Innovation Funding Incentive Annual Report 2008/09 Section 3

Gas Transmission R&D Programme Detailed Reports

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National Grid Gas Transmission R&D Programme Detailed Report

During the financial year 2007/2008 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

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2 Research into Connections to X80 Grade Pipeline Material
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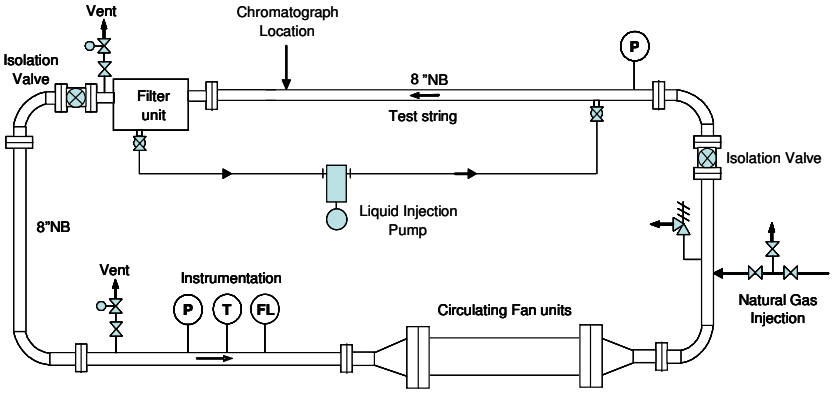
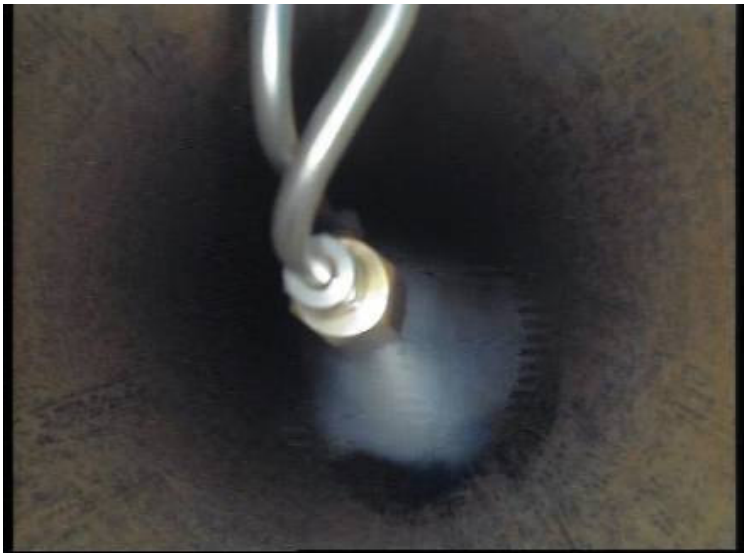
1) **External Contamination Detection and Measurement at Entry Points**

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 liquid 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 £6k External £607k Total **£613k**	Expenditure in previous (IFI) financial years	**£0**
Total project costs (collaborative + external + internal)	**£732k**	Projected 2009/10 costs for National Grid	£124k
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". 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. There are two main suspected mechanisms for liquid contamination: 1. Gas producers may accidentally allow liquids produced by process failures to contaminate the gas. Such liquids are glycols, methanol and gas condensates. 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. The instruments currently used to monitor the gas composition at NTS entry points have the following limitations: a) 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. b) There are no instruments in place to monitor the concentrations of some potential liquid contaminants (glycols and methanol). c) The instruments which monitor higher hydrocarbon concentration and calculate hydrocarbon dew-point 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. The photograph below shows liquid contamination found during the routine pigging of Feeder 1 near Paull.		

<table>
<tr><td></td><td colspan="4">Fig 1 – Liquid contamination in an operational gas pipeline
  </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>16</td><td>0</td><td>16</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">1) Compliance:
As a gas transporter, National Grid is responsible for ensuring that the gas they supply complies with GS(M)R.
2) Financial:
a) If gas supplied directly by National Grid is proved to cause damage to customer's equipment, then National Grid are liable for compensation.
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.
c) Whenever liquid events are discovered, they must be resolved immediately by diverting staff from their usual duties.
3) Knowledge:
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>2 years</td><td>Duration of benefit once achieved</td><td colspan="2">10+ years</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">£1.2m</td></tr>
</table>

Potential for achieving expected benefits	The work up to the end of the year concentrated on establishing and proving the test rig. However, the potential for achieving the expected benefits remains good, due to the number of techniques being evaluated.
Project progress **[Year to End of March 2009]**	A test loop has been built at the Spadeadam Test Site run by GL Industrial Services. A schematic is shown below. Fig 2 – Diagrammatic Representation of Proposed Layout  The test loop is pressurised with natural gas and liquids under investigation are injected via a spray nozzle capable of forming aerosols down to 1µ in size. The photograph below shows the spray nozzle injecting octane into the test loop. Fig 3 – Injection of octane into the test loop 

	The gas conditions inside the loop can be controlled to simulate those found in the NTS; gas pressure up to 100bar and velocity up to 15sm^{3}s^{-1}. The first set of experiments will test the performance of the multi-detector instrument currently installed at NTS entry points. Ultra-sonic meters will also be tested. Preliminary experiments to establish that the test loop and spray nozzle operates as expected are underway. **New Instrumentation:** In the absence of an "off-the shelf" analyser which can analyse gas components in gas, aerosol and liquid form, a project has been set up between GL Industrial Services and IMA Ltd., a supplier of laser based analytical instruments. The modelling of a photon counting Raman spectrometer suitable for detecting the presence of aerosols and the concentrations of gas phase methanol, MEG, TEG and benzene (to identify gas condensate) has been completed. The modelling showed that a very complex scanning spectrometer would be required to detect all four components whilst still in the gas phase, since the concentrations of gaseous TEG are extremely low. A relatively simple dichroic system would be able to analyse for the presence of aerosols in addition to benzene and methanol at gas phase concentrations. The compromise is that MEG and TEG would only be detected at concentrations at which aerosols have already formed.
Collaborative partners	None.
R&D provider	GL Industrial Services (UK) Ltd

2) Research into Connections to X80 Grade Pipeline Material

Project title	• X80 Hot Tap • Mechanical Testing of X80 Hot Tap Circumferential Fillet Weld			
Project Engineer	Richard Wilkinson			
Description of project	This programme area covers two R&D projects. The first project addresses the development of welding procedures for repairs, diversions and connections on X80 pipelines. The second project is research into the fracture toughness of the heat affected zones of pipes and fittings on X80 pipeline hot taps.			
Expenditure for financial year	Internal £10k External £92k Total **£102k**	Expenditure in previous (IFI) financial years	**£158k**	
Total project costs (collaborative + external + internal)	**£267k**	Projected 2009/10 costs for National Grid	£15k	
Technological area and/or issue addressed by project	The first project was commissioned in response to the increasing use of X80 pipelines and the increasing likelihood that National Grid will be required to carry out a 'hot tap' (a connection that is made while the pipeline is in service) on X80 pipe. A 'hot tap' may be required in order to maintain supplies or to connect a third party to the National Transmission System under license condition 4B of the Public Gas Transporters License. The second project was commissioned because there was no data available for fusion line toughness of welds made on grade X80 pipelines using low hydrogen, basic vertical down consumables. The closest information available was for fusion line toughness of welds made on P460NL1 high strength normalised steel plate using Filarc 27P vertical down electrodes. The first project produced two welds using consumables of this type that could be investigated in the second project, which involved a full mechanical test programme of these welds to provide information on the fusion line toughness of X80 'hot tap' welds.			
Type(s) of innovation involved	Incremental	Project Benefits Rating 7 to 9	Project Residual Risk 1 to -3	**Overall Project Score** 8 to 10
Expected benefits of project	The expected benefits of the projects were:- • Ensure all 'under pressure' connections are undertaken in a safe manner. • Ensure National Grid complies with it's obligations under license condition 4B with regards third party connections. • Unless the 'hot tap' welding approach for X80 is validated, shut down of pipelines may be required to facilitate connections. • Ensure compliance with statutory requirements i.e. Pipeline Safety Regulations 1996.			

	• Ensure technical specifications are robust for the full range of pipeline diameters and material grades. Additionally, the results of the second project 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.		
Expected timescale of project	4 years	Duration of benefit once achieved	10 years
Probability of success	80%	Project NPV = (PV benefits – PV costs) x probability of success	£61k
Potential for achieving expected benefits	This area of work is largely complete, although a further piece of work is being commissioned to iron out remaining problems with the material properties following the existing weld procedures.		
Project progress **[Year to End of March 2009]**	Work on the simulated P9 weld and the controlled thermal severity tests (CTS) has been completed. Figure 1 - Simulated P9 Weld at completion  Macro examination and Vickers hardness testing of the welds indicated high hardness values on the fitting side weld toe, although no cracking was observed in the weld. Subsequent impact tests also revealed some low toughness values in the heat affected zone on the X80 pipe. The project has developed viable welding procedures for 'hot tap' welding of X80 pipelines. Recommendations on the update of P9 specification to include welding procedures for X80 were provided. However, it was determined that a further programme of work should be undertaken first to		

	reduce the high hardness values observed, whilst the significance of the isolated low toughness values should also be assessed. This was the purpose of the second project. The second project to undertake mechanical testing of the X80 'hot tap' weld has been completed and a report has been issued. 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. The key findings of the test programme were: • Low impact values on the pipe's heat affected zone • High hardness values on the pipe fitting weld toe. The project will now investigate the cause of the low impact results and develop weld procedures to reduce the hardness values.
Collaborative partners	None
R&D provider	GL Industrial Services (UK) Ltd

3) Effects of Higher Hydrocarbon Content on the Safety of Natural Gas Transmission

Project title	Effects of Higher Hydrocarbon Content on the Safety of Natural Gas Transmission		
Project Engineer	Dave McCollum		
Description of project	Research into the impact that gas with higher hydrocarbon content has on low toughness steel pipelines and other safety risks.		
Expenditure for financial year	Internal £5k External £8k Total **£13k**	Expenditure in previous (IFI) financial years	**£3k**
Total project costs (collaborative + external + internal)	**£16k**	Projected 2009/10 costs for National Grid	£0
Technological area and/or issue addressed by project	An increasing amount of the natural gas transported by the UK national gas transmission system is coming from non-traditional sources, for example imported Liquified Natural Gas (LNG). These sources can contain greater proportions of higher order hydrocarbons (methane is classed as the first order hydrocarbon, ethane is second order etc). 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 facilities?		

Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		10	3	7

Expected benefits of project	To allow National Grid to understand the safety risk implications of transporting gas derived from LNG and to manage the risks appropriately. For example: 1. 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. 2. Avoiding losses in transportation costs through long repair times and loss of strategic import capability. 3. 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).

Expected timescale of project	3 years	Duration of benefit once achieved	5+ years
Probability of success	80%	Project NPV = (PV benefits – PV costs) x probability of success	£140k
Potential for achieving expected benefits	The project is starting to provide the information that National Grid needs to be able to mitigate against the various areas of risk which could be increased by higher concentrations of higher hydrocarbons.		
Project progress **[Year to End of March 2009]**	A methodology for assessing the risks from low toughness pipelines has been developed and applied to assess the risks associated with Feeder 5. The assessed risks for low toughness and normal toughness pipelines have been used to investigate feasibility of using crack arrestors to manage risks on low toughness pipelines. Work is ongoing but work done so far indicates that costs associated with installing crack arrestors would be disproportionate to any risk reduction achieved. The project is scheduled to continue with work to address the other safety risks relating to lower flammable limit, safety distances, zoning and thermal radiation levels and how these affect the safety modelling of pipelines and above ground facilities.		
Collaborative partners	None		
R&D provider	GL Industrial Services (UK) Ltd		

4) Detection & Management of Corrosion

Project title	• Detection & Management of Corrosion on Above Ground Insulated Pipework and Pipe Supports • Above Ground Installation Paint Systems		
Project Engineer	Peter Martin		
Description of project	This programme area consists of two main projects. The first project is looking at new ways to detect corrosion in difficult-to-access locations (under insulation and between a pipe and its supports) and has two main objectives;- 1) A market review of corrosion inspection systems for pipework that does not require the removal of insulation materials or the dismantling of pipework supports. 2) Practical evaluation of the most applicable corrosion inspection system(s), established by the market review. The second project in this programme aims to develop new painting practices for the National Grid Gas Transmission system's above ground installations (AGIs) to minimise the costs of future maintenance painting activities.		
Expenditure for financial year	Internal £9k External £78k Total **£87k**	Expenditure in previous (IFI) financial years	**£0**
Total project costs (collaborative + external + internal)	**£291k**	Projected 2009/10 costs for National Grid	£137k
Technological area and/or issue addressed by project	The issue being addressed by the first 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. 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. It has also become clear to National Grid that unless action is taken to improve the corrosion management of AGI assets, there will be a significant increase in repair/replacement costs and the potential for corrosion related failures. A second project has therefore been instigated on the development of National Grid's painting policy and practices for its above ground installations to minimise the cost of maintenance painting. This objective of the second project will be achieved by two developments: ▪ 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 and will provide temporary protection until the next scheduled maintenance paining		

<table>
<tr><td></td><td colspan="4">programme.

Identification of over-coating paint systems which can be applied to entire sites to extend the life of the existing coating. This will mitigate having to grit-blast pipe work and structures back to bare metal and re-apply a complete paint system.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Tech Transfer</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>10 to 13</td><td>2 to -1</td><td>11</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">It is expected that the first project, will benefit National Grid in a number of ways:
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)
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 future.
3. National Grid can demonstrate to the Certifying Authority (HSE) that they are using the best available technology to improve safety on AGI sites.

It is envisaged that the second project will ensure the integrity of equipment and a pro-active approach to corrosion management which will deliver financial benefits through:
1. Reduced un-scheduled pressure reductions and outages due to corrosion related repairs
2. Reduced repair costs
3. Maximisation of asset life</td></tr>
<tr><td>Expected timescale of project</td><td>3 years</td><td>Duration of benefit once achieved</td><td colspan="2">10+ years</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">£65k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">The projects to detect hidden corrosion and manage the costs of dealing with corrosion are both evaluating a large number of techniques that could be applied. This will improve the chances of finding solutions that work.</td></tr>
</table>

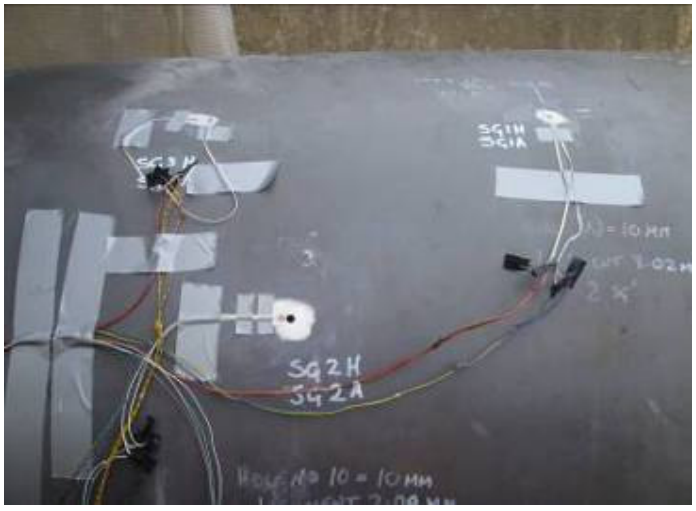
Project progress **[Year to End of March 2009]**	The market review of corrosion inspection systems for the first project has been successfully completed and reported. The study considered a total of 17 inspection techniques that are currently being used by other industry sectors (including offshore and petrochemical) for corrosion detection, where access is difficult. These included the use of thermal imaging to literally detect "hot-spots" of corrosion under the insulation cladding and the use of a circumferential ultrasound scanner system to detect corrosion at pipe supports. Fig 1 - Circumferential ultrasound scanner system  Of the 17 techniques considered, nine 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, will be assessed. The inspection equipment to perform the shortlist of techniques will be 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 will be analysed and, where corrosion is indicated, the pipework will be examined further to confirm whether corrosion is present. A second report will be complied on the results of the site trials. On the second project, 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, and their long term performance in a range of accelerated corrosion tests have all been assessed. The materials will be ranked and suitable systems will be identified for large-scale site application trials.
Collaborative partners	None
R&D provider	GL Industrial Services (UK) Ltd

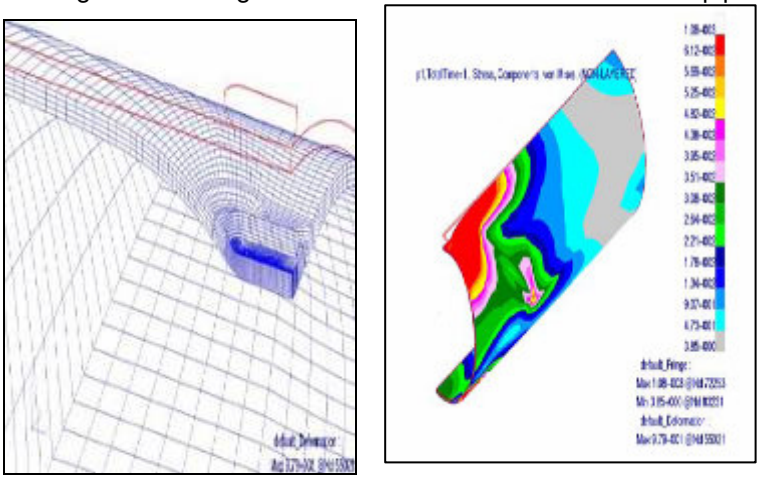
5) Pipeline Fatigue Factors and Pipeline Repair Techniques

Project title	• Line Pipe Integrity (Small Drilled Holes) • Pipeline Repairs P11		
Project Engineer	Rob Bood		
Description of project	This programme of work consists of two main projects. The first project involves the testing of an X80 pipe spool assembly with calibrated part-through-wall drilled holes, simulating malicious damage experienced in the field. The test involved with this project were : • Pressure tests • Pressure cycling fatigue testing • Post-test metallurgical assessment The second project is 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 £8k External £52k Total **£60k**	Expenditure in previous (IFI) financial years	**£4k**
Total project costs (collaborative + external + internal)	**£144k**	Projected 2009/10 costs for National Grid	£79k
Technological area and/or issue addressed by project	The first project is contributing to the assessment of the significance of small drilled part wall holes suffered following an incident of vandalism on a 48 inch diameter X80 pipeline. The second project has been commissioned because 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 could result in a very large cost to assess relatively minor pipe dents that can be common in pipe-laying activity The above recommendation was based on the results of ring tension tests with smooth dent damage where low failure pressures and/or axial cracking were observed. 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 to introduce dents that suitably represent those that occur during the installation of a pipeline. The second project is therefore 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.		

<table>
<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>11 to 15</td><td>2 to -4</td><td>13 to 15</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">For the first project, finite element analysis has previously shown that part wall holes of up to 10mm diameter in a pipeline can extend to leave remaining ligaments of just 1mm and still retain an adequate fatigue life. The full-scale tests undertaken during the first project are intended to validate this conclusion. If the project is successful, National Grid will not have to replace the vandalised section of pipeline.

The second project aims to demonstrate that X80 grade pipelines are tolerant to a certain amount of dent damage, despite the observations from dented ring expansion test specimens suggesting this not to be the case. 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>4 years</td><td>Duration of benefit once achieved</td><td colspan="2">10+ years</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">-£53k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">The fatigue tests undertaken for the first project have shown that drilled holes are unlikely to pose a threat to the integrity of the X80 pipeline. However, further work is required to ensure that the locations of any other similar sabotage can be detected, so that it can be monitored over time. There is also a good chance that the second project has at least demonstrated that the X80 ring specimen denting rig should be re-designed (or allowance made for its over-conservativeness).</td></tr>
</table>

Project progress **[Year to End of March 2009]**	For the first project, a 48 inch diameter test vessel was constructed that contained a total of 24 drilled holes of 3mm, 5mm and 10mm diameter. These drilled holes were situated both internally and externally and were of varying depths. The vessel was subjected to a 24 hour hydrostatic pressure test at 149barg to simulate the commissioning hydrostatic pressure test. The vessel was then subject to a 150,000 cycle fatigue test, cycling between 64barg and 94barg. The vessel completed both tests without any of the drilled holes failing. Following the completion of the above tests, the vessel was sectioned to allow a selection of the drilled holes to undergo metallurgical analysis. Fig 1 - The “drilled holes” test vessel during the tests.  Fig 2 – Selection of external drilled holes on the test vessel. 

	The next stages for the first project will include: • Completion of the metallurgical tests on the post-hydro-test drilled hole sections. • Demonstration that In-Line Inspection vehicles can be tuned to detect these types of drilled holes For the second project, work is nearing completion on a report entitled, "Numerical Study to Compare the Failure Behaviour of Dents in Ring Expansion and Vessel Tests using Grade X80 Line-pipe" 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 line-pipe. 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. Fig 3 - Modelling of a 5% indentation in a 48" diameter pipe  The potential next steps under consideration are: • 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. • Full scale tests on X80 line-pipe to determine the safety margin that is offered by conservative ring test specimen results.
Collaborative partners	None
R&D provider	GL Industrial Services (UK) Ltd

6) Research into the Potential for Vegetation to Damage Transmission Pipelines

Project title	Assessment of the Potential for Vegetation to Damage Gas Transmission Pipelines		
Project Engineer	Joanne Harris		
Description of project	Research the potential effects of trees and other vegetation growing in gas transmission pipeline corridors, in terms of their ability to affect the integrity of the pipeline.		
Expenditure for financial year	Internal £4k External £5k Total **£9k**	Expenditure in previous (IFI) financial years	**£0**
Total project costs (collaborative + external + internal)	**£9k**	Projected 2009/10 costs for National Grid	£0
Technological area and/or issue addressed by project	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 which takes considerable effort. Therefore National Grid needs to understand the impact of vegetation on the pipelines to understand what mechanisms pose genuine concern to the ongoing integrity of the pipeline network. • Identify credible damage mechanisms from the interaction of vegetation with pipelines. • Undertake a review to assess how the potential threat to pipelines are assessed and managed by other pipeline operators. • Undertake a review of failure data to assess if there is evidence of root or other vegetation damage to high pressure pipelines. • Determine if it is appropriate to carry out any form of generic risk assessment where there is evidence of vegetation growth as an alternative to easement clearance. • If appropriate, 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. (Note: it was not deemed to be appropriate to carry out this part of the project) • Produce a report to summarise the findings.		

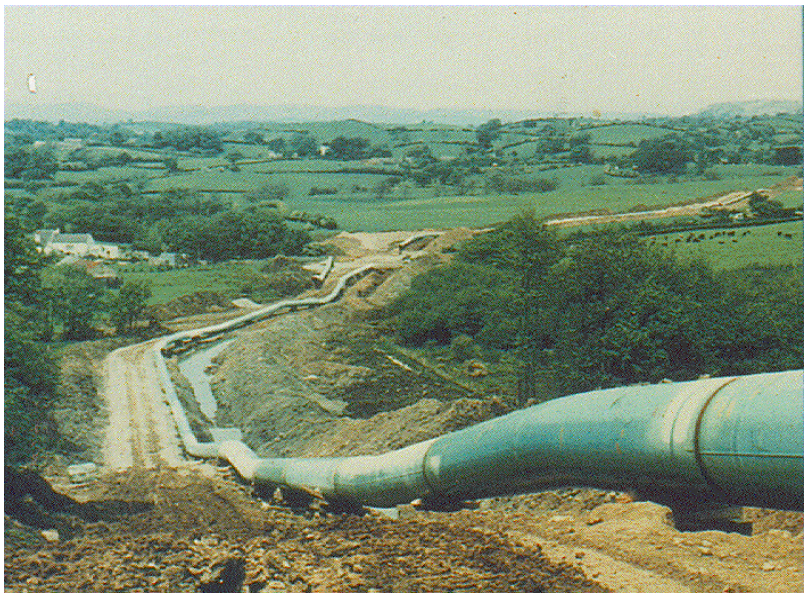
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		12	-4	16

Expected benefits of project	The project will enable National Grid to understand the credible risks and failure mechanisms which vegetation growth can have on the pipeline network. This information will enable National Grid to prioritise clearing operations in relation to the risk of pipeline damage.		
Expected timescale of project	1 year	Duration of benefit once achieved	5+ years
Probability of success	80%	Project NPV = (PV benefits – PV costs) x probability of success	-£9k
Potential for achieving expected benefits	The project has completed and the benefits are being achieved, subject to site-by-site assessment where there were concerns about specific locations.		
Project progress **[Year to End of March 2009]**	Final report delivered March 2009. 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. Fig 1 – A young tree growing directly over a gas pipeline: 		
Collaborative partners	None		
R&D provider	GL Industrial Services (UK) Ltd		

7) Software Tools for Hazard and Risk Assessment of Major Hazard Gas Pipelines

Project title	• ORDER • PIPESAFE		
Project Engineer	Dave McCollum		
Description of project	This programme area consists of two projects. The first project addresses the management of safety risks on above ground installations. This involves the development of models and procedures through the joint venture 'ORDER' collaboration. The second project addresses improvements to software and associated databases for the management of safety risks on gas transmission pipelines. This involves the development of models and procedures through the joint venture 'PIPESAFE Group' collaboration.		
Expenditure for financial year	Internal £18k External £20k Total **£38k**	Expenditure in previous (IFI) financial years	**£74k**
Total project costs (collaborative + external + internal)	**£160k**	Projected 2009/10 costs for National Grid	£47k
Technological area and/or issue addressed by project	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). The first project aims to help National Grid achieve this. Fig 1 – Above ground plant on a NG compressor station 		

<table>
<tr><td></td><td colspan="4">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). The second project aims to help National Grid achieve this.

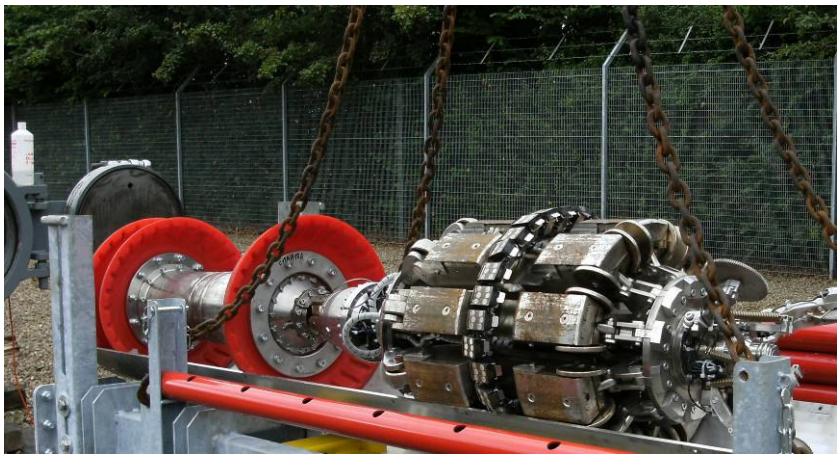
Fig 2 – Gas transmission pipeline under construction
  </td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>9</td><td>0</td><td>9</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">This projects support 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 AGIs on the high pressure gas transmission pipeline network.
• Achieving ongoing improvements in the efficiency and effectiveness of the management of risk associated with high pressure gas transmission pipelines.</td></tr>
<tr><td>Expected timescale of project</td><td>5 years</td><td>Duration of benefit once achieved</td><td colspan="2">10+ years</td></tr>
</table>

Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£54k
Potential for achieving expected benefits	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, with has more opportunity to learn from incidents.		
Project progress **[Year to End of March 2009]**	During this year, software developed as part of the ORDER collaborative project has been taken and developed specifically for National Grid to predict the risks at compressor sites and AGIs. The software has been designed to be easy to use. The procedure for specifying the sites has been simplified in a new user interface. The model automatically selects the correct 'release scenarios' to consider based on a description of the site. Output is produced in the form of a database that can be interrogated by the program to produce pictures and tables of use in reports. The results will be used to develop a full picture of the risks from the transmission system. Supporting research studies undertaken through the ORDER collaboration have enabled the methods for modelling explosions at AGIs to be reviewed and updated guidance issued. This new guidance should allow the ORDER software to be used more easily by a less experienced user. Fig 3 – Effect of a horizontal jet fire on adjacent above ground pipework  A new version of PIPESAFE was developed and issued, incorporating a number of improvements and extensions to the functionality of the software, including the ability to take into account possible weather conditions in more detail and the inclusion of an updated model for predicting pipeline failure frequencies due to third party damage. A number of supporting research activities were also carried out including: • The derivation of a correlation for ignition probability (implemented in PIPESAFE and published at the International Pipeline Conference). • The development of methodology for handling the effect of valves in		

	pipeline risk assessments (to provide guidance for risk assessors using PIPESAFE). • Uncertainty and sensitivity analysis (to provide guidance for risk assessors using PIPESAFE). • Development of a mathematical model to predict the dispersion behaviour of un-ignited pipeline rupture releases (implemented in PIPESAFE). • Initial development of a methodology for handling long-running fractures in low toughness pipelines (ongoing). Review and refinement of modelling of initial highly transient behaviour immediately following a pipeline rupture failure (ongoing).
Collaborative partners	Collaborative partners for the "ORDER" group include (but are not limited to) GDF SUEZ (France), Gasunie (Netherlands), Enagas (Spain), Energinet.dk (Denmark) and Fluxys (Belgium). Collaborative partners for the "PIPESAFE" group include (but not limited to) National Grid (UK), Energinet.dk (Denmark), Enagas (Spain), Fluxys (Belgium), Gasunie (Netherlands), StatoilHydro (Norway) and TransCanada PipeLines (Canada).
R&D provider	GL Industrial Services (UK) Ltd

8) Pipeline Inspection Techniques

Project title	• On-Line Inspection Intervals Review • Revision of the Intervals Methodology for Scheduling of In-Line Inspection			
Project Engineer	Joanne Harris			
Description of project	Trial implementation of new in-line inspection Intervals specification using a number of case studies.			
Expenditure for financial year	Internal £14k External £52k Total **£66k**	Expenditure in previous (IFI) financial years	**£13k**	
Total project costs (collaborative + external + internal)	**£79k**	Projected 2009/10 costs for National Grid	£0	
Technological area and/or issue addressed by project	Research into the current methodology used to determine the inspection intervals for in line inspection of pipelines to ensure that an appropriate risk-based model is used. This stage of the work is designed to look at the practicalities of applying the new model, together with its impact on the maintenance regime.			
Type(s) of innovation involved	Incremental	Project Benefits Rating 9 to 14	Project Residual Risk -2 to -3	**Overall Project Score** 12 to 16
Expected benefits of project	The risk-based model being produced from the intervals project will take into account maintenance history and the performance of the asset. The use of a risk based model may have an impact on the frequencies of some inspections, but will ensure compliance with policy. This stage of the work will prove the validity of the tool and will give an insight into the work required to assess each pipeline using the available data and the new model. It is anticipated that the model can be rolled out across the NTS and possibly UKD.			
Expected timescale of project	3 years	Duration of benefit once achieved	5+ years	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£392k	
Potential for achieving expected benefits	National Grid is confident that the project will now move towards a successful conclusion. The addition of collaborative partners will mitigate some of the remaining risk.			

Project progress **[Year to End of March 2009]**	Results obtained on a trial basis for a number of pipelines showed the following: • The new model is capable of being used for planning the National Grid OLI1 programme on a rational risk/reliability basis, but had a considerable impact on the frequencies of some pipelines. • Most of the data required in order to implement the recommended model was found to be available. Although there were issues when relaying this back to the specification developed in an earlier stage of the project. • Improved record management practices for On Line Inspection data and repairs were recommended in order to implement risk/reliability-based scheduling. This was an area of concern as the project was requested to address the issue of missing historical data. • Future corrosion growth rates were confirmed as a critical parameter in the model. Recommendations were made regarding the suitability of the currently applied distributions to ensure that they continue to provide an accurate reflection of pipe condition. • The model did not provide the flexibility to be able to assess what if scenarios – e.g. what would happen if the CP system was improved? What would happen to the frequencies? This would be a bespoke run overnight by a service provider. A potential conflict of interest arose from GL being the supplier of the new OLI scheduling software, whilst also being the technical authority, responsible for approving the methodology. The project became driven by the requirement to implement a software solution and not to deliver a methodology/model. National Grid therefore decided to seek another supplier in order to gain independence. PB Rune is now working towards the completion of this project. At the end of the year, they had completed a review and description of the existing corrosion model Fig 1 – PIG – Pipeline Inspection Gauge 
Collaborative partners	None yet confirmed, but negotiations are ongoing with Gas Distribution Network operators

R&D provider	GL Industrial Services (UK) Ltd (Project 1) PB Rune (Project 2)

9) Use of Alternative Techniques to Reduce Third Party Interference

Project title	• Automatic Risk-Based Handling of Plant Enquiries • Pipeline Impact Detection System • Aerial Surveillance Studies • Unmanned Aerial Vehicles		
Project Engineer	Phil Brewer, Aroon Parmar and Duncan Hoyle		
Description of project	Third party interference presents one of the most serious risks to the integrity of buried gas pipelines. National Grid has four projects covering this area. The first project is a joint project with National Grid Electricity Transmission and National Grid Gas Distribution to develop and trial an automated web-based response service to advise developers of construction restrictions in the vicinity of National Grid energy transmission assets. The second project is the evaluation of the first use of a Threatscan remote-by-satellite pipeline acoustic monitoring system for the detection of third party interference. The third project is a technology update on pipeline corridor surveillance methods, other than helicopters The fourth project is a joint project with National Grid Electricity Transmission to investigate whether an unmanned aerial vehicle (UAV) is capable of carrying out the same tasks as a manned helicopter. For the gas side of the business, this means observing for third party interference on NTS pipelines and undertaking TD1 surveys.		
Expenditure for financial year	Internal £26k External £52k Total **£78k**	Expenditure in previous (IFI) financial years	**£345k**
Total project costs (collaborative + external + internal)	**£479k**	Projected 2009/10 costs for National Grid	£52k
Technological area and/or issue addressed by project	The first 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. For more information, see Section 45 of the detailed reports for Electricity Transmission. For the second project, the objective 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 National Grid's No 7 feeder for a first-application trial. The third project investigated technologies that could potentially replace or reduce the use of manned helicopter flights. Currently, all gas transmission pipelines are patrolled on a fortnightly basis using a fleet of helicopters and National Grid is concerned about the associated history of fatalities, together with the environmental		

<table>
<tr><td></td><td colspan="4">impact of helicopter flights and the high cost of providing the service.

The fourth project is a more detailed assessment of one of the techniques covered by the third project. Pilot-less surveillance drones would certainly reduce the risk of pilot fatality and environmental impact of aerial surveillance and should also reduce the cost. The questions are whether they would be permitted to fly by air traffic control; and whether they can provide effective surveillance.</td></tr>
<tr><td>Type(s) of innovation involved</td><td>Tech Transfer</td><td>Project Benefits Rating
10 to 13</td><td>Project Residual Risk
1 to -6</td><td>Overall Project Score
9 to 19</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">For the first project, see Section 45 of the detailed reports for Electricity Transmission.

For the second project, once the Threatscan system has been installed on No 7 feeder it will enable National Grid to identify location of 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.

For the third and fourth projects, the potential benefits of this project are to reduce fatalities, environmental impact and cost of Pipeline Surveillance. It may also be possible to improve the safety and security of the gas supply through the gas transmission system by improving the protection from Third Party Interference.

The basis for assessing the cost benefit of viable alternatives is that the cost of providing helicopter surveillance will be around £2m by 2012. This is before considering the value attached to the lives of helicopter crew or the reduction of carbon emissions associated with helicopter flights.</td></tr>
<tr><td>Expected timescale of project</td><td>5 years</td><td>Duration of benefit once achieved</td><td colspan="2">5+ years</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">£930k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">This programme area includes projects which can have impacts at different stages. The first project is moving towards a successful outcome that will be of immediate use. The second project has suffered some delays in commissioning and, as a result, the system has yet to be put through its paces. The other two projects are reviewing the potential for solutions that are still some years away.</td></tr>
<tr><td>Project progress

[Year to End of March 2009]</td><td colspan="4">For the first project, a pilot system is available for a trial evaluation. For more details, see Section 45 of the detailed reports for Electricity Transmission.

For the second project, equipment was installed at five above ground</td></tr>
</table>

installations on Feeder 7 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.

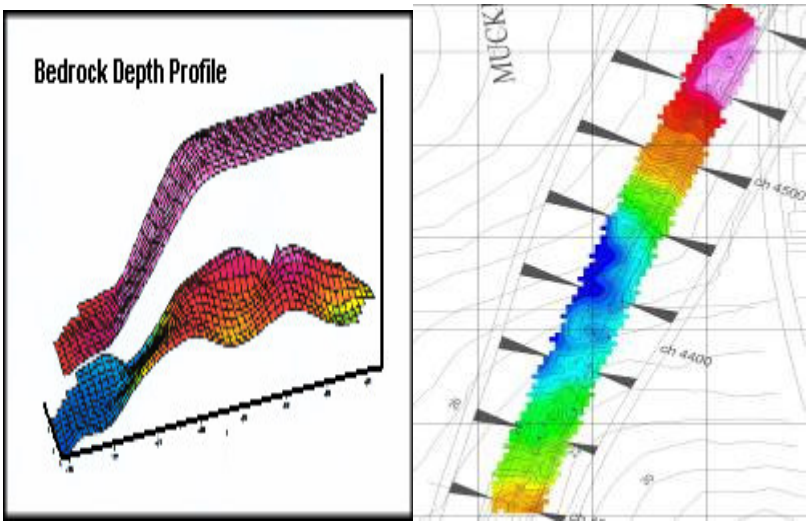
Fig 1 – Instrument cabinet and solar panel installation work

Fig 2 – Hydrophone installation at one of the sites

	The initial set of raw shock detection data has been analysed to give an indication of GE's tuning process. The post-installation tuning process is designed to enable the system to differentiate between potential impacts from general background noise in the vicinity of each hydrophone. The next stage of the work will involve GL undertaking 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. The third project focused on remote sensing technologies but also briefly looked at a couple of impact detection systems. Most impact detection systems would be very expensive to retro-fit and the process of retro-fitting the sensors risks damaging the pipeline. These technologies are therefore more suitable for newly laid pipelines. They would also not report on activities some distance away from the pipeline and also some quiet activities, for example flooding and fires may not be detected at all. For these reasons, impact detection systems would not be able to fully replace the helicopter patrols. Remote sensing technologies are more likely to be a viable alternative to helicopter patrols but it will be at least 5 to 10 years before they are ready. Technical issues surrounding the unmanned aircraft systems will be resolved within the next few years which would allow a UAV to fly some of the pipelines. This is helped by the amount of commercial interest in UAVs at the moment and the high level of development being carried out. However, regulatory issues are likely to take much longer, possibly another decade, before a UAV would be allowed to fly a patrol in un-segregated airspace. High Altitude Platform Systems (HAPS) are also likely to be technically ready to fly in the next few years, providing that development continues as there appears to be a lot less commercial interest in HAPS. Only a small number of organisations are carrying out any development in this area which is primarily military driven. Again, regulatory issues may prevent HAPS from flying above the UK for some time after they are technically ready. Although all of the satellites covered by the study are commercial satellites they also play an important role providing imagery to governments, security services, etc. These activities generally take priority over the type of commercial activity that we are interested in which means that availability could be limited. The resolution of imagery from satellites continues to improve and current high resolution optical satellites easily meet the requirements laid down for detecting third party interference. High-resolution SAR imaging satellites also continue to improve although still falls short of the 0.5 metre image resolution requirements. It will not be until the next generation of satellite sensor technology before all of the requirements can be met for pipeline monitoring.

	The end-to-end service being offered by RapidEye comes very close to meeting the high level requirements for pipeline monitoring. However, RapidEye falls short with its limited 5 metre optical resolution and the fact that it has no SAR capability. There could be value in talking further with operators like RapidEye to help shape their next generation technology. In the meantime their current technology may provide a reasonable alternative to the traditional TD1 aerial surveys. It was concluded that there was not likely to be an alternative to helicopter patrols within the next five years. The fourth project picks up on the likely availability of UAV technology for pipeline surveillance within the next few years. This project is being undertaken by Qinetiq, who are familiar with the military application of UAV systems. Key issues for UAVs on pipeline monitoring applications include the fact that they can currently only fly within the visible range of their operators.
Collaborative partners	National Grid Electricity Transmission (Project 1 & Project 4) National Grid Gas Distribution (Project 1)
R&D provider	GL Industrial Services (UK) Ltd (Projects 1, 2 & 3) Qinetiq (Project 4)

10) Assessment of Ground Conditions on Asset Construction and Performance

Project title	• Combined Geophysical Tool for Pipeline Routing and Risk Assessment • Seismic Design Screening Procedure for Pipelines • Geotechnics (Soil Restraint, Support Modelling & Pipe Strain Criteria for Pipelines and Pipework)
Project Engineer	Matthew Sumerling, Tony Stonehewer, Alan Hodder
Description of project	This programme of work is designed to study how ground conditions can affect the construction of assets and how pipeline assets perform once they have been commissioned. The programme includes three projects. The first project was initiated with the primary objective 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 during the preparation work prior to the construction of a new gas transmission pipeline. It is hoped that the project will demonstrate a cost effective method for providing detailed geological information prior to beginning site works on pipeline construction projects with the objective of establishing the optimum pipeline route. Fig 1 – Examples of the type of data which could be achieved  The second project is 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. The third project is research into soil restraint, support modelling and pipe strain criteria for pipework and installations.

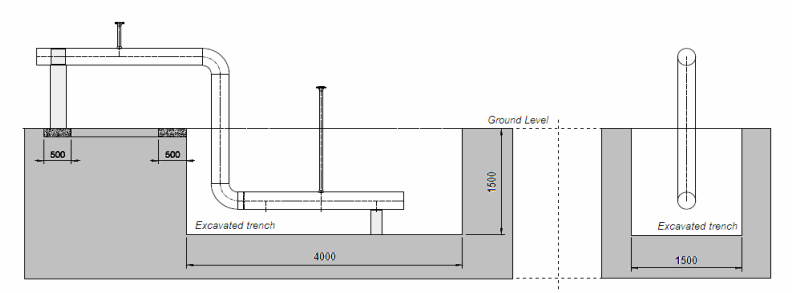
<table>
<tr><td>Expenditure for financial year</td><td>Internal £15k
External £41k
Total £56k</td><td>Expenditure in previous (IFI) financial years</td><td>£3k</td></tr>
<tr><td>Total project costs (collaborative + external + internal)</td><td>£454k</td><td>Projected 2009/10 costs for National Grid</td><td>£352k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="3">The first project addresses how best to combine the multitude of available geophysical survey techniques on one platform meaning that one survey will provide the majority of information required for construction projects. Although multi-sensor platform technologies exist, they have not been used 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.

The second project aims to ensure that seismic design measures are only included on new pipeline projects where they can be shown to be reasonably expected. This will ensure that a decision to not include seismic design measures on a new pipeline can be easily justified by reference to the collated information on international best practice.

The third project aims to develop further understanding of the dynamic behaviour and damping of buried pipework and installations, with regard to the risk of fatigue failure and associated safety hazards. The project has been initiated in response to the requirement to calculate soil restraint properties and validate the effectiveness of buried pipework and installations in reducing vibration to acceptable low levels. The results will be used to provide design guidance for incorporation into all works contracts.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental to Tech Transfer</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>9 to 14</td><td>3 to 0</td><td>6 to 13</td></tr>
<tr><td>Expected benefits of project</td><td colspan="3">For the first project, it is widely recognised that the use of a mobile multi-sensor platform, compared to traditional subsurface survey methods achieve cost savings of 5:1 (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. 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.

For the second project, the expected benefit will be a screening process that will indicate that specific seismic design measures are not required in most cases of high pressure gas transmission pipelines in the UK. This could save the estimated £1m additional</td></tr>
</table>

	cost of specific seismic design measures on a typical new pipeline project. It could also speed up the process of dealing with planning objections relating to seismic concerns. The third project is expected to provide important design guidance for the avoidance of vibration fatigue failures on buried pipelines. This is an important part of the strategy for new builds in particular. The increased knowledge will lead to a greater understanding of buried pipeline and pipe support behaviour for more accurate analysis and a safer high-pressure pipeline system. Consequential benefits include: • Increased scope for pressure up-rating of pipelines • Less conservative designs on new pipeline installations • Reduced costs of assessment and monitoring • Reduced costs of remediation, protection and replacement of steel pipelines • Maintenance of pipeline safety standards to satisfy the HSE		
Expected timescale of project	4 years	Duration of benefit once achieved	5+ years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£1,000k
Potential for achieving expected benefits	The first and second projects are still at an early stage, but are now on track. The third project should conclude during the next year.		
Project progress **[Year to End of March 2009]**	For the first project, lengthy contractual negotiations mean that the project is now due to start in Spring 2009. The progress achieved through 2008/2009 was to scope and assess the benefits of the project and get the necessary contracts in place. For the second project,, an initial review has been undertaken of the following to identify the key documents for a detailed review: o UK Codes, Guidance and Recommendations relating to seismic design. o Most of the recent Brecon-Tirley pipeline project documents, prepared as deliverables for 'seismic analysis specifications' rev 02. o US and Japanese Codes. o UK National seismic hazard map (BGS). o Operational issues. o Permanent ground movements resulting from an earthquake. The third project is a continuation of the review of existing knowledge on dynamic behaviour and soil damping effect of buried pipework, finite element analysis and numerical analysis work that was completed last year. A test rig has been constructed to obtain experimental data. The test rig (sketch below), which has been		

	designed and built at the Pipelines Maintenance Centre, will enable a range of conditions to be tested for main pipework and small bore connections, in the unburied and buried states. Fig 1 – Sketch of test rig  Experimental testing on the pipework in its unburied state has been completed, with a comprehensive set of data collected, measuring the response of the main pipework and two attached stabbings using hammer impacts and a vibration shaker to excite the pipework. The photograph below shows the test rig during the testing of the pipework in unburied state with the shaker mounted on the concrete plinth. Fig 2 – Testing of pipework in the unburied state  The underground section of pipework was then buried and tests to determine the effect of burying on the response of the pipework should be completed by the end of May 2009. A draft report for data analyses on soil restraint calculation has been produced and work is ongoing to incorporate feedback received.
Collaborative partners	None
R&D provider	Zetica (Project 1) GL Industrial Services (UK) Ltd (Projects 2 & 3)

11) Efficient Asset Management

Project title	• Demonstration of VSD Air Compressor Capability to Reduce Energy Consumption on Compressor Stations • Improved Internal Flow Regime for Pipelines		
Project Engineer	Wayne Jackson & Mick Cook		
Description of project	This programme of work aims to improve efficiency and reduce environmental impact of operating assets. To do this, two projects are looking into modification of existing assets and introduction of new technologies into existing assets. The first project is trialling the implementation of new compressed air generation components and evaluating the potential to reduce electrical energy utilisation on National Grid gas compressor stations. The second project is assessing the feasibility of using of a textured surface (sharkskin effect) on the internal surface of gas transmission pipelines. A similar technology has been used to reduce drag on ships, aircraft and even swimwear. It has also been used on the internal surfaces of cardiovascular implants to improve circulation and thereby reduce the potential for clotting. The project will determine whether the technology can be realistically applied to gas transmission pipelines and, if so, the project will quantify the business benefits and associated implications.		
Expenditure for financial year	Internal £15k External £65k Total **£80k**	Expenditure in previous (IFI) financial years	**£0**
Total project costs (collaborative + external + internal)	**£92k**	Projected 2009/10 costs for National Grid	£12k
Technological area and/or issue addressed by project	The first project aims to demonstrate a significant reduction in electricity usage on a compressor station by the system that provides the compressed air supply for pneumatic valve actuators and nitrogen charging for dry gas seals on the gas process compressors. This system typically represents the largest use of electricity on a number of National Grid's compressor stations. At Nether Kellet and other similar sites, the existing selection of air compressors had been made on a lowest capital cost basis. However, these units run continuously, whether or not there is a demand for compressed air. By contrast, it is claimed that Variable Speed Drive (VSD) compressors can be configured to only run when there is a demand for compressed air. Atlas Copco, who provided the original air compressor units at Nether Kellet, also supplies VSD air compressors. Using the same supplier for the replacement units will reduce implementation costs, due to their familiarity with the plant and its connections. The first project will therefore aim to clearly demonstrate the benefits of using variable speed drive (VSD) air compressors on a National Grid compressor station. A potential saving in excess of 60% has been identified if the two existing air compressors are replaced by VSD air compressors. For the second project, it is widely understood that pipeline flow		

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<tr><td></td><td colspan="4">capacity is dependent on gas pressure. Pipe wall friction progressively reduces the gas pressure (and as the gas pressure reduces, the pipe wall friction also 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 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 diameter.

National Grid transmission pipelines are already constructed with an internal epoxy coating that is applied at the pipe mill, mainly for the purpose of corrosion protection between fabrication and construction. The epoxy surface has a lower friction than that of the bare metal. The project therefore needs to demonstrate that the textured surface is a significant improvement on the plain epoxy surface with respect to pipe wall friction. The project also needs to demonstrate that it is possible to fabricate the textured surface without affecting its primary corrosion protection capability.

The potential business benefit of the technology would be enhanced if it can be successfully retrofitted to existing pipelines, as well as being fabricated into new pipe materials.

Other potential areas for future consideration of the textured surface technology would include process compressor impeller vane surfaces (to improve flow efficiency) and gas turbine compressor blades (to reduce fouling).</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Tech Transfer</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>8 to 11</td><td>3 to -4</td><td>5 to 15</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">For the first project, the cost of supply for two new VSD compressors from Atlas Copco (to replace one of two air compressors on each gas compressor unit) is £30,460. The electricity savings for the two VSD compressors (only running when there is a demand for compressed air) are estimated as £33,000 per year, based on 9.5p/kWhr. This will provide a useful step forward towards the company target of 80% carbon footprint reduction by 2050 – and should act as a catalyst for further energy saving suggestions from the site personnel. The VSD compressors should also last significantly longer, because they will be running for a fraction of the time that the existing compressor run (no “unloaded” running), thereby reducing maintenance costs and increasing system reliability.

For the second project, the expected benefit is understanding the potential benefit of the technology and whether it can be realistically applied to gas transmission pipelines, particularly existing ones. 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 and may also have beneficial impacts on Opex.</td></tr>
</table>

Expected timescale of project	2 years	Duration of benefit once achieved	5+ years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£15k
Potential for achieving expected benefits	The first project has achieved a better than expected result, due to the identification of further 10-15% energy savings. The second project is showing that there is a benefit, but it remains to be seen whether it can be achieved as a retrofit to existing pipelines.		
Project progress **[Year to End of March 2009]**	For the first project, the original two GA45 compressor units have been replaced with GA30 VSD compressor units at Nether Kellet. The post installation energy survey demonstrated that the result was within 1% of the projected savings. The following photograph shows one of the newly installed VSD compressor units. Fig 1 – VSD unit installed on the compressor station air system  A few delays were experienced during the installation process, but the associated problems were all overcome. This experience and lessons learnt will be useful in keeping costs down on the subsequent roll-out to other compressor stations. 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:

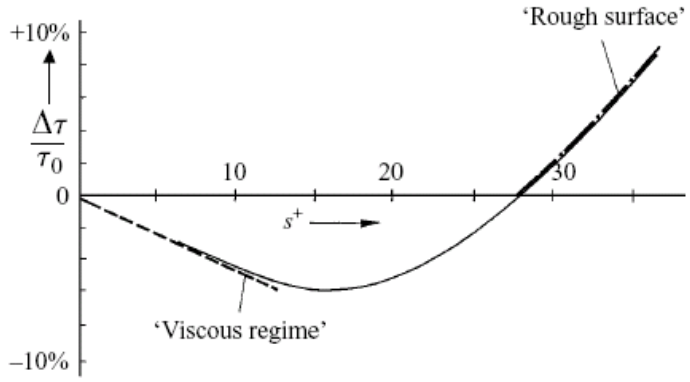
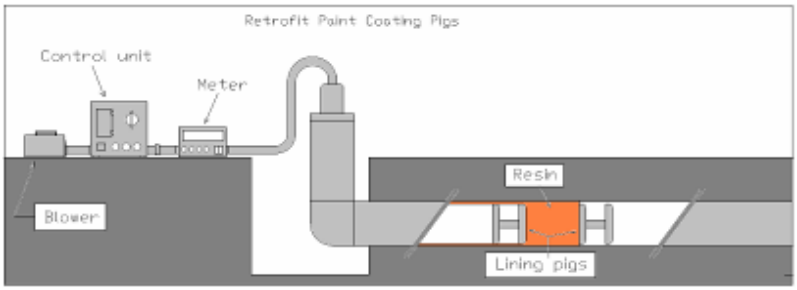
A small amount of effort is required to complete the project, but National Grid are already looking at other compressor stations to see whether the energy savings can be repeated elsewhere.

Fig 2 – Purge control unit installed on the station's air system

For the second of these projects an interim report has been produced on the feasibility of applying an internal textured surface to gas transmission pipelines. The final report is scheduled to be produced for the end of June 2009.

The key findings to date are:

- Although the study is focussing on 36" pipelines, optimum riblet dimensions (height and spacing) are not significantly affected by pipe diameter.
- The optimum "L" riblet height is thought to be of the order of 1mm, with a spacing of about 0.5mm.
- Excessive feature dimensions result in flow reduction, rather than drag reduction.

	Fig 3 – Drag reduction curve  ○ Most prior experience of lining pipelines centres on pre-construction treatments. Exceptions include: ○ Swagelining, which is used in lower pressure domains (permeability and low collapse pressure makes it likely to be unsuitable for gas transmission applications). ○ Epoxy paint pig train processes e.g. www.intracoat.com/cleancoat.asp (e.g. cleaning pig; followed by paint slug between two pigs, the second of which controls the paint depth; followed by a curing pig), which have potential to be adapted for retrofit of internal surface modification Fig 4 – Retrofit coating using a "pig" train  ○ Consideration may be given to the use of a grit/paint mix or "hammerite" paint that will cure to form a surface that is similar to sharkskin riblets. ○ As it may be impractical to internally coat a complete pipeline, consideration should be given to concentrating retrofit to relatively short distances either side of compressor stations, where the effect would be greatest.
Collaborative partners	None
R&D provider	National Grid (Maintenance Delivery (Gas) & Atlas Copco (Project 1) London Offshore Consultants & University of Southampton (Project 2)

12) Compressor Asset Research

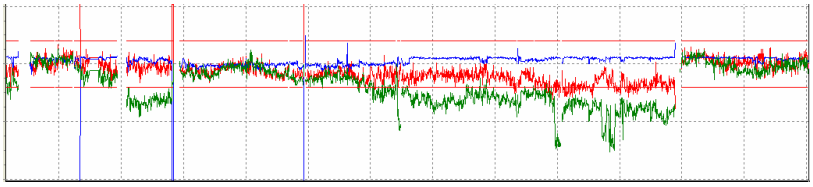
Project title	• Research into Compressor Power and Temperature Limits • IRIS Centrifugal Separator Trial • Ultrasonic Gas Leak Detection in Compressor Cabs		
Project Engineer	Tony Green, Stephen Pickard, Dave McCollum		
Description of project	This area includes three projects focussing on the performance, reliability and safety of compressor plant. The first project is research aimed at improving the understanding of operational limits that are applied to compressor operation, specifically: • The amount of power that is available from gas turbines to drive the process compressors – and how this varies. • The maximum allowable temperature of the compressor station discharge pipework. The second project is an evaluation of a centrifugal separator device to remove liquids from the fuel supply lines to the gas turbine engines, which drive most of National Grid's compressors. The third project is research into the suitability of ultrasonic gas leak detectors in the ventilated enclosures that house gas turbine driven compressors.		
Expenditure for financial year	Internal £23k External £24k Total **£47k**	Expenditure in previous (IFI) financial years	**£55k**
Total project costs (collaborative + external + internal)	**£131k**	Projected 2009/10 costs for National Grid	£29k
Technological area and/or issue addressed by project	The first project will determine: • Realistic maximum power characteristics for each different type of gas turbine used to drive gas compressors on the NTS gas transmission system where, historically, National Grid has relied on information provided by gas turbine suppliers. • The reasoning behind the discharge temperature limits that are set on each of the compressor stations. Such limits can restrict the capacity of the network under some operating conditions, so it is hoped that a better understanding of the reasons behind the limits may provide opportunities to either increase the temperature limits or reduce the process temperature. The second project tackles one of the consequences of liquid contamination, described in Section 1 of the Gas Transmission detailed reports. There is a mandatory requirement from all the Gas Turbine OEM's to provide a clean, dry gas supply system within certain limits and it is hoped that the centrifugal separator device will help National Grid to achieve this when there is liquid contamination in the system. The effect of liquid contamination could be considerable		

<table>
<tr><td></td><td>damage to gas turbine hot gas path components, resulting in loss of efficiency and increased operational, overhaul and repair costs. If the technology can be proven it could also possibly be used for gas treatment on dry gas seal systems, which is another technical problem area

The third project is assessing the potential of using ultrasonic leak detection in compressor cabs to replace traditional gas detectors, which detect the quantity of gas in a gas-air mixture. According to HSE: PM84 guidance, a good ventilation system dilutes small leaks and prevents localised build-up of potentially explosive air-gas mixtures. However, the high ventilation flow rates that are typical in National Grid compressor cabs 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. The project is evaluating whether the effectiveness of ultrasonic detectors is limited by interference from the operation of rotating machinery and other systems in the enclosed operational environment.</td></tr>
<tr><td>Type(s) of innovation involved</td><td>
<table>
<tr><td></td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>Incremental
To
Tech Transfer</td><td>9 to 11</td><td>3 to 0</td><td>7 to 10</td></tr>
</table>
</td></tr>
<tr><td>Expected benefits of project</td><td>For the first project, a better understanding of the power and discharge temperature limitations of compressors will lead to more realistic capital 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.

For the second project, the result is expected to be a cost effective solution to liquid contamination of fuel gas supply systems on gas turbines. It would be an effective alternative to coalescing filters that have proven on recent site builds to be less that effective and are expensive to install/maintain.

For the third project, the expected benefits are:
• Fewer gas detection sensors will be required to provide full coverage for the compressor cab.
• Potential for much smaller gas leaks (<0.1kg/s) to be detected, leading to earlier intervention.
• Reduced maintenance, because there are fewer sensors, they are self-diagnosing and they can be wall-mounted.
• Improved safety of the gas turbine enclosure, while still protecting critical assets from overheating (by decoupling gas detection from cab ventilation).</td></tr>
</table>

Expected timescale of project	3 years	Duration of benefit once achieved	5+ years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£66k
Potential for achieving expected benefits	The first project has so far produced a good level of improved understanding relating to power and temperature limits. The remaining work will determine in particular whether the improved understanding of temperature limits can be exploited. The second project has not started the trial of the equipment yet. The third project continues to provide information to confirm the potential of ultrasonics, the pace of the project has been hampered by difficulties of fitting in the required tests on operational sites.		
Project progress **[Year to End of March 2009]**	For the first project, 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. Fig 1 – Monitoring the power deterioration, resulting from fouling  Research has also 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. Fig 2 – Damage caused by excess temperature 		

A small amount of work remains to complete the temperature limit aspect of the project. This will review the scope to improve compressor station flexibility within the 50˚C temperature limit.

For the second project, delays have been experienced in finalising the trial compressor station. Of the two sites that have been considered to date, Warrington has been undergoing a major control system re-fit; while Moffat has been running substantially less since the new Avonbridge compressor station was commissioned. It is hoped that a trial can be run next year.

For the third project, noise mapping operations have been carried out within two compressor cab designs at two different sites. These were designed to assess the following:

- Whether the ultrasonic noise regime within the running cab environment was low enough to allow the detectors to operate well.
- The number of detectors that would be required to detect a leak occurring anywhere within the cab.
- The smallest leak size detectable with the prevailing background noise

Fig 3 – Ultrasonic detector A (top right) shown in position adjacent to a gas compressor at a National Grid compressor station

Low utilisation of the compressor stations, originally selected for the field work, has led to delays on the project. Meanwhile, there is an increased interest in reviewing alternatives for the other “fire and gas” safety detection systems in compressor cabs, particularly where they are traditionally mounted in the cab ceiling area, which makes maintenance potentially hazardous. Therefore, consideration is being given to broadening the scope of this project to cover all “fire and gas” safety systems in the compressor cab.

	Fig 4 – Ultrasonic detector B (top middle) in position adjacent to a gas turbine at a National Grid compressor station 
Collaborative partners	None
R&D provider	GL Industrial Services (UK) Ltd (Projects 1 & 3) Dresser Rand (Project 2)

13) Research into Valve Life , Maintenance and Replacement

Project title	• Ball Valve Deterioration • Ball Valve Sealant • Plumley Block Valve Removal • Pipeline Isolation Philosophy for a SMART Gas Transmission Network		
Project Engineer	Steve Johnstone		
Description of project	National Grid are undertaking four projects in this area. The first project is 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. The second project is research into the chemical properties of components within a 42" ball valve, with respect to the potential injection of solvents to improve maintenance. The third 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. The fourth project is a 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 £18k External £42k Total **£60k**	Expenditure in previous (IFI) financial years	**£0**
Total project costs (collaborative + external + internal)	**£142k**	Projected 2009/10 costs for National Grid	£82k
Technological area and/or issue addressed by project	The first project aims to develop an understanding of deterioration mechanisms of in-service transmission ball valves. The second project was commissioned in response to a number of Nuovo Pignone ball valves being removed from service at Aberdeen Compressor Station due to their poor performance in 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. The third project has been commissioned when the opportunity arose 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		

<table>
<tr><td></td><td colspan="4">Policy.

The fourth project addresses the fact that 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. 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.</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 16</td><td>2 to 0</td><td>6 to 14</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">For the first project, the expected benefit is identification and development of asset deterioration measures to establish the level of current asset deterioration and enable predictions of future deterioration.

For the second project, if the investigation is successful, the result will be 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.

For the third project, if an ageing block valves fail 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) into the atmosphere. National Grid therefore has to consider replacing or repairing these assets, together with models that could be used to prioritise such actions. This project will therefore develop and evaluate prioritisation models and new techniques for conducting repairs, rather than replacing them.

• Cost to repair this type of asset = £100k
• Cost to replace this type of asset with new = £200k
• 66 Block valve sites in pits times the difference between repair/replace (£100k) = £6.6M potential cost saving.

For the fourth project, the benefit 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</td></tr>
</table>

	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	3 years	Duration of benefit once achieved	10+ years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£407k
Potential for achieving expected benefits	These projects are at varying stages, but are all still on track and expected to deliver the expected benefits.		
Project progress **[Year to End of March 2009]**	For the first project, a second 30" Cort valve for testing has 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. 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. A report has been issued detailing the test results and comparing them to those from the previous Cort valve investigation. Fig 1 – 30" Cort valve under hydrostatic pressure test 		

Fig 2 – Dismantling the valve after the hydrostatic pressure test

For the second project, 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 is 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.

Fig 3 – Hardened valve sealant an the surface of the ball

Fig 4 – Distribution of hardened sealant on the inner sealing face

The third project has been scoped ready for the opportunity to remove a valve early in financial year 202009/10. The picture below shows a valve installation similar to the one being considered for the removal project.

Fig 5 – Example of a pit valve

The fourth project is in the early data-gathering stage. 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.

Fig 6 – An above-ground block valve in southern Scotland

	Fig 7 – A buried block valve in southern Scotland 
Collaborative partners	None
R&D provider	GL Industrial Services (UK) Ltd

14) AGI Meter Modification to Increase Efficiency

Project title	AGI Meter Enhancement and Boiler Capability Study			
Project Engineer	John Wilson & Richard Lingard			
Description of project	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 offtake.			
Expenditure for financial year	Internal £4k External £145k Total **£149k**		Expenditure in previous (IFI) financial years	**£0**
Total project costs (collaborative + external + internal)	**£149k**		Projected 2009/10 costs for National Grid	£0
Technological area and/or issue addressed by project	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. 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. The improvements will also allow gas quality and key process data, including record of validation and flow configuration, to be retained and interrogated remotely.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		11	2	9
Expected benefits of project	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. 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). 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.			
Expected timescale of project	1 year		Duration of benefit once achieved	5+ years

Probability of success	80%	Project NPV = (PV benefits – PV costs) x probability of success	£40k
Potential for achieving expected benefits	The first part of the project has been successfully completed with the installation of the metering enhancements. The situation will be monitored to determine whether the operational expenditure predictions have been achieved. The evaluation into the condition of the AGI pre-heat boiler unit has yet to commence.		
Project progress **[Year to End of March 2009]**	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. Fig 1 – New instrumentation to meet ISO5167 & ISO5168 requirements  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 202009/10/12.		

	Fig 2 – New flow computer and supervisory system panel with upgraded flow computer, supervisory system and new gas chromatograph controller, 2350A 
Collaborative partners	None
R&D provider	GL Industrial Services (UK) Ltd

15) Research into the Effect of Design and External Factors on Metering Assets

Project title	• Orifice Plate Contamination CFD Modelling & Meter Asset Operation • LDZ Installation Effects		
Project Engineer	Quentin Mabbutt, Luke Fieldhouse		
Description of project	This programme area covers two R&D projects. The first project is 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. The second project is research into suitability of CFD modelling to assist in the assessment of flow measurement bias, caused by flow disturbance (swirl and non-laminar flow) that is generated by bends and other fixtures upstream of orifice plates at metering installations. If suitable, the method will be used to assess the implications for all metering installations measuring gas flow out of National Grid Gas Transmission's network (NTS).		
Expenditure for financial year	Internal £8k External £75k Total **£83k**	Expenditure in previous (IFI) financial years	**£0**
Total project costs (collaborative + external + internal)	**£83k**	Projected 2009/10 costs for National Grid	£0
Technological area and/or issue addressed by project	The first 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 is potential to reduce the frequency of maintenance relating to these assets, resulting in OPEX savings. 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. Some previous reconciliations 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		

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<tr><td></td><td colspan="4">existing suite of CFD software with the latest experimental data.

The second project was commissioned to assess whether it is possible to use CFD to predict measurement bias from information on the upstream pipework configurations of the metering installations that measure gas flow out of the NTS.

ISO 5157:2003 sets out the method by which gas flow through orifice plate meters is calculated and the extra uncertainty that needs to be declared when upstream pipe straight length is non-compliant. A previous NEL report identified that there is potential for compliant and non-compliant orifice plate metering installations to under-register or over-register, depending on operating conditions.

This project will therefore use CFD to analyse all the orifice plate installations that measure gas flow from the NTS into one gas distribution network. The particular gas distribution network (or LDZ) was chosen to provide a good level of diversity of metering installations. This would allow the results to be scaled for most of the other NTS metering installations.</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>12</td><td>0 to -1</td><td>12 to 13</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">For the first project, 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 under0-registration, so this will lead to cost recovery.

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.

For the second project, analysis of uncertainty associated with the topology of the pipework upstream of a metering system will be available to inform future designs of gas flow measurement installations. This will enable the design to be optimised, particularly on its footprint, which could be reduced if upstream straight lengths can be reduced below the compliance figure in ISO 5167:2003.

ISO 5167:2003 requires the addition of 0.5% uncertainty to measurements where the upstream length is sub-compliant. However, experimental results show that the result of non-compliant upstream length is a bias, rather than uncertainty. For a “typical” site with a capacity of 1mscm/day at 2p/kWh, a 0.5% uncertainty represents about ±£1k/day, which could be quantified by better understanding of the characteristics of the bias seen in the experimental results. National Grid Transmission have metering systems at 32 exit points where the capacity is between 0.15 and 6.0 Mscm/day.</td></tr>
</table>

Expected timescale of project	1 year	Duration of benefit once achieved	5+ years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£245k
Potential for achieving expected benefits	For the first project, the probability of CFD modelling being able to produce results that resembled the existing experimental data, was estimated as 60%. For the second project, the expectation was high of a successful outcome to the project, based on the experience gained with the supplier on a smaller scale project in 2007-08.		
Project progress **[Year to End of March 2009]**	For the first project: A report has been produced covering the results of the investigation, whereby experimental data from contaminated orifice plate tests conducted by GL Industrial Services (formerly Advantica) 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. • 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. 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. For the second project: A report has been produced covering the results of the investigation,		

	whereby the measurement bias on the seven offtake metering installations were predicted using CFD modelling. The highest bias predicted using CFD modelling was for the one installation that had sub-compliant length of upstream straight pipework (ref ISO 5167:2003), although the presence of a flow straightener could not be determined. However, measurement bias was also predicted for two of the six compliant installations. There were also indications that the magnitude of the bias was affected by which upstream filter was in use, where there was a choice. The report concluded that CFD modelling methods had been used to realistically assess the measurement error for the seven metering installations operating at typical conditions. The results were tested against a range of similar published data to confirm this. It was also concluded that the predicted measurement errors were not strongly related to Reynolds number, such that the results could be inferred for the full operating range of the metering systems. National Grid is now considering implementation of the CFD assessment method across all the other metering systems covering the gas flows into the other LDZs.
Collaborative partners	None
R&D provider	TUV NEL

16) Ensuring Safety on Gas Transmission Sites

Project title	• Fire Protection for Fire Water Mains • Ignition Potential of PDA Devices on Gas Transmission Above Ground Installations		
Project Engineer	Michael Daniel, David Godwin		
Description of project	This area of our portfolio is made up of two projects. The first project is a review of the pipe material options that could be used to mitigate corrosion on buried steel firewater mains, and the factors that might prevent firewater mains being sited above-ground to mitigate corrosion problems. The second project is research into the safety risks for operational staff using standard PDA devices in hazardous areas, where there is a small possibility of an explosive gas-in-air mixture.		
Expenditure for financial year	Internal £10k External £8k Total **£18k**	Expenditure in previous (IFI) financial years	**£0**
Total project costs (collaborative + external + internal)	**£37k**	Projected 2009/10 costs for National Grid	19k
Technological area and/or issue addressed by project	National Grid currently has below-ground steel fire water mains at AGIs, Compressor Stations, Reception Terminals and LNG facilities. 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. The first project will therefore 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: • Flammable and Combustible Liquids Storage • Flammable Liquefied Gases Storage • High Pressure Natural Gas Storage • Storage of Flammable Materials in Containers, Drums and Cylinders The second project will determine whether or not a standard (i.e. not IS certified) portable data apparatus (PDA) devices will be able to be used for routine maintenance work in potentially gas hazardous areas, in conjunction with appropriate and approved operating procedures. The work will involve assessing a specific PDA to determine under what circumstances it could produce a spark/ignition. NG will use the		

<table>
<tr><td></td><td colspan="4">device assessment report to develop a risk assessment and to decide any potential policy impact.</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>9 to 13</td><td>-2 to -3</td><td>12 to 15</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">For the first project, the expected benefits are that it will assist National Grid in identifying the followi9ng for fire water pipework systems:
• The materials that could be used below-ground to mitigate the problems currently being experienced on steel firewater mains.
• Whether an above-ground firewater main would be at any greater risk from Major Accident Hazards than below-ground mains.
• Which materials are appropriate for the construction of above-ground firewater mains
• What precautions should be taken to:
o Prevent freezing of the fire water
o Protect the main and its supports against flame impingement and thermal radiation.
For the second project, the 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 and the development cost would be passed on to National Grid. As NG only expects to purchase around 200 PDA units for Gas Transmission, the cost per unit would be extremely high.
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 specific PDA unit that is being used by NG for maintenance operatives is not currently available as an IS version.
If safe procedures can be developed to utilise the specific PDA device by Gas Transmission maintenance operatives, NG can than benefit from extending favourable terms already negotiated for Electricity Transmission.</td></tr>
<tr><td>Expected timescale of project</td><td>2 years</td><td>Duration of benefit once achieved</td><td colspan="2">5+ years</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">£4k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">Both these projects were at early stage at the end of the year, with</td></tr>
</table>

	nothing yet to suggest that the potential to achieve benefits had reduced.
Project progress **[Year to End of March 2009]**	For the first project, 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 (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 For the second project, the test rig has been prepared for testing of the PDA units, the unit comprises of a $3m^3$ explosion chamber fitted with a blow-off roof panel. In the rear of the chamber an idealised spark generator is fitted to which a PDA battery is attached. The chamber is purged filled remotely with a stoichiometric mix of gas and air and when stable conditions are achieved the idealised spark generator is started to conduct a test. The test arrangement is shown below. Fig 1 – This test rig will be used next year at the start of a series of tests to evaluate the suitability of using the PDA devices on gas transmission sites 
Collaborative partners	None
R&D provider	GL Industrial Services (UK) Ltd

17) Reducing Environmental Impact by Understanding/Reducing Methane Emissions

Project title	• "M5" Emissions • Improving the Integrity of Pig Trap Door Seals • Alternatives to Venting from the NTS		
Project Engineer	Pete Smith , Matt Secombe, Steve Johnstone & Ian Briggs		
Description of project	This programme of work is made up of three projects. The first project is an assessment of techniques to quantify fugitive emissions of methane (in natural gas) from compressor station pipework systems. The second project is conducting research into the integrity management of the elastomer seal and seal housing, with respect to the reduction of fugitive methane emissions to the atmosphere from pig trap door seals. The third project is to study and 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 £13k External £50k Total **£63k**	Expenditure in previous (IFI) financial years	**£53k**
Total project costs (collaborative + external + internal)	**£400k**	Projected 2009/10 costs for National Grid	£260k
Technological area and/or issue addressed by project	For the first project, fugitive leakage from National Grid's National Gas Transmission System (NTS) has been estimated to be of the order of 4000 tonnes per annum. Therefore, National Grid needs to be able to locate and quantify fugitive methane emissions so that the impact on the environment can be managed and mitigated. However, the existing safety-related gas detection systems (fixed point and hand-held gas-in-air concentration sensors) are not appropriate for this. Therefore, this project is evaluating a selection of techniques that could be brought together to conduct effective surveys with. The second project addresses the integrity of the large seals on pig trap doors. Although critical to the integrity of most hydrocarbon containment systems elastomer seals may easily be overlooked. They can fail through mechanisms such as 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, although the leaks may be small enough not to be readily detected, but leading to significant fugitive emissions between inspections. The second project therefore considers the principal types of closure employed on the National Transmission System and, for each of these, examines the typical modes of failure of the seal. Cross-industry failures are also considered. To mitigate the potential for seal failure, controls are investigated in an effort to define good practice in materials selection, maintenance & assurance practices.		

Fig 1 - Pig trap door with Ringlock closure at Paull AGI

The third project addresses the potential to reduce the amount of natural gas (typically 85-93% methane) that is vented to atmosphere by introducing new technologies and operating practices.

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.

- 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.
- Pipeline pressure is typically reduced to 7barg by recompressing it into an adjacent pipeline. However, the last 7barg can not be sensibly recompressed using the available equipment. It is therefore safely vented to atmosphere. Historical trends suggest that in excess of 150,000m^3 of pipework volume is vented to atmosphere in this way each year (about 1000 tonnes of gas).

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:

- Distance between pipeline block valves. These isolation distances are tending to increase and thus lead to increased vented volumes during decommissioning.
- Installation of Booster Units at Pig Trap or Block Valve Sites to enable better management of the decommissioning activities.

To improve the environmental performance of final stages of the decommissioning process several options are available including:

<table>
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Collect the gas and use elsewhere with the network.
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.
Use the gas at the decommissioning site.

</td></tr>
<tr><td>Type(s) of innovation involved</td><td>
<table>
<tr><td rowspan="2">Tech Transfer to Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>15 to 17</td><td>-1 to -2</td><td>17 to 19</td></tr>
</table>
</td></tr>
<tr><td>Expected benefits of project</td><td>
It hoped that the first project will lead to implementation of the techniques being evaluated, which will in-turn lead to a number of benefits, including:-

More complete understanding of methane emissions at compressor sites
Information to target remedial maintenance to reduce emission levels
Quantification of emissions with the aim of providing input into PPC reporting requirements
Development of a historical track record upon which to build an on-going improvement plan.

The expected benefits from the second project will be the transfer of knowledge 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

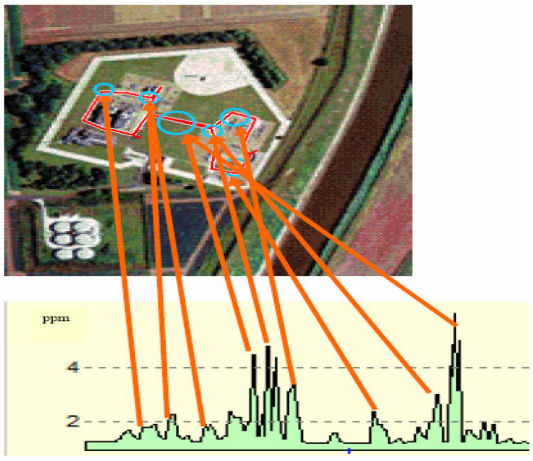
The expected benefits from undertaking the third project are:

Development of new best practice for lowering methane emissions during decommissioning activities prior to maintenance
Reduction in National Grid’s methane emission inventory
Improved energy management

A financial benefit can be derived from consideration of reduced methane emissions. Natural gas emissions are recognised to be twenty times more damaging to the environment, such that methane might be expected to trade at around 25 times the £/tonne figure that CO2 is currently traded at, when methane is added to the European Emissions Trading Scheme.

Planned venting down of gas transmission pipelines for maintenance accounts for about 960 tonnes of methane emissions per year
Operational venting of NTS compressor units during emergency scenarios and for maintenance accounts for more than 1800 tonnes (Advantica Report 6446) of methane emissions per year
If the gas can be captured and stored, it could be used to fuel generators to provide 5kWe / tonne of gas

</td></tr>
</table>

Expected timescale of project	4 years	Duration of benefit once achieved	5+ years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£1,000k
Potential for achieving expected benefits	The first project is complete and has demonstrated that a combination of techniques can be used to develop a detailed fingerprint of methane emissions. For the second project, an increasing number of known failures on pig trap door seals is highlighting the importance of developing improvements, but the project is still in its early stages. The third project has only just started.		
Project progress **[Year to End of March 2009]**	For the first project, pilot emissions surveys have now been completed at four compressor sites to demonstrate the effectiveness of new techniques. The results from the surveys include • "Emissions fingerprint" using mobile monitoring and GPS to identify main sources of emission. Portable meteorological data is also taken to use wind speed and direction to assist in pin-pointing sources of emission. • Site perimeter surveys to establish ground level emissions and quantify methane levels to determine if site emission affect by emissions from an external source. Also, this enables an "over-the-fence" estimate of emissions from the site impacting on the local environment. • High-flow sampling results using proprietary equipment to quantify leakage from accessible site gas infrastructure. The data produced by the trial surveys enabled an estimate of the overall site methane leakage to be established. An example of the "emissions fingerprint" approach is shown in the cluster diagram below. Fig 2 – Fugitive emissions fingerprint of a compressor station 		

Plans have been developed for the survey techniques to be implemented on surveys of all other compressor sites around the UK.

For the second project, an assessment has been completed and a report is in preparation. 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. Analysis of the data enabled trends to be determined and a definition for good practice to be formulated. A list of recommendations will be produced to enable the findings of the project to be readily implemented. Each recommendation is graded to allow prioritisation.

Fig 3 - Close-up of failed Ringlock seal (courtesy of GD Engineering)

The third project was fully scoped and sanctioned, ready to commence at the year end.

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%. It is anticipated that other new technologies will be identified as part of this project to improve this further.

	Fig 4 – Mobile re-compression unit 
Collaborative partners	None
R&D provider	GL Industrial Services (UK) Ltd

18) Reducing National Grid's Carbon Footprint

Project title	Reducing National Grid's Carbon Footprint			
Project Engineer	Ian Welch			
Description of project	Knowledge and innovation search external to the existing energy providers, with a specific target being reducing energy losses, seeking alternatives to SF6 gas and reducing environmental impacts. This project is collaborative piece of work, which has both Gas and Electricity elements.			
Expenditure for financial year	Internal £4k External £12k Total **£16k**	Expenditure in previous (IFI) financial years	**£20k**	
Total project costs (collaborative + external + internal)	**£36k**	Projected 2009/10 costs for National Grid	£0	
Technological area and/or issue addressed by project	To search for and import technology propositions and solutions from non energy related R&D sectors (ie in this case the major UK provider for defence) which have potential for electricity (and gas) transmission			
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		10	0	10
Expected benefits of project	The expected benefits of this project are that it will help inform National Grid's strategy on how best to deal with a number of environmental issues and in doing so will potentially contribute financial savings in the form of Opex reductions and reductions in both financial and reputational risk to National Grid.			
Expected timescale of project	2 years	Duration of benefit once achieved	5 years	
Probability of success	85 %	Project NPV = (PV benefits – PV costs) x probability of success	-£97k	
Potential for achieving expected benefits	Medium/High – Knowledge that solutions available to the defence sector are equivalent to / no better than those available to the energy sector would be treated as a successful outcome.			

Project progress **[completion March 2009]**	This two-year project is now complete. Work commenced with Qinetiq to import knowledge into the energy sector of emerging research from the military sector. The project methodology was to undertake a sweep of emerging technologies and see how these might map across to electricity and gas transmission. The initiating idea, a search for alternatives to SF6, proved not to be successful. However a number of other promising areas were assessed. The areas are: • Unmanned aerial vehicles for surveillance of gas transmission assets and condition monitoring of overhead lines – with reduced carbon footprint and increased safety to personnel • Import of "stealth" technology to reduce the audible impact of transmission assets (e.g. reduced noise emissions) • Specialised coatings e.g. lower thermal vulnerability to solar • Possible energy scavenging from waste heat sources Where appropriate follow-on projects have been, or will be commenced
Collaborative partners	National Grid Electricity Transmission
R&D provider	Qinetiq

19) Flooding Risk Analysis

Project title	Flooding Risk Analysis Pluvial Flooding Risks		
Project Engineer	Doug Dodds		
Description of project	This is a joint project with National Grid Electricity Transmission to improve the understanding of pluvial flooding (also known as "flash flooding"), by relating potential fluvial, pluvial flooding and inundation maps to the National Grid Transmission assets on the National Grid GIS system, so that it can be used for planning and risk assessment purposes.		
Expenditure for financial year	Internal £4k External £4k Total **£8k**	Expenditure in previous (IFI) financial years	£0
Total project costs (collaborative + external + internal)	**£8k**	Projected 2009/10 costs for National Grid	£0
Technological area and/or issue addressed by project	The traditional assessment of flood risk is based on river levels (fluvial flooding) and coastal flooding. However, recent experience has shown the impact and potential impact of pluvial flooding, whereby local ground conditions and/or topography cannot handle severe rainfall over a sustained period of time. This project therefore aims to develop an improved understanding of how pluvial flooding (or "flash flooding") could affect National Grid Transmission assets. For Electricity Transmission, these include towers and substations; while, for Gas Transmission, these include metering offtakes, block valve sites, multi-junctions and compressor stations.		
Type(s) of innovation involved	Significant	Project Benefits Rating: 6	Project Residual Risk: 0 — **Overall Project Score**: 6
Expected benefits of project	National Grid's Transmission licences require operation of networks with the minimum of disruption to service. Any preventable losses of service due to flooding should be mitigated through appraisal management and reduction of the flood risk. Climate change appears to be resulting in a greater frequency of flash flood events, similar to that experienced in June/July 2007. Currently, National Grid undertake post flood surveys of all National Grid assets each time they potentially have been affected by a flooding event. It is envisaged that the solution being developed by this project will enable most assessments to be carried out remotely by cross-referencing details of at-risk components of the asset against the new data on pluvial flooding resulting from sustained heavy rainfall. This will result in significant OPEX savings in the aftermath of flash flooding events.		

Expected timescale of project	1 year	Duration of benefit once achieved	5+ years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£24k
Potential for achieving expected benefits	There is a high likelihood of delivering the expected benefits.		
Project progress **[Year to End of March 2009]**	Based on progress to the end of the year, delivery of the first round of LIDAR (Light Detection and Ranging) maps for the 1 in 100 risk sites is expected during summer 2009. Internal work is ongoing to assess National Grid Transmission assets against the Environment Agency's surface water flooding data. Engagement on flood resilience has been initiated with CIRIA (Construction Industry Research & Information Association).		
Collaborative partners	National Grid Electricity Transmission		
R&D provider	Environment Agency, Network Mapping		

20) Asset Management and Performance of Energy Systems (Amperes)

Project title	Asset Management and Performance of Energy Systems		
Project Engineer	Jenny Cooper		
Description of project	The overall "Amperes" project is a collaboration between six universities and ten industrialists (including National Grid), addressing the following strategic key issues: • The need to maintain reliable energy supply • Ageing plant • Changing requirements (environment) • Renewable and distributed power generation • Reduced skills base For this part of the project, GL are interacting with the universities on the gas transmission aspects, such as the modelling of the gas network and the interaction between gas and electric network models.		
Expenditure for financial year	Internal £4k External £89k Total **£93k**	Expenditure in previous (IFI) financial years	**£0**
Total project costs (collaborative + external + internal)	**£104k**	Projected 2009/10 costs for National Grid	£11k
Technological area and/or issue addressed by project	The convergence of vectors for energy generation, supply and use is causing increasing interplay between gas and electricity networks. This interaction is being modelled through close cooperation between GL and Edinburgh University		

Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		7	0	7

Expected benefits of project	This overall project aims to improve the understanding of the impact on Gas and Electricity networks of current and future trends in energy supply and energy use. This will allow improved decisions to be made on the management of assets, and if a demand side approach to energy management can be adopted, it should allow CAPEX and OPEX to be reduced on energy transmission infrastructure.		
Expected timescale of project	4 years	Duration of benefit once achieved	5+ years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£96k

Potential for achieving expected benefits	The supply of gas network modelling software and provision of integration support from GL should help the overall project achieve its objectives.
Project progress **[Year to End of March 2009]**	Methodologies to progress the project were formulated and agreed between GL and Edinburgh University. GL 'Synergee' network simulation software was licensed to Edinburgh University to allow them to construct network management models. GL 'Synergee' software was used by Edinburgh University with additional modules to allow simulation of impact of changes in energy use and supply patterns. Integration with the additional modules was undertaken with support from the GL team.
Collaborative partners	SUPERGEN V Amperes Consortium, specifically Edinburgh University.
R&D provider	GL Industrial Services (UK) Ltd

21) PRCI

Project title	PRCI (Pipeline Research Council International)		
Project Engineer	Tony Stonehewer		
Description of project	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.		
Expenditure for financial year	Internal £9k External £20k Total **£29k**	Expenditure in previous (IFI) financial years	**£76k**
Total project costs (collaborative + external + internal)	**$9m**	Projected 2009/10 costs for National Grid	£40k

Technological area and/or issue addressed by project	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.
	
	The areas (and research objectives) covered by the PRCI programme launched in 2008 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:
	
	• Time-dependent Threat Management (including External Corrosion and Mechanical Damage): 32%
	  ○ Development of technologies to enable operators to accurately identify and evaluate the effects of coating disbondment and shielding coatings.
	  ○ Develop technologies to locate and characterize corrosion in difficult to inspect areas.
	  ○ Develop and validate tools and inspection-based procedures for the accurate and reliable location, sizing and characterization of mechanical damage defects.
	• Time-independent Threat Management (including Mechanical Damage, Weather and External Force): 47%
	  ○ Conceptual demonstration of a combined pipeline integrity and security management surveillance system and the development an overall framework for its implementation.
	  ○ Development of quantitative validated mechanics-based methods for assessing the severity and		

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<td colspan="4">
remaining life of gouges and dents + gouges.
○ Conduct field testing and demonstrate the capabilities of the intrusion sensor system.
○ Development of improved, qualitative and validated assessment tool for ranking and screening the severity and remaining life of plain dents, with/without associated corrosion or welds to improve industry's response to concerns about the continuing occurrences of damage to pipelines.
○ Investigation to better define the effectiveness of geo-fabric applications for reducing soil loads.
• Design and Construction: 9%
○ Development of next generation tensile strain limit models to support strain-based design procedures.
○ Develop a risk based design and standards to measure and improve the safety of natural gas and liquid pipelines and gain the broad acceptance regulators and industry.
○ Reduce the uncertainty of Automated Ultrasonic Technique (AUT) detection and sizing with the goal of dramatically improving the predicted reliability of pipeline.
• Compressor & Pump Stations: 7%
○ Reduce the total costs of ownership & operation of gas turbines.
○ Characterize compressor station greenhouse gas emissions and identify mitigation opportunities.
○ Characterize Facility Integrity status and issues, and investigate Balance of Plant (non-driver, non-compressor) to identify opportunities to reduce losses, increase reliability, and reduce O&M costs of subsystems & components.
• Measurement: 5%
○ Reduce lost and unaccounted for gas expense via improved accuracy, reduced bias and increased operating range of conventional measurement options.
○ Create a comprehensive summary of all available research related to gas flow measurement
</td>
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<tr>
<td rowspan="2">Type(s) of innovation involved</td>
<td rowspan="2">Incremental To 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>
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Expected benefits of project	PRCI's value proposition: "Formal cost / benefit studies of member 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" National Grid Transmission and National Grid Gas Distribution this year used their combined annual contribution of $131k to help launch 24 PRCI projects with a total cost of $2.68m. This provides an average leverage on projects of over 20:1.		
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
Potential for achieving expected benefits	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.		

Project progress
 	
[Year to End of March 2009]
	The following National Grid supported projects were launched this year by PRCI:
	• Time-Dependent Threat Management
	  ○ Large-Scale Cathodic Disbondment Testing for Coal Tar Enamel (CTE)
	  ○ Variable Cathodic Protection Criteria
	  ○ Determine In-Line Inspection Tool Performance Characteristics
	  ○ Pipeline Facility Incident Data Review and Statistical Analysis
	  ○ Pipeline Facility Threat Identification and Failure Susceptibility Methodology
	  ○ Above Ground Surveys For Difficult to Assess Areas
	  ○ Enhanced Mechanical Damage Database by Improving Mechanical Damage Assessment in the Ditch
	  ○ Ultrasonic Measurements of Strains in Pipelines
	• Time-Independent Threat Management & Operational Efficiency
	  ○ Conceptual Pipeline Integrity & Security Management
	  ○ Acoustic Source Level and Signature Measurement of Pipeline Scratches and Gouges
	  ○ Field Tests and Advanced Development of Pipeline Sensor System
	  ○ Full-scale Experimental Validation of Mechanical Damage Assessment Models
	  ○ Full-scale Experimental Validation of Mechanical Damage Assessment Models (Inspections & Repair)
	  ○ Model for Predicting the Likelihood and Severity of Newly		

	Created Damage o Full-Scale Buried Pipe Tests to Determine and Reduce Soil Loads on Buried Pipelines • Design & Construction o Tensile Strain Limits for Strain Based Design o Standardization of Natural Gas Reliability Based Design and Assessment Methodology o Advanced Technologies and Methodology for Automated Ultrasonic Technique (AUT) Systems Qualification • Compressor & Pump Station o Gas Turbine Component Research Prioritization o Methods to Reduce the Carbon Footprint of Pipeline Stations o Compressor & Pump Station Facility Integrity ▪ Measurement o Flow Measurement with Low Differential Pressure o Assessment of Dirty Meter Performance o Measurement Research Compendium Reports were delivered by PRCI during the year for the following National Grid supported projects: • Projects Launched in 2007/08 o Understanding Magnetic Flux Leakage (MFL) Signals from Mechanical Damage in Pipelines o Development of a pipeline encroachment prediction model o Evaluate Existing Hydrocarbon Dewpoint Measurement Equipment o Clamp-on Ultrasonic Meter to Confirm Conditioned Flow at Primary Meter o Meter Station Measurement Uncertainty Analysis Tool • Projects Launched in 2008/09 o Pipeline Facility Incident Data Review and Statistical Analysis
Collaborative partners	National Grid Gas Distribution (UK) and 38 other companies with energy pipeline interests (27 based in the USA 5 European; 4 Canadian; 1 South American; 1 Middle-Eastern)
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.

22) Carbon Capture and Storage (Strategic Overview)

Project title	Carbon Capture and Storage		
Project Engineer	Dominic Harrison		
Description of project	High level technology review of carbon capture and storage, including the impact it will have on energy markets, the key issues facing its deployment in Europe and developments around the world where appropriate, and potential impact on gas and electricity networks • Carbon Capture – Key developments for coal and gas-fired plant and implications of different technologies for CO2 network operators – e.g. contaminants, reliability etc • Carbon Storage – Status of CO2 storage projects (e.g. Snøhvit) and future developments.		
Expenditure for financial year	Internal £4k External £41k Total **£45k**	Expenditure in previous (IFI) financial years	**£0**
Total project costs (collaborative + external + internal)	**£45k**	Projected 2009/10 costs for National Grid	£0
Technological area and/or issue addressed by project	The project will produce a report addressing the following issues: **Short Term** Transportation – Just an overview for completeness, because National Grid already has projects in this area. Policy Environment – Particularly focussing in on the recent EU proposals and developments. Use of Existing Pipelines – Gaseous CO2 vs. Supercritical (Dense Phase) CO2 and the potential re-use of existing gas transmission assets. Legalisation – Review of the main legal frameworks that will impinge on development of CCS, with particular regard to the CO2 pipeline system (e.g. OSPAR contaminant levels). Regulations – More immediate term outlook for Regulatory frameworks, including how a Cos transport system might be regulated, particularly in respect of HSE and adopting methodologies already in place for natural gas. **Longer Term** Policy Environment – Developments at EU and National level and the potential for policy accelerators and brakes. Technical Standards – Review of European and UK approaches and the development paths of likely frameworks. Regulation – Likely evolution at EU and Member States levels with special regard to developments in the UK. Legislation – Longer term evaluation. System Operating Characteristics – Handling of transient conditions, together with requirements and implications.		

<table>
<tr><td></td><td colspan="4">CCS Deployment in UK – State of play in UK, CCS competition and longer term outlook for attractive sites.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Radical</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>11</td><td>3</td><td>8</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Having knowledge about potential markets and the impacts that these can have on the National Grid business is critical if consideration is to be given to the conversion of some existing gas transportation assets to transport CO2.</td></tr>
<tr><td>Expected timescale of project</td><td>1 year</td><td colspan="2">Duration of benefit once achieved</td><td>5+ years</td></tr>
<tr><td>Probability of success</td><td>60%</td><td colspan="2">Project NPV = (PV benefits – PV costs) x probability of success</td><td>-£39</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">The work has been completed, the output being a comprehensive high level review, which gave National Grid the confidence to commission a more detailed project to assess the re-use of a gas transmission pipeline for CO2 transportation (see next project).</td></tr>
<tr><td>Project progress

[Year to End of March 2009]</td><td colspan="4">National Grid commissioned Pöyry Energy Consultants in May 2008 to undertake an assessment and provide a detailed report of the scale and impact of a potential CCS (Carbon, Capture & Storage) market developing in the UK. This report would further National Grid's understanding of CCS, and in particular provide an indication of the potential for re-use of its NTS assets by considering the potential CO2 volumes involved, and the location of possible CCS markets.

The report provided by Pöyry examined the key issues facing the deployment of CCS, focusing on Europe, but also assessing the developments around the World where relevant. The report examined the key developments of coal and gas-fired plant and considered the different technologies being considered for different plant types. The implications that these had on transportation of CO2, such as level of contaminants and operating pressures, were also considered. The report also included an assessment of the most likely locations in the UK where CCS could be deployed, again providing an insight into the extent of any role National Grid could offer in the roll-out of CCS.

The report met the objectives of the Project Sanction and was delivered within the budget.</td></tr>
<tr><td>Collaborative partners</td><td colspan="4">None</td></tr>
<tr><td>R&D provider</td><td colspan="4">Pöyry Energy</td></tr>
</table>

23) Re-Use of Transmission Assets for the Transportation of CO2

Project title	Reuse of Transmission assets for the Transportation of CO_2			
Project Engineer	Julian Barnett			
Description of project	Develop knowledge on how the existing National Transmission System (NTS) pipeline network could be utilised to transport anthropogenic CO_2 and how current assets will perform when transporting gas with different physical properties. The work will also consider the potential health and safety implications from transporting CO_2 in the existing NTS network.			
Expenditure for financial year	Internal £4k External £92k Total **£96k**		Expenditure in previous (IFI) financial years	**£0**
Total project costs (collaborative + external + internal)	**£475k**		Projected 2009/10 costs for National Grid	£383k
Technological area and/or issue addressed by project	The issue being addressed by this project is to determine the ability of National Grid's existing NTS assets to transport anthropogenic CO_2.			
Type(s) of innovation involved	Radical	Project Benefits Rating: 12	Project Residual Risk: 2	**Overall Project Score**: 10
Expected benefits of project	The benefits of this study would be to enable National Grid to assist in reducing the CO_2 emissions of the UK's energy industry as a whole by providing the ability to transport CO_2. The project potentially helps to improve security of supply for the UK by allowing the continued use of fossil fuels (such as coal) for power generation, which are available in the UK. The project will also allow National Grid to gain knowledge on how to utilise existing assets to allow the transport of CO_2 through the existing pipeline network. It is hoped that the work will demonstrate that it is economic and efficient to re-use National Grid assets to help meet the environmental and energy challenges of the future as well as providing improved "green" credentials for the business.			
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	£5,000k	

Potential for achieving expected benefits	The project needs to explore a large number of technical issues and many of these still need a lot of work before the potential can be meaningfully assessed.
Project progress **[Year to End of March 2009]**	The services of Pipeline Integrity Engineers (PIE) Limited were engaged in the autumn of 2008 to assist National Grid develop its understanding of Carbon Dioxide (CO_2) and the application of its pipeline knowledge to potential Carbon Capture and Storage (CCS) projects. During the period up to end of the 2008/09 financial year the following preliminary analysis work was undertaken by PIE: • CO_2 gas dispersion and the likely hazard distances. • Derivation of individual risk transects for two gas CO_2 pipeline release scenarios. • Development of a possible specification for anthropogenic CO_2. • Obtaining information regarding knowledge and experience on CO_2 pipeline systems in America. • Application of current pipeline codes. • Initial assessment of material and integrity issues. PIE have also been working closely with National Grid to develop a detailed Research and Development (R&D) programme to underpin and develop knowledge relating to CO_2 and CCS transportation infrastructure. The intention is to also engage the services of Penspen Limited to: • Conduct front end engineering work into the possible use of existing National Grid pipeline assets and the development of independent pipeline networks for the transportation of CO_2. • Develop an understanding of and acceptable approach to managing fracture mechanics issues associated with CO_2 pipelines in the UK. Engagement of Penspen has been delayed while the range of the work required from them has been more fully developed based on the preliminary analysis undertaken by PIE and agreement is reached between National Grid and Penspen regarding the Terms and Conditions (T&Cs) for the contract proposed. The intention is for Penspen to commence work shortly.
Collaborative partners	None
R&D provider	Pipeline Integrity Engineers (PIE) Penspen