RISE Fire Research

The Norwegian Fire Research Laboratory

Key notes

- Introduction: RISE & SH_2IFT2
- Risk and safety
- Practical “how to”
- Practice makes perfect
- Experiential methodology
  - Different test setups
- Gaseous H_2 Jet fire characteristics
  - Steady state (250 bar)
  - Blowdown scenario (896 bar)
- Results and conclusion

Introduction: RISE & SH_2IFT2

RISE Fire Research

Research Institute and
accredited fire testing laboratory

Based in Trondheim, Norway

40 employees

Offers: Resistance and reaction to fire, Extinguishing, Jet Fire, CDF modelling, Battery testing, Investigations, tunnel fires, large scale experiments, ect.

Visit: www.risefr.no

SH_2IFT-2 (Funded by The Research Council of Norway)

Duration: Oct. 2021 – Sept. 2025

Primary goal: Enhance understanding of hydrogen safety and support hydrogen use across industries.

WP1: Experimental Investigations (RISE)

- **Studying flammable/toxic cloud formation, explosion mitigation, and jet fire scenarios with and without PFP.**

WP2: Model Validation (GEXCON)

WP3: Risk Assessment and Strength-of-Knowledge (UiB)

WP4: Risk-Based Operational Safety (NTNU)

Visit: www.sh2ift-2.com

Risk and safety

- **Flammability and Explosive Range:** gaseous H_2 is highly combustible, with flammable concentrations ranging from 4% to 77% in open air and detonation possible between 18% and 59%.
- **Invisible Flames:** Pure gaseous H_2 burns with invisible flames unless interacting with objects or particulates. Detection of leaks often requires specialized equipment or techniques like the soap test.
- **Rapid Dispersion:** In open air, gaseous H_2 disperses rapidly — 3.8 times faster than natural gas. This means minor leaks may quickly dilute into non-flammable mixtures if unobstructed.
- **Jet Flames and Hazards:** A leak from a pressurized gaseous H_2 container typically results in a jet plume. If ignited, this flame is extremely destructive, and proper ventilation or dispersion is crucial for safety.
- **Regulations:** Norway's H_2 regulations, especially for explosive zones (Zone 0 and 2), are often unclear and challenging to apply, given hydrogen's emerging status and evolving standards.

Practical

- High-pressure rated equipment: tank, piping, and pressure regulator installed by a certified technician.
- Tank consisted of a 500 liter, capable of holing 23 kg of H2 at 895 bar.
- Booster pump supplies hydrogen, nitrogen, and air using a compressor.
- Purge system uses nitrogen to eliminate air-hydrogen mixtures in pipes
- Nitrogen is used for long-term storage to maintain safety

Challenges and Improvements: Practice Makes Perfect

- ❑ Risk and safety assessments were more complex than anticipated.
- ❑ Initial tests required significantly more time than expected.
- ❑ Heat management challenges led to a measurement equipment getting caught on fire.

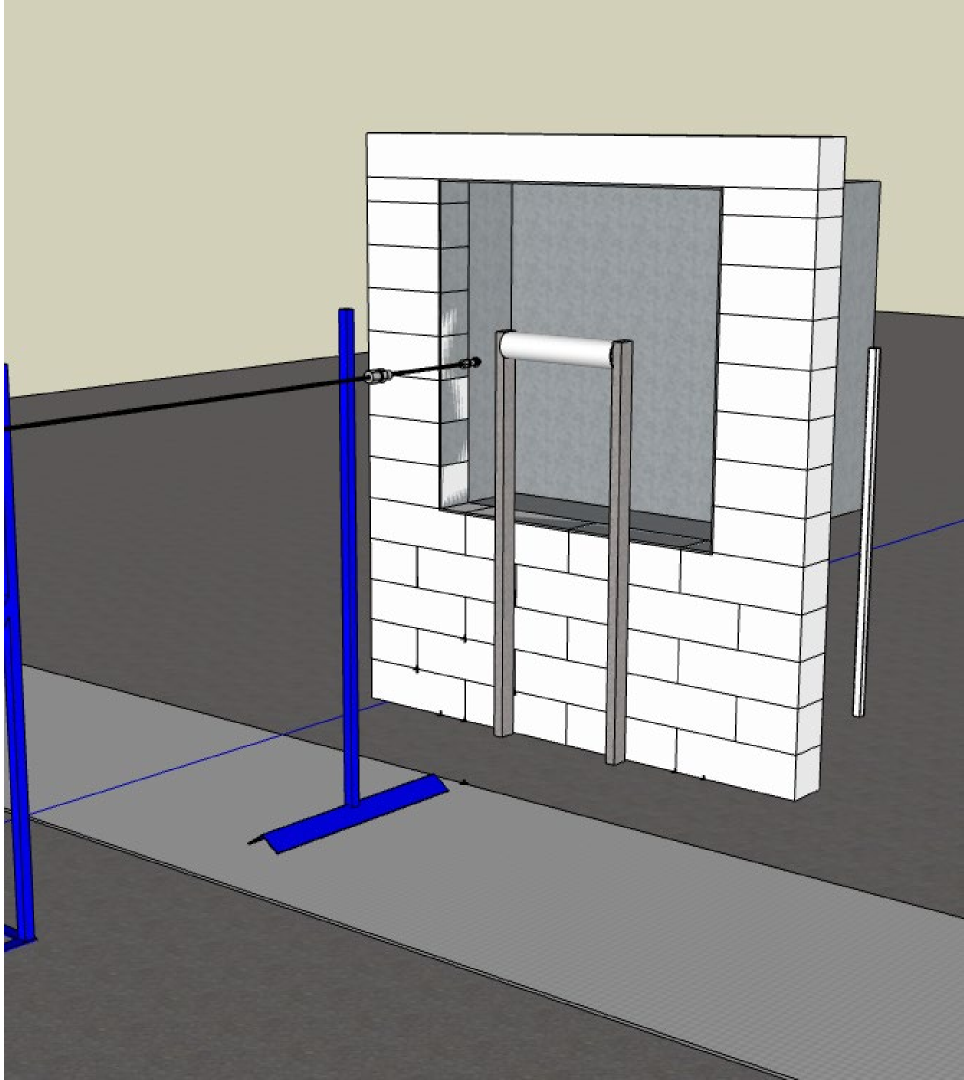
Pressure Release Tests: Constant vs. Blowdown Release

- **Scenario A** involves a **constant pressure release at 250 bar** through a **1-mm nozzle**, positioned **0.5 m from the target**. Pressure is allowed to drop at the experiment's conclusion.

- **Scenario B** features a **full tank blowdown** from a tank pressure of 896 bar through a
2-mm nozzle, located **1 m from the target.**

- Large pipes are typically used for long-distance hydrogen transport. Smaller, high-pressure pipes are more common in refueling stations.

- Based on these considerations and blind simulations, a 60.3-mm diameter (2-inch) carbon steel pipe with a 6.3-mm wall thickness was selected as the most suitable target for the SH2IFT-2 campaign.



SH2IFT II

Conducted GH2 jet fire tests

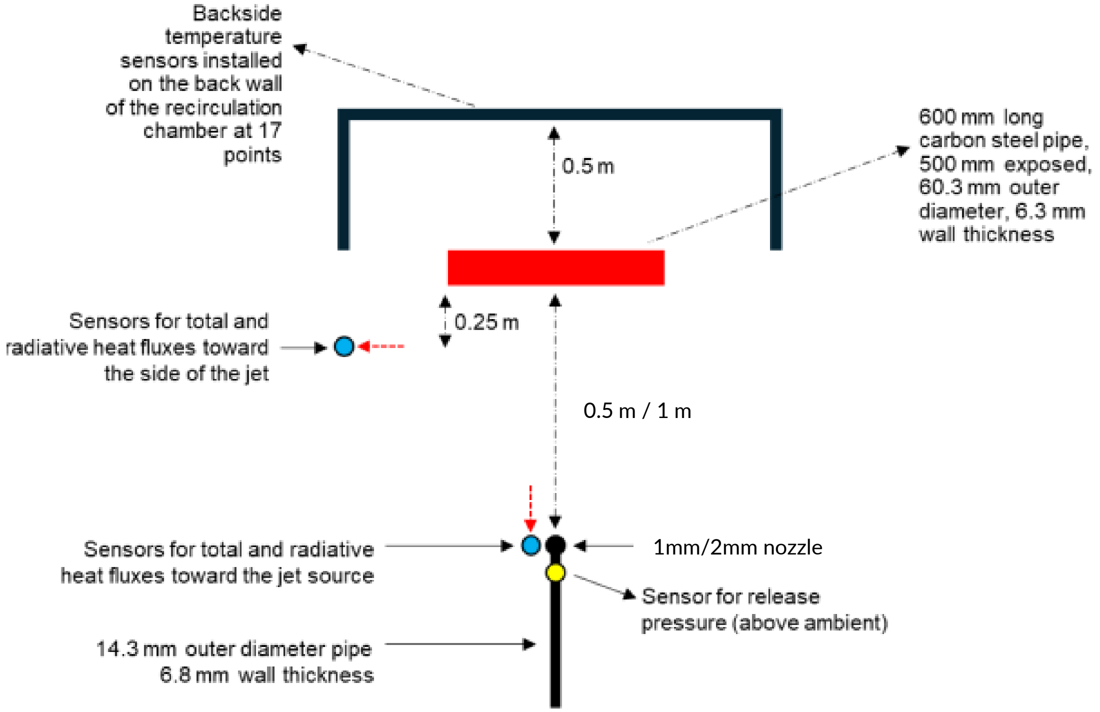
#	Leak pressure	Target	PFP
1 ✅	250 bar	Pipe	None
2 ✅	250 bar	Pipe	Yes
3 ✅	250 bar	Pipe	Yes
4 ✅	250 bar	Pipe	Yes
5 ✅	250 bar	Pipe	Yes
6 ✅	855 → 100 bar	Pipe	None
7 ✅	250 bar	Pipe	Yes
8 ✅	250 bar	Pipe	Yes
6.b ✅	855 bar (brief)	Pipe	None
1.b ✅	250 bar (brief)	Pipe	None

- ❑ Conducted 7 tests with a jet release pressure of 250 bar (6 tests with PFP and 1 test without PFP).
- ❑ Conducted 1 test with a jet blowdown from 855 bar to 70 bar (without PFP).
- ❑ Observed extensive combustion farther away from the recirculation chamber during the 855 bar test, suggesting the use of excessive hydrogen for local exposure testing.
- ❑ Velocity / pressure tests 6.b and 1.b for a brief release to compare 855 bar and 250 bar tests in terms of peak erosive forces. Precise measurements of pressure and velocity are costly and prohibitive, so relative comparisons are prioritized.

RI. SE

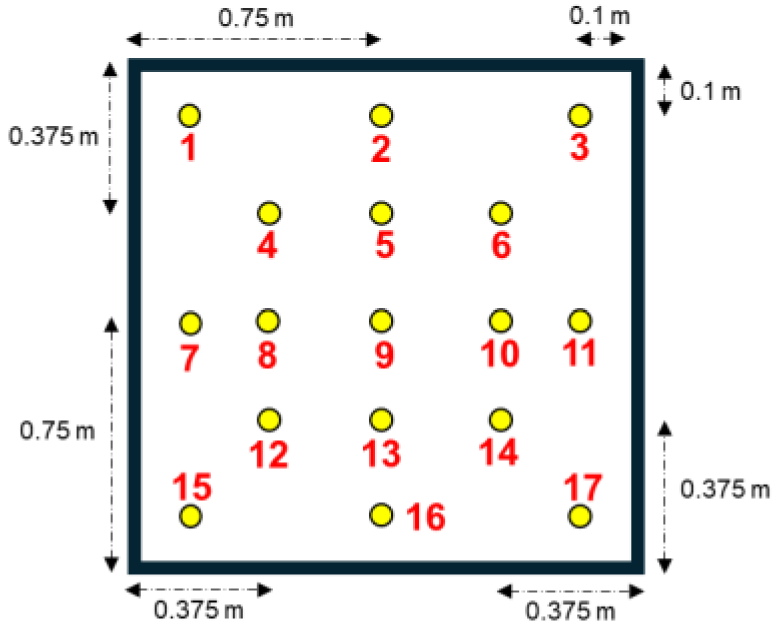
Top view for the two setups

- ❑ Top view of test setup
    - ❑ Constant pressure release at 250 bar through a 1-mm nozzle, positioned 0.5 m from the target.
    - ❑ Full tank blowdown from a tank pressure of 855 bar through a 2-mm nozzle, located 1 m from the target.



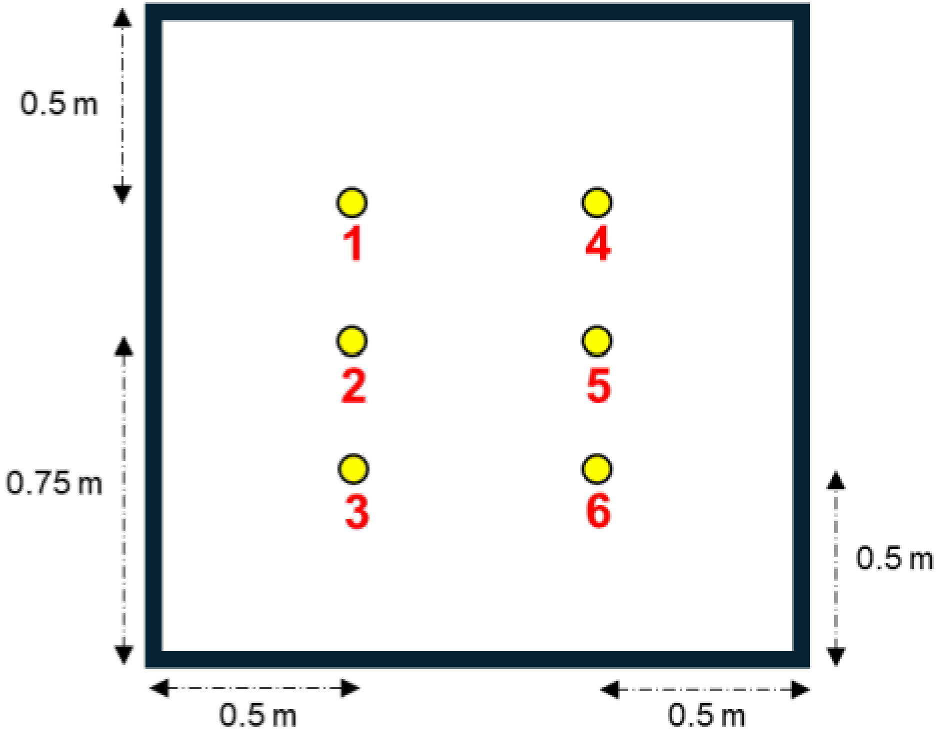
Temperature measurements on steel backplate (unexposed side)

- Backside thermocouples type K, 1.5 mm were installed on the back wall of the recirculation chamber.
- A 3-cm layer of ceramic fiber insulation was placed behind the thermocouples, covering the entire back wall.



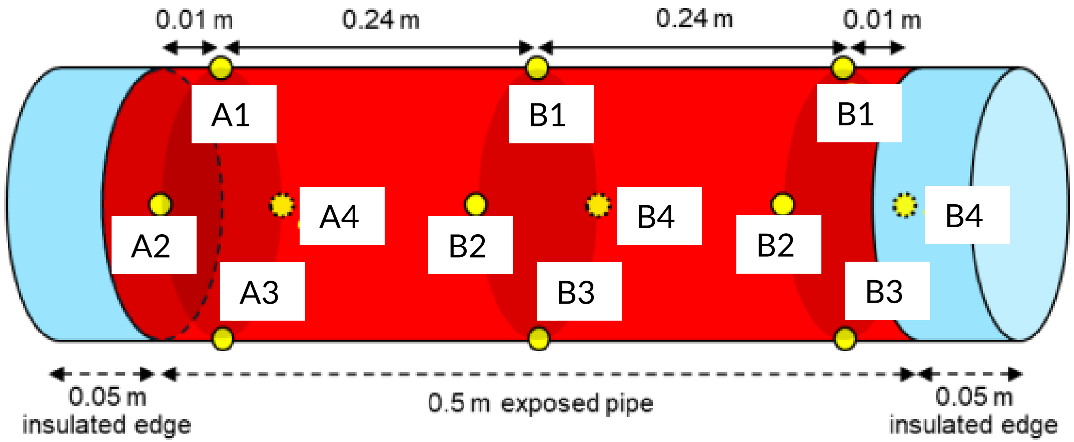
Temperature measurements on fire-exposed side

- Thermocouples type K are installed on the front side of the recirculation chamber at 6 points.
- These thermocouples are flush with the front face of the chamber, positioned 0.5 m away from the back wall.



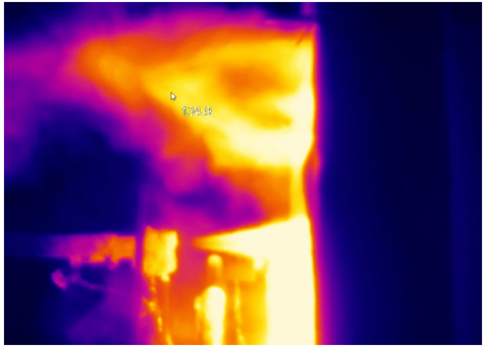
Temperature measurements on test specimen

- ❑ Thermocouples type K were installed in 3 regions on the top, front, bottom, and back side of the target pipe.
- ❑ These thermocouples were fastened using peening, as described in ISO 22899-1.

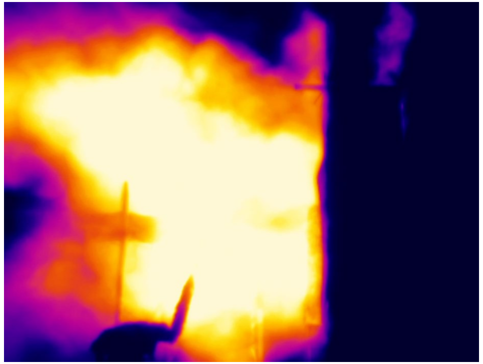


Visual comparison between the scenarios during testing

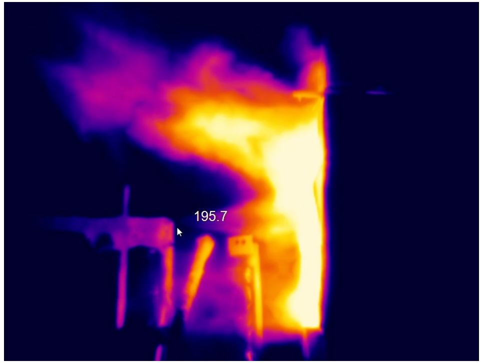
Test 1 - **constant pressure release at 250 bar**



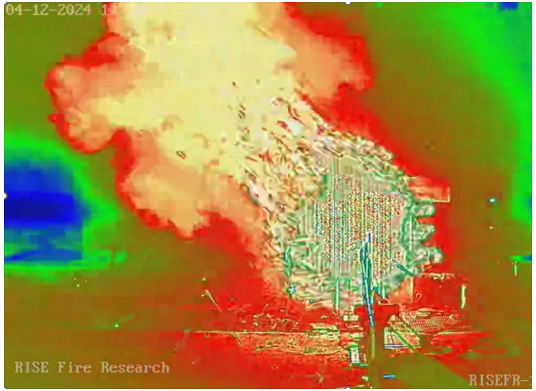
Test 6 - **full tank blowdown from a tank pressure of 896 bar, start of test**



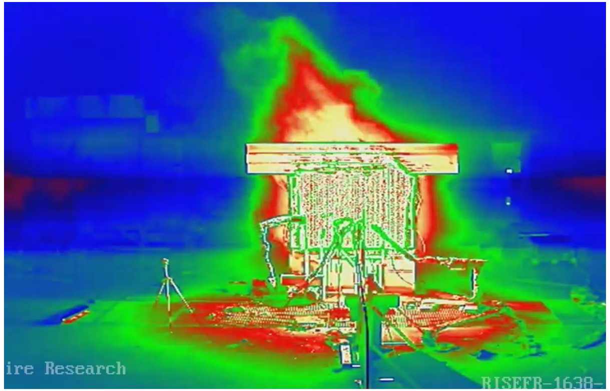
Test 6 - **full tank blowdown from a tank pressure of 896 bar, after 4 minutes (at 250 bar)**



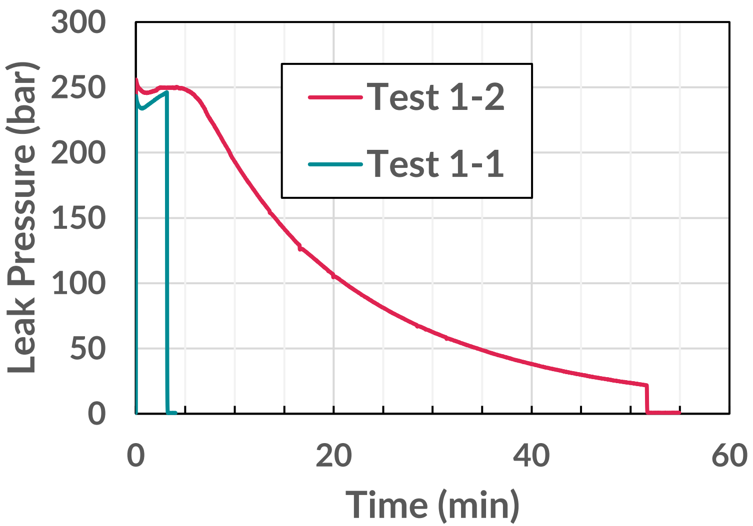
Test 6 - **full tank blowdown from a tank pressure of 896 bar, start of test**

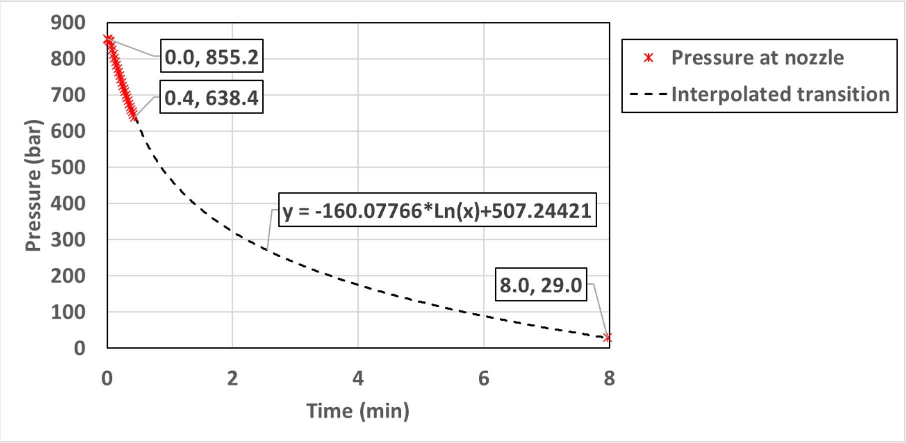


Test 6 - **full tank blowdown from a tank pressure of 896 bar, after 4 minutes (at 250 bar)**



Pressure release curves from the two scenarios

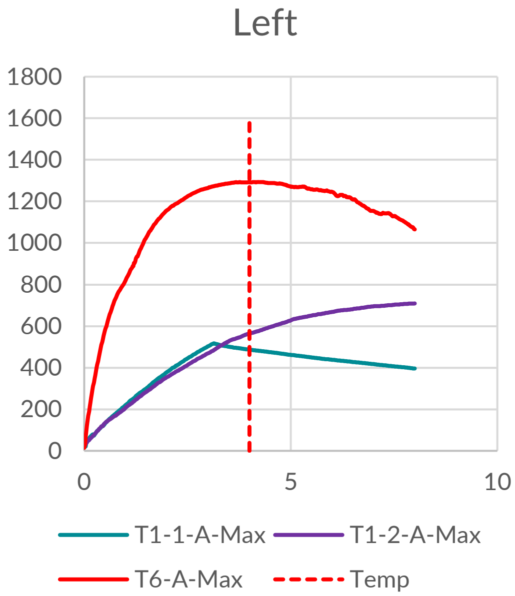


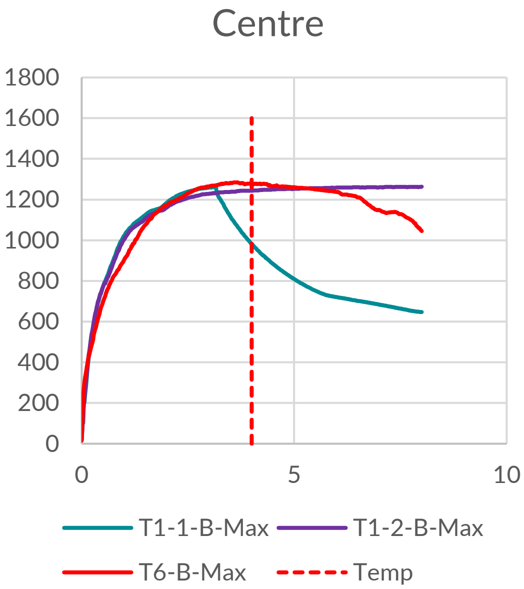


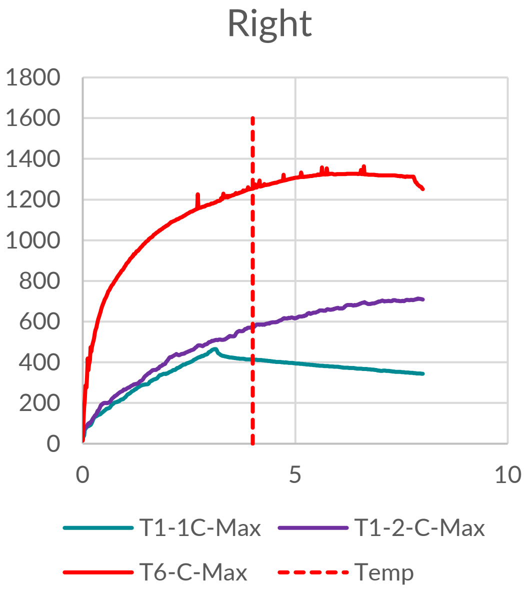
- Test 1-1 - **constant pressure release at 250 bar** for 3 minutes
- Test 1-2 - **constant pressure release at 250 bar** followed by a blowdown
- **Full tank blowdown** from a tank pressure of 855 bar

Comparison of max steel pipe temperature

Constant pressure release vs. Full tank blowdown



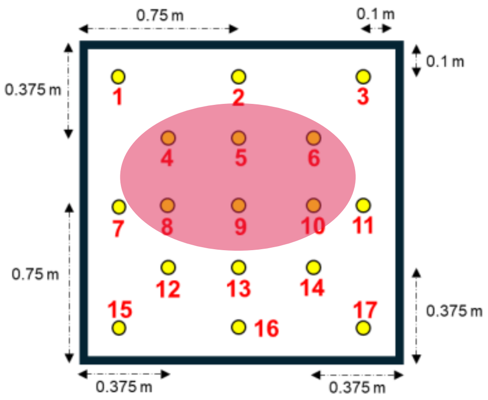


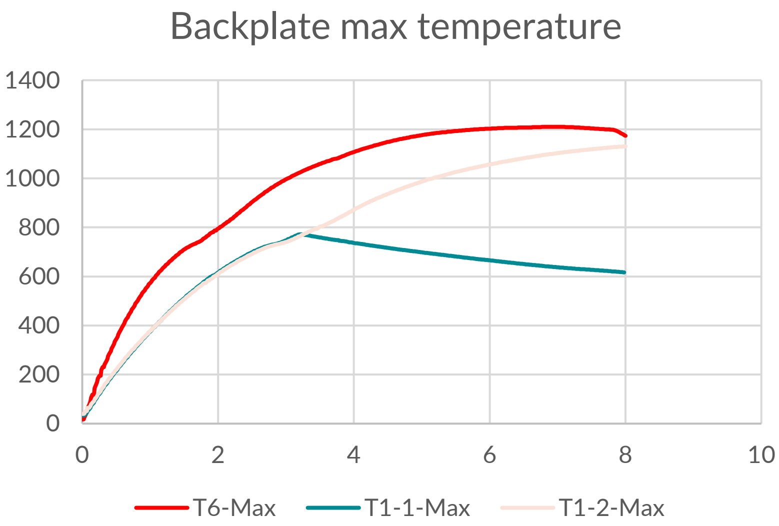


Comparison of max backplate temperature

Constant pressure release vs. Full tank blowdown

- **The maximum temperatures were measured in the central area.**

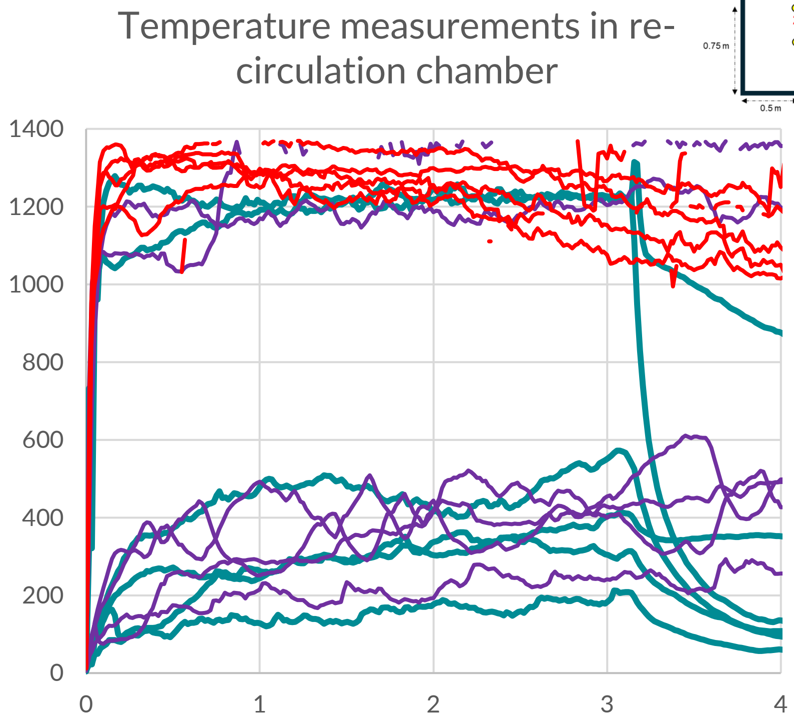


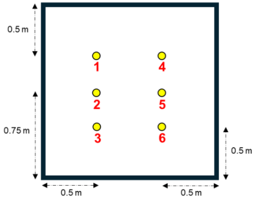


Comparison of temperature measurements in re-circulation chamber

Constant pressure release vs. Full tank blowdown

- ❑ **More uniform heating conditions were observed during the full tank blowdown release.**
- ❑ **Maximum temperatures were reached faster due to the increased energy release from the full tank blowdown.**
- ❑ **Some uncertainties in maximum temperatures were noted due to the limitations of the thermocouples used (Type K, 1.5 mm).**





Findings on resistance of PFP products in gaseous hydrogen jet fire tests

- **PFP Effectiveness:** PFP systems can withstand high-pressure hydrogen releases, even close to the protected substrate.
- **PFP Selection:** Not all PFP systems can handle the unique conditions of hydrogen jet fires, so careful evaluation of materials is essential
- **Comparison with ISO 22899-1:** The bare steel pipe reached 400°C faster in hydrogen release experiments than in ISO 22899-1 jet fire tests, indicating quicker heating.
- **PFP Thickness:** Thicker PFP may enhance protection and improve performance beyond tested levels
- **Hydrogen Jet Erosion:** Erosion from high forces and temperatures of hydrogen jets is likely why PFP products underperform in hydrogen jet fires compared to propane jet fire tests.

Conclusions

- The SH2IFT-2 project chose specific release scenarios primarily based on the storage of gaseous hydrogen, rather than focusing on process conditions for hydrogen generation.
- Hydrogen release conditions faced by industry and consumers may differ from the assumptions typically made in standard jet fire testing
- Some conditions, similar to those evaluated in these tests, may be more onerous than standard jet fire testing and may be more challenging.
- Further research may be required to fully assess fire protection in other hydrogen jet fire scenarios to determine if they can be aligned with the conditions outlined in ISO 22899-1 standards.
- Data-driven insights are crucial for making informed safety decisions.

Thank you!

If you'd like to learn more about our capabilities, please feel free to reach out to us. We'd be happy to discuss how we can support your testing needs.

Erik Westbye Jacobsen - Mikael Steiner Bergius

RISE Fire Research – (+47) 464 18 000 – post@risefr.no – www.risefr.no
Visiting address: Tillerbruvegen 202, 7092 Tiller, Norway – Mail adress: P.O. Box 4767 Torgarden, 7465 Trondheim, Norway