Notes on Completion: Please refer to the appropriate NIA Governance Document to assist in the completion of this form. The full completed submission should not exceed 6 pages in total.

NIA Project Registration and PEA Document

Date of Submission

Aug 2023

Project Reference Number

NIA_CAD0094

Project Registration

Project Title

Effect of 100% hydrogen on cast iron assets

Project Reference Number

NIA_CAD0094

Project Licensee(s)

Cadent

Project Start

May 2023

Project Duration

1 year and 8 months

Nominated Project Contact(s)

James Whitmore

Project Budget

£641,333.00

Summary

In the UK, cast iron was the material of choice for the gas distribution network pipework up until the 1970's. At this time, it was acknowledged that the susceptibility of cast iron to corrosion was greater than polyethylene or steel pipelines which were available as alternative construction materials. Since 1974, there has been a national strategy to replace cast iron mains with alternative materials, however its scope does not cover all iron mains present within the networks.

DESNZ are committed to making a policy decision on hydrogen for heating in 2026. Therefore, there is a need to understand the interaction of cast iron and iron based materials with hydrogen to determine the risks associated with re-purposing cast iron for hydrogen service

Preceding Projects

NGGDGN03 - HyDeploy

Third Party Collaborators

Institution of Gas Engineers and Managers

DNV

Nominated Contact Email Address(es)

Innovation@cadentgas.com

Problem Being Solved

In July 2022 the HSE published a guidance paper titled "HSE Paper for the Hydrogen Heating Programme on Cast Iron use with

Hydrogen" /2/. This paper outlined the HSE's position on the further evidence that they would require in order to accept the use of cast iron in 100% hydrogen service, including:

- • the legislative requirements;
- • definitive statements within industry standards and guidance;
- • considering ageing cast iron infrastructure
- • potential for adverse effect of hydrogen on cast iron's mechanical properties;
- • potential for increased leakage at joints etc., and
- • an absence of substantive scientific evidence to contradict existing standards and guidance

Therefore, there is a need to understand the interaction of cast iron and iron based materials with hydrogen to determine the risks associated with re-purposing cast iron for hydrogen service. The fundamental question being:

Are iron based components at pressures of up to 7 bar more likely to fail under hydrogen service than natural gas service?

Method(s)

The gas networks recognise the importance of determining the suitability of iron based materials for use with hydrogen and have developed a programme to undertake this assessment. The programme contains 3 elements:

1. Materials Science Programme – which aims to close the gap in substantive scientific evidence that's available today to contradict existing standards and guidance

2. Risk assessment of operating iron pipes with hydrogen – which will re-evaluate the methodology used to manage the risk of iron mains for use with hydrogen

Peer Review – where the evidence produced by the programme will be peer reviewed by an appropriate technical panel

Scope

The scope of assessment is relevant to all gas facing iron based assets within the gas distribution networks.

The project is utilising an asset identification process which has identified that gas facing iron based assets could be operating up to 7 bar(g).

Objective(s)

Materials Science

The scope of this research will assess the suitability of all iron based assets that could be exposed to hydrogen within the GB distribution networks. A robust methodology of identifying gas facing iron based assets has found that iron pipework is only present operating up to 2 barg, components such as ductile and malleable iron valve bodies are operating up to 7 barg, and no iron gas facing components have been identified operating above 7 barg, bounding the scope of the assessment to all iron gas facing components operating up to 7 barg.

The question being addressed by this programme is:

Are iron based pipes and components operating under their associated distribution pressures more likely to fail in hydrogen service than natural gas?

To answer this question, the networks will generate evidence and provide discussion in relation to the following sub-questions:

1. How could hydrogen gas interact with iron?

a. Is it mechanistically possible for hydrogen to enter the iron based materials and potentially change its mechanical properties?

This will be addressed using calculations of the diffusion behaviour of hydrogen

b. At what rate could hydrogen be realistically expected to enter the material?

 Building on the point above, data will be collected to identify the concentration of hydrogen already present in cast irons found on the network. These values can then be used to calculate the possible rates of hydrogen uptake more accurately into the material.

a. Which parts of the metallographic structure does the hydrogen interact with (cast iron is more complex structure than steels and therefore the interaction of hydrogen with different phases of the structure may have implications on an effect on the mechanical properties of the material)

 Using Secondary Ion Mass Spectrometry, it is possible to visualise the presence of hydrogen within the metallographic structure of the cast iron. It is also then possible to determine whether more hydrogen is detected in the iron or carbon based phases of the material.

b. What is the maximum possible uptake of hydrogen by iron based materials?

Literature is available which discussed the electrochemical charging of iron based samples and has characterised the hydrogen content achieved in these conditions.

2. Do the mechanical properties of iron based materials change in the presence of hydrogen?

a. Experimental test data will be available that investigates the tensile and fatigue behaviour of ex-service cast iron pipe and malleable iron in air and in hydrogen

If no significant change in properties is observed, it can be concluded that the presence of hydrogen has had no noticeable effect on the material.

· The expected hydrogen uptake of the material during these tests can also be calculated and compared to the theoretical values mentioned previously.

Risk Assessment

It is proposed to model the incident risk of operating cast iron, ductile iron and unprotected steel mains containing hydrogen.

The current Iron Mains Risk Reduction Programme (IMRRP) is replacing all iron mains operating at low and medium pressure that are up to and including 8” in diameter that are within 30m of a property, however it is only replacing a small proportion of larger diameter iron mains and does not include within its scope the replacement of steel mains or iron mains that are further than 30m from premises. Some steel mains benefit from cathodic protection and have characteristics similar to high integrity high pressure pipelines however others are unprotected and so are more prone to damage by corrosion and have mechanical as opposed to welded joints. Steel mains are not subject to replacement under the IMRRP.

The IMRRP is expected to be completed by the end of 2032, which means that from that date the only iron mains that will be in operation are mains that are larger than 8” in diameter and mains that are more than 30m from property.

With a possible large scale transition to hydrogen occurring after 2032 it is important to understand what risk the likely mains population at that date might pose were it to be required to convey hydrogen. Once this is known the information can be used to inform both the hydrogen roll out and future investment plans.

There is an existing risk model that is used to assess the iron and steel mains population. It is called the Mains Replacement Prioritisation System (or MRPS). It uses a large amount of asset, asset performance and asset location data to predict the expected incident frequency of individual iron and steel mains enabling replacement work to be targeted on those mains which pose greater risk.

It is proposed to adjust the model so that it is able to predict the risk that would be posed were the mains to contain hydrogen instead of natural gas.

The modelling process will look at the current 30m distance to property limit as well as the risk posed by pipes of different operating pressure, material, size and operating history and determine how substituting hydrogen for natural gas would change the risk exposure for people occupying premises exposed to iron and steel mains.

The modelling will examine all deterioration and ground movement related pipeline failure modes that could result in gas entering premises and potentially igniting.

It will look at the risk posed to individuals and to society as a whole of making the change to hydrogen. It will determine whether hydrogen is likely to increase the risk posed. It will quantify this risk and also identify the cause of any increase in risk so that potential mitigations may be identified. This information can be used to inform a potential future investment programme. It will inform decision makers in respect of the trade-off that may be required, of minimising costs that impact consumer bills vs the benefit of maintaining or improving the level of safety.

Peer Review

To support ongoing hydrogen heat policy decision and trials, the HSE require this evidence to:

• be in line with the type and weight of demonstration submitted to develop a new standard;

• include the breadth and depth required of a new standard;

• be developed with wider industry and technical consultation; and

• be delivered in a format and made available for wider technical review.

The project will arrange for the evidence to be peer reviewed by an appropriate technical panel.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

The insight this work supports will help to establish a clearer view of the impacts of the transition to Net Zero one of these will be cost and the impact on the customer.

We conclude that this project will have a low impact on consumers in vulnerable situations. This is because the project methodology and the solution will not deliver outputs that will impact the financial or well-being of any consumers. It is envisaged that this project will enable a future low carbon safe, secure, and reliable energy supply.

Success Criteria

The project will have been successful if:

· A conclusive and substantive scientific evidence base is produced that can inform DESNZ policy decision on hydrogen for heating

· The project develops an understanding of any risk assessment methodology changes or impacts required for conveying hydrogen.

Project Partners and External Funding

Cadent will fund 100% of the project under NIA.

Potential for New Learning

A conclusive and substantive scientific evidence base is produced that can inform DESNZ policy decision on hydrogen for heating – will be new evidence that can be used by all gas network operators in the UK, and internationally.

The project develops an understanding of any risk assessment methodology changes or impacts required for conveying hydrogen – will inform any risk assessment methodologies adopted by the gas distribution networks if converting to hydrogen

Scale of Project

The overall cost of this project is expected to be a maximum of ca. £700k (if additional testing is required), which will inform national energy strategy for hydrogen heating.

In comparison, without any substantive evidence demonstrating the suitability of 100% hydrogen in cast iron, any cast iron would have to be removed prior to hydrogen conversion, costing the UK £m's.

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL3 Proof of Concept

Geographical Area

The research is lab based, but the results will be applicable to all UK areas.

Revenue Allowed for the RIIO Settlement

Not applicable to this R&D project

Indicative Total NIA Project Expenditure

An indication of the Total NIA Expenditure that the Funding Licensee expects to reclaim for the whole of the Project (RIIO2).

£641,333

Project Eligibility Assessment Part 1

There are slightly differing requirements for RIIO-1 and RIIO-2 NIA projects. This is noted in each case, with the requirement numbers listed for both where they differ (shown as RIIO-2 / RIIO-1).

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations (Please complete sections 3.1.1 and 3.1.2 for RIIO-2 projects only)

Please answer **at least one** of the following:

How the Project has the potential to facilitate the energy system transition:

The project has the potential for demonstrating the long term suitability of cast iron assets for 100% hydrogen service, a key enabler for converting existing gas networks to decarbonise domestic heating.

How the Project has potential to benefit consumer in vulnerable situations:

It is envisaged that in the long term, this project, along with other programme's of work will enable a future low carbon safe, secure, and reliable energy supply.

Requirement 2 / 2b

Has the potential to deliver net benefits to consumers

Project must have the potential to deliver a Solution that delivers a net benefit to consumers of the Gas Transporter and/or Electricity Transmission or Electricity Distribution licensee, as the context requires. This could include delivering a Solution at a lower cost than the most efficient Method currently in use on the GB Gas Transportation System, the Gas Transporter's and/or Electricity Transmission or Electricity Distribution licensee's network, or wider benefits, such as social or environmental.

Please provide an estimate of the saving if the Problem is solved (RIIO-1 projects only)

Not required - RIIO2 project

Please provide a calculation of the expected benefits the Solution

Not applicable – research project

Please provide an estimate of how replicable the Method is across GB

The research will be applicable to all Gas Distribution Networks

Please provide an outline of the costs of rolling out the Method across GB.

Not applicable – research project

Requirement 3 / 1

Involve Research, Development or Demonstration

A RIIO-1 NIA Project must have the potential to have a Direct Impact on a Network Licensee's network or the operations of the System Operator and involve the Research, Development, or Demonstration of at least one of the following (please tick which applies):

☐ A specific piece of new (i.e. unproven in GB, or where a method has been trialled outside GB the Network Licensee must justify repeating it as part of a project) equipment (including control and communications system software).

☐ A specific novel arrangement or application of existing licensee equipment (including control and/or communications systems and/or software)

☐ A specific novel operational practice directly related to the operation of the Network Licensees system

☐ A specific novel commercial arrangement

RIIO-2 Projects

☐ A specific piece of new equipment (including monitoring, control and communications systems and software)

☐ A specific piece of new technology (including analysis and modelling systems or software), in relation to which the Method is unproven

☑ A new methodology (including the identification of specific new procedures or techniques used to identify, select, process, and analyse information)

☐ A specific novel arrangement or application of existing gas transportation, electricity transmission or electricity distribution equipment, technology or methodology

☐ A specific novel operational practice directly related to the operation of the GB Gas Transportation System, electricity transmission or electricity distribution

☐ A specific novel commercial arrangement

Specific Requirements 4 / 2a

Please explain how the learning that will be generated could be used by the relevant Network Licensees

Learning from this project can be used by all Gas Distribution networks to inform the long term suitability of their iron assets for hydrogen service.

Or, please describe what specific challenge identified in the Network Licensee's innovation strategy that is being addressed by the project (RIIO-1 only)

N/A

Is the default IPR position being applied?

☑ Yes

Project Eligibility Assessment Part 2

Not lead to unnecessary duplication

A Project must not lead to unnecessary duplication of any other Project, including but not limited to IFI, LCNF, NIA, NIC or SIF projects already registered, being carried out or completed.

Please demonstrate below that no unnecessary duplication will occur as a result of the Project.

All networks are aware of the research and will be kept informed as the project develops avoiding any duplication in other projects.

If applicable, justify why you are undertaking a Project similar to those being carried out by any other Network Licensees.

N/A

Additional Governance And Document Upload

Please identify why the project is innovative and has not been tried before

There is a gap in substantive scientific research into the suitability of iron assets for hydrogen service at distribution pressures. This project seeks to close such gap.

Relevant Foreground IPR

The project will generate test data (foreground IP) on cast iron assets, which will be used as evidence to be provided to the HSE.

Data Access Details

Current expectation is that all data used in this project will be sourced from published documentation and from lab based testing, the test cases will be available upon request.

Data for this project and all other projects funded under the Network Innovation Allowance (NIA), Network Innovation Competition (NIC) or the new Strategic Innovation Fund (SIF) can be found or requested in a number of ways:

- A request for information via the Smarter Networks Portal at https://smarter.energynetworks.org, to contact select a project

and click ‘Contact Lead Network’. National Grid already publishes much of the data arising from our innovation projects here so you may wish to check this website before making an application.

Via our managed mailbox box.GT.Innovation@nationalgrid.com

Please identify why the Network Licensees will not fund the project as apart of it's business and usual activities

This is research in support of the energy transition which does not fall within usual business activities.

Please identify why the project can only be undertaken with the support of the NIA, including reference to the specific risks(e.g. commercial, technical, operational or regulatory) associated with the project

This is research in support of the energy transition which does not fall within usual business activities. Time constraints require the project to mobilise quickly, ruling out other funding routes, and flexibility is required as the research develops.

This project has been approved by a senior member of staff

☑ Yes