FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

PRESLHY
Safety of LH2 Storage

Online workshop on
Safe Storage of Compressed Gas Hydrogen
in road transport applications
and related infrastructure

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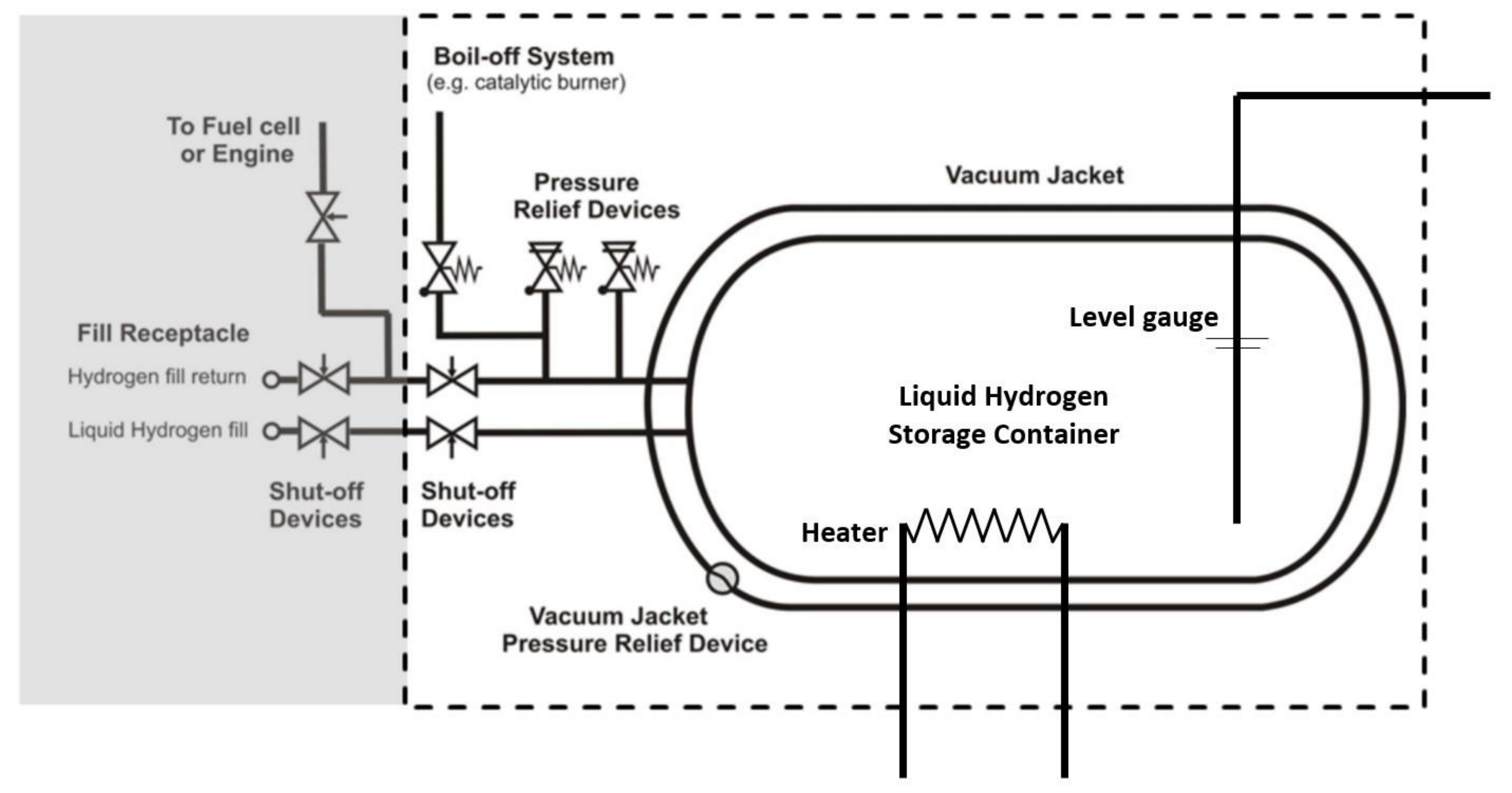
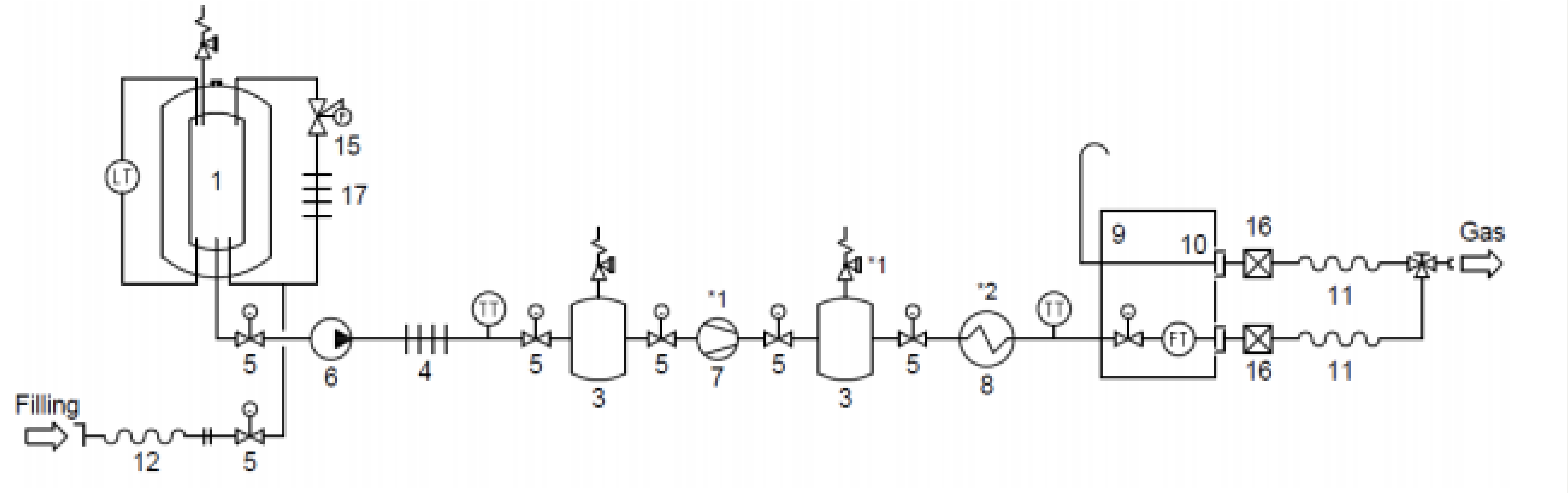
LH2 Storage



(Photo source HyCentA)

LH2 based fuelling station

LH2 based HFS (courtesy of Linde)



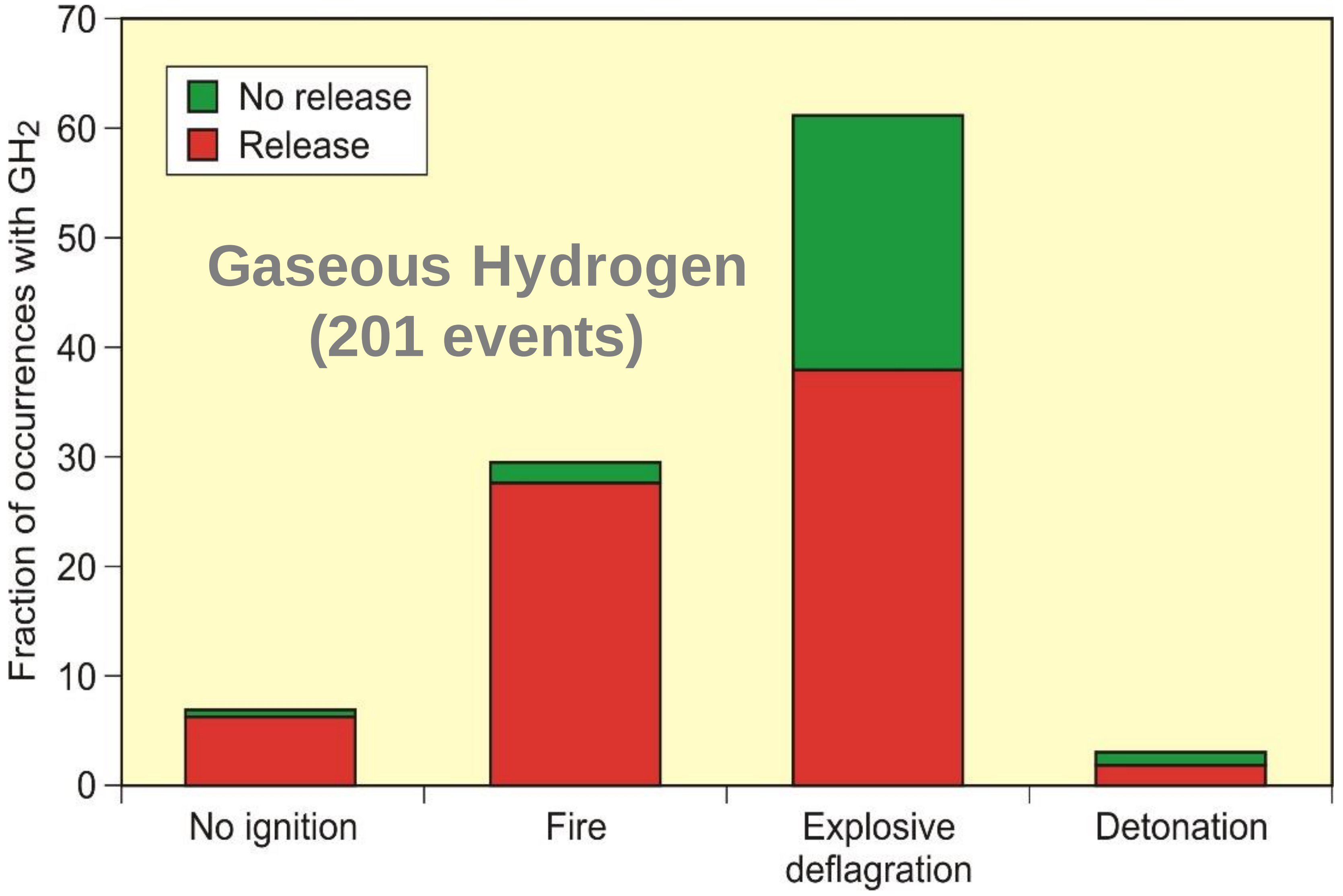
- Simpler set-up
- Smaller footprint
- Flexible supply of LH2, CCH2, CGH2
- Higher efficiencies
- Potential multiple use of cooling capacity

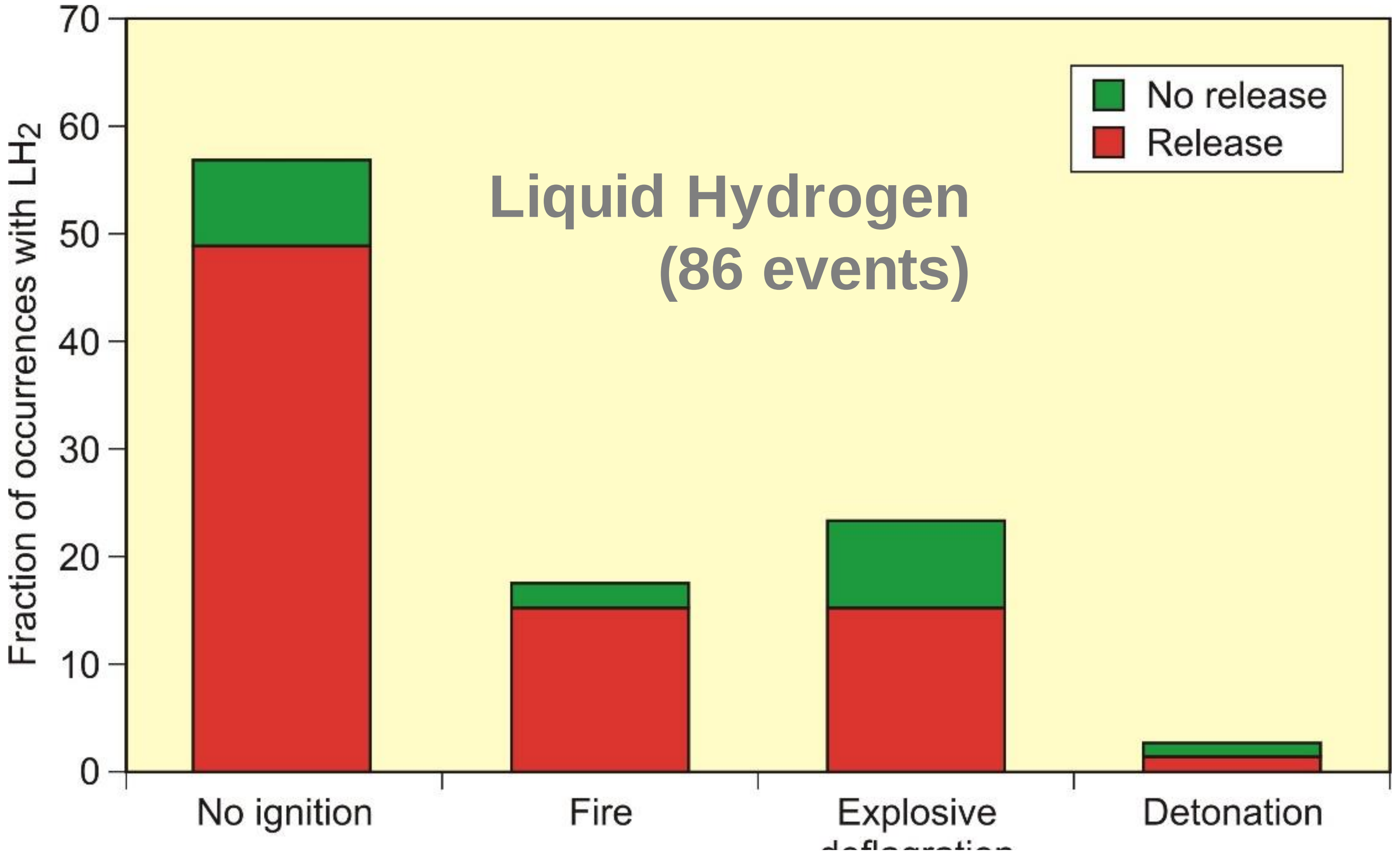
Supply of a CGH2 vs LH2 based station

LH2:

- Reduces frequencies of transport, fillings with connections and de-connections
- Reduces weight and corresponding stresses on components and infrastructure
- Reduces complexity
- Introduces cold gas venting (boil-off and flash gases)

Accident statistics





Source Kreiser 1994

Events around hydrogen road transportation

Design/Construction failure/inadequate Hazard Assessment	0 (0%)
Equipment failure	6 (33%)
Incorrect operation / procedural deficiency/poor maintenance	8 (44%)
Impact or Road Traffic Accidents RTA	3 (17%)
Contamination	0 (0%)
Natural causes/Terrorism	1 (5%)
Escalation	0 (0%)

Events around hydrogen liquefaction/storage

Liquefier/Purifier	2 (5%)
Vent system and pipework	11 (28%)
Storage vessels including fittings, valves and reliefs	14 (36%)
Valves/Components/Fittings	6 (15%)
Pumps/Compressors/Vaporizers	6 (15%)
Transfer lines/ pipelines	5 (13%)

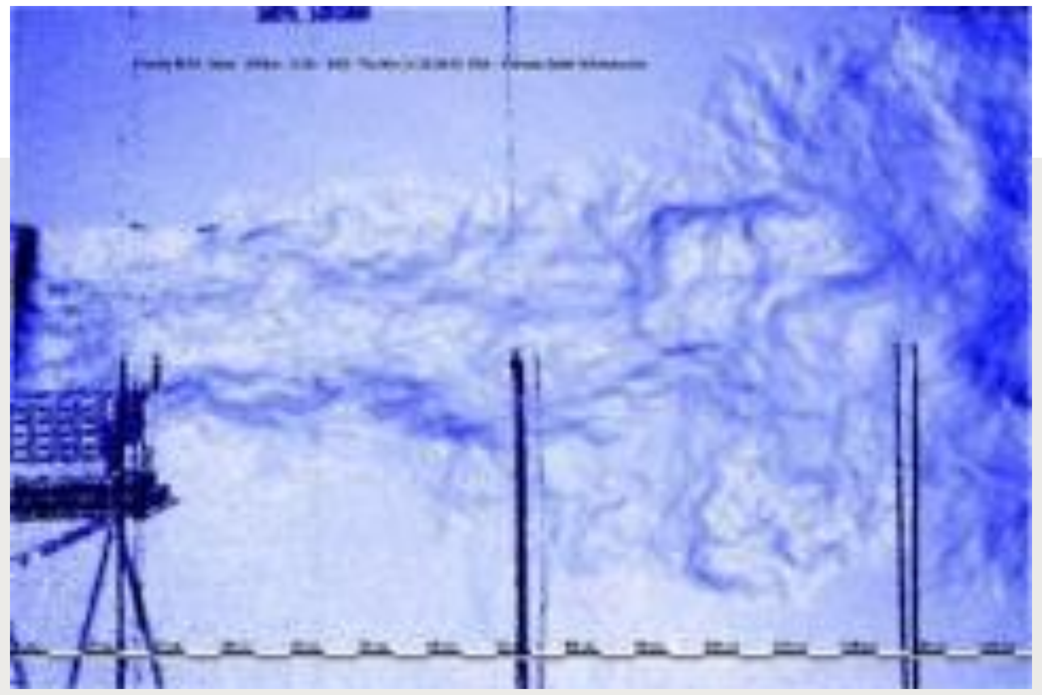
Closed Knowledge Gaps
Release

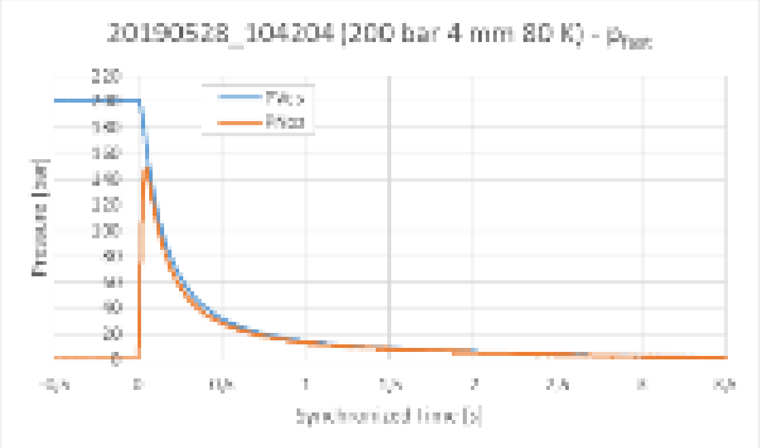
- 1 D model for multi-phase release including non-equilibrium processes

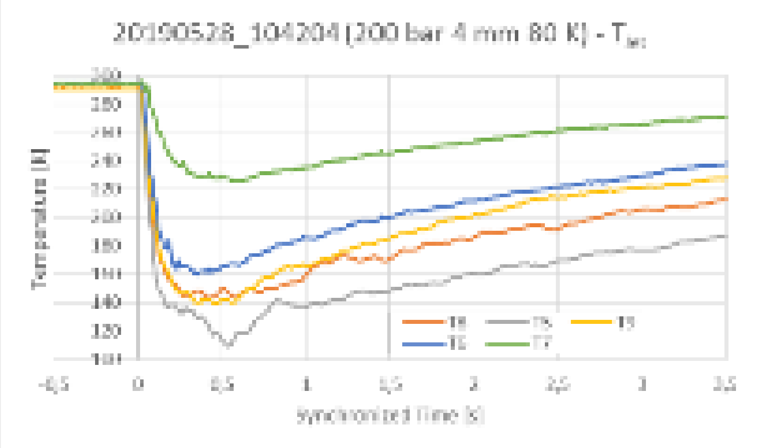
- Discharge coefficients for circular nozzles D=0.5-4 mm
  5 - 200 bar; 20 – 300K (KIT/PS E3.1 DISCHA tests)
  see https://doi.org/10.5445/IR/1000096833

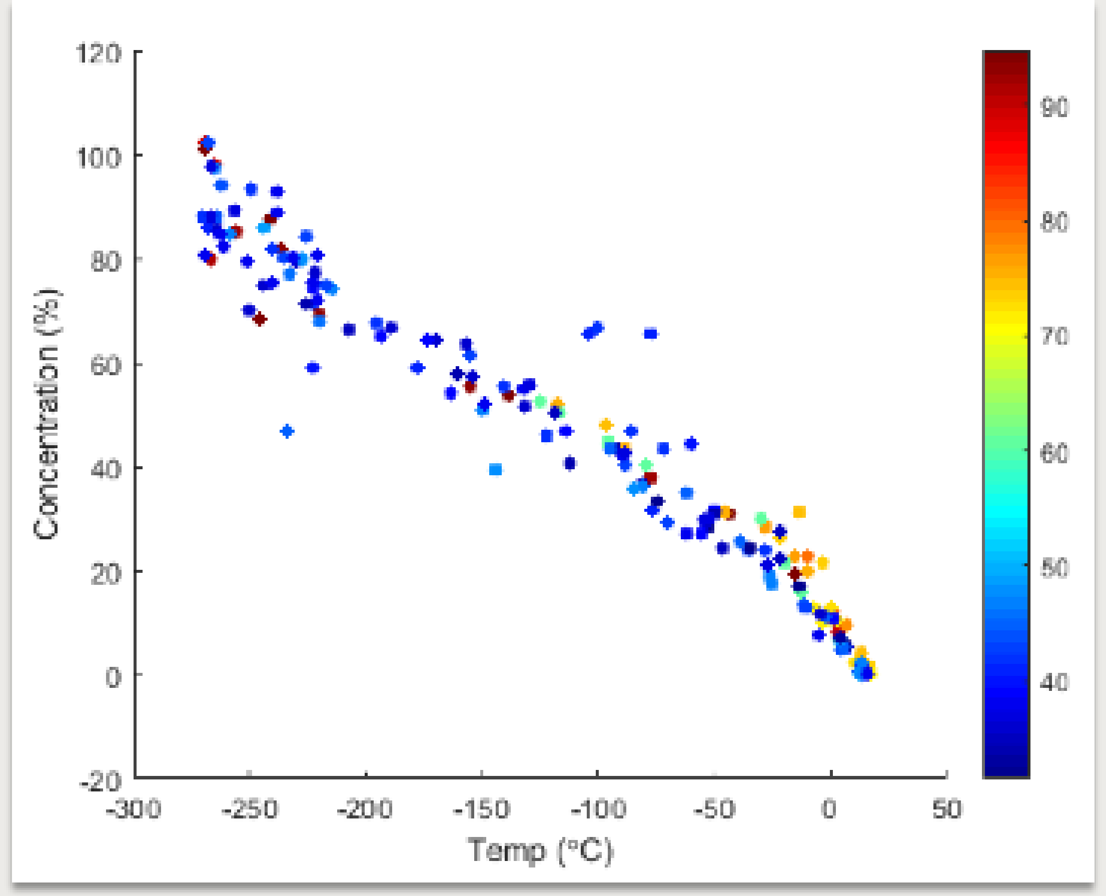
- No rainout for large scale above ground horizontal releases (HSE E3.5: rainout tests)

- Correlation of T and concentration of mixtures of H2 with cryogenic origin and air

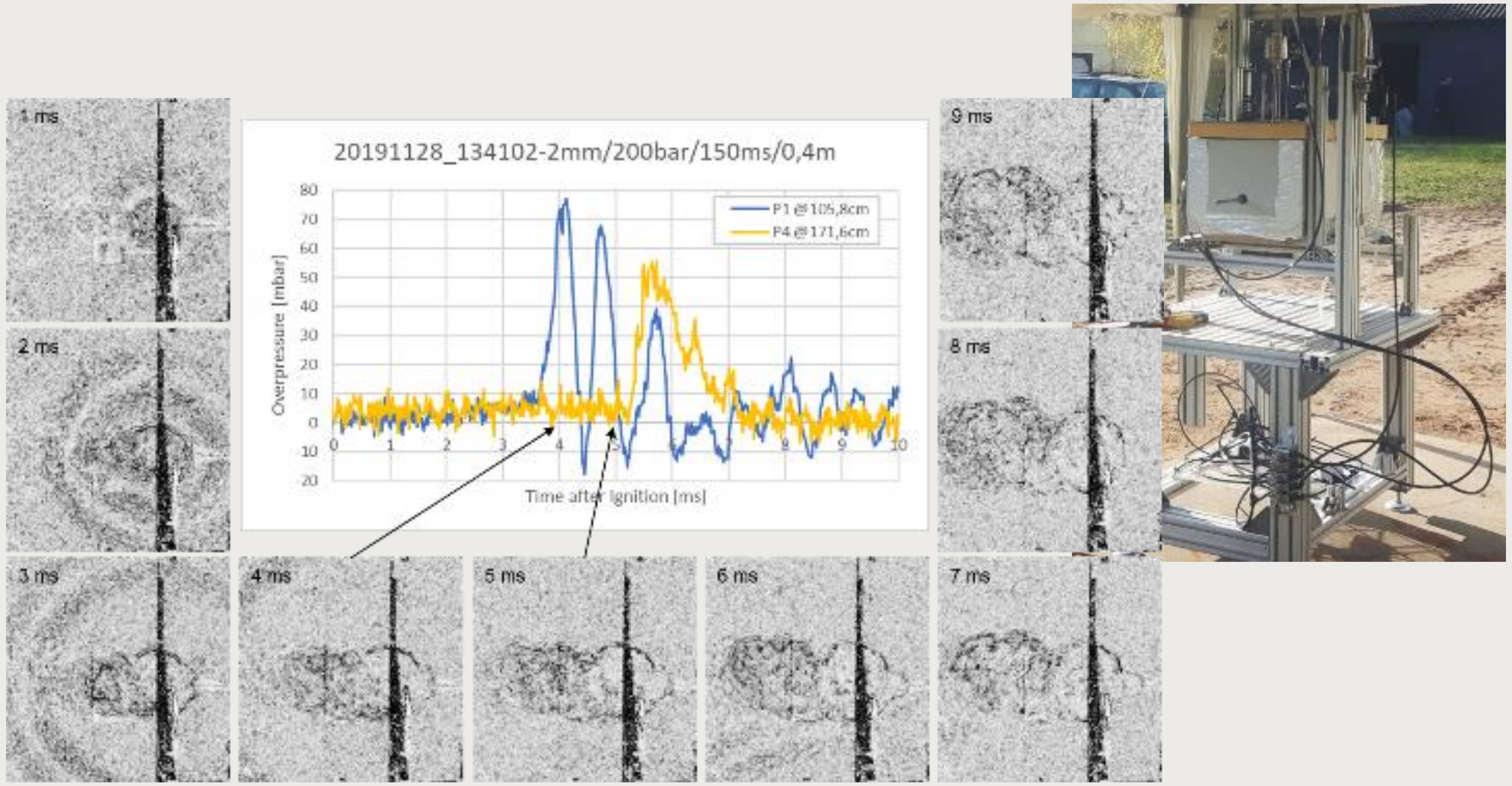








Closed Knowledge Gaps
Transient Combustion Effects



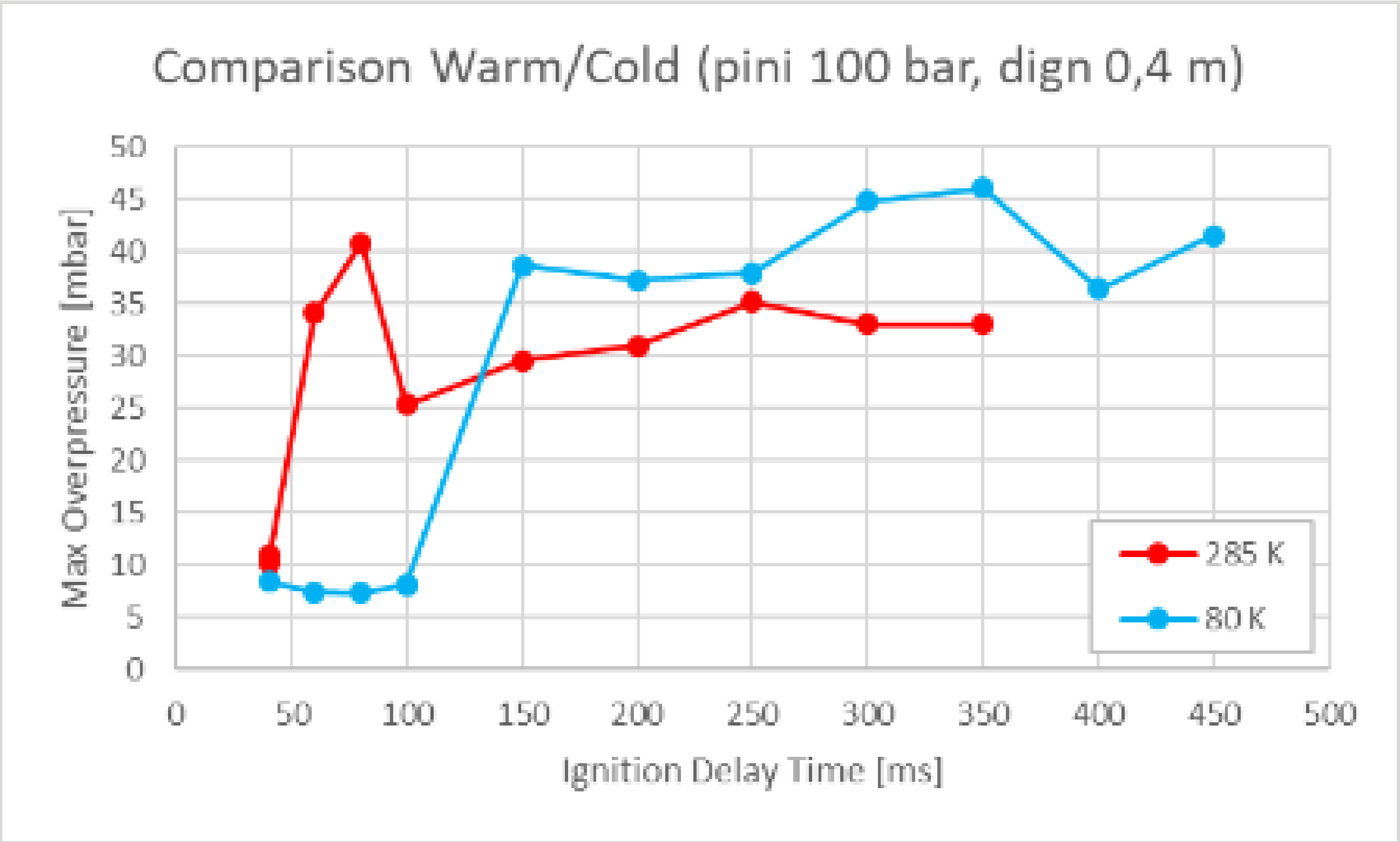
> 100 Ignited jet tests combined with discharge experiments E5.1

T = 80K .. 300K

p = 5 .. 200bar

D_{nozzle}= 0.5 .. 4mm

Iterative procedure for identifying most critical ignition time and location

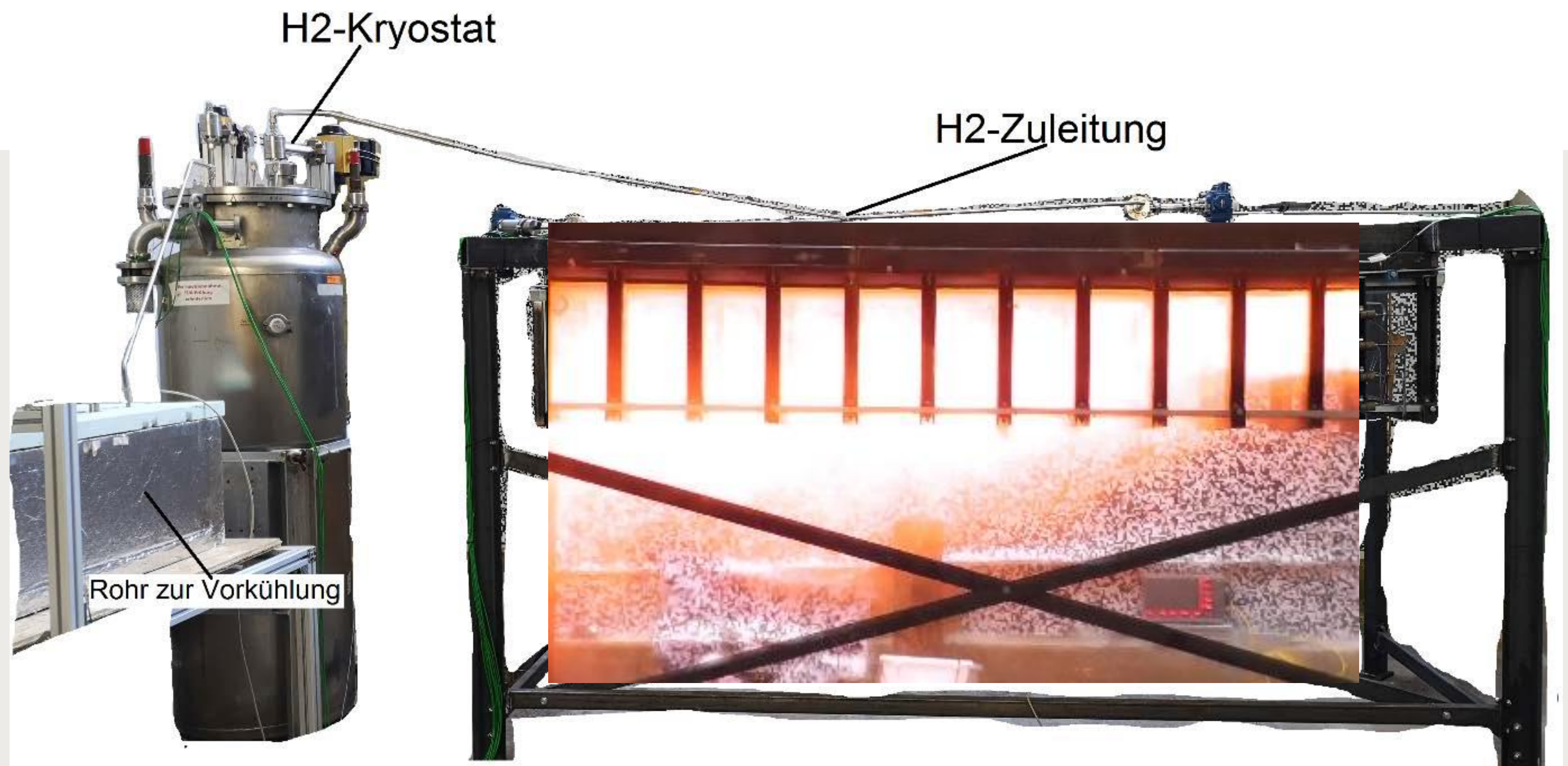


- Better understanding of transient jets and combustion processes
- Inventory based map of worst effects (pressure & thermal)
  - to be extrapolated to large inventories for RCS

Closed Knowledge Gaps

Combustion in confined/congested domains

- Stronger pressure loads for cold tests in comparison with warm tests with the same volume, hydrogen concentration and blockage ratio



E5.3 Semi-confined channel at KIT/PS


E5.5 Test set-up at HSE, Buxton

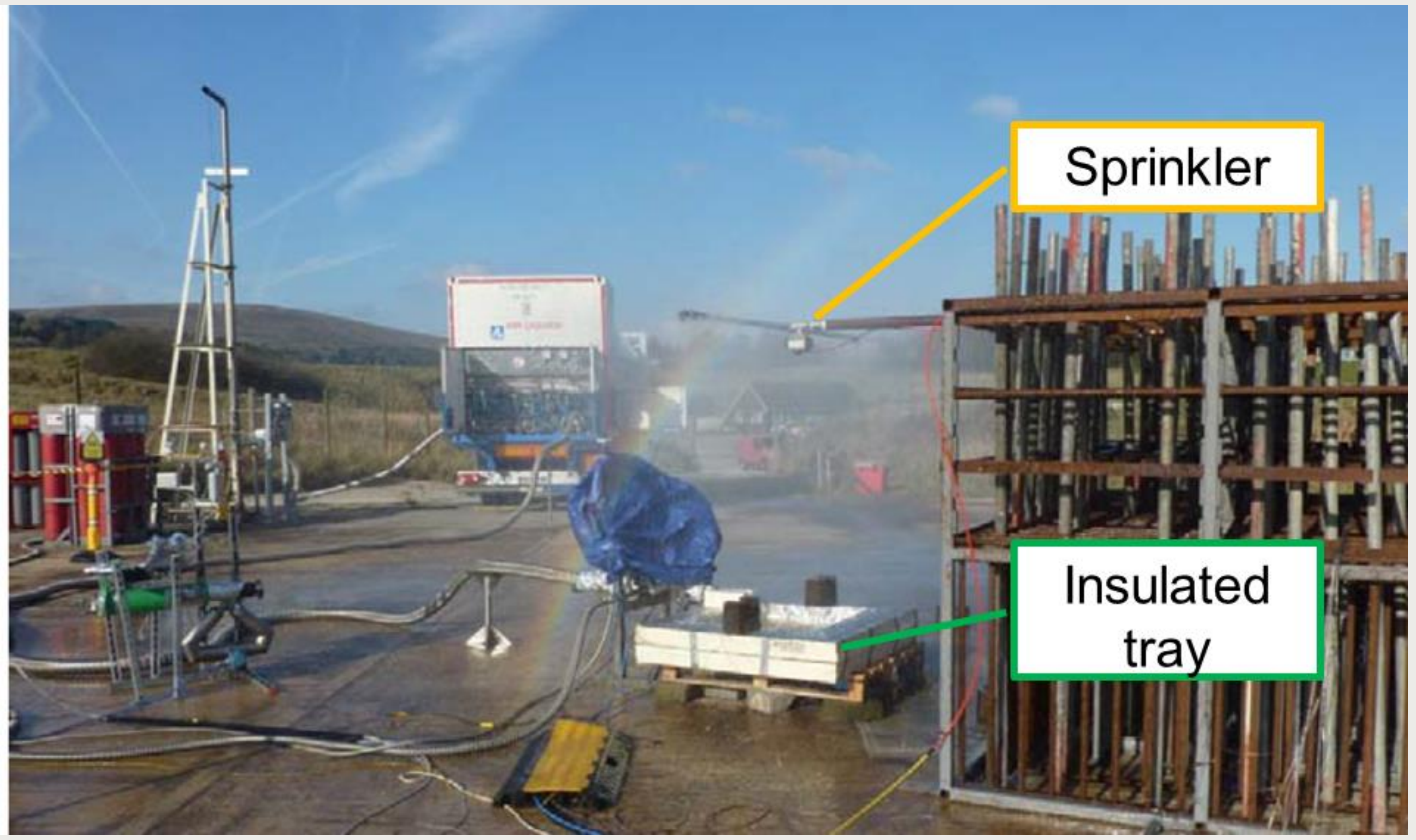
- Increase in critical and effective expansion ratios determine flame acceleration in cryogenic mixtures
- Reduced run-up distance for detonation transition DDT in cryogenic mixtures (← density effects)
- Influence of blockage ratio on DDT less pronounced
- Effects in free unconfined domains to be investigated

Closed Knowledge Gaps

Multi-phase accumulations with explosion potential

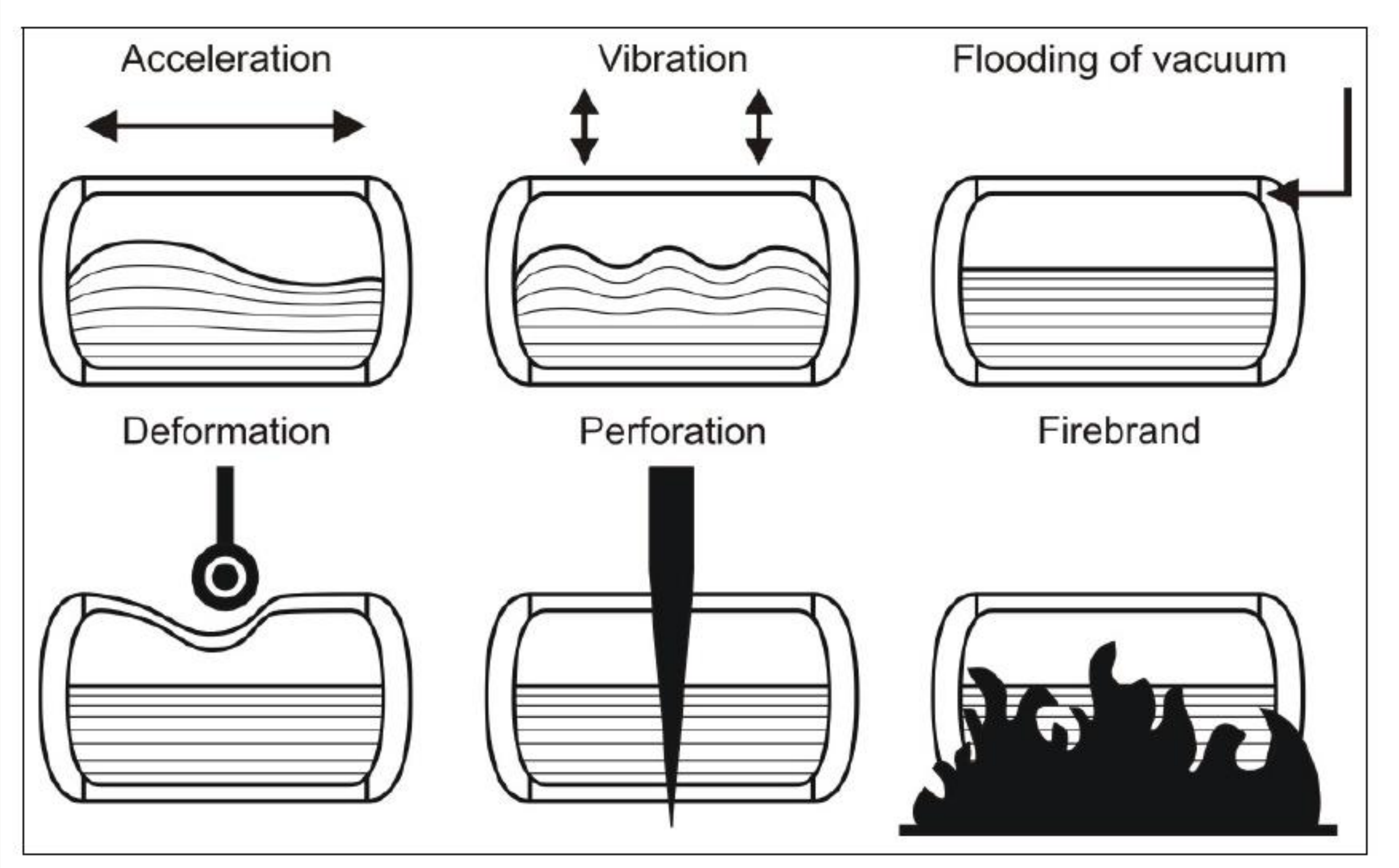
- Repeated spills in gravel bed might generate highly reactive condensed phase mixtures –
  not on other substrates (E4.4 Ignition above pool)

- Water sprays on LH2 and LH2 spills on small water pools non critical (E4.4 and E4.X)



Possible Loads on LH2 Tanks

Actually developed for vehicle tanks



Source: Pehr 1995

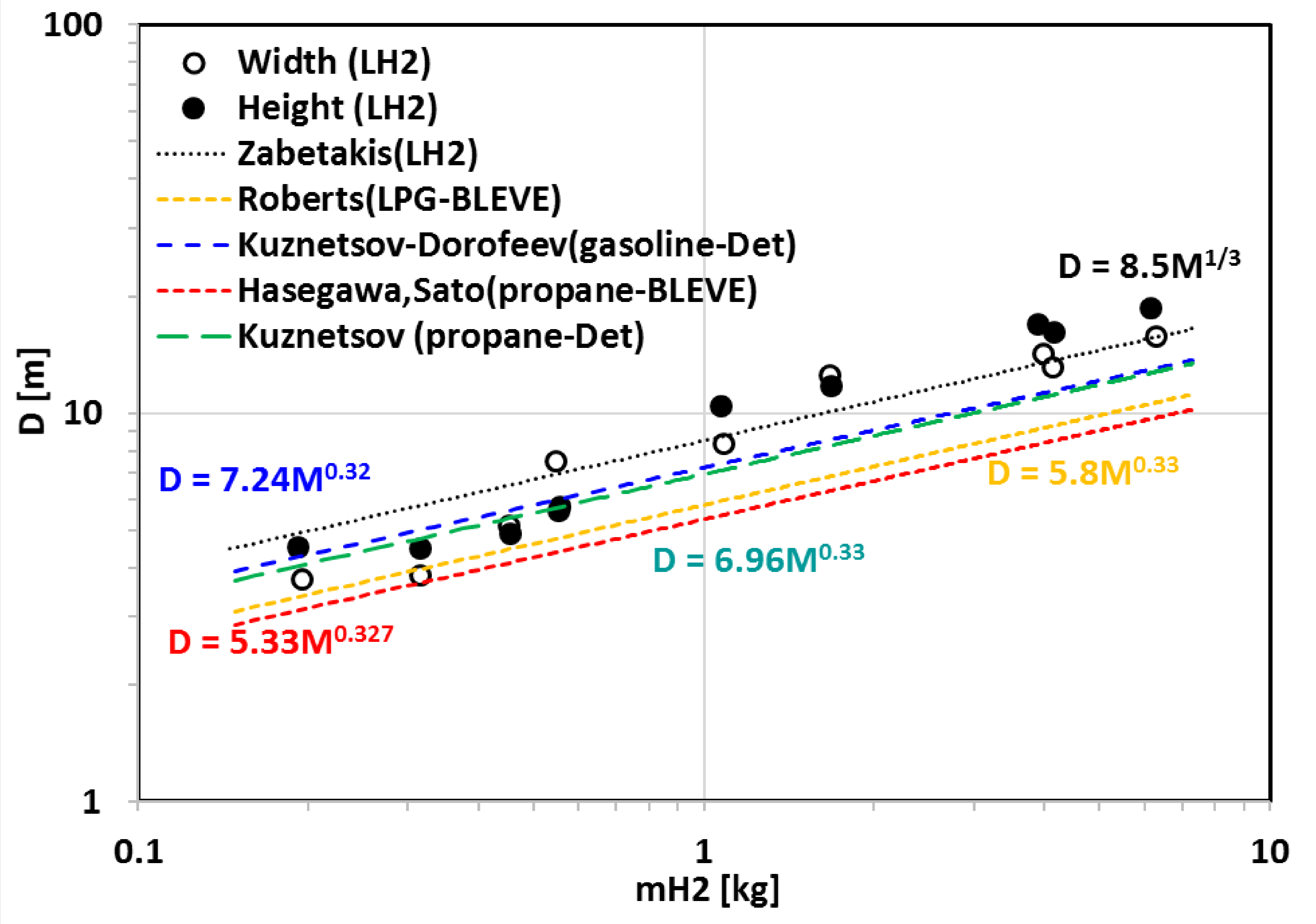
Open Knowledge Gaps
BLEVE

- Requires failure of heat insulation and the pressure envelop
- Release of mechanical, chemical **and thermal energy (latent heat)**

1998 BLEVE at Buchon South Korea LPG Gas station

BLEVE

Scale correlations



Hydrocarbons

$D=5.33 \cdot M^{0.327}$

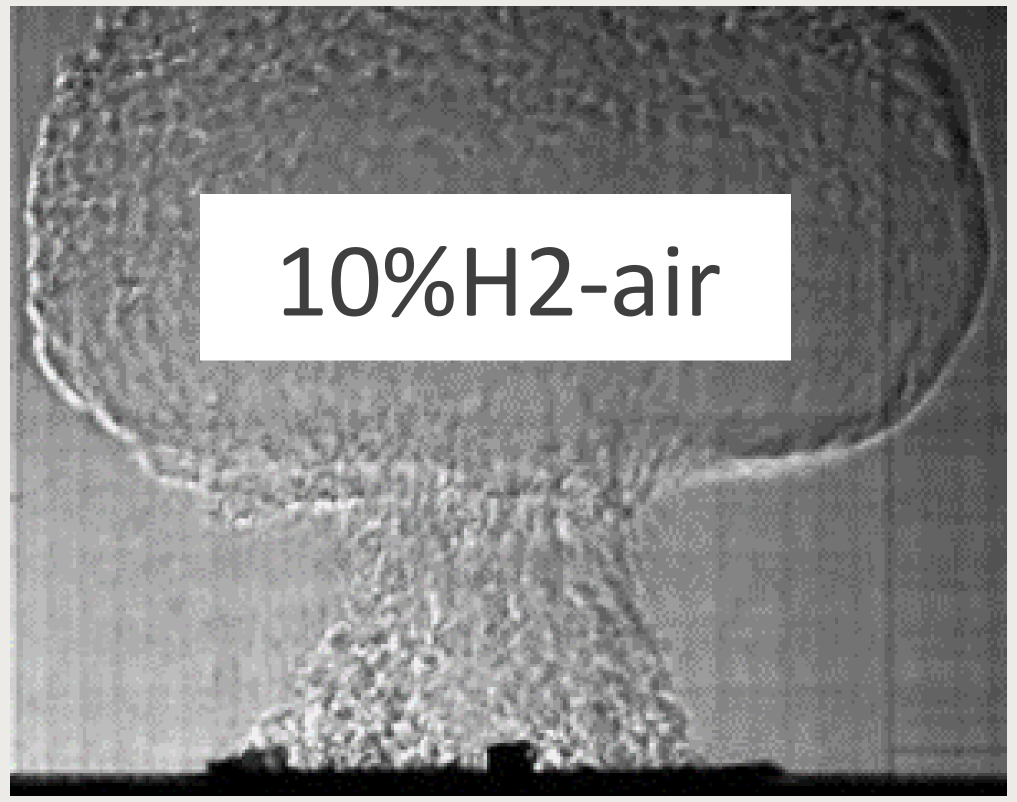
$t_d = 0.45 \cdot M_f^{1/3}$.

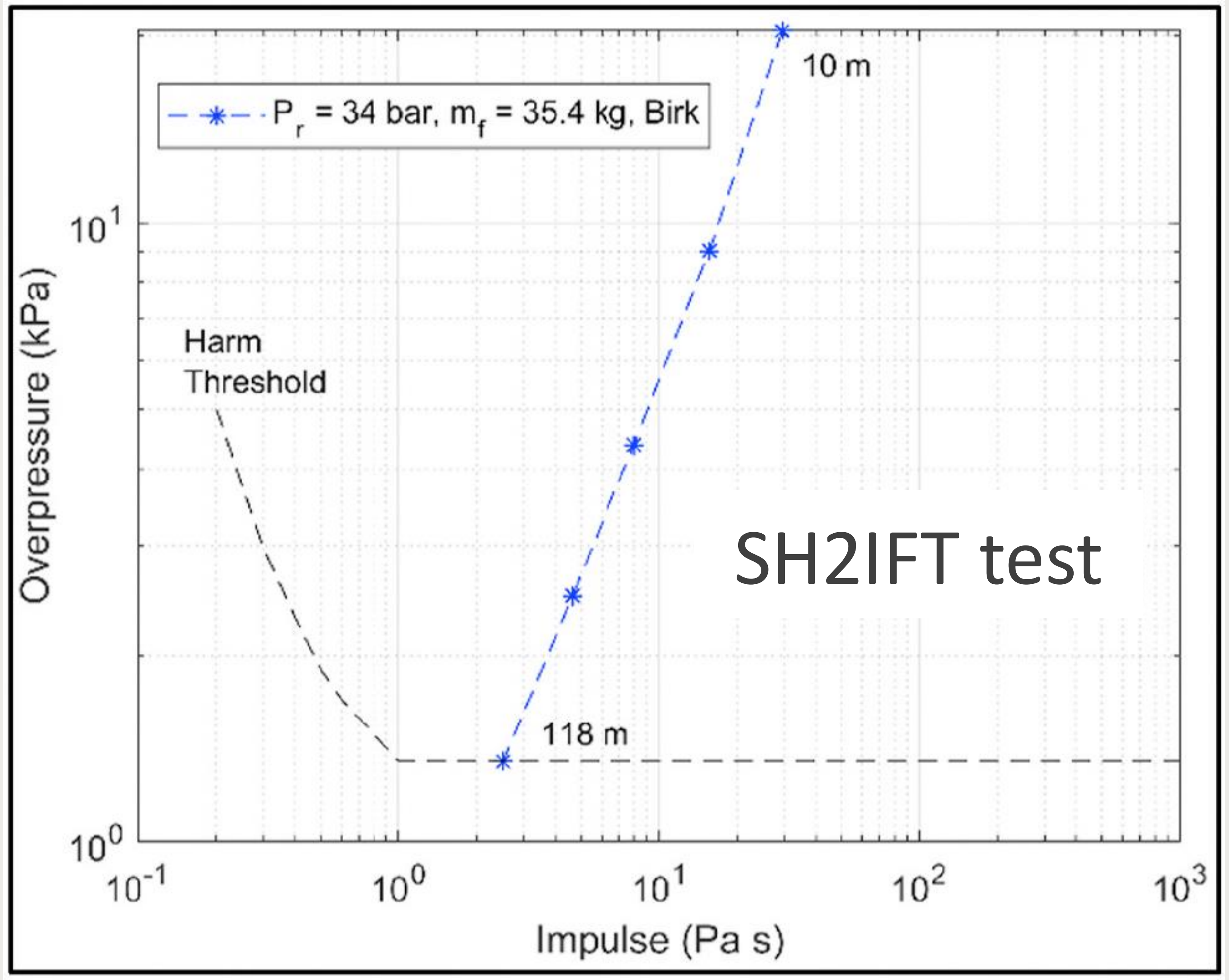
$E = 8.085 \cdot M_f$.

Hydrogen

$D=8.5M_f^{1/3}$

- 1.6 times larger LH2 fireball size than for hydrocarbons
- D=25.9m compared to calculated D=28 m for SH2IFT project (m=35.4 kg H2)





- Safety distance is proportional to the mass of hydrogen