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Successful Collaboration Projects

A range of technological developments to enhance Asset Management Performance

Authors:

Wez Little – BEng (Hons) CEng MIEE – Innovations Director – UK

Simon Langdale – MEng (Hons) AMIMechE – Principal Mechatronics Engineer - UK

John White – MDes BSc (Hons) AIGEM – Principal Mechanical Engineer - UK

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Background

Collaboration is no guarantee of success but doing nothing is a guarantee of failure. This paper discusses the approach taken by Synthotech Ltd, where collaboration with gas network owners, academia and other likeminded Small Medium Enterprise (SME's) has been key to delivering compelling 'must have' technologies for asset management leading to the utopia of total network management.

For over four decades the UK Gas Industry, namely British Gas/Transco, developed a world leading reputation regarding Research, Development & Innovation. Following privatisation in the 1980's and in subsequent decades, investment in the UK Gas Distribution market has declined to an extent where a number of new Regulatory funding mechanisms have evolved to stimulate the appetite for research & development.

It is important to understand how such funding mechanisms are formulated and accessed and the following paper sets out the rationale behind what is currently happening within the UK gas/energy regulatory framework. Office of Gas and Electricity Markets (OFGEM) the UK regulator must ensure that energy is delivered at a fair price for consumers. To help achieve this, a new performance based model for setting the network companies' price controls was developed which will last for 8 years (2013 to 2021). This model is known as RIIO (Revenue=Incentives+ Innovation + Outputs). Over the next decade the gas network companies face a significant challenge of securing sufficient investment to maintain a reliable and secure network, whilst dealing with the changes in demand and generation that will occur in a low carbon future.

RIIO is designed to encourage network companies to:

- Put stakeholders e.g. consumers, general public and employees at the heart of their decision-making process
- Invest efficiently to ensure continued safe and reliable services e.g. provide network integrity
- Innovate to reduce network costs for current and future consumers
- Play a full role in delivering a low carbon economy and wider environmental objectives.

Prior to the introduction of RIIO, innovation projects were funded using the Innovation Funding Initiative (IFI), however it was felt that this was not stimulating consumer focused innovation. As part of the RIIO price controls OFGEM have introduced the Network Innovation Allowance (NIA). The NIA is a set annual allowance that allows National Grid, and other Network Licensees a funding opportunity of 0.7% of revenue to be spent on innovation projects, 90% of which can be recovered through the incentive mechanism

The NIA provides limited funding to RIIO network licensees to use for two purposes:

1. To fund smaller technical, commercial, or operational projects directly related to the licensees network that have the potential to deliver financial benefits to the licensee and its customers; and/or
2. To fund the preparation of submissions to the Network Innovation Competition (NIC)

The Gas NIC is an annual opportunity for Gas Distribution Networks (GDN's) to compete for up to £18m in innovation funding for the development and demonstration of new technologies, along with operating and commercial arrangements. Funding is provided for the best innovation projects which help all network operators understand what they need to do to provide environmental benefits, cost reductions and security of supply as Great Britain (GB) moves to a low carbon economy.

Using funding mechanisms as described above, UK GDN's have embarked on a number of projects that have significantly regenerated and accelerated innovation. These projects were undertaken for the UK market but with an intention for international application and have resulted in proven asset management tools that provide a range of significant benefits.

From the projects delivered to date one of the most significant challenges has been the 'change in management processes' where cultural and behavioural evolution must be achieved. It has been said that changing culture does not change culture, changing behaviour will change culture.

Implementation of new innovation must be underpinned by an approach that simultaneously integrates and evolves technological, business and human processes.

The availability of the OFGEM funding mechanism has provided the required stimulus to allow gas distribution and transmission to invest in technology at all levels of the business.

Aim

There is a compelling need for a technology to enable the gas asset owner and operators to access, inspect and assess the condition of the pipelines regardless of the material and age. It is an absolute certainty that Regulatory bodies in each country will insist that assets are monitored as far as reasonably practicable, determining the residual lifetime of their systems. In the UK, even Polyethylene (PE) is approaching its original design lifetime (50 years) and therefore assurances must be sought to assist in any company Asset Management Plan.

Synthotech Ltd (SL) is a UK based Small Medium Enterprise (SME) specialising in the development of 'must have' technologies for the utilities industry and are an innovative engineering company providing 'Turn Key' solutions to specific problems. SL has undertaken innovation funded projects with all of the major UK GDN'S. These projects include: Establishing collaborative agreements with the GDN owners, concept to delivery targets which include the development of new commercial agreements, technical specifications and engineering procedures, along with a global review of available technologies that may support these projects. Many of these projects have proven to save considerable sums of money.

An example of such a project is the development of a safe, effective and proficient system to 'live-launch' in-pipe inspection and assessment devices using a combination of CCTV, laser and other evolving techniques that are currently under development.

Method

Any equipment attached to a pipeline under pressure will be subject to forces acting upon it. This is due to the differential pressure in the pipe and the pressure in the outside environment, the following section details the current industry approach and the innovative approach taken by SL.

Methods of introducing "live gas launch" inspection devices

The standard approach to controlling the vertical movement of the insertion systems is to mechanically lock them into position. This has to be controlled by an operator and failure to control this operation could lead to a forceful ejection of the insertion head and could lead to an uncontrolled release of gas if the pipe pressure is high enough.

Current insertion systems typically adopt the method of using safety restraining chains, locking pins and catches to prevent the movement during camera inspection. This limits the

maximum operating pressure due to the amount of physical force an operator can exert on the system e.g. The force pushing out from the pipeline is too great to insert the launch system safely while manually locking it into position.

Technological Developments

SL has successfully developed live insertions systems for metallic and PE distribution mains with operating pressures up to 6 barg. In addition, there is the ability to scale the system up to operating pressures of 10 barg whilst still ensuring that the maximum size camera head can be inserted and long inspection lengths can be achieved. Therefore, continued development of novel access systems will pave the way for new and innovative technologies to be applied within pipelines around the world ensuring that increased qualitative and quantitative data can be captured from pipeline assets. These developments are described in the following 'work packages':-

Work Package 1: *Launch System for PE / PVC Pipelines*

The resultant success of these systems enabled SL to fund the development of a suite of systems for Medium (2 barg) and High Pressure (6 Barg) PE networks. The result is a patented (pending) insertion system that can equalise the pressure such that the equipment/operator is not subjected to any loads irrespective of the pipeline pressure. Therefore, the system is not subject to a load that imparts dynamic movement and cannot be forcefully ejected from the pipeline into the housing under full operating pressure. This is achieved by using a piston to push down at the same force as the gas pressure pushing upwards, the system is pressure balanced.

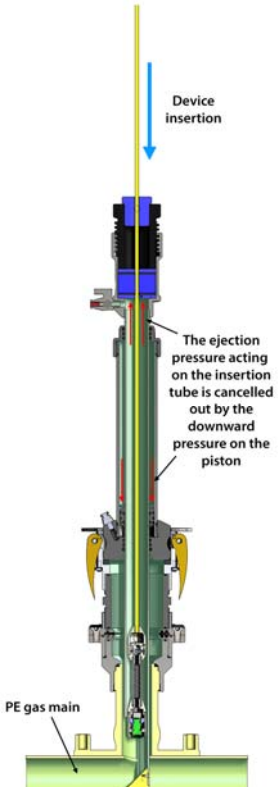


Fig 1. Patent Pending PE Insertion System

Work Package 2: *Launch System for CI Mains*

In collaboration with a UK GDN, SL have developed a new metallic insertion system for 4" to 8" mains that allows vertical camera access followed by angled insertion to enable up to 100% increase in push distance (circa 95m in each direction), to be surveyed compared to fixed angle insertion designs. During this development, SL introduced the first design of its 'dynamic' movement control (DMC) for use on up 2 barg. This is effectively a 'spring actuated locking paddle' which acts like a one-way valve, enabling downward movement into the pipe, but automatically locks when the pressure pushes back against it. This prevents the ejection of the insertion system and maintains operator safety at the critical part of the operation.

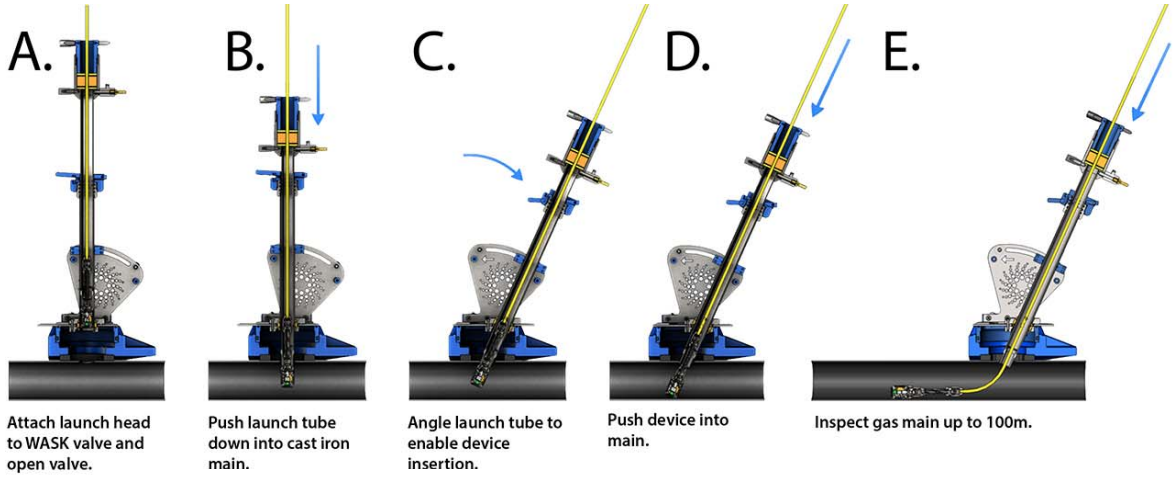


Fig 2. Launch System for CI Main - Operation

Work Package 3: *Launch System for Metallic Mains*

In collaboration with a major international T&D Asset Owner, funding from BG Group allowed SL to further develop the system to enable the insertion system to operate at higher pressures (5 Barg) where physical force required of the operator to overcome the internal gas pressure is too great.

A 'scissor lift and screw drive' system enables a greater insertion force to be obtained under controlled conditions giving better positional control and preventing pipe ejection.

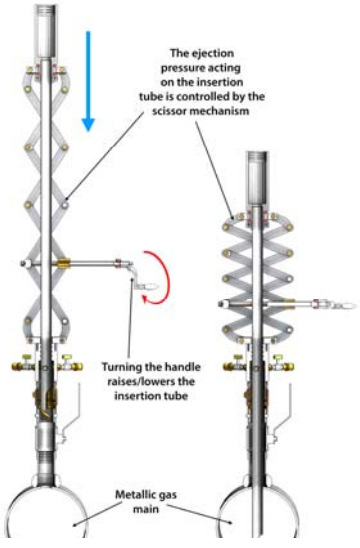


Fig 3. Scissor System

Importance of Innovative Asset Management

Having described the success in achieving access into 'live' gas mains at a range of pressures, diameters and materials, the ability to introduce innovative and intelligent inspection devices is an exciting opportunity for utilities to assess the conditions of their assets and formulate a robust Asset Management Plan.

In addition to the inspection aspect of 'live launch', there is an extremely interesting and innovative initiative underway to introduce robotic devices into mains not only to inspect but also to undertake remote service connections from within the pipe. Such a system is being developed by Synthotech Ltd (SL) and is known as the 'Tier One Replacement System' (TORS).

Work Package 4: Tier One Replacement System (TORS)

In November 2012 Synthotech Ltd (SL) and NGG initiated a five month research & development project to determine if it was possible to replace a section of aged cast iron distribution pipeline (main), along with the service pipes connecting to consumer properties. The aim was to enable remote service replacement from an underground location using highly innovative' polymorphic' (makes decisions and performs tasks based on its environment) robotic technology.

The current method of replacing gas mains and services involves excavating (digging holes) to expose the main at either end of the area to be renewed in order to decommission the existing pipe work. Further excavations are undertaken where each service connects to the metallic main to complete the renewal of the mains and services. These additional excavations can be in the public highway or on private land. This project has the potential to offer significant cost savings and benefits.

The ultimate aim of the TORS project is to design and develop a robotic system that is capable of remotely undertaking 10 off Service to Mains connections in a 100m section of cast iron main from only two excavations, will eliminate the need for service connection excavations.

The following website provides a TORS Showcase video, this video was produced for NGG as part of the 2014 UK Low Carbon Network Initiative Conference:

https://www.youtube.com/watch?v=NIRTbx1HPiw

Development Process

The approach taken by SL was to design and develop a series of tools that would allow a step by step process to undertake a remote service to mains connection. This system would need to operate inside a PE pipe range of 63mm to 180mm and cope with all the associated internal geometries such as bends, any ovality in the PE pipe and different wall thicknesses (SDR's).

Following successful completion of the initial research and development work on a larger robotic platform based on adapted Synthotrax (TORS1 - See below image), a 'proof of concept' stage was undertaken.

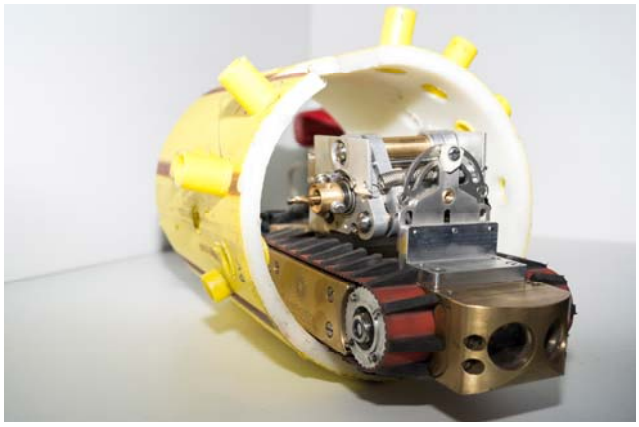
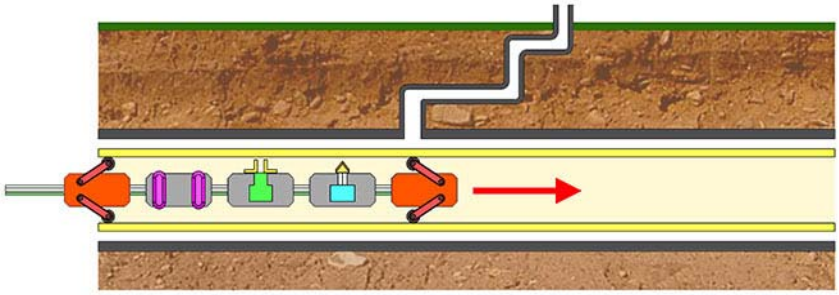


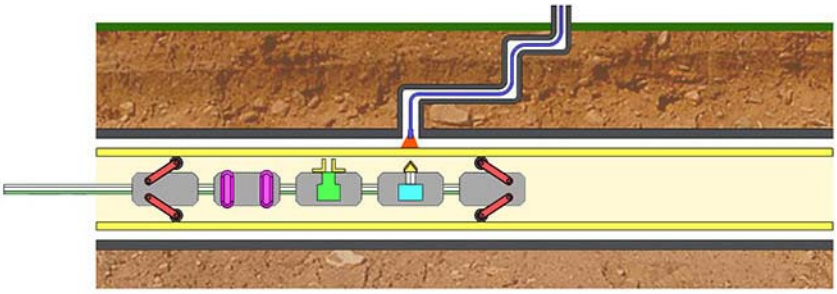
Fig 4. TORS1 Modified Robotic Platform

The 'proof concept' stage known as TORS2 (July 2013 to November 2013) simulated a buried section of 4" cast iron metallic main that has been renovated by the insertion of a 90mm SDR 17.6 polyethylene (PE) pipe. The technological challenge was to develop a 'practical working' system that could remotely;

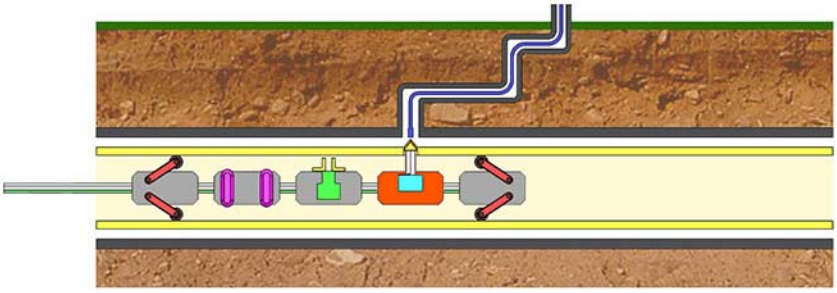
(a) Fig.5 - Enter and travel along the bore of inserted PE pipe



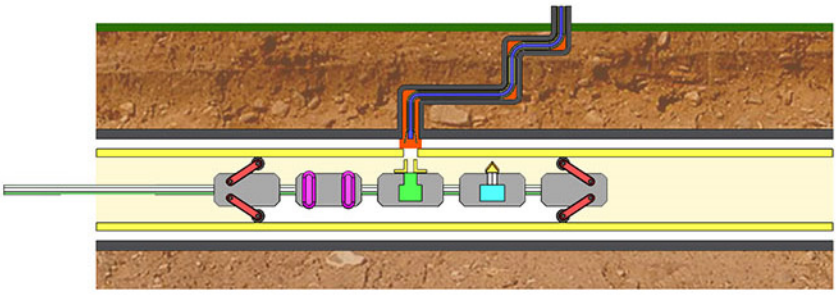
(b) Fig.6 - Identify the exact position of existing service connections through the PE Pipe



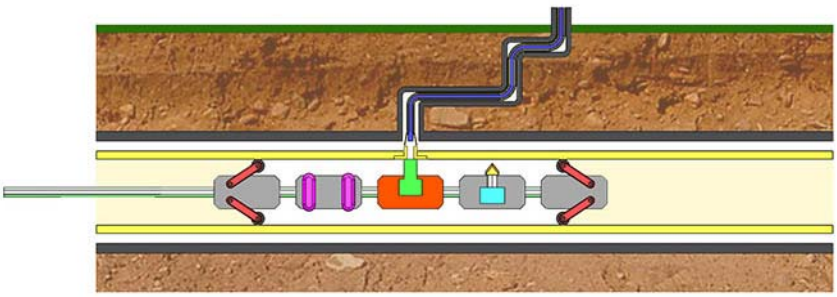
(c) Fig.7 - Drill a new connection hole from inside the PE pipe in alignment with the existing service connection



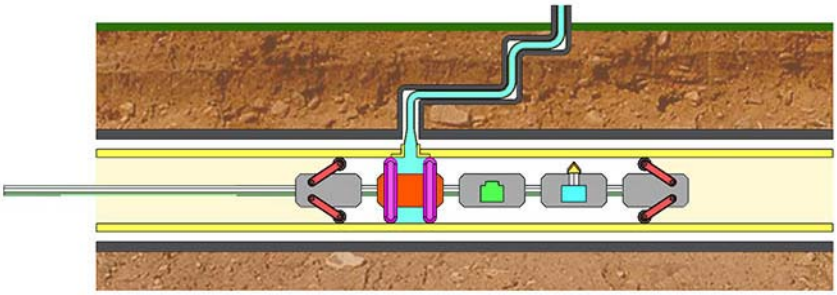
(d) Fig.8 - Re-line the old gas service pipe from the existing connection



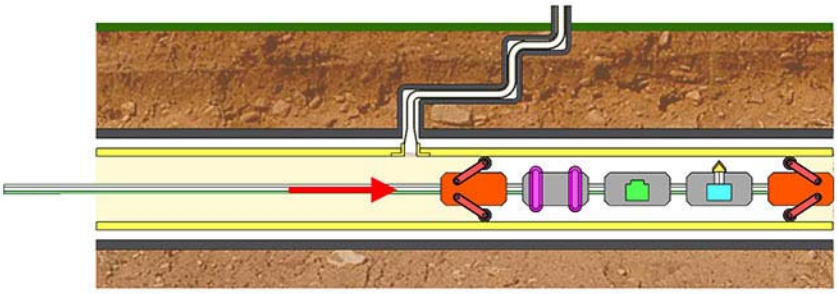
(e) Fig.9 - Make a service connection between the new service liner and inserted PE main



(f) Fig.10 - Carry out an integrity test on the new connection and service



(g) Fig.11 - Travel to the next service connection and repeat the activities (a) to (f).



The 'proof of concept' development is an Electro-Pneumatic robotic system that is constructed as a train of modules designed to carry out specific tasks. The modules are interfaced and controlled by a bespoke software program.

In November 2013 a remote service to mains connection was successfully demonstrated to a group of NGG Senior Stakeholders thus demonstrating the 'proof of concept'. The demonstration clearly and successfully demonstrated the above process steps proving that TORS could be undertaken as one continuous process.

The next section of this paper shows the CAD Models and actual robot images (Fig 12 to 18) from the TORS2 demonstrator described above. The TORS2 platform, was designed, manufactured, assembled and tested in house.

Fig. 12 - Wall Press drive module – This moved all other modules laterally though the 90mm PE pipeline.

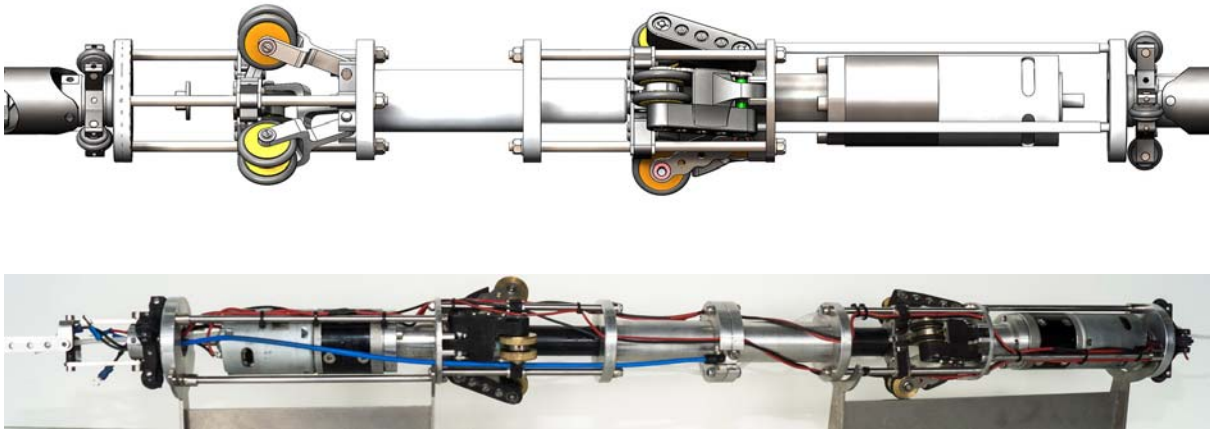


Fig.13 - Alignment Module – This rotated all modules to allow internal radial alignment.

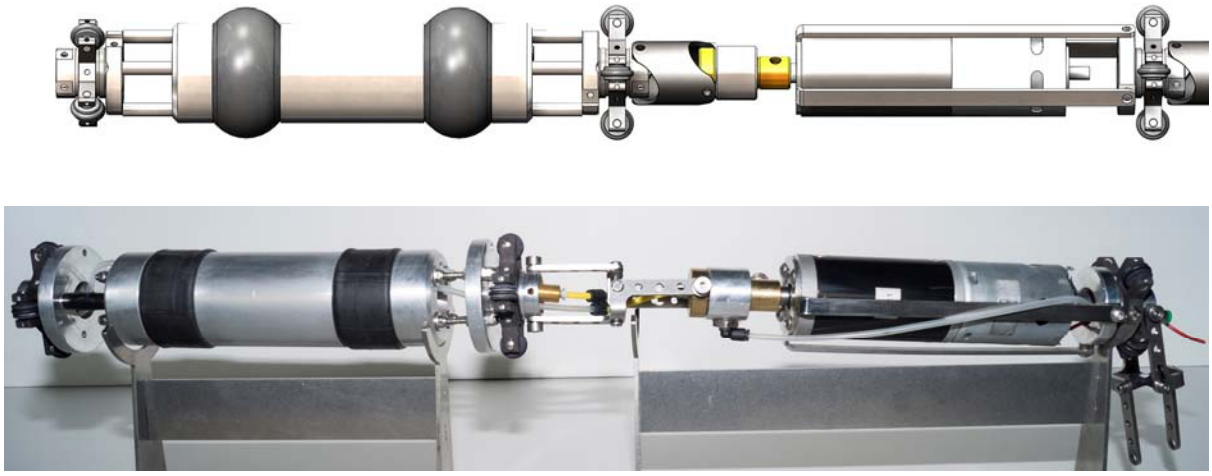


Fig.14 - Drill Module – This repeatedly drilled a hole at the service location using a camera to pin point an optical source penetrating though the 90mm PE Pipe.

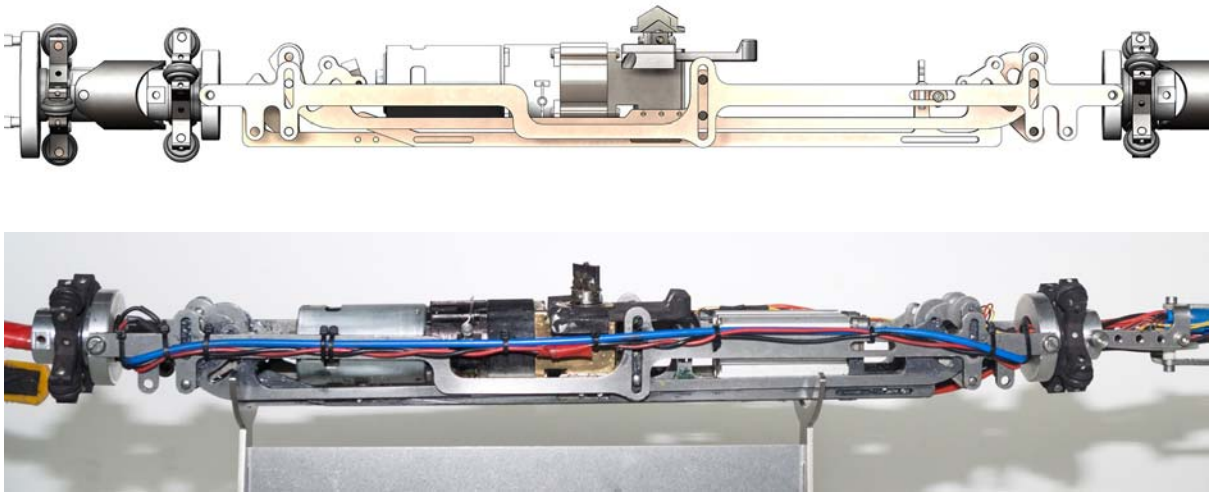


Fig.15 - Weld Module – This heated and inserted a remote connection fitting into the wall of the 90mm PE Pipe, using a bespoke vision system to align the fitting and the drilled hole.

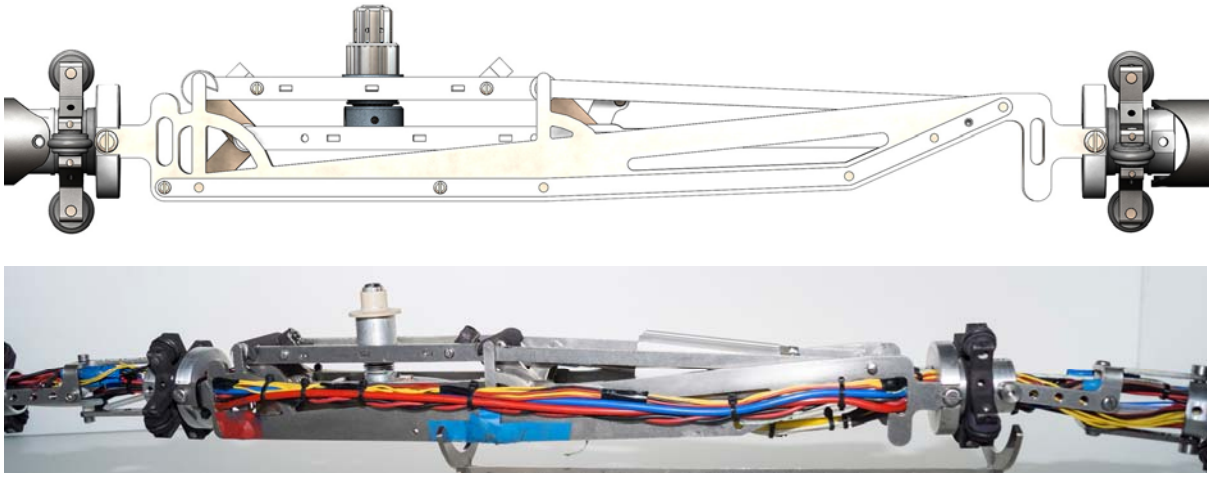
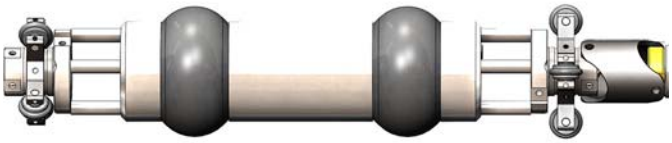


Fig.16- Service Insertion Module – This inserted the semi-rigid Service Pipe into the metallic service and connected the pipe to the remote connection fitting.

Fig 17 - Test Module – This performed a non-destructive integrity test on the remote connection and service.



Control System – This is a computer program and interface system that controlled the power supplied to individual robot modules, providing a platform for future 'polymorphic' control.

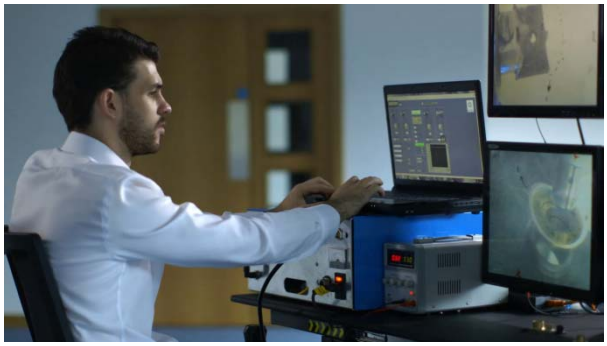


Fig.18 – Operating System TORS2 Robot

In January 2014 a 3-year NIA funded development project commenced to refine and build field robust equipment to take "concept to reality". In addition, an important aspect of this three year project is focussed on an implementation plan to fully realise the potential cost benefits of such a system. The aim is to undertake remote service to mains connections, replacing 100m sections of aged cast iron main (4"–8"), their associated gas service pipe and complete a service relay whilst eliminating the need for service excavations. The TORS platform itself is designed to operate in PE pipes of 75mm to 180mm inclusive, which are the typical insertion replacement sizes used in the UK.

Fig.19 – The latest development of the 3D Prototype TORS system (75mm to 90mm)

The system will become a closed loop process, with the robotic platform undertaking the decision making, capturing process data and ensuring that the work carried out is repeatable, efficient and satisfies the regulatory requirements associated with the construction and design life of the pipeline asset.

Work Package 5: Robotic systems for the inspection of High Pressure Transmission Pipelines

The developments described within this paper have been aimed at pipelines and materials used in UK gas distribution systems. Typically, the challenges are live access into 'aged' cast iron (CI) pipes, ductile iron pipes and even PE systems where gas pressures vary from low pressure (LP) 75mbar through to medium pressure (MP) 2 barg and intermediate pressures (IP) above 7 barg.

However, vast savings in operating costs can be realised if it were possible to use robotic systems to inspect unpiggable high pressure transmission pipelines.

Recently, National Grid Gas Transmission (NGGT) was awarded £15m through the NIC for two projects with one of the projects awarded £5.7m to develop a system that will allow a robot to undertake the inspection of gas pipelines at high pressure.

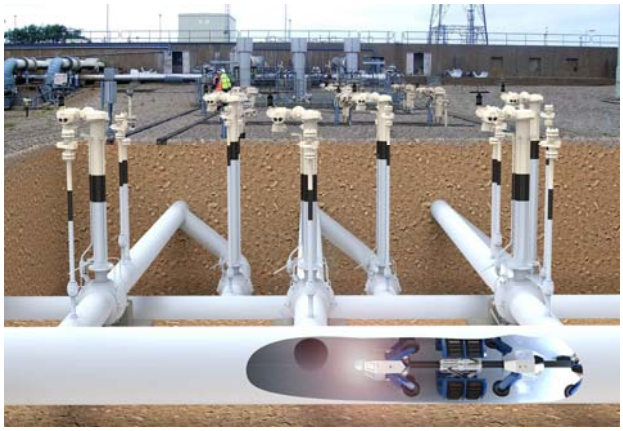


Fig.20 - Artists impression of Inspection Robot for unpiggable high pressure pipe lines

The new robot (GRAID) is being designed to travel through '*unpiggable'* underground pipework at pressures of up to 94 barg with velocities of up to 40m/s. Successful development would enable NGGT to accurately assess the condition of buried pipes, avoiding the need for complex deep excavations. This means that NGGT will only need to replace assets when absolutely necessary thus saving a suggested £58m over 20 years.

Use of this technology could reduce UK carbon dioxide by around 2,145 tonnes per year by avoiding unnecessary pipe replacements. These savings are equivalent to the carbon emissions from approximately 477 UK households per year.

National Grid are running this project alongside three SME's of which one is Synthotech Ltd (SL) whose historical performance, in successful innovation projects, has been recognised by NGGT in their confidence in collaborative work. Premtech Ltd will undertake the design of the launch system and detailed modelling of the National Transmission System (NTS) sites, with Pipeline Integrity Engineers (PIE Ltd) acting as the independent technical experts to review the data that is collected during the inspection process.

This is a complex project that will take around four years in development and will draw on not only the gas industry but academia to develop simple but innovative solutions for inspecting previously inaccessible sections of the UK's national transmission networks. This is a true example of the success of the NIC to stimulate collaborative innovation.

Results

In summary, it is important to discuss a number of aspects and not simply the technology described. In the current economic climate and within an industry so strictly regulated, working capital is at a premium. Regulators must ensure fair price structures for consumers but at the same time allow energy companies to make a profit and still invest in future technologies. Technologies are needed that will deliver environmental benefits, cost reductions and better security of supply as countries move toward low carbon economies.

The UK Industry regulator has recognised that investment is essential in order to realise such benefits and has a mechanism to enable this to happen. At the same time, energy companies are not the huge and sometimes nationalised companies that were around 30 years ago and therefore budgets for research and development are almost non-existent in this day and age. At the same time, transparency is essential so that industry regulator and consumers can see that investments do deliver benefits.

Innovation, development and delivery are the way forward to bring about change and this is apparent in the technologies described in this paper. However, it hasn't been an easy process because there is a requirement on all parties to embrace change in that cultural and behavioural evolution must be achieved. Implementation of new innovation must be underpinned by an approach that simultaneously integrates and embeds technological, business and human processes.

The technologies described in this paper represent a successful approach to 'delivering innovation' whereby a SME's enterprise such as Synthotech Ltd (SL) has collaborated with gas networks and regulators to deliver innovative technologies successfully to market. In

particular, 'live-access' systems that allows inspection devices such as cameras, or robotic systems to be launched into gas pipelines. This technology reduces customer disruption, duration of operation and increases operator safety over a range of operating pressures.

In addition to the technological advances in equipment that has been described here, an extremely important aspect that requires highlighting is the massive benefit that internal inspection of pipelines brings to the management of the asset. Asset management requires accurate information to enable decisions to be made in respect of asset lifetime. Condition of the existing pipelines can be determined accurately and without major disruptions. Replacement policies can be justified where necessary and timescales determined. Pressure uplift is another area where accurate information on pipeline condition can bring about benefits. But more importantly, Utilities can demonstrate to the Regulatory bodies that they are actively monitoring the systems and as such can use the information to influence where and how much funding can be invested back into their infrastructure.

Conclusions

Innovative solutions can also bring about evolution and this is well demonstrated in the Tier One Replacement (TORS) project. Robots that can power themselves through a pipeline and conduct a number of operations remotely will bring about enormous financial and operational benefits. The TORS 'proof of concept, demonstrator has proven such a system can work and has confirmed to NGG that further investment will bring about long term benefits. At every step of the project, new technologies have supported the development of the system including additive manufacturing and subtractive CNC machining (metal parts) of complex parts that otherwise would have been time consuming and costly to produce by any other means. New avenues of manufacture along with new materials are bringing about robust solutions and this is encouraging to all parties with an interest in new technology.

Finally, to develop further the concept of robotic systems into high pressure transmission pipelines, again confirms how innovation evolves into other areas. High pressure transmission systems pose significantly greater problems than typical distribution systems. However, using a collaborative approach, different skills and abilities can be brought together from different companies to achieve a common goal. No doubt there are difficulties to overcome but past experience would indicate that with robust project and financial control, advances in technology can result in innovative, cost effective working solutions. This is borne out by the obvious confidence shown by Gas Transporters and Gas Networks in specialist companies such as Synthotech Ltd and indeed other enterprises throughout the UK.

Notwithstanding the benefits that innovation bring to the UK gas industry, these exciting technologies will be transferable throughout the world where similar problems have yet to be identified or addressed.

The collaborative technologies can provide vital information to assist Asset Management programmes. Such methods of data gathering will allow the Utility to make informed decisions on pipeline integrity which in turn influence whether the Asset is to be replaced, repaired, renovated, down-rated or abandoned. Notwithstanding the obvious advantages of this ability, the technologies have been developed in consideration of the operator safety thus improving Engineering Procedures. The availability of the OFGEM funding mechanism has provided the required stimulus to allow gas distributors and transporters to invest in technology at all levels of the business.

Collaboration is no guarantee of success but doing nothing is a guarantee of failure. Synthotech Ltd look forward to continuing this collaboration with other SME's and non-UK asset owners and operators with a desire to provide compelling 'must have' technologies for total network management.

References

National Grid Gas TORS LCNI Video: https://www.youtube.com/watch?v=NIRTbx1HPiw

National Grid Gas GRAID: www.nationalgridconnecting.com/Robotic_innovation/

Synthotech Ltd: www.synthotech.com

Photography by: Stephanie White Photography – www.stephwhite.co.uk