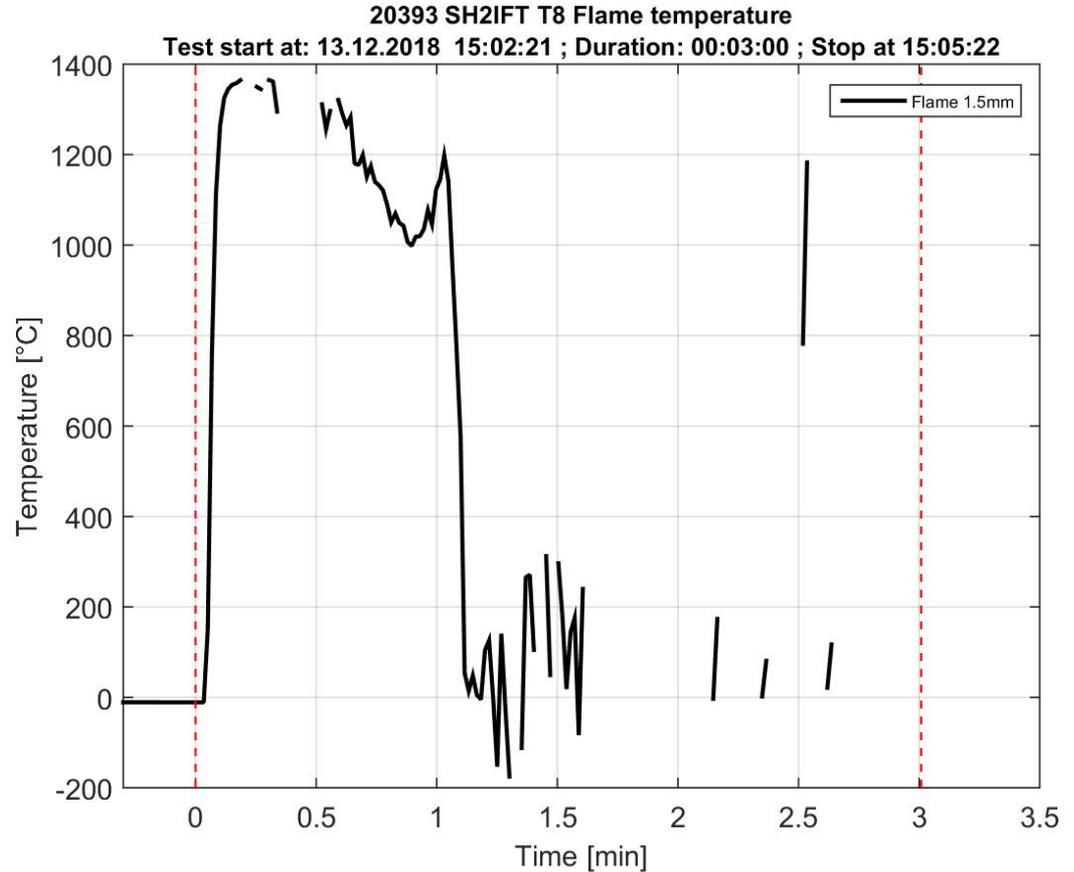
## Test 8

- 4 x 50 liter
- 254 bar
- 6 mm nozzle
- 4.4 kg H<sub>2</sub>
- 8.7 kg/min
- > 8 m flame length



# Gas temperature

- Measured with type K thermocouple
- Centre of jet
- 2 m from nozzle
- Thermocouple peaked and was moved/destroyed by the jet in all tests.
- Indicates gas temperatures  $>1370\text{ }^{\circ}\text{C}$



# The interaction of hydrogen jet releases with walls and barriers

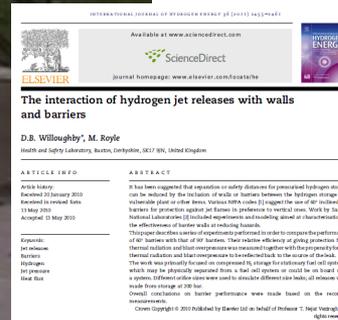
D.B. Willoughby\*, M. Royle

Health and Safety Laboratory, Buxton, Derbyshire, SK17 9JN, United Kingdom



## Enclosed hydrogen jet fire tests

- Test setup inspired by the illustrated test setup by Willoughby and Royle
- Measure the thermal exposure from the enclosed flame.
- Increase the enclosure further
- Ignited release from vehicle inside some structure



### 1. Introduction

The aim of this work is to provide data on the effectiveness of barriers with an associated indication and physical description of the flow behaviour of flames. The results could be used to inform safety decisions for hydrogen storage at fuel cell installations, being high-pressure, released normally, the effectiveness of barriers at preventing physical fire spread, reducing flame flux and heat exposure were investigated. The work was primarily focused on compressed hydrogen storage but compression, which may be physically represented from a fuel cell system or could be an onboard storage system.

The effectiveness of 90° and 60° barriers were investigated and compared with results from flame jets.

### 2. Test facility and setup

#### 2.1. Test facility

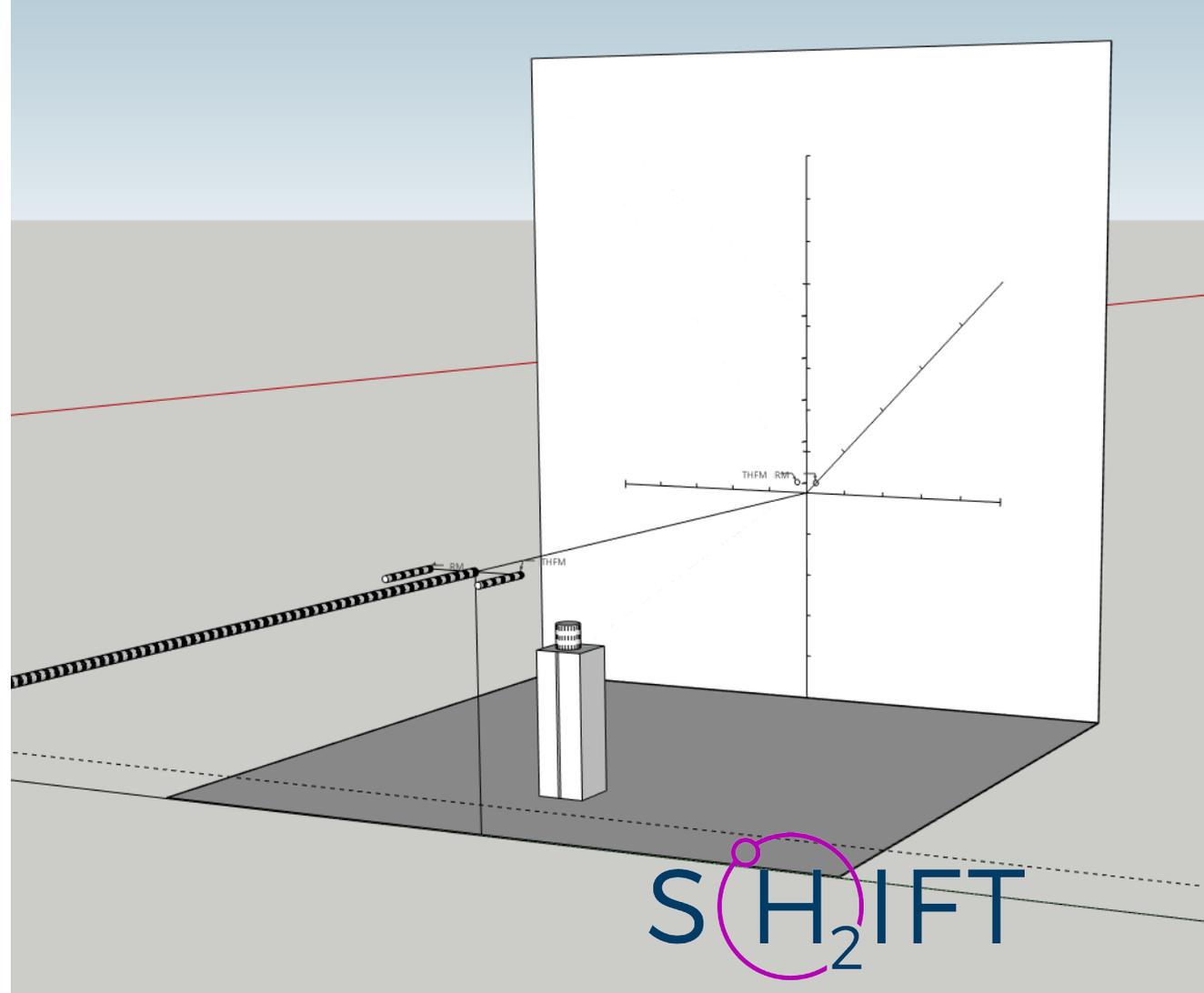
The main test facility comprised a purpose-built concrete pad, measuring 10 m × 10 m (total is 18 m × 18 m in total) pad, 3 m in diameter.

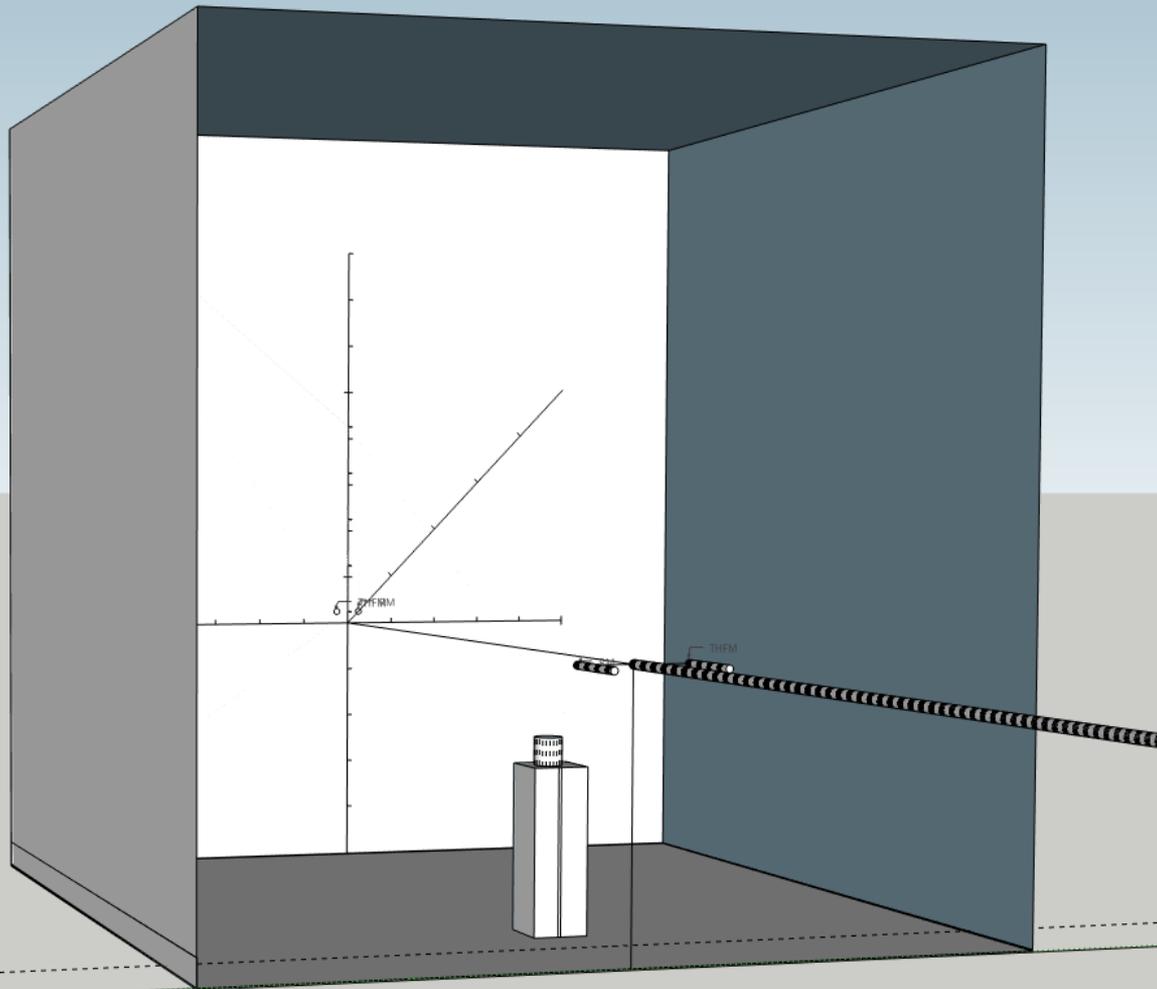
\* Corresponding author. Tel.: +44 1296 283370; fax: +44 1296 283823.  
E-mail address: d.bwilloughby@hsl.gov.uk (D.B. Willoughby).  
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# Enclosed fire tests

- Thin steel surface
- Insulated on rear side
- Impinged by horizontal hydrogen jet
  - Steel surface temperatures
  - Gas temperatures
  - Heat flux
  - Radiation
  - Velocity
  - ...



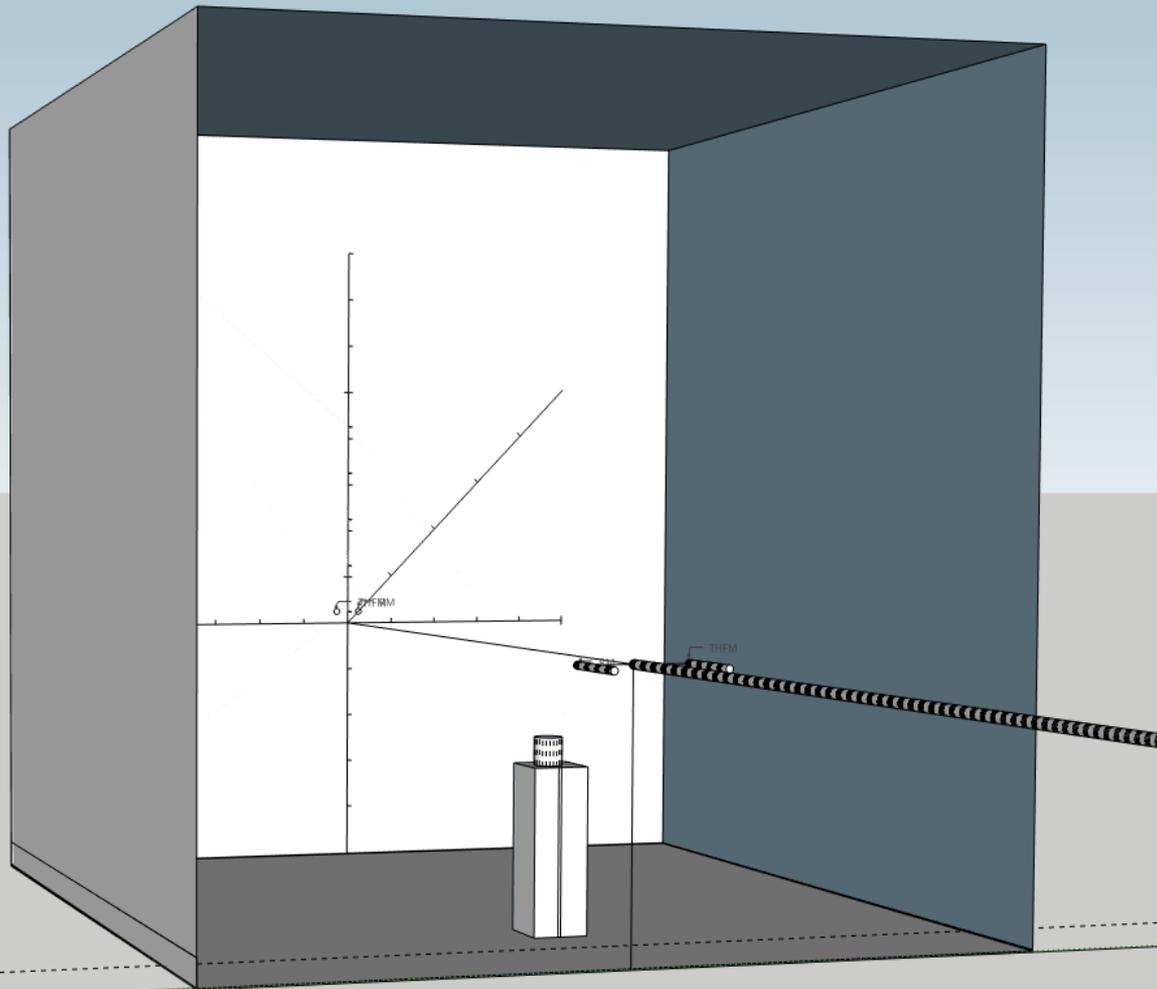


## Increased enclosure

- Add side walls and roof to the rear wall
- Repeat the same jet fire tests

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## Parameters to adjust

- Enclosure level
- Jet position / direction
- Hydrogen volume / Nozzle diameter / duration
- 300 bar / 200 bar bottles
- Fuel mixture
- Other....?

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**Reidar Stølen**

Reidar.Stolen@risefr.no

+47 402 403 47

