Hydrogen Projects – Business as Usual?

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Welcome

- Historical Gas Provision in the United Kingdom
- The Drive for Change
- The Requirement to Demonstrate Hydrogen Safety
- Designing for Hydrogen
- Process Safety Lifecycle Concept
- The Challenges
- The Successes

Historical Gas Provision in the UK

Town Gas

- Methane, hydrogen and carbon monoxide
- Hydrogen >50% v/v
- Industrial, domestic cooking and heating

Continental Shelf Act

- Passed in 1964
- Exploration of the North Sea for hydrocarbons
    - Perception the this was ‘clean’ and ‘cheap’

Conversion

- Passed in 1964
- Took nearly 10 years to complete

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The Drive for Change

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"Hydrogen is one of a handful of new, low carbon solutions that will be critical for the UK's transition to net zero."

- The UK Hydrogen Strategy

Greenhouse Gas Emissions

- Extreme Climatic Events.
- Global trend in weather patterns.
- Global mean surface temperature rises.

Net Zero

- Blueprint for a fully decarbonised UK.
- Reduction in emissions.
- Cleaner, more efficient fuel.

Hydrogen

- UK Ambition of 5GW of low carbon H2 production by 2030.
- Successful research and innovation to date
- Initial network regulatory and legal framework in place by the mid-2020s

Demonstration of Safety

Ground-breaking Trials

- HyNet
- HyDeploy
- Industrial Fuel Switching

Safe Production and Use of H_2

Experience

- Steam-methane reforming (SMR).
- Town Gas.

Current codes, standards and regulations

- The controlled quantity of hydrogen for The Planning (Hazardous Substances) Regulations 2015 is 2 Tonnes.
- COMAH regulations specify hydrogen as a named dangerous substance.
    - The threshold quantity is 5 Tonnes (lower tier).
    - The threshold quantity is 50 Tonnes (upper tier).
- Dangerous Substances and Explosive Atmospheres Regulations (DSEAR).
- Pressure Equipment (safety) Regulations (PER).
- Carriage of Dangerous Goods and Use of Transportable Equipment Regulations (CDG).

What can we expect from future regulation, codes and standards?

- More hydrogen specific …?
- Address low-carbon hydrogen..?
- IGEM Hydrogen knowledge centre

Designing for H_2

Hydrogen's inherent physical properties, much like other flammable compounds such as natural gas, can be safely managed through lifecycle management of a facility – from design to operation and modification.

- Know the properties
- Assess the implications
- Implement design solutions

The earlier the identification of risks, the more time-efficient and cost-effective the solution.

Hydrogen Properties

Property		Implication	Design and Operation Solutions
Appearance and Odour	Colourless, odourless, and tasteless.	Difficult to detect.	Provision of appropriate types of gas detection equipment – fixed, portable and personal.
Toxicity	Non-toxic, however, does not support life and may act as an asphyxiant.	Large clouds may cause oxygen deficiency if not ignited, and affect the ability to escape.	Appropriate layout should be considered. Confined or congested spaces providing an opportunity for gas build up should be avoided. Preferentially facilities and equipment should be located outdoors. If indoors, good ventilation should be ensured. Potential leak points should be identified and appropriate inspection and maintenance regimes should be put in place.
Flammability	Extremely flammable in air.	Potential for fires and explosions.	Identify loss of containment scenarios for pressurised pipework and equipment and ensure adequate layers of protection are in place. For 'expected' small leaks, such as those covered by hazardous area classification, appropriate extents of zones should be calculated, potential ignition sources identified, and eliminated or controlled as appropriate. Emergency response plans should be put in place.

Property		Implication	Design and Operation Solutions
Ignition	Ignition energy is lower than methane and it burns in air with a very hot and almost invisible flame.	Pure hydrogen and high percentage hydrogen flames are difficult to see. Fires or flames may be harder to detect.	Tight control of ignition sources is necessary. Thermal imaging cameras (fixed) or portable may aid staff to detect an incident and avoid/escape the area.
Detonation	Greater propensity to detonate in mixtures of air than more common flammable fuels. Maximum burning velocity of a hydrogen-air mixture is about eight times greater than those for natural gas.	Deflagration to detonation transition is more likely than with a methane or natural gas explosion. Blast overpressure will be higher than for a deflagration detonation and the effects may extend over larger areas.	The design should consider where oxygen-hydrogen boundaries exist, such as vents to atmosphere. Appropriate detonation arresters should be fitted. Vent line design should be targeted where detonation may be a concern. This will include minimising fittings and bends and accommodating a higher diameter to length ratio where practicable. Consequence assessment and perhaps QRA modelling may be required to fully understand the consequences from a detonation event, especially if consequences are likely to extend beyond the site boundary.
Density and Viscosity	Low density and low viscosity.	Leak prevention is difficult. Hydrogen is likely to pool at high points, such as roof apexes.	If a hydrogen leak occurs in an open or well-ventilated area its diffusivity and buoyancy will help to reduce the likelihood of a flammable mixture forming in the vicinity of the leak. Ensuring good ventilation and no 'dead spots' is key. Hydrogen leak detection should be placed accordingly.

Liquid Hydrogen

Hazard		Design and Operation Solutions
Boil Off Gas	Cold boil-off gas, as well as the liquid hydrogen, can produce severe burns upon contact with the skin.	Segregation of people and equipment. Identification of likely leak points. Well documented inspection and maintenance procedures, including details of correct personal protective equipment (PPE).
Rapid Phase Transition (RPT)	Liquid Hydrogen carries a potential for rapid phase transition (RPT) explosion – this is when cold liquid comes into contact with a liquid that is above the boiling temperature (-253°C for LH2 at atmospheric pressure) of the cold liquid.	Keeping potential loss of containment points away from pools of water where possible. This may include the requirement for avoidance of entry into water pools or directly into rainwater drainage. Drainage.
Material Degradation	Liquid hydrogen presents severe challenges to the materials it comes into contact with, due to low temperature exposure and hydrogen embrittlement. The thermal expansion and contraction of equipment when exposed to temperature fluctuations of ambient to LH2 temperatures can cause wear and premature failure.	Selection of correct materials of construction. Pipe stress analysis. Inspection and maintenance regimes.

Hazard		Design and Operation Solutions
Liquid Spills	The release of gaseous hydrogen from a spill would be initially very cold, denser than air and start accumulating at low level. All gases will be condensed and solidified should they be exposed to liquid hydrogen. Leaks of liquid hydrogen in air will cause oxygen to preferentially condense out leading to oxygen enrichment of the solidified material. Oxygen-enriched air reduces the ignition energies, increases the combustion rate of flammable and combustible materials and increases the likelihood of a detonation. Spills of liquid hydrogen can result in air condensing out in and around the pool of liquid. This can result in the formation of zones in the pool, containing an explosive mixture of liquid hydrogen and solidified oxygen-enriched air. These mixtures are shock-sensitive and can detonate with a yield similar to an explosive.	Placement of gas detection at low level around areas of potential liquid spills. Ensuring low occupancy in areas identified with potential for LH2 loss of containment incidents.

Hazardous Area Classification

Work carried out by Health and Safety Laboratory, Buxton (HSL) for the HyDeploy Trial at Keele University looked at concentrations of up to 20% hydrogen blended in Natural Gas (NG).

- Volumetric release rates could be up to 10% higher for the blend than NG.
- Dispersion distances (to ½ LFL) could be up to 15-25% further for the blend.
- HSL proposed pragmatic, conservative modified criteria to be applied at HyDeploy to the Natural Gas Standard IGEM/SR/257 for the blend. Further work will be required to allow these criteria to be used outside the HyDeploy Project.

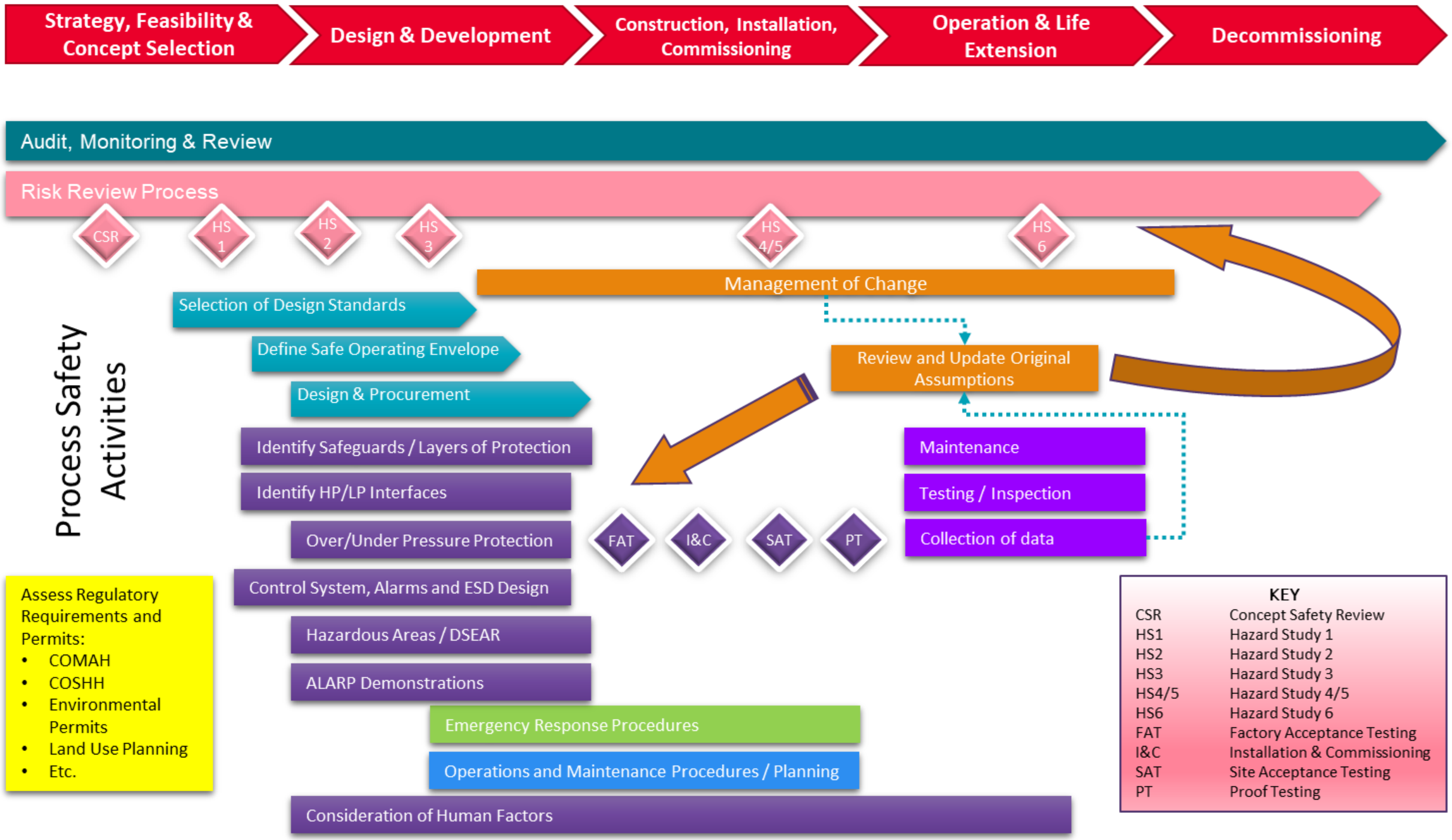
BS EN 60079-20-1:2010

- *NG with up to 25% hydrogen is Group IIA*
- *Hydrogen is Group IIC*
- *Both NG and hydrogen have a T1 temperature class*

Standards addressing Hazardous Area Classification for pure hydrogen or hydrogen blends above 20% are in wide use already.

- The Energy Institute (EI) Model Code of Safe Practice EI 1510 guides that any mixture containing above 30% volume hydrogen should be treated as hydrogen.
- EI representative fluid category is G(ii).
- HSL tool, Quadvent, is also recommended for classifying zones and calculating extents

Project Lifecycle



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The Challenges

Exemptions to GS(M)R

- The current limit of hydrogen in the natural gas supply is 0.1% (molar) according to the regulations.
- For any project wishing to exceed these limits, official exemption must be granted by HSE.
- Significant effort on the part of the project to demonstrate the safety case

Gas Industry Best Practice

- Gas industry standards and practices are tailored to the definition of natural gas as mandated by the GS(M)R regulations.
- Company or IGEM standards are the norm – which can be prescriptive rather than risk-based.
- Good communications and flexible interpretation is required.

Trials and Demonstrations

- Physically fitting new equipment into an existing facility, finding the best layout solutions.
- Planning for equipment and plant that can be removed at the end of a trial.
    - Reinstating the plant to its 'as-was' condition.
    - Potentially moving trial equipment to another location or 'mothballing' for later use.
- Installing and commissioning without affecting current production throughput or quality.
    - Potentially narrow and fixed windows during a planned shutdown.
- Sourcing a temporary hydrogen supply.
- Getting the trial results within the allocated window – there is little time to 'tweak' or optimise during a commissioning phase.

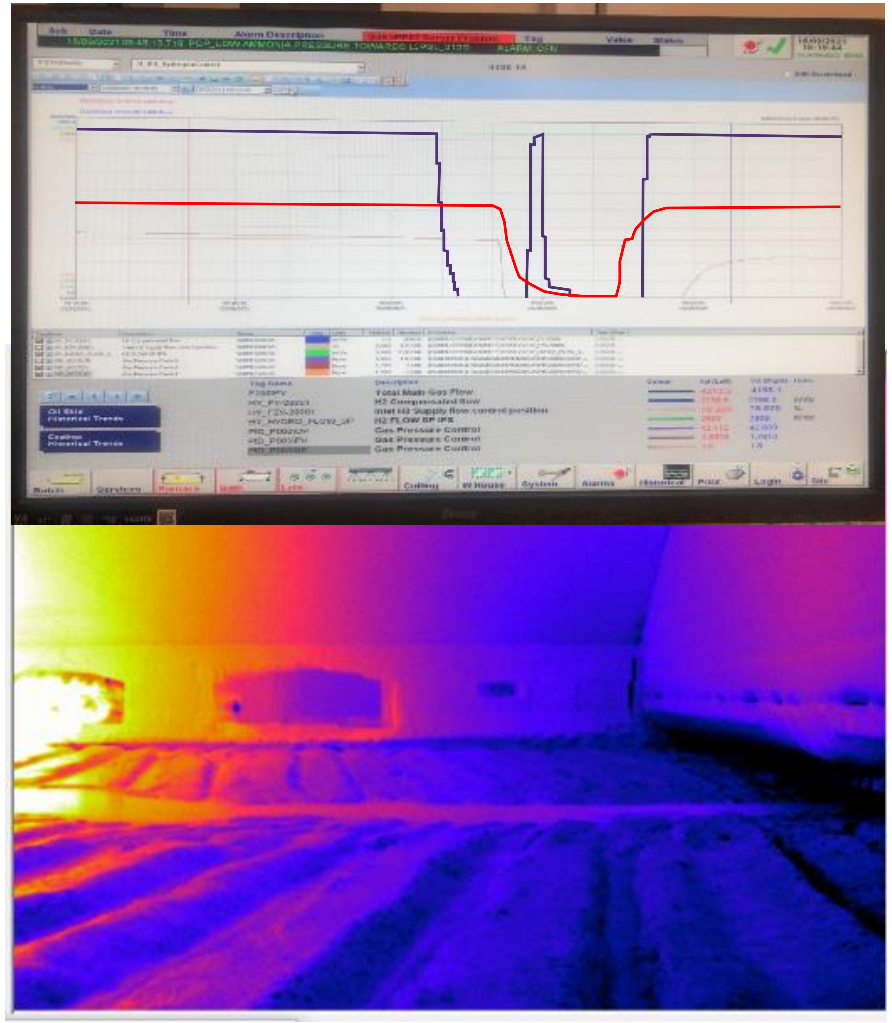
Successes

HyDeploy @Keele

- Customers at Keele have been using the blend normally and have reported that they have noticed no difference.
- Positive media attention.

Industrial Fuel Switching @NSG

- Fuel flow increased roughly in line with modelling predictions.
- Modifications made to burners as fuel flow rate increased.
- Furnace monitored using thermal imaging camera as flames became invisible.
- Modest increase in energy required firing hydrogen compared to methane.
- Other furnace parameters monitored with no issues noted.



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Summary

Based on experiences to date, a hydrogen energy project can and should be treated like any other with regards to the process safety elements. Success can be achieved if the project:

- Follows best practice;
- Schedules the appropriate risk assessments;
- Allows for inherent properties within the design;
- Plan for the right deliverables;
- Is creative and flexible;
- Maintains good working relationships between all parties.

Over the next decade, as the hydrogen roadmap is achieved, I fully expect hydrogen projects to become, "business as usual".

Thank You

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