July 2010

# Innovation Funding Incentive Annual Report 2009/10 - Section 3

## Gas Transmission R&D Programme Detailed Reports

nationalgrid
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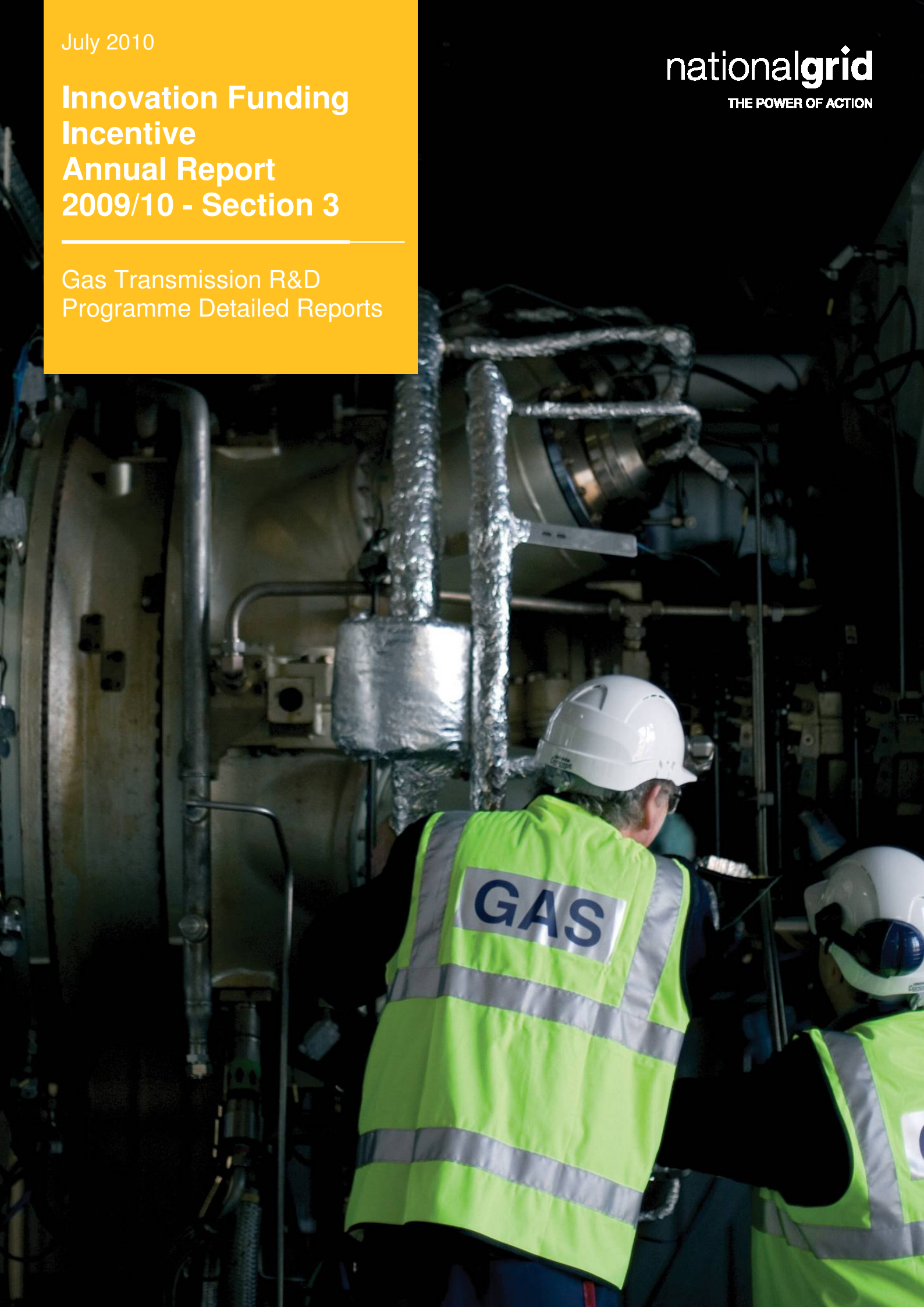

## National Grid Gas Transmission R&D Programme Detailed Report

During the financial year 2009/2010 National Grid Gas Transmission utilised the Innovation Funding Incentive across a number of projects. In accordance with Innovation Good Practice Guide for Energy Networks (ENA Engineering Recommendation G85 Issue2), projects with an annual spend of under £80,000 have been combined with other projects to form programme areas. These programme areas can be seen below and the progress reports can be seen over the next few pages.

## National Grid Gas Transmission R&D Programmes

## 1. Advances in Pipework Vibration Monitoring and Stabbing Encapsulation

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| **Project title** | **Advances in Pipework Vibration Monitoring and Stabbing Encapsulation**<br>This programme of work consists of the following projects:<br>• Advances in Compressor Pipework Vibration Monitoring<br>• Effectiveness of Instrument Stabbing Encapsulation to Reduce Vibration Response | | |
| **Project Engineer** | Brian Woodhouse | | |
| **Description of project** | **Advances in Compressor Pipework Vibration Monitoring Surveys**<br>This project will evaluate how recent technological advances can be used to improve the reliability and performance of long-term vibration monitoring on compressor station pipework, while reducing the cost and increasing the safety of such operations.<br>Vibration monitoring surveys are used by National Grid to identify high-pressure pipework attachments that may fail if remedial action is not taken. Such failures can be RIDDOR-reportable because they can involve a large uncontrolled release of natural gas from high pressure into the surrounding environment.<br>**Effectiveness of Instrument Stabbing Encapsulation to Reduce Vibration Response**<br>This project aims to prove that a convenient encapsulation technique (that has so far only been applied on a temporary trial basis) can be considered as a permanent approved mitigation measure against fatigue failure that would otherwise result as a response to nearby vibration sources. | | |
| **Expenditure for financial year** | Internal £2k<br>External £113k<br>Total £115k | **Expenditure in previous (IFI) financial years** | N/A |
| **Total project costs**<br>**(collaborative + external + internal)** | £123k | **Projected 2010/11 costs for National Grid** | £8k |
| **Technological area and/or issue addressed by project** | Vibration of instrument stabbings and other pipework at National Grid's compressor stations and terminals has previously given rise to fatigue failures, and a large programme of work has been undertaken to modify pipework identified as being at risk. As part of this work, pipework vibration monitoring at National Grid's compressor stations and terminals has been used to assess the risk of fatigue failure following any incidents, and as part of a screening exercise. Where the risk is high, remedial action has been taken to reduce the risk by encapsulating the instrument stabbing. | | |

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| **Type(s) of innovation involved** | Tech Transfer | **Project Benefits Rating** | **Project Residual Risk** | **Overall Project Score** |
| | | 15 | -1 | 16 |
| **Expected benefits of project** | National Grid currently spends about £200k conducting long-term surveys of vibration on 4 compressor stations each year. This is likely to continue for the next 3-4 years. It is possible that this annual cost could be reduced to some degree by the introduction of new technology. However, such savings would likely not cover the cost of purchasing the new equipment. Bigger savings would be expected to come from improvements to the either the quality / reliability of the resulting surveys; or the number of stations that could be surveyed simultaneously (or perhaps even permanently).<br><br>If "temporary" encapsulation of stabbings can be made permanent, there is no need for a maintenance outage to undertake invasive pipework modifications. The encapsulation method is also very low cost, especially compared to an operational pipework design modification (and associated safety and documentation processes). | | | |
| **Expected timescale of project** | 2 years | **Duration of benefit once achieved** | 5 years plus | |
| **Probability of success** | 60% | **Project NPV = (PV benefits – PV costs) x probability of success** | £27k | |
| **Potential for achieving expected benefits** | Finding a monitoring system that can replace the current surveys has a medium chance of success due to the cost that may be involved with the role out of the monitoring system.<br><br>As stabbing encapsulations are already in use as a temporary mitigation measure, the likelihood of success can be considered high. | | | |
| **Project progress as of March 2010** | **Advances in Compressor Pipework Vibration Monitoring Surveys**<br><br>This project has looked at ten different monitoring techniques and the equipment has been analysed, providing a cost benefit analysis on the different systems.<br><br>In addition to the different techniques the different communication mediums were also investigated, ranging from fibre-optic to WLAN. Out of the ten techniques, three have been proposed to be taken forward for technological trial. These trials will deem their true effectiveness in the field.<br><br>**Effectiveness of Instrument Stabbing Encapsulation to Reduce Vibration Response**<br><br>The test rig for the stabbing section of this project has been constructed and the testing of un-encapsulated stabbing and encapsulated stabbing has been completed. The study has shown that encapsulation proves a successful long-term measure for mitigating vibration. Testing on a failed bonding (dirty stabbing) also proved that the encapsulation still had an effective mitigating effect on | | | |

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| | the vibration. |
| **Collaborative partners** | None |
| **R&D provider** | GL Noble Denton |

## 2. Alternatives to Venting from the NTS Gas Transmission System

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| **Project title** | Alternatives to Venting from the NTS Gas Transmission System | | |
| **Project Engineer** | Ian Briggs | | |
| **Description of project** | The key objective of this study is to develop practical methods to reduce the emissions of methane that would otherwise occur during venting to the atmosphere from the natural gas transmission network. | | |
| **Expenditure for financial year** | Internal £5k<br>External £173k<br>Total £178k | **Expenditure in previous (IFI) financial years** | £4k |
| **Total project costs**<br>**(collaborative + external + internal)** | £508k | **Projected 2010/11 costs for National Grid** | £326k |
| **Technological area and/or issue addressed by project** | Natural gas, which is typically 85-93% methane, is released to the environment from gas transmission networks in a number of ways, including:<br>• Infrastructure containment failures (e.g. elastomer seals, small bore pipework connections, pipework failures)<br>• Operational venting for decommission/repair or extension of networks<br>• Process venting from equipment (planned and unplanned)<br>• Fugitive leakage from pipeline equipment<br>Venting and fugitive leakage constitutes a significant part of the overall methane losses to atmosphere. Fugitive leakage from the NTS has been estimated to be of the order of 4000 tonnes per annum. Although this project will not address fugitive emissions, the figure is given here to compare with operational venting of methane (i.e. planned venting for maintenance or automated venting of compressor units during emergency shutdowns).<br>Planned venting can arise from a number of sources around the network, including venting at compressor sites and pipeline decommissioning prior to repairs, replacement or modification activity.<br>Planned venting at compressor sites is monitored and recorded through the on-line control system. For 2007, NTS reported to the Environment Agencies that there had been 1887 tonnes of natural gas emitted by planned vented from compressor stations.<br>Pipeline pressure is typically reduced to 7barg by recompressing it into an adjacent pipeline. However, the last 7barg cannot be sensibly recompressed using the available equipment. It is therefore safely vented to atmosphere. Historical trends suggest that in excess of 150,000m3 of pipework volume is vented to atmosphere in | | |

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<tr><td></td><td colspan="4">this way each year (about 1000 tonnes of gas).<br><br>Clearly there are sound environmental and energy efficiency reasons for developing methods to reduce the amount of vented natural gas. There are several points that influence the current venting best practice, including both commercial and operational factors in addition to energy saving and environmental concerns. These concerns include the consideration of:<br><br>• Distance between pipeline block valves. These isolation distances are tending to increase and thus lead to increased vented volumes during decommissioning.<br><br>• Installation of Booster Units at Pig Trap or Block Valve Sites to enable better management of the decommissioning activities.<br><br>To improve the environmental performance of final stages of the decommissioning process several options are available including:<br><br>• Collect the gas and use elsewhere within the network.<br><br>• Flare the gas. Methane is recognised as having a significantly greater “Global Warming Potential” (GWP) than carbon dioxide, approximately twenty times. Thus flaring will reduce the environmental impact.<br><br>• Use the gas at the decommissioning site.</td></tr>
<tr><td>Type(s) of innovation involved</td><td>Significant<br><br>Radical</td><td>Project Benefits Rating<br><br>18</td><td>Project Residual Risk<br><br>-1</td><td>Overall Project Score<br><br>19</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The benefits from undertaking this work include:<br><br>• Development of new best practice for lowering methane emissions during decommissioning activities prior to maintenance<br><br>• Reduction in National Grid’s methane emission inventory<br><br>• Improved energy management<br><br>A financial benefit can be derived from consideration of reduced methane emissions. CO2 emissions are currently traded at £25/tonne. Natural gas emissions are recognised to be twenty times more damaging to the environment, such that £500/tonne might be expected when methane is added to the European Emissions Trading Scheme.<br><br>Planned venting down of gas transmission pipelines for maintenance accounts for about 960 tonnes of methane emissions per year (£480,000 per year).<br><br>Operational venting down of NTS compressor units during emergency scenarios and for maintenance accounts for more than 1800 tonnes (Advantica Report 6446) of methane emissions per year (£900,000 per year).<br><br>If the gas can be captured, stored and used to fuel generators to</td></tr>
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| | provide 5kWe / tonne, and we assume that the cost of bought-in electricity is 8p per kW-hr:<br>Alternatives to pipeline venting operations could provide a proportion of 8760 hours * 500kWe * 8p = £350,000<br>Alternatives to compressor venting could provide a proportion of (1800 / 960) * £350,000 = £552,000 | | |
| **Expected timescale of project** | 3 years | **Duration of benefit once achieved** | Lifetime |
| **Probability of success** | 60% | **Project NPV = (PV benefits – PV costs) x probability of success** | £655k |
| **Potential for achieving expected benefits** | On target | | |
| **Project progress as of March 2010** | Data capture from all Transmission Pipelines, Compressor Sites and LNG facilities is now complete. Bathgate, Scotland is identified as a site to decommission from 60barg down to 0.0barg (approx 3km x 900mm pipe size) utilising the Flaring and Low Pressure Recompressor in conjunction with National Grid's own Recompression Fleet during April 2010. This project was fully scoped and sanctioned, ready to commence at the year end.<br>The picture below shows one of the large mobile recompression units which are already used to transfer gas between pipelines and thereby reduce the amount of gas vented to atmosphere prior to pipeline maintenance by 80-85% and it is anticipated that other technology will be identified as part of this project.<br>  <br>A feasibility study and laboratory scale demonstration has also addressed the potential use of adsorbed natural gas (ANG) storage on compressor stations. Gas that would otherwise be vented | | |

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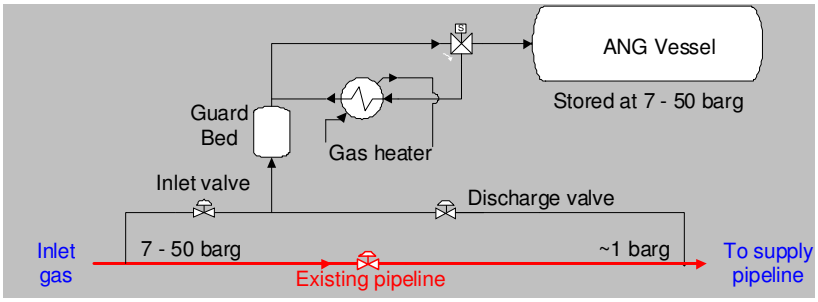
| | following compressor unit shut-down can be stored, to be used as fuel when the compressor re-starts. Plans are now underway to construct a half-scale demonstration of this technology at Bishop Auckland test site.<br><br>The schematic below illustrates the concept, although for the compressor station application, it will be necessary to utilise a small compressor to fully charge the ANG vessel and to fully discharge the stored gas into the gas turbine fuel system.<br><br>  |
| **Collaborative partners** | None |
| **R&D provider** | GL Noble Denton |

## 3. Research into Requirements for Gaseous $CO_2$ Transmission

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| **Project titles** | **Research into Requirements for Gaseous $CO_2$ Transmission**<br>This programme of work consists of the following projects:<br>• Research into Requirements for Gaseous $CO_2$ Transmission<br>• Review of 'state of the art' modelling for $CO_2$ pipeline failures | | |
| **Project Engineer** | Russell Cooper / Julian Barnett | | |
| **Description of project** | National Grid is considering the change of use of existing gas National Transmission System (NTS) transmission pipelines so that they can be capable of transporting of anthropogenic Carbon Dioxide ($CO_2$) from large emitters, such as power stations, to a location where the $CO_2$ can be safely stored. This will require full demonstration, through preparation of a safety case that the activity can be carried out safely.<br>The project involves a range of research, development and feasibility activities to be undertaken in order that a robust safety justification for the design and operation of gaseous phase $CO_2$ pipelines can be prepared. | | |
| **Expenditure for financial year** | Internal £61k<br>External £1,019k<br>Total £1,081k | **Expenditure in previous (IFI) financial years** | Internal £4k<br>External £92k<br>Total £96k |
| **Total project costs**<br>**(collaborative + external + internal)** | £2.75m | **Projected 2010/11 costs for National Grid** | £1.22m |
| **Technological area and/or issue addressed by project** | A recent review by the Health and Safety Executive (HSE) has called attention to the safety issues that are involved with the transportation of $CO_2$. Two of the issues that have been raised concern the lack of validated mathematical models and large-scale data concerning releases of $CO_2$ from pressurised pipelines. Obtaining full-scale data to help further validate any mathematical models would be costly. Therefore, it is important that any experiments carried out to obtain such information are well planned and provide sufficient data to allow the proper development or validation of the models. The experiments would also need to provide convincing and irrefutable evidence that could be used to demonstrate a thorough understanding of the behaviour that would be observed at full scale should a pipeline fail.<br>The nature of pure $CO_2$ changes from gaseous condition to a dense phase condition at the critical point. In the gaseous phase, $CO_2$ behaves as a heavy gas, but in the dense phase, the "fluid" has the viscosity of a gas and the density of a liquid. While transmission of dense phase $CO_2$ offers efficiencies due to the properties of the fluid, National Grid's immediate interests are in transmission of gaseous $CO_2$. The complex phase characteristics require specialist | | |

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<tr><td></td><td colspan="4">modelling to assess the hydraulic behaviour on pipeline design and operation.<br><br>The heavy gas behaviour of gaseous phase $CO_2$ affects the dispersion of the gas and therefore the distances over which it disperses poses a hazard to people. Anthropogenic $CO_2$ contains impurities, and the effects of these impurities on the phase boundary, hydraulic behaviour, hazard distance and pipe integrity require assessment.</td></tr>
<tr><td>Type(s) of innovation involved</td><td rowspan="2">Significant<br><br>Radical</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td></td><td>14 to 19</td><td>2 to 5</td><td>12 to 14</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">This research enables $CO_2$ networks to be developed through the re-use of existing natural gas pipeline assets. This change of use will enable natural gas consumers to be protected against the decommissioning costs and associated liabilities that would otherwise be required if a natural gas pipeline is no longer required for natural gas transmission. Further value can be captured for gas consumers by re-using existing pipelines for other applications. The value in question may well be underpinned by calculations of residual asset value.<br><br>Wider energy consumers, including electricity consumers, stand to benefit if the research enables the development of $CO_2$ networks to support carbon capture from coal-fired generators. It is possible that without this technology there will be a much diminished role for coal in the UK energy mix, leading potentially to higher electricity prices and an impaired outlook for electricity security of supply.<br><br>Consumers will benefit from the clear environmental benefits that will be delivered to the UK through the effective mitigation of $CO_2$ emissions. The UK Government and European Union both believe that CCS presents an important opportunity for reducing $CO_2$ emissions. This research can be seen to be aligned with the environmental policies of both national and supra-national bodies, potentially presenting real opportunities to efficiently re-deploy existing natural gas assets in the service of mitigating climate change.<br><br>GLND will undertake work to review its knowledge of the state of the art of modelling failures of pipelines transporting $CO_2$. Rather than provide an extensive, and potentially time consuming literature review, the aim would be to provide a way forward based on current knowledge and experience. The review would cover how $CO_2$ will behave within and at the exit of the pipeline in the event of a release, the behaviour within any below ground crater that is formed and the subsequent dispersion of the $CO_2$ in the atmosphere.<br><br>Fracture control on pipeline systems is very important and requires consideration of fracture initiation and propagation behaviour. The various codes and specifications covering pipelines require that adequate fracture control measures are in place for all high-pressure gas pipelines, as gas decompression can provide a fracture driving</td></tr>
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| | force which can lead to propagating fractures if the pipe toughness specification is not adequate. This project develops National Grid's knowledge on ductile fracture in $CO_2$ pipeline systems and the dispersion of $CO_2$. | | |
| **Expected timescale of project** | 3-5 years | **Duration of benefit once achieved** | 40 years |
| **Probability of success** | 60% | **Project NPV = (PV benefits – PV costs) x probability of success** | £5,063k |
| **Potential for achieving expected benefits** | Good - CO2 transportation through pipelines has been in operation in the United States since the 1970's. These activities have been mainly focussed on the transport of naturally occurring $CO_2$ from the source to various oil fields for the purposes of delivering Enhanced Oil Recovery (EOR). The knowledge that these pipelines exist and have been in operation for a substantial period of time provides a high degree of confidence that a successful $CO_2$ transportation network can be developed in Europe.<br><br>Similar work was carried out for natural gas in the 1970s and 1980s and forms the basis of the safety justification for National Grid's high pressure transmission network. The results of the work are not directly relevant to the transmission of $CO_2$, but the logic applied and learning obtained will be applied as appropriate which assists in minimising timescales by the application of "lessons learnt".<br><br>National Grid is utilising a range of service providers who have a wealth of experience with this type of R&D work and knowledge of $CO_2$ systems.<br><br>To date good progress has been made on the R&D work and National Grid continues to monitor and review the R&D programme. | | |
| **Project progress as of March 2010** | **A1 INTRODUCTION**<br><br>The R&D work for gaseous phase Carbon Dioxide ($CO_2$) follows on from the initial studies completed by Phil Cleaver (GLND) covers the following four main work streams:<br><br>1. Thermodynamic characteristics of gaseous phase $CO_2$ (section A2).<br>2. Fracture control (section A3),<br>3. Quantified risk assessment (section A4) and<br>4. Pipeline design and integrity (section A5).<br><br>The following sections outline several of the major work elements undertaken for the four main R&D work streams over the last financial year regarding the reuse of existing National Transmission System (NTS) pipeline assets for the transportation of anthropogenic, gaseous phase, $CO_2$.<br><br>**A2 THERMODYNAMIC CHARACTERISTICS OF GASEOUS PHASE $CO_2$**<br><br>This work stream involves the investigation, modelling and analysis | | |

of the thermodynamic behaviour of gaseous phase $CO_2$. This is of particular significance in understanding the behaviour of gaseous phase $CO_2$ in the event of an uncontrolled release, as the energy released by the decompressing fluid provides a driving force which could possibly cause defects to propagate.

### A2.1 Equation of State position paper

The thermodynamic behaviour of $CO_2$ (i.e. enthalpy, entropy and density changes as pressure and temperature conditions vary) is predicted using Equations Of State (EOS). The EOS are semi-empirical, and are based on empirical data which means that the EOS are accurate within the experimental error associated with the measured data. Anthropogenic $CO_2$ contains a number of different impurities which influence the thermodynamic behaviour and changes the location of the phase boundary. For gaseous phase pipeline transportation of $CO_2$, this is of particular importance at higher pressures and lower temperatures where two phase conditions may occur.

The concentrations of impurities are limited to low percentage volumes by the specification developed by National Grid and it has been concluded that the thermodynamic behaviour of gaseous phase $CO_2$ is unlikely to be significantly affected by the presence of impurities at the levels defined in the National Grid $CO_2$ worst-case acceptable specification. An expert position paper has been prepared by Atkins Boreas to support and justify this position and concludes that the EOS for gaseous $CO_2$ containing impurities at the level specified in the National Grid $CO_2$ specification are the same as those for pure $CO_2$ within the variation of experimental data. This means that the existing EOS can be used in assessments to predict reasonably the decompression, dispersion and flow behaviour of gaseous phase $CO_2$ with impurities. In addition, the phase diagram based on the EOS for pure $CO_2$ can be used to determine pressure and temperature levels which will not pose a risk of two-phase flow under operating conditions.

### A2.2 Decompression Studies

Decompression studies are required in order to provide an accurate knowledge of decompression behaviour which is vital in setting the minimum toughness levels for shear fracture arrest and for ensuring that the existing pipeline material has the level required.

Atkins Boreas have calculated the minimum pipe toughness needed using a recognised model which was originally developed for predicting the decompression curves for hydrocarbons, including natural gas and rich gas. The model has now been modified for use with $CO_2$. The predictions will be validated by the shock tube testing to be undertaken (which is described in section A6).

The work undertaken further develops the analysis produced by Dr Andrew Cosham of Atkins Boreas and Robert Eiber (formerly of the Battelle Memorial Institute in America) into the decompression behaviour of $CO_2$.

The work conducted by Atkins Boreas has confirmed that the toughness levels required in existing pipelines for the safe transport of natural gas under current operating conditions, are also expected

to be appropriate for the safe transport of $CO_2$ under the anticipated operating conditions There is high confidence regarding these predictions but, due to the paucity of experimental decompression data, it is intended to carry out confirmatory shock tube tests. An initial review of material certification for the existing NTS pipelines has been undertaken and it has been confirmed that the pipe has the toughness level needed.

**A3 FRACTURE CONTROL**

Fracture control on pipeline systems is very important and requires consideration of fracture initiation and propagation behaviour. Pipeline codes require that adequate fracture control measures are in place for all high-pressure gas pipelines, as gas decompression can provide a fracture driving force which can lead to propagating fractures if the pipe toughness specification is not adequate.

Further to the work conducted by Atkins Boreas regarding the minimum level of pipe toughness required. Penspen Limited were engaged to review current guidance on fracture control in pipelines carrying $CO_2$, generate an initial fracture control plan for the existing pipelines and identify any knowledge gaps which require filling. The fracture control plan for the existing pipelines concluded that there was acceptable resistance and barriers to fracture initiation and acceptable toughness for fracture arrest. The work also assisted in developing an understanding of an acceptable approach to managing fracture mechanics issues associated with $CO_2$ pipelines in the UK.

The decompression models which are being used as part of the fracture control work to predict the decompression curve for gaseous phase $CO_2$ with impurities have been previously verified against validated predictions of rich gas shock tube tests. The predictions for $CO_2$ will be validated by the shock tube tests to be undertaken (which is described in section A6).

**A4 QUANTIFIED RISK ASSESSMENT**

Quantified Risk Assessment (QRA) is required to establish an individual risk based pipeline routeing corridor, consider societal risk aspects and confirm that the risks associated with a $CO_2$ pipeline are As Low As Reasonably Practicable (ALARP) in accordance with the current legislation (e.g. the Pipelines Safety Regulations 1996).

Specialist expertise from Pipeline Integrity Engineers (PIE) Limited and Germanischer Lloyd Nobel Denton (GLND) have conducted fundamental studies relating to:

- Consequences (source model).
- The dispersion of $CO_2$ from pipeline failure events.
- Effects of $CO_2$ on humans.
- The assumptions to be made regarding shelter and escape from a pipeline failure event.

A QRA methodology has been developed and is currently undergoing internal review. The shock tube testing will also be used to investigate some of the assumptions made in modelling the

dispersion of $CO_2$ (which is described further in section A6).

The results of this work are being utilised to examine the route of the existing pipelines that could be reused. Initial indications are that the risks associated with the current pipeline routes are considered to be in the ALARP region.

Penspen Limited have conducted a topographical assessment on the existing pipelines to identify low points where dispersing $CO_2$ could collect and classify whether there are developments/populated areas located within the low points identified. Several areas requiring further investigation were identified.

**A5 PIPELINE DESIGN AND INTEGRITY**

Two areas PIE have been actively involved with include:

1. Development of pipeline routeing guidelines.
2. Work relating to gas treatment and monitoring.

Routeing guidelines are a basic requirement for any major accident hazard pipeline and involve determining the population density within a defined corridor centred on the proposed pipeline route, and the application of a minimum separation distance to occupied buildings. Work is well advanced on developing the routeing guidelines which will be finalised shortly.

With regards treatment and monitoring requirements. An initial corrosion review has concluded that internal corrosion in gaseous phase $CO_2$ pipelines can be eliminated if dry operation is maintained. This will require treatment, monitoring and emergency shutdown facilities to cater for any upstream equipment malfunction. A further study is to be carried out to assess the likelihood and rate of corrosion should water enter the pipeline.

GLND were commissioned to review the situation regarding the metering of $CO_2$ which included a literature search of existing work on $CO_2$ metering, a review of existing specifications and technologies for $CO_2$ metering and a theoretical review using GLND's software package GasVLe to assess the impact of impurities on the gas properties (phase behaviour). The work identified that there is still much to be understood about the transmission and metering of $CO_2$ for Carbon Capture and Storage (CCS[1]) applications, although the metering technologies that have been used to meter $CO_2$ were identified.

Penspen Limited were engaged to undertake a range of work elements, including but not limited to, the following:

**Fatigue analysis** - Perform a fatigue fracture mechanism assessment on the existing pipelines in order to demonstrate that the existing pipelines would be "fit for purpose" for the change of use in terms of fatigue life. The assessment confirmed that the existing pipelines were "fit for purpose" for the change of use in terms of

[1] CCS is the removal, capture and storage of $CO_2$ from fossil fuels either before they are burnt (pre-combustion) or after (post-combustion). The captured $CO_2$ is then contained in some kind of long-term storage (sequestration sites) such as depleted oil and gas fields or deep saline aquifers.

fatigue life, based on the worst-case scenario pressure cycles.

**"Warm pre-stressing" -** Investigation of the phenomenon referred to as "warm pre-stressing" which is considered to elevate the fracture toughness of pipeline steels by preloading. In pipelines, this preload is usually provided by the pre-service hydrostatic pressure test for welding, construction and material defects. For defects that occur in-service, this preload is the operational stress acting immediately prior to the defect failing. The investigation identified that "warm pre-stressing" cracks present in the pipe at lower temperatures allowed failure loads to be recorded that are above the loads at the warm pre-stress and above the failure loads without the warm pre-stress.

## A6 SHOCK TUBE TESTS

Investigations have indicated that there are no published decompression measurements for gaseous phase pure $CO_2$ nor gaseous phase $CO_2$ mixtures with impurities. Decompression characteristics, in terms of pressure and temperature, changes with time during decompression and can be experimentally determined from shock tube tests.

National Grid is intending to conduct a series of experiments to measure the decompression of various compositions of $CO_2$ and also to validate phase boundary conditions (pressure and temperature) which have been used to define the maximum operating pressure and minimum operating temperature at which a phase change from gas to liquid will occur. The experiments will be initiated by rupturing a disc at one end of a pipe which has been filled with $CO_2$ or $CO_2$ mixtures (gas phase $CO_2$ plus impurities) to leave an open end through which the $CO_2$ will discharge horizontally into the atmosphere. The resulting pressure decay within the pipeline will be monitored using fast response instrumentation.

As the tests will be discharging into the atmosphere. National Grid are also intending to record dispersion measurements which will be used to validate dispersion predictions using "flat earth" models or, if necessary, for model development so that dispersion predictions can be predicted in line with the test results.

### A6.1 Test rig design

As there are no suitable test rigs for the experimental work proposed, National Grid produced a design specification with the assistance of PIE and Atkins Boreas for the test rig needed, based on previous experience and information from experimental reports available in the public domain. The design of the test rig has been informed by previous work carried out by British Gas (and others) relating to rich gas in the 1980s.

The test rig design parameters and test programme proposed were validated by specialist studies using Computational Fluid Dynamics (CFD)[2] undertaken by University College London Consultants Limited (UCLCL) to simulate pipeline decompression, outflow and

[2] A branch of fluid mechanics which uses numerical methods and algorithms to solve and analyse problems that involve fluid flow. Computers are used to simulate/predict the response of a fluid given a set of boundary conditions.

dispersion behaviour for pipelines transporting gas phase $CO_2$.

### A6.2 Test rig build

The design specification was then used as part of a competitive procurement event and issued to two organisations to ensure costs reflected current market forces, promote cost certainty and maximise the opportunity to gain value for money. Both organisations were invited to provide a costed proposal which were subjected to detailed commercial and technical evaluations. The evaluations identified that GLND provided the most economically advantageous proposal from the cost, timescales, technical and previous experience points-of-view.

GLND are currently constructing the test rig at their Spadeadam Test Facility. The test rig is a 144 metres long length of pipe with a nominal diameter of 150 mm (6 inches). Reference Figures 1 and 2 for photographs of the test rig during construction.

The test rig is due to be commissioned at the beginning of June and the experimental tests will be conducted during June and July.

**Figure 1 Photograph of the test rig during construction**

**Figure 2 Photograph of the end of the test rig**

## A7 SPECIALIST TECHNICAL SUPPORT

PIE were engaged to provide specialist technical support and assist with managing the various facets/work elements of the R&D work on behalf of National Grid due to their experience of developing R&D programmes and safety standards for the pipeline sector with the Health and Safety Executive (HSE) via the United Kingdom Onshore Pipeline operators' Association (UKOPA) and the Institution of Gas Engineers and Managers (IGEM), and having staff with the requisite specialist technical skills.

Some of the primary work activities PIE have been involved are outlined below:

- PIE were actively involved with developing the R&D programme and identifying the detailed work requirements to ensure the programme proposed was robust and will withstand scrutiny by the various Regulators. PIE has also produced the strategy for safety justification for reuse of the existing pipeline assets based on the proposed R&D programme.
- PIE have been undertaking a significant amount of work to further National Grid's understanding on safety zones around pipelines including leading the QRA work outlined in section A4.
- PIE has identified several specialist resources who have been utilised as part of the R&D program and who have been invaluable in assisting with the work due to their wealth of knowledge and experience.

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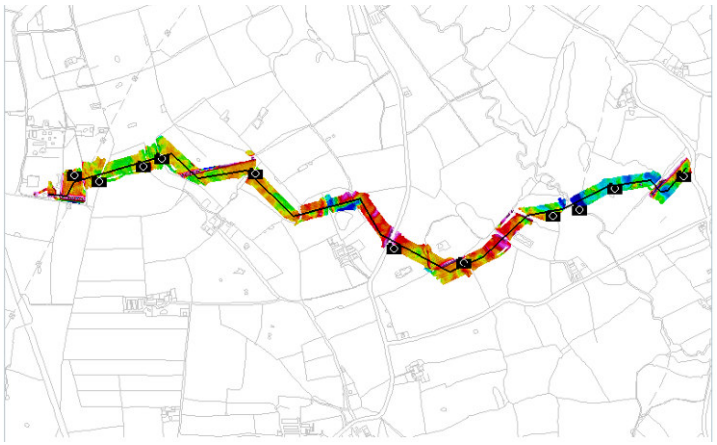
| | **A8 IN SUMMARY**<br><br>Coal will continue to provide a significant percentage of the electricity generated in the United Kingdom (UK) and around the world as it is reliable, low cost, there are abundant reserves available and coal fired generation can easily respond to fluctuations in energy demand. However, coal is also the fuel with the highest carbon emissions and generates significant quantities of $CO_2$.<br><br>The use of CCS has the potential to reduce $CO_2$ emissions from fossil fuel power stations by up to 90%.<br><br>The Government believes that CCS is an important way of reducing $CO_2$ emissions given that a significant proportion of the increase in world energy demand is expected to be met by fossil fuels, in particular from coal. CCS can help to meet the UK's increasing energy needs whilst maintaining the security of the energy supply by making coal a more viable option and assists in reducing dependence on gas imports.<br><br>CCS is a critical part of the UK's decarbonisation strategy and it facilitates the transition to a low carbon economy.<br><br>National Grid's potential involvement in CCS is through offering pipeline transportation services. National Grid has identified the potential for utilising existing NTS pipeline assets, which are near to or at the end of their regulatory economic life and that are nearly fully depreciated, for the transport of $CO_2$.<br><br>Utilising the existing NTS pipeline assets for $CO_2$ transportation provides the following benefits:<br><br>• Speeds up the initial deployment of CCS technology whilst reducing costs and minimising risks. This will benefit the UK economy by providing an efficient technical solution to the practical problems posed by CCS.<br><br>• Helps tackling climate change by allowing faster testing of the feasibility of CCS as a means of substantially abating carbon emissions.<br><br>• Provides an opportunity for gas consumers to extract residual value from the pipelines being reused which are otherwise expected to be relatively under utilised in the medium term.<br><br>The R&D work undertaken provides a good foundation for the facilitation of CCS. |
| **Collaborative partners** | None |
| **R&D providers** | Pipeline Integrity Engineers (PIE) Limited, GL Noble Denton, Penspen Ltd, Atkins Boreas, UCL Consultants Ltd. |

## 4. Combined Geophysics Tool for Pipelines Routeing & Risk Assessment

| | | | |
|---|---|---|---|
| **Project title** | Combined Geophysics Tool for Pipelines Routeing & Risk Assessment | | |
| **Project Engineer** | Matthew Sumerling | | |
| **Description of project** | The project objective is to trial new approaches to subsurface (geophysical) surveying, which will reduce the cost of pipeline construction projects caused by unforeseen or avoidable sub-surface ground conditions. The project will trial these new approaches on two construction projects to cover all areas of the research and prove the technology<br>It is hoped that the project will provide a cost effective method to give detailed geological information prior to beginning site works on construction projects and allow for the optimum route to be found.<br>  | | |
| **Expenditure for financial year** | Internal £5k<br>External £241k<br>Total £ 246k | **Expenditure in previous (IFI) financial years** | £5K |
| **Total project costs**<br>**(collaborative + external + internal)** | £391k | **Projected 2010/11 costs for National Grid** | £140k |
| **Technological area and/or issue addressed by project** | The issue addressed is how best to combine the multitude of geophysical techniques on one platform meaning that one survey will provide the majority of information required for construction projects. Although the technologies exist a multi-sensory platform has not been done before in the UK energy sector. The research will examine the benefits of greater integration of geophysical data into the pipeline routing process at an earlier stage of project design. | | |

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| **Type(s) of innovation involved** | Tech Transfer<br>Significant | **Project Benefits Rating** | **Project Residual Risk** | **Overall Project Score** |
| | | 14 | 1 | 13 |
| **Expected benefits of project** | Cost savings of 5:1 are claimed for the use of a mobile multi-sensor platform, compared to traditional subsurface survey methods (saving on costs of liaising with landlords and matching up disparate datasets from individual specialists). It is claimed that a corridor 2.5km x 40m could be surveyed each day with the mobile multi-sensory platform. By undertaking subsurface surveys of the soil composition before and after a pipeline is laid, National Grid has the data available to deal with (e.g. counter) any compensation claims from the landlord that the soil composition (i.e. soil type and %clay) has been changed.<br>The development of a best practice manual, decision support tool and survey data visualisation will help to ensure that the above benefits are available for future pipeline construction projects. | | | |
| **Expected timescale of project** | 4 years | **Duration of benefit once achieved** | Lifetime of inserting pipes | |
| **Probability of success** | 60% | **Project NPV = (PV benefits – PV costs) x probability of success** | £3,669,493 | |
| **Potential for achieving expected benefits** | The approach has been used for the clearance of areas affected by military activity and for the mapping of archaeological features, with proven results in these areas. This project involves incremental innovation to adapt established toolsets used in different industries to the needs of gas pipeline construction route selection and reinstatement verification. | | | |
| **Project progress as of March 2010** | The project started in Spring 2009. Phase 1 of the Hornsea-Beeford Geophysical survey works is now complete and the draft Phase 1 report will be delivered early next year. Access to the land to complete Phase 2 of the works is currently being negotiated.<br>Pre-Construction Surveys have taken place on the Hole House Farm Pipeline construction project. The Post-Construction surveys will take place one the pipeline route has been reinstated.<br>Progress on the Best Practice Manual has also been made, but completion of this will follow completion of physical works in order that all lessons learned can be included. | | | |
| **Collaborative partners** | None | | | |
| **R&D provider** | Zetica | | | |

## 5. Compressor Related Research

<table>
<tr><td>Project title</td><td colspan="3">Compressor Related Research<br>This programme of work includes the following projects:<ul><li>Research into Compressor Power and Temperature Limits</li><li>Demonstration of VSD Air Compressors Capability to Reduce Energy Consumption of Compressor Stations</li><li>IRIS</li><li>Strainer Vibration</li></ul></td></tr>
<tr><td>Project Engineer</td><td colspan="3">Tony Green, Wayne Jackson, Paul Sinclair, Brian Woodhouse</td></tr>
<tr><td>Description of project</td><td colspan="3">Projects looking specifically into issues that are related solely to compressor stations checking current operating models and improving efficiency where possible.</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £11k<br>External £72k<br>Total £83k</td><td>Expenditure in previous (IFI) financial years</td><td>£152k</td></tr>
<tr><td>Total project costs<br>(collaborative + external + internal)</td><td>£345k</td><td>Projected 2010/11 costs for National Grid</td><td>£26k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="3">This project will determine:<ul><li>Realistic maximum power characteristics for each different type of gas turbine used to drive gas compressors on the NTS gas transmission system</li><li>The reasoning behind the discharge temperature limits that are set on each of the compressor stations</li><li>The improved efficiencies and environmental benefit of using a VSD air compressor on compressor sites.</li><li>A solution to effectively remove liquid contamination from the gas network.</li><li>The mechanisms that cause vibrations as well identifying the pressure loss caused by vibrations (CFD modelling). Identifying a preferred configuration of filtration for the NTS.</li></ul></td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental<br>Tech Transfer<br>Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>9 to 11</td><td>0 to -4</td><td>9 to 15</td></tr>
<tr><td>Expected benefits of project</td><td colspan="3">Better understanding of the power and discharge temperature limitations of compressors will lead to more realistic capital</td></tr>
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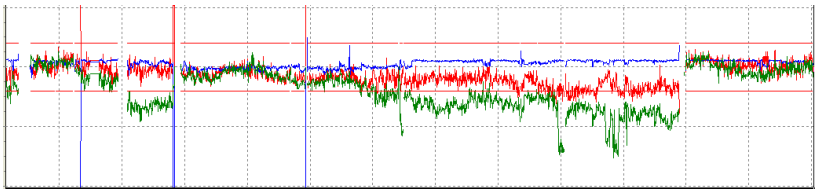
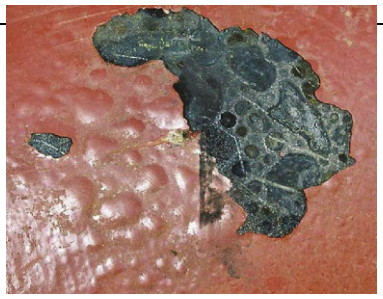
<tr><td></td><td colspan="3">investment decisions on the potential upgrading of the existing compressor stations (for example, delayed or reduced capital costs). Alternatively, it might lead to timely capital investment (or actual changes to operating limits) to prevent future failures to deliver capacity.<br><br>The VSD compressors will provide a useful step towards the company target of 80% carbon footprint reduction by 2050. As well as increasing the asset life of the compressors as they will only be running for a fraction of the time that the existing compressors run, reducing maintenance costs and increasing system reliability.<br><br>Incursions of high molecular weight contaminants at entry points can condense out as liquid under some pressure and temperature conditions within the network. Removal of such liquids upstream of compressor station assets can help to reduce maintenance costs.<br><br>Fewer associated failures with strainers and a lower pressure drop across the compressor, leading to improved selection of strainers to provide appropriate filtration and increased fuel efficiency on compressor sites.</td></tr>
<tr><td>Expected timescale of project</td><td>2-5 years</td><td>Duration of benefit once achieved</td><td>Lifetime of asset</td></tr>
<tr><td>Probability of success</td><td>60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>£191,335</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="3">On target</td></tr>
<tr><td>Project progress as of March 2010</td><td colspan="3">Research into Compressor Power and Temperature Limits<br><br>Research into gas turbine power limits has been completed and incorporated into a guidance document for use within National Grid. As well as referencing manufacturer’s data, the guidance builds in practical experience, such as the power deterioration shown in the following time graph:<br><br>  <br><br>Research has been completed into the temperature limits that are applied to gas transmission pipelines and the reasons for them. Essentially, a limit of 49 – 50˚C is applied to prevent disbondment of pipework protective coatings. A couple of examples of pipework that has been exposed to excessive temperature are shown in the following pictures:</td></tr>
</table>



Having established the reason for the temperature limit, a nine-point guide was produced for implementation of a common approach to the control of compressor station temperature that would maximise the flexibility of operation below 50˚C.

**Demonstration of VSD Air Compressors Capability to Reduce Energy Consumption of Compressor Stations**

The following photograph shows one of the newly installed VSD compressor units:


A few delays were experienced during the installation process, during installation of the new compressor units; the project team also looked for ways to achieve further energy savings. They established that the original compressed air systems had been installed with dryers that regenerate on a timed basis, whether or not regeneration is actually needed.

Therefore, 'Purge Control Saver' systems, which only regenerate the dryer when it reaches a certain dew point, were also procured for each compressor unit. These will save a further 10 – 15% more energy. The trial installation of the purge control savers is shown in the following photograph:


National Grid is already looking at other compressor stations to see whether the energy savings can be repeated elsewhere.

**IRIS**

National Grid has procured the IRIS filters from Dresser Rand, albeit after a number of delays. In the meantime, the proposed site has seen a reduced running profile, making the trial less relevant at this location. The trial has therefore been further delayed while a new site was selected. Operational difficulties in designing the filters into the system at the new site have added additional work, but this has now been completed by Mouchel. The installation plans have been finalised and the project is set to install 2 IRIS filters on two different fuel supply systems. A version of the IRIS filter can be seen below.

**Strainer Vibration**

The initial CFD modelling of flow and through suction strainers initially proved interesting. However, when attempting to scale the model up to a relevant size, the CFD modelling proved not to be cost-effective. So this approach was stopped, in favour of a technology and best practice review.

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| | Benchmarking the current National Grid specifications against other industrial partners and different industries has taken place with strainer and compressor suppliers giving information on maximum particle size and ability to redesign strainers. Best practice guidelines currently are not in existence for filtration in compressor stations.<br><br>National Grid and GL are now looking to hold workshops to develop a risk-based decision process to select the most appropriate filtration techniques on its compressor sites. |
| **Collaborative partners** | None |
| **R&D providers** | GL Noble Denton, Atlas Compressors, Dresser Rand |

## 6. Demand Side Modelling

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| **Project title** | Demand Side Modelling | | | |
| **Project Engineer** | Chandima Dutton | | | |
| **Description of project** | The primary aim of the project is to develop risk models that may be used to inform long-term planning decisions made by National Grid Gas Transmission. The models are also anticipated to provide information for shorter-term operational decision-making. | | | |
| **Expenditure for financial year** | Internal £2k<br>External £101k<br>Total £103k | **Expenditure in previous (IFI) financial years** | | |
| **Total project costs**<br>**(collaborative + external + internal)** | £130k | **Projected 2010/11 costs for National Grid** | £27k | |
| **Technological area and/or issue addressed by project** | The project will involve the identification and development of:<br>○ A gas flow monitoring process<br>○ A risk-analysis methodology (e.g. utilising Monte Carlo simulation)<br>It should be possible for National Grid to easily update the models on an ongoing basis in order that the risk models may be embedded within the planning process. The models may be shared with Ofgem to support discussions on investment plans. | | | |
| **Type(s) of innovation involved** | Incremental | **Project Benefits Rating** | **Project Residual Risk** | Overall Project Score |
| | | 17 | 2 | 15 |
| **Expected benefits of project** | The primary benefit for the work is ensuring that security of supply is maintained by the integrated gas Transmission and Distribution networks, as new arrangements come into play. However, through better knowledge of how the DN operators will change their behaviour with the new arrangements, National Grid Transmission would also hope to introduce more efficiency into their investment plans and operational planning. For example, every 1km of new pipeline that can be avoided will result in a saving of around £1m-£2m. | | | |
| **Expected timescale of project** | 2 years | **Duration of benefit once achieved** | Duration of current demand situation | |
| **Probability of success** | 70% | **Project NPV = (PV benefits – PV costs)** | £108k | |

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| | | **x probability of success** | |
| **Potential for achieving expected benefits** | Due to GL Noble Denton's background in network mathematics and statistical modelling and the ability to obtain information on localised demand through meters, there is a high probability of success. | | |
| **Project progress as of March 2010** | A draft report has been developed to explain the planning processes and high-level assumptions that the DNs use (as understood by GL).<br>Excel-based Monte Carlo Simulation models have been developed for an LDZ for offtake behaviour. Further work on these models is expected following workshops between NG and GL. | | |
| **Collaborative partners** | None | | |
| **R&D provider** | GL Noble Denton | | |

## 7. Detection & Management of Corrosion on Above Ground Insulated Pipework and Pipe Supports

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| **Project title** | Detection & Management of Corrosion on Above Ground Insulated Pipework and Pipe Supports | | | |
| **Project Engineer** | Peter Martin | | | |
| **Description of project** | • A market review of corrosion inspection systems for pipework and pipework supports that are normally covered by insulation materials.<br>• Practical evaluation of the most applicable corrosion inspection system(s), established by the market review. | | | |
| **Expenditure for financial year** | Internal £5k<br>External £77k<br>Total £82k | **Expenditure in previous (IFI) financial years** | £23k | |
| **Total project costs**<br>**(collaborative + external + internal)** | £105k | **Projected 2010/11 costs for National Grid** | £0 | |
| **Technological area and/or issue addressed by project** | The issue being addressed by this project is the condition of pipework on above ground facilities. External corrosion can develop and be hidden under noise insulation cladding or between the pipe and its mechanical supports. Complete removal and refitting of all insulation cladding and pipe supports to allow thorough inspection is prohibitively expensive.<br>Sample removal does not guarantee that all corrosion is identified. Therefore, alternative methods are required to locate areas of hidden corrosion without removal of insulation cladding or dismantling of pipe supports. | | | |
| **Type(s) of innovation involved** | Tech Transfer | **Project Benefits Rating** | **Project Residual Risk** | **Overall Project Score** |
| | | 14 | -3 | 17 |
| **Expected benefits of project** | By using new inspection systems, National Grid will benefit in a number of ways:<br>1. Non-invasive inspection techniques will allow 100% coverage of assets, resulting in improved confidence in above ground pipework integrity and identification of problem corrosion prior to failures (and their associated impacts on safety, security of supply and the environment)<br>2. Invasive maintenance can be targeted only where it is needed, leading to a faster conclusion to remedial action programmes, followed by reduced maintenance costs in the | | | |

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| | future.<br>3. National Grid can demonstrate to the Certifying Authority (HSE) that they are using the best available technology to improve safety on AGI sites. | | |
| **Expected timescale of project** | 3 years | **Duration of benefit once achieved** | Lifetime of NTS |
| **Probability of success** | 60% | **Project NPV = (PV benefits – PV costs) x probability of success** | -£57k |
| **Potential for achieving expected benefits** | Given the high number of techniques deemed suitable on the first stage of the project there is now a high chance that the project will be successful. | | |
| **Project progress as of March 2010** | The first part of the project has been successfully completed and reported. The study considered a total of 17 inspection techniques that are currently being used by other industry sectors (including offshore and petrochemical) for corrosion detection where access is difficult. Of these, 9 were considered suitable for further evaluation by pilot trials on National Grid sites, where their ability to detect corrosion, without having to remove the insulation material or dismantle the pipe supports, was be assessed.<br>The inspection equipment to perform the shortlist of techniques was hired in and used to conduct trial inspections of selected pipework systems on a number of different National Grid above ground facilities. The inspection results were analysed and, where corrosion was indicated, the pipework was examined further to confirm whether corrosion was actually present. A second report was complied on the results of these site trials.<br>Two of the techniques that were considered are illustrated here:<br>• The use of thermal imaging to detect corrosion “hot-spots” under insulation (images © Inspectahire Ltd.):<br>  <br> | | |

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| | • The use of a circumferential ultrasound scanner system to detect corrosion at pipe supports and clamps (CHIME method):<br>  <br>After studying the results one method provided the most timely and effective supplementary method of identifying likely corrosion hotspots associated with water ingress. This method is commonly known as 'neutron backscatter'.<br>Although this project was successful and identified the most promising technique for identifying areas of potential corrosion, further work is now needed to understand how the measurements relate to ranking or priority-scoring when applied to National Grid's assets. These 'calibration' tests will be undertaken next year. |
| **Collaborative partners** | None |
| **R&D provider** | GL Noble Denton |

## 8. Efficient Asset Management

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| **Project title** | **Efficient Asset Management**<br>This programme includes the following projects:<br>• AGI Paint Systems<br>• Development of Standard Pressure Cycle Information for 94 barg Pipelines<br>• Trial of Artesis Motor Condition Monitoring<br>• Optimisation of Integrity Management at Sleeved Crossings<br>• Improving the Integrity of Pig Trap Door Seals | | |
| **Project Engineers** | Peter Martin, Julian Barnett, Michael Daniel, Rob Stockley / Joanne Harris, Steve Johnstone | | |
| **Description of project** | This set of projects is looking to ensure the integrity of National Grid's assets through a pro-active approach to corrosion management, condition monitoring and applied policy. This is undertaken by taking a view on other industries that could be applicable and also challenging National Grid's current knowledge and viewpoint creating new techniques and procedures. | | |
| **Expenditure for financial year** | Internal £14k<br>External £125k<br>Total £166k | **Expenditure in previous (IFI) financial years** | £80k |
| **Total project costs**<br>**(collaborative + external + internal)** | £323k | **Projected 2010/11 costs for National Grid** | £77k |
| **Technological area and/or issue addressed by project** | These projects will seek to improve the efficient asset management of the NTS system through a variety of approaches and techniques on different parts of the NTS system. The main aims are identified below:<br>• The selection and identification of single coat paint systems that can be used to perform local patch repair on existing paint coatings without the requirement for grit-blasting providing temporary protection as well as the identification of over-coating paint systems which can be applied to entire sites to extend the life of the existing coating<br>• Development of a "standard" set of pressure cycle information for pipelines operating at 94 barg supplements the information currently available for pipeline systems operating at all other transmission pressure levels.<br>• Identifying critical equipment that continues to be un-monitored, or has minimal Condition Monitoring in place, and identifying how the NTS would benefit from relatively cheap and diverse Condition Monitoring asset reliability diagnostic | | |

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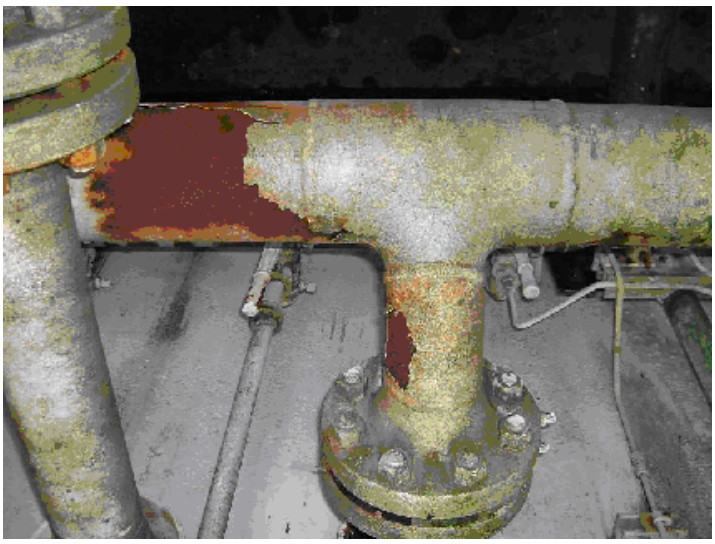
<tr><td></td><td colspan="4">tool.<br>• Finding alternative solutions to the use of nitrogen in sleeved crossings. The alternative needs to provide an inert atmosphere and seal within the sleeve. Proving the products fitness for purpose and long-term performance is a necessity. The level of proven operator experience also needs to be considered.<br>• Reduction of “fugitive” emissions of natural gas from pig trap doors. Elastomers are employed extensively for gas containment, for example as O-ring seals for pig trap doors. They may fail through several mechanisms, including extrusion damage, compression set, temperature and chemical degradation, swell/shrinkage and wear, or through rapid decompression damage. Elastomer failure may ultimately lead to loss of gas containment.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental<br>Tech Transfer</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>10 to 16</td><td>3 to -2</td><td>7 to 18</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">AGI Paint Systems<br>In addition to ensuring the integrity of equipment, a pro-active approach to corrosion management has major benefits through:<br>▪ Reduced un-scheduled pressure reductions and outages due to corrosion related repairs<br>▪ Reduced repair costs<br>▪ Maximisation of asset life<br>  <br>The outcome of this project will be the identification of two coat paint systems that are compatible with existing materials. Maintaining the existing coating system, rather than effecting its complete removal and replacement, will provide a more cost effective solution to</td></tr>
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| | maintenance painting.<br>**Development of Standard Pressure Cycle Information for 94 barg Pipelines**<br>Optimise the fatigue life on pipeline assets developed whilst ensuring:<br>• National Grid compiles with legal requirements (such as the Pipeline Safety Regulations (PSR) 1996)<br>• Compliance with company policies and procedures<br>• A consistent design approach across pipelines designed for 94 barg operation<br>• The correct line pipe is used.<br>**Trial of Artesis Motor Condition Monitoring**<br>Permanent ''relatively cheap' condition monitoring of high criticality equipment and 'reliable', automatic fault indication. An estimate of possible electrical issues identified from the condition monitoring system will lead to electrical efficiencies.<br>The condition monitoring will increase the security of gas transmission supplies, reducing the vulnerability National Grid are exposed to by continuing to run rotating equipment 'blind' without any Condition Monitoring.<br>In addition long term, applications can be integrated into sites' existing SCADA Systems.<br>**Optimisation of Integrity Management at Sleeved Crossings**<br>The purpose of this project is to determine and quantify the potential benefits for the UK gas transmission system of using alternative methods for providing an inert atmosphere within existing pipe sleeves. This project will also aim to identify the costs of these alternative techniques, ease of installation, ongoing maintenance requirements, performance and overall reliability compared to current practice.<br>This work will include a review of the appropriate fill mechanism for each product.<br>**Improving the Integrity of Pig Trap Door Seals**<br>Knowledge will be transferred from other related industry sectors to National Grid, enabling a plan to be produced to ensure good practice to be achieved in managing the integrity of elastomer seals in pig trap door closures mitigating the potential for seal failures. Seeking the reduction in leaks and fugitive emissions across the NTS. | | |
| **Expected timescale of project** | 10 years plus – Due to ongoing testing of the paint systems | **Duration of benefit once achieved** | 5-20 years |

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| **Probability of success** | 60% | **Project NPV = (PV benefits – PV costs) x probability of success** | £113k |
| **Potential for achieving expected benefits** | The individual projects inside this programme all have a reasonable chance of making a significant different in their specific areas. However, the diverse portfolio as a whole has a good chance of producing changes to the way that efficient asset management is approached throughout the gas transmission system. | | |
| **Project progress as of March 2010** | **AGI Paint Systems**<br><br>A total of nine '2-coat' paint systems, from five paint manufacturers have been applied to a range of substrates and subjected to a suite of accelerated corrosion tests. The application characteristics of these paint systems, the compatibility with coatings likely to have been previously applied to National Grid sites, the minimum prep time requires, and their long term performance in a range of accelerated corrosion tests have all been assessed. The materials were then ranked using suitable systems and then the identified paints have started a large-scale site application trial.<br><br>Sites have been identified and selected due to their coastal proximity or due to their proximity to heavy industry providing a harsh testing ground for the 5 paints that have been identified for longer trials. These ongoing trials will need monitoring for a couple of years to assess the success of the different paints.<br><br>**Development of Standard Pressure Cycle Information for 94 barg Pipelines**<br><br>GL successfully completed the work as required in accordance with National Grid's requirements and the work undertaken is detailed in the GL report 9380. Four sets of possible pressure cycles were produced and investigated using recognised fatigue and fracture assessment techniques and all were shown to be acceptable. Therefore any of the four pressure cycle arrangements identified could be adopted as a "standard" set for future fatigue analysis on 1200 mm (48") nominal diameter pipelines, a wall thickness of 15.9 mm, grade L555 linepipe material and with a MOP of 94 barg.<br><br>**Trial of Artesis Motor Condition Monitoring**<br><br>The project progressed with the purchase of the Artesis Motor Condition monitoring system and the initial prep work completed at Partington to trial the system.<br><br>Unfortunately, on further investigation into the high voltage (HV) system at Partington, it was discovered that this was arranged in a non-standard form. Alterations were attempted using a variety of current transformers but the decision has been made to trial the monitoring system on a standard HV system so the trial has been halted at Partington.<br><br>This trial is now due to take place at Avonmouth station for the autumn peak to provide a decent test of the monitoring system. | | |

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| | Prep work is underway at Avonmouth.<br><br>**Optimisation of Integrity Management at Sleeved Crossings**<br><br>The project has been completed and the report details upwards of 8 materials that could be used as an alternative fill for the sleeves other than nitrogen. These vary from gels to gasses, all selected due to there ability to control corrosion and also be injected into he sleeve through the existing connections (or with minimal alterations).<br><br>After further consultation with National Grid, gases were removed from the option list, because of the issues with maintaining gas pressure. Therefore, 4 materials (gels and viscous fluids) are to be taken forward to further trials.<br><br>**Improving the Integrity of Pig Trap Door Seals**<br><br>The assessment has been completed and a report compiled, whereby a list of recommendations has been produced to enable the findings of the project to be readily implemented.<br><br>  <br><br>**Photograph of a 'typical' Ring lock closure at Paull AGI** |

**Close-up photograph of a failed Ringlock seal**

**(Images courtesy of GD Engineering)**

Data was collected through a variety of means including database and literature searches, interviews with personnel (both within National Grid and other operators and closure manufactures) and laboratory testing of components. This was comprised of the following types of tests & failure analysis:

- Extrusion Damage
- Compression set
- Temperature effects
- Explosive Decompression Damage (EDD)
- Swell & Shrinkage
- Wear
- Chemical degradation

Analysis of the data enabled trends to be determined and a definition for good practice to be formulated, including the ability to compare seal materials from recent failures.

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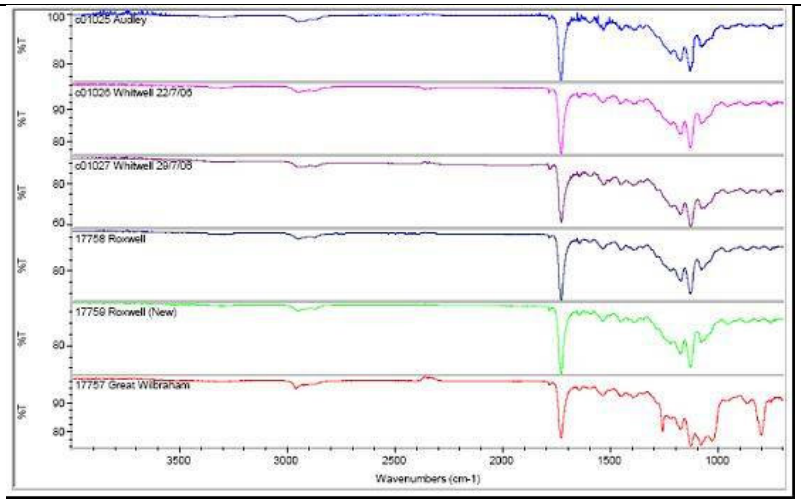
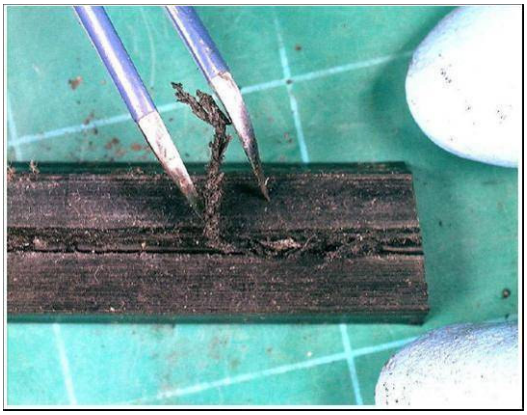
| |  <br>**Comparison of the infrared spectra analysis from recently failed seals**<br><br>  <br>**Close-up view of a torn & scored failed seal** |
| **Collaborative partners** | None |
| **R&D provider** | GL Noble Denton |

## 9. Enhanced Probabilistic Supply Modelling

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| **Project title** | Enhanced Probabilistic Supply Modelling | | | |
| **Project Engineer** | Joe Foxon | | | |
| **Description of project** | A probabilistic model of gas supply behaviour, which takes into account the range of supply drivers, in order to enable National Grid to determine the likelihood of various supply scenarios that could constrain the NTS. | | | |
| **Expenditure for financial year** | Internal £5k<br>External £22k<br>Total £27k | | **Expenditure in previous (IFI) financial years** | N/A |
| **Total project costs**<br>**(collaborative + external + internal)** | £54k | | **Projected 2010/11 costs for National Grid** | £27k |
| **Technological area and/or issue addressed by project** | A key aspect of National Grid's role as Gas Transporter is to provide sufficient entry capacity to the NTS. National Grid is obligated to release entry capacity for sale up to a "Baseline" level defined in the Gas Transporters Licence. Capacity is sold by auction on an annual basis, at a minimum of 3 years in advance. Capacity above the Baseline level can also be requested, subject to economic tests. Any spare capacity is subsequently sold on in shorter-term auctions.<br>Entry capacity confers the right to flow gas into the NTS. There are considerable volumes of historical data available for existing terminals; however flow patterns are becoming less predictable. This is a direct result of the diversification of natural gas supply, and liberalisation of the market. Furthermore, different types of gas may be affected by a range of drivers, such as the weather price of gas/oil, level of demand, contractual flows, and the behaviour of other countries e.g. Japan's need for LNG due to a an extended nuclear plant failure, or the seasonal LNG imports to the United States.<br>As the work is of an exploratory nature, re-sanction may be necessary at a later date to accommodate any changes in scope identified during the development of the model. | | | |
| **Type(s) of innovation involved** | Incremental | **Project Benefits Rating** | **Project Residual Risk** | Overall Project Score |
| | | 15 | 1 | 14 |
| **Expected benefits of project** | Investment in a new high-pressure gas pipeline can easily be of the order of £100M of capital expenditure. Without a full statistical understanding of the supply situation, the risk of constructing a stranded asset is relatively high. | | | |

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| | A recent example would be the Aberdeen to Lochside pipeline, where National Grid was disallowed the recovery of a proportion of the capital costs. It is therefore clear that the savings to both consumers and National Grid have the potential to be very large. The proposed project shall provide a clearer understanding of the supply position, and in turn will allow National Grid to make the best possible decision based on the currently available information and in accordance with a reasoned methodology. (Based on conservative estimate of one applicable project in 20 years, this project is likely to achieve 5% of the estimated £100m). | | |
| **Expected timescale of project** | 2 years | **Duration of benefit once achieved** | 20 years |
| **Probability of success** | 60% | **Project NPV = (PV benefits – PV costs) x probability of success** | £1,020k |
| **Potential for achieving expected benefits** | High potential due to the advance knowledge of modelling and mathematical experience at Warwick University. | | |
| **Project progress as of March 2010** | After some delays, work is progressing well. The initial phase of the project involved giving the team at Warwick University a good understanding of the supply situation, from the location/ types of gas at each terminal to the commercial entry process. With this understanding Warwick has now begun to investigate the relationships between historic flows at each entry point (both with each other and external drivers). A full project update is due on the 3rd of June when Warwick will present their work to date to National Grid. | | |
| **Collaborative partners** | None | | |
| **R&D provider** | Warwick University | | |

## 10. Ensuring Safety on Site

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| **Project title** | **Ensuring Safety on Site**<br>This programme of work includes the following projects:<br>• Ignition Potential of PDA Devices on Gas Transmission Above Ground Facilities<br>• Replacements for Cadmium Plating on Fasteners<br>• Fire Protection for Fire Water Mains | | |
| **Project Engineer** | David Godwin, Peter B Martin, Michael Daniel | | |
| **Description of project** | Research into the safety risks for operational staff who work on the NTS; ensuring the tools they are using, and potentially relying on, perform as expected. | | |
| **Expenditure for financial year** | Internal £7k<br>External £112k<br>Total £119k | **Expenditure in previous (IFI) financial years** | £ 18k |
| **Total project costs**<br>**(collaborative + external + internal)** | £137k | **Projected 2010/11 costs for National Grid** | £0 |
| **Technological area and/or issue addressed by project** | **Ignition Potential of PDA**<br>The project will determine whether or not a standard (not IS certified) portable data apparatus (PDA) device will be able to be used for routine maintenance work in potentially gas hazardous areas, in conjunction with appropriate and approved operating procedures.<br>The work will involve assessing PDA devices from two different suppliers to determine under what circumstances they could produce a spark/ignition. National Grid will use the device assessments to develop a risk assessment and to decide any potential policy impact.<br>**Replacements for Cadmium Plating**<br>National Grid UK Transmission has been using cadmium plated fasteners on above ground installations for many years. Due to their very thin film build the coating is easily damaged during make-up. Where damage to the cadmium plating occurs, the sacrificial nature of cadmium (relative to steel) allows protection to be afforded to the steel substrate. Due to the thin film build of the cadmium plating, this sacrificial protection is short lived and serious rusting of the underlying steel occurs.<br>Cadmium plating is also known to give serious health and environmental concerns both during the plating operations and during handling and disposal of cadmium plated components. | | |

<table>
<tr><td></td><td colspan="4">Fire Protection for Fire Water Mains<br><br>National Grid currently has below ground steel fire water mains at AGIs, Compressor Stations and Reception Terminals. However, a number of fire water mains have experienced leakage resulting from internal and external corrosion. There are also concerns about replacing the below ground pipework on sites with contaminated land. Therefore, National Grid would like to consider the feasibility of above ground fire water mains, such that inspection, maintenance and replacement could be undertaken with less expense.<br><br>This project will assess the additional risks that above-ground fire water mains will be exposed to. For example, flame impingement or thermal radiation in the event of a hydrocarbon pool or jet fire, blast damage due to a gas explosion, vehicle impact etc. The project will cover the risks associated with the following hazards:<br><br>• Flammable and Combustible Liquids Storage<br>• High Pressure Natural Gas Storage<br>• Road Loading and Unloading Facilities<br>• Storage of Flammable Materials in Containers, Drums and Cylinders</td></tr>
<tr><td>Type(s) of innovation involved</td><td>Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td></td><td></td><td>9 to 16</td><td>3 to -3</td><td>12 to 19</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Ignition Potential of PDA<br><br>Development of the design of a specific PDA device for use in potentially explosive atmospheres would be prohibitively expensive. Such a development would need to be led by the manufacturer. National Grid expects to purchase around 200 PDA units for Gas Transmission.<br><br>Rule of thumb is that data acquisition devices that have already been certified as intrinsically safe (IS) are typically around 4 times the purchase cost of standard devices. However, the PDA units that are being used by National Grid for maintenance operatives are not currently available as IS versions.<br><br>If procedures can be developed to utilise a standard PDA device by Gas Transmission maintenance operatives, National Grid can than benefit from extending favourable terms already negotiated for Electricity Transmission.<br><br>Replacements for Cadmium Plating<br><br>National Grid has been experiencing corrosion problems associated with the use of cadmium-plated fasteners and require cost comparable alternative coatings capable of providing improved corrosion protection. Management of corrosion of fasteners is a major risk to the business, failure to address this issue could result in a ‘security of supply’ or safety risk. In addition, there is a clear health and environmental hazard related to the use of cadmium;</td></tr>
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| | introduction of alternative materials will eradicate this risk.<br><br>The question of project net present value was considered. However, given the long working life of pipeline joint fasteners, the financial benefit of increased working life of the replacements (compared to simply replacing with cadmium-plated fasteners) would not be seen for a considerable length of time. Similarly, any potential for health claims arising from handling cadmium-plated components would not go away until there was a substantial population of alternative fasteners in use. Again, this would not be the case for a considerable length of time. Therefore, while there are good reasons to investigate alternatives to cadmium plating for pipeline fasteners, there is no obvious way to claim a positive net present value.<br><br>**Fire Protection for Fire Water Mains**<br><br>The project will assist National Grid in identifying:<br><br>• The materials that could be used belowground to mitigate the problems currently being experienced on steel firewater mains.<br><br>• Whether an aboveground firewater main would be at any greater risk from Major Accident Hazards than belowground mains.<br><br>• Which materials are appropriate for the construction of above-ground firewater mains<br><br>• What precautions should be taken to:<br><br>o Prevent freezing of the fire water<br><br>o Protect the main and its supports against flame impingement and thermal radiation. | | |
| **Expected timescale of project** | 2-5 years | **Duration of benefit once achieved** | 5 to lifetime |
| **Probability of success** | 60% | **Project NPV = (PV benefits – PV costs) x probability of success** | - £6k |
| **Potential for achieving expected benefits** | On Target | | |
| **Project progress as of March 2010** | **Ignition Potential of PDA**<br><br>The 3m$^3$ explosion chamber fitted with a blow-off roof panel that was prepared last year was used to carry out tests on two types of PDA (from Motorola and HP respectively). Both PDA models underwent testing in an ethylene/air environment without causing an ignition; as a result testing in a less severe natural gas/air environment was not required.<br><br>During the process of obtaining the detailed design information necessary to complete the evaluations of the PDA devices, it became apparent that one of the two devices had almost certainly been designed with possible use in hazardous areas in mind. The cost of obtaining certification for a device that can operate in a Zone 2 natural gas hazardous area is only £10k-15k, providing there is no | | |

design change required.

As a result, the project was discontinued. There was no benefit to continuing tests to help demonstrate that an uncertified device could be used safely, if it would cost less to obtain certification through the usual channels.

**Fig 1 – This test rig was used to evaluate the suitability of using the PDA devices on gas transmission sites**

**Replacements for Cadmium Plating**

An investigation of the market produced a series of alternatives to cadmium plating, which were then tested in the laboratory along with a standard set of cadmium-plated fasteners. Samples were subjected to a vigorous series of tests including cutting the bolts in half to check the bonding of the plating under an electron microscope. Real world scenarios were tested where the bolts were made and broken to simulate damage under actual duty and a series of undamaged control samples were also tested using a number of laboratory tests including being subjected to 1000 hr salt spray at 100% humidity wet and dry cycles.

The results showed that the cadmium plating was one of the lowest performers and that the plating could be improved dramatically. The standard that was identified to provide the best solution to the cadmium plating was the less expensive Zinc Nickel alloy which whilst more expensive than the standard B7 bolts performed very well in aggressive environments and may be considered as a suitable alternative. There was however no way of being able to claim a net present value from the use of Zinc Nickel within an appreciable time period.

**Fire Protection for Fire Water Mains**

The Major Accident Hazards that may put an above-ground firewater main at greater risk than a buried main have been reviewed. The Hazards considered have included external causes (aircraft damage), natural causes (earthquakes), external failure events

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| | (design/construction/inspection/testing, foundation failure, fatigue, corrosion), on-site causes (frost damage and ground heave, impact damage/missiles, explosion/overpressure effects, exposure to thermal radiation and flame impingement, human factors) and site-specific issues.<br>This report could be used as an additional resource when evaluating the cost benefit of for water mains fire systems on a variety of sites. |
| **Collaborative partners** | None |
| **R&D provider** | GL Noble Denton |

## 11. Environmental Design

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| **Project title** | **Environmental Design**<br>This programme of work includes the following projects:<br>• Environmental Study for Future Above Ground Facility Developments<br>• Improved Internal Flow Regime | | |
| **Project Engineer** | Russell Cooper, Mick Cook | | |
| **Description of project** | These projects cover two different aspects of environmental improvement by design.<br>New above ground facilities are subject to environmental best available technique (BAT) studies. However, pressures of cost and time generally mean that the range of options considered by these individual BAT studies is not as broad as National Grid would prefer. Therefore, this project takes a more radical look to develop a wider up-front options pool for subsequent consideration by future BAT studies.<br>A number of other industry sectors have reduced fluid drag on external and internal surfaces through the use of a textured surface (shark skin effect). This project weighs up the evidence for its potential use on the internal surfaces of gas transmission pipelines. | | |
| **Expenditure for financial year** | Internal £4k<br>External £72k<br>Total £76k | **Expenditure in previous (IFI) financial years** | £ 29k |
| **Total project costs**<br>**(collaborative + external + internal)** | £105k | **Projected 2010/11 costs for National Grid** | £0 |
| **Technological area and/or issue addressed by project** | **Environmental Study for Future Above Ground Facilities**<br>A major source of planning delay has been objections that relate to the environmental impact of our proposed developments. In order to respond to such challenges National Grid needs to be able to discuss the merits of technologies that may have been rejected as well as those that are actually utilised. This type of information is not available to National Grid at present and represents a significant risk National Grid in the planning process.<br>**Improved Internal Flow Regime**<br>Pipeline flow capacity is dependent on gas pressure. Pipe wall friction progressively reduces the gas pressure (and as the gas pressure reduces, the pipe wall friction increases). Compressors are therefore positioned at intervals to boost the pressure and thereby overcome the effect of pipe wall friction. If pipe wall friction can be reduced, compressor usage would be reduced, with associated fuel | | |

<table>
<tr><td></td><td colspan="4">savings and reduction of emissions of carbon dioxide. For new pipelines, it would be possible to give consideration to either: (a) smaller or less frequent compressor stations; or (b) a smaller pipeline diameter.</td></tr>
<tr><td>Type(s) of innovation involved</td><td rowspan="2">Incremental<br>Tech Transfer</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td></td><td>7 to 8</td><td>3 to 4</td><td>3 to 5</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Environmental Study for Future Above Ground Facilities<br>The results of this piece of work will be used by National Grid to;<br>1. Support future planning applications for all above ground facilities, with complexity up to and including gas compressor stations. It will provide evidence of extensive research undertaken to specify the minimum range of innovative options that were required to be considered during project-specific environmental BAT studies.<br>2. Where appropriate rewrite its policies for design of gas installations.<br>This should enable National Grid to reduce the delays associated with addressing public concerns over the environmental impact of a new facility, by being proactive and having suitable information in advance of potential projects (and the ensuing objections).<br>National Grid should also be able to reinforce itself as a good steward of the environment, because it will be seen to be proactively managing, and seeking to reduce, its impact on the environment.<br>Improved Internal Flow Regime<br>National Grid needs to consider some imaginative schemes to achieve its stated target of 80% carbon footprint reduction by 2050. Reducing the utilisation of compressors (fuel usage and operating life usage) would make an impact in the right direction.</td></tr>
<tr><td>Expected timescale of project</td><td>2 years</td><td>Duration of benefit once achieved</td><td colspan="2">Lifetime of pipeline or AFI</td></tr>
<tr><td>Probability of success</td><td>60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td colspan="2">£198k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">The environmental study has already identified numerous ideas. However, these need to be assessed in detail to fully assess their practicality and value.<br>Whilst the improved internal flow regime looks promising in theory, the benefit will only be realised if it can be retrofitted to existing pipelines.</td></tr>
<tr><td>Project progress as of March 2010</td><td colspan="4">Environmental Study for Future Above Ground Facilities<br>This project has so far produced 49 ideas deemed worthy of further</td></tr>
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| | investigations and 25 “best” ideas for reducing the environmental impact of future AGI's.<br><br>These ideas will now go through a technical appraisal process for improvements and eliminating improvements which are not deemed practical. The remaining improvements will have their environmental gains quantified using Life Cycle Assessment when compared to off the shelf designs.<br><br>Quick wins will be identified and cases will be presented for adoption of improvements in new builds and retrofitting into existing facilities.<br><br>**Improved Internal Flow Regime**<br><br>London Offshore Consultants (LOC) and the University of Southampton (UoS) have carried out a study for National Grid that demonstrates that the application of an internal textured surface has the potential to improve the energy efficiency of new transmission pipeline systems.<br><br>The study has demonstrated that the application of a textured surface (riblets) of specified properties has the potential to improve flow rates between 2.2 to 4.6% and reduce pressure requirements about 2 to 3% (power reduction of 4~6%).<br><br>The mathematical analysis was carried out using a moderate range of Reynolds number (a dimensionless flow parameter). The research has shown that the percentage drag reduction using riblets is potentially higher when a ‘rough surface friction value’ is used in comparison to the conventional internal coatings. The study was also based on typical gas product properties carried in the UK’s national gas transmission system and the principle could also be applied to component areas of compressors to improve efficiencies.<br><br>The proposal would be to use grit of a specified size and properties in conjunction with the current application of internal coatings to create a specific textured surface. Internal coatings are normally applied in factory conditions and the addition of the grit process to the technology is considered feasible and cost effective.<br><br>The technology could therefore be considered for future new pipeline projects, provided the coating process/material is proven not to be a contamination risk to the gas and filter systems by deterioration and would need to be developed as a commercially available option by the pipeline suppliers. Retrofit of the technology to existing pipelines is not considered to be currently viable. |
| **Collaborative partners** | None |
| **R&D providers** | GL Noble Denton,<br><br>London Offshore Consulting & University of Southampton |

## 12. External Contamination Detection and Measurements at Entry Points

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| **Project title** | External Contamination Detection and Measurement at Entry Points | | |
| **Project Engineer** | John Harris | | |
| **Description of project** | This project will provide recommendations on the device, or array of devices, that would be required to detect high molecular weight contamination at the entry points to the NTS gas transmission system. The project will also evaluate the capability of such devices to provide quantitative measurements, initially targeting "order of magnitude" as a level of uncertainty. | | |
| **Expenditure for financial year** | Internal £3k<br>External £91k<br>Total £94k | **Expenditure in previous (IFI) financial years** | £606k |
| **Total project costs**<br>**(collaborative + external + internal)** | £804k | **Projected 2011/12 costs for National Grid** | £104k |
| **Technological area and/or issue addressed by project** | Compliance with GS(M)R and National Grid network entry agreements with regard to "solid or liquid material that may interfere with the integrity or operation of pipes or any gas appliance within the meaning of regulation 2(1) of the Gas Safety (Installation and Use) Regulations 1998 that a consumer could reasonably be expected to operate".<br><br>Each year there are several serious incidents of liquid contamination within the NTS, some of which have caused damage to equipment owned by either NG (compressors) or large industrial customers. The annual bill to repair damage and compensate customers is in excess of £1M.<br><br>There are two main suspected mechanisms for liquid contamination:<br><br>1. Gas producers may accidentally allow liquids produced by process failures to contaminate the gas. Such liquids are glycols, methanol and gas condensates.<br><br>2. Gas that enters the NTS in compliance with GS(M)R may have a composition which, when certain physical conditions such as temperature, pressure and flow are changed, condenses out as liquid in an unexpected manner.<br><br>The instruments currently used to monitor the gas composition at NTS entry points have the following limitations:<br><br>▪ All sample points and measuring instruments are designed to sample and analyse dry gas. Any liquid contamination picked up by the sample probe causes damage to the analysers.<br><br>▪ There are no instruments in place to monitor the concentrations of some potential liquid contaminants (glycols and methanol).<br><br>▪ The instruments which monitor higher hydrocarbon concentration and calculate hydrocarbon dewpoint do not analyse on a continuous basis; a typical time interval for sampling is every 30 minutes. This may be too infrequent to detect a liquid event.<br><br>The photograph below shows liquid contamination found during the routine | | |

<table>
<tr><td></td><td colspan="4">pigging of Feeder 1 near Paull.<br>  </td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant<br>Radical</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>16</td><td>0</td><td>16</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">1) Compliance:<br>As a gas transporter, National Grid is responsible for ensuring that the gas they supply complies with GS(M)R.<br>2) Financial:<br>a) If gas supplied directly by National Grid is proved to cause damage to customer’s equipment, then National Grid are liable for compensation.<br>b) NTS equipment is designed to operate or monitor dry gas. Contamination of the gas by liquids causes major damage to expensive items such as compressors.<br>c) Whenever liquid events are discovered, they must be resolved immediately by diverting staff from their usual duties.<br>3) Knowledge:<br>If a liquid event is caused by a gas producer, National Grid need robust data to justify either terminating gas flow and/or seeking compensation.</td></tr>
<tr><td>Expected timescale of project</td><td>3 years</td><td>Duration of benefit once achieved</td><td colspan="2">Lifetime of the NTS</td></tr>
<tr><td>Probability of success</td><td>60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td colspan="2">£1,044k</td></tr>
<tr><td>Potential for achieving</td><td colspan="4">It had been expected that gas quality measurement systems that are typically installed at NTS entry points would be able to register some characteristic</td></tr>
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| **expected benefits** | indications of high molecular weight contaminants in the gas stream, even though this is not their primary function. However, the project has revealed new information about the way such contaminants behave in a pressurised gas flow environment. This means that the project has to take a new direction, albeit with more certainty about the behaviour of the contamination that is required to be detected. |
| **Project progress as of March 2010** | A test loop was built and operated successfully at the Spadeadam Test Site (run by GL Noble Denton) to allow test monitoring of high molecular weight contaminants, which were added to the simulated NTS conditions of high pressure flowing gas.<br>  <br>The test work focussed primarily on the response of a multi-detector instrument (as currently installed at NTS entry points) and an ultrasonic gas-flow meter following the progressive addition of liquid aerosols. Events of severe contamination were not tested due to the risk of damage to the measurement instruments.<br>The test work highlighted a previously unrecognised mechanism by which high molecular weight contamination may occur in the NTS. High molecular weight contaminants can preferentially deposit as liquid on pipe walls even when the ambient conditions are such that they would be expected to remain in the gas phase. In such a scenario the true concentration of contaminants present therefore cannot be measured by process gas analysers such as those currently installed on the NTS for monitoring GS(M)R compliance.<br>There is potential for a microwave or ultrasonic-based measurement to detect small changes in the surface properties that would indicate the presence of small amounts of liquid. However, the project has shown that commercial ultrasonic devices, such as those tested would not be suited to such a task, being geared to look at changes within the overall gas flow. A potential device could still be a simple clamp-on device, based on ultrasound scanning technology, but this would not be able to identify the type of liquid |

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| | contamination.<br><br>New Instrumentation:<br><br>In the absence of an apparent “off-the shelf” solution, GL Noble Denton and IMA Ltd., a supplier of laser based analytical instruments, have given more consideration to the type of instrument that could be put together for the task.<br><br>This pause for thought followed last year’s work on the modelling of a photon counting Raman spectrometer and its suitability for detecting the presence of aerosols and the concentrations of gas phase methanol, MEG, TEG and benzene (to identify gas condensate). The modelling had showed that a very complex scanning spectrometer would be required to detect all four components in the gas phase, since the concentrations of gaseous TEG are extremely low. However, if all the contaminants are likely to exist in the liquid phase at the point of measurement, this approach may not be so difficult.<br><br>At the end of the year, GL Noble Denton and IMA were still in discussions with National Grid regarding the best way forward. Arrangements were also underway to re-use some of the equipment that had been tested at Spadeadam on the upgrade project for one of the NTS entry points. This would provide the project with revenue to cover some of next year’s costs. |
| **Collaborative partners** | None. |
| **R&D provider** | GL Noble Denton |

## 13. Ultrasonic Gas Detection

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| **Project title** | Ultrasonic Gas Detection | | | |
| **Project Engineer** | Dave McCollum | | | |
| **Description of project** | Research into the suitability of ultrasonic gas leak detectors in the ventilated enclosures that house gas turbine driven compressors. | | | |
| **Expenditure for financial year** | Internal £3k<br>External £2k<br>Total £5k | | **Expenditure in previous (IFI) financial years** | £58k |
| **Total project costs**<br>**(collaborative + external + internal)** | £63k | | **Projected 2010/11 costs for National Grid** | £0 |
| **Technological area and/or issue addressed by project** | Ventilation air flow is typically high in compressor cabs. This is because it is primarily designed to cool the gas turbine enclosure.<br>Ventilation is also a key component of the safety strategy for compressor cabs (reference HSE: PM84). A good ventilation system dilutes small leaks and prevents localised build-up of potentially explosive air-gas mixtures. However, a high ventilation flow rate can cause excessive leak dilution, such that large gas leaks cannot be detected by traditional gas detectors. An alternative method of gas detection is therefore sought, which can detect gas leaks reliably and independently of the ventilation flow rate.<br>This project is evaluating whether ultrasonic gas leak detectors can provide the solution. In particular, the project is assessing whether their effectiveness is limited by interference from the operation of rotating machinery and other systems in the enclosed environment. | | | |
| **Type(s) of innovation involved** | Incremental | **Project Benefits Rating** | **Project Residual Risk** | Overall Project Score |
| | | 13 | 1 | 12 |
| **Expected benefits of project** | The expected benefits are:<br>• Fewer gas detection sensors will be required to provide full coverage for the compressor cab.<br>• Potential for much smaller gas leaks (<0.1kg/s) to be detected, leading to earlier intervention.<br>• Reduced maintenance, because there are fewer sensors, they are self-diagnosing and they can be wall-mounted.<br>• Improved safety of the gas turbine enclosure, while still protecting critical assets from overheating (by decoupling gas detection from cab ventilation).<br>Key benefits from the project will be that the ventilation system can be sized to provide optimal cooling of plant and instrumentation and | | | |

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| | reduce instances of stagnant areas; The system provides a wide volume coverage so that a leak in any part of a cab can be detected with fewer detectors; Shorter detection time of a pressurised leak and potentially at a lower flow rate than traditional detectors; Reduced maintenance requirements | | |
| **Expected timescale of project** | 4-5 years | **Duration of benefit once achieved** | 5 years |
| **Probability of success** | 60% | **Project NPV = (PV benefits – PV costs) x probability of success** | £145k |
| **Potential for achieving expected benefits** | On target | | |
| **Project progress as of March 2010** |  <br>   <br>Previous interim reports from this project have addressed:<br>• Functionality of ultrasonic sensors;<br>• Identification of suitable installation locations in a range of different compressor cab layouts, based on a noise mapping procedure;<br>• Assessment of the general background noise level with gas turbines operating close to base load.<br>The latest practical tests have investigated the transient ultrasonic background noise in a compressor cab during the operation of the gas turbine (including start-up and shut-down).<br>As well as assessing the results for the particular compressor cabs that have been used for tests during the course of the project, a procedure has now been developed for the positioning and commissioning of ultrasonic systems on similar and dissimilar compressor cabs. | | |

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| **Collaborative partners** | None |
| **R&D provider** | GL Noble Denton |

## 14. Development of AC Over Line Survey System

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| **Project title** | Development of AC Over Line Survey System | | | |
| **Project Engineer** | Peter Martin | | | |
| **Description of project** | This project will deliver a suitable over line AC survey system that will be used for the initial identification of areas where the levels of induced AC current on gas pipelines may require mitigating action.<br>When implemented, the survey system will enable the improved detection and assessment of AC-induced corrosion in gas pipelines, thereby reducing the likelihood of leakage or failure though this particular potential corrosion process. | | | |
| **Expenditure for financial year** | Internal £25k<br>External £63k<br>Total £88k | **Expenditure in previous (IFI) financial years** | £22k | |
| **Total project costs**<br>**(collaborative + external + internal)** | £195k | **Projected 2010/11 costs for National Grid** | £85k | |
| **Technological area and/or issue addressed by project** | AC corrosion has been documented in the UK, mainland Europe and North America. Through-wall failures have been recorded and corrosion rates as high as 1.4 mm/yr calculated. A 2004 report indicates that 24 known cases of AC corrosion were reported in Europe (but likely that this is only a small percentage of the total). These pipelines were not shown to have any defects during conventional DC CIPS surveys. Increasing installation of power lines, rail transit systems and improvements to pipeline coating quality will all continue to increase AC corrosion instances. | | | |
| **Type(s) of innovation involved** | Radical | **Project Benefits Rating** | **Project Residual Risk** | **Overall Project Score** |
| | | 12 | 6 | 6 |
| **Expected benefits of project** | The business benefit is attained through developing a clear view of the levels of AC interference along a pipeline, rather than just at the test points (as is presently the case). Through this process, mitigation measures can be applied, if necessary, enabling the issue to be effectively monitored and controlled. | | | |
| **Expected timescale of project** | 3 years | **Duration of benefit once achieved** | Lifetime | |
| **Probability of success** | 60% | **Project NPV = (PV benefits – PV costs) x probability of success** | £44k | |

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| **Potential for achieving expected benefits** | If there are no suitable survey devices available from suppliers of potential survey equipment to be adapted to perform the required AC surveys, it should be possible to adapt some existing GL equipment for the purposes of the test surveys.<br><br>If no suppliers are willing to develop a suitable product, GL could carry out the design of a suitable device and then arrange for a contract manufacturer to produce it.<br><br>Note that it will be important to ensure prior to project initiation that a suitable AC-affected pipeline on the NTS is available for access to enable the AC-corrosion detection system to be evaluated. |
| **Project progress as of March 2010** | The theoretical study has been completed showing that it is possible to carry out corrected AC CIPS (close interval potential surveys) on the NTS system.<br><br>Taking this study forward a suitable survey device currently due for release has been identified which meets all of the limitations and performance criteria as set out in the initial study to enable the principals to be tested in the field on a number of existing pipelines with known AC interference.<br><br>Currently the project is experiencing delays in the product release of the field survey device and a fall back position to modify an existing device is currently being considered. It is still envisaged that the practical trials will be completed this year and the results and performance of the technique and principal will be able to be quantified against a series of benchmarks and performance indicators. |
| **Collaborative partners** | None |
| **R&D provider** | GL Noble Denton |

## 15. Flood Risk Analysis

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| **Project title** | Flood Risk Analysis | | | |
| **Project Engineer** | Doug Dodds | | | |
| **Description of project** | To gain an understanding of which of National Grids sites at risk from Pluvial or flash flooding.<br>To understand which of National Grids Gas Transmission assets are at risk and the risks associated with dam and reservoir failure.<br>To have available on National Grid Transmission GIS system data showing the potential Fluvial, pluvial flooding and inundation maps for planning and risk assessment purposes. | | | |
| **Expenditure for financial year** | Internal £23k<br>External £17k<br>Total £40k | | **Expenditure in previous (IFI) financial years** | £ 42k |
| **Total project costs**<br>**(collaborative + external + internal)** | £ 240k | | **Projected 2010/11 costs for National Grid** | £ 0k |
| **Technological area and/or issue addressed by project** | Flooding of National Grid assets. | | | |
| **Type(s) of innovation involved** | Tech transfer | **Project Benefits Rating** | **Project Residual Risk** | **Overall Project Score** |
| | | 10 | -3 | 13 |
| **Expected benefits of project** | Our Transmission licence requires us to operate the system with the minimum of disruption to service with this in mind any preventable losses due to flooding should be mitigated through appraisal management and reduction of the risks associated with flooding.<br>As climate change is resulting in greater frequency of flood events similar to the flooding experienced in June/July 2007 In order to reduce the requirements to initiate an assessment of all sites after each of these high profile flooding events it is envisaged that a robust strategic solution will be flexible enough that in depth site assessments will not be necessary with data being retained and made available for future use mitigating the need to employ resources.<br>Greater visibility of pluvial flooding risks to sites.<br>There is an urgent business need to mitigate the risks posed by all types of flooding and to make the data available to other departments within National Grid Transmission. | | | |

| | | | |
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| | In order to gain a clear picture of exactly what items are at risk on site surveys will be carried out to identify the site levels, the lowest points and also the plant and building site levels and their 'critical heights'. This will be done as part of the temporary barrier site surveys on the 1 in 100 and 1 in 200 risk sites at an approximate cost of £1500 per site (£30,000 for the twenty 1 in 100 risk sites). | | |
| **Expected timescale of project** | 2 Years | **Duration of benefit once achieved** | 10+ Years |
| **Probability of success** | 60% | **Project NPV = (PV benefits – PV costs) x probability of success** | -£50k |
| **Potential for achieving expected benefits** | High | | |
| **Project progress as of March 2010** | The modelling that has been completed to date is not accurate enough to provide a realistic picture of the expected flooding that could occur on the NTS.<br><br>As this partnership has not produced the expected result National Grid are currently seeking alternatives and have engaged with other suppliers who seem to be more promising in terms of producing a realistic a working model of the risk to pluvial flooding of National Grids assets.<br><br>Consequent of flooding that has occurred on the NTS a work stream has been set up this project will now be feeding directly into this scheme which is looking at the wider issues regarding flooding and the NTS. | | |
| **Collaborative partners** | National Grid Electricity Transmission | | |
| **R&D provider** | Environment Agency, Network Mapping | | |

## 16. Linepipe Integrity

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| **Project title** | Linepipe Integrity | | | |
| **Project Engineer** | Rob Bood | | | |
| **Description of project** | Testing of an X80 grade pipe spool assembly with calibrated part-through-wall drilled holes, simulating small diameter loss of weld defects. The tests involved with this project were:<br>• Pressure tests<br>• Pressure cycling fatigue testing<br>• Post-test metallurgical assessment<br>• Pull through tests with Magnetic Flux Leakage (MFL) inspection vehicle | | | |
| **Expenditure for financial year** | Internal £5k<br>External £80k<br>Total £85k | **Expenditure in previous (IFI) financial years** | £48k | |
| **Total project costs (collaborative + external + internal)** | £133k | **Projected 2010/11 costs for National Grid** | £0 | |
| **Technological area and/or issue addressed by project** | This work is being performed to assist in understanding the short and long term integrity of pipework that may have small diameter part-wall defects in them. | | | |
| **Type(s) of innovation involved** | Significant | **Project Benefits Rating** | **Project Residual Risk** | **Overall Project Score** |
| | | 15 | 2 | 13 |
| **Expected benefits of project** | Finite element analysis has previously concluded that part wall holes of 3 mm, 5 mm and 10 mm diameter in a pipeline can be deep enough to leave a remaining ligament of just 1mm and still have sufficient strength to survive a hydrotest and retain an adequate fatigue life. The full-scale tests undertaken during the first project are intended to validate this conclusion. The project will enable National Grid to understand the integrity of large diameter pipelines containing small part-wall holes. This will allow National Grid to make objective decisions if a pipeline containing such a defect can be safely allowed to remain in service or whether it needs to be repaired, perhaps by replacement of the damaged section. | | | |
| **Expected timescale of project** | 2 years | **Duration of benefit once achieved** | Lifetime knowledge | |
| **Probability of success** | 90% | Project NPV = (PV benefits – PV costs) x probability of success | -£122k | |
| **Potential for achieving** | The fatigue tests have shown that small diameter part-wall loss-of- | | | |

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| **expected benefits** | weld defects are unlikely to pose a threat to the integrity of X80 grade pipelines. The further work is required to ensure that the locations of this type of defect can be detected, so that they can be monitored over time. |
| **Project progress as of March 2010** | A 48” diameter test vessel was constructed that contained a total of 24 holes of 3mm, 5mm and 10mm diameter. These holes were situated both internally and externally and were of varying depths.<br><br>The vessel was subjected to a 24 hour hydrostatic pressure test at 149barg to simulate the commissioning hydrostatic pressure test. The vessel was then subjected to a 150,000 cycle fatigue test, cycling between 64barg and 94barg. The vessel completed both tests without any of the drilled holes failing.<br><br>The vessel was subsequently sectioned to allow a selection of the drilled holes to undergo metallurgical analysis and inspection for evidence of cracking. No cracking was observed in any of the defects, thereby demonstrating their resistance to fatigue loading and supporting previously conducted numerical analysis.<br><br>  <br>**Image showing test vessel in-situ.** |

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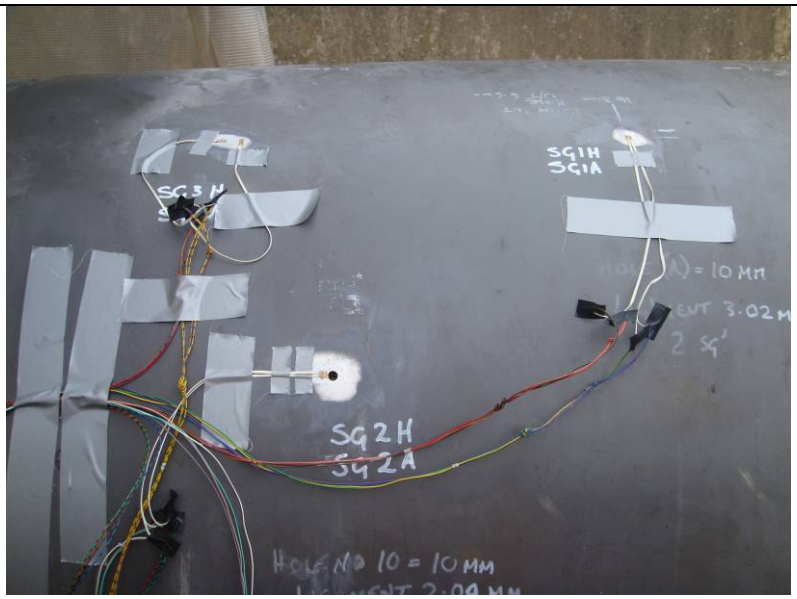
|---|---|
| |  <br>**Image showing the detail of holes and strain gauge instrumentation**<br><br>A 48” diameter pipe spool approximately 6 metres long was produced with approximately 100 part-wall holes of diameter 3mm, 5mm or 10mm, internally and externally and of varying depth. This was incorporated into a test rig at the research headquarters of Rosen in The Netherlands. Rosen subsequently pulled their MFL inspection tools through this spool to determine their ability at detecting holes of this size. A draft report on this and on the results of numerical work using magnetic flux leakage has been received. The results demonstrate that Rosen’s MFL tools will detect such defects with a high degree of confidence.<br><br>To finish this project off, the final report from Rosen needs to be delivered. |
| **Collaborative partners** | None |
| **R&D provider** | GL Noble Denton & Rosen b.v. Europe |

## 17. Meter Asset Management

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|---|---|---|---|
| **Project title** | **Meter Asset Management**<br>This programme of work includes the following projects:<br>• AGI Meter Enhancement<br>• Orifice Plate Contamination CFD Modelling & Meter Asset Operation | | |
| **Project Engineer** | John Wilson, Richard Lingard, Quentin Mabbutt | | |
| **Description of project** | AGI Meter Enhancement. A pilot demonstration of orifice plate metering installation being upgraded to meet the requirements of ISO5167:2003 and reduce future maintenance costs on a high pressure NTS off take.<br>Orifice Plate Contamination CFD Modelling & Meter Asset Operation. An investigation into the suitability of Computational Fluid Dynamics (CFD) modelling to assist in the assessment of measurement error in orifice plate metering systems where contamination is found. If suitable, the method will be used to assess how maintenance scheduling can be changed to reduce overall costs, while focussing on those metering installations that require cleaning to keep measurement uncertainty within acceptable limits. | | |
| **Expenditure for financial year** | Internal £4k<br>External £22k<br>Total £26k | **Expenditure in previous (IFI) financial years** | £198k |
| **Total project costs**<br>**(collaborative + external + internal)** | £250k | **Projected 2010/11 costs for National Grid** | £0 |
| **Technological area and/or issue addressed by project** | **AGI Meter Enhancement**<br>This project aims to demonstrate that the gas flow metering on high pressure offtakes, which supply Power Stations and large industrial users, can be maintained within required measurement uncertainty limits without significant future maintenance intervention.<br>The improvements that are being demonstrated will comply with ISO5167:2003 (existing installation was ISO5167:1991), bringing the metering into line with industry best practice.<br>The improvements will also allow gas quality and key process data, including record of validation and flow configuration, to be retained and interrogated remotely.<br>**Orifice Plate Contamination Modelling & Meter Asset Operation**<br>This project was commissioned to assess whether the cost of periodic calibrations and maintenance on National Grid Transmission's metering assets could be reduced. Orifice plates in gas metering systems are inspected and calibrated annually. If the effects of orifice plate contamination can be better understood, there | | |

<table>
<tr><td></td><td colspan="4">is potential to reduce the frequency of maintenance relating to these assets, resulting in OPEX savings.<br><br>The latest orifice plate contamination programme using fixed and viscous contaminant has produced a comprehensive data set for future in-service contamination instances. However, there is considerable variation in actual contamination cases, such that for the existing data to be of use, it would be advantageous to be able to use a CFD type modelling technique to assist in the determination of measurement error.<br><br>Some previous reconciliation have been high profile and attracted significant interest from the natural gas metering community. Contaminated orifice plates act as an early warning system for contamination of other downstream meters, which may result in large reconciliations from directly connected customers. If the CFD technique is to have applicability, it will be necessary to calibrate the existing suite of CFD software with the latest experimental data.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>11 to 12</td><td>-2 to 0</td><td>12 to 13</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">AGI Meter Enhancement<br><br>The new metering system will achieve the required (contractual) uncertainty with a significantly lower maintenance frequency (reduction of maintenance cost and associated environmental impact of travel to site) and with less potential for effort-consuming disputes over metering accuracy.<br><br>On the pilot implementation, the total reduction of effort could be more than 300 days/year (although the average for the 27 sites would be quite a bit lower).<br><br>In addition to direct technician call out costs, there could also be reductions in the costs associated with processing data for meter error reconciliations. Each meter error can typically require up to 30 man days effort for data processing and there are around 3 meter errors per year across the 27 high pressure offtake sites.<br><br>Orifice Plate Contamination Modelling & Meter Asset Operation<br><br>The work will enable an informed view of the maintenance cycle. Clear assessment of the bias introduced to metering systems by contamination will allow swift and transparent reconciliation. These errors have a propensity to result in under-registration, so this will lead to cost recovery.<br><br>Following completion of the programme, there is potential to reduce maintenance intervals at National Grid Transmission sites. National Grid Transmission operates 32 sites at present; 25 of these have a six monthly rolling validation cycle. The CFD analysis aims to allow a structured evaluation of sites where the maintenance interval could be extended to an annual visit.</td></tr>
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| | | | |
|---|---|---|---|
| **Expected timescale of project** | Installation completed in May 2010. | **Duration of benefit once achieved** | 12 years (the expected life of the replacement asset installed) |
| **Probability of success** | 60% | **Project NPV = (PV benefits – PV costs) x probability of success** | £168k |
| **Potential for achieving expected benefits** | **AGI Meter Enhancement**<br>The equipment installed has reduced the overall measurement uncertainty at this site. The instrumentation e.g. Differential Pressure and Pressure transmitters should drift less and therefore there is scope to assess whether periods between validation can be extended. This would be done by monitoring validation results and then inputting into calculation package such as Orifunci and using Maximum Permissible Bias and Maximum Permissible Error assessments to track performance of each component of the measurement system. The data logging now being carried out at this site will reduce effort and improve accuracy in the event of a meter error being discovered because key process data is being captured to allow offline flow calculations to be undertaken.<br>**Orifice Plate Contamination Modelling & Meter Asset Operation**<br>TUV-NEL has identified a number of areas where further work could resolve remaining ambiguities. However, the project has produced sufficient information to implement the findings for the majority of cases. | | |
| **Project progress as of March 2010** | **AGI Meter Enhancement**<br>The pilot metering upgrades have been implemented. The new system benefits from improved instrumentation which reduces flow and energy uncertainties considerably, giving the customer and the operator much higher confidence levels that the system operates with 'current' standards and best practice procedures.<br>  <br>Figure 1. New instrumentation to meet the requirements of ISO 5167 | | |

and ISO 5168

The new system also provides additional benefits, such as historical data storage and new, approved validation capability. The new supervisory system allows 18 months of historical data storage to enable the operator to calculate much more accurately the flow and energy usage if there were failure of any of the secondary instrumentation or flow and energy calculations. This is feature is unique for this site and will be implemented to all of the other UKT sites during 2010-12.

Figure 2. New flow computer and supervisory system panel with upgraded flow computer, supervisory system and new gas chromatograph controller, 2350A

**Orifice Plate Contamination Modelling & Meter Asset Operation**

A report has been produced covering the results of the investigation, whereby experimental data from contaminated orifice plate tests conducted by GL Noble Denton was reviewed by TUV-NEL against their CFD modelling and their experience of conducting related experimental work.

The experimental data had covered tests with clean orifice plates, orifice plates contaminated with resin and orifice plates contaminated with grease. The amount of contamination was varied and applied in different ways to the orifice plate (front, back, 50% of surface, 100% of surface).

- For the clean orifice plates, it was noted that the discharge coefficient increased with Reynolds number, contrary to the guidance in ISO 5167:2003.
- For the contaminated orifice plates, it was found that the results were in line with previous work by TUV NEL. However, it was noted that there was a significant level of uncertainty associated with the associated change in discharge coefficient.
- For the grease contamination, it was noted that measurement error was very sensitive to the distribution of grease, particularly where this was close to the edge of the orifice.
- For 50% contamination, the shift in discharge coefficient was

| | |
|---|---|
| | about 50% that for a fully covered plate.<br>• Tests performed at TUV-NEL have shown that the discharge coefficient shift can be negative or positive, depending on the height of contaminant. However, this is not replicated in CFD analysis, as the mechanism involved is not yet fully understood.<br>TUV-NEL identified a number of areas where further work could be considered to resolve ambiguities in some of the data. However, for the moment, National Grid believes it has sufficient information to implement the findings for the majority of cases. |
| **Collaborative partners** | None |
| **R&D provider** | GL Noble Denton<br>TUV-NEL |

## 18. Monitoring/ Advising and Use of Alternative TPI Techniques

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|---|---|---|---|
| **Project title** | **Monitoring/ Advising and Use of Alternative Third Party Interference (TPI) Techniques**<br>This programme of work includes the following projects:<br>• Pipeline Impact Detection System<br>• Automatic Risk-Based Handling of Plant Enquiries<br>• Third Party Surveillance from Pipeline Marker Posts | | |
| **Project Engineer** | Aroon Parmar, Rob Greaves / Phil Brewer, Roger Alexander / Tony Stonehewer | | |
| **Description of projects** | **Pipeline Impact Detection System**<br>Evaluation of the first use of a Threatscan remote-by-satellite pipeline acoustic monitoring system for the detection of third party interference.<br>**Automatic Risk-Based Handling of Plant Enquiries**<br>Development and trial of an automated web-based response service to advise developers of construction restrictions in the vicinity of National Grid energy transmission assets.<br>Phase 2 of this project aims at development of the web based pilot system to provide a fully functional trial run by plant protection team on behalf of Distribution and Transmission for handling all enquires sent to National Grid. Phase 3 will be to develop an external facing web-based trial to receive direct enquiries and provide immediate responses with maps and safety information.<br>**Third Party Surveillance from Pipeline Marker Posts**<br>The project will determine whether it is possible, practical, legal and cost-effective to remotely monitor, using cameras in marker posts, the planned activities of third parties engaged in excavation or construction activity within the agreed exclusion zone around National Grid buried pipeline assets. | | |
| **Expenditure for financial year** | Internal £12k<br>External £8k<br>Total £20k | **Expenditure in previous (IFI) financial years** | £ 392k |
| **Total project costs**<br>**(collaborative + external + internal)** | £1,059k | **Projected 2010/11 costs for National Grid** | £333k |
| **Technological area and/or issue addressed by project** | **Pipeline Impact Detection System**<br>The objective of the project is to examine the feasibility of an impact detection system for transmission pipelines. GE has developed a solution which has been tested on an operational pipeline in the USA and Germany. The impact detection system will be installed on No 7 feeder for trial. | | |

<table>
<tr><td></td><td colspan="4">Automatic Risk-Based Handling of Plant Enquiries<br><br>This project is evaluating whether the risk of third party interference can be reduced by automatic handling of developers' enquiries relating to critical National Grid assets. Such interference can have consequences for security of energy supply, public safety and the environment, together with the associated operational costs and costs from potential prosecution and/or damages claims.<br><br>Interference damage from third party developers, causing a London blackout, is a credible and potentially costly incident. Having a system that gives instant, repeatable, reliable responses to those third parties (including utilities, contractors and local government) involved in development work in the vicinity of National Grid assets should reduce the risk of interference damage.<br><br>Third party interference causing environmental damage is also a credible possibility. Methane released from gas pipelines is 20 times more damaging than carbon dioxide.<br><br>Third Party Surveillance from Pipeline Marker Posts<br><br>A third party, responsible for carrying out civil works in the proximity of a gas transmission pipeline, must contact National Grid to establish the exclusion zone around the pipeline that they must adhere to.<br><br>During third party civil works, a National Grid representative will visit the site every two weeks. However, busier traffic makes these visits increasingly costly to keep up against a backdrop of driving down OPEX. Also, a lot of damage could be done by the third party in the space of two weeks. Therefore the ability to have a quick look at the activity at numerous locations on a daily basis from a central location would provide increased security for the pipeline, potentially at much lower cost.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>6 to 13</td><td>-3 to -6</td><td>6 to 19</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Pipeline Impact Detection System<br><br>Once the system has been installed on No 7 feeder it is hoped that it will enable National Grid to identify location of Third Party plant and equipment working in close proximity to the pipeline without physical impact damage taking place. This will allow National Grid to take proactive precautionary measures to safeguard the system integrity before damage occurs.<br><br>Automatic Risk-Based Handling of Plant Enquiries<br><br>The proposed system is designed to mitigate the risk of third party damage.<br><br>The system will provide comprehensive, accurate and timely asset information and advice based on agreed plant protection rules. Known areas of critical supply and priority/vulnerable customers can be defined in the system and monitored for high-risk works. Notification emails can be triggered to National Grid engineers when enquiries are</td></tr>
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| | received matching criteria setup in the system, such as the examples listed above or when monitoring named users/organisations that may be causing frequent damage or near misses.<br><br>National Grid Transmission Land and Development previously handled plant location enquiries from external organisations on a manual basis, utilising a team of about 7 fulltime employees. With an automated response service in place, this team could focus more time on any exceptions, for example the more difficult enquiries, as well as conducting quality assurance and identifying potential improvements to the automated response service.<br><br>The additional phase 2 and 3 of the project will add further benefits to the EAGLES response system.<br><br>Increased customer focus to ensure that the system is easier to use for enquirers with potential for direct external input and immediate response via web based system. This will generate and encourage take up and use of the EAGLES system and lead to consequential further benefits in safety and reliability for National Grid assets :-<br><br>• Decreased chance of damage to assets<br>• Reduced consequential loss of supply or service<br>• Reduced safety risk for those working in or near assets and general public<br>• Improved efficiencies – Staff able to focus on high risk issues<br>• Immediate benefits of using Linesearch as a portal into this system (72,000 enquiries/month)<br><br>**Third Party Surveillance from Pipeline Marker Posts**<br><br>OPEX reduction, resulting from only having to visit the third party work area if an incursion is detected, rather than once every two weeks. Additional reduction in the risk to the integrity of the asset. | | |
| **Expected timescale of project** | 2-6 years | **Duration of benefit once achieved** | Lifetime of system |
| **Probability of success** | 60 % | **Project NPV = (PV benefits – PV costs) x probability of success** | £249k |
| **Potential for achieving expected benefits** | Over the portfolio there is a good percentage chance that a large proportion of the benefits will succeed. | | |
| **Project progress as of March 2010** | **Pipeline Impact Detection System**<br><br>Equipment was installed at five above ground installations between 24th September 2008 and 23rd January 2009. The system was initialised and data transmission started on 1st February 2009. The equipment on two of the sites is powered by a combination of wind and solar power. | | |

**Instrument cabinet and solar panel installation work**

**Hydrophone installation at one of the sites**

During the last year, the project has been the subject of a number of delays. The reasons included

- Correcting low quality of installation work

- Review of Solar and turbine requirements for each site
- Unreliability of components
- Installation of upgrades by GE
- Concerns over spurious reporting.
- Availability of operational staff to assist GE with remedial work required for each site

During the next financial year, GL will be attempting to complete an independent evaluation of the installed system performance, including a series of controlled impact tests that will demonstrate functionality of the hydrophones and GE's reporting procedure.

**Automatic Risk-Based Handling of Plant Enquiries**

Extract from the Conclusion in the "Risk-Based Automatic Handling of Plant Enquiries Stage Two: Post-Trial Report":-

*"The extended trial has successfully demonstrated that the EAGLES system is able to generate appropriate rules-based responses to the high volumes of plant enquiries received by the National Grid Plant Protection Team."*

The feedback from users of the system has also confirmed the usability of the system. The system has also provided significant support during the merging of the National Grid Plant Protection teams into a single team at Hinckley.

The system is in a good position to drive the National Grid vision of providing a single point of entry for Asset Location enquiries, via the traditional means of post, email and telephone and also via direct self-service access by third parties to a website. The system is also in a position to provide a single repository for all data relating to these Asset Location Enquiries."

Looking forward, the EAGLES system may also provide a platform for National Grid to participate in national initiatives in the field of inter-utility records exchange, and could act as a "client application" servicing pass through enquiries from other portals as well as acting as a portal in its own right.

**Third party surveillance from pipeline marker posts**

The project has covered a review of currently available remote monitoring systems and the associated legal issues of installing cameras for surveillance. The report concluded that a number of options were potentially available, but that site trials should be undertaken to test out functionality, reliability, connectivity and battery life under various conditions before giving consideration to full implementation.

An extension to the project is therefore underway, adapting marker posts to house the preferred monitoring systems, confirming functionality in the lab, and registering a number of field trial surveillance activities with the Information Commissioner's Office. Three systems (one camera phone and two remote camera systems) will each be evaluated at two sites. Up to four different sites will be used during the trials which will take place during 2010/11.

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| **Collaborative partners** | None |
| **R&D providers** | GE Oil & Gas<br>GL Noble Denton<br>National Grid Electricity Transmission |

## 19. New Pipe Materials

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| **Project title** | **New Pipe Materials**<br>This programme of work includes the following projects:<br>• Mechanical Testing of X80 Hot Tap Circumferential Fillet Weld<br>• Pipeline Repairs P11 | | |
| **Project Engineer** | Richard Wilkinson, Rob Bood | | |
| **Description of project** | **Mechanical Testing of X80 Hot Tap Circumferential Fillet Weld**<br>Research into the fracture toughness of the heat affected zones of pipes and fittings on X80 pipeline hot taps.<br>**Pipeline Repairs P11**<br>A numerical study to understand differences in the behaviour of dent defects created in X80 ring test samples, with the behaviour of real dent defects in X80 pipelines. | | |
| **Expenditure for financial year** | Internal £5k<br>External £20k<br>Total £25k | **Expenditure in previous (IFI) financial years** | £33k |
| **Total project costs**<br>**(collaborative + external + internal)** | £62k | **Projected 2010/11 costs for National Grid** | £0 |
| **Technological area and/or issue addressed by project** | **Mechanical Testing of X80 Hot Tap Circumferential Fillet Weld**<br>Some information is available for fusion line toughness of welds made on P460NL1 high strength normalised steel plate using Filarc 27P vertical down electrodes. However, there is no data for fusion line toughness of welds made on grade X80 pipelines using low hydrogen, basic vertical down consumables.<br>A recent hot tap trial for X80 pipelines produced two welds using consumables of this type (See project report for "X80 Hot Tap"). A full mechanical test programme of the welds was therefore undertaken to provide information on the fusion line toughness of X80 'hot tap' welds.<br>**Pipeline Repairs P11**<br>The current recommendation for pipelines constructed from grade X80 linepipe is that any defect that is thought to be, or has been categorised as a smooth dent shall be assessed by an expert in pipeline integrity. This recommendation was based on the results of ring tension tests with smooth dent damage where low failure pressures and/or axial cracking were observed.<br>The test results raised questions over the suitability of the ring tension specimen to define dent acceptance limits for X80 grade pipelines, and the appropriateness of the ring specimen-denting rig | | |

<table>
<tr><td></td><td colspan="4">to introduce dents that suitably represent those in a pipeline.<br><br>The work reported here is aimed at investigating these concerns by assessing the stresses and strains in and around dents of comparable type and depth in ring specimens and pipe sections and quantifying the differences between the two as the ring/pipe diameter and/or wall thickness is varied. The work undertaken is a numerical study, with reference to the experimental results from earlier test programs.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>7 to 11</td><td>-3 to -4</td><td>10 to 15</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Mechanical Testing of X80 Hot Tap Circumferential Fillet Weld<br><br>The results of the testing will provide NG with indicative weld mechanical properties obtained from the X80 ‘hot tap’ welding procedure. This information can be used for analysis of future X80 ‘hot tap’ welds and offer improved confidence in the welding procedure.<br><br>Pipeline Repairs P11<br><br>To demonstrate that X80 grade pipelines are tolerant to a certain amount of dent damage. The work itself will not be sufficient to enable dent acceptance limits to be prescribed and incorporated into the P11 document. It is expected that this will be done via follow on full-scale tests on line-pipe with smooth dent damage and/or a redesign of the ring specimen denting rig to enable ring testing to be undertaken on more realistic dent damage.</td></tr>
<tr><td>Expected timescale of project</td><td>2-4 years</td><td>Duration of benefit once achieved</td><td colspan="2">Duration of time material is in use</td></tr>
<tr><td>Probability of success</td><td>70%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td colspan="2">- £2k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">On target</td></tr>
<tr><td>Project progress as of March 2010</td><td colspan="4">Mechanical Testing of X80 Hot Tap Circumferential Fillet Weld<br><br>The mechanical testing of the X80 ‘hot tap’ weld has been completed and a report has been issued.<br><br>The results were compared with P2 requirements, so they could be quantified. However, it should be noted that P2 requirements do not necessarily apply to ‘hot tap’ welds.<br><br>The key findings of the test programme were:<br>• Low impact values on the pipe’s heat affected zone<br>• High hardness values on the pipe fitting weld toe.</td></tr>
</table>

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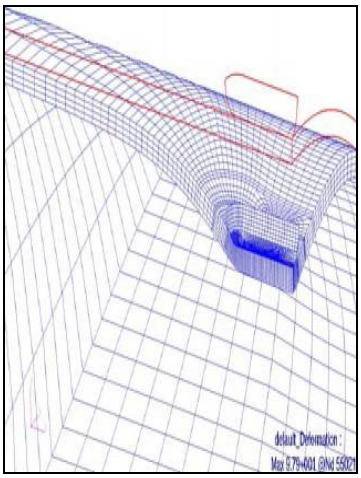
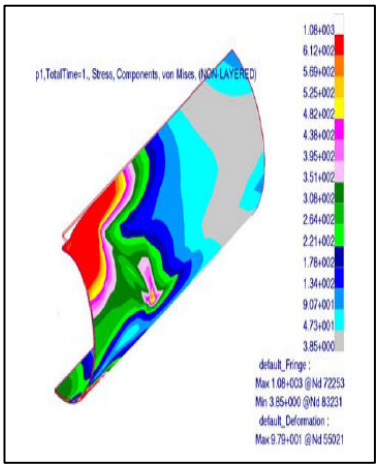
| | The project will now investigate the cause of the low impact results and develop weld procedures to reduce the hardness values.<br><br>**Pipeline Repairs P11**<br><br>A report entitled, “Numerical Study to Compare the Failure Behaviour of Dents in Ring Expansion and Vessel Tests using Grade X80 Linepipe” has been completed.<br><br>The numerical study has shown that the maximum plastic strain experienced in a model of a ring test specimen is greater than that experienced in a model of the corresponding linepipe. This deviation appears to increase with as pipe diameter increases and it also appears to increase with dent depth. The effect of increasing wall thickness in the models was found to be small.<br><br>  <br>  <br><br>**The above figures show modelling of a 5% indentation in a 48” diameter pipe.**<br><br>The potential next steps under consideration as part of another project are:<br><br>• Re-design of the ring specimen denting rig to ensure that the damage introduced for a given dent depth is independent of pipe diameter and more representative of that which would be introduced into a pipe.<br><br>Full scale tests on X80 linepipe to determine the safety margin that is offered by conservative ring test specimen results. |
| **Collaborative partners** | None |
| **R&D provider** | GL Noble Denton |

## 20. Plumley Block Valve Removal

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|---|---|---|---|---|
| **Project title** | Plumley Block Valve Removal | | | |
| **Project Engineer** | Steve Johnstone | | | |
| **Description of project** | Research into factors affecting valve condition within pits. This information will be used as evidence for helping the business to determine valve technical asset lives and updating Maintenance Policy where appropriate. | | | |
| **Expenditure for financial year** | Internal £3k<br>External £145k<br>Total £148k | | **Expenditure in previous (IFI) financial years** | £5k |
| **Total project costs**<br>**(collaborative + external + internal)** | £153k | | **Projected 2010/11 costs for National Grid** | £0 |
| **Technological area and/or issue addressed by project** | An opportunity has arisen to remove a pit-installed, life-expired block valve from service. This will allow further detailed condition analysis on a typical block valve installation, where the output from these findings will provide evidence to the business on Technical Asset Lives for valves installed within pits and where appropriate update Maintenance Policy. | | | |
| **Type(s) of innovation involved** | Significant | **Project Benefits Rating** | **Project Residual Risk** | **Overall Project Score** |
| | | 13 | 1 | 12 |
| **Expected benefits of project** | If an ageing block valve fails closed, it can negatively affect the security of the energy supply. If an ageing block valve fails open, it could significantly increase the severity of a pipeline failure incident. Ageing block valves are also responsible for unplanned emissions of natural gas (including 85-93% methane, which is a greenhouse gas) into the atmosphere.<br>National Grid therefore is considering replacement or repair of these assets, together with methods to prioritise such actions.<br>This project will therefore develop and evaluate prioritisation models and new techniques for conducting repairs, rather than replacing them.<br>Cost to repair this type of asset = £100k<br>Cost to replace this type of asset with new = £200k<br>66 Block valve sites in pits x difference between repair/replace (£100k) = £6.6M potential cost saving. | | | |

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| **Expected timescale of project** | 4 years | **Duration of benefit once achieved** | 20 years – As long as similar valves are in situate in the NTS |
| **Probability of success** | 60% | **Project NPV = (PV benefits – PV costs) x probability of success** | £144,767 |
| **Potential for achieving expected benefits** | Moderate. | | |
| **Project progress as of March 2010** | Several locally-operated ball valves and associated pipework have been removed from a Block Valve installation at Plumley (which formed part of the Pipeline Primary Asset Group) on No.4 Feeder between Holmes Chapel and Warburton. These consist of 1-off 36" ball valve, 2-off 8" ball valves and 3-off 8" plug valves. Their removal provided an opportunity to conduct detailed analysis on the valves' performance and condition after 40 years in service, and to further understand levels of valve deterioration, and their deterioration mechanisms. This study also complemented previous work of a similar nature carried out by GL, reported in GL report 8920 revision 2, and the results from this test programme will be compared to those obtained previously.<br><br>Phase 1 of the programme of work is complete and consisted of the following activities:<br><br>**36" Cort Ball Valve**<br>• Visual inspection of the condition of the valve including ball surface and valve fittings<br>• Review of historical valve operation data<br>• 100 psig pneumatic body cavity test<br>• 153 barg hydrostatic strength test<br>• 135 barg hydrostatic seat test (both sides)<br>• Post test inspection of valve internals and dismantling of valve<br>• Valve seal & spring deterioration testing<br>• Removal of gearbox and visual inspection of gearbox internals<br>• Report<br>**8" Bridle and Associated Valves (5-off)**<br>• Visual inspection of the condition of the valves<br>• End preps and welding of bridle pipework into test vessel as per the original installation configuration<br>• 100 psig pneumatic body cavity tests (ball valves only)<br>• 153 barg hydrostatic strength test | | |

- 135 barg hydrostatic seat tests (ball valves only)
- Series of pneumatic leakage tests (ball valves only)
- Post test inspection of valve internals
- Report

However, a number of planned activities could not be completed for the following reasons:

**36" Cort Valve**

- Ecosolv valve flushing and Valtex sealant injection under pneumatic pressure – as the valve did not pass the strength test it was not possible to conduct the pneumatic testing.
- Series of pneumatic leakage tests following sealant injection (both sides) – as above
- Visual inspection of sealant lines - no sealant lines were present on the valve

**Sealant Lines**

- Select suitable sealant lines for test and fabricate into test vessels – no sealant lines were present on the valves
- Conduct burst tests – as above
- Report – as above

Phase 2 of this work is ongoing and is intended to be in the form of an additional suite of inspections, tests and analyses to the work described above. This will typically include the following activities:

- Radiography of a 1" welded connection on a body vent pipe
- Pipe material analysis of the above
- Clean up of small bore pipework to investigate potential P20 inspections
- Magnetic Particle Inspection (MPI) of welded attachment and arc strikes on 24" dome ends
- Radiography of the 24" girth welds & weldolets
- Wall thickness checks of the 24" sections
- Removal of the bolts from the 8" bypass flanged joints & condition assess
- Several hardness tests, chemical analysis, material identification, Charpy impact and tensile testing on 8", 24" and 36" line pipe and welds.
- Report on the above

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| | **The pictures below show Plumley BV through its stages of removal.**<br>  <br>  |
| **Collaborative partners** | None |
| **R&D provider** | GL Noble Denton |

## 21. Strategic Asset Management (Gas)

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| **Project title** | **Strategic Asset Management (Gas)**<br>This programme of work includes the following projects:<br>• PRCI (Pipeline Research Council International)<br>• EPRG (European Pipeline Research Group)<br>• Supergen V - AMPerES | | |
| **Project Engineer** | Tony Stonehewer, Rob Bood, Jenny Cooper | | |
| **Description of project** | **PRCI**<br>The PRCI facilitates a collaborative R&D programme, funded by contributions, based on the total length of pipelines operated by each member company. Each member company contributes to the projects that most closely address their needs, but all member companies have access to the output of the complete programme.<br>**EPRG**<br>The EPRG undertakes jointly funded pipeline research to mitigate issues and risks associated with the high pressure network. The group also provides opportunities for sharing information on best practice and incidents with other European pipeline operators.<br>**AMPerES**<br>Supergen is an EPSRC strategic partnership programme incorporating a collection of projects across a number of UK academic establishments. This fifth call, Supergen V is entitled Asset Management & Performance of Energy Systems (AMPerES). | | |
| **Expenditure for financial year** | Internal £22k<br>External £106k<br>Total £128k | **Expenditure in previous (IFI) financial years** | £199k |
| **Total project costs**<br>**(collaborative + external + internal)** | £10.5m | **Projected 2010/11 costs for National Grid** | £102k |

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| **Technological area and/or issue addressed by project** | **PRCI**<br>The PRCI aims to conduct a collaboratively-funded research & development programme that enables energy pipeline companies around the world to provide safe, reliable, environmentally compatible, cost-efficient service to meet customer energy requirements.<br>The areas (and research objectives) covered by the PRCI programme launched in 2009 that were supported by National Grid included the following. Also shown for each area is the proportion of National Grid's contribution and the supported research objectives:<br>Corrosion: 10%<br>• Re-inspection intervals for corroded pipelines<br>• Location and evaluation of coating disbondment and shielded coatings<br>Operations & Integrity: 56%<br>• Human factors analysis of pipeline monitoring & control operations<br>• Location and characterisation of corrosion in difficult to inspect areas<br>• Conceptual pipeline integrity & security management<br>Design, Materials and Construction: 9%<br>• Alternate gas products<br>Compressor & Pump Stations: 12%<br>• Gas turbine operating cost reduction<br>Measurement: 14%<br>• Measurement reliability<br>**EPRG**<br>EPRG addresses issues of common interest concerning the technical integrity of gas transmission pipelines, in the areas of pipe manufacture, pipeline design, construction, operation and maintenance.<br>Materials and manufacturing<br>• The measurement and specification of the strength and deformation properties of welded pipes and fittings for onshore and offshore applications.<br>• The measurement, specification and control of fracture initiation and propagation in pipeline components<br>• Pipes and fittings that combine improved combinations of strength, toughness and weldability with economically attractive prices.<br>Corrosion and corrosion protection<br>• The selection and application of pipe steels to achieve satisfactory resistance to internal corrosion by the contained products |

<table>
<tr><td></td><td colspan="4">
<ul>
<li>The properties and performance of corrosion-resistant external coatings for pipelines</li>
<li>The avoidance of environmentally-assisted in-service degradation and crack development</li>
</ul>
Design and operation
<ul>
<li>The assessment of weld defects and establishment of acceptance standards</li>
<li>The tolerance and resistance of pipelines to damage resulting from external mechanical interference,</li>
<li>The accommodation of cyclic pressure loading, and the assessment of defect growth due to fatigue, during pipeline operation</li>
<li>The continued safe use of older pipelines, constructed in accordance with previous-generation specifications and standards</li>
</ul>
For existing pipelines the management and mitigation of the threats of leaks and failures during service, for example due to corrosion, mechanical impact or load cycling of defects, has been a major focus of attention. For new pipelines, effort has historically been directed towards the development of effective materials specifications and performance standards. The project aims to support and utilise the collaborative research done by EPRG to improve asset management.<br><br>
The work of EPRG is managed through a Plenary committee and membership is funded through a membership fee. For 2009/10 additional support is being provided by GL Noble Denton to review the EPRG programme of projects and assess the potential implications and suitability of the intended output for adoption or implementation into National Grid. GL will also develop a work plan that assists National Grid in managing their contribution to this group that will the enable the business to maximise the full intended benefits from the EPRG programme.<br><br>
AMPerES<br><br>
WP 1: Programme delivery, outreach and implementation<br><br>
WP 2: Enhanced network performance and planning<br><br>
WP 3: Adaptable protection and control techniques<br><br>
WP 4: Infrastructure for reducing environmental impact<br><br>
WP 5: Ageing mechanisms<br><br>
WP 6: Condition monitoring techniques
</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental<br>To<br>Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>11</td><td>-2</td><td>13</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">PRCI<br><br>PRCI’s value proposition: “Formal cost / benefit studies of member</td></tr>
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| | participation show a consistently positive ratio of 4:1 to 7:1 from reduced costs of operations and maintenance, inspection, materials, design, construction and testing"<br><br>National Grid Transmission and National Grid Gas Distribution this year used their combined annual contribution of $161k to help launch 15 PRCI projects with a total cost of $2.81m. This provides an average leverage on projects approaching 20:1.<br><br>**EPRG**<br><br>EPRG is an association of European pipe manufacturers and gas transmission companies. EPRG undertakes a wide range of research directed to increase integrity and safety of gas transmission pipelines.<br><br>Benefits are also gained through networking with other pipeline operators. For example, knowledge gained from attendance at EPRG meetings fed into the in-line inspection (pigging) re-tendering contract.<br><br>Adoption of knowledge obtained from completed projects will be implemented into the business as quickly and efficiently as possible, using pro-active support from GL.<br><br>**AMPerES**<br><br>The expected aims of the project are:<br>• To deliver a suite of intelligent diagnostic tools for plant<br>• To provide platform technologies for integrated network planning and asset management<br>• To progress plans to develop and implement improved and reduced environmental impact networks<br><br>To develop models and recommendations for network operation and management | | |
| **Expected timescale of project** | 5 years | **Duration of benefit once achieved** | 5+ years |
| **Probability of success** | 35% | **Project NPV = (PV benefits – PV costs) x probability of success** | £124k |

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| **Potential for achieving expected benefits** | **PRCI**<br>The PRCI collaborative programme gives National Grid the opportunity to benefit from a significant number of highly leveraged projects which compliment much of the work on the overall IFI programme.<br>**EPRG**<br>The EPRG collaborative programme gives National Grid the opportunity to benefit from a large number of leveraged projects which compliment other work on the overall IFI programme. The leverage is typically between 15 and 20:1 (based on value of projects undertaken by EPRG and the total contribution from NG Transmission to EPRG and GL). The European focus of the EPRG dovetails well with the mainly North American focus of the PRCI, with the potential for overlap mitigated against by high level cooperation between the two organisations.<br>**AMPerES**<br>Asset management is core to the business. The appropriate use of the emerging opportunities for condition monitoring is key to optimising performance, both financially and in quality of supply. Some of the technologies being developed in this programme are likely to be utilised, however much more important is the broader window this work gives to the global research community. Through demonstration sites the true value of condition monitoring will be identified, enabling appropriate business decisions on adoption of technologies. |
| **Project progress as of March 2010** | **PRCI**<br>The following National Grid supported projects were launched this year by PRCI:<br>Corrosion:<br>• Detailed Procedures for Comparing Successive ILI Runs to Establish Corrosion Growth (Leverage = 54)<br>• Evaluation of the Current Understanding of External MIC and Gap Analysis (Leverage =18)<br>• Determination of a Recommended Upper Limit to Cathodic Protection for FBE Coatings (Leverage =12)<br>Operations & Integrity:<br>• Influence of Human Factors on Pipeline Damage Prevention (Leverage = 3)<br>• Above Ground Surveys For Difficult to Assess Areas (Leverage = 16)<br>• ECDA in Dynamic Stray Current Areas (Leverage = 9)<br>• Conceptual Pipeline Integrity & Security Mgmt (Leverage = 49)<br>Design, Materials and Construction: |

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| | • $CO_2$ Transmission and Storage - Research Plan Development (Leverage = 7)<br><br>Compressor & Pump Stations:<br><br>• Improve Part-Load Fuel Efficiency of Solar DLN Units (Leverage = 39)<br><br>• Synthetic vs. Std Oils for Gas Turbines (Leverage = 6)<br><br>• Method & Procedure to Remaining Life Assessment of Combustion Turbine Disks (Leverage = 24)<br><br>Measurement:<br><br>• High Pressure Differential Pressure Calibration (Leverage = 18)<br><br>• Performance Verification of Perforated Plate Flow Conditioners Installed Upstream of Multipath Ultrasonic Meters (Leverage = 19)<br><br>• Extended Low Flow Range Metering (Leverage = 21)<br><br>• Performance of Dirty or Worn Flow Conditioners (Leverage = 22)<br><br>Reports were delivered by PRCI during the year for the following National Grid supported projects:<br><br>Projects Launched in 2007<br><br>• Measuring the Effectiveness of Current ROW Monitoring Techniques/Practices (Leverage = 14)<br><br>• Investigate MEMS Technology for Application to Gas/Liquid Quality Measurement (Leverage = 18)<br><br>Projects Launched in 2008<br><br>• Acoustic Source Level and Signature Measurement of Pipeline Scratches and Gouges (Leverage = 7)<br><br>• Model for Predicting the Likelihood and Severity of Newly Created Damage (Leverage = 15)<br><br>• Flow Measurement with Low Differential Pressure (Leverage = 58)<br><br>Projects Launched in 2009<br><br>• Conceptual Pipeline Integrity & Security Management (Leverage = 49)<br><br>**EPRG**<br><br>The current EPRG projects are:<br><br>• (EPRG 124) DWTT Round Robin<br><br>• (EPRG 127) Reliability Based Analysis<br><br>• (EPRG 129) Hostile environmental effects on residual mechanical resistance of damaged pipes<br><br>• (EPRG 130) DWTT Testing philosophy<br><br>• (EPRG 134b) Development of tests for assessment of long term |

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| | resistance to adhesion loss in 3-layer polyolefin external pipeline coatings<br>• (EPRG 137) Assessment of delayed failure under constant pressure<br>• (EPRG 138) Clarification of European view towards inline pipe standards ISO3183/2007 and EN 10208-2<br>• (EPRG 139) Hostile environmental effects on residual mechanical resistance of damaged pipes – supplementary tests<br>• (EPRG 141) Discrimination for mill features using MLF pigs for baseline inspections- Phase 1<br>• (EPRG 142) Model of ultimate limit state design to predict combined loading capacity of line pipes<br>• (EPRG 143) Extension of FFP and puncture resistance criteria to X80<br>• (EPRG 144) Revision of EPRG guidelines on weld defect acceptance criteria<br>• (EPRG 145) Assessment of bending wrinkles<br>• (EPRG 146) Development of a reliable model for evaluating the ductile fracture propagation resistance for high grade steel pipelines<br>• (EPRG 147a) Development of an improved model for the burst strength of dent-gouge damage under sustained internal pressure loading – Phase 2 part 1 – Modelling<br>• (EPRG 147b) Development of an improved model for the burst strength of dent-gouge damage under sustained internal pressure loading – Phase 2 part 2 Experimental<br>• (EPRG 148) Investigation of automated ultrasonic testing concept for longitudinally SAW pipe and coupling control<br>• (EPRG 149) HIC Assessment of low alloy steel line pipe for sour service application Phase 2<br>• (EPRG 150) HIC Assessment of low alloy steel line pipe for sour service application Phase 3<br>• (EPRG 151) Assessment of sensitivity to hostile environments of damaged pipe, under cathodic protection and internal pressure<br>• (EPRG 152) The effect of toughness on the integrity of HFI pipe seam welds<br>Completed reports, issued by EPRG:<br>○ Recommended revisions of the EPRG Tier 2 Guidelines for the assessment of defects in transmission pipeline girth welds [R M Denys, R M Andrews, M Zarea and G Knauf] October 2009<br>○ EPRG approach for ductile crack arrest in gas transmission pipelines [G Knauf and G Demofonti] 2009<br>○ Existing methods to evaluate fracture resistance of high grade steel pipelines [G Demofonti, G Mannucci and P Roovers] |

January 2008

The European Pipeline Research Group - Recent research activities directed towards improved pipeline safety and reliability [G Knauf and R Howard] April 2008

**AMPerES**

Project Progress

This project was originally due to be completed in January 2010. As a result of delays in recruiting PhD students a number of these will continue to be in place until September 2010. In addition some funds, left for contingency have been re-allocated to the Universities to complete some key activities. This was managed through the project Steering Committee.

The renewal bid was submitted to EPSRC in May 2009. The proposal was rejected by EPSRC with no option of resubmission. A number of comments by the reviewers missed the key point; that over £900k of funding for this project would have come from IFI funding. Consequently, a significant portion of the work was intended to increase the impact of the academic work through more applied activity. Options for taking this work forward are still being considered.

Technology & trials:

The project has shown remarkable progress. The use by the universities of real data and real substations for test sites has proved a great catalyst for exchange of information, and a driver for the technologies.

The annual review by EPSRC said:

This project has brought together and created a community of researchers that had previously never worked together before. It has developed a research network of academics and industrialists that has generated five separately funded spin off projects that have pulled in the wider academic community.

Their impact in gas transmission has been specifically in network placing models with different, new energy processes to optimise.

At the annual review held in IET's Austin Court in Birmingham, there were over 70 attendees, including those from academia and the UK utilities. 15 papers were presented in addition to many excellent posters, all of which led to valuable and exciting technical exchanges.

Some particular highlights from the last 12 months include:

System level modelling

- The collaborative work on gas and electricity interaction between Edinburgh, National Grid and Germanischer Lloyd is still progressing. Valuable insights into the differences between assumed and actual intra-daily gas consumption by CCGT stations particularly with regard to wind integration were gained.
- Valuable work on transmission risk and specifically generation adequacy has been completed. It delivered preliminary work on

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| | integrating wind variability and capacity credit into National Grid's planning approaches and featured in the Winter Outlook Report 2009/10. This has been followed up with Chris Dent being seconded to National Grid.<br><br>All publications and reports are available to all the partners from a secure web site: http://www.supergen-amperes.org/ |
| **Collaborative partners** | **PRCI**<br><br>National Grid Gas Distribution (UK) and 34 other companies with energy pipeline interests (23 based in the USA; 5 European; 4 Canadian; 1 South American; 1 Middle-Eastern)<br><br>**EPRG**<br><br>National Grid Gas Distribution (UK) and 16 other companies in 7 different European countries.<br><br>**AMPerES**<br><br>National Grid, Scottish Power, Scottish and Southern, United Utilities, Western Power Distribution, Central Networks, CE Electric, NIE, GL Noble Denton & EDF Energy Networks. |
| **R&D provider** | PRCI uses a selection of Research Contractors, including large, multi-discipline corporations, non-profit institutions, small, pipeline niche firms, major colleges and universities.<br><br>EPRG and GL Noble Denton<br><br>AMPerES: Universities of Manchester, Southampton, Edinburgh, Liverpool, Strathclyde, Queens (Belfast). |

## 22. Research into Valves (Maintenance, Life and Placement)

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| **Project title** | **Research into Valves (Maintenance, Life and Placement)**<br>This programme of work includes the following projects:<br>• Ball Valve Deterioration<br>• Ball Valve Sealant Testing<br>• Pipeline Isolation Philosophy for a SMART Gas Transmission Network | | |
| **Project Engineer** | Steve Johnstone | | |
| **Description of project** | These three projects are looking into the current situation and degradation of the NTS ball valves as well as seeking to improve the efficiency of the network operations and minimising the safety risk presented.<br>**Ball Valve Deterioration**<br>Research to establish the level of deterioration in a second 30" Cort isolation valve, which has experienced higher operating temperature and many more movements over its 17 years of operation than the first valve tested.<br>**Ball Valve Sealant Testing**<br>Research into the chemical properties of a 42" ball valve, with respect to the potential injection of solvents.<br>**Pipeline Isolation Philosophy for a SMART Gas Transmission Network**<br>Feasibility study addressing the potential of developing an isolation philosophy for a SMART gas National Transmission System that maximises the use of new technology and the existing asset footprint, whilst maintaining reliability, minimising safety risk and improving the efficiency of network operation and maintenance.. | | |
| **Expenditure for financial year** | Internal £10k<br>External £73k<br>Total £83k | **Expenditure in previous (IFI) financial years** | £56k |
| **Total project costs**<br>**(collaborative + external + internal)** | £156k | **Projected 2010/11 costs for National Grid** | £17k |
| **Technological area and/or issue addressed by project** | **Ball Valve Deterioration**<br>To develop an understanding of deterioration mechanisms of in-service transmission ball valves.<br>**Ball Valve Sealant Testing**<br>A number of Nuovo Pignone ball valves were removed from service at Aberdeen Compressor Station due to their poor performance in | | |

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<tr><td></td><td colspan="4">terms of pressure containment. An investigation found that the lack of sealant and the inability to inject further sealant was the underlying cause. This project seeks to determine whether old sealant can be removed in situ with the use of solvent, to allow the injection of new sealant.<br><br>Pipeline Isolation Philosophy for a SMART Gas Transmission Network<br><br>The period since the mid-1980's has seen a progressive evolution in the design recommendations for the spacing (positioning, design and installation) of isolation valves on gas transmission pipelines (IGE/TD/1), whereby the recommended separation has increased. However, the latest recommendations set out the factors that should be taken into account, but leaves development of a suitable spacing rationale to the discretion of the responsible engineer.<br><br>The continued drive for operational efficiencies has reduced the number of maintenance teams which would be available to respond to emergencies and attend sites to manually isolate the flow of gas. In the event of an incident, there would be a requirement to reduce gas flows as soon as possible and it is therefore likely that remotely operable valves would be used to isolate the affected pipeline(s). However, these are only currently located at critical points in the network (e.g. multi-junctions, off-takes and compressor stations) and their operation could result in the loss of supply to a large number of Distribution Networks and/or isolation of hundreds of km of pipeline.<br><br>The project will:<br>○ Review IGE/TD/1 recommendations along with other relevant industry documents.<br>○ Document current operational philosophies and the reasons for them<br>○ Develop potential options for revised philosophies<br><br>The project will then use the results of the above to determine the possibility of:<br>○ Using techniques, such as the following, to quantify the impact of changing the philosophy<br>○ Assessing operational benefits from changing the philosophy, including the potential benefits from use of advanced technologies<br><br>Producing a decision support tool that could be used to determine whether each existing isolation point should be converted to remote operation, cocooned or removed.</td></tr>
<tr><td>Type(s) of innovation involved</td><td>Incremental<br>Significant</td><td>Project Benefits Rating<br>6 to 13</td><td>Project Residual Risk<br>0</td><td>Overall Project Score<br>6 to 13</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Ball Valve Deterioration<br><br>Identification and development of asset deterioration measures to</td></tr>
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| | establish the level of current asset deterioration and enable predictions of future deterioration.<br>**Ball Valve Sealant Testing**<br>This investigation, if successful, will result in a procedure that can be used to flush and re-inject sealant into Nuovo Pignone ball valves which will eliminate the need to remove further valves from service.<br>**Pipeline Isolation Philosophy for a SMART Gas Transmission Network**<br>The benefit of this project will be a better appreciation of the potential for adopting and implementing a SMART pipeline isolation philosophy, involving selective modifications to the existing pipeline isolation asset base. For example, a SMART isolation philosophy might reduce the number (and therefore the overall maintenance cost) of isolation block valves that are currently maintained, while introducing advanced technologies (e.g. remote testing to further reduce maintenance costs) to take advantage of the conversion of a number of remaining isolation block valves to be remotely operable (to reduce the impact of emergency block valve closure on the security of supply). | | |
| **Expected timescale of project** | 2-5 years | **Duration of benefit once achieved** | 10 years |
| **Probability of success** | 60% | **Project NPV = (PV benefits – PV costs) x probability of success** | £137k |
| **Potential for achieving expected benefits** | This research is going to advance the knowledge on ball valves and aging. No matter if the life can be extended or not. Also additional techniques have a high probability that they will work as lab results have been promising. | | |

| Project progress as of March 2010 | **Ball Valve Deterioration**<br><br>A second 30” Cort valve for testing had been identified from a number removed from Wormington Compressor Station. Its selection was based on it seeing more movements and being subject to higher in service temperatures during its operational life than the Cort valve tested previously. The valve has undergone a series of pneumatic and hydrostatic strength and leakage tests.<br><br>The valve has been dismantled on one side and the components have been inspected and assessed. The valve seal and springs were sent for specialist assessment to determine the level of degradation of the mechanical properties of the polymer seal and the difference in spring rate compared to new springs.<br><br>A ‘Draft’ report has been issued detailing the test results and comparing them to those from the previous Cort valve investigation.<br><br>  <br><br>30” Cort valve under hydrostatic pressure test |
|---|---|

Dismantling the valve after the hydrostatic pressure test

**Ball Valve Sealant Testing**

Three 42” Nuovo Pignone valves were identified for this trial, including the valve used in the original performance investigation. Samples of residual sealant have been recovered from various locations around the ball along with samples from the sealant injection lines.

These samples have been chemically analysed to identify the type of sealant used originally. They have also been subject to solubility/dispersion tests in solvent to provide an indication of whether or not the old sealant would break down sufficiently to allow fresh sealant to be injected.


The polymeric valve seal has also been subject to solvent compatibility testing to ensure there are no adverse effects to its sealing capability.

The results suggest that the solvent chosen for this trial is suitable for this purpose.

The next stage was to trial the solvent in the three valves to gauge its effectiveness during a full-scale test, and to develop a procedure for use on valves in service.

Image to show hardened valve sealant on the surface of the ball and the distribution of hardened sealant on the inner sealing face of the valve.

A trial has taken place on one of the removed valves, with the results being inconclusive and inconsistent.

Valve being tested

Solvent dispersion

Therefore, further testing is still required to prove that the selected product is fit for purpose for use in this situation. This will also include some level of testing within a 'live' environment for potential valve recovery scenarios.

**Pipeline Isolation Philosophy for a SMART Gas Transmission Network**

An initial survey of information held at Ambergate has been completed. A search of the Institution of Gas Engineers and Managers (IGEM) archives was delayed by their office relocation.

The following photographs show a manually operated block valve installation and a remote operated block valve installation.

Stage 1 - Block valve philosophy

This stage has been completed in 'Draft' for review with the conclusions from the report are that impacts of change to isolation

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| | philosophies can be quantified, the benefits arising from existing block valves can be assessed, and that a decision support tool can be produced in order to determine the optimum action for existing block valves. The recommendations arising from the review include for the development of methodologies for the assessment of existing block valves along with an associated decision support tool.<br><br>Stage 2 – Block valve methodology<br><br>Workshop<br><br>A workshop was held with nominated National Grid engineers to identify generic options for existing block valve sites and the extent of work required at NTS sites of various standard designs e.g. above-ground, below-ground, pits, actuation, bypasses, etc.<br><br>Methodology<br><br>The methodology for assessment of existing block valves, as outlined in Stage 1 are being developed to account for additional options for block valve sites and the latest NTS block valve reliability data. Whereby generic costs will be produced for each option.<br><br>Decision support tool<br><br>A 'Draft' procedure has been developed to use the above methodology in conjunction with appropriate site-specific assessments such that the optimum actions can be decided in a consistent manner for individual block valve sites. The procedure contains algorithms to illustrate the decision making process. |
| **Collaborative partners** | None |
| **R&D provider** | GL Noble Denton |

## 23. Tools for Hazard and Risk Assessment of Major Hazards

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| **Project title** | **Tools for Hazard and Risk Assessment of Major Hazards**<br>This programme of work includes the following projects:<br>• Hydrocarbons [Effects of Higher Hydrocarbon Content on the Safety of Natural Gas Transmission]<br>• Risk Assessment Methodologies for Above-Ground Installations (ORDER)<br>• Transmission Pipeline Risk Assessment Methodologies (PIPESAFE) | | |
| **Project Engineer** | Dave McCollum | | |
| **Description of project** | **Hydrocarbons**<br>Research into the impact that gas with higher hydrocarbon content has on low toughness steel pipelines and other safety risks associated with the gas industry through the development of models and procedures.<br>**ORDER**<br>Research into the management of safety risks on above ground installations. Development of models and procedures through the joint venture 'ORDER' collaboration.<br>**PIPESAFE**<br>Research into the ongoing improvement of risk management software and associated databases for the management of safety risks on gas transmission pipelines. Development of models and procedures through the joint venture 'PIPESAFE Group' and other collaborations. | | |
| **Expenditure for financial year** | Internal £16k<br>External £91k<br>Total £107k | **Expenditure in previous (IFI) financial years** | £62k |
| **Total project costs**<br>**(collaborative + external + internal)** | £473k | **Projected 2011/12 costs for National Grid** | £106k |
| **Technological area and/or issue addressed by project** | **Hydrocarbons**<br>An increasing amount of the natural gas transported by the UK national gas transmission system is coming from non-traditional sources, for example imported LNG. These sources can contain greater proportions of higher order hydrocarbons (methane is classed as the first order hydrocarbon, ethane is second order etc).<br>This project addresses how gas compositions with a greater proportion of higher order hydrocarbons could impact the safety risks associated with gas transmission pipelines. For example, which pipelines could be adversely affected by these gas compositions in terms of ductile fracture propagation? Also, what is the effect on lower flammable limit, safety distances, zoning and thermal radiation levels on safety modelling of pipelines and above ground | | |

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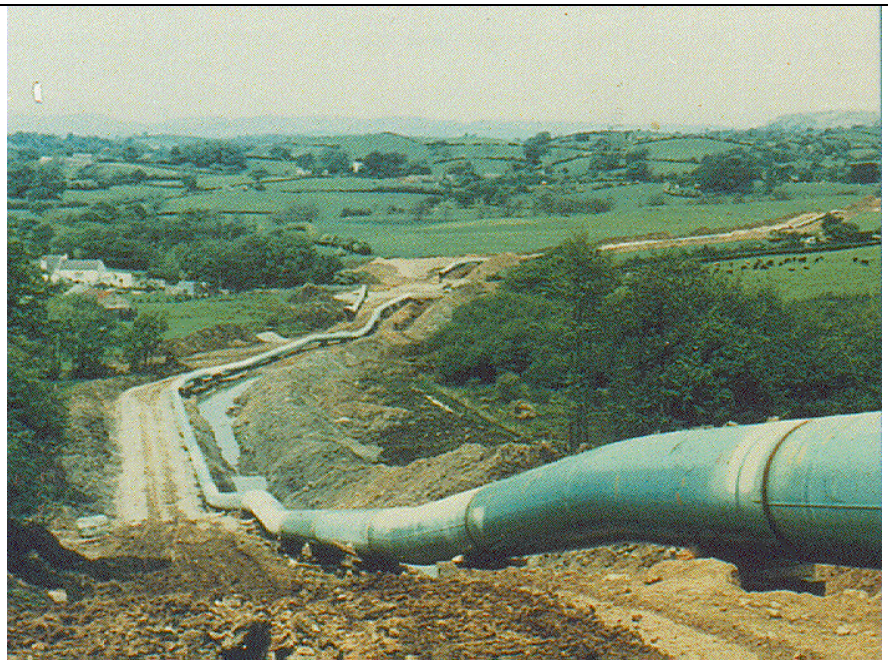
| | facilities?<br>**ORDER**<br>Above-ground installations or AGIs (e.g. compressor stations, terminals, etc.) associated with high pressure natural gas transmission pipelines present potential major hazards (i.e. fires or explosions) in the unlikely event of accidental releases of gas, due to a range of potential causes. Under the Pipeline Safety Regulations and the COMAH Regulations, National Grid is required to manage the risks associated with these assets effectively, and to be able to demonstrate to HSE that risk is managed to a level which is ALARP (As Low As Reasonably Practicable).<br>  <br>**PIPESAFE**<br>High-pressure natural gas transmission pipelines present potential major hazards (i.e. fires) in the unlikely event of accidental releases of gas, due to a range of causes, but particularly accidental interference damage by third parties. Under the Pipeline Safety Regulations, National Grid is required to manage the risks associated with these assets effectively, and to be able to demonstrate to HSE that risk is managed to a level which is ALARP (As Low As Reasonably Practicable). |



| Type(s) of innovation involved | Incremental<br>Significant | Project Benefits Rating | Project Residual Risk | Overall Project Score |
|---|---|---|---|---|
| | | 10 to 12 | 3 to -1 | 7 to 13 |

**Expected benefits of project**

**Hydrocarbons**

To allow National Grid to understand the safety risk implications of transporting gas derived from LNG and to manage the risks appropriately. For example:

- Avoiding long running fractures on failure (a failure situation that is not identified in National Grid's current safety case). Such events could trigger fines of £15m+ and associated costs would be at least as much again.
- Avoiding losses in transportation costs through long repair times and loss of strategic import capability.
- Avoiding reputation damage of not being aware of the impact on National Grid's risk profile for this change in the operating environment.

By knowing which pipelines are potentially affected by the higher hydrocarbon content expected in future sources of natural gas; decisions can be made on the possible installation of crack arresters.

**ORDER**

This project supports National Grid in optimising the safety of new facilities through appropriate layout and design, and in achieving ongoing improvements in the efficiency and effectiveness of the management of risk associated with AGI's on the high-pressure gas transmission pipeline network.

Through collaboration with other gas transmission companies, National Grid is able to participate in, and benefit from, the development of international best practice in risk management, and to share learning from incidents.

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| | **PIPESAFE**<br>This project supports National Grid in achieving ongoing improvements in the efficiency and effectiveness of the management of risk associated with high-pressure gas transmission pipelines.<br>Through collaboration with other gas transmission companies, National Grid is able to participate in, and benefit from, the development of international best practice in risk management, and to share learning from incidents. | | |
| **Expected timescale of project** | 3-10 years | **Duration of benefit once achieved** | 10 years |
| **Probability of success** | 60% | **Project NPV = (PV benefits – PV costs) x probability of success** | £178k |
| **Potential for achieving expected benefits** | **Hydrocarbons**<br>The project has identified 11 pipeline sections on 6 different feeders where there is potential concern. However, a review of the assumptions made about the likely gas compositions suggests that this outcome is over-pessimistic. It is therefore expected that the number of pipeline sections which need mitigating measures will be lower than 11.<br>**ORDER** and **PIPESAFE** are consortiums that National Grid are part of and therefore have a higher potential for achieving the expected benefits due to the number of interested parties willing to assist with the research. | | |
| **Project progress as of March 2010** | **Hydrocarbons**<br>The work on the integrity risks associated with transporting rich gases in the UK transmission pipeline network was presented in two GL Noble Denton Reports 9293 – "Review of the Distribution of Low Toughness Transmission Pipelines", and 9719 – "Battelle Two Curve Analysis of Low Toughness Transmission Pipelines for Rich Gas Operation".<br>After a pause to consider the implications of the findings to-date, a further report is to be commissioned to detail predicted risk-of-fracture propagation in terms of estimated fracture length for a number of pipeline sections. These pipeline sections were highlighted in the above-mentioned reports as being high risk, but there is sufficient uncertainty about the validity of the gas composition assumptions used. Therefore, the further report will take advantage of better predictions of the gas compositions that the pipeline sections will be exposed to.<br>If this study shows that significant fracture propagation is a credible scenario for any of these pipelines it may be necessary to assess the safety risk implications by undertaking site-specific quantified pipeline risk assessments.<br>**ORDER**<br>During this year, the capability was added to COMPCAB to model the risk to congested pipework regions on above ground sites from the explosion of a drifting cloud.<br>Work has also commenced on the development of a generic CFD (computational fluid dynamics) model of National Grid compressor cabs. The purpose is to validate and, if necessary, improve the non-CFD analysis method | | |

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| | in COMPCAB that is used to assess the ventilation dilution of leakage from the process pipework and the gas turbine fuel supply.<br><br>As well as providing funding for the ORDER collaboration, the project is now also contributing to an international collaborative project to derive failure frequencies for use in risk assessments of Above Ground Installations (AGIs). In assessing low risk, high consequence events, it is hugely advantageous to share experience with other companies.<br><br>  <br><br>**PIPESAFE**<br><br>During this period, the project contributed to the PIPESAFE Group collaboration and a collaborative project conducting research into the effectiveness of safety-improving measures for buried pipelines. The project also provided National Grid data on pipeline incidents and populations; installation incidents and populations; and failure frequencies to the collaborative projects.<br><br>An update was made to the HATS (Hazard Assessment of the Transmission System) document, which provides an overview of the risk to the public presented by the population of gas transmission pipelines operated by National Grid. It is updated periodically to reflect changes in the pipelines, residential population and methodologies. The previous update was prepared in 2005, shortly after the Network sales. This latest update reflects changes in the risk assessment methodology (documented in National Grid's Hazard Assessment Methodology Manual last year under this project), as well as changes in pipeline population (e.g. new pipelines such as the Milford Haven pipeline). The study covered the NTS pipelines operated by UKT and the high-pressure pipelines operated by UKD. |
| **Collaborative partners** | Collaborative partners in the ORDER group are GdF Suez (France), Gasunie (Netherlands), Enagas (Spain), Energinet.dk (Denmark), Tokyo Gas (Japan), Osaka Gas (Japan) and Fluxys (Belgium).<br><br>International collaboration of gas companies including (but not limited to) National Grid (UK), Gasunie (Netherlands), Enagas (Spain), Energinet.dk |

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| | (Denmark), Fluxys (Belgium), Statoil (Norway) and TransCanada PipeLines (Canada). |
| **R&D provider** | GL Noble Denton |

## 24. Understanding Ground Condition and Performance

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| **Project title** | **Understanding Ground Condition and Performance**<br>This programme of work includes the following projects:<br>• Geotechnics<br>• Seismic Design Screening Procedure for Pipelines<br>• Assessment of the Potential for Vegetation to Damage Gas Transmission Pipelines | | |
| **Project Engineers** | Alan Hodder / Brian Woodhouse, Tony Stonehewer, Joanne Harris | | |
| **Description of project** | These projects aim to further increase National Grid knowledge of how pipes are effected by seismic events as well as looking at localised issues regarding buried pipes. Reviewing current best practise and improving the design phase of the assets life by taking account of any findings. | | |
| **Expenditure for financial year** | Internal £6k<br>External £63k<br>Total £69k | **Expenditure in previous (IFI) financial years** | £64k |
| **Total project costs**<br>**(collaborative + external + internal)** | £137k | **Projected 2010/11 costs for National Grid** | £0 |
| **Technological area and/or issue addressed by project** | **Geotechnics**<br>The aims of this research and development project were to reduce uncertainty in the evaluation of soil restraint to, and vibration behaviour of, buried pipework and thus improve confidence in the stress analysis of pipework, thereby enhancing safety, supply reliability and cost efficiency in the design and maintenance of the gas transmission pipeline systems. This has been done by:-<br>(i) Reviewing previous corporate recommended practice for the evaluation of static soil restraint parameters used in pipework stress analysis in the light of additional published test data and restraint prediction theories, and<br>(ii) Investigating the response of buried pipework to vibration and developing design guidance to mitigate failure risk, noting previous instances of fatigue failure in small bore “stabbing” connections.<br>The outputs from the project will be used to enhance design guidance for incorporation into company specifications and contract for new-build assets and for the assessment or modification of existing assets.<br>The work included in this project is now complete and the results are under review within National Grid to assess:<br>• Needs for additional work; and | | |

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- Revisions to corporate design/analysis specifications and practice.

**Seismic Design Screening Procedure for Pipelines**

Research into international best practice on designing pipelines and other major infrastructure for earthquake resilience, with respect to the development of a new seismic design screening procedure for use during the preliminary design stage on new pipeline projects.

**Assessment of the Potential for Vegetation to Damage Gas Transmission Pipelines**

National Grid specifies minimum planting distances for different trees and shrubs. However, over time, it is possible for trees and shrubs to seed the pipeline corridor. Maintaining the pipeline corridor free of trees and shrubs is an expensive proposition. Therefore National Grid needs to develop a body of knowledge to determine which tree or shrub species, if any, pose genuine concern to the ongoing integrity of the affected pipelines.

- Identify credible damage mechanisms from the interaction of vegetation with pipelines.
- Undertake a literature review to assess how the potential threat to pipelines would vary with tree type and distance away from the pipeline.
- Determine engineering calculations that could be undertaken to quantify the likelihood of failure for ranges of pipeline diameters, depths of cover, tree type and distance from the pipeline.
- Perform engineering calculations to assess likelihood of pipeline failure via the credible damage mechanisms for ranges of pipeline diameters, depths of cover, tree type and distance from the pipeline.

Produce a report to summarise the findings.

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<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental Tech Transfer<br><br>Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>9 to 12</td><td>3 to -4</td><td>6 to 16</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">

**Geotechnics**

This research has provided:

- Substantial improvements in the ‘confidence level’ in the evaluation of buried pipework soil restraint; and
- Significant data, knowledge and consequent design guidance for the avoidance/reduction of vibration fatigue failures on buried pipework.

The additional data and knowledge gained will directly feed into improved design and analysis practices and hence contribute to enhanced safety, supply reliability and cost efficiency of the high-pressure gas transmission system. Example consequential benefits

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| | include:<br>• Increased scope for pressure up-rating of pipelines, less conservative designs on new pipeline installations, reduced costs of remediation, protection and replacement of steel pipelines. (Where the pipe stress outputs is more favourable than before the project), **or**<br>• Reduction in failure risk (especially from fatigue effects) both from new-build or modification projects and from more reliable prediction of intervention needs and timing on pipelines subject to ground movement and/or defective existing assets. . (Where the pipe stress outputs is less favourable than before the project)<br>• In all cases, the project outputs contribute to the maintenance and continued development of pipeline safety standards to satisfy company requirements and give confidence to others (e.g. HSE, public at large).<br>• The development of design guidance packages to incorporate the knowledge gained into future work will ensure 'consistency' of best practice across the company and thus satisfy a primary HSE concern<br>**Seismic Design Screening Procedure for Pipelines**<br>Ensuring that seismic design measures are only included on new pipeline projects where they can be shown to be reasonably expected. Ensuring that decisions to not include seismic design measures on new pipelines can be easily justified by reference to international best practice.<br>**Assessment of the Potential for Vegetation to Damage Gas Transmission Pipelines**<br>Depending on the outcome of the project, National Grid may be able to save significant OPEX that could be incurred in keeping the gas pipeline corridors of the NTS clear of trees and shrubs.<br>Alternatively, the project results will enable National Grid to prioritise clearing operations in relation to the risk of pipeline damage. | | |
| **Expected timescale of project** | 2-5 years | **Duration of benefit once achieved** | 20 years |
| **Probability of success** | 60% | **Project NPV = (PV benefits – PV costs) x probability of success** | £441k |
| **Potential for achieving expected benefits** | On target to date. | | |
| **Project progress as of March 2010** | **Geotechnics**<br>1) "Static" soil restraint:-<br>Following the literature review completed in January 2007, the | | |

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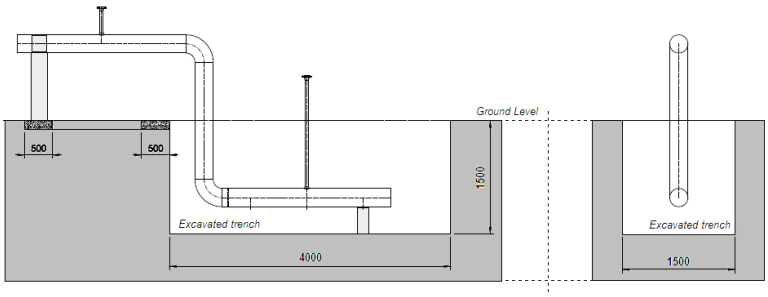
| | collation and analysis of the test data and the comparison with multiple published theories for evaluation of the various soil restraint parameters has now been completed and a "Soil Restraint Calculator" (SRC) spreadsheet has been produced.<br><br>In addition to considering the (approx.) 60 tests carried out in the "Soil Pipe Interaction Collaborative Project" of the 1990s – in which National Grid's predecessor (Lattice / Transco) took part with four other international gas pipeline companies – the study collated all former Gas Corporation, British Gas & BG test results with those from (or referenced by) several other sources, including Kesteren (which contributed significantly to Annex C2 of the Dutch code, NEN 3650), Hyodo, Tohda, Shimamura & Takagi, Trautmann & O'Rrourke, Trautmann, O'Rourke and Kulhawy, Dickin, and the work of Ladanyi & Hoyaux on the 'trap door' problem.<br><br>The comparison of the data with published restraint prediction equations (including the commonly used ASCE/ALA/PRCI and NEN codes and the work of many other authors) clearly demonstrated that significant changes were required to previous National Grid practice (which was essentially as per NEN 3650:1992). For many of the numerous permutations of soil type, movement direction and stiffness component the 'best fit' algorithms developed as a result of the project show a strong similarity to the ASCE/ALA/PRCI "family" of predictions, although for some permutations other proposals give a significantly better fit.<br><br>The project also considered various proposed methods for assessing the contributions of both the trench backfill and 'natural ground' (i.e. trench base and wall) soils to the 'combined' soil restraint parameter required for input into typical pipeline stress analysis software – the ATV 127 method generally yielded the best fit. Improved guidance was also derived for other details relevant to soil restraint evaluation, e.g. soil test data interpretation and the threshold between "general' and 'local' shear failure behaviour (typically at a pipe axis depth to pipe diameter ratio of 3) for lateral pipe movement in loose sand.<br><br>The SRC developed following the above work allows the stiffness, ultimate load and ultimate displacement of soil restraint (to buried pipework) to be readily evaluated in the axial, lateral, downward and uplift direction for both granular and cohesive soils (of varying densities/strength).<br><br>2) Vibration behaviour of buried pipework:-<br><br>Following on from:<br><br>• The review of existing knowledge on dynamic behaviour and soil damping effect of buried pipework;<br><br>• The finite element analysis and numerical analysis work completed last year,<br><br>…an experimental test rig (shown below) was designed and built at the Pipelines Maintenance Centre. The test rig consisted of 300mm diameter, 10.9mm wall thickness main pipework with two attached stabbings (50mm diameter weldolet, pipe and weldoflange constructions). |




Experimental testing on the pipework in both unburied and buried states utilised hammer impacts (from 1,2 and 5.4kg hammers) and a vibration shaker to excite the pipework, thus mimicking both 'impulse' and 'sustained' excitation events over a range of frequencies. Impact tests were applied at the stabbings, at selected points on the main pipework and around the circumference of the pipe at one section. The shaker was used (adjacent to the above-ground bend) in both broadband (random) and swept-sine modes with excitation applied in orthogonal directions in each mode. Response data collection was via accelerometers installed at 14 points along the main pipework and strain gauges installed at the 'roots' of the stabbings. Three accelerometers, placed in the region of the 'buried' stabbing, were tri-axial whilst the remainder were single-axis devices. Modal analysis software (ME'scopeVES) was used to extract the frequency response functions from the measurements for whole body vibration on both the main pipework and the stabbings and for shell modes on the main pipework.

The photograph below shows the test rig during the testing of the pipework in an unburied state with the shaker mounted on the concrete plinth. .

Following a sequence of tests in the unburied state, the main pipe was backfilled (using a sand surround and then selected as-dug material) but with an annulus around the stabbings left open. Repeat

tests were carried, and then the stabbing annulus was backfilled prior to a further round of repeat tests.

As expected, burial of the main pipework restrained its whole body motion (compared to the unburied state) and generally increased damping for all modes, although the observed change in frequency was less marked for similar high frequency modes. Similarly, burial had little effect on the response of the aboveground stabbing. For the belowground stabbing, burial with the annulus open showed either unchanged or reduced levels of damping; subsequent backfilling of the annulus increased damping levels but these were not significantly higher than the unburied condition.

The frequencies of both the aboveground and belowground main pipework shell modes were relatively unaffected by burial; all 'remaining' modes in the belowground section and some in the aboveground pipework exhibited increased damping levels.

Soil damping levels determined in all tests were consistent with commonly published ranges.

The work has given a useful insight into the vibration behaviour of buried pipework and will facilitate improved design and installation practice. Further work may be considered, notably with respect to the effects of (historical) 'soft fill' around below-ground stabbings and the variation in vibration response which may arise as backfill characteristics change over the life of an installation (e.g. due to self-weight consolidation or rainwater percolation).

**Seismic Design Screening Procedure for Pipelines**

The project has delivered a feasibility report, which proposed an outline procedure that could be developed for use during the preliminary design stage of pipeline projects.

The proposed procedure will be able to identify whether seismic design measures are required during the subsequent design stages and it is considered to be in line with the Euro codes and in particular BS PD6698:2009 (Recommendations for the design of structures for earthquake resistance to BS EN 1998).

The procedure requires further development and validation before it can be considered for implementation within NG policy.

The required developments would include:

A GIS dataset of expected intensity at ground surface level (expressed as peak ground acceleration) during a 1 in 2,500 year seismic event.

A refinement of consequence classes for:

- The marginal loss of human life attributable to a pipeline failure during a significant seismic event.
- Economic, social (security of supply) and environmental considerations.

The validation of the proposed procedure could be undertaken by considering past projects (e.g. Brecon/Tirley) or future projects.

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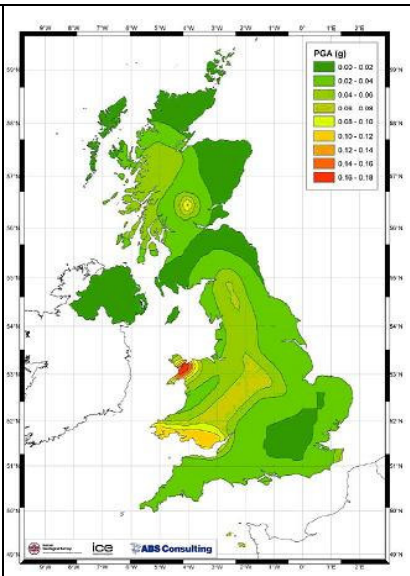
| |  <br>The adjacent diagram is shown, courtesy of BGS, ICE and ABS Consulting. It shows a statistical summary of historical peak ground acceleration (PGA) at the rock head for a 1 in 2500-year seismic event. However, ground surface PGA can be significantly greater than the rock head PGA due to the magnifying effects of soil depth and other topographical features. Therefore the proposed procedure for seismic screening requires the development of a new dataset to illustrate expected ground level PGA variations.<br><br>**Assessment of the Potential for Vegetation to Damage Gas Transmission Pipelines**<br><br>Final report delivered March 2009 and reviewed in May2009.<br><br>The review showed that vegetation growing in the vicinity of gas transmission pipelines does not pose a significant threat to pipeline integrity. There does not appear to be a mechanism whereby the tree roots would damage deeply buried steel gas transmission pipes where the coating is in good condition. Therefore, the project did not go on to undertake generic calculations for damage mechanisms. However, it was recommended that site-specific analysis should be considered on a case-by-case basis, if there were concerns about individual locations. |
| **Collaborative partners** | None |
| **R&D provider** | GL Noble Denton |

## 25. Revision of the Intervals Methodology for Scheduling of Inline Inspections

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| **Project title** | Revision of the Intervals Methodology for Scheduling of In-Line Inspection Frequency | | |
| **Project Engineer** | Jo Harris | | |
| **Description of project** | To demonstrate the feasibility of an alternative methodology that can legitimately be used as an alternative to intervals to optimise inspection frequencies.<br>This project will review the current methodology of In-Line Inspections frequencies it will do this by:<br>• Reviewing the current corrosion model<br>• Develop a new methodology for dealing with this<br>• Also test the sensitivity and run some case studies<br>• Finally producing a feasibility report into changing the current system. | | |
| **Expenditure for financial year** | Internal £16k<br>External £82k<br>Total £95k | **Expenditure in previous (IFI) financial years** | £ 38k |
| **Total project costs**<br>**(collaborative + external + internal)** | £136k | **Projected 2010/11 costs for National Grid** | £0 |
| **Technological area and/or issue addressed by project** | National Grid has historically used the Intervals methodology for scheduling of in-line inspections frequencies. This is no longer appropriate for the business needs. Cost factors had an influence on the model such that the price of inspections and repairs drive the frequencies of inspection.<br>The new methodology determines an optimum inspection frequency taking into account:<br>• Maintenance history and condition data.<br>• Priority of a pipeline on the NTS and the implications of taking it out of service.<br>• The optimum period in order to fix and features without the need for an outage. | | |

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| **Type(s) of innovation involved** | Significant | **Project Benefits Rating** | **Project Residual Risk** | **Overall Project Score** |
| | | 12 | -4 | 16 |
| **Expected benefits of project** | National Grid are not currently satisfying legalisation (PSR 1996 & IGEM TD/1) with regard to pipeline in-line inspection intervals scheduling TD/1 Clause 11.2.4.3 gives a full list of requirements, only some of which are covered by the current methodology. The competent authority has granted dispensation to freeze the cost term. This project will aim to produce an acceptable longer-term solution. This project will also address the Tier 1 Audit Report no. 20175/08/NG (Pipeline Inspection & Repair on sampled pipelines) which identifies that the current approach is not purely risk-based and that the programme used is based on a cost-optimising approach.<br><br>Optimising inspection frequencies should increase asset life by improving the efficiencies of the inspections made. Enabling better management of the assets.<br><br>Pipeline failures could potential lead up to costs of £100M. Pipeline failures also have the potential to cause multiple fatalities as seen in Belgium in 2004 when 15 people were killed. | | | |
| **Expected timescale of project** | 2 years | **Duration of benefit once achieved** | Until a new methodology on pipelines is formed | |
| **Probability of success** | 80% | **Project NPV = (PV benefits – PV costs) x probability of success** | -£127k | |
| **Potential for achieving expected benefits** | Model has been shared with the HSE, the Competent Body under PSSR and with the iDN's/UKD. It is in use for the current outage programme and an implementation plan is currently underway for future years. Although it has increased the inspection frequencies on a number of pipelines, the frequencies are based on risk and condition rather than cost. | | | |
| **Project progress as of March 2010** | Model being taken through to implementation.<br><br>UKD further developing tool through separate IFI initiative for UKD use (some modelling changes required for UKD plant). | | | |
| **Collaborative partners** | None | | | |
| **R&D provider** | Rune via PB (actual work carried out by *PIE)* | | | |