Review of the Current Understanding of Hydrogen Jet Fires and the Potential Effect on Passive Fire Protection Performance

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Background information

DNV Spadeadam

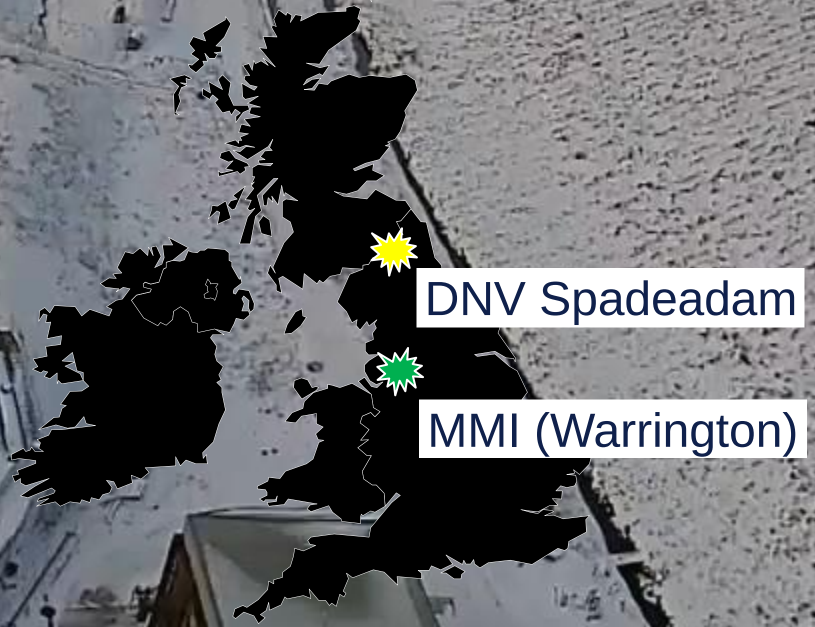
Large Scale Experimental Test Site:

- Fires, explosions, pipelines, vessels, hazardous materials

MMI Thornton Tomasetti

Engineering consultants:

- Energy, fire & explosion, structures, fluids, many others



Problem and assessment basis

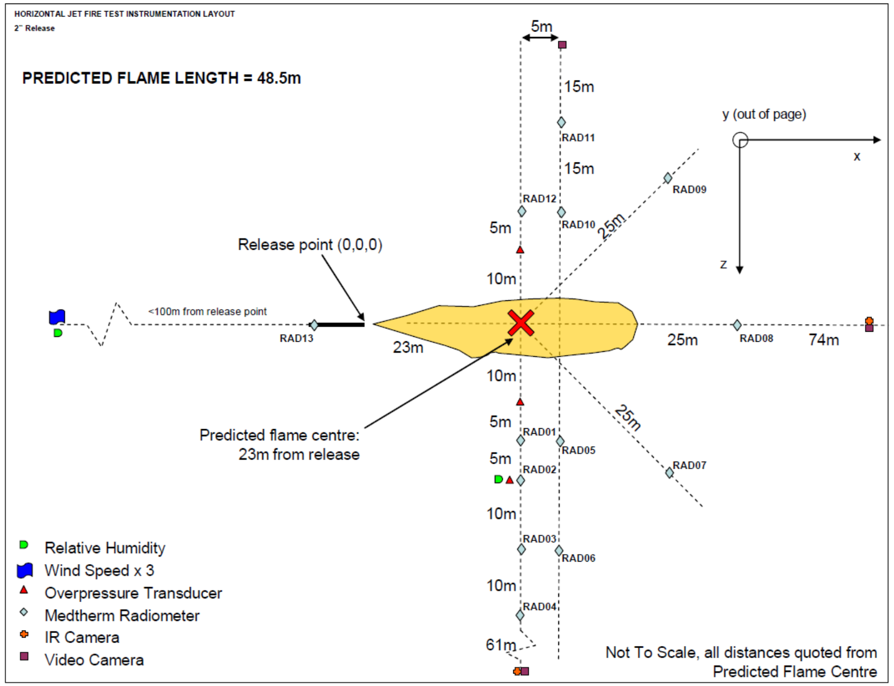
- Passive fire protection materials are widely used to protect steel structures from heat flux and damaging forces from hydrocarbon jet fires
- To what extent are existing test methodologies & existing products insufficient for hydrogen jet fires?

- Compare hydrogen and natural gas jet fires
  - Relationship between natural gas and other hydrocarbons is already known to acceptable detail.
  - Not considering liquid fires

- This was a desktop exercise
- Plenty of information of H2 releases at small ‘bench’ scale
- Little information at large scale
  - Some data from Spadeadam and other sources
- What is large scale?
  - PFP Net have commissioned a ‘hydrogen hazards’ desktop exercise to consider likely release scenarios of a scale of interest for both gaseous and liquid releases
- How does the initial outflow compare? And how does the outflow change?
  - Appreciate that a comparison of equal mass flow rate or equal volumetric flow rate might make more sense for some listeners

THE LARGE SCALE HYDROGEN JET FIRE DATA

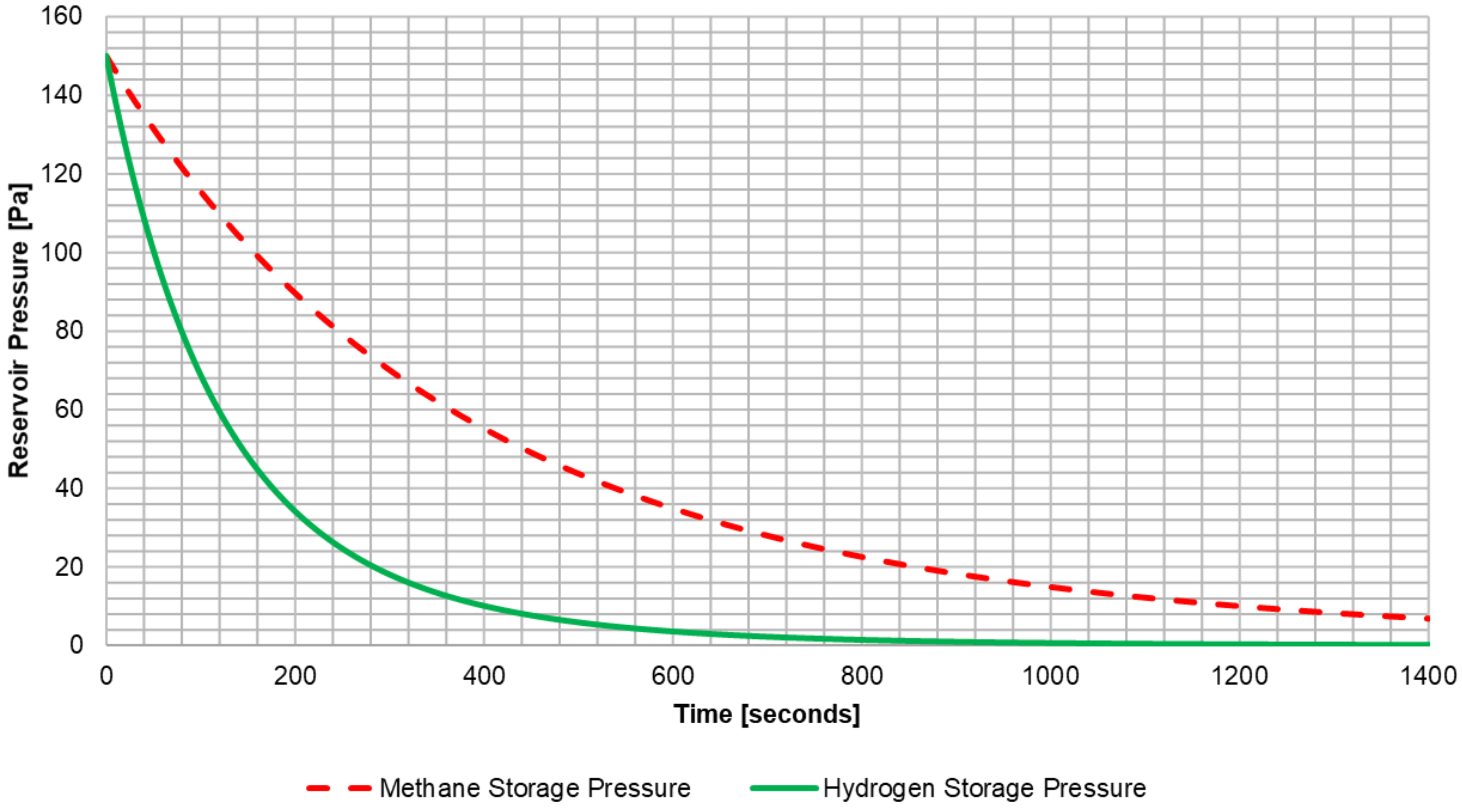
Test	D [mm]	MFR [kg/s]	P0 [bg]	U0 [m/s]	Radiation [%]
1	20.9	1.0	60	3.4	12
2	52.5	7.5	60	2.6	19



Rian KE. Modelling and numerical simulation of hydrogen jet fires for industrial safety analyses – comparison with large scale experiments. 8th International Conference on Hydrogen Safety

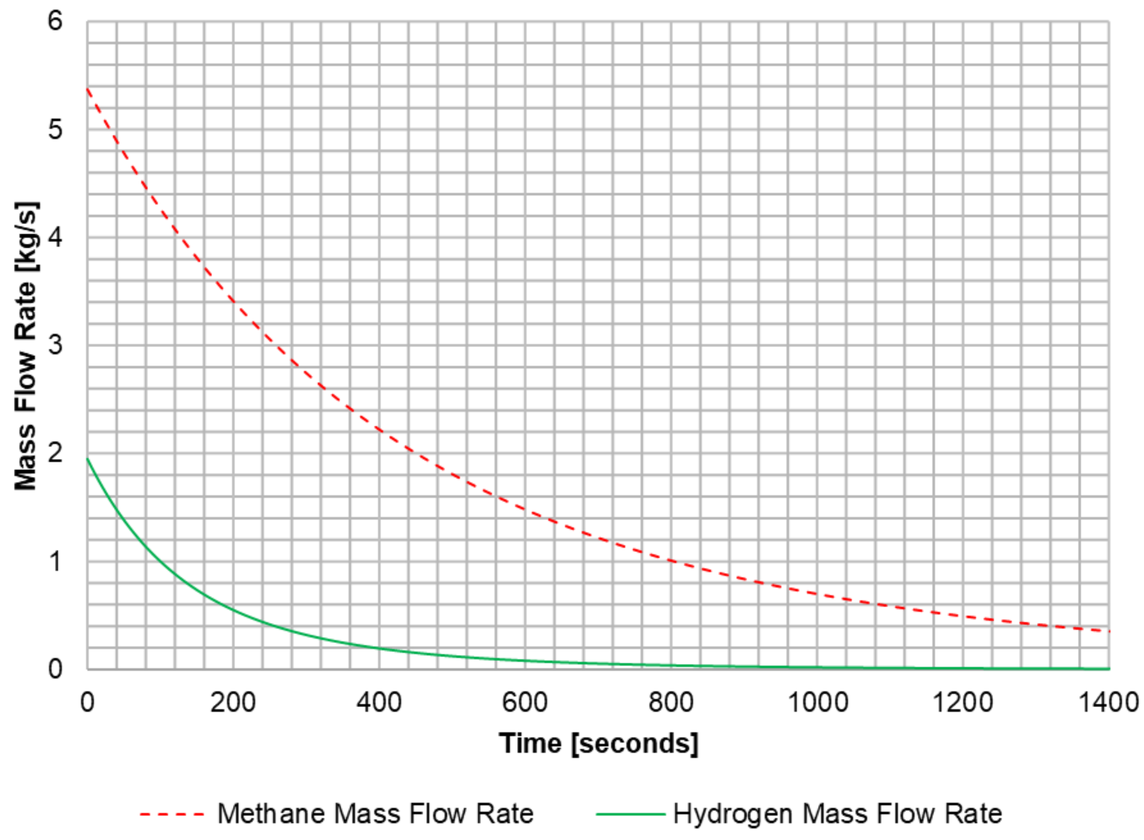
Depressurisation of a stored volume
(27.4 m^3, 150 bara, 20mm hole size)

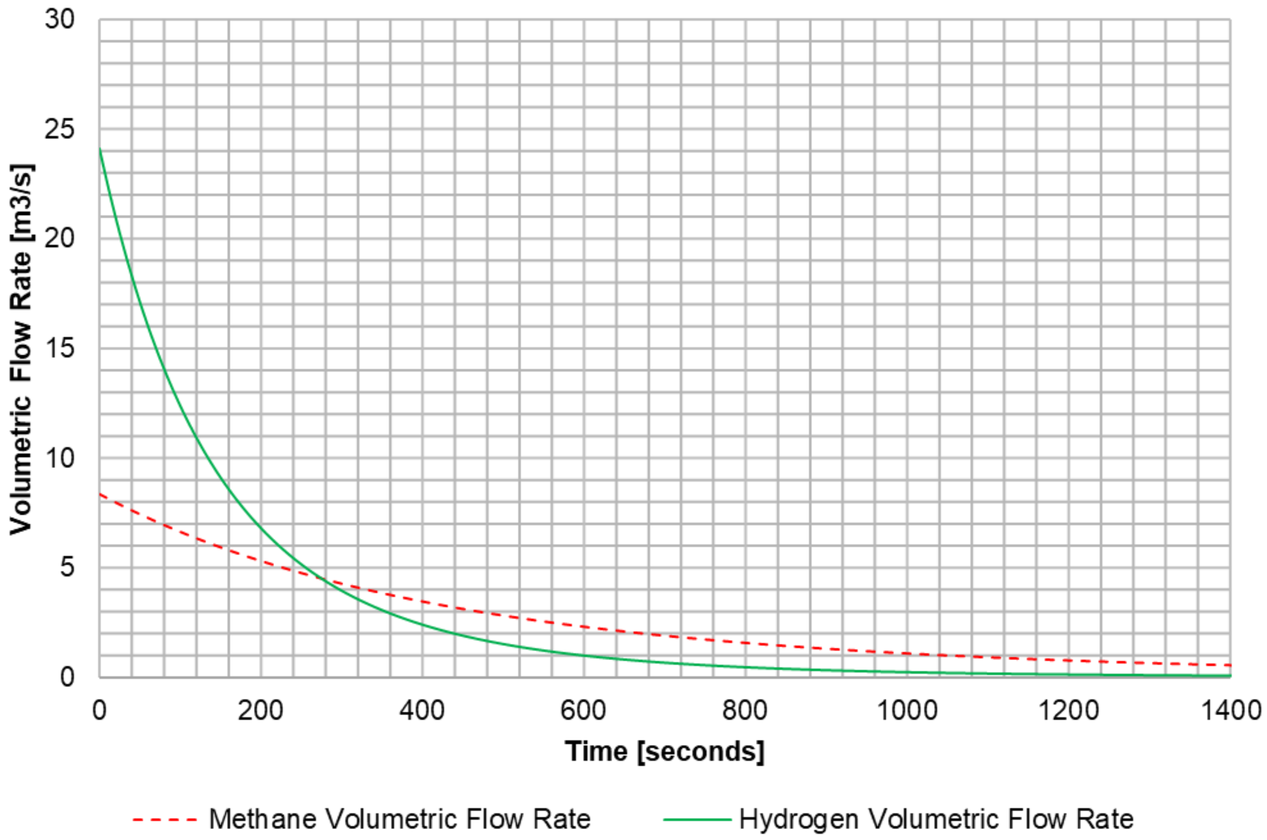
- Initial pressure is the same
- Hydrogen storage depressurises faster



From the perspective of mass and volume

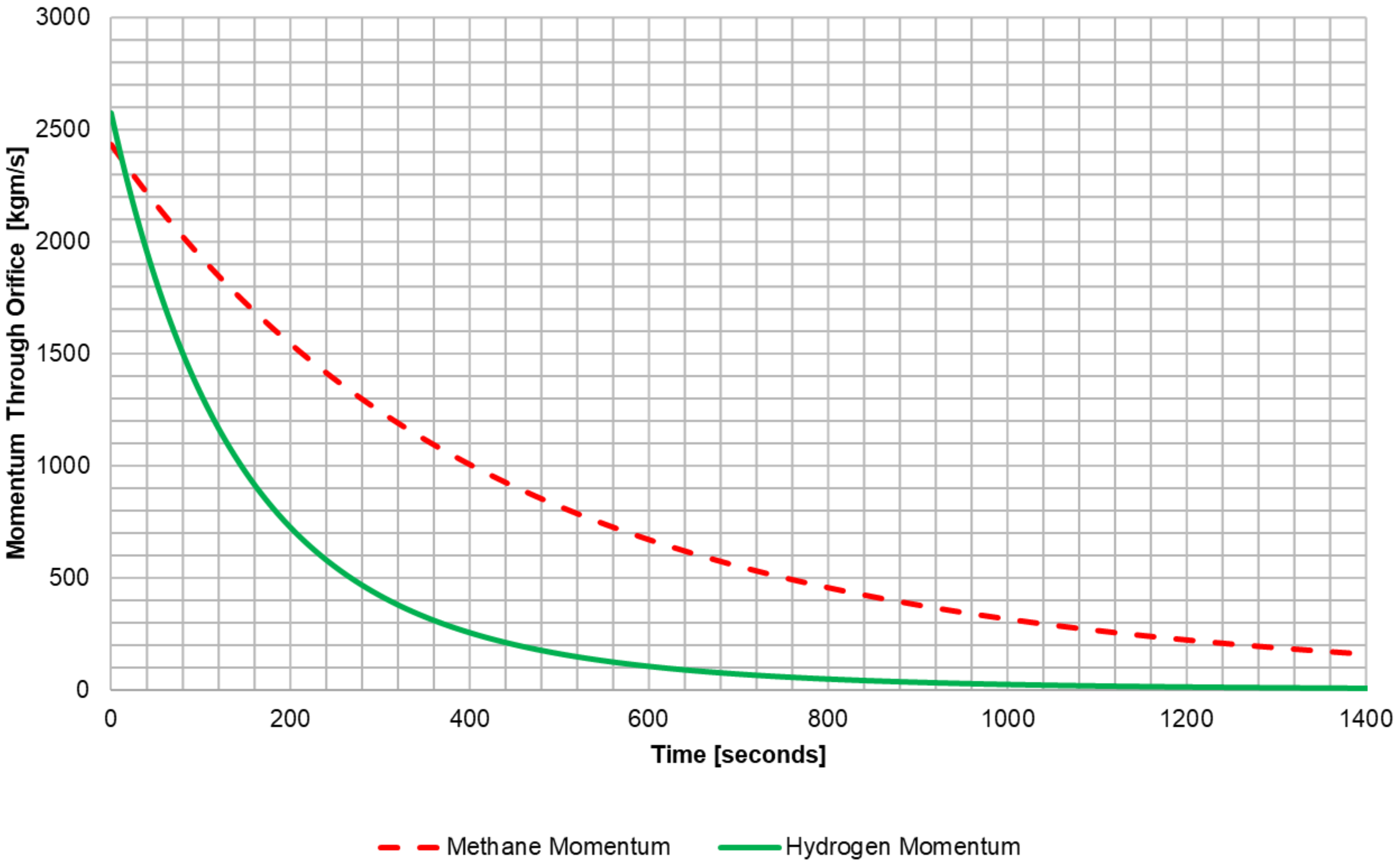
mass flow rate is lower. Initial volumetric flow rate is lower





Momentum

- Momentum = mass x exit velocity
- Exit velocity = speed of sound
- Releases are sonic in all meaningful scenarios
- Choked flow occurs at just over 0.8 barg for both gases
- Initial momentum shared with surrounding atmosphere is similar

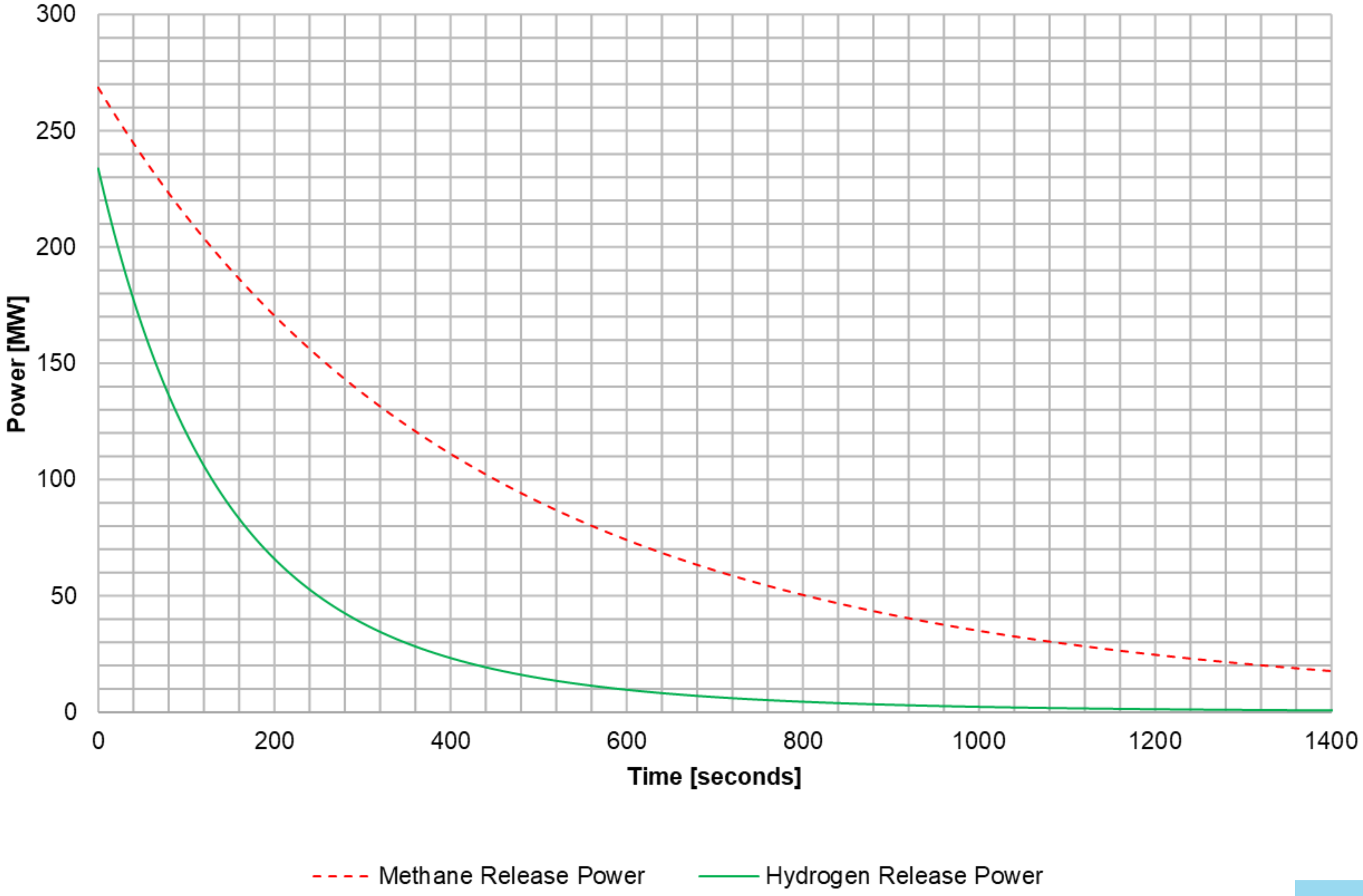


Release power
(ratio of calorific values is similar to ratio of sonic velocities)

Power = MFR x heat of combustion

Heat of combustion:
120 MJ/kg vs 50 MJ/kg

Speed of sound
1320 m/s vs 466 m/s



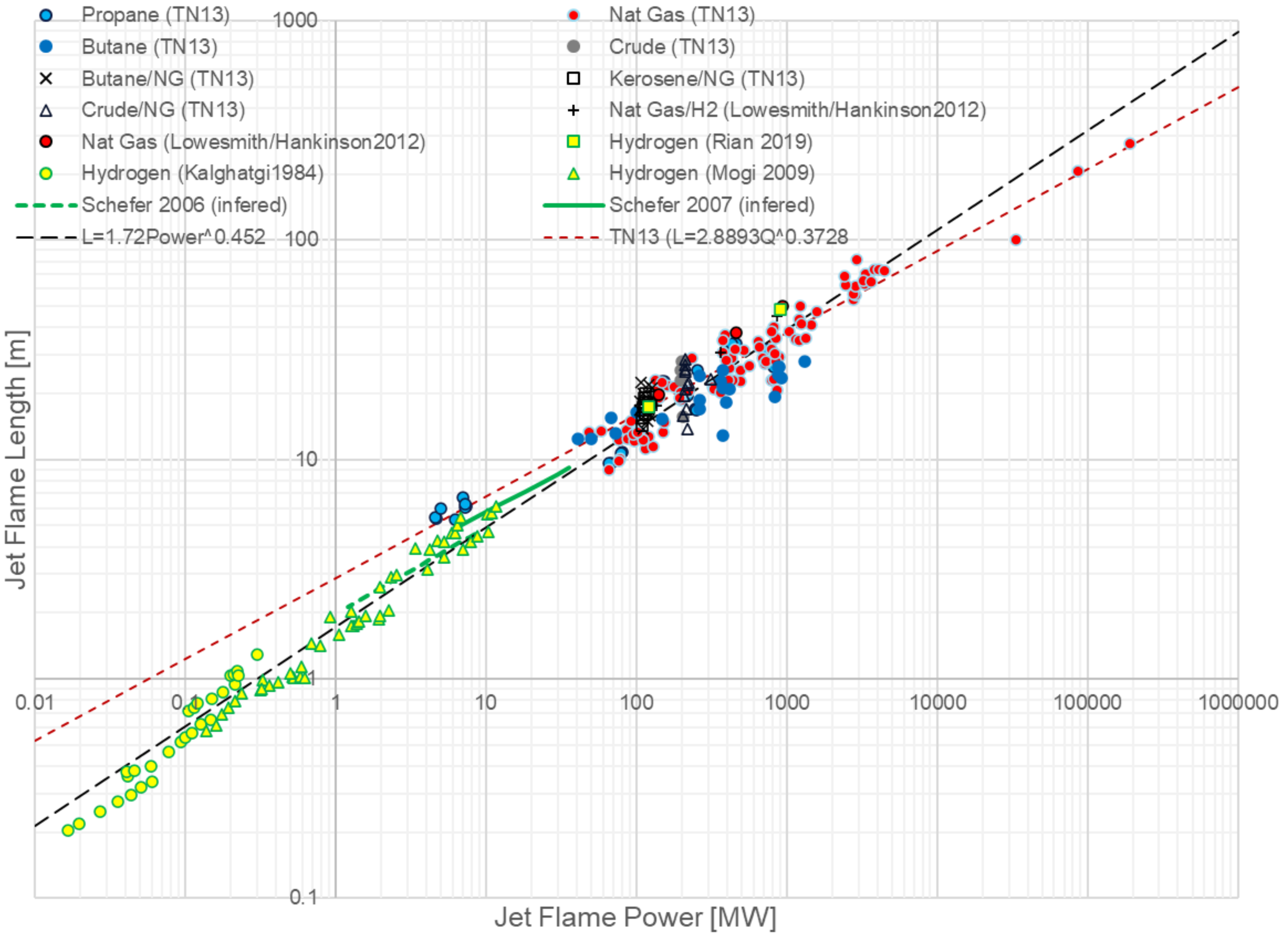
Flame length
Plotted vs release power.

FABIG TN13 contains an empirical plot that correlates jet fire flame length with release power

Adjacent plot takes data from TN13 and adds various H2 jet fire data.

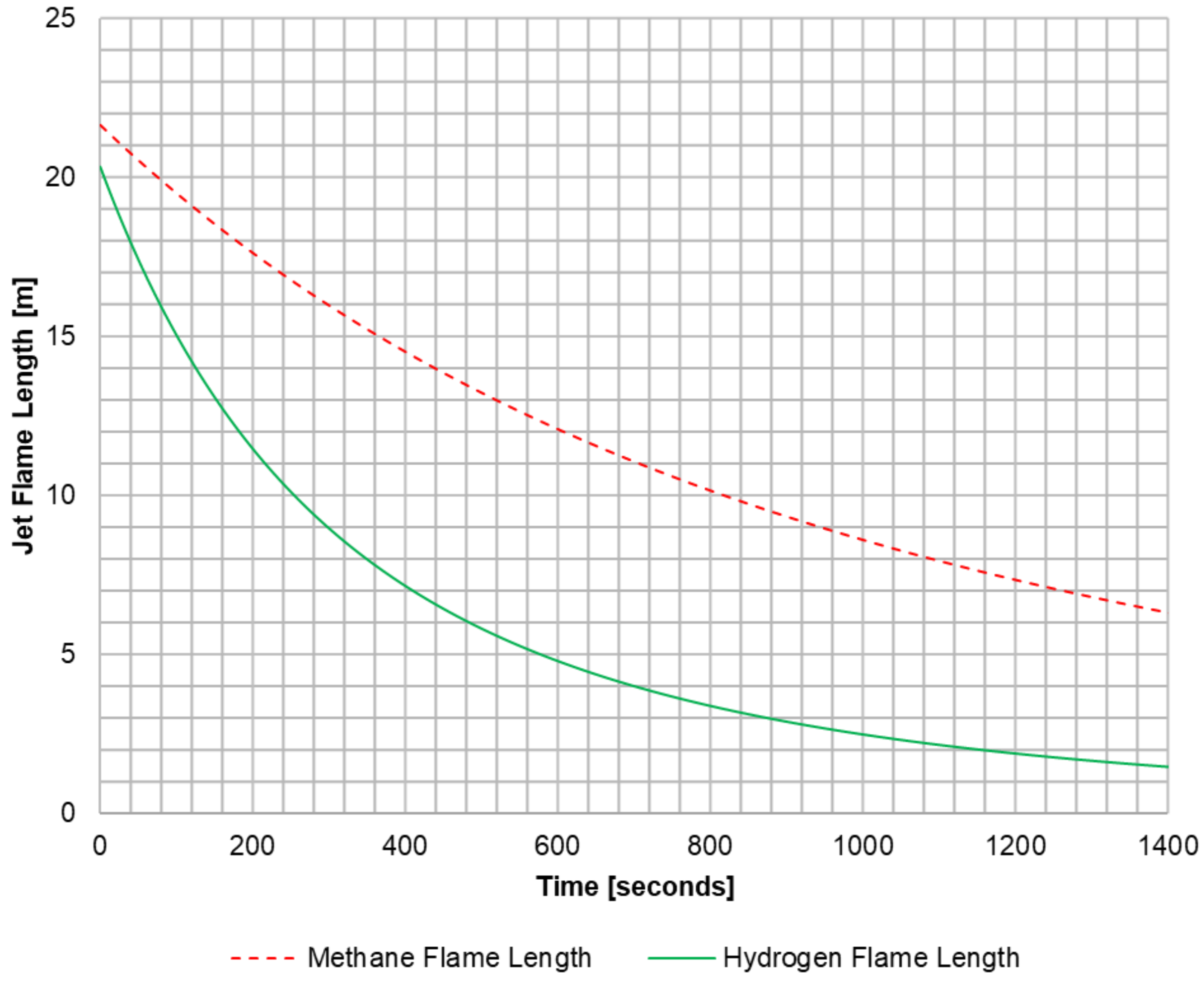
Plot shows good agreement for the large scale H2 data

Line of best fit is different from correlation in FABIG TN13



Similarities: Predicted jet fire flame length

- Using the correlation from previous slide, jet fire flame lengths are plotted for hydrogen and natural gas.
- For the same release conditions, hydrogen and natural gas initial flame lengths are similar.
- KFX has been used to model the large scale H2 data in earlier slide.
- Jet fire model THRAIN and outflow model CORCE have predicted similar relationship between mass flow rates of H2 and CH4.
- THRAIN predicts similar centreline flame velocities and densities along jet fire length



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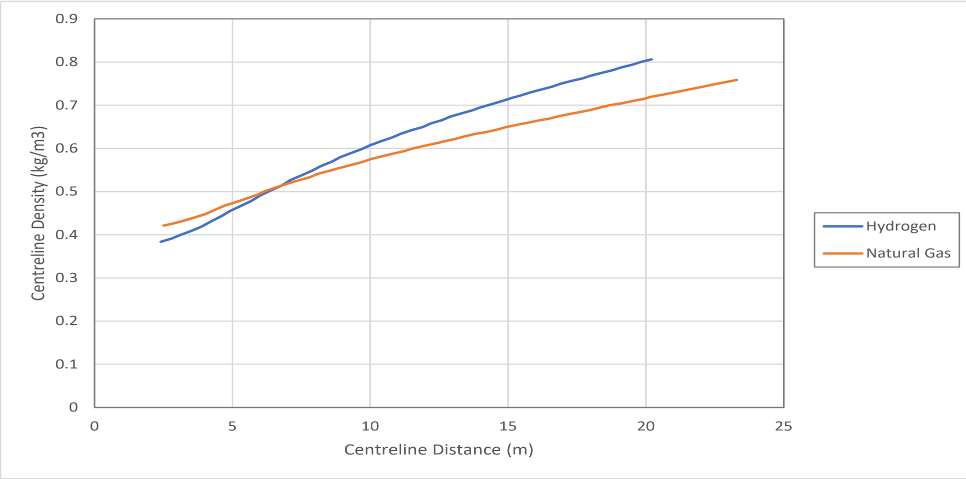

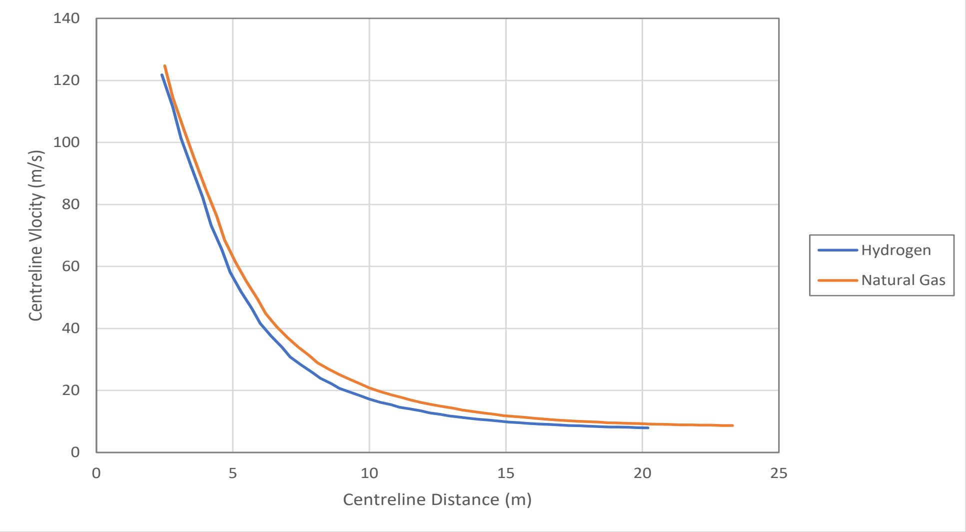

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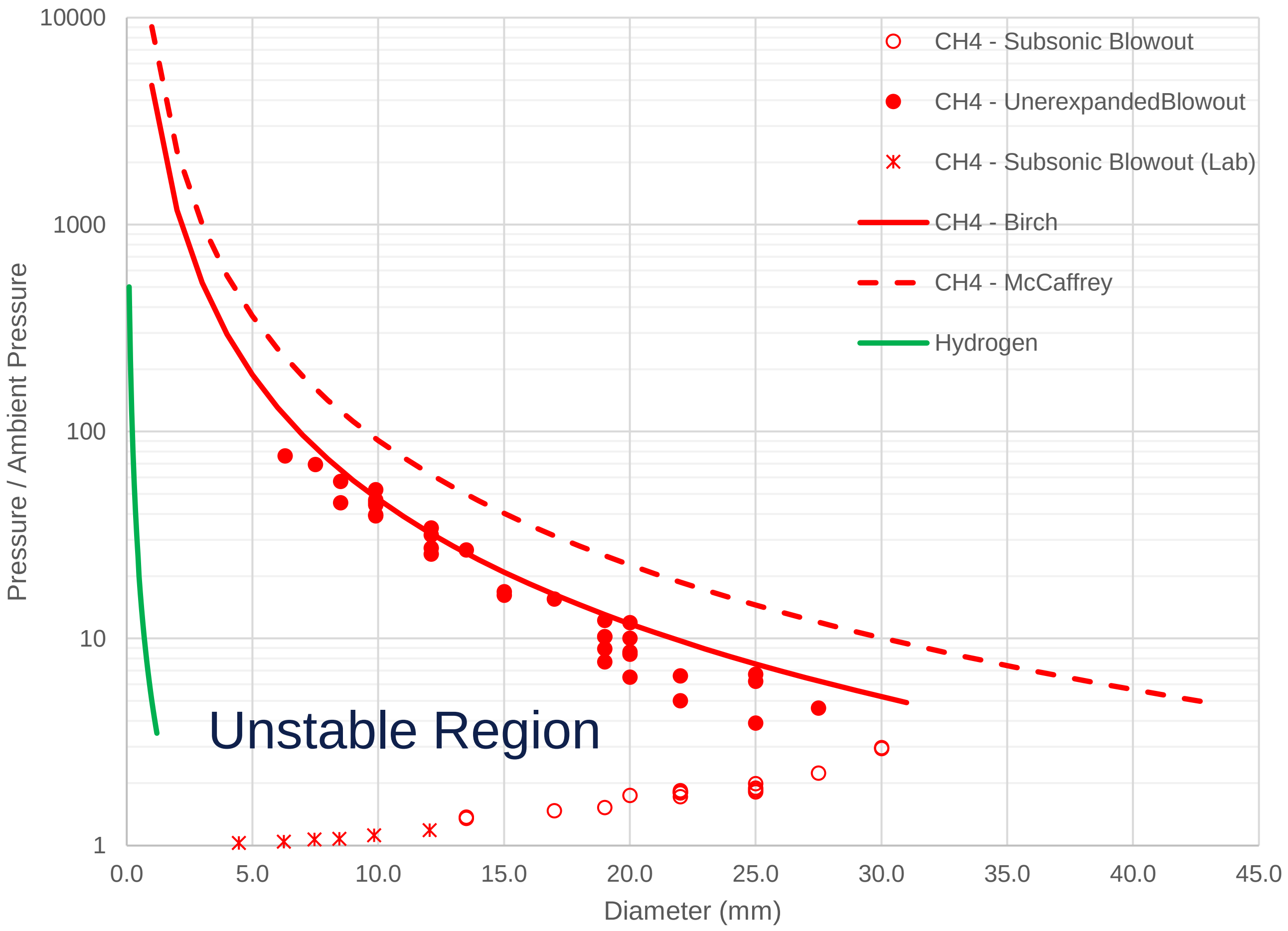
Similarities: Radiation from flame

- Measured radiation: 12% and 19%
- KFX modelling predicted 15% and 18%
- Similar to quoted values from FABIG wrt natural gas
  - Admittedly flame would be less luminous
- Other sources in the literature suggest that fraction of release emitted as radiation should be lower for hydrogen than for hydrocarbons
- But also it is expected that fraction of energy released as radiation will increase as the release size grows

Differences: Flame Stability

- Flame stability of hydrogen is expected to be very different to natural gas
- Due to higher burning velocity and wider flammable limits, it is expected that hydrogen flames will:
  - stabilise closer to the release source
  - be very stable
- This could give rise to high velocity flame with damaging flow forces
- Also flame is less likely to blow off leading to an explosion



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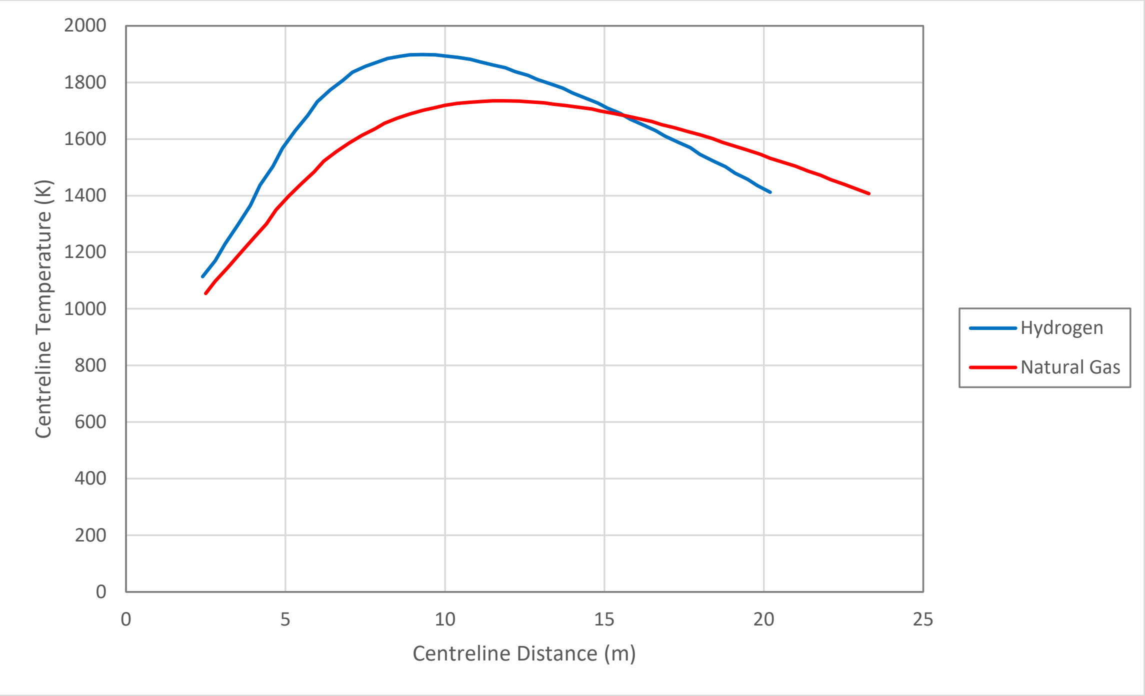
Differences: Flame temperature

- Most sources expect flame temperature to be higher in H2 jet fires
- THRAIN predictions show significant increase in flame temperature in some locations in the flame
  - Approx. 200C.
- Is this an important difference for straps and bands? Or fibres? Or meshes?



Consequence for Passive Fire Protection Materials

- Jet fire testing is currently performed mainly with the ISO 22899-1 jet fire test
  - Uses propane at 0.3 kg/s released into a recirculation chamber to simulate damage caused by a 3 kg/s natural get jet impinging onto a pipe.
  - The propane jet is not ignited at the point of impact, so the maximum flow velocities do not necessarily coincide to the point of maximum damage.
- Hydrogen jet fires are expected to have similar flow velocities in the fully developed flame, but are also expected to stabilise close to the burner.
- Hydrogen jet fires may have similar or lower proportion of radiative heat transfer.
  - Where reactive coatings are concerned, they will ‘donate’ carbon and particles to the fire
- Hydrogen jet fires may have higher maximum flame temperature

- Standard test might be a good replicate for a fully developed hydrogen jet fire
- Standard test might not be adequate for PFP performance at short impingement distances or highly congested areas

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