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

Apr 2024

Project Reference Number

NIA_CAD0103

Project Registration

Project Title

Hydrogen Environment Testing of Girth Welds

Project Reference Number

NIA_CAD0103

Project Licensee(s)

Cadent

Project Start

April 2024

Project Duration

1 year and 0 months

Nominated Project Contact(s)

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Project Budget

£504,000.00

Summary

Hydrogen pipeline design codes currently offer two design options – low stress and high stress. Adopting a high stress design approach can offer significant advantages. However, requires more detailed qualification based on fracture mechanics.

This project will determine the identification of a realistic worst case hydrogen environment for the testing and will focus on the qualification tests for pipe and welds to demonstrate the required properties of a high stress design approach to achieve a minimum of 40 years operational life based on Engineering Critical Assessment.

This supports the efficient construction of major capital hydrogen pipeline projects. Girth welds will be made using modern welding techniques on high-strength steel line pipe with two different heat treatment conditions.

Nominated Contact Email Address(es)

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Problem Being Solved

Hydrogen pipeline design codes such as ASME B31.12 and IGEM/TD/1 Supplement 2 currently offer two design options – low stress and high stress / Option A and Option B. Using the low stress approach, where hoop stress is limited due to the code limitations on grade and design factor, can lead to extremely thick pipe walls. Where the pipe wall is excessively thick, there are a number of disadvantages and issues that arise. Such issues include increased steel cost for line pipe, increased welding consumable cost, difficulties with transportation and lifting operations due to size and weight, increased carbon from steel manufacture and construction operations, low welding productivity, and unable to inspect with current in-line inspection tools during operation.

Adopting a high stress design approach can mitigate these issues. However, the high stress design approach requires more detailed qualification based on fracture mechanics. As well as the limitation on hoop stress, there is also a limit on longitudinal stress. Therefore, fracture mechanics qualification of pipe, seam weld and girth weld are required.

In addition, pipelines have typically been constructed using manual welding techniques with a wide bevel angle. The construction of hydrogen pipelines can be improved through the use of automated welding processes with a narrow bevel. The fracture mechanics approach needs to incorporate these modern welding practices.

Method(s)

This project is being delivered by DNV, with laboratory testing being carried out in Columbus, Ohio and Engineering Critical Assessment support being provided by the UK team in Loughborough and Aberdeen. The Cadent team will manage the delivery of the project.

In order to progress with a high stress design approach, a fracture mechanics based qualification plan has been developed. The qualification includes the testing of pipe, seam weld and production girth weld samples in a hydrogen environment. The girth welds have been produced using the automated Cold Metal Transfer (CMT) and twin head pulsed GMAW technique, with a narrow gap for main lining, and a manual Surface Tension Transfer (STT) with mechanised flux core for tie-ins.

The testing approach takes place in two phases.

Phase 1 focuses on the identification of a realistic worst case hydrogen environment for the testing. As hydrogen production may include “blue” hydrogen, which is reformed from methane, there are certain components that may be contained within the hydrogen that are detrimental to fracture performance.

Phase 2 will focus on the qualification tests for pipe and girth welds to demonstrate the required properties of a high stress design approach.

The testing includes:

ASTM E384 Standard Test Method for Micro-indentation Hardness of Materials,

ASTM E92 Standard Test Method for Vickers Hardness of Metallic Materials,

ASTM E399 Standard Test Method for Plane-Strain Fracture Toughness of Metallic Materials,

Rising displacement fracture toughness testing: ASTM E1820-20b,

Standard Test Method for Measurement of Fracture Toughness,

Fatigue crack growth rate testing: ASTM E647-15, Standard Test Method for Measurement of Fatigue Crack Growth Rate.

Fracture toughness and fatigue crack growth testing will be carried out on pipe body, seam weld centreline, seam weld heat-affected zone, girth weld centreline and girth weld heat-affected zone.

Two pipe materials are being tested; X65 grade seam welded thermomechanical rolled – representative of pipe used in main lines and seamless quench and tempered – representative of pipe used in spur lines. Both line pipe materials have a chemistry compliant with Annex H of API 5L and ferritic / bainitic microstructure.

Automated girth welding processes will be tested using procedures for mainlining and tie-ins.

The results from the fracture and fatigue testing will be implemented into an Engineering Critical Assessment for a transmission pipeline network to justify the use of the high stress design option. This ensures that the network can operate for a minimum of 40 years.

Scope

In order to address the problem outlined in Section 2.1, the following scope is being delivered. The scope is split into two phases of work.

The aims of the scope are to support with line pipe specification and pipeline design requirements and confirm that material performance for the pipe, seam weld and girth welds meets the requirements of pipeline operation in a transmission network. The ultimate aim is to give confidence that the material used in the pipeline can operate safely for its design life. Phase 1 relates to hydrogen environments, testing pipe body and longitudinal seam weld and Phase 2 relates to testing of girth welds. Testing of grade two X65 line pipe materials is being carried out, with different heat treatment conditions. The pipes are representative of ones that will be used in new build hydrogen pipeline networks.

Phase 1 will identify the realistic worst case environment that can be seen in a hydrogen network. The environments will range from dry 100% H2 to moist H2 with H2S and CO2. Control tests in air will also be carried out.

Phase 2 will take the worst case environment from Phase 1 and carry out testing on girth welds to demonstrate fracture and fatigue performance.

The results from testing will be used to confirm that the materials can perform to the requirements calculated in an Engineering Critical Assessment for a high stress hydrogen pipeline network operating for a minimum of 40 years.

The benefits of this project support the efficient construction of new build hydrogen transmission pipelines with steel, welding consumable and carbon savings compared to using a low-stress design approach and standard welding practices.

Objective(s)

The objectives of the project lead to achieving the aim set out in Section 2.3. The objectives are broken down as follows:

- Development of a test matrix for Phase 1 and Phase 2
- Production of detailed testing procedures
- Inspection of as-received pipe and welds
- Preparation of samples for testing
- Determination of Phase 1 testing environments
- Control of testing environments during tests
- Carrying out testing inc. crack growth measurement
- Analysis and reporting of testing results
- Detailed interpretation of testing results

Review of Engineering Critical Assessment based on testing results.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

N/A

Success Criteria

The success criteria for this project are broken down by Phase.

The success criteria in Phase 1 will be to demonstrate the influence of “contaminants” such as moisture, H2S and CO2 on the fracture and fatigue performance of the line pipe materials tested.

The success criteria in Phase 2 will be to demonstrate the suitability of high-strength line pipe materials with differing heat treatment conditions for a high stress design approach.

Project Partners and External Funding

DNV (as an external supplier) will be managed and contracted by Cadent. The value of the external contract is £504,000. However, Cadent will also provide internal ‘contributions in kind’ via labour time (for up to circa £168,000 equivalent value, 25% of total Cadent budget).

Potential for New Learning

The new learning from the project includes the following:

· Influence of microstructure / heat treatment condition on fracture and fatigue performance i.e. thermomechanical rolled vs quench and tempered.

· The influence of “contaminants” such as moisture, H2S and CO2 on fracture and fatigue performance.

· The fracture and fatigue performance of narrow gap girth welding techniques in a hydrogen environment.

The learning will be disseminated through reports, presentations and journal papers. Learning will be shared with NGT, SGN, NGN and WWU through industry forums and groups such as NSI, IGEM and UKOPA.

Scale of Project

The project is 12 month duration from April 2024 to March 2025. The external budget is £504,000.

The potential benefits to major capital projects are large, saving £10,000,000s in steel costs alone through the adoption of the high stress approach compared to the low stress approach. The test matrix has been optimised so that the minimum number of tests are required to achieve the outcomes of the project. The project cannot be delivered through desktop assessment as physical testing results are required for qualification.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL6 Large Scale

Geographical Area

The project will take place both in the UK and US. DNV in Columbus, Ohio will undertake the hydrogen testing due to their proven track record of reliable and accurate hydrogen tests.

The project results are applicable to the full UK gas network footprint and worldwide.

Revenue Allowed for the RIIO Settlement

N/A

Indicative Total NIA Project Expenditure

External Costs: £504k (DNV) – Cadent 100%

Internal Costs: £168k for Cadent (25% of external contribution, representing the labour time for an Innovation Programme Manager, Technical Project Lead, Technical Team and PMO in support of the project).

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:

This project supports the efficient construction of new build hydrogen transmission pipelines with steel, welding consumables and carbon savings compared to using a low-stress design approach. The project demonstrates the use of the high stress design approach which can be applied to any hydrogen transmission project, including industrial clusters.

Benefits include: reduced steel cost for line pipe, reduced welding consumable cost, ease of transportation and lifting operations, reduced carbon from steel manufacture, higher welding productivity, and increased ability to inspect with in-line inspection tools during operation.

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

N/A

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)

N/A

Please provide a calculation of the expected benefits the Solution

The potential benefits to major capital projects are large, saving £10,000,000s in steel costs alone through the adoption of the high stress approach compared to the low stress approach. The exact saving per project depends on the pipeline diameters and lengths.

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

This project would not necessarily need to be replicated for each major capital project as the results are applicable and can be used to inform the design of other hydrogen pipelines.

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

This project provides evidence for the use of the high stress design approach and the performance of girth welds. While the results can be used to inform any future hydrogen pipeline project, there still needs to be specific design work and qualifications.

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

The learning from this project can be used to inform the design and qualification requirements for future hydrogen pipeline projects. The learning will be applicable to any new-build or modification project involving hydrogen transmission pipelines.

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.

This project proposal has been presented to the Gas Innovation Governance Group (GIGG) on which all of the gas networks are represented. The proposal has also been presented at NSI.

While materials testing in a hydrogen environment has and is being carried out as part of other projects, none are focusing on the areas outlined in this proposal.

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

N/A

Relevant Foreground IPR

N/A

Data Access Details

N/A

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

This project is not BAU as gas networks are used to working with mature material and construction specifications. This project looks to inform new practices which have not previously been applied. As with all new practices, the technical readiness level is low which brings risk which cannot be funded through BAU.

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 project looks to support the development of hydrogen pipeline projects, including industrial clusters. In order to meet the Net Zero targets, it is vital that this research and development takes place quickly. As the project is so innovative, doing something which has not been done before, there is risk involved. There are no guarantees that the testing results will be favourable and may show that the fracture performance is inadequate to give a minimum operational life of 40 years.

This project has been approved by a senior member of staff

☑ Yes