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

Mar 2017

### Project Reference Number

NIA_NGGD0094

## Project Registration

### Project Title

Composite Repairs to Complex Shapes

### Project Reference Number

NIA_NGGD0094

### Project Licensee(s)

Cadent

### Project Start

March 2017

### Project Duration

2 years and 10 months

### Nominated Project Contact(s)

Dina Mihsein / Tatiana Prieto-Lopez– National Grid Gas Distribution Nancy Thomson – SGN Lucy Mason– WWU Chris Rodgerson – NGN Robert Bood– NGGT

### Project Budget

£999,999.00

### Summary


The work proposed below will be undertaken in three stages;

Stage 1

- Development of a composite repair design methodology document
- An analytical/numerical study to identify an optimum fitting size for testing in Stage 2 and Stage 3
- Testing for possible debonding due to pressure reduction/depressurisation
- Long term (fatigue) testing of bends

Stage 2

- Static testing of Tees
- Long term (fatigue) testing of Tees
- Stiffness and flexibility studies of repaired Tees

Stage 3

- Assessment of environmental variables on composite performance


### Nominated Contact Email Address(es)

Innovation@cadentgas.com

## Problem Being Solved

Since the early 1980's, National Grid and the Gas Networks have been repairing pipeline damage using a full encapsulation epoxy filled steel shell. The quality of repair using the steel shell is not in question; the reliability of the UK gas transmission and distribution system is testimony to this. However, given the advances in composite technology over recent years, and the outstanding results of the IFI43 research program, there is interest in the potential use of this system for the repair of other 'complex' shaped piping components, both as an emergency repair system and as a permanent 'long term' repair solution. Application of the composite repair systems to complex shaped components such as bends and Tees is an immature area of research; although some guidance is given in the standards, it is acknowledged that further research is required.

## Method(s)

The main objective of the proposed scope of work is to verify the suitability of the design equations in ISO 24817 by testing and evaluation, to ensure that the repaired piping component has sufficient reinforcement to mitigate a failure due to static internal pressure and pressure cycling, without impacting on the stiffness and/or flexibility of the piping system. Consideration is given to part through-wall, blunt, metal loss defects such as corrosion, and gouges that are ground to a smooth profile prior to application of a repair.

The ISO standard considers long term as 20 years; this is reflected in the design equations when calculating the repair thickness for pipeline components. On achieving the 20 years design life, the ISO standard recommends that the composite repair is either replaced, or an analysis be undertaken towards revalidation of the system. It is not the intention of the work proposed to extend the design life beyond 20 years.

The repair thickness for the different piping components is calculated using the standard equation for a straight pipe section, multiplied by a repair thickness increase factor which is dependent on the piping component; 1.2 for a bend, 2 for a tee and 1.1 for a reducer.

Verification of the long term suitability of the repair system will be via full-scale test, supported by analytical and numerical studies, as required.

Based on the performance of the Furmanite and T D Williamson composite systems that were tested in IFI43, further testing of these manufacturer's products is recommended. However, the testing proposed herein will only be undertaken on the Furmanite product, to verify its suitability for the gas transmission and distribution system and to obtain base-line performance data. If a new candidate product comes to market, National Grid and the Networks will be able to specify what testing the manufacturer will be required to undertake in order to demonstrate the suitability of their system; the results of those limited tests will be compared against the Furmanite bench-mark test results.

For the purposes of this proposal, installation of the repair system will be undertaken by trained Furmanite Engineers.

In a composite material, the fibre is the primary load carrying element of the system. The composite material is only strong and stiff in the direction of the fibres; their behaviour is said to be anisotropic (in contrast, steel is an isotropic material, with uniform properties in all directions). To achieve desired properties in different directions, fibre orientation is key; for example, the Furmanite system (FurmaCarbon) used for the bend tests in IFI43 was a bi-directional fabric, fibres orientated in the 0° and 90° directions to give good strength and stiffness in the hoop and axial directions. Compared with steel, composite systems exhibit very complex failure mechanisms under static and fatigue loading.

Although both the Furmanite (and T D Williamson) composite system preformed will under static loading conditions (IFI43), its performance when subjected to repeated load cycles (fatigue) may be significantly different to that of the pipeline. Fatigue of composite systems causes extensive damage (matrix cracking, delamination, fibre breakage and interfacial debonding) through the thickness of the repair, leading to failure from general degradation of the material, instead of a predominant 'single' crack that would initiate and propagate in steel. As a result, for application to complex shape geometries, prediction of the fatigue performance is complex. However, pipelines have a design fatigue life; for example, the fatigue life of a pipeline subjected to a high level pressure test in accordance with the requirements of IGEM/TD/1 will not be less than 15,000 cycles of a hoop stress range of 125N/mm². If the pipeline has been subjected to a lower level test pressure, the fatigue design life may be less; National Grid's specification, T/SP/TR/19 provides a detailed method and screening charts for predicting the fatigue life of a pipeline, depending on its maximum operating pressure (MOP) and hydrotest pressure. Hence, it is not necessary to be able to predict the fatigue performance of the repair system; rather, the repair system must not fail prior to expiry of the fatigue design life of the pipeline.

On that basis, the fatigue performance of the repaired piping component will be assessed against the fatigue design life of a pipeline subjected to a high level pressure test, 15,000 cycles of 125N/mm² hoop stress range. For consistency with the design philosophy of the epoxy shell, the target number of stress cycles for the fatigue tests will incorporate a factor of safety of 10 on life; i.e., the target number of cycles will be 150,000.

While the mechanical properties of composite repairs for pipelines will be the focus of this programme of work, the performance of the entire metal-composite system also needs to be considered with regard to corrosion of the substrate, water intrusion at the composite-metal interface, cathodic disbondment behaviour and adhesion loss etc., and aspects of this have been covered in the proposed Stage 3.

An overview of each Stage, and Task within each stage, is given below.

## Scope

The work proposed below will be undertaken in three stages;

Stage 1

- Development of a composite repair design methodology document
- An analytical/numerical study to identify an optimum fitting size for testing in Stage 2 and Stage 3
- Testing for possible debonding due to pressure reduction/depressurisation
- Long term (fatigue) testing of bends

Stage 2

- Static testing of Tees
- Long term (fatigue) testing of Tees
- Stiffness and flexibility studies of repaired Tees

Stage 3

- Assessment of environmental variables on composite performance

## Objective(s)

The objectives of the scope of work proposed are;

- Development of a guidance document detailing the design and installation requirements for the repair of part-wall, blunt, metal loss defects associated with complex geometry components
- Verification of the suitability of the composite repair system through full scale testing supported by analytical and numerical analysis, as appropriate
- Assessment of environmental variables on the integrity of the composite repair.

## Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

## Success Criteria

The success criteria for the work proposed will be;

- Verification and implementation of new technology enabling repairs of part through-wall, blunt, metal loss defects associated with complex shaped geometries at a reduced cost and reduced downtime compared with conventional techniques/methods.
- A consistent approach to the repair of part through-wall, blunt, metal loss defects for the UK gas transmission and distribution system.
- Verification of the ISO recommendations and industry practice guidance for the design and installation of composite systems, and development of a comprehensive guidance document governing the design and installation of composite systems.

## Project Partners and External Funding

The project partners are listed below.

National Grid Gas Distribution NGGD

Northern Gas Networks NGN

Scotia Gas Network SGN

Wales & West Utilities WWU

National Grid Gas Transmission NGGT

The project is to be wholly NIA funded

## Potential for New Learning

The work proposed herein is new and innovative, and will provide the Gas Networks with the required confidence to use this system going forward. Furthermore, the work undertaken will advance Industry knowledge and provide necessary support to future updates of the ISO and ASME standards.

## Scale of Project

This project will verify the ISO recommendations and industry practice guidance for the design and installation of composite systems, and development of a comprehensive guidance document governing the design and installation of composite.

## Technology Readiness at Start

TRL4 Bench Scale Research

## Technology Readiness at End

TRL8 Active Commissioning

## Geographical Area

The UK mainland.

## Revenue Allowed for the RIIO Settlement

None

## Indicative Total NIA Project Expenditure

**National Grid Gas Distribution** - £333,333.34 external, £111,111.11 internal

**Northern Gas Networks** - £83,333.33 external, £27,777.77 internal

**Scotia Gas Network** - £166.666.67 external, £55,555.55 internal

**Wales & West Utilities** - £83,333.33 external, £27,777.77 internal

**National Grid Gas Transmission** - £83,333.33 external, £27,777.77 internal

# 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:

n/a

### 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)

Since the early 1980's, National Grid and the Gas Networks have been repairing pipeline damage using a full encapsulation epoxy filled steel shell. The quality of repair using the steel shell is not in question; the reliability of the UK gas transmission and distribution system is testimony to this. However, given the advances in composite technology over recent years, and the outstanding results of the IFI43 research program, there is interest in the potential use of this system for the repair of other 'complex' shaped piping components, both as an emergency repair system and as a permanent 'long term' repair solution. Typical benefits include;

- A reduction in loss of revenue; the period over which the pipeline is operating at a reduced pressure until the repair is undertaken,
- Reduced repair costs; i.e., the process of design, fabrication (required for a steel shell), and installation,
- Security of supply; should an emergency situation arise, resulting in isolation of a section of the pipeline, the composite repair system will enable a quicker repair than a steel sleeve.

### Please provide a calculation of the expected benefits the Solution

The potential repair cost benefits are highlighted below.

Over a 6 month period (June-December 2015), National Grid has undertaken a number of repairs of damage to their pipeline system using steel sleeves (bends and straight sections).

Following a review of the costs for each repair, it has been possible to estimate the likely cost savings assuming the damage could be repaired using a composite 'wet wrap' system. The costs are presented as a function of pipe size.

Looking at the bends only, the six month saving for National Grid Gas Distribution alone is circa £75k. Extrapolating this to all the networks equates to approximately £300k per annum

{£75 x 2 (4:1:2:1 network ratio) x 2 (increase from 6months)}

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

The project will develop a new Gas Industry Standard that will be applicable for and implemented by all the GDNs.

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

There will be no direct cost for GDNs associated with rolling out this new standard. The standard will be published on the Energy Networks Association Gas Industry Standards Portal (http://www.energynetworks.org/info/gas/regulation/published-industry-standards/gas-members-area.html ) and will be available free of charge to all GDNs and other interested / relevant parties.

### 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

This project will verify the ISO recommendations and industry practice guidance for the design and installation of composite systems, and development of a comprehensive guidance document governing the design and installation of composite for use by all GDNs.

### 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

☑ Has the Potential to Develop Learning That Can be Applied by all Relevant Network Licensees

### 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.

Composite repair systems are not new; there has been a lot of research undertaken in the US by notable organisations such as the Gas Technology Institute, GTI (formerly the Gas Research Institute, GRI) and the Pipeline Research Council International Inc., (PRCI). Early 2000, National Grid investigated the potential use of the ClockSpring® method for the repair of pipeline damage, reviewing published research and industry experience. However, due to limitations in application of the repair system for the different damage types considered in P11, the epoxy shell was favoured. Since those early investigations, composite repair technology has evolved significantly; some key highlights are given below;

- Development of international standards, ISO 24817 (European) and ASME PCC-2 (US) for the qualification and design, installation, testing and inspection of composite repair systems
- Use of composite repair systems, both on and offshore, by major pipeline operators
- Research work is on-going; in 2010 PRCI initiated a study to evaluate the long term performance of composite repair systems from 13 manufacturers

The basic design philosophy of the two standards; ISO 24817 (first published in 2006 as a Technical specification, than as a Standard in August 2015) and ASME PCC-2 are similar; the ISO standard formed the basis for the ASME guidelines for composite repairs, although the ASME guidelines are not as comprehensive.

Most repairs have been undertaken on damaged straight pipe sections. However, with the advances in composite repair technology, there is increasing application towards the repair of more complex shaped components.

Industry research is on-going. As mentioned above, in 2010 PRCI initiated a long-term (10 year) study, which involves full scale testing of 13 different manufacturers repair systems; an overview of the project is available from the project website, http://compositerepairstudy.com/index.php. In summary, the repairs are all installed on straight pipe sections with simulated corrosion 40, 60 and 75% of the pipe wall thickness in depth. The pipes are all subjected to cathodic protection. Initial tests were pressurised to failure to obtain base-line data for the long-term study. The remaining pipes are buried, pressurised (including periodic pressure cycling), and removed for burst testing at 1, 2, 3, 5, 7.5 and 10 years, as appropriate. Both Furmanite and T D Williamson are participating in the study.

During a Joint Technical Meeting between PRCI, EPRG and AGPA in Paris, 2015, an overview of the long term study was presented, in addition to a gap analysis showing the maturity of composite repair systems with regard to pipe, fitting and defect type, loading (static, pressure cycling and external loads), and non-destructive examination. For complex shape geometries (e.g., tees and bends) it was noted that further work was required, acknowledging that while there had been some field installations and independent research undertaken, there had been no dedicated research undertaken and further work was required to verify the guidance provided within ISO 24817 and ASME PCC-2.

This is a collaborative piece of work being undertaken which has representatives fro

### 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

n/a

### 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

n/a

### This project has been approved by a senior member of staff

☑ Yes