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Hydrogen Fires - Is ISO 22899-1 appropriate for PFP?

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Gaseous Hydrogen Fires

Characterisation

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Contents

- Hydrocarbon fire characteristics
- What do hydrogen fires look like?
- What are the typical releases?
- What is the impact on the type of protection required?
- Is testing in accordance with ISO 22899-1 appropriate?
- Should mitigation measures be more onerous than standard 2 hour pool fire considerations as stated in API 2218?

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Fire Types

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Hydrocarbon **pool fire** - characteristics

- Diffuse fires with little momentum.
- Items engulfed by the fire experience 100-250kW/m^2
- At 204kW/m^2, the fires are viewed as being represented by the UL1709 time temperature furnace control curve (1100C after 5 minutes)
- There is significant radiative (luminous fire) component responsible for the incident heat flux (FABIG technical note 11)

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Hydrocarbon **jet fire** - characteristics

- Focussed fire with high degree of momentum. Some PFP types can be significantly impacted and be “eroded” away
- In specific zones objects experience 250-350kW/m^2 peak heat flux
- Testing of PFP in ISO 22899-1 is typically considered to represent a 250kW/m^2 peak heat flux with 350kW/m2 the target for testing conducted in accordance with ISO 22899-3 (draft)
- There is significant radiative (luminous fire) and convective component responsible for the incident heat flux (FABIG technical note 11)

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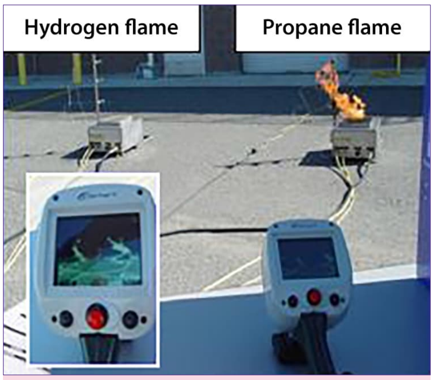
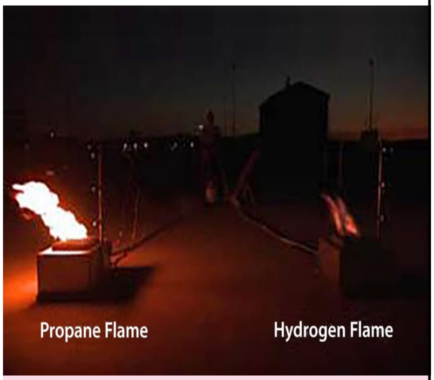
Hydrogen **jet fire** - characteristics

- Radiative component appears not high when compared with hydrocarbon fuels
- However, flames can be more luminescent under certain conditions (e.g. higher humidity)
- Hydrogen can ignite over a wider range of concentrations with air and requires significantly lower ignition energy



- Hydrogen and Propane Flames in Daylight
(Photo courtesy of HAMMER)



- Hydrogen and Propane Flames at Night
(Photo courtesy of ImageWorks)

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Release Considerations

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Hydrogen **jet fire** – typical releases

- Hydrogen, in its gaseous state, is stored at very high pressures for transportation and storage – Sufficient fuel density to be viable (350barg or 700barg is typical for use as transportation fuel although pressure can be as high as 1000barg)
  - Release may impinge on other objects within close proximity – 0.5m would not be uncommon
- Processing conditions to generate gaseous hydrogen varies depending upon the method. Typical pressure at production tends to be ~50-75 barg
  - Release for onshore production facilities rarely impinge objects withing 3m.

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Test Finalisation

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Hydrogen **jet fire** – Characterised by ISO 22899?

- For tests approximating to ISO 22899 using gaseous Hydrogen:
  - *Determine if performance of passive fire protection approximated to response from standard hydrocarbon jet fire tests (ISO 22899-1)*
- From review of potential releases of hydrogen carry out a representative test designed to understand the response from mainstream PFP solutions
  - *Consider high storage pressures of hydrogen containers*
  - *Temperature of the flame from typical release*

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Hydrogen **jet fire** – Rationale

- Modelling studies were conducted to evaluate various test set-up conditions
- Limitations due to equipment meant only small orifice releases (0.5-1mm) were possible for 10-15 minute fire duration

Outcome from Gexcon's simulations

- Optimal pipe diameter: 60 mm
- Optimal pipe wall thickness: 6 mm
- Optimal length of pipe in total: 0.6 m
- Optimal exposed length of pipe: 0.5 m
- Optimal distance of jet source to pipe: 0.5 m
- Optimal diameter of jet source orifice for a steady pressure: 1 mm
- Optimal release pressure for a steady release: 250 bar

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Test Outcomes

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Tests conducted

- Test characteristics:
  - *From the side, no visible flame*
  - *From the front only heating of the test object and rear to the box showed evidence of heating*
  - *Temperature of the flame appeared higher than predicted from modelling*
  - *Aggressiveness of jet increased with respect to standard hydrocarbon jet fire tests*

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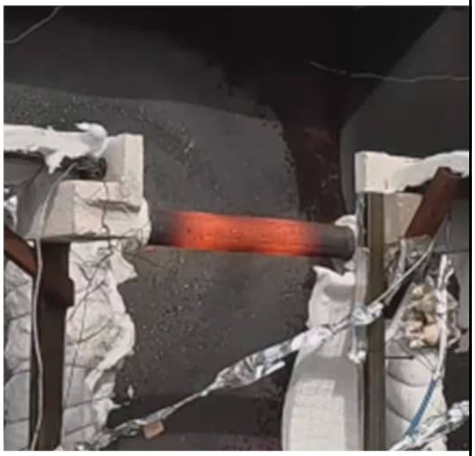

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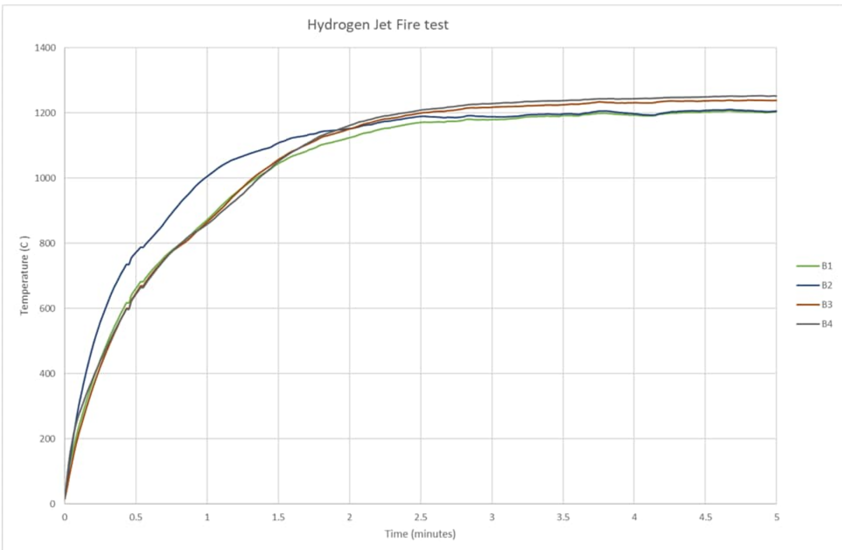
Hydrogen **jet fire** – Testing Outcomes



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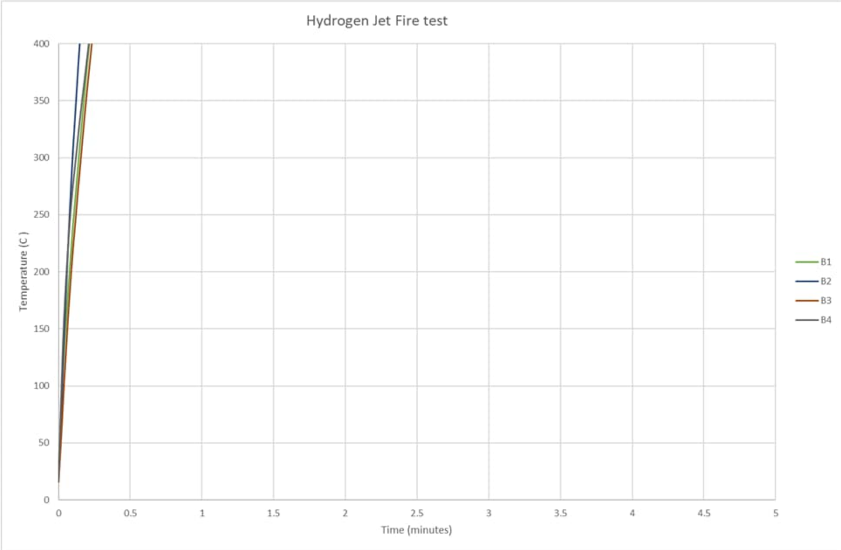
Hydrogen **jet fire** – Testing Outcomes



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Hydrogen **jet fire** – Testing Outcomes

- **Simulations used an effective flame temperature of 2000C as opposed to 1200C for ISO 22899-1**

- For process conditions, model simulations suggest the flame temperature for the hydrogen releases to be close to 2000C
- Carefully tested solutions are required to ensure protection from releases
  - For 0.5m releases, *50% of protection duration expected, Greater erosion of char coupled with high heat fluxes*
  - *For 1m releases, initial heat flux appears similar to ISO 22899-1 testing, Greater char erosion results in 2/3 of the expected duration*
  - *PFP solutions with a robust reinforcement system (carbon fibre) were able to resist the hydrogen jet for ~25 minutes (limit of test duration). Depending upon section factor of the steel, protection is possible for intumescent PFP.*

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Summary – Gaseous Hydrogen Fires

- Care is required in the selection of PFP solutions for gaseous hydrogen fires
- Releases from high pressure storage may be significantly challenging for PFP in relation to char integrity
- Appropriately tested PFP solutions have been shown to be an effective means of mitigation
- It may be possible to propose a thickness from ISO 22899-1 testing using heat transfer methods using an effective flame temperature of 2000C for releases 0.5m from the impinging substrate for PFP solutions which show similar erosion behaviour to that in ISO 22899-1 testing
- When releases are at 1m from the impinging substrate, initial heat flux appears similar to ISO 22899-1 however erosion appears higher for the test set up used for this study
- Whilst the flame is nearly invisible, even with a PFP which can burn, the heat flux experienced from this test scenario appears in excess of that generated from high heat flux jet fires

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Summary – API 2218

- Should mitigation measures be more onerous than standard 2 hour pool fire considerations as stated in API 2218?
- Specifications need to be re-thought – cannot automatically adopt hydrocarbon specifications typically used for downstream oil and gas assets

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Questions and Answers

Q&A