



The pressure peaking phenomenon for cryogenic releases

ELVHYS Dissemination Conference
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HySAFER centre, Ulster University
17 September 2026, Brussels, Belgium



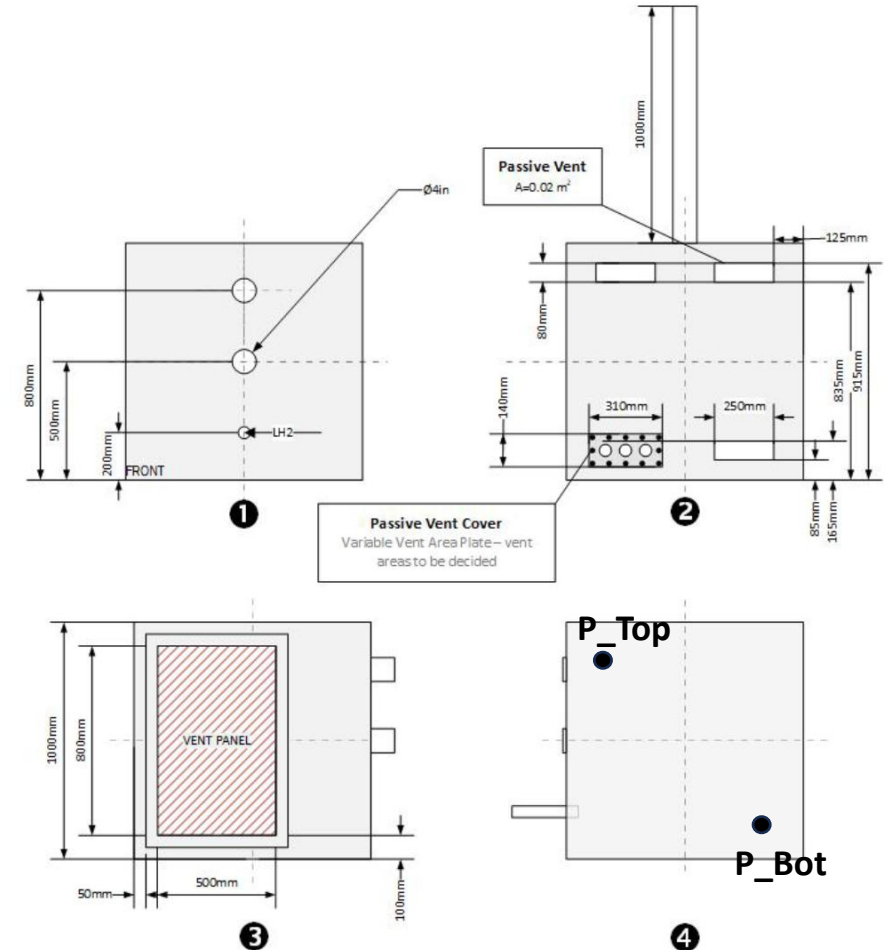
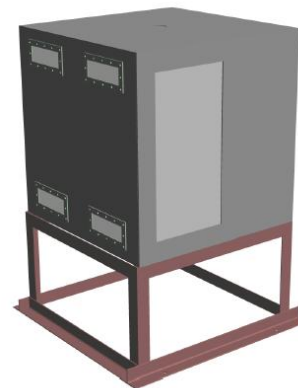
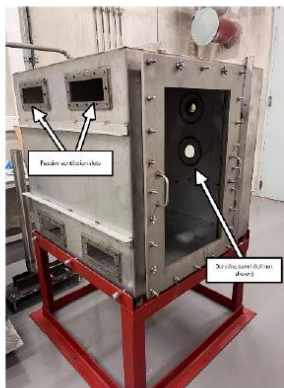
ELVHYS project No. 101101381 is supported by the Clean Hydrogen Partnership and its members. UK participants in Horizon Europe Project ELVHYS are supported by UKRI grant numbers 10063519 (University of Ulster) and 10070592 (Health and Safety Executive)

Introduction

- Releases of hydrogen gas in a confined space, e.g. hydrogen storage rooms in marine vessel, plane or rail carriages, are found to produce pressure dynamics with a distinctive peak that exceeds the steady-state release pressure level, defined as the pressure peaking phenomenon (PPP).
- The PPP was first revealed theoretically at Ulster University in 2010 (Brennan et al., 2010). The magnitude of the pressure peak depends mainly on the hydrogen release rate, enclosure vent size and volume.
- The PPP has been widely investigated for gaseous hydrogen releases at ambient temperature.
- Experiments performed in ELVHYS project demonstrated that pressure peaking can occur during unignited LH2 releases into vented enclosures.
- This study aims at investigating numerically the occurrence of the pressure peaking phenomenon for LH2 hydrogen releases and providing a validated contemporary CFD tool for the use by stakeholders.

HSE tests: experimental facility

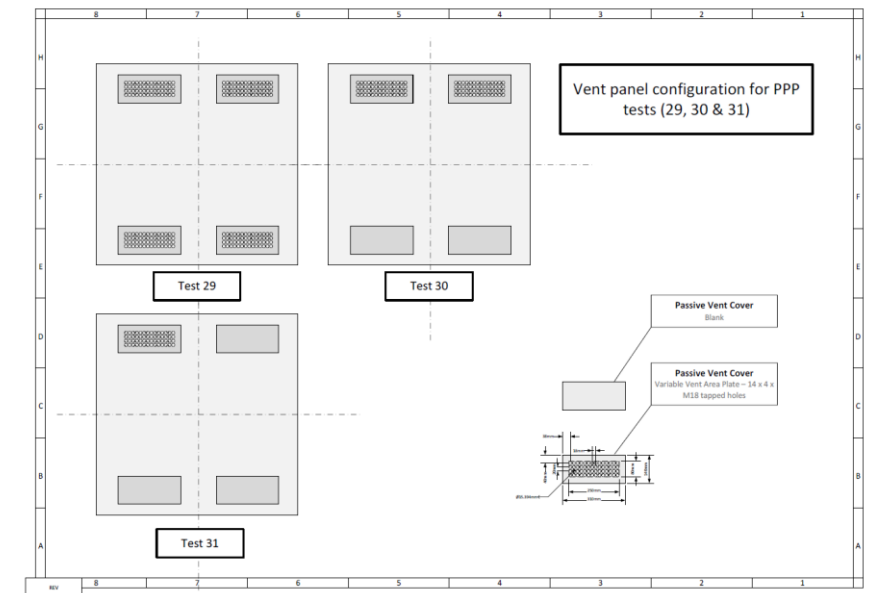
- Enclosure with volume 1 m³.
- The vent stack is removed for the PPP test.
- The vent panel is sealed.
- Four rectangular passive ventilation openings with flow area 0.01 m².
- LH2 is released horizontally at a height of 0.2 m and centre of the lateral wall.
- Overpressure is measured at two locations within the enclosure.



HSE tests: main parameters

- Three tests were performed with release nozzle 25.4 mm and variable venting area.

Case No.	29	30	31
Nozzle diameter, mm	25.4	25.4	25.4
Number of open vents	4	2	1
Initial pressure at release rig, kPa(g)	230	250	250
Ambient relative humidity, %	~99	~91	~86
Ambient temperature, K	282	274	275
Ambient pressure, Pa	~99000	~96000	~96000

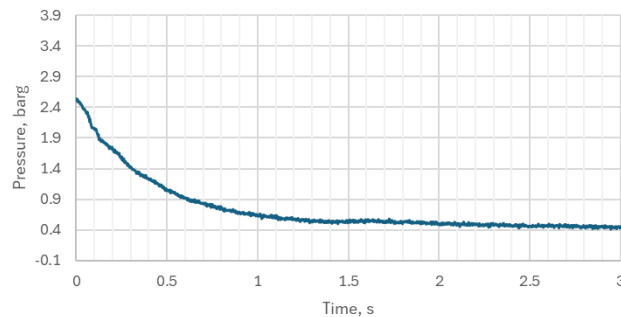


Experimental measurements

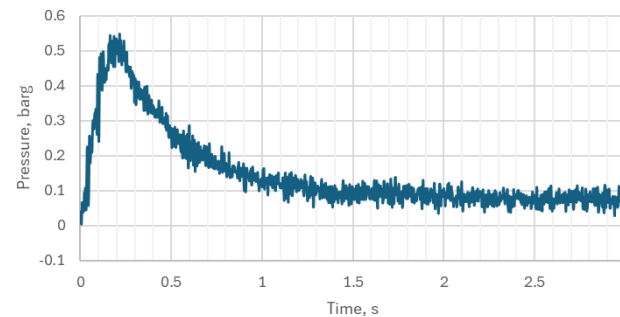
Test 31: one passive vent open

- Experimental measurements in the release system and the enclosure.
- Valve opening duration: 0.3 s.

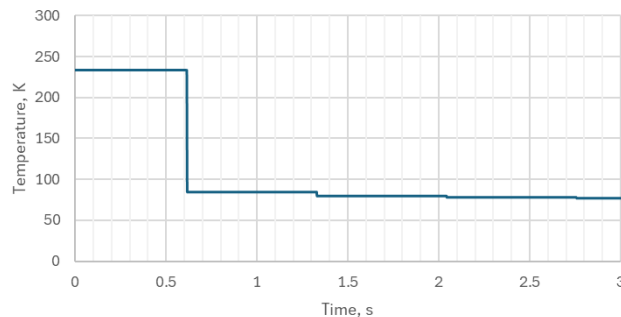
PT1 - release rig



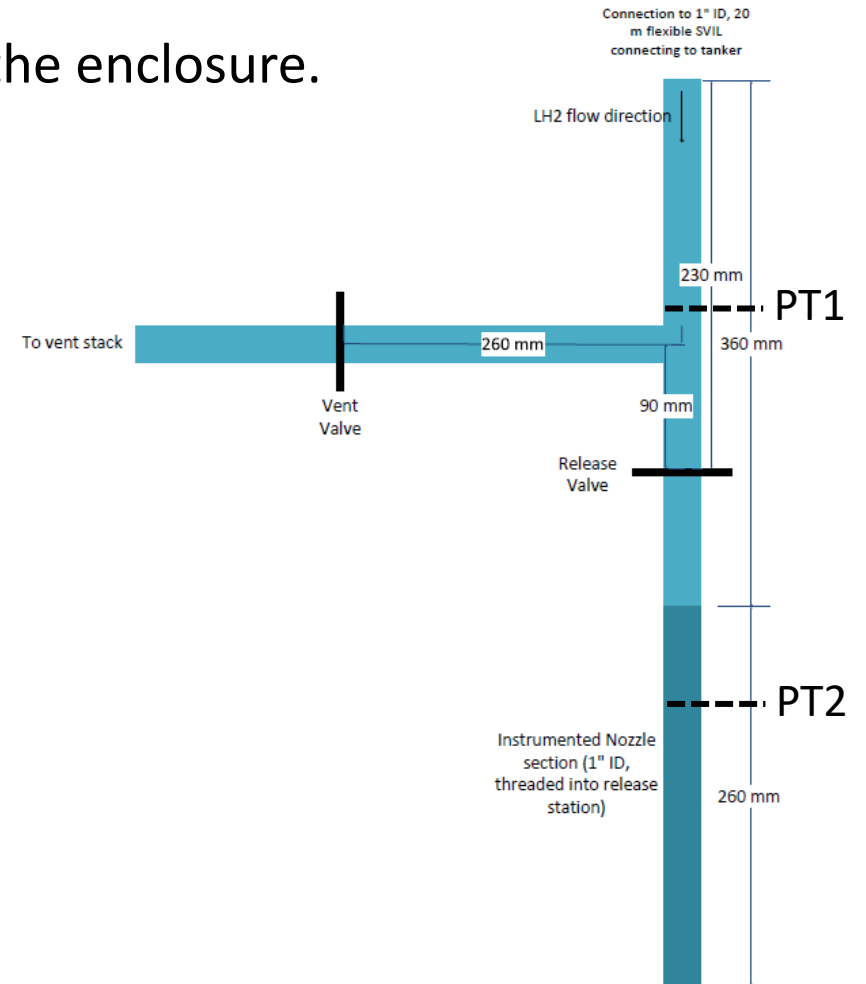
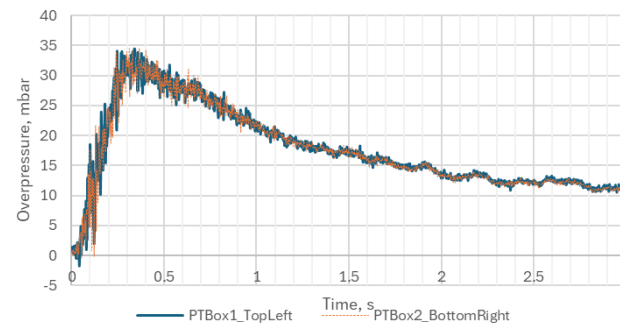
PT2 - nozzle



Temperature - nozzle

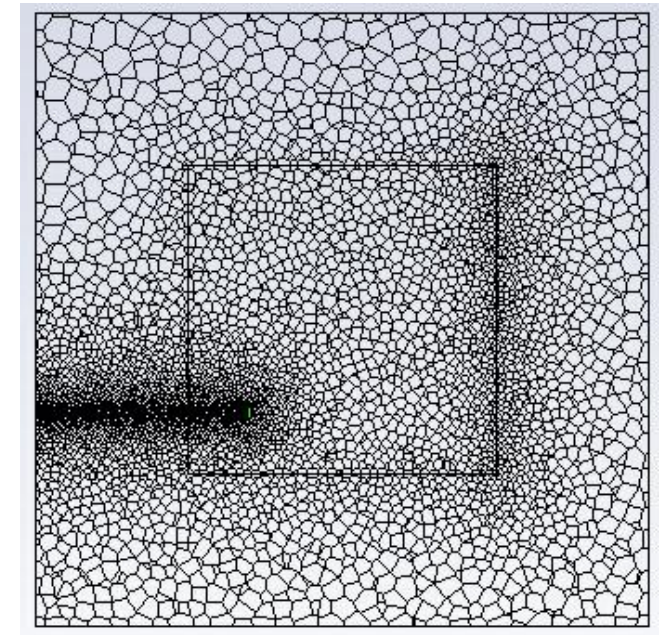
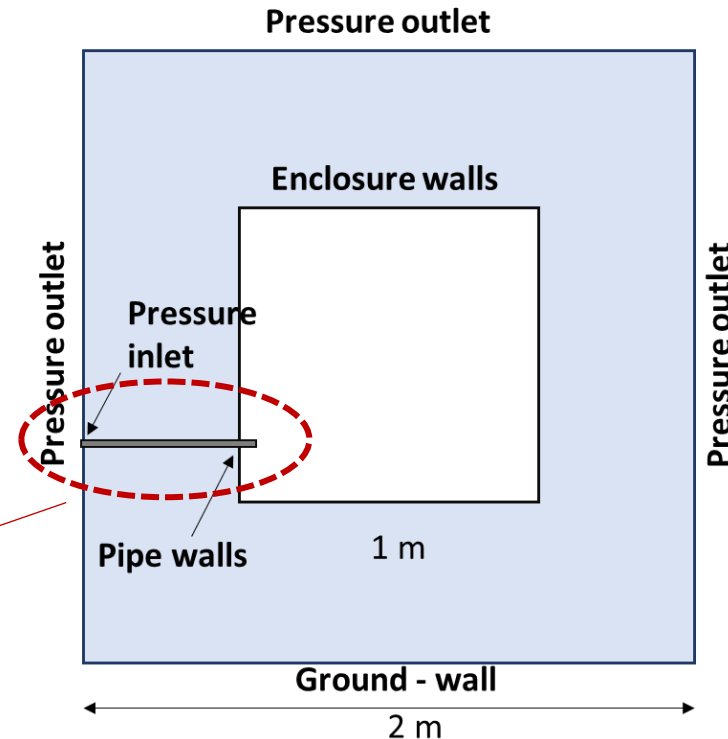
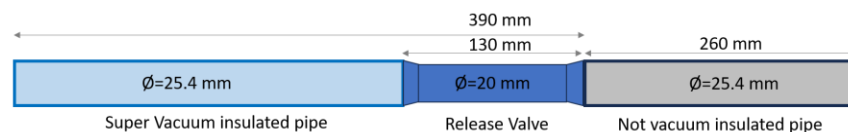


Overpressure in the enclosure



Numerical model and domain

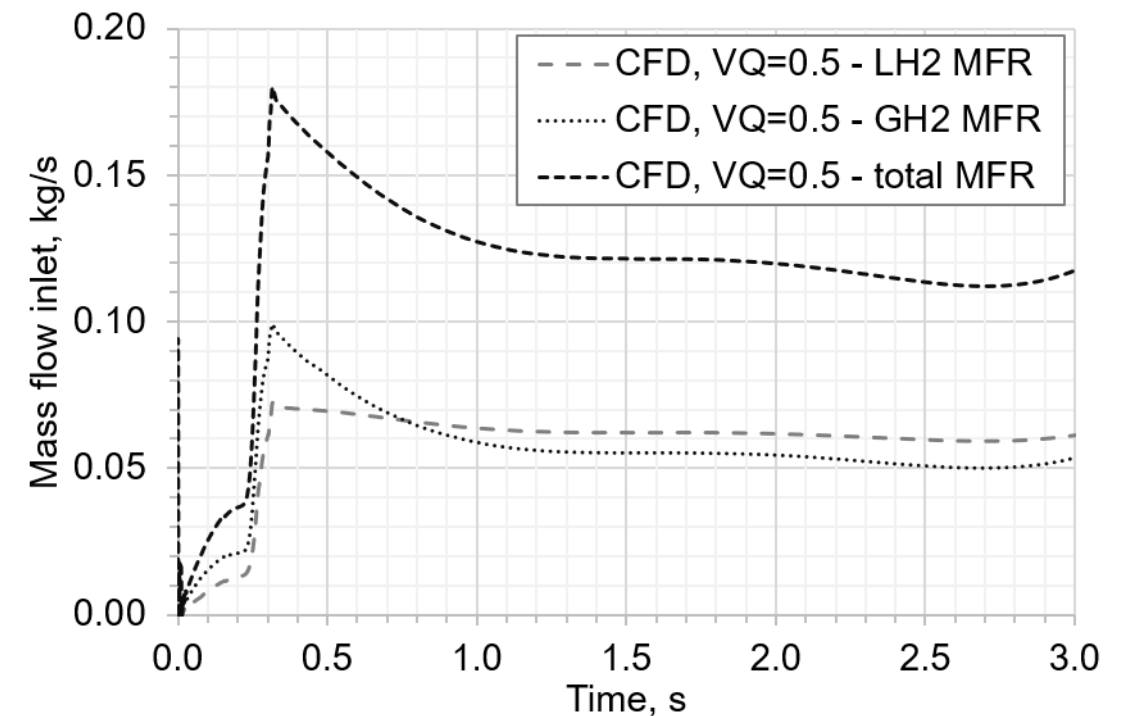
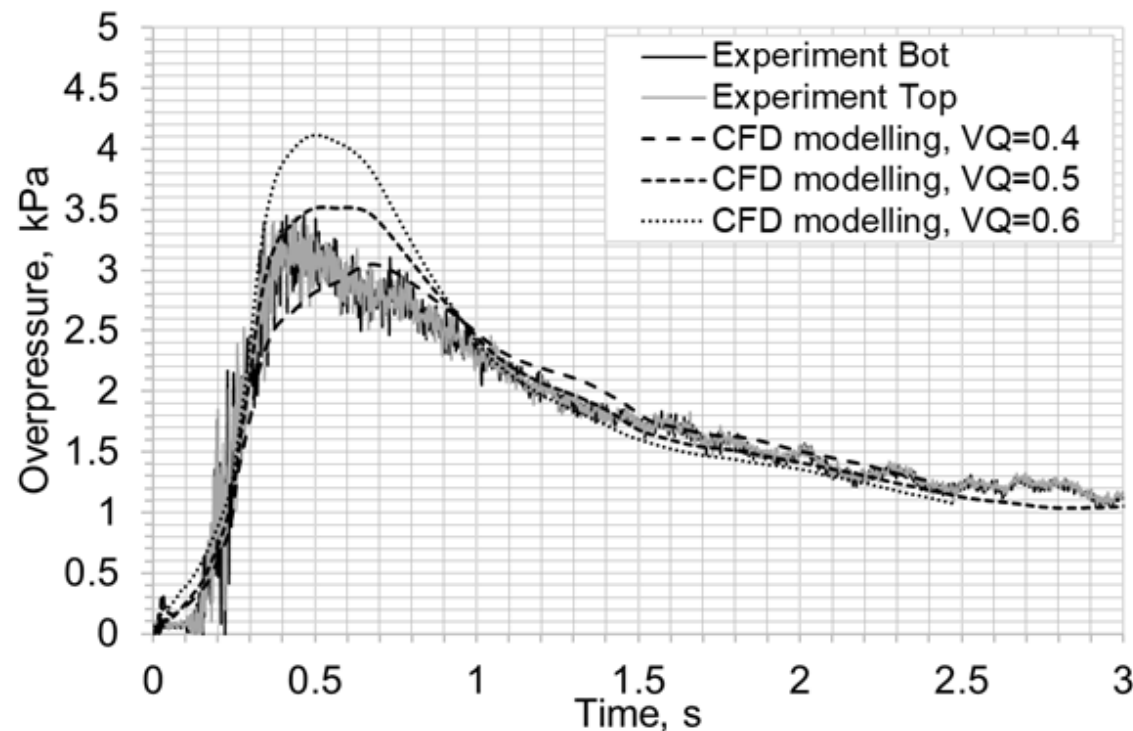
- SST κ - ω approach for turbulence modelling.
- Volume of Fluid for multiphase modelling with Lee's model for evaporation and condensation.
- The numerical domain is a polyhedral grid (200k CV). Time step equal to 0.2 ms.
- **Inclusion of flow modelling in the pipe:**
 - Inlet conditions dictated by the experimental pressure measured in the release rig.
 - Inertial opening of the release valve.



CFD results: overpressure dynamics (1/2)

Test 31: one passive vent open

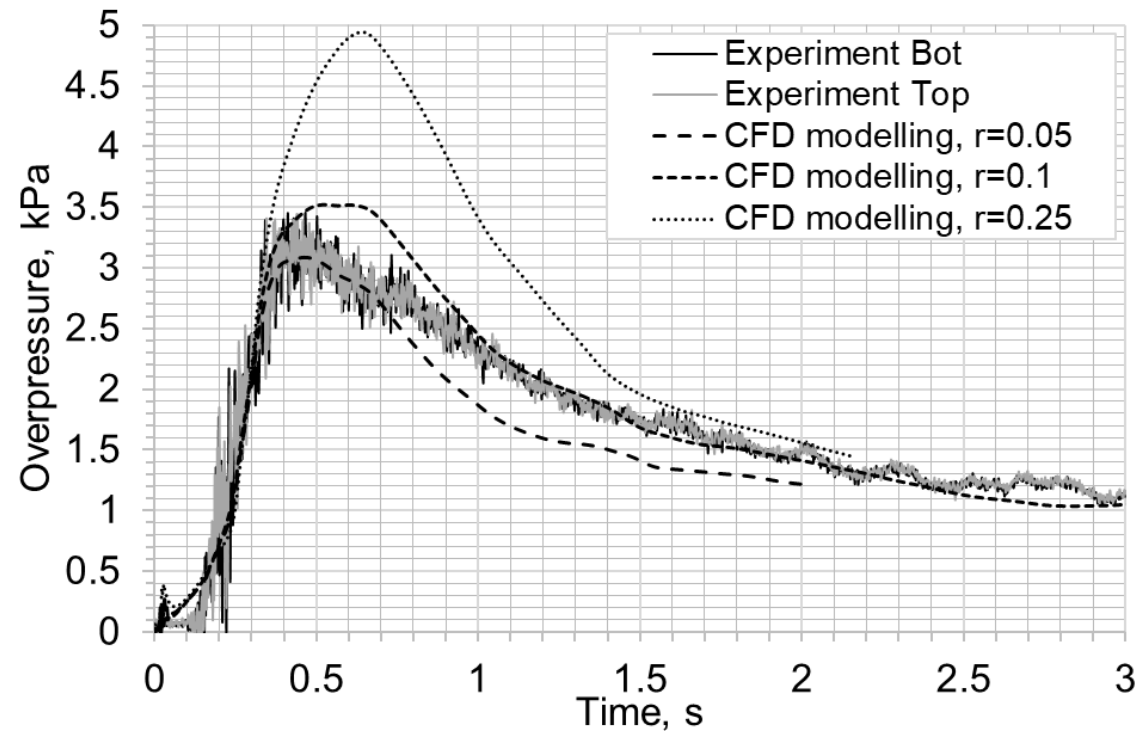
- Effect of vapour quality (VQ) at the pipe pressure inlet.
- Simulated mass flow rate for VQ=0.5 establishes to about 110-120 g/s, close to experimental mass flow rate estimated as 109 g/s.



CFD results: overpressure dynamics (2/2)

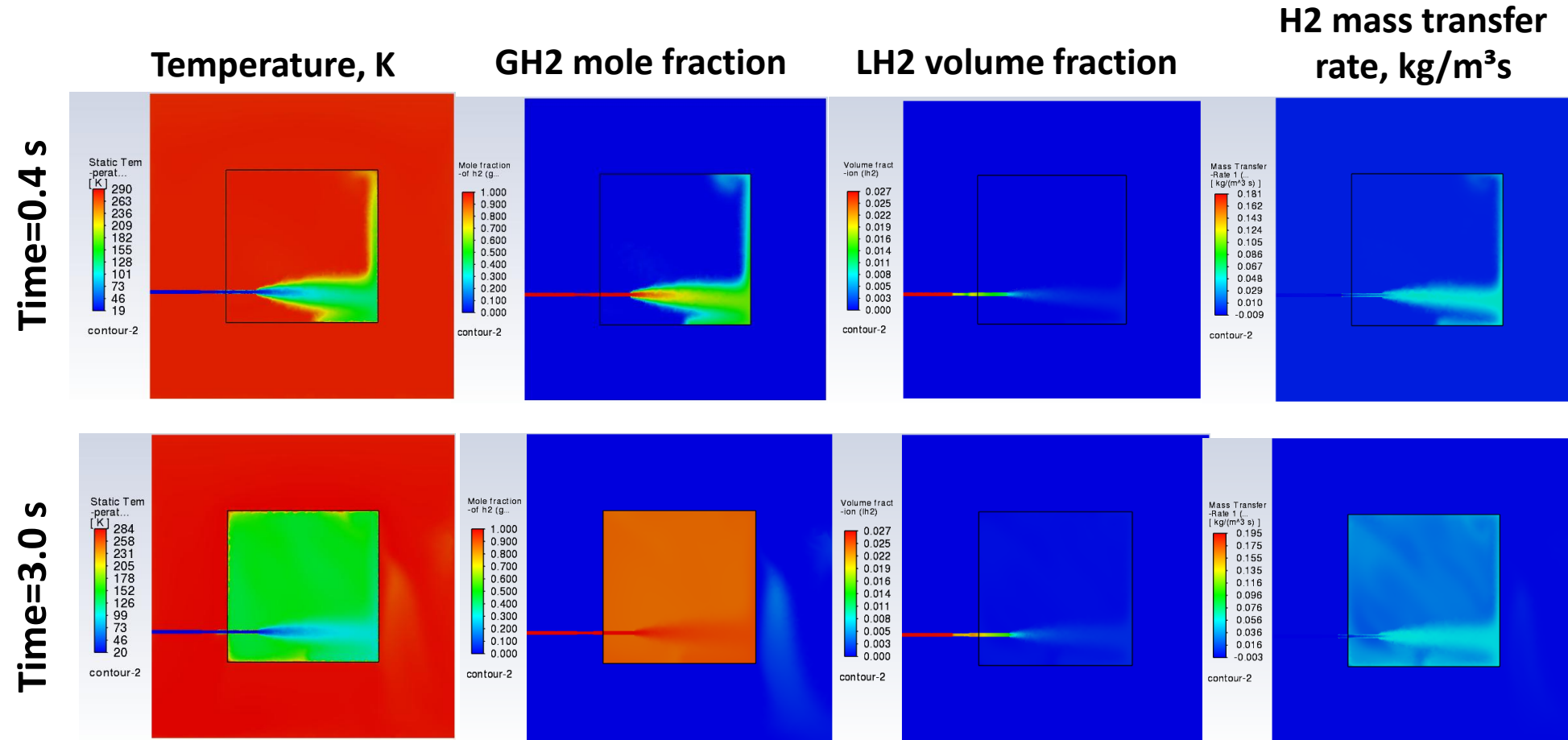
Test 31: one passive vent open

- Effect of LH2/GH2 evaporation/condensation coefficient (r) for $VQ=0.5$.
- Simulated mass flow rate is not significantly affected by given variation of r coefficient.
- Experimental overpressure is closely reproduced by a coefficient $r=0.1$.



CFD results: mass and heat transfer dynamics

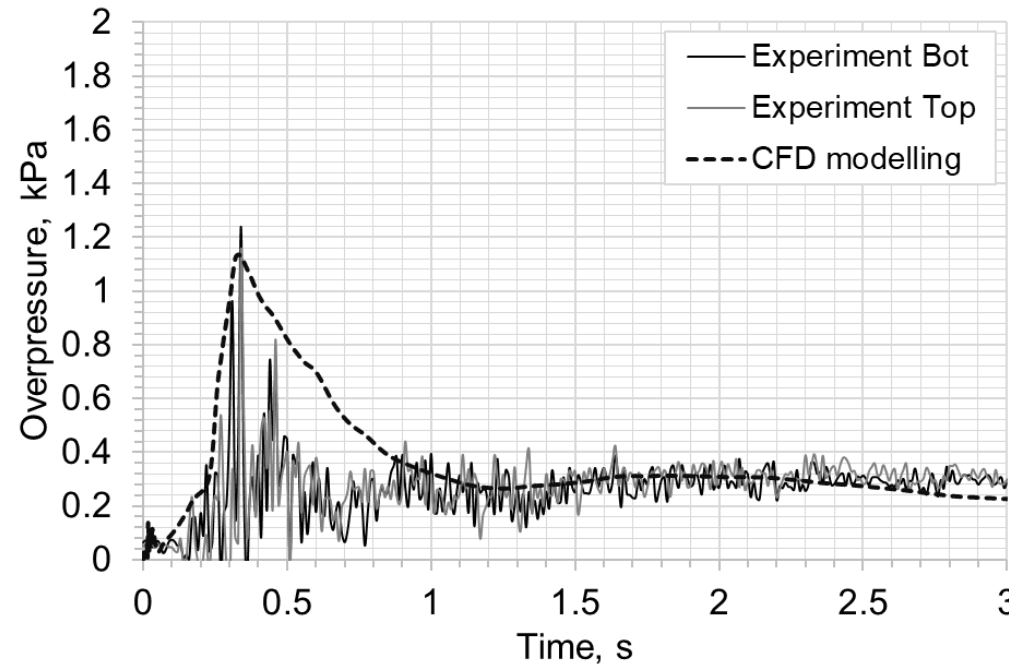
Test 31: one passive vent open



CFD results: overpressure dynamics

Test 30: two passive vents open

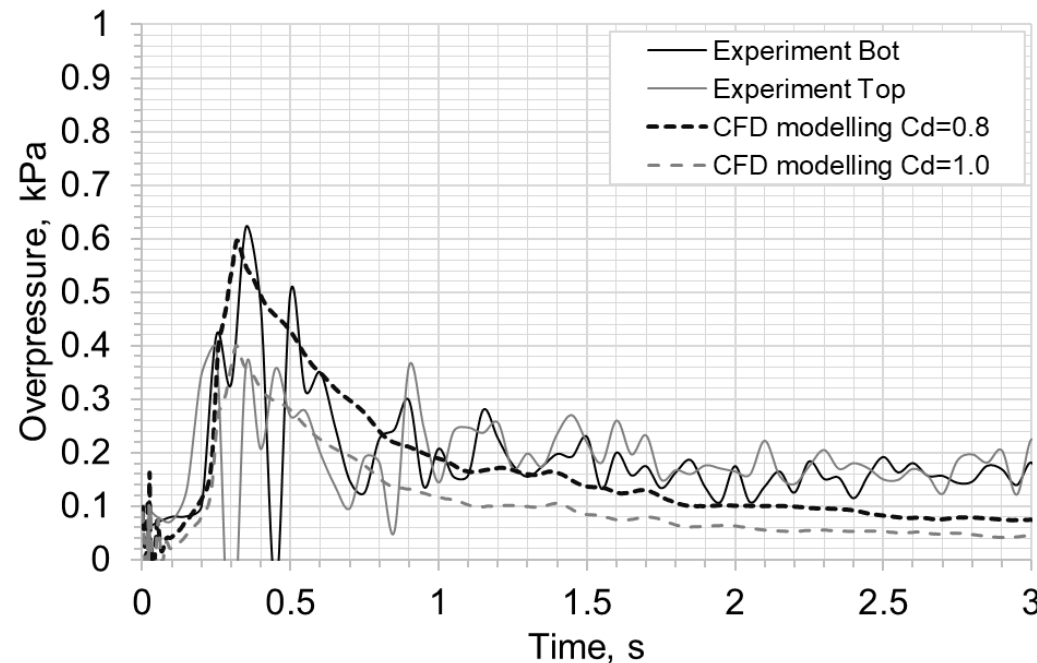
- Experimental overpressure dynamics presents a strongly oscillating behaviour.
- The smoother simulated overpressure dynamics is capable to capture the experimental overpressure peaks magnitudes up to the quasi-steady state stage.



CFD results: overpressure dynamics

Test 29: four passive vents open

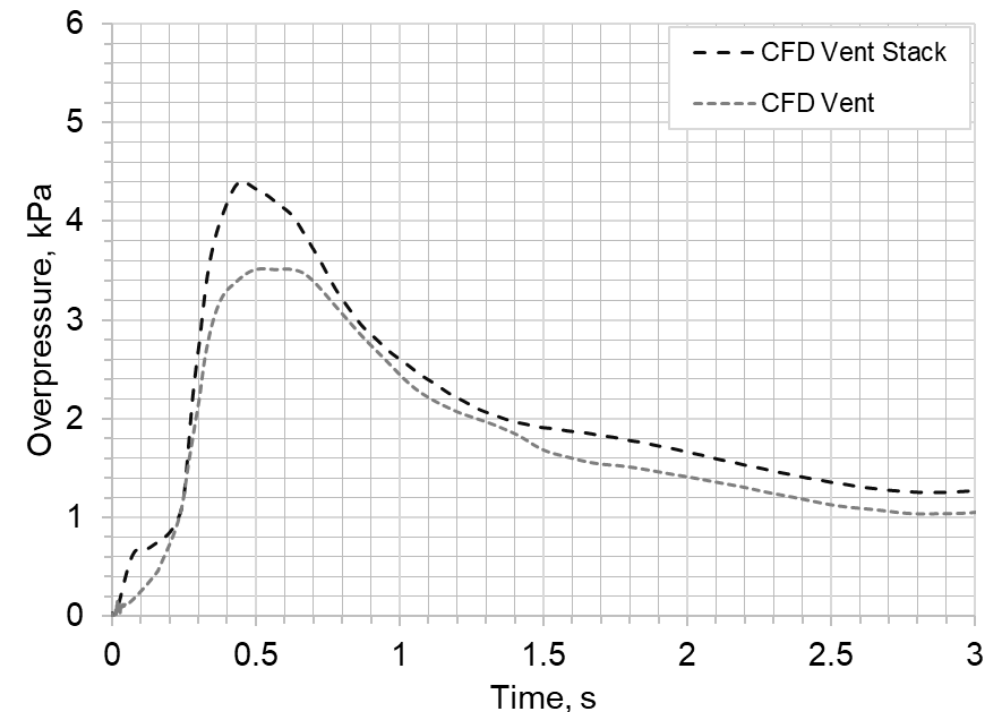
- Experimental overpressure dynamics presents a strongly oscillating behaviour and a 30% difference between the recorded maximum overpressure at the two sensors locations.
- This behaviour could be associated with the logging rate of the pressure sensors (20 Hz), which was increased for Tests 30 and 31.



CFD results: overpressure dynamics

Effect of a vent stack

- Vent stack with height 1 m and cross section equal to one passive vent area: $A_{vr} = A_{vs} = 0.01 \text{ m}^2$.
- The heat transfer and pressure losses across the vent stack line cause a reduction of the vent release efficiency, comparable to a decrease of efficient rectangular vent area into the atmosphere by a multiplier of 0.9.
- Increasing the vent height from 1 m to 3 m, resulted in an increase of overpressure peak by 72%, thus potentially resulting in a lower multiplier of efficient rectangular vent area



Conclusions and future research

- The PPP overpressure peak occurs within the first fractions of seconds from the start of the release.
- The PPP overpressure peak and dynamics is strictly dependent on the characteristics and phase composition of the multiphase flow, which can significantly vary during the initial stage of the LH2 release.
- Accurate modelling requires precise definition of experimental set-up and measurements across the entire line from a storage tank through the piping system to the atmosphere.
- Further research should be performed on advancing the understanding of two-phase flows from LH2 equipment.
- The validated CFD approach can be used as a contemporary tool for hydrogen safety engineering.



Thank you for your attention

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Co-funded by
the European Union



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