EVALUATING THE OPPORTUNITY TO REPURPOSE GAS TRANSMISSION ASSETS FOR HYDROGEN TRANSPORTATION

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ABSTRACT

The UK National Transmission System (NTS) is a key enabler to decarbonise the gas network in Great Britain (GB) in order to meet the UK government's target of net-zero emissions by 2050. FutureGrid is National Grid's research programme assessing the capability of the transmission system to transport hydrogen. Our goal is to accelerate the decarbonisation of power, industry and heat by delivering a safe supply of energy to all customers both during, and after, the energy transition. FutureGrid will lead to a better understanding of what the technical parameters are around the ultimate role of the NTS in the energy system, and how the transition can be managed.

Under FutureGrid, National Grid will construct a NTS hydrogen test facility at DNV's Spadeadam testing and research site. NTS assets, due to be decommissioned in early RIIO2, will be reconstructed to create a test network that can be used to answer some of the fundamental questions around safety and operation of a converted network. Flows of hydrogen/natural gas blends, including 100% hydrogen, will be tested for the first time in GB at transmission pressures. This system will connect to the existing H21 distribution network test facility at Spadeadam to prove a complete beach-to-meter network can be decarbonised, to develop a comprehensive programme for the hydrogen transition.

The project will provide a transmission facility which is a key enabler for more advanced hydrogen testing on industrial equipment such as hydrogen separation technology, hydrogen compressors and/or purification of hydrogen for transport. Our paper will detail the current position and aims of the project.

1.0 INTRODUCTION

Since the UK's declaration of Net Zero by 2050 the country has made significant advances to decarbonise our energy systems. Reductions to date have largely come from significant quantities of renewable generation displacing the legacy coal fired generation on the system.

With three quarters of GB energy still coming through the gas networks we have to consider more fundamental steps to decarbonize, and over the recent years the gas industry has been reviewing the potential to replace natural gas with hydrogen to continue to supply industry and heat our homes. Significant research has already been published on the role of distribution networks and the repurposing that will be required to ensure a safe network.

Focus now turns to the transmission network, and early desktop research is suggesting that they too might be repurposed under a revised safety case. National Grid has developed the HyNTS (Hydrogen into the National Transmission System) programme to develop this research and is now commencing a full-scale trial of decommissioned NTS assets under a range of hydrogen blends up to 100%.

The current NTS is a 7,600km network which carries 881TWh on an annual basis. It was developed from the 1960's through to the 1990's to take advantage of the UK's discoveries of natural gas primarily in the North Sea. Today's primary importation terminals at St Fergus, Easington and Bacton are supported by the LNG terminals at the Isle of Grain and Milford Haven. Two interconnectors from the continent into Bacton, and a further connector from Moffat to Ireland, provide additional import/export links.

2.0 BACKGROUND TO OUR RESEARCH

2.1 Previous National Grid research

National Grid have undertaken a number of initial studies assessing the feasibility of transitioning the NTS to hydrogen service. These have generally focused on high level concepts to inform future development work.

Hydrogen in the NTS [1]: This work primarily examined the existing literature on high pressure hydrogen transportation within pipeline systems. There is a wealth of knowledge in this area and the key findings of the study showed that at high pressures hydrogen has significant effects on pipeline material properties; however, these can be effectively mitigated. There were also findings around other key risk areas to be addressed, such as gas escape rates and hazardous areas.

Project Cavendish [2]: A feasibility study assessing whether the existing energy infrastructure located on the Isle of Grain in Kent could be used to assist in the production and transportation of hydrogen to decarbonise London and the South East of England. A roadmap was developed culminating in 7.4GW of hydrogen production by 2040.

Flow Loop [3]: This project aimed to assess the hydrogen performance of standard X52 steel against a new pipeline construction method, MASIP (Mobile Automated Spiral Interlocking Pipe). The study showed a slight improved fatigue performance for the MASIP pipe but was concluded to be too short a test to be representative.

Feasibility study into 2% hydrogen blending at St Fergus and H2 pipeline and hub at Aberdeen Vision [4]: This was a collaborative project with SGN who operate the distribution network in Scotland. The project had two parts; assessing the feasibility of producing hydrogen at the St Fergus gas terminal and injecting it into the NTS at up to 2% by volume, and fully decarbonising Aberdeen through a purpose-built hydrogen pipeline from St Fergus. A number of injection methods were proposed at St Fergus and all had promise. One of the main challenges noted was managing the variation in demand versus hydrogen production. This could be done through modular units or local storage.

Hydrogen Deblending in the GB Gas Network [5]: This study was done in collaboration with all GB distribution networks (NGN, SGN, Cadent and Wales & West Utilities) and assessed the feasibility of using industrial gas separation technology to ‘deblend’ hydrogen from a blended gas stream for key end users. The study showed that this was a feasible approach for a number of different scenarios, however the costs of deblending vary substantially depending on the local requirements and operating conditions.

Roadmap to FutureGrid: In preparation for the detailed design of a full-scale test facility it was necessary to do initial design and feasibility work to ensure the test facility could be successfully developed. This included sending samples of pipeline to DNV’s materials testing laboratory for qualification.

2.2 Learning from European transmission operators

The repurposing of gas transmission assets to carry blends or full conversion to hydrogen is currently being considered by many pipeline operators around the world. The key focus of early research has been on the ‘readiness’ of assets to take hydrogen with primary concerns being accelerated degradation of materials e.g. hydrogen embrittlement of pipelines, and whether hydrogen presents any more risk through increased leakage given a smaller hydrogen molecule.

In Europe a number of operators have conducted trials of hydrogen within transmission assets:

- In the Netherlands, Gasunie have converted an existing 12km natural gas pipeline to a hydrogen blend [6]. This pipeline, at circa 70% hydrogen blend, was retrofitted with new control valves and has been operating continually now since 2018.

- In Italy, SNAM the national operator, conducted trials on blends of hydrogen on a small part of the network. Low level blends of 5%, and then 10%, were successfully injected into the network and tracked through to a number of industrial users.

- In Denmark, the Danish Gas Technology Centre have been trialling hydrogen up to 24% at transmission pressures 40-80 Bar in a small diameter offline pipeline facility. The trials are due to conclude in 2021.

Independently of the trials, a proposed hydrogen backbone concept has been developed for a 23,000km pan European network across 11 countries. The report, which has been developed by Guidehouse, suggests that approximately 75% of pipelines could be repurposed to carry hydrogen and the cost of repurposing could be around half the cost of a new build network [7].

3.0 EXPECTED REQUIREMENTS OF THE NETWORK IN 2050

There are a number of estimates for the amount of hydrogen which the UK will require in 2050. The Climate Change Committee in the 6th Carbon Budget [8] currently suggest 225TWH will be required whereas National Grid's Future Energy Scenario's [9] developed by the independent ESO suggest 450TWH in the System Transformation scenario which assumes a wider hydrogen roll-out.

To evaluate the capabilities of the current NTS, existing hydraulic models have been converted to model hydrogen instead of natural gas to test the overall capacity of the current network. To achieve this, it should be noted, that it was assumed that hydrogen will be supplied at the current natural gas supply points; this will clearly impact the results and will be updated in the future as more information on hydrogen production becomes available.

Accepting the assumptions, the results showed that the NTS could broadly carry the volumes of hydrogen required in 2050. Increased velocities were observed in some parts of the network and some additional reinforcement may be required depending on the future supply scenarios as the hydrogen demand may increase.

Modelling the future potential scenarios will be a major focus of National Grid's efforts through 2021 as we define potential routes for Project Union, a proposed hydrogen backbone.

4.0 KEY CHALLENGES TO REPURPOSING ASSETS

Whilst hydrogen shares many similarities with natural gas, there are a number of key differences in its behaviour and impact on the existing gas network. These can broadly be split into the following categories: materials impacts, changes to operation, safety considerations and network management.

4.1 Materials impacts

Hydrogen is the first, and smallest, atom in the periodic table and therefore it's molecular form, H_2, is the smallest possible molecule. This presents some unique challenges when transporting it at high pressures in a gas system.

Hydrogen molecules can be adsorbed onto the metallic inner surface of a pressure vessel, such as a pipeline, through a combination of physisorption and chemisorption. Once a hydrogen molecule has adsorbed to the metal surface it will disassociate into two hydrogen atoms and either be absorbed into the bulk material or recombine with another hydrogen atom and desorb from the surface.

The free hydrogen atoms absorbed into the bulk metal are now free to pass through the metal structure where they can become trapped at notable sites within the metal structure such as grain boundaries and vacancies.

There are three main ways through which this internal hydrogen can work to reduce the material properties: Hydride-induced embrittlement, Hydrogen enhanced localised plasticity and Hydrogen enhanced decohesion. Studies have shown that hydrogen, without mitigations in place, could impact pipeline steels in the following ways in Table 1.

Tensile properties	• Hydrogen reduces elongation ratios to a factor of 0.37-0.79 • Hydrogen reduces elongation to failure from ~35% to ~15%
Fracture properties	• Initiation toughness was roughly half after exposure to hydrogen • Tearing resistance is reduced by up to half • Fatigue crack growth rate increases by a factor of between 5 and 67
Strength properties	• Hydrogen has not been shown to have significant effects on Yield Strength or Ultimate Tensile Strength

Table 1. Material properties identified through the ‘Hydrogen in the NTS’ NIA project [1]

These material effects are given with very wide ranges due to the differences in material grade, pressure and operating conditions. As part of the FutureGrid programme, tests will be undertaken using assets and operating conditions representative of the NTS.

The most notable factors in exacerbating hydrogen embrittlement effects are the partial pressure of the hydrogen and the loading rate experienced by the pipeline.

4.1.1 Mitigations

These findings would seem to indicate that existing steel pipeline systems are unsuitable for transporting hydrogen. However, there is strong evidence demonstrating that the effects of hydrogen embrittlement can be successfully mitigated, or even negated, through number of different methods.

Oxygen has been repeatedly shown to inhibit crack growth rate and restore fracture toughness. Including just 500ppm oxygen in a hydrogen gas stream has been demonstrated to restore the fatigue crack growth rate to within 10% of that of air/natural gas.

Pressure reductions and the management of pressure cycling can also reduce risk, particularly from fatigue crack growth. Furthermore, advanced polymer coatings can be used to prevent hydrogen from bonding to the steel surface. These could be combined with other mitigation techniques to be applied to areas of the network considered a particular risk.

4.2 Changes to operation

The existing network has dozens of different equipment types from valves, filters and regulators to analysers, meters and compressors. Many of these rely on the specific chemical and pneumatic characteristics of natural gas in order to operate and therefore are not inherently compatible with hydrogen. A number of these may be modifiable to operate with hydrogen, for example changing the trim on a flow control valve. Some, such as filters, may be easily replaceable. However, it is likely that there will be many large assets which will require replacement. Thankfully, these assets are all above ground which will significantly reduce replacement costs as compared to the cost of replacing buried assets.

A literature review and OEM engagement study was undertaken to develop an understanding of the available evidence for existing natural gas assets to transport hydrogen. The results were compiled and summarised in Figure 1. This represents a general understanding of compatibility of key assets, however there is a great deal of variation in the materials, operating mechanisms, age, and construction standards of these assets and therefore each asset must be individually verified before allowing hydrogen service.

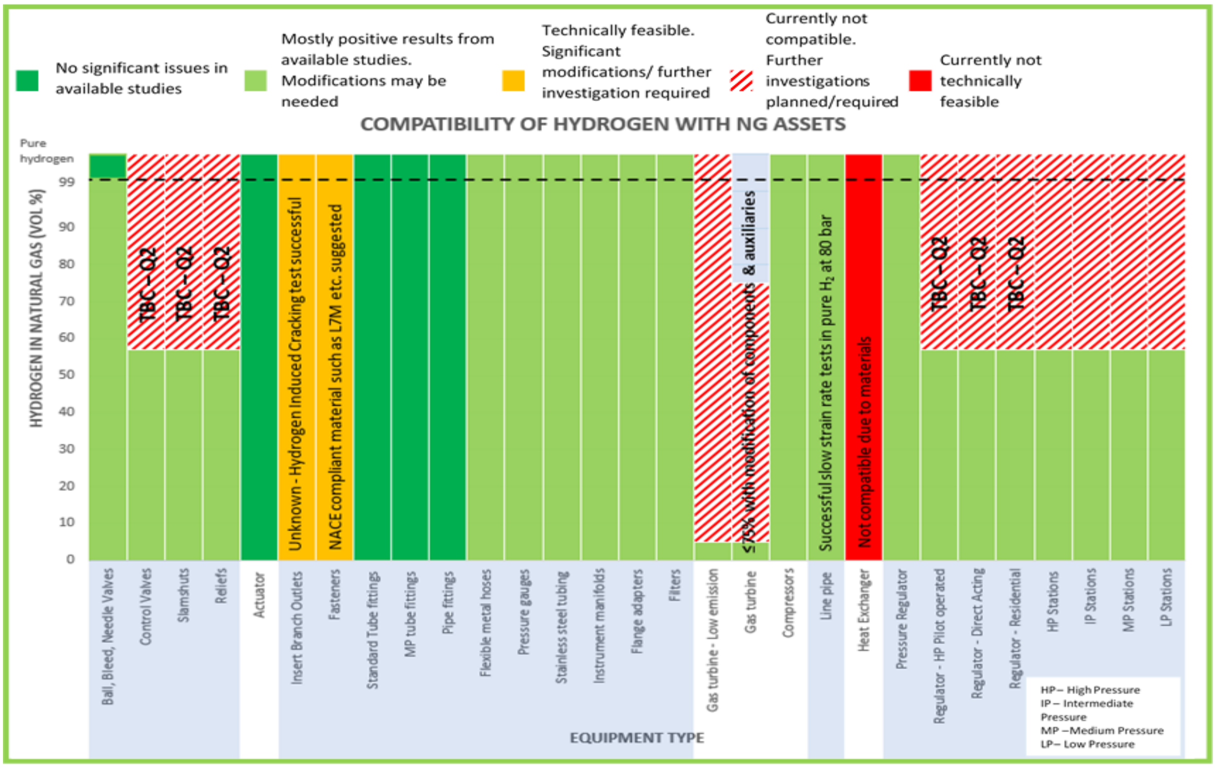


Figure 1. Initial review of NTS asset capability for hydrogen service

Table 2 shows a summary table giving some of the key tests which are required to determine the suitability of existing assets when switched to hydrogen service. Hydrogen blends have also been considered when developing these tests and it is likely that a number of assets will be compatible with hydrogen blends but not a pure hydrogen stream. Many of these tests are only possible when operating the assets at representative pressures and gas flow rates, and therefore a full-scale demonstration facility is required to definitively prove the assets' capabilities.

Asset type	Permeation/ Leak Test	Material Degradation	Differential pressure	Vibration	Responsive-ness	Accuracy
Flange and Gaskets	X	X				
Filters	X		X	X		
Valves	X	X	X			
Meters & Gas analysis	X				X	X
Pig Traps	X	X				
Regulators/ Flow control	X	X	X	X	X	X
Boilers/ Heat exchangers	X	X			X	
Vents	X	X				

Table 2. High-level testing requirements for NTS assets

4.3 Safety considerations

Although in principle hydrogen is very similar to natural gas (they are both colourless, odourless flammable gases) there are a number of key ways in which they differ. These will impact on our management of safety on the network and necessitate a number of changes to assets and operation.

4.3.1 Leak rates and diffusivity

Hydrogen is incredibly light and is the smallest possible molecule. This contributes to its very high rate of diffusivity in air which is over three times that of natural gas ($0.756 cm^2/s$ and $0.21 cm^2/s$ respectively). This is a significant advantage over natural gas as hydrogen is much less likely to form a lingering gas cloud which is one of the most significant risks for the operation of above ground installations on natural gas networks.

However, the same characteristics which contribute to this increased diffusivity also increase the leak rate of hydrogen from pressurised systems. For small orifices, for example a defect in the seal of a valve, the leak rate will increase by a factor of 1.25. However, for larger orifices the leak rate can be up to 2.89 times greater. Counterintuitively, this results in less total energy lost due to the much lower energy density per unit volume of hydrogen, around one third that of natural gas.

4.3.2 Ignition properties

The existing network has been designed to account for the risks associated with the ignition of natural gas, both to reduce the risk of ignition and to mitigate any resulting effects. Both of these risk factors change significantly when considering the introduction of hydrogen. Hydrogen has a much lower energy required to initiate an ignition and much wider limits describing a flammable concentration in air.

To reduce the likelihood of ignition, above ground installations are designed in such a way as to maximise the distance between gas containing equipment and possible sources of ignition, as well as ensuring that these sources present the lowest possible risk. For example, electrical equipment must be ATEX IIA certified for use in proximity to natural gas containing equipment. When moving to hydrogen service this equipment will no longer be compliant and electrical equipment must conform to the ATEX IIC standard.

Measures to mitigate the effects of an explosion must also be reassessed. For example, some regulator control buildings have rooves designed to vent the overpressure created by natural gas. These will no longer be compliant in hydrogen service as the overpressure from hydrogen is greater. Similarly, pipeline building restrictions are designed based on the characteristics of a natural gas release and ignition. Comparatively, hydrogen will have a higher overpressure but a lower level of thermal radiation from the following continuous jet fire. This could suggest that the immediate proximity of the pipeline corridor would have to be managed more stringently but the building burning distance could be relaxed.

Hydrogen is also known to self-ignite when vented to atmosphere at high pressure. This could cause issues for venting or purging pipeline sections as well as emergency venting of compressor stations. Vent designs and site locations may be modified to account for these risks.

4.3.3 Environmental impacts

The principle local environmental impact of the NTS is the noise generated by venting gas. Due to its greater gas velocity, hydrogen is known to generate more noise when vented and so this will need to be managed to reduce the impact of network operations on our local communities. This could be done through a redesign of vent stacks or resizing to reduce the rate at which gas is vented.

4.3.4 Gas detection

One of the principle ways in which risks are mitigated on above ground installations is through fire and gas detection systems. All installed systems are calibrated for natural gas and so new sensors would be required for hydrogen operation. Furthermore, due to the differing dispersal properties of hydrogen, the location of these on sites would need to be reconsidered.

4.3.5 Defect management

Certain processes for defect management on live pipe, such as hot taps, would have to be reconsidered for hydrogen service. Each process would have to be evaluated to determine whether the level of risk is below the acceptable threshold.

4.4 Network management

Once the safety and local operational challenges have been addressed there still remains the challenge of operating the transmission network with a different gas. The main challenge in network operation will be to maintain an equivalent energy throughput transporting a gas with around one third the energy per unit volume. There are three ways in which this can be done in a pipeline system; increase the pipe diameter, increase the operating pressure or increase the gas velocity. Increasing the pipe diameter is only possible when installing a new pipeline. Uprating of pressure has been done previously on NTS pipelines, though without a simultaneous change of fluid. Therefore, the preferable option would be to increase the gas velocity. The main limiting factors for gas velocity are saltation and vibration. Because hydrogen has such a lower density than natural gas, around one eighth the molar mass it is expected that gas velocity could be increased above current natural gas limits.

Hydrogen can be compressed in much the same way as natural gas, however there are two key differences which will impact how gas flow is managed within the network. Firstly, hydrogen requires a significantly greater energy input to generate a similar pressure lift to that which is seen on the network today. In contrast, hydrogen loses significantly less pressure when transported along a length of pipe and therefore the distance between points of compression can be increased. The combination of these factors would suggest that optimal management of a future hydrogen network would be done by larger compressor units on fewer sites with a greater distance between them.

5.0 FUTUREGRID OVERVIEW

Phase 1 of the FutureGrid project will bring together a range of existing NTS assets in building a hydrogen test facility. The facility will test flows of hydrogen and natural gas blends at concentrations of up to 100% hydrogen at typical NTS pressures. The data gathered from the testing programme will then be used to assess the impact of hydrogen on different NTS assets and inform future decision making around conversion of NTS assets to support hydrogen.

As the facility is based at Spadeadam, alongside the existing H21 facility, the transmission test facility will connect to the downstream H21 gas distribution facility to create a complete beach-to-meter gas network test system for hydrogen. Phase 1 will be split into three sub phases: phase 1a consists of building the offline NTS test facility, phase 1b of completing the Master Test Plan to test the compatibility and integrity of NTS assets with hydrogen blends up to 100% hydrogen, and phase 1c to perform a high level assessment of safety and risk, considering how converting the NTS to transport blends of up to 100% hydrogen will affect public safety.

5.1 Design

The test facility has been designed to include a representative cross-section of the types of assets and materials used in the NTS today. The assets that will be used to build the test facility have been identified as they are either planned to be, or have already been, decommissioned. National Grid’s RIIO-2 decommissioning strategy has highlighted these assets as no longer required but, in most cases, they are fully operational. Studies will be performed in situ to ensure the identified assets are fit for purpose before being relocated to the test facility.

Figure 2 shows an illustrative representation of the FutureGrid test facility. The hydrogen gas will arrive at the site via road tanker trailer and will be stored in a 60m long high-pressure reservoir. This will then be connected via 18inch pipe to the inlet slam shut valves which will provide overpressure protection, and a vent stack which provides the ability to vent down in the event of an emergency.

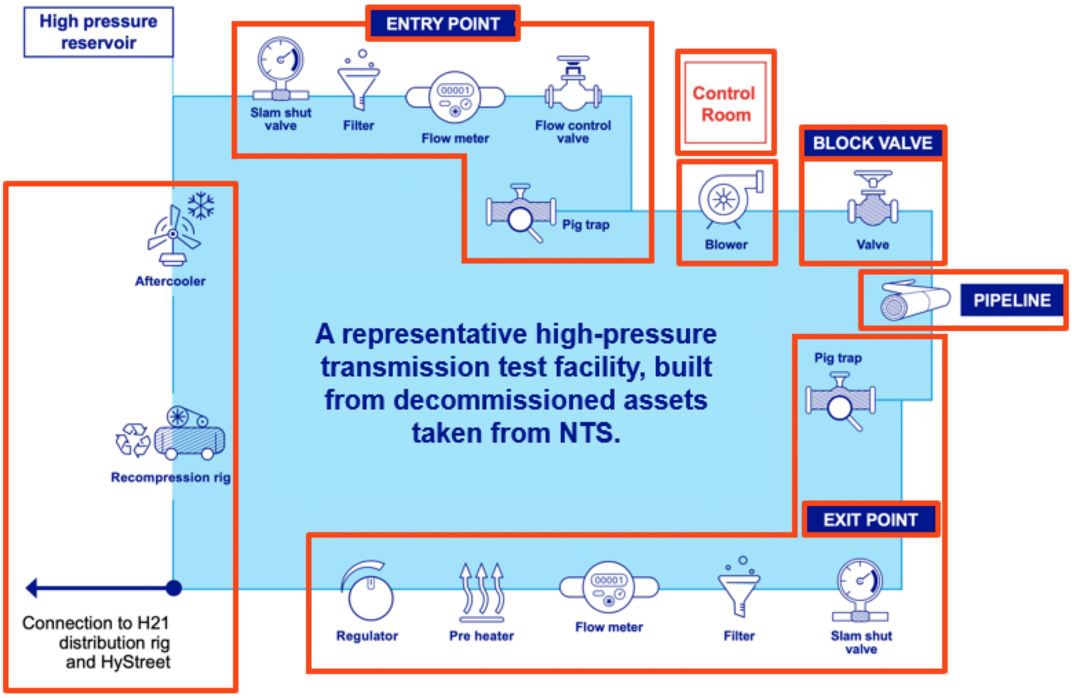


Figure 2. FutureGrid high-level design

The gas enters the main section of the test loop via an Entry Point which consists of: inlet filters to remove any dust and debris from the gas flow, inlet flow meters, to measure the flow of gas coming on to the facility, an entry point flow control valve which will be used to control the flow and pressure of the gas being moved through the facility.

The pipeline sections used in the facility are of varying age, grade and manufacturer in order to give a representative range of the existing NTS. These pipelines will connect sections of the facility to one another using in line block valves and isolation valves.

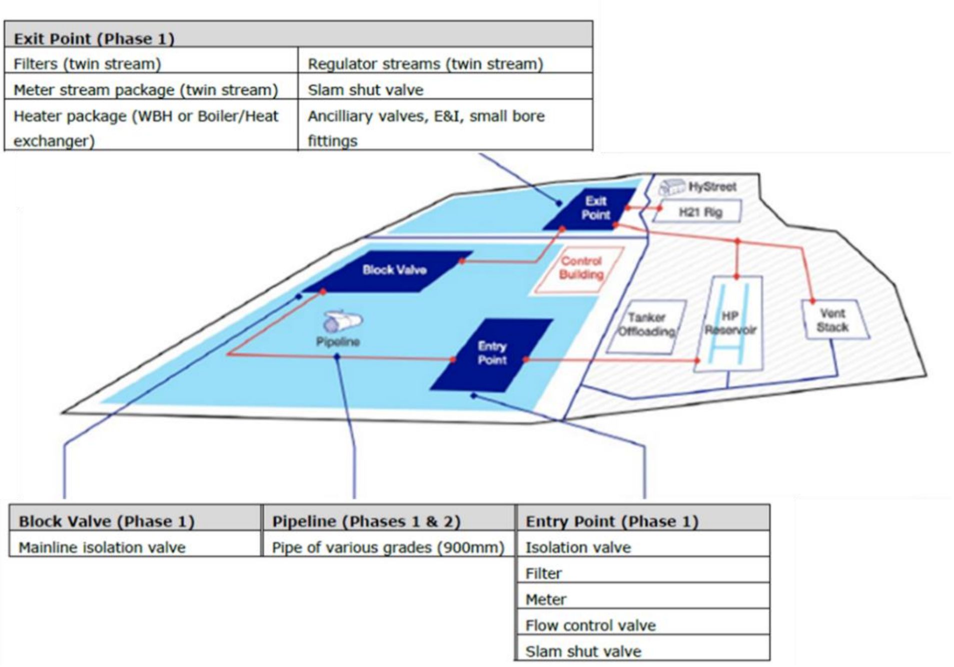
The gas will then be directed to an Exit Point. These are typically found on the NTS as supply points to Gas Distribution Networks or industrial customers, such as power stations. The Exit Point assets include filters, flow meters, a heat exchanger boiler package and pressure reduction. A small section of pipe and a small flow control valve has been installed at the facility to enable bypass of the Exit Point which will allow the gas to be sent around the loop to test high flows and high velocities, rather than pressure reduction, when desired.

The reduced pressure gas will leave the Exit Point and will be stored in a low-pressure reservoir to then be directed either through the recompression facility to recompress the gas back up to the high-pressure reservoir, allowing the gas to be recirculated around the FutureGrid facility once again, or alternatively, as a supply to the adjacent H21 gas distribution system.

A control room will be included as part of the design and construction, which will include systems for controlling pressures and flows and gathering test data, such as velocity, temperature, pressure and gas composition.

5.2 Test plan

The test plan for the Phase 1 details the tests to be undertaken on the flow loop at the hydrogen test facility at Spadeadam. The plan details test requirements of each asset, sequences, priorities and process conditions. The objective of these tests is to provide evidence and understanding as to whether it is possible, and safe to flow high-pressure hydrogen blends of up to 100% hydrogen through existing NTS assets, while maintaining containment and operation of the NTS. In addition to tests to be carried out on the test facility, the test plan also includes several tests which need to occur prior to, and in parallel with, the build and commissioning stages. These offline tests will consist of both laboratory scale and full-scale tests. Laboratory tests will be used as a quick and cost-effective method for establishing likely performance and confirming preparation times for full-scale tests. Full-scale offline tests are required to provide a safe and controlled test environment. These tests also include tests that, if done on the test facility, could compromise the integrity of the assets. The test plan covers all possible tests. Certain tests will be prioritized initially, and the outcome of these tests will determine future tests.



Exit Point (Phase 1)	
Filters (twin stream)	Regulator streams (twin stream)
Meter stream package (twin stream)	Slam shut valve
Heater package (WBH or Boiler/Heat exchanger)	Ancilliary valves, E&I, small bore fittings

Block Valve (Phase 1)	Pipeline (Phases 1 & 2)	Entry Point (Phase 1)
Mainline isolation valve	Pipe of various grades (900mm)	Isolation valve
		Filter
		Meter
		Flow control valve
		Slam shut valve

Figure 3. FutureGrid assets to be tested in phase 1

Figure 3 provides an overview of the assets that fall into the phase 1 test programme. Offline tests will initially be carried out with 100% natural gas to attain a baseline case. The test will then be performed using a 100% hydrogen composition as these tests can be performed in a controlled environment. Offline pressure tests will typically be performed at pressures ranging from 27.5 bar – 110 bar. At the test facility, decommissioned NTS assets will be tested initially with 100% natural gas to attain a baseline case for assessment. The blend of hydrogen within the natural gas will then be increased to 2%, 20% and ultimately 100% hydrogen. Pressures will be representative of typical of the NTS, around 70 bar.

Table 3 outlines the types of assets and the tests to be performed on them either offline or at the test facility.

Asset	Types	Offline Tests	Test Facility Tests
Flange and Gaskets	Spiral wound gasket and Raised Face flange Ring joint gasket and groove flange	• Leak test • Permeation	• Permeation • Leak test (Fugitive)
Fittings	Weldolet, Sweepolet, Threadolet and Nipolet	• Leak test • Permeation • Fatigue performance	
Welds	Longitudinally Submerged Arc Weld, Helical Submerged Arc Weld, Electric Weld, Girth Weld, Repair Weld	• Permeation rate • Leak test • Permeation • Resilience to hydrogen cracking • Fatigue performance	• Permeation
Line pipe	X60 and X80 Different wall thicknesses Coatings: Fusion Bonded Epoxy, Various MCL, Coal Tar Enamel & associated Field Joint Coatings, 3-Layer Polyethylene.	• Permeation rate • Impact of CP on hydrogen permeation • Adhesion / disbandment of coatings • Impact of pin brazed joints • Leak test • Permeation • Fatigue performance	• Permeation
Filter	Swinney Quick Release, GD Enclosure	• Permeation rate • Closure leak tightness • Permeation • Fatigue performance • Contamination	• Permeation through cast component • Leak Test (Fugitive) • Pressure drop across filter
Valves	Ball, Plug. Flow Control Valve, non-return and relief valves.	• Seat test • Stem leak tightness • Permeation • Sealant • Leak test ("let-by") • Fatigue performance	• Permeation (including soft parts (stem seals etc.)) • Leak test (Fugitive and "let-by" • Vibration • Normal operation (including control valve lift)
Meters and Gas analysers	Meters: Orifice plate, Ultrasonic Metering Gas Analysers: TBC	• Leak test including seals • Calibration of meters	• Accuracy and performance of meter • Accuracy of gas analyser
Regulator	Main regulator slamshut Gas preheat regulator	• Leak test	• Leak test • Vibration (and safe limit) • Run through working range • Slamshut sensitivity
Boiler/ Heat exchanger	Heat Exchanger / IGA Fuel Gas skid / Boiler Package	• Leak test of heat exchanger	• Leak test • Vibration (and safe limit) • Validation of expected heat loading of preheat
Vent			• Vibration • Visual impact • Noise impact • Auto-ignition • Dispersion

Table 3. FutureGrid asset specific tests

6.0 EXPECTED OUTPUTS OF TEST PROGRAMME

6.1 Materials and asset operations

The material testing in FutureGrid Phase 1 is being done in collaboration with Fluxys, the Belgian transmission system operator. Combined it is expected that the project will develop a much greater understanding of the mechanical properties of pipeline grade steels (X42, X52, X60, X65, X70) after sustained exposure to hydrogen. These projects will also generate findings on the permeability of the steels and the impact of inhibitors to hydrogen embrittlement such as oxygen.

The offline weld spool in FutureGrid Phase 1 will also demonstrate the capability of transmission pipelines to safely contain hydrogen for extended periods through the accelerated fatigue testing.

As shown in Table 3, FutureGrid is testing a wide range of assets. Following the successful completion of the project, these assets will be determined to either be suitable for use in hydrogen service, in requirement of additional modifications or unsuitable and in need of replacement. For those assets deemed capable of transporting hydrogen, the findings from the project will inform discussions with OEMs and the wider review of NTS assets to develop a comprehensive asset replacement programme.

6.2 Ways of working and gap analysis

The processes required for the construction and operation of the facility, such as HAZOP and permits to work, will be first of their kind for high pressure hydrogen transmission in the UK. These learnings will be captured and feed into the change recommendations for existing standards and the development of new standards.

Whilst it is expected that the FutureGrid project will address many of the existing knowledge gaps it is likely that many new gaps will be uncovered during the course of the project and, so following the completion of the test programme, it will be required to assess these new knowledge gaps and recommend actions to address them.

7.0 FUTURE PHASES

Phase 1 of the programme will begin in April 2021 and completion is expected in April 2023. Beyond this, it is expected this project will progress into phases 2 and 3.

Phase 2 will run from 2022-2024 and will focus on hydrogen blending and compression looking at three key focus areas:

- Cryogenic separation: which uses gas pressure drop to drive the refrigeration process with hydrogen remaining as a vapour as most impurities drop out as liquids
- Pressure swing absorption: a two-stage process with a polymer membrane for bulk separation and Pressure Swing Adsorption to remove remaining impurities
- Driving Turbines with hydrogen: the use of hydrogen to drive turbines and gearing to meet the same compression rates as natural gas. Testing the ability of the compressors to compress hydrogen blends of up to 100% hydrogen.

From 2023 onwards, phase 3 will see the facility open to become a unique world leading training site. Employees will be able to use the facility to learn how their jobs are now different in a hydrogen environment. The site will provide both the ability to learn onsite with the assets and in a classroom style onsite or nearby. The site will also become available for third party testing, providing the gas industry with the opportunity to develop tests and trials that accelerate development and facilitate third party access costs effectively.

8.0 CONCLUSIONS

The potential repurposing of gas transmission assets could play a major role in the transition to hydrogen. The development of FutureGrid has been built on extensive desktop research which has identified the current state of the art and understanding of asset performance. Building on that solid foundation, FutureGrid now moves to the practical testing of legacy natural gas assets in hydrogen service at full transmission scale and pressures. To date, a number of key challenges have been identified in transitioning the gas system to hydrogen delivery, and an end to end test programme has been developed to specifically explore these and identify any required mitigations.

In summary, FutureGrid will provide vital analysis of the potential, opportunities, risks and mitigations of a transfer to hydrogen. National Grid are adopting a ‘digital first’ approach to research dissemination and will be providing regular updates throughout the test programme both online and through regular webinars.

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