Project closure report

Acoustek

NIA_SGN0044

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Document control

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1. Introduction

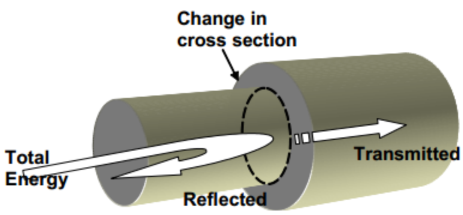
1.1. Executive summary

During the life of a pipeline there are occasions when a Network Licensee is required to excavate in order to enable the following activities:

- Locate blockages or obstructions which may have caused water ingress or debris build up and require removal
- Locate specific parts of buried assets i.e. valves, bends, tees etc. which require pin pointing for maintenance
- Determine valve open/closed status

The only existing method is to insert remote video cameras at regular intervals along the pipeline being surveyed. Typically, for remote video surveys, holes must be dug approx every 50 metres (m). Surveying long lengths of pipeline (> 100m) using this method is impractical. Other than remote video cameras there is currently no method to identify the exact location of problems or features of interest. Current techniques are typically multiple excavations supported (if appropriate to the problem under investigation) by pressure testing in the locality until the obstruction or asset can be found. There is a significant opportunity to reduce excavation, costs and time if a method to rapidly identify the location of features and causes of network problems can be developed.

Researchers at the University of Manchester had developed an acoustic monitoring system that was capable of surveying short and long lengths of pipe. The system had recently been commercialised for use in offshore natural gas pipelines and for surveying the relatively small tubes within shell and tube heat exchangers.



The system works by fires a sound pulse using a gas safe pulse injection system, it then “listens”to the return pulse waveform with a microphone, recording the reflected signal. The system analyses the return signal using purpose designed software.

The purpose of this collaborative project was to extend the technique and develop a tool that is capable of surveying pipes with lengths of up to 300m, diameters ranging from 25-200mm and rated for pressures of up to 350mbar, such that it can be used to survey the pipelines used in domestic gas distribution networks. The developed tool could be used for both planned and emergency reactive work in gas networks, where it has the following possible applications.

This document details the processes and learning from the project along with a summary of the field trials conducted which guide the recommendations and next steps. Following approval from all participating GDNs, this project began in May 2014 and progressed to field trial status in 2015/16. This document marks the closure of this project.

1.2. Summary of recommendations

It is recommended that the Acoustek system be improved, under an additional Network Innovation Allowance (NIA) Project Acoustek Ph2, to increase the accuracy of the equipment and allow it's use in 600mm core excavations prior to further field trials being undertaken by Gas Network Operations staff.

In this project a number of field trials were initially completed in Northern Gas Networks (NGN) and proved the ability of the Acoustek system to identify features within a pipeline network. A series of further trials on known pipework layouts were then completed in Scotland. The pipe layouts were varied with a range of pipe lengths and sizes. In all occasions the Acoustek system identified know pipe features including connections, cap ends and blockages accurately. In addition the system also identified features in pipes which had not or could not be inspected using CCTV. These also included connections in a pipe which could not be visually inspected due to excess debris within the main and a siphon in a main which had not be visually inspected.

Analysis of the results of all the field trials conducted proved the system was capable of accurately detecting pipe features, typical errors on the field trials were less than 0.5m over 100 metre survey lengths. The system also proved accurate over a range of sizes from 3" upwards over a number of field trials.

After analysis of the field trial data it is obvious that the system, although not a direct replacement for CCTV surveys, is a useful tool over extended lengths to supplement and target the use of CCTV. The extended survey length achieved by Acoustek (in one case in excess of 300 metres) would require multiple camera insertion points and, when looking for blockages in particular, this can become costly and time consuming. Using the system to target the use of CCTV would allow a much quicker response to water ingress incidents.

The system outputs are graphical and require some training to be able to accurately identify the feature which had been identified. Also there were some issues with accuracy due to an "uncertainty" in the speed of sound in the pipeline being surveyed. University of Manchester have suggested some modifications to the system to address the above issues as well as providing a training tool to allow operatives to be able to quickly and accurately identify the features.

Although several field trials were carried out they were all done in the presence of University staff and not carried out wholly by Gas Network Operatives.

An additional project phase would allow for the modification to the instruments to be completed and Acoustek kit to be made available for Networks to operate and evaluate independently over an extended trial period. It is also recommended that the existing system is approved for use on SGN's Networks as an inspection and location tool in the interim period.

1.3. Project background

During the operational life of a pipeline there are occasions when a main can be blocked or obstructed with water or debris. Historically there were no methods to identify the exact location other than excavating in various locations until the obstruction was found. More recently cameras have been introduced to survey the main; however, their range is limited to approximately 50 metres and they don't cope with sharp bends or large amounts debris or liquid.

Researchers at the University of Manchester have developed an acoustic based technique that, within minutes, is able to survey pipelines with lengths ranging from a few meters to 10km and diameters from a few millimetres to a metre or more. The technique injects an acoustic signal into the gas that then propagates along the pipeline. Part of this signal will be reflected whenever it encounters a restriction or expansion in the cross-sectional area of the pipeline, as will occur where there is a blockage, hole in the pipe wall, valve, T-piece etc. By monitoring the reflected signals and measuring the time of flight, blockages (full or partial), leakages and other features in a pipeline can be detected and located to within a few centimetres. The technology has been commercialised for use on high pressure offshore pipelines by Pipeline Engineering where it has been successfully applied to detect and locate stuck PIGs and is currently being commercialised by Phoenix Inspection Systems Ltd. for detecting corrosion, holes and blockages in short lengths of heat exchanger tubing.

1.4. Network Innovation Allowance Funding

Innovation is a key element of the new RIIO (Revenue = Incentives + Innovation + Outputs) model for price controls, introduced in to the gas distribution market from 1st April 2013. One of the key innovation proposals was the introduction of the Network Innovation Allowance (NIA) and for all Network Licensees funded under the RIIO framework.

The purpose of this funding mechanism is to provide a consistent level of funding to Network Licensees to allow them to carry out Research, Development and Demonstration projects which when at an early stage yield uncertain commercial returns. In addition, where benefits are linked to the decarbonisation of the network, it may be difficult to commercialise the respective carbon and/or environmental benefits and shareholders may be unwilling to speculatively fund such Projects.

Network Innovation Allowance (NIA) – to fund smaller innovation Projects that will deliver benefits to Customers as part of a RIIO-Network Licensee's price control settlement; or to fund the preparation of submissions to the NIC.

1.5. University Of Manchester

The University of Manchester's School of Electrical and Electronic Engineering have research interests in applied controls systems, robotics and pulse reflectrometry for monitoring pipelines. Their work has previously led to the development of several products that have been commercialised and successfully applied in the North Sea, USA and Asia to detect and locate blockages in subsea pipelines and heat exchangers. The purpose of this project is to extend the developed technique so that it can be applied to the more complex challenge of detecting and locating blockages, holes and corrosion in gas distribution pipeline networks

1.6. Acoustek System

The Acoustek system was developed from technology that The University of Manchester had used in Oil industry pipelines.

The basic principle of the system uses the principles of reflectometry. This involves sound waves being sent into the pipeline and the device then "listens" for the reflected sound. Analysis of the reflected sound can then be used to identify features in the pipe which the soundwave has encountered.

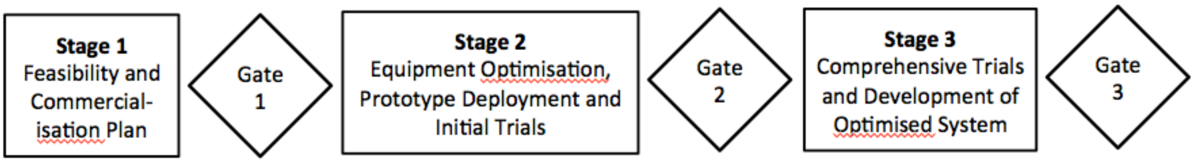
1.7. Project scope and objectives

The objectives are to:

- Identify the capabilities and limitations of using APR in gas distribution pipelines. In particular, this will develop a better understanding of the internal characteristics of gas distribution pipelines (i.e. build-up of deposits, water, and potentially other characteristics such as pipe wall condition and crack location etc) and the effect that they have on the attenuation of acoustic signals
- Determine whether the signals produced by the instrument can be interpreted and how effectively water ob structions and holes can be detected, located and characterised as the behaviour of acoustic signals in distribution network pipes is not well understood
- To determine the practical location range and accuracy of the above for different pipe diameters and scenarios

- Determine the most appropriate manner by which the instrument is connected to the pipeline.
- Develop the necessary data processing algorithms to enable features in the pipeline to be readily detected and identified. For example, distinguishing between the signals received from a partial blockage and a hole
- Trial the technology in the laboratory environment, abandoned mains and live network
- Produce three intrinsically safe prototype devices
- Train Network Licensee personnel in the use of the prototypes to enable them to trial the Method directly

The Project was broken down into three distinct phases with stage gates at the end of each phase.



Stage 1: the business case for the project will be established, together with the principal application areas for the technology. Initial laboratory work will be completed to better understand the behaviour of acoustic signals within gas distribution pipelines and to determine the most suitable method to connect the equipment to live distribution pipelines. A prototype system will be developed and initial tests in the lab and a limited number of field trials, using abandoned pipes, conducted to better identify the capabilities and limitations of the system in gas distribution pipelines.

Stage 2: Following the stage 1 trials, the equipment will be modified to improve its capabilities and enable it to be applied to live residential gas distribution pipelines. Theoretical modelling work will be completed so that the response of a distribution network can be predicted. This modelling work will be incorporated in to a software package that will both operate the equipment and analyse and interpret the results from any survey. Approximately 15 field trials will be undertaken during this stage of the project and the results from these trials will feedback in to the optimisation of the equipment and the validation (and modification where necessary) of the modelling work and software. The design for a prototype system will be available at the end of this stage.

Stage 3: Three prototypes will be developed and two of these will be distributed to teams of maintenance staff working for either the gas distribution companies or Steve Vick International Ltd. Training courses will be held for these teams, who with technical support from the University of Manchester, will complete at least 20 field trials of the technology. The results of these trials will be continuously fed back to the technical team at the University of Manchester, who will continue to modify and improve the system.

Full project registration, progress and closure information which was submitted to Ofgem can be found at: http://www.smarternetworks.org/Project.aspx?ProjectID=1481#downloads

2. Investment Proposal

This project aimed to develop a new method of accurately surveying live gas pipes with the minimum amount of excavation required

This project formed part of the Gas Distribution Networks (GDNs) new funding mechanism for innovation projects known as the Network Innovation Allowance (NIA). Total expenditure was estimated to be £646.9k costs under NIA. The project aligns to the target high cost areas of Emergency and repair identified in the Innovation Strategies of all GDNs.

The project was approved by all GDNs in 2014 and work commenced in May 2014.

3. Design and Development

3.1. Summary

This project involved development of existing technology used in the offshore gas industry to allow it's use and prove it's benefits when used in the GB gas distribution network.

During the first phase of the project a prototype system that can be deployed on air filled pipes was developed, tested and evaluated in the laboratory and in the field. In accordance with the project plan, the following key project milestones were achieved:

1. Specify requirements which must be satisfied by the pipeline monitoring tool that is to be developed in this project.
2. The development of a working prototype system for testing on abandoned mains.
3. Generation of a mathematical model able to estimate the acoustic behaviour of a straight length of pipe.
4. The use of a laboratory based pipe arrangement to simulate typical problems and evaluate hardware, software and mathematical models.
5. Successful field trial on an abandoned gas main.

3.2. Prototype system

The prototype hardware is a speaker-microphone system that can be connected to a gas main using a 1" BSP threaded connection. A schematic showing the hardware layout is presented in Figure 001.

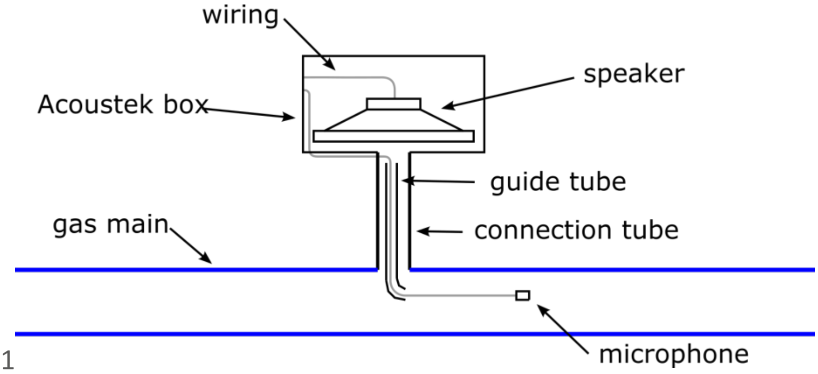


Figure 001

The microphone is inserted 200-500 mm into the gas main while the speaker is located outside the main but is in direct contact with air in the main. The hardware is connected to a laptop via a Peli case that contains all the necessary amplification and data acquisition equipment. Figure 002 is a photograph of the system including the Peli case.

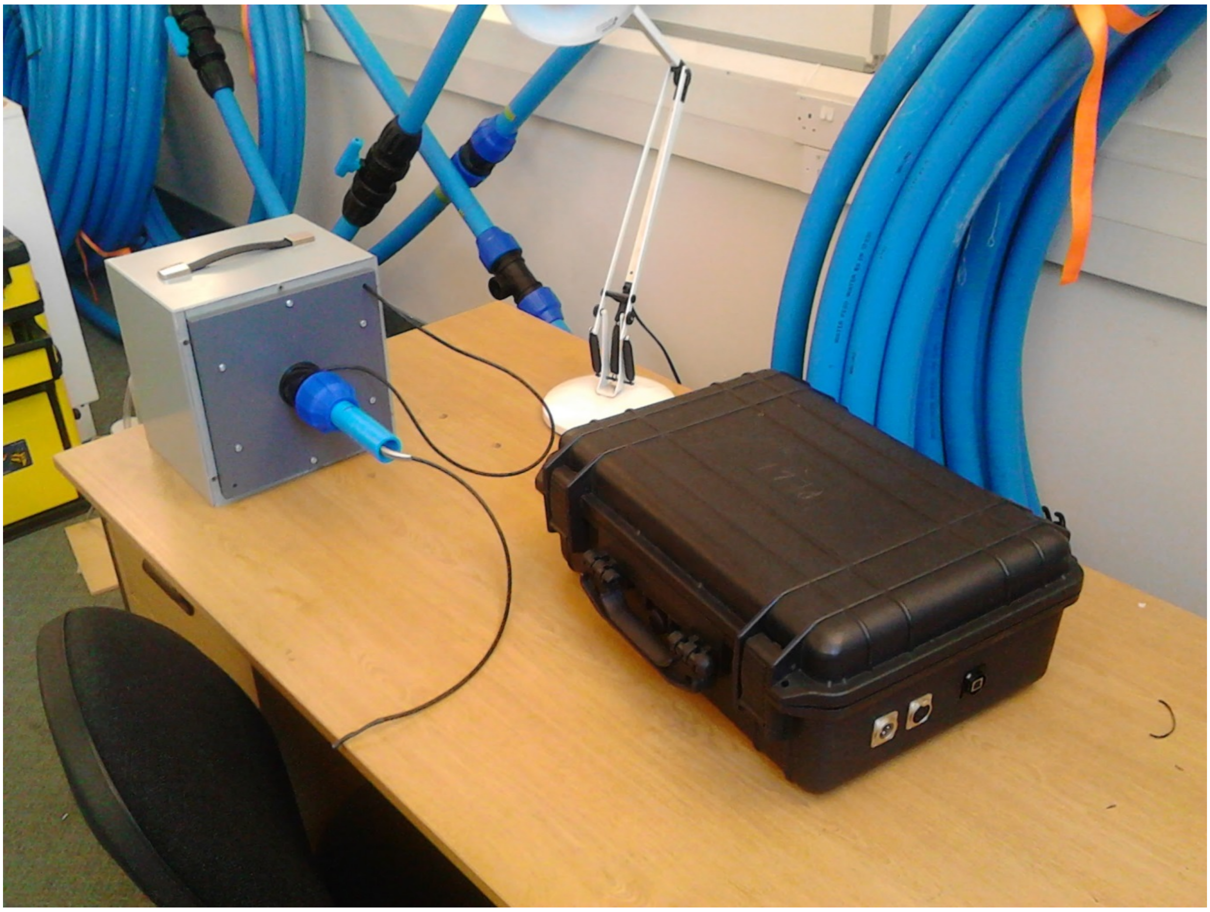


Figure 002

3.3. Laboratory testing

To evaluate the prototype system and the mathematical model a series of tests were performed in the laboratory using 50 mm MPDE pipe, Figure 003 shows the layout used for testing.

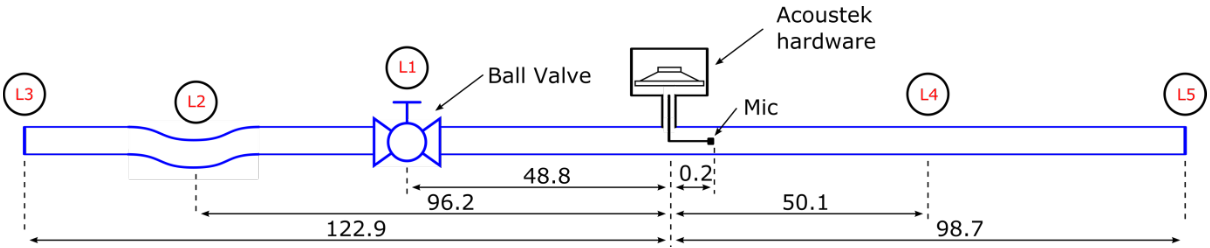


Figure 003

Table 001 lists the features present in the pipe and their location for each of the six tests. For each test two measurements were taken, first with the microphone installed in the main to the right of the Acoustek hardware facing L4 (as shown in Figure 003 and second with the microphone installed in the pipe to the left of the Acoustek hardware, facing L1. Taking readings at two different microphone locations gives directionality, allowing us to determine if a given feature is in the pipe section to the left of the Acoustek hardware or in the section to the right.

	Pipe feature	Location
Test 1	Clear pipe	n/a
Test 2	Partially closed ball valve	L1
Test 3	Fully closed ball valve	L1
Test 4	300 ml water pool	L2
Test 5	25 ⌀ 200 mm long solid cylinder inside pipe	L4
Test 6	25 ⌀ 200 mm long solid cylinder inside pipe 32 ⌀ 200 mm long solid cylinder inside pipe	L4 L2

Table 001

Figure 004 shows the simulated and measured responses of the pipe system shown in Figure 003 when it is free from features, as per test 1 in Table 001. Appendix 1Figures 004-009 present the results from tests 2-6 (Table 001) where additional features are present in the pipe. In tests 2-6 the results were analysed in a way that mimics the proposed analysis method of real pipe systems. The top plot inAppendix 1Figures 004-009 shows a simulation of the clear pipe that can be generated once the expected pipe layout is known but before testing. The second plot is the measured response, as would be taken on site. By comparing the expected response (top plot) with the actual response (middle plot) it is possible to identify any unexpected signal features and give an idea of the location and geometry of the item(s) causing these signal features. The bottom plot in Appendix 1 Figures 004-009 shows a simulation of the pipe that includes the physical item(s) that are suspected to be causing unexpected signal features. This simulation is used to confirm the presence of unexpected pipe features (water pools, misbehaving valves, unknown services), to give precise location of both expected and unexpected pipe features and to give information regarding the size of any unexpected pipe features. The results and analysis from each of the six tests are discussed in the captions of Appendix 1 Figures 004-009.

3.4. Case study - Survey of abandoned gas main on Westmorland Road

3.4.1. Test details

Date of testing: 6th October 2014

Location: 73 Westmorland Road, Greenock, Inverclyde, PA16 0TS

Network operator: Scotia Gas Networks

Persons present: Keir Groves (UOM), Omar Aldughayem (UOM), Alex Stewart (SGN), Alex Gardner (SGN)

Pipe details: 190 m, 4" spun steel main with access at one end

The testing was performed using the prototype Acoustek® hardware as shown in Figure 002. Appendix 2 Figure 010 shows the layout of the abandoned gas main, the location of the attached Acoustek® hardware and the location of significant features in the pipe system. All measurements were taken with a measuring wheel. Photos of the excavation and the connected hardware are included in the attached folder. The gas main and all connected spurs were made of 4" spun steel pipe. Prior to our arrival on site the gas main had been abandoned, capped and purged with air.

3.4.2. Results

Appendix 2 Figure 011 shows the acoustic impulse response of the pipe system. In Appendix 2 Figure 011 the primary reflections from each of the features marked inAppendix 2 Figure 010 can be clearly seen. As well as the primary reflections, several other features are present in the signal; the location and shape of these features correlate well with the expected location and shape of re-reflected signals, e.g. at ≈42 m the second reflection of F2 is clearly seen.

The speed of sound was calculated to be 406 m/s by calibration with the known location of F4, this is much higher than expected. At the measured temperature (11.6 °C) the speed of sound in air at atmospheric pressure is ≈338.4 m/s. The most reasonable explanation for this discrepancy is that there is still a large quantity of natural gas in the pipe system. Using gas composition software it was determined that a mix of 90% natural gas and 10% air results in a speed of sound close to 406 m/s, a PDF screen shot of the gas composition software output is included with this report.

3.5. Conclusion – stage 1

Using the newly developed hardware and mathematical models a tool has been developed that is capable of locating and characterising unknown features in unbranched air filled pipelines. The efficacy of the new hardware, software and mathematical model has been validated using a set of well controlled laboratory tests. The tool was also evaluated on an abandoned gas main and was shown to perform well, giving clear indication of all known features in the branched gas main. After discussion with the Gas Networks it was also decided that the system did not need to be ATEX certified but merely a pressure vessel which could be attached through existing means to a live gas main. This allowed the project to continue without the need for specialist certification.

4. Prototype System

4.1. Summary

Stage two of the Acoustek® project was largely concerned with three key deliverables;

1. A prototype hardware system that can be deployed on live gas mains;
2. Operational software that drives the hardware and includes pipe simulation facilities
3. Successful completion of 15 or more field trials and delivery of a report detailing the findings.

All deliverables were completed in full and on schedule.

The full Acoustek® echo location system, comprising hardware and software, performed without fault in 18 field trials on live gas mains. Figure 012 shows the complete Acoustek® system in use on a live gas main.

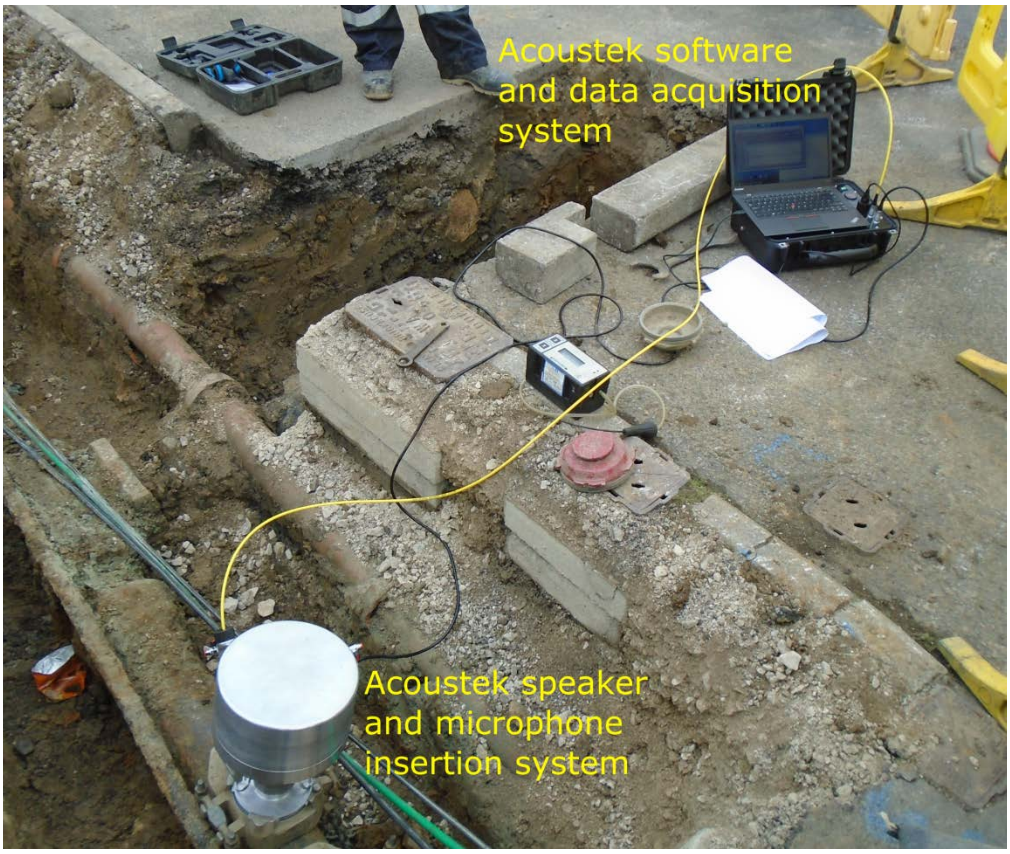


Figure 012

The Acoustek® system produced results that were predominantly in line with specification, as set out in stage one. During the field trials, the tool was able to detect, locate and characterise numerous pipe features that were either out of range of the CCTV or in one case simply missed by CCTV. The only significant aspect of the tool's performance that did not meet specification was location accuracy. This was due to a difficulty in calculating the speed of sound in a gas flow. The gas composition, speed of flow and relative humidity of the gas all contributed towards this difficulty which meant the accuracy of the system was reduced over the live trials. A method for improving this is laid out in the proposal for the next phase of the Acoustek® project.

4.2. Acoustek® system for use on live mains

4.2.1. The equipment

The present system is comprised of three main elements, the Acoustek® hardware that attaches directly to the gas main, the measurement and analysis Peli case and a laptop running the Acoustek® software.

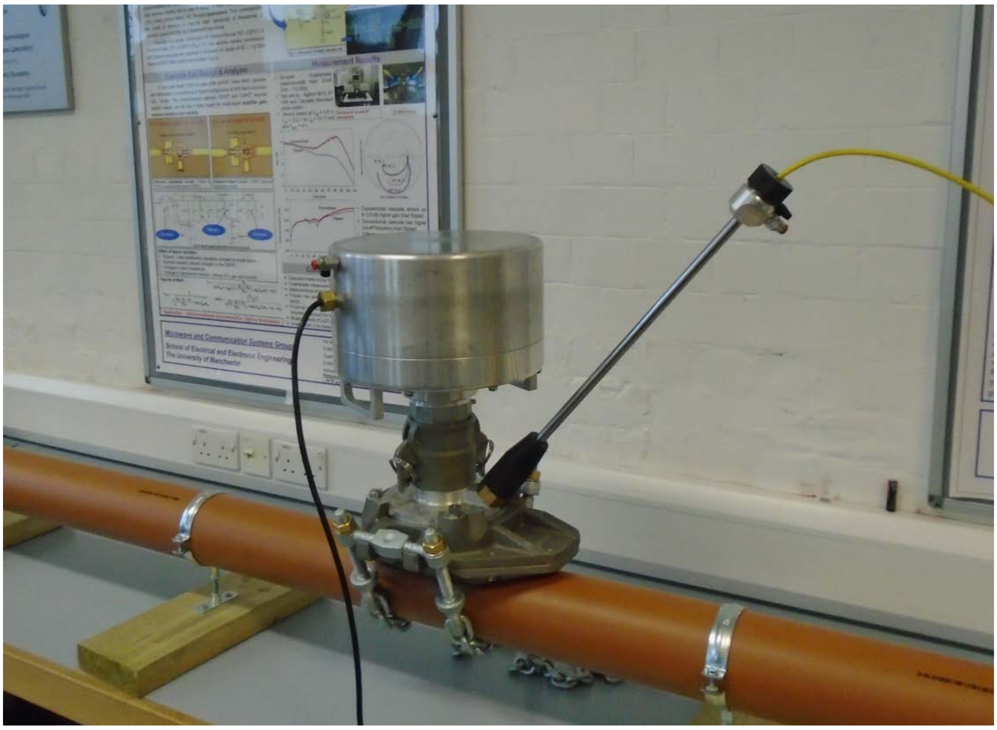


Figure 013

Figure 013 shows the complete hardware assembly that attaches to the gas main; this assembly is made up of 5 components, the WASK base, the WASK adapter, the speaker, the microphone launch tube and the microphone cable, as per Figure 014.

Figure 014

The Peli case (Figure 015) contains all of the electronics required to drive the Acoustek® system; the laptop (Figure 016) sits neatly inside the Peli case.

Figure 015

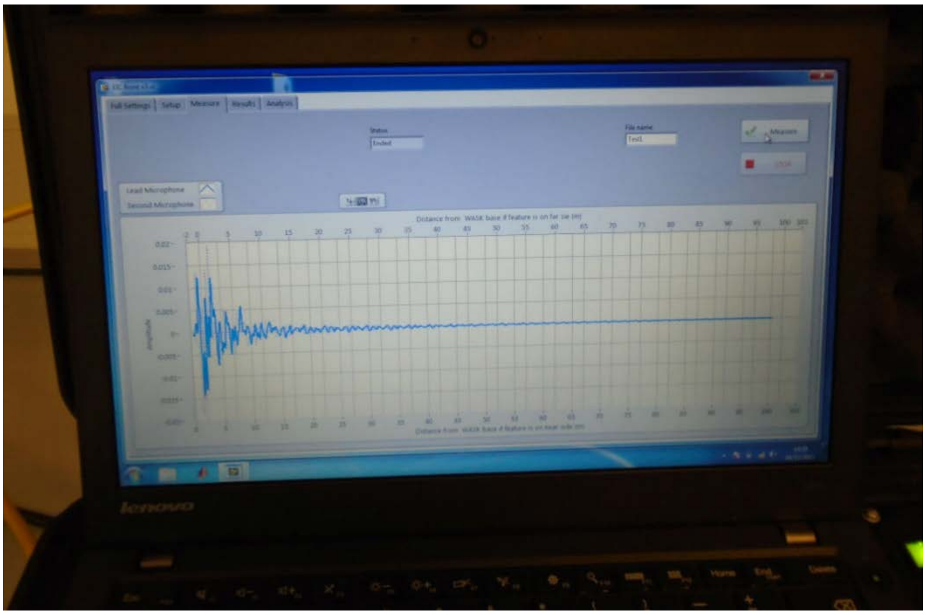


Figure 016

4.2.2. Safety and documentation

During stage one it was ascertained that the Acoustek® system would not need to be fully ATEX certified in order for it to be approved for use on live gas mains. After discussion all the Gas networks agreed thatthis may not be necessary and, Instead, the equipment has the facility to be fully purged with gas thus removing the explosion risk. Alongside the production of the hardware, appropriate safety documentation (G23 documentation including risk assessment and method statement) was produced and has been approved by NGN, SGN and NGG ready for live field trials.

5. Field trials

5.1 Introduction

The purpose of the live field trials was:

- To determine the practical location range and accuracy of the above for different pipe diameters and scenarios
- Determine the most appropriate manner by which the instrument is connected to the pipeline.
- Develop the necessary data processing algorithms to enable features in the pipeline to be readily detected and identified. For example, distinguishing between the signals received from a partial blockage and a hole
- Confirm the outputs of the lab tests are replicable in a real world environment
- Produce the Method statement and draft work procedure to form part of the G23 field trial approval document (Included in Appendix 3)

During the field trial stage a total of 41 field trials were completed successfully on live mains across both Northern Gas Networks and SGN. These initial trials were completed in NGN and were confirmed by partial CCTV camera surveys.
SGN compiled a comprehensive Operations procedure and risk assessment. In addition operating instructions were compiled and added by University of Manchester staff in order to provide a full field instruction manual which included all procedural and safety requirements to operate Acoustek in a live mains environment. In additional a comprehensive Feedback form for Operatives was compiled and completed for each job to give instant feedback on the system performance. This allowed SGN to complete a further 10 trials were the mains were fully CCTV survey. A further 10 trials were also completed in NGN.

The fully survey CCTV jobs proved the system to be fairly accurate in locating known features within the pipeline. It also proved the ability of the system to locate a number of different types of feature from offtakes, cap ends, blockages, size reductions and syphons.

5.1.1. Summary of stage 2 live field trials

During stage two, the Acoustek® Hardware was used in 21 live trials on the NGN network. At each of the 21 trials the Acoustek® system, both hardware and software, functioned properly and delivered results in line with its specification. The tool proved capable of reliably detecting large pipe features such as tees and capped ends at long range; in live trial 12 an excavated equal tee was clearly detected and characterised at a distance of 164 m. Throughout the course of the testing the readouts from the Acoustek® equipment were clear and repeatable; in live trial 15 the pipe layout was known over the functional range and all signal features tied in with features present in the pipe network. Appendix A presents the results from the 8 field trials that best highlight the ability of the tool to detect features such as tees and blockages at long range, as per the specification.

During the course of the trials it became apparent that the speed of sound in the gas present in the network was not as constant as expected, rather the speed of sound changed with time and location. The speed of sound is used to calculate the distance to a pipe feature and therefore having an accurate measurement is vital to good location accuracy. Calculating the speed of sound from gas mix information, as was initially proposed, is less than ideal due to a lack of reliable gas mix data. It is proposed that in the future a device is constructed that measures the speed of sound in the gas directly; this tool should be incorporated into the Acoustek equipment. To reduce the size of excavations and facilitate the use of Acoustek® equipment with core and vac systems it is suggested that a future redesign should reduce the system size to below 600 mm diameter. Other suggested design modifications include; further ruggedisation of the hardware, the incorporation of an automated feature detection algorithm and simplification of the user interface that controls the pipe simulation element of the Acoustek® software.

5.1.2. Key findings and lessons learned

- The stage 2 field trials have proved that the Acoustek® echo location tool is capable of detecting large features such as equal tees, capped ends and siphon pots at distances of up to 200 m. It is believed that the tool would work over an even greater range but no suitable trial sites have been available. Live trials 8, 12 and 17 demonstrate the efficacy of the system at long range.
- Readouts from the Acoustek® system always agree well with what is visible on the ground or using an inspection camera. At locations where the makeup of the network was known, all significant signal features on the Acoustek® readouts could be accounted for.
- The system produced highly repeatable results in noisy environments. Furthermore, results were repeatable when the microphones were removed and reinserted between measurements.
- Although the system has proven to be very effective at identifying pipeline features, its distance readings at long range were out by up to 1.4 % (Live trial 12). This would equate to a maximum excavation length of 4.7 m. To further the ability of the Acoustek® tool in reducing excavations in number and size, the location accuracy of the tool should be improved.
- The location accuracy of the tool is currently limited by the accuracy of the speed of sound estimate. During the live trials it became apparent that calculating the speed of sound at a given site using the gas properties is unreliable due to the lack of accurate data concerning the gas mix, fluid temperature and fluid pressure. It should be possible to overcome this limitation by measuring the speed of sound in the fluid directly.
- The trials were conducted by following a camera operative and testing alongside them. Since the camera was generally being used to locate services over a relatively short range, not all locations were well suited to verifying the performance of the Acoustek® tool. Better vetting of test locations would help to clarify the savings in terms of time, money and disruption that the tool can facilitate.
- The hardware and software developed proved to be robust. The system performed flawlessly at all 18 sites, sometimes in very bad weather.
- The large size of the hardware that connects to the main was an issue in some excavations. The large diameter of the speaker housing and the angle of the insertion tube meant that, on several occasions, fitting the equipment to the pipe was difficult and the orientation of the microphone insertion was restricted.
- Simulating pipe layouts on site was impractical due to the complexity of the simulation interface.

5.1.3. Suggested improvements

- To improve location accuracy it is proposed that a small device capable of measuring the speed of sound in the gas main on site is developed and incorporated in the system.
- Change to an embedded PC or ruggedised laptop to reduce susceptibility to water damage.
- Reduce hardware size - presently a smaller speaker and housing are being produced. In the future the system should be redesigned such that it may be used with a core and vac system.
- The front end of the simulation software should be simplified. Preferably a graphical interface where pipes and features (such as tees and reducers) can be dragged and dropped into the layout.
- Add software functionality to automatically identify and characterise large signal features.

6. Stage three – Test and optimise the prototype

6.1. Summary

The focus of this stage of the project was to test and optimise the prototype such that by the end of the stage the system is ready for commercialisation. Twenty live field trials were planned during this stage of the project, 10 with NGG and 10 with SGN. However, live trials with NGG were delayed beyond the project end date and as such only 10 live trials were conducted on the SGN network. All the live trials performed in stage three were done with all necessary SGN G23 documentation in place.

6.2. Stage 3 live field trials

6.2.1. Summary of stage 3 live field trials

During stage three of the Acoustek® project 13 live trials were performed on the SGN network. 20 trials were planned for this stage of the project spread across the SGN and NGG networks; however, trials with NGG were not possible within the project time-frame. In all of the 13 trials the Acoustek® hardware and software worked well and gave clear and accurate results that were in line with specifications. In live trial 19, a 4” main with known layout was scanned and all significant features were detected, including an equal tee and change to PE at 108 m. In live trial 20 the Acoustek® system gave useful information regarding a 6” main that could not be inspected with a camera due to its poor condition. In live trial 23 a siphon that was not known to the site operatives was found at 95 m, and later confirmed to be present by inspection camera. Live trial 31 saw the Acoustek® system used to check that around 500 m of main was free of blockages following a water ingress problem - features were found in a 6” main as far away as 354 m. The location accuracy of the system was always within 2 %. In keeping with ongoing system development, a new smaller sized speaker housing and ruggedised microphone assembly was used throughout the SGN trials. The upgraded components functioned well: Despite its smaller size, the new speaker caused no loss of power and the microphone assembly showed negligible wear. Good alignment is shown between performance specifications set out in stage one and system performance in field trials.

6.2.2. Lessons learned during stage three field trials

- The new smaller size speaker and housing has no detrimental effect on readings, signals received are slightly larger and sharper than those attained using the larger speaker.
- The new microphone assembly proved to be more robust than the initial design, showing no significant signs of wear after 13 trials.
- Siphons appear as very large expansions and the system cannot see beyond them.
- Stand pipes can be clearly located in 3” and 4” mains.
- The system can detect features at a range of 350 m in clean mains that are 6” or more in diameter.
- The system is not yet field ready for commercialisation due to issues which will be addressed if Phase 2 of the project goes ahead. Phase 2 would also see further improvements in the software and the ability to use the equipment from a 600mm core excavation.

6.3. Comparison between field trial performance and equipment specification

In stage one of the project system requirements were identified and documented. Table 003 presents the specifications set out in stage one and compares the specified performance to the performance achieved in live trials.

	Specification set out in stage one	Field trial findings
Target area	Detecting water ingress and locating the deposit of water.	Although only a small section of the live trials was related to a water ingress problem, the results suggest that the tool can detect water slugs in gas mains. In live trial 31 the system was used to check for water remaining in the network following a water ingress problem. The Acoustek® system proved to be useful in locating both known and unknown features such as tees, capped ends, siphons, stand pipes and blockages. The system was also used to confirm that features were not present in the gas main before insertion works went ahead.
Sensitivity	Detecting a 20% blockage that is sustained for > 1 m.	In live trial 21 a partial blockage caused by an anaerobic sealant build up was detected. The exact dimensions of the blockage were not confirmed but they are thought to be similar to the 20% for > 1 m specification.
Range	50 mm pipe: up to 100 m either side of insertion point. 100+ mm pipe: up to 250 m either side of insertion point.	The smallest pipe tested was 3" cast iron where the furthest confirmed feature detected by the system was 80.5 m away. In a 4" main the furthest confirmed feature was at 163.1 m. in a 6" main a feature was detected at 354.2 m. Range testing of the equipment was limited by the spacing of known features in the main rather than by limitations of the Acoustek® equipment. It was noted that the range of the equipment is reduced in gas mains that are particularly dirty and where large features are present in the path of the acoustic signal.
Pipe properties	Diameters ranging from 50 – 1200 mm.	The fitting system selected to connect to a live main is the standard WASK base. As such we are limited to metallic mains between 3" and 12" diameter. Testing was successfully performed on 3", 4" ,6" , 8" 10" and 12" metallic mains during the course of the trials.
Pipe material	Steel, cast iron, plastic.	As stated above, The system currently only works on to metallic mains because of the launch system. However, the echo location technique works with any pipe material because the sound travels in the gas and not in the pipe wall.
Location accuracy	Error of 0.5 m over a distance of 100 m.	The error of the current system is up to 1.5 m over 100 m. As discussed in the stage two field trial report, this is thought to be caused by variations in the speed of sound in the gas present in the main at different locations. A solution to this issue is proposed for phase two of the project.
Operating pressure	75 mbar or less; typically 25 mbar.	The equipment has been pressure tested and is rated to work on pipe pressures of up to 2 bar.
Connection	Via main following excavation; possibly by standard fittings.	The equipment is fitted to the main using a WASK base.
Portability	Equipment to weigh < 20 kg and fit in one or two Peli cases.	The current system weighs 18kg and fits in two Peli cases.

Table 003

7. Conclusion

From the output of the various project stages the Acoustek system proved it was fit for purpose as a survey tool on the GB gas Network. The initial offsite and subsequent on site live field trial tests proved the system was capable of locating pipe features in pipe ranges from 3" upwards and over distances in excess of 100 metres with very little loss of accuracy. The system was easy to use and used existing technology that all networks are familiar with, to allow insertion of the microphone and speaker system onto the live main. The results and outputs from the system were accurate and initial trials have suggested that, with training, Network Operatives will be able to identify features and target additional works with minimal excavation as the system has been proven over extended lengths >200 metres from a single survey location.

The real benefit of this system comes from reducing the number of excavations required to locate a leak. Based on the experience from a sample of successful applications of this system and the time saving shown it can be estimated that approximately two excavations, with an average volume of $0.25m^3$, were saved on average for each successful application.

If we apply a cost of £393/m^3 of reinstatement material plus £65/hour of contractor labour we can estimate a cost saving of £587.00 for each successful application of this system.

For clarity these calculations have been laid out in the table below.

Benefit	Quantification	Rate	Total Saving/Successful job
Reduction in Excavations	$0.5m^3$	£393/m^3	£197
Reduction in labour hours	6 hours	£65/hour	£390
			£587

Based on the outputs from the field trials the system is capable of surveying over 200 metres from single location with accuracy of 2% of distance (in certain circumstances much greater). On this basis when compared to a conventional camera survey on a job 200 metres long the CCTV system would require a minimum of two excavations to survey the same length. On jobs where we survey much longer lengths, and in particular on water ingress type jobs, the number of excavations would rise considerably.

Given that the system would appear to reduce the number of excavations required and that the survey can be carried out with results available in 10 minutes compared to hours it would appear that the system has potential to provide considerable savings over conventional survey techniques. It should be noted that this technique is not seen as a replacement for conventional cctv surveys but is seen as a supplement to target the CCTV survey instead.

8. Recommendations

Although results of the project proved favourable, with the equipment producing accurate and replicable results on all live trials there were some issues identified.

- The speed of sound used by the system appeared to vary due to the makeup and flow characteristics of the gas network being surveyed. This led to reduced accuracy on location of the features being identified.
- The graphical outputs require some knowledge of the technology to be able to interpret accurately
- The built in system simulator although a useful tool is time consuming and unlikely to be used in the field
- The output software needs some additional functionality to make interpretation of the results in the field quicker and more accurate.

In order to improve both the accuracy and the usability of the equipment for Gas Network Field Operatives it was thought that some improvements to the systems would enhance its use. The additional of a self-calibration system for the speed of sound within the gas flow would provide much improved accuracy of detection and improved software functionality would make the interpretation of results much easier for field staff. These combined with the reduced size and the ability to use the system within a 600mm core excavation would increase the scope of use to include deployment by core and vac techniques.

It is, therefore, recommended that a further Project Phase be undertaken to address the issues raised above by inclusion a calibration system, software updates and a change in the use of the simulator to be used for training rather than onsite analysis. This additional phase would also provide each of the participating Gas Networks with equipment which would allow an extended field trial of the updated system by Network Operatives.

Appendix A - Stage 2 field trial results

All 18 field trials were successful and produced readouts in line with expectations. However, some of the trial sites were not suited to testing the full capabilities of the system. Presented below are the results from the 8 field trials that best highlight the ability of the tool to detect features such as tees and blockages at long range, as per the specification.

Live trial 5 - Mount Ave, Huddersfield

Date: 10/09/15

Main: 4” spun iron

Condition: Some debris in both directions, a lot of tappings and repairs local to the excavation.

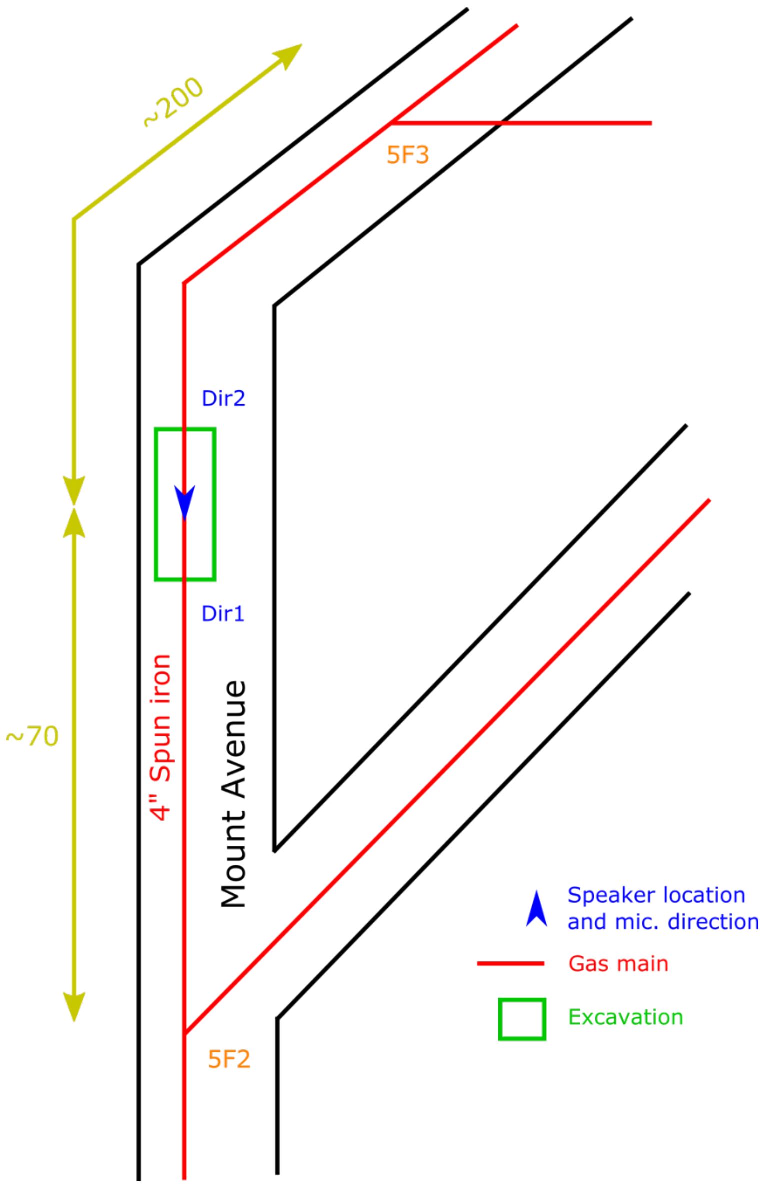
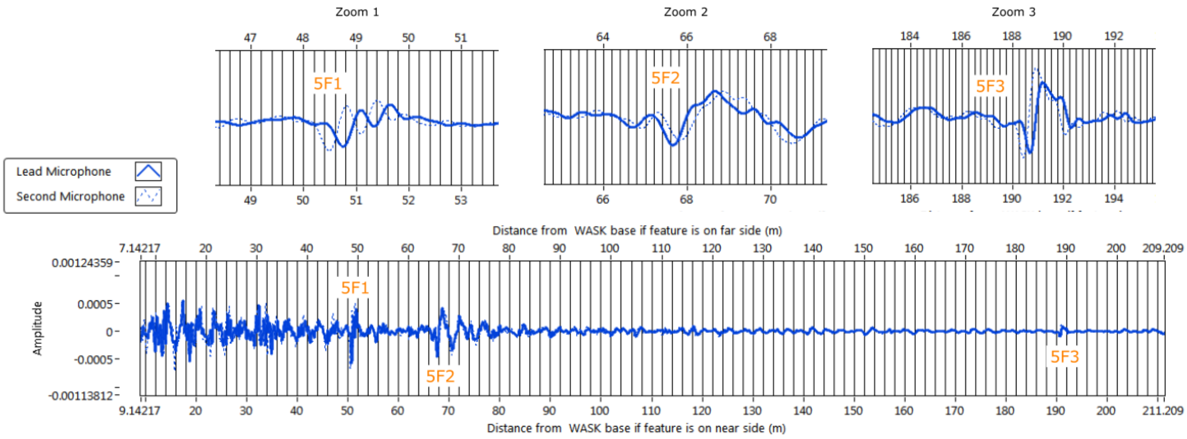


Figure 017



Feature code	Features detected	Direction	Distance	Confirmed
5F1	Large branch/expansion	Dir 2	48.7 m	No
5F2	Large branch/expansion	Dir 1	67.7 m	Present on drawings
5F3	Large branch/expansion	Dir 2	188.7 m	Present on drawings

Figure 018

Notes: Figure 017 gives the site layout and Figure 018 shows the overview plot from the Acoustek® software and presents the table of features detected by the Acoustek® equipment. The main was inspected with a camera 22.5 m in Dir 1 and 21.1 m in Dir 2 investigating a leakage report; it was then tested using the Acoustek® Equipment. Feature 5F1 could not be confirmed on site; features 5F2 and 5F3 lined up well with drawings but no accurate location information was available.

Live trial 6 - Dawtrie Street, Castleford

Date: 08/10/15

Main: 4” steel,

Condition: Main looks clean and free of debris.

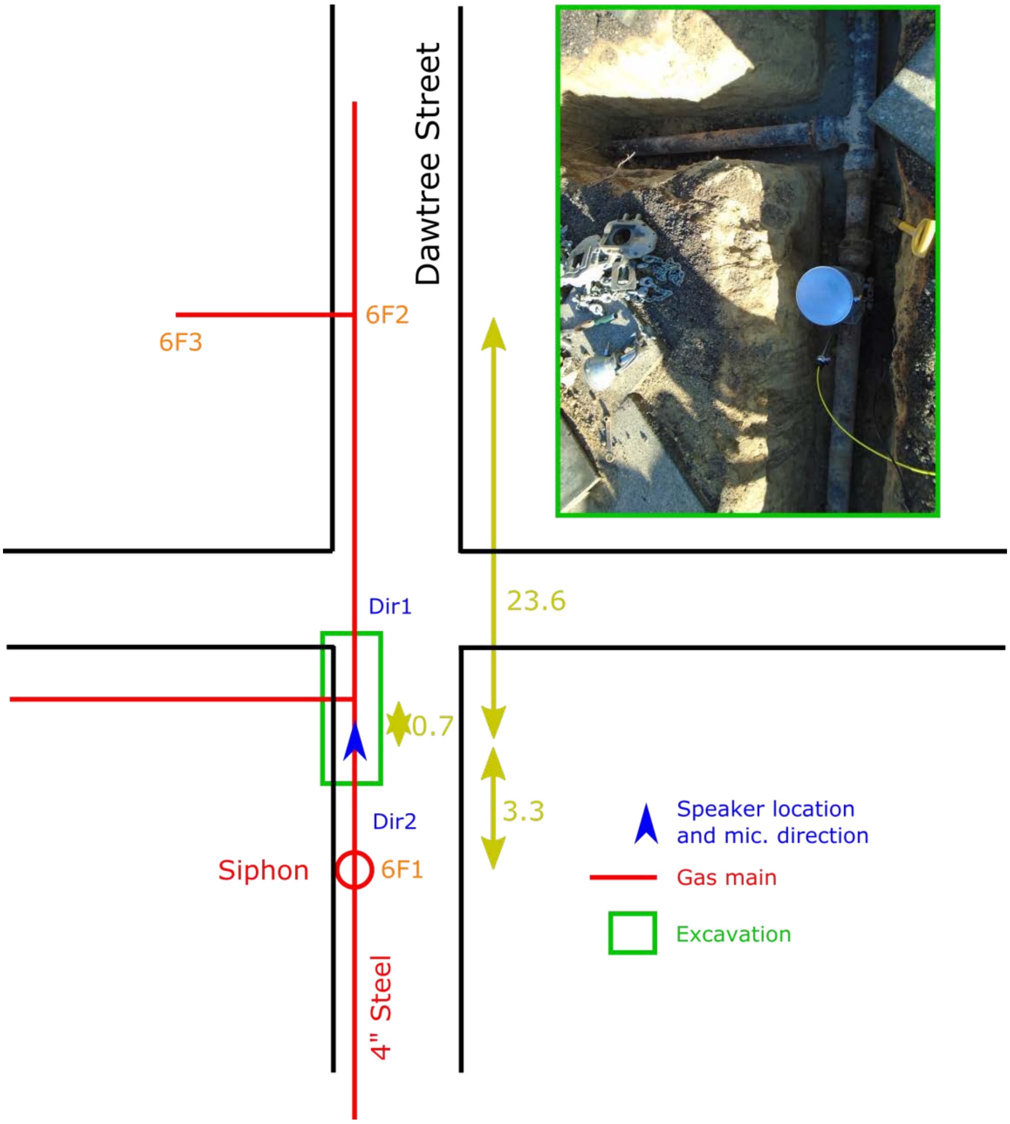
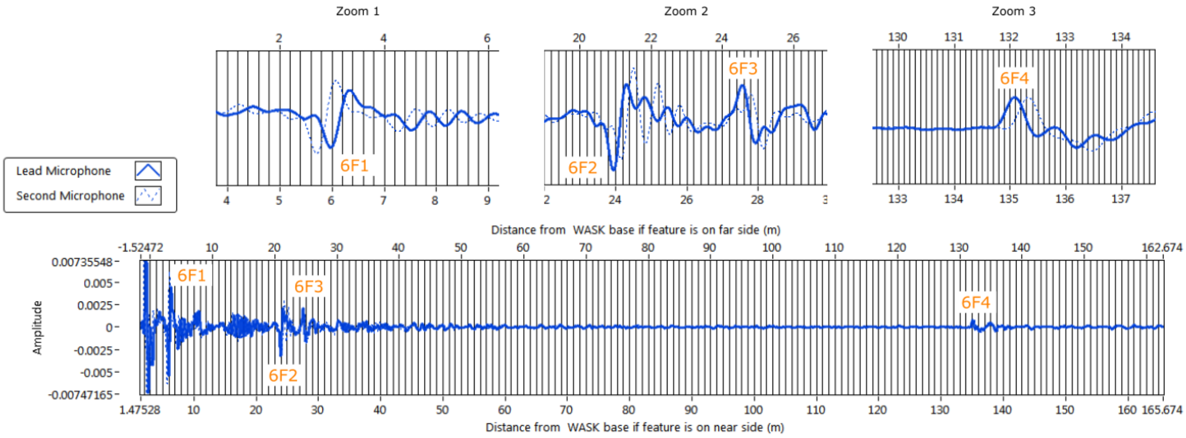


Figure 019



Feature code	Features detected	Direction	Distance	Confirmed	Location error
6F1	Large branch/expansion	Dir 2	3 m	Siphon visible at 3.3 m	9.1 %
6F2	Large branch/expansion	Dir 1	23.7 m	Equal tee found by camera at 23.6 m	0.4 %
6F3	Suspected branch cap	Dir 1	27.3 m	No	N/A
6F4	Large blockage or cap	Dir 1	134.8 m	No	N/A

Figure 020

Notes: Figure 019 gives the site layout and Figure 020 shows the overview plot from the Acoustek® software and presents the table of features detected by the Acoustek® equipment. The main was inspected with a camera 61 m in Dir 1 to check for problems prior to insertion with 90 mm PE; it was then tested using the Acoustek® Equipment. To reduce interference from the branch immediately in front of the speaker location the microphones were inserted 3 m into the main. Confirmed features 6F1 and 6F2 were clearly visible in the Acoustek® results (Figure 020), as would be expected the siphon pot gave a signal shape similar to a branch. Feature 6F4 could not be confirmed since the section of main tested was not present on drawings.

Live trial 7 - Lindsay Avenue, Wakefield

Date: 08/10/15

Main: 4" steel

Condition: Main looks clean and free of debris.

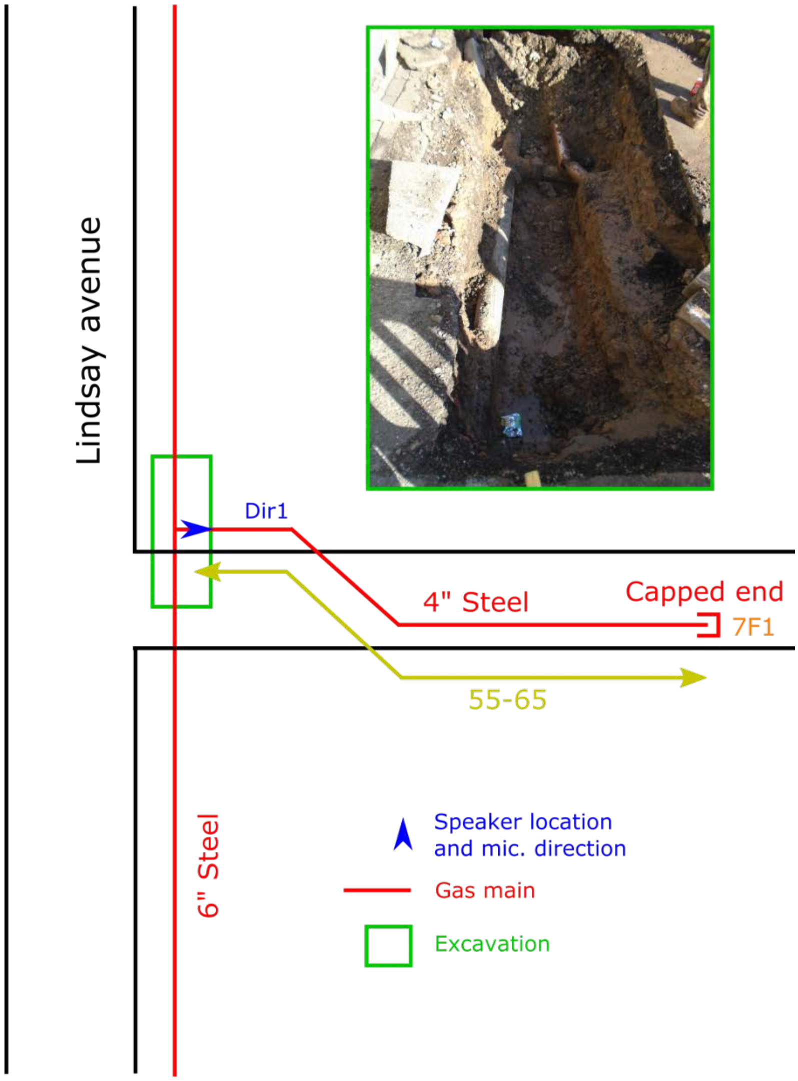
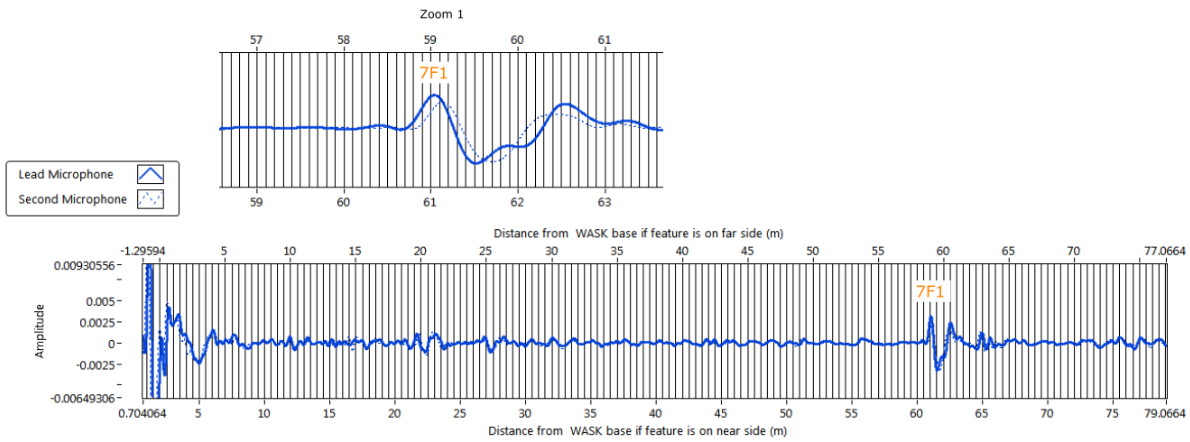


Figure 021



Feature code	Features detected	Direction	Distance	Confirmed
7F1	Large blockage or cap	Dir 1	61.0m	Cap on drawings

Figure 022

Notes: Figure 021 gives the site layout and Figure 022 shows the overview plot from the Acoustek® software and presents the table of features detected by the Acoustek® equipment. Site operatives were interested in locating services and the capped end. The main was inspected with a camera 26.5 m in Dir 1 to find services; it was then tested using the Acoustek® equipment. The camera was able to pinpoint local services but was not able to locate the capped end. The Acoustek® equipment successfully located the capped end at 61.0 m.

Live trial 8 - Moor Bottom Rd, Halifax

Date: 08/10/15

Main: 4” steel

Condition: Main looks clean and free of debris.

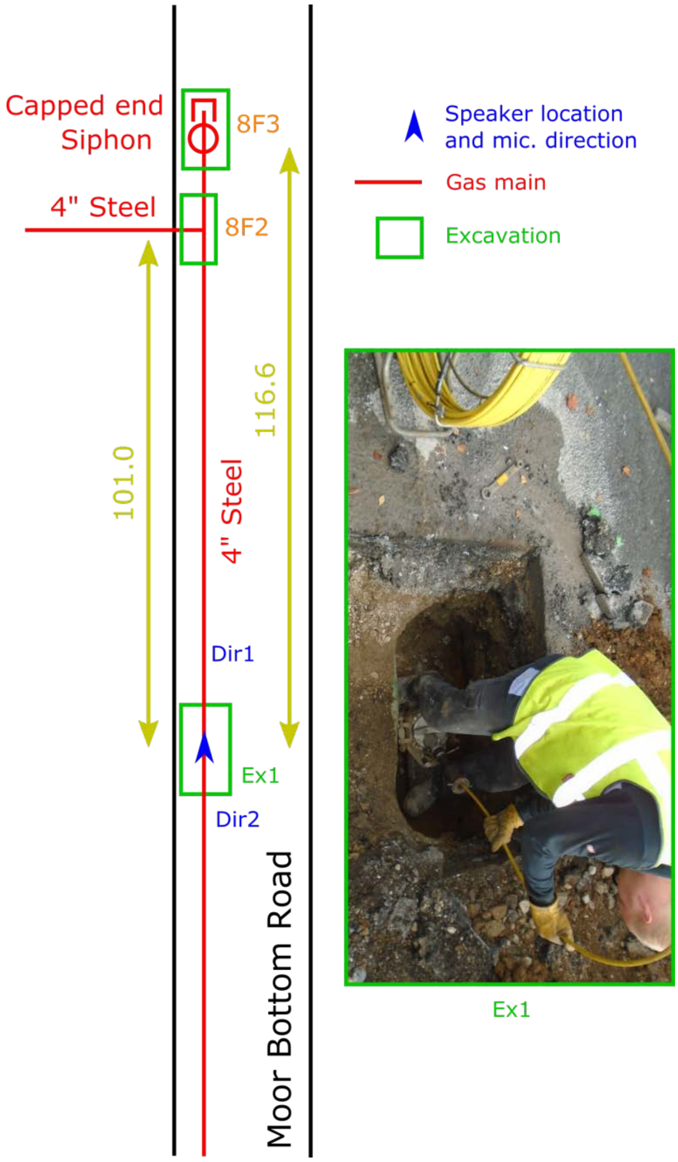
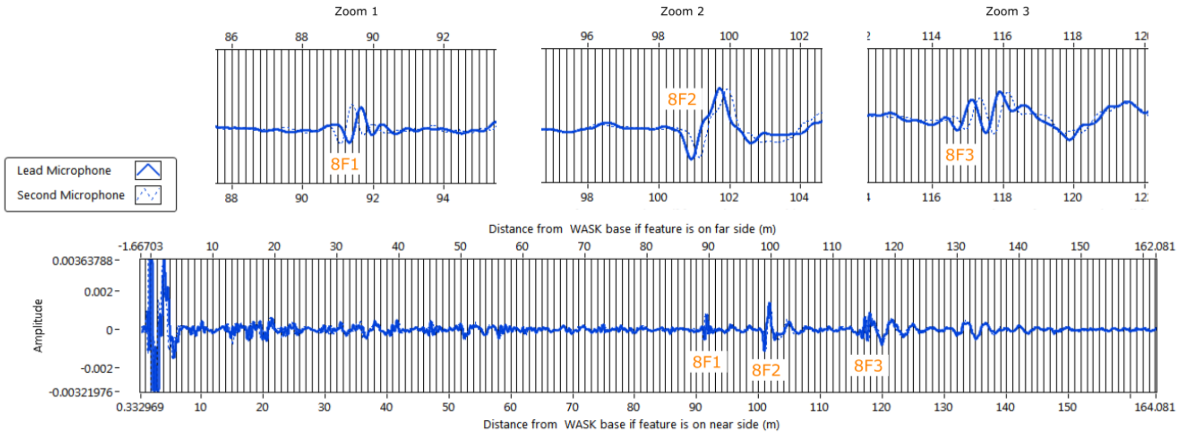


Figure 023



Feature code	Features detected	Direction	Distance	Confirmed	Location error
8F1	branch/expansion	Dir 2	89.3 m	No	N/A
8F2	Large branch/expansion	Dir 1	100.9 m	Branch visible at 101.0 m	0.1 %
8F3	Large feature, strangely shaped	Dir 1	117.1 m	Siphon then cap visible at 116.6 m	0.4 %

Figure 024

Notes: Figure 023 gives the site layout and Figure 024 shows the overview plot from the Acoustek® software and presents the table of features detected by the Acoustek® equipment. The gas main was inspected with camera 62 m in Dir 1 and 56.8 m in Dir 2 to find services; it was then tested using the Acoustek® Equipment. Distances were measured using a surveyor's wheel as excavations were present at significant locations. This measurement was used to calibrate the speed of sound for all other plots, hence the high accuracy of the readings.

Live trial 10 - Owton Manor Lane, Hartlepool

Date: 30/11/15

Main: 6” steel

Condition: Main looks clean and free of debris.

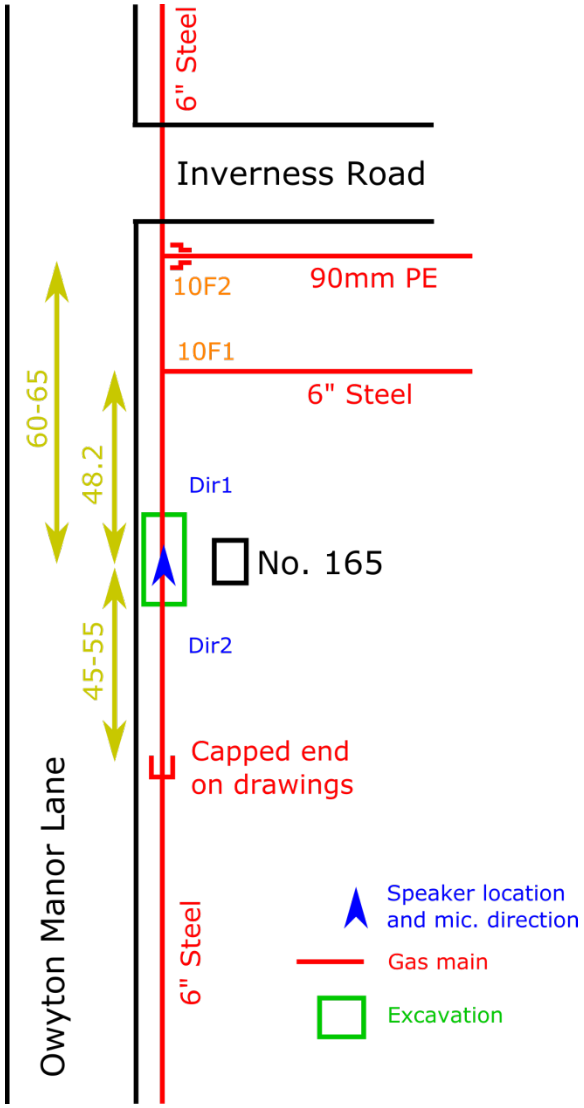
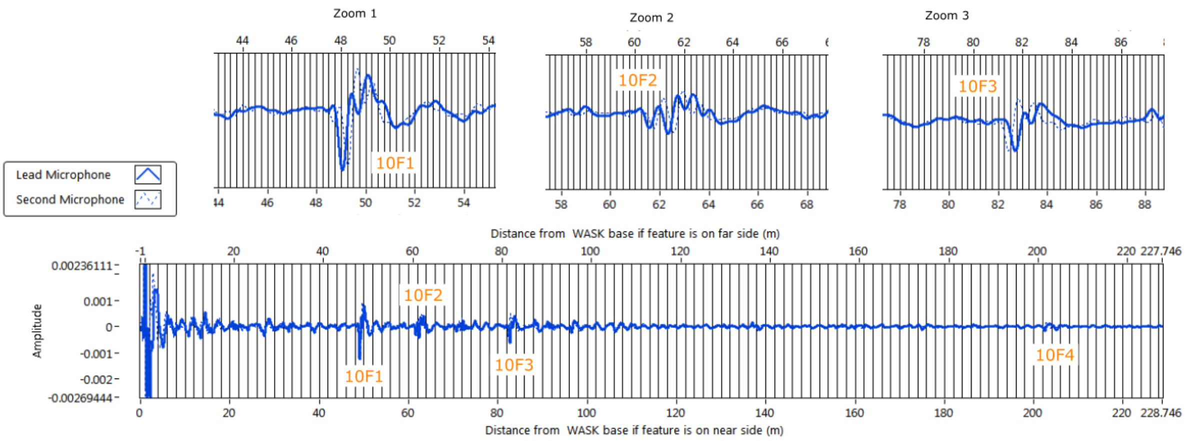


Figure 025



Feature code	Features detected	Direction	Distance	Confirmed	Location error
10F1	Large branch/expansion	Dir 1	49.1 m	Found with camera at 48.2 m	1.9%
10F2	Branch/expansion followed by feature	Dir 1	61.6 m	No	N/A
10F3	Large branch/expansion	Dir 2	81.4 m	No	N/A
10F4	Large branch/expansion	Dir 2	201.4 m	No	N/A

Figure 026

Notes: Figure 025 gives the site layout and Figure 026 shows the overview plot from the Acoustek® software and presents the table of features detected by the Acoustek® equipment. The main was due for replacement and drawings showed it to be capped somewhere between 45 m and 55 m in Dir 2. The main was inspected with a camera approximately 50 m in both Dir 1 and Dir 2 and no capped end was found; however, it was not possible to confirm that there was not a capped end using the camera alone due to its limited range. The Acoustek equipment was applied at the same location and due its greater range was able to confirm that there was no capped end in Dir 2, as is clear from the plot in Figure 026. The feature 10F1 in Figure 025 was located with the camera, marked out and measured using the surveyor's wheel. Other measurements are approximations based upon drawings, features on the road and the knowledge of site operatives.

Live trial 12 - Garth Meadows, High Etherley

Date: 30/11/15

Main: 8” steel

Condition: Main looks clean and free of debris.

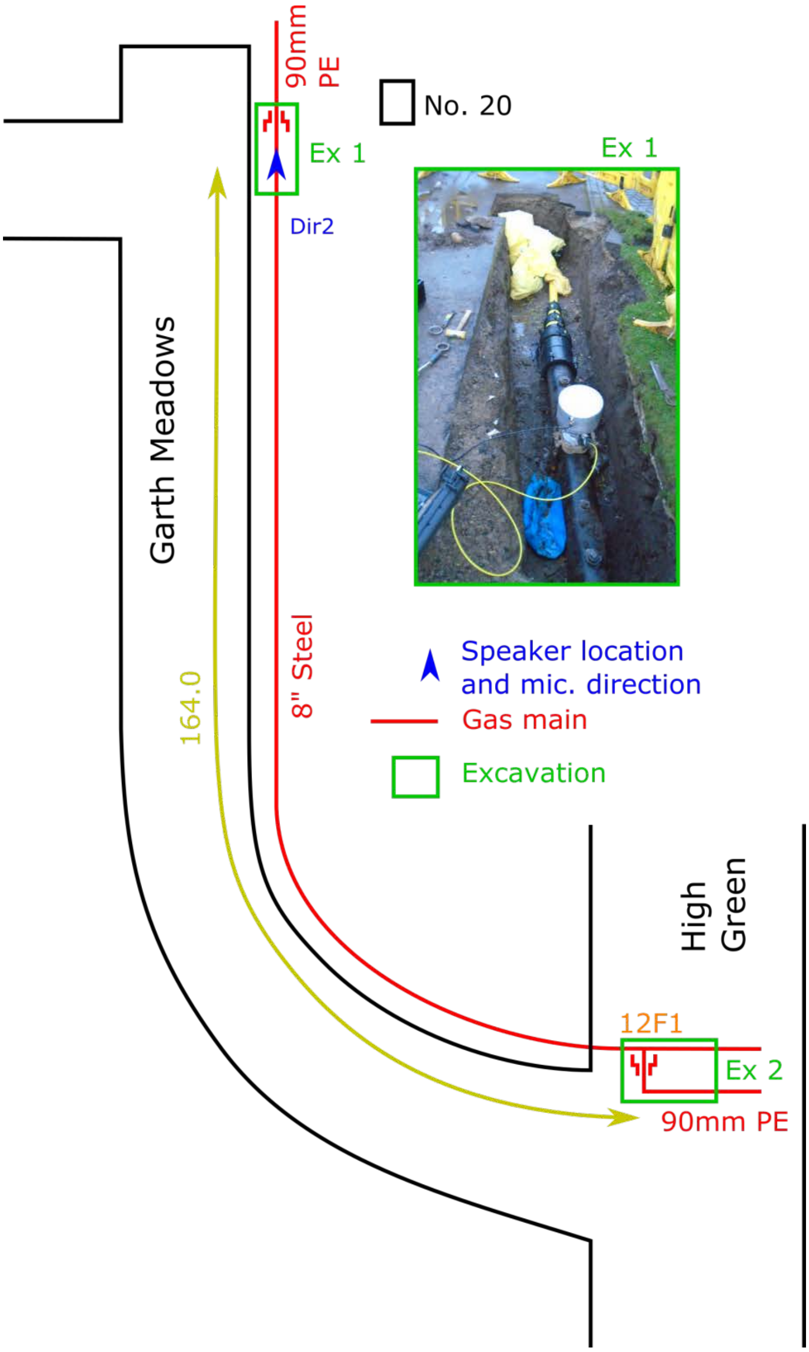
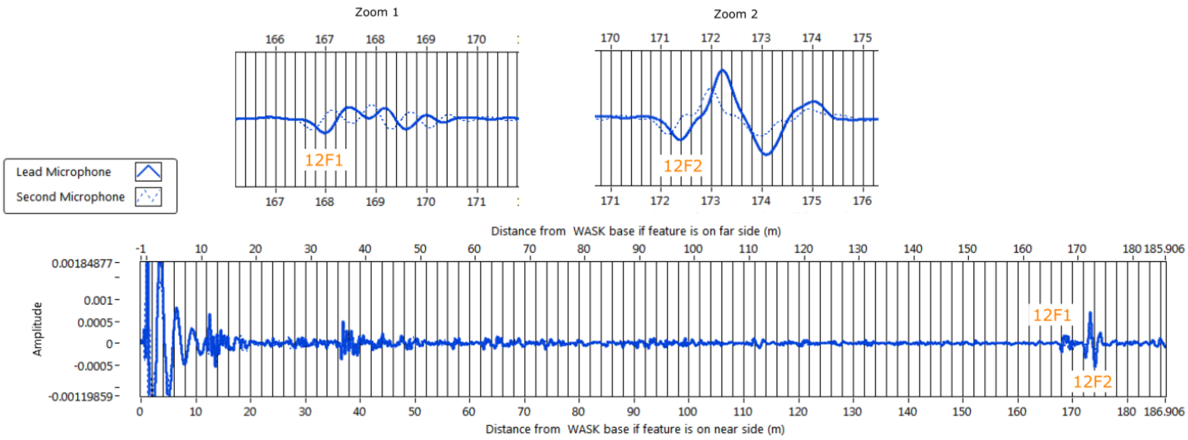


Figure 027



Feature code	Features detected	Direction	Distance	Confirmed	Location error
12F1	Branch/expansion	Dir 2	166.7 m	Measured with wheel at 164.0 m	1.6 %
12F2	Large branch/expansion	Dir 2	171.4 m	No	N/A

Figure 028

Notes: Figure 027 gives the site layout and Figure 028 shows the overview plot from the Acoustek® software and presents the table of features detected by the Acoustek® equipment. Main was due for insertion with 90 mm PE in Dir 2. The main was inspected with a camera in Dir 2 to locate services; it was then tested using the Acoustek® Equipment.. The Acoustek equipment clearly located feature 12F1 starting at 164 m, location error was 1.6 %. Feature 12F2 in Figure 028 was not confirmed on site although an equal tee on the far side of High Green (Figure 027) would be expected.

Live trial 15 - Stirling Road, Redcar

Date: 02/12/15

Main: 4” cast iron

Condition: Main looks relatively clean, some swarf and light debris.

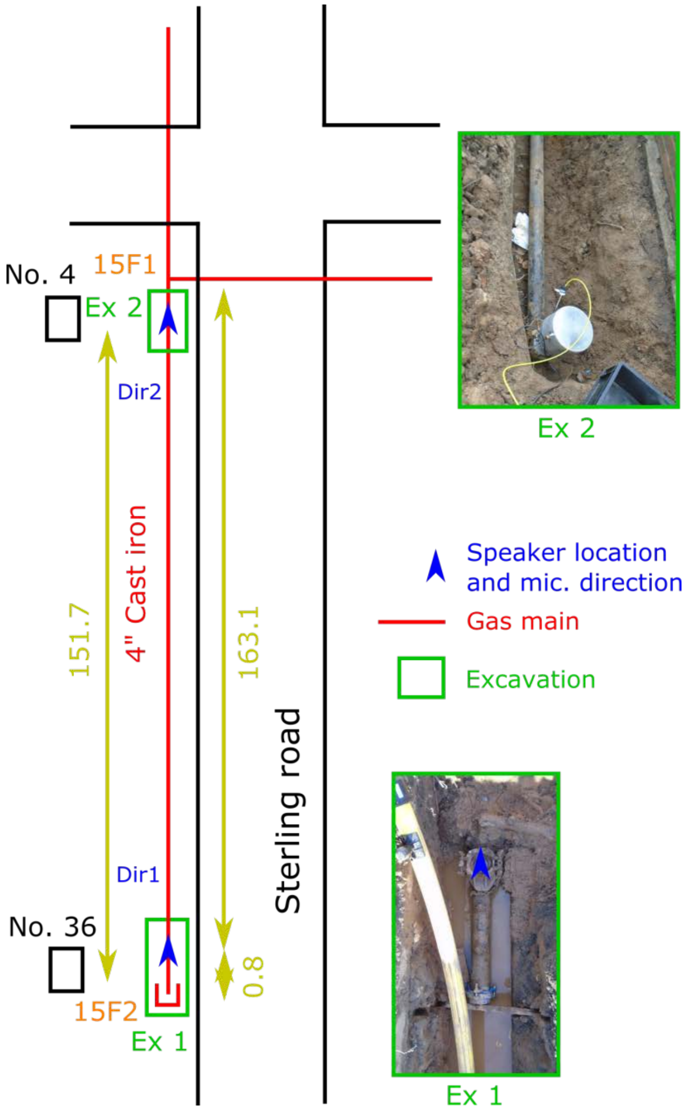
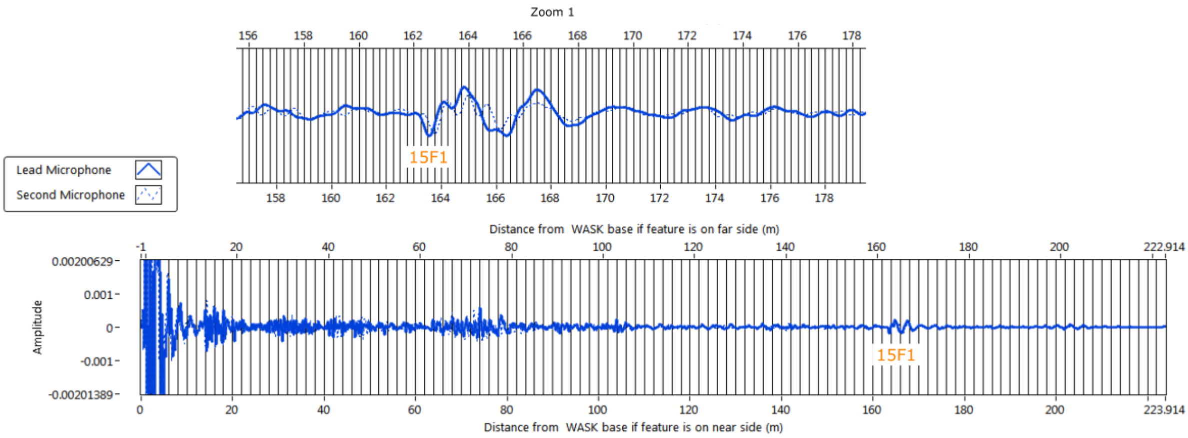
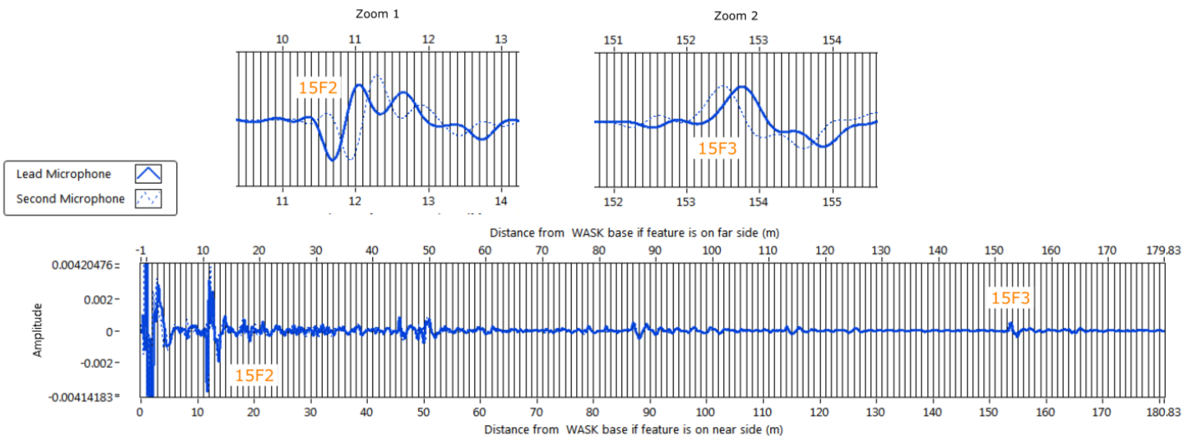


Figure 029



Feature code	Features detected	Direction	Distance	Confirmed	Location error
15F1	Branch/expansion	Dir 2	163.5 m	Measured with wheel at 163.1 m	1.6 %

Figure 030



Feature code	Features detected	Direction	Distance	Confirmed	Location error
15F2	Large branch/expansion	Dir 1	11.7 m	Found with camera at 12.2 m	4.1 %
15F3	Large blockage or cap	Dir 2	152.5 m	Measured with wheel at 151.7 m	0.5 %

Figure 031

Notes: Figure 029 gives the site layout, Figures 030 and 031 show the overview plots from the Acoustek® software and the tables of features detected by the Acoustek® equipment at locations Ex1 and Ex2. Main was due for insertion with 90 mm PE between the two excavations. Because of the large distance between the excavations and the visibility of significant features this was a unique opportunity to validate the capabilities of the Acoustek® system. The main was inspected with a camera to locate services and identify the feature 15F1. As shown in Figures 030 and 031, the Acoustek® system successfully located and characterised features 15F1 and 15F2 in tests at both excavations with acceptable accuracy.

Live trial 17 - Garth Meadows, High Etherley

Date: 02/12/15

Main: 8” steel

Condition: Main looks clean and free of debris.

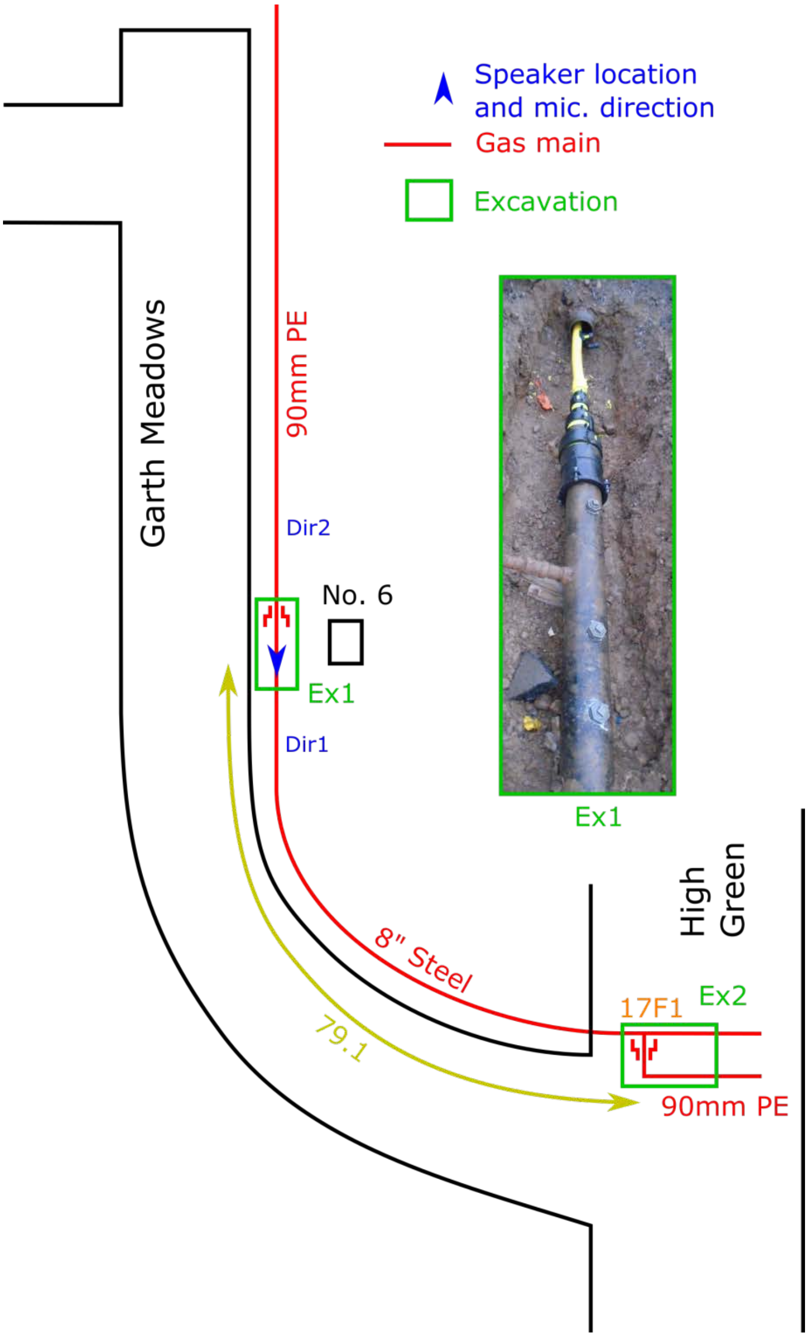
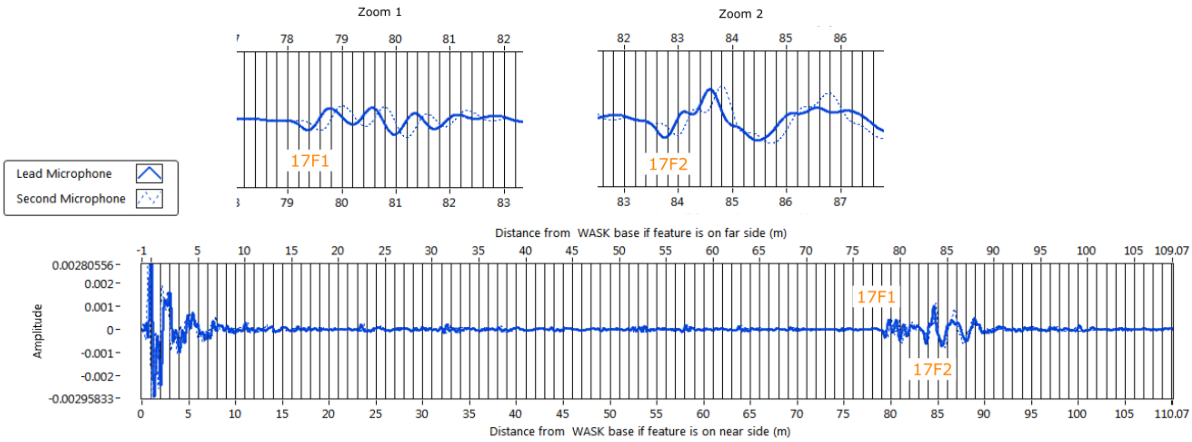


Figure 032



Feature code	Features detected	Direction	Distance	Confirmed	Location error
17F1	Branch/expansion	Dir 1	79.4 m	Measured with wheel at 79.1.0 m	0.4 %
17F2	Large branch/expansion	Dir 1	83.8 m	No	N/A

Figure 033

Notes: Garth Meadows was revisited following the initial stage of the replacement work. Figure 032 gives the site layout and Figure 033 shows the overview plot from the Acoustek® software and presents the table of features detected by the Acoustek® equipment. The main was due for insertion with 90 mm PE in Dir 1 between the two excavations. The Acoustek® equipment clearly located feature 17F1 at 79.4 m with an error of 0.4 %. Feature 17F2 in Figure 033 was not confirmed on site although an equal tee on the far side of High Green (Figure 032) would be expected. Comparing Figure 033 to Figure 028 it is possible to cross validate the Acoustek® readings, since two separate measurements performed on different days with a different pipe setup produce signals that are very similar but distance shifted due to the new test location.

Appendix B - Stage 3 field trial results

Presented below are the results from 5 of the 13 field trials performed on the SGN network. The 5 field trials presented were selected to show the system performing over long distances, a range of pipe sizes and in variable pipe conditions.

Live trial 19 - Thornly Park Rd, Paisley,

Date: 23/02/2016

Main: 4" cast iron

Condition: Unknown

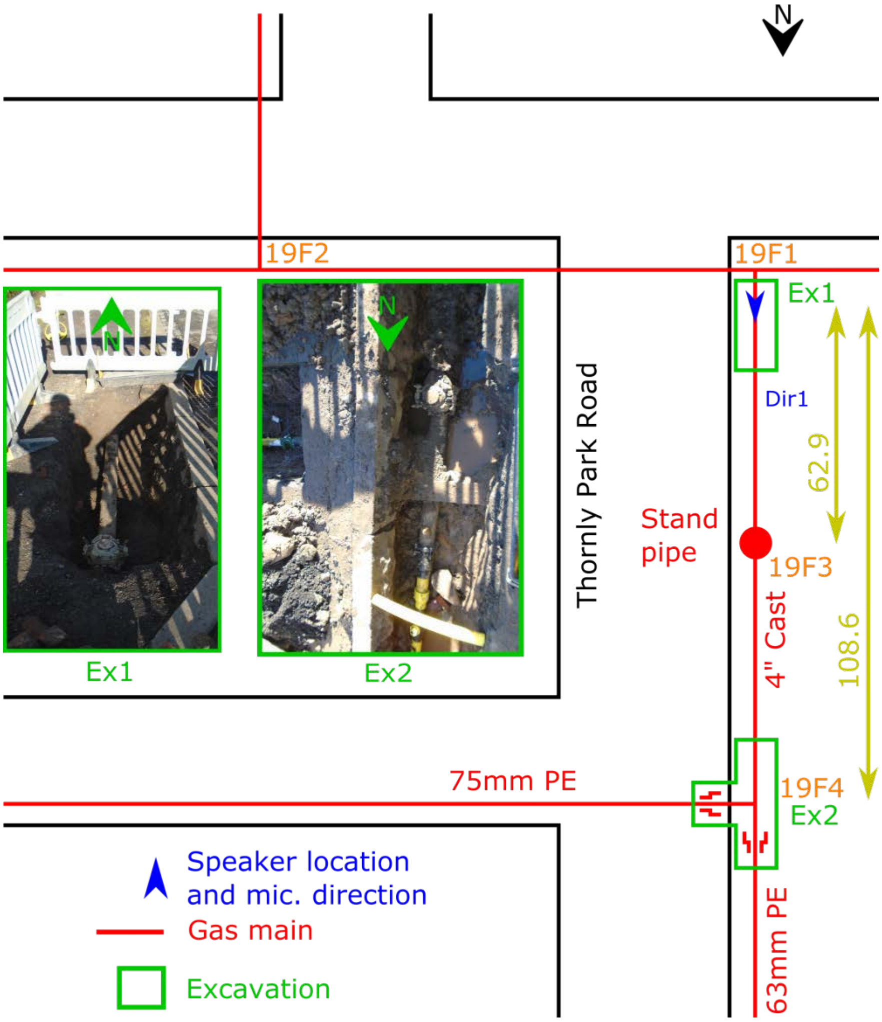
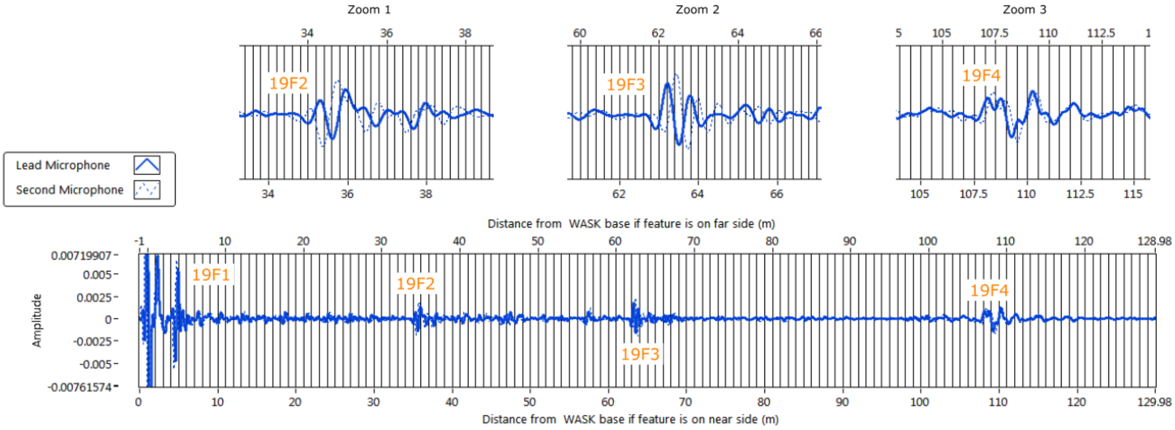


Figure 034



Feature code	Features detected	Direction	Distance	Confirmed	Location error
19F1	Branch/expansion	Dir 2	3.6 m	Present on drawings	N/A
19F2	Branch/expansion	Dir 2	34.6 m	Present on drawings	N/A
19F3	Blockage/reduction/cap	Dir 1	62.2 m	Stand pipe present at 62.9 m	-1.1 %
19F4	Large feature, strangely shaped	Dir 1	108.1 m	Tee and reductions to PE visible at 108.6 m	-0.5 %

Figure 035

Notes: Figure 034 gives the site layout and Figure 035 shows the overview plot from the Acoustek® software and presents the table of features detected by the Acoustek® equipment. The section of main tested using the Acoustek® equipment was due to be inserted with PE. Live trial 19 clearly demonstrates the ability of the system to detect and locate multiple pipeline features at long range in a 4” gas main.

Live trial 20 - Newmains Rd, Renfrew

Date: 23/02/2016

Main: 6” ductile iron

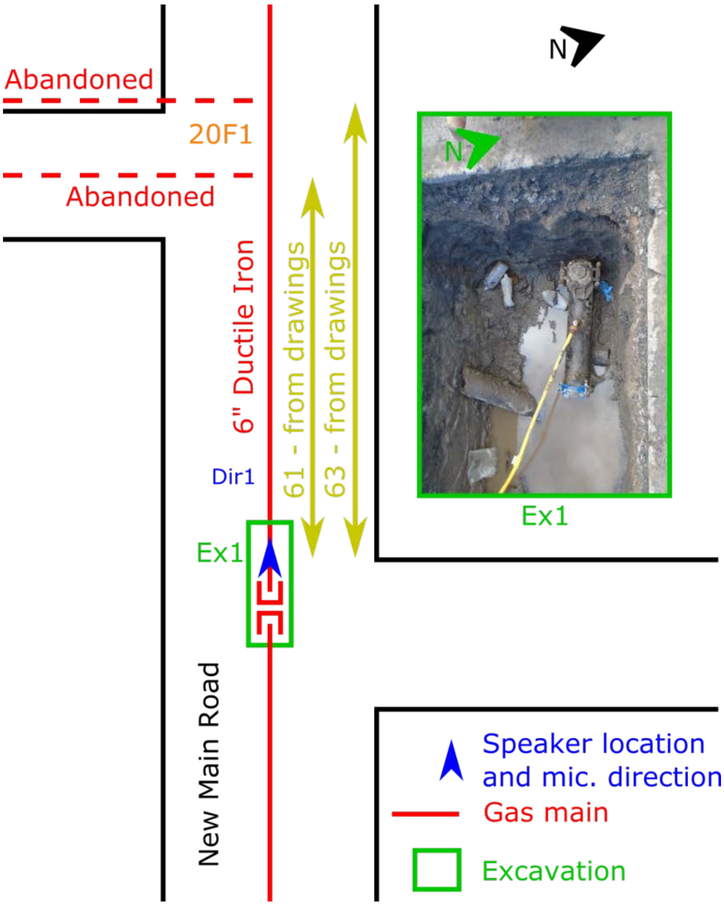
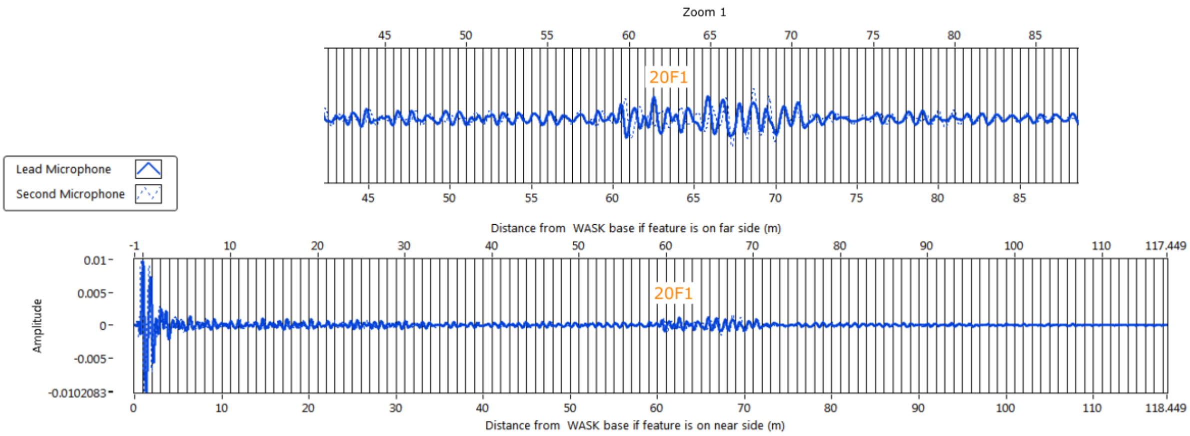


Figure 036



Feature code	Features detected	Direction	Distance	Confirmed	Location error
20F1	Raise in signal level	Dir 1	61.1	Abandoned mains on maps at 61 m and 63 m	N/A

Figure 037

Condition: Extremely dirty - filled with gravel like substance.

Notes: Figure 036 gives the site layout and Figure 037 shows the overview plot from the Acoustek® software and presents the table of features detected by the Acoustek® equipment. This trial result has been included to show the performance of the system in very bad conditions. The 6" main was so dirty that a camera could not be inserted and attempts were being made to pump the main clear of debris prior to replacement. The debris in the main causes a high noise level on the signal obtained from the Acoustek® equipment but still some information can be gained: at the suspected location of the two abandoned mains (presumably cut and capped) there is a clear feature in the signal.

Live trial 23/24 - Crocus Grove, Irvine

Date: 24/02/2016

Main: 4” spun iron

Condition: Main looks clean and free of debris.

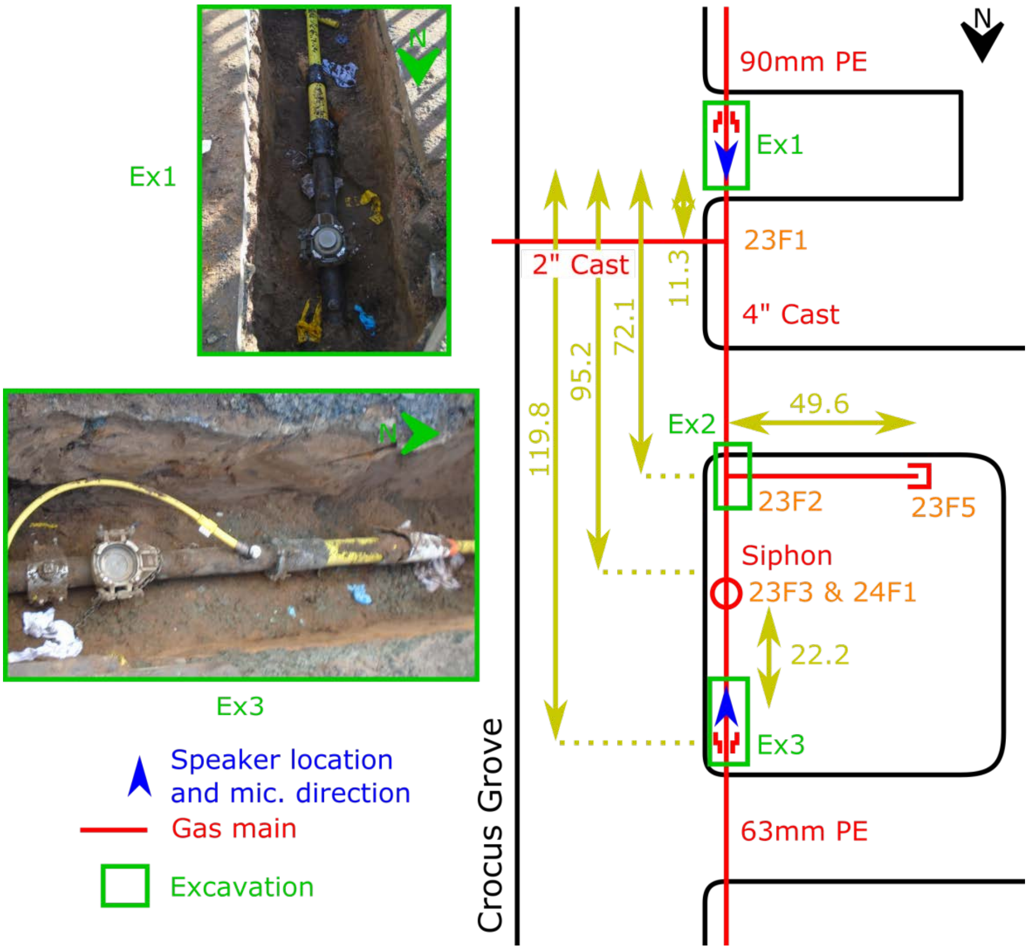
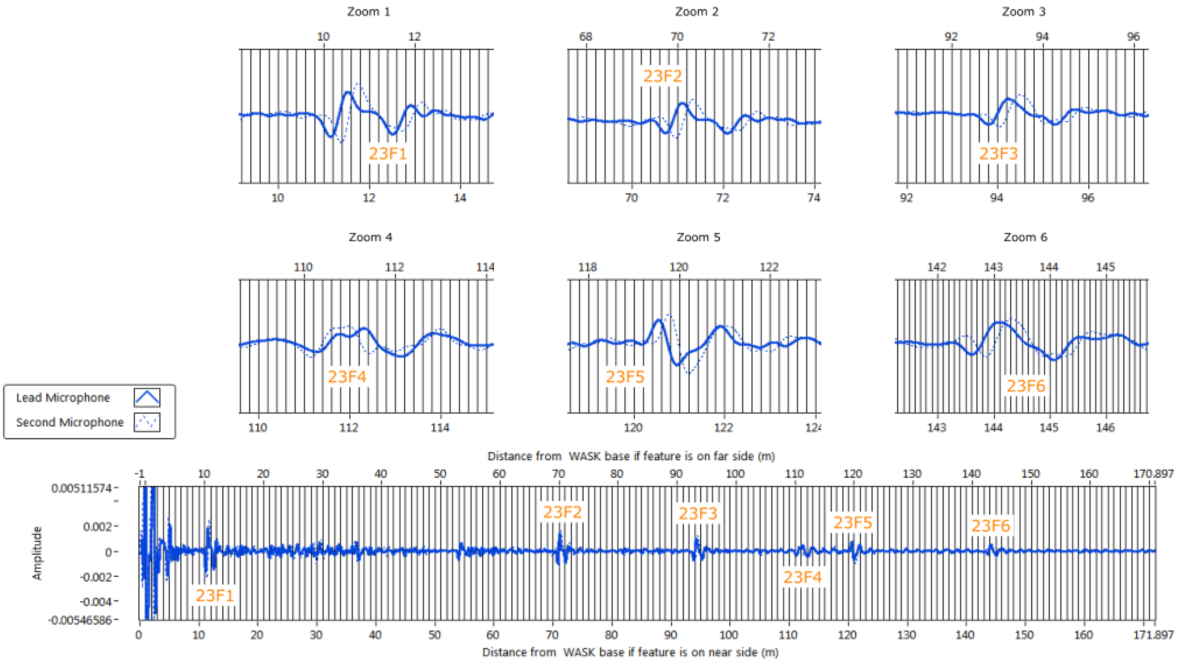
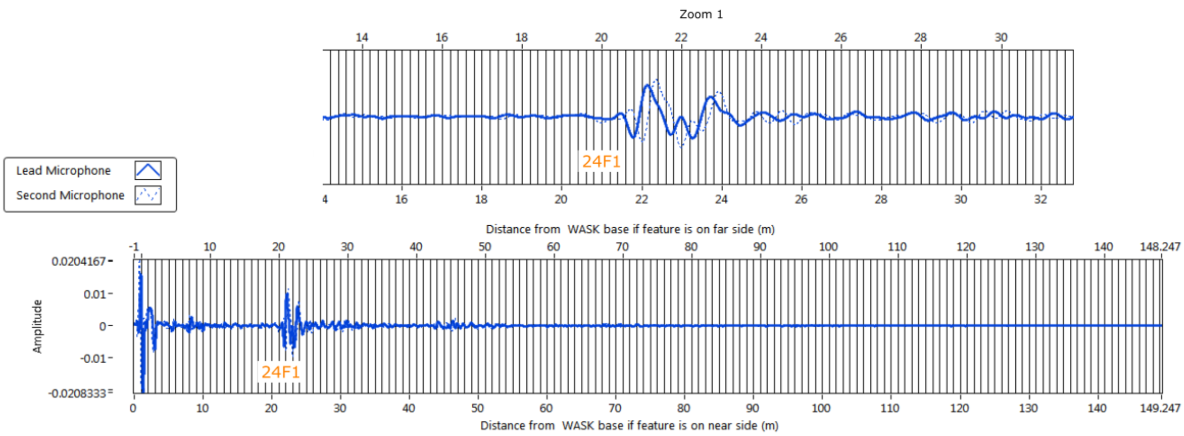


Figure 038



Feature code	Features detected	Direction	Distance	Confirmed	Location error
23F1	Branch/expansion	Dir 1	11.2 m	Unequal tee found by camera at 11.3 m	-0.9 %
23F2	Branch/expansion	Dir 1	70.7 m	Equal tee visible at 72.1 m	-1.9 %
23F3	Branch/expansion	Dir 1	93.8 m	Siphon found by camera at 95.2 m	-1.5 %
23F4	Suspected expansion	Dir 2	110.3 m	No	N/A
23F5	Large blockage/reduction or cap	Dir 1	119.5	Capped end found by camera at 121.7 m	-1.8 %
23F6	Suspected re-reflection	Dir 1	143.6	Confirmed by simulator	N/A

Figure 039



Feature code	Features detected	Direction	Distance	Confirmed	Location error
24F1	Suspected siphon	Dir 1	21.8 m	Siphon found by camera at 22.2 m	-1.8 %

Figure 040

Notes: Live trial 23 and 24 were performed at different locations on the same site. Figure 038 gives the site layout while Figures 039 and 040 show the plots from the Acoustek® software and present the table of features detected by the Acoustek® equipment. Prior to our arrival most of the site had been inspected using a camera; however, the siphon (23F3 and 24F1) was unknown and was not present on any maps. In trial 23 a significant unexpected feature was detected at 93.8 m and due to an equal tee this signal feature could relate to one of two sections of 4" main. To confirm which stretch of pipe the feature was in, another trial (Live trial 24) was performed at Excavation Ex3 (Figure 038). Live trial 24 confirmed that the feature was directly in front of the test location and that the feature was large enough to stop any signal passing it, a suspected siphon. Following the Acoustek® trial the main was inspected with a camera and a siphon was found at the suggested location. As well as finding the unexpected siphon the Acoustek® system correctly located all other large features present on the site.

Live trial 25 - Haylie Gardens, Largs

Date: 25/02/2016

Main: 3” spun iron

Condition: Unknown

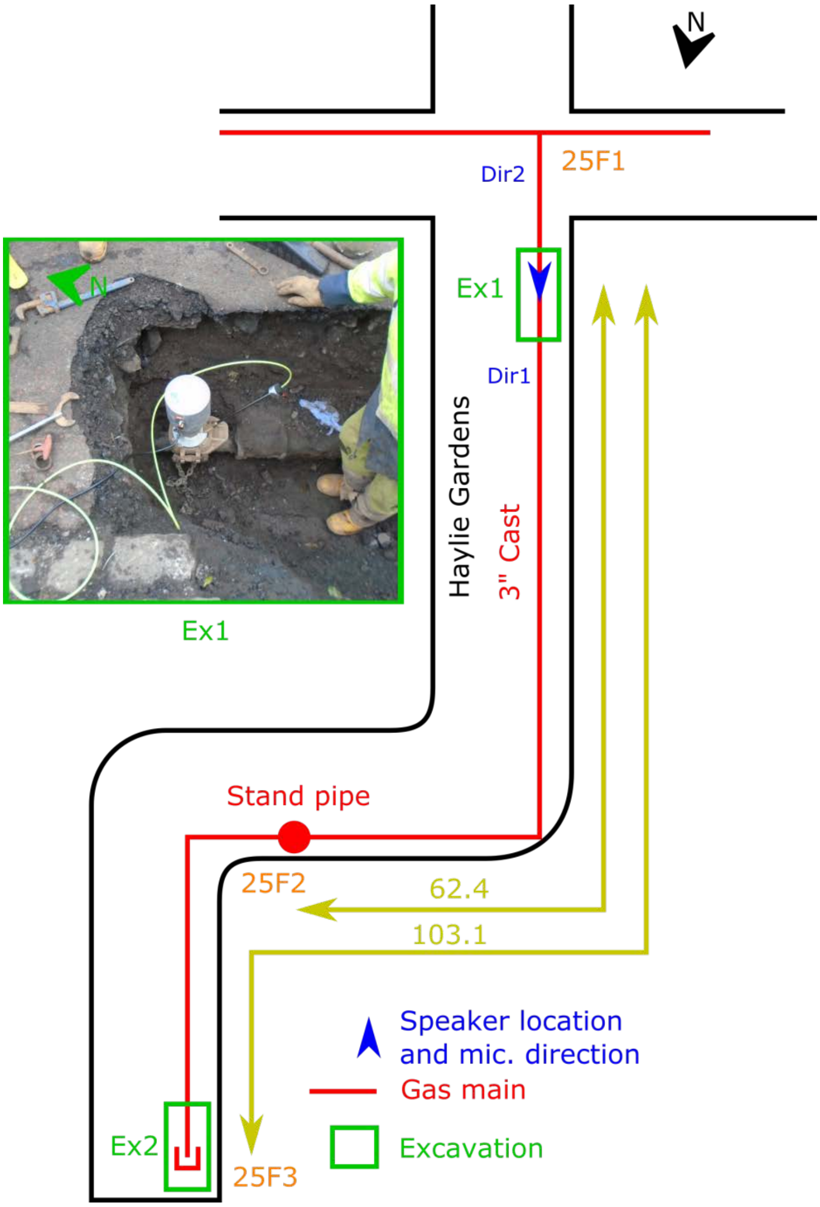
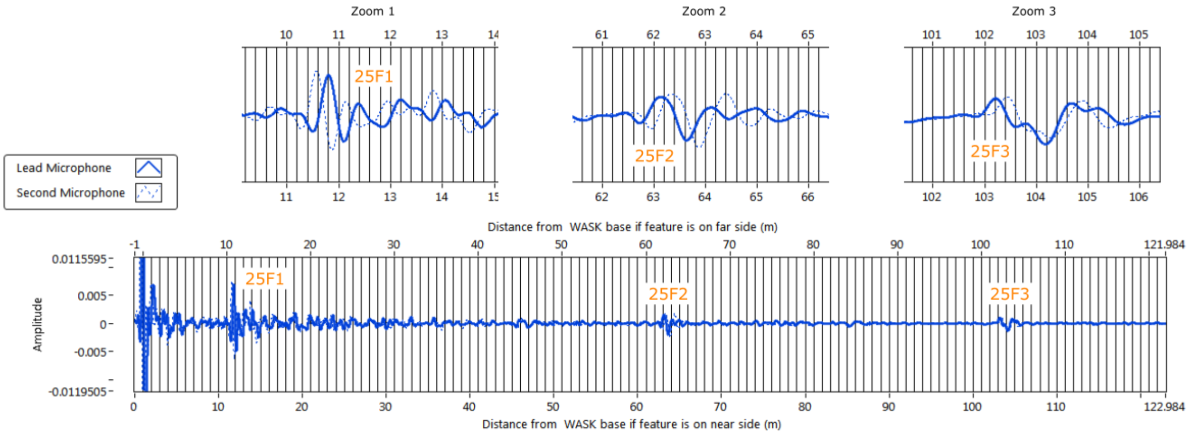


Figure 041



Feature code	Features detected	Direction	Distance	Confirmed	Location error
25F1	Blockage/reduction	Dir 2	10.8 m	No	N/A
25F2	branch/expansion	Dir 1	63.1 m	Stand pipe at 62.4 m	- 1.1 %
25F3	Large blockage/reduction or cap	Dir 1	103.2 m	Capped end visible at 103.1 m	+ 0.1 %

Figure 042

Notes: Figure 041 gives the site layout and Figure 042 shows the overview plot from the Acoustek® software and presents the table of features detected by the Acoustek® equipment. Live trial 25 demonstrates that the system is easily capable of detecting and locating features a in a relatively small 3” pipe at over 100 m range.

Live trial 31 - Harburn Ave, Livingston

Date: 14/04/2016

Main: 200 mm ductile iron

Condition: Clean

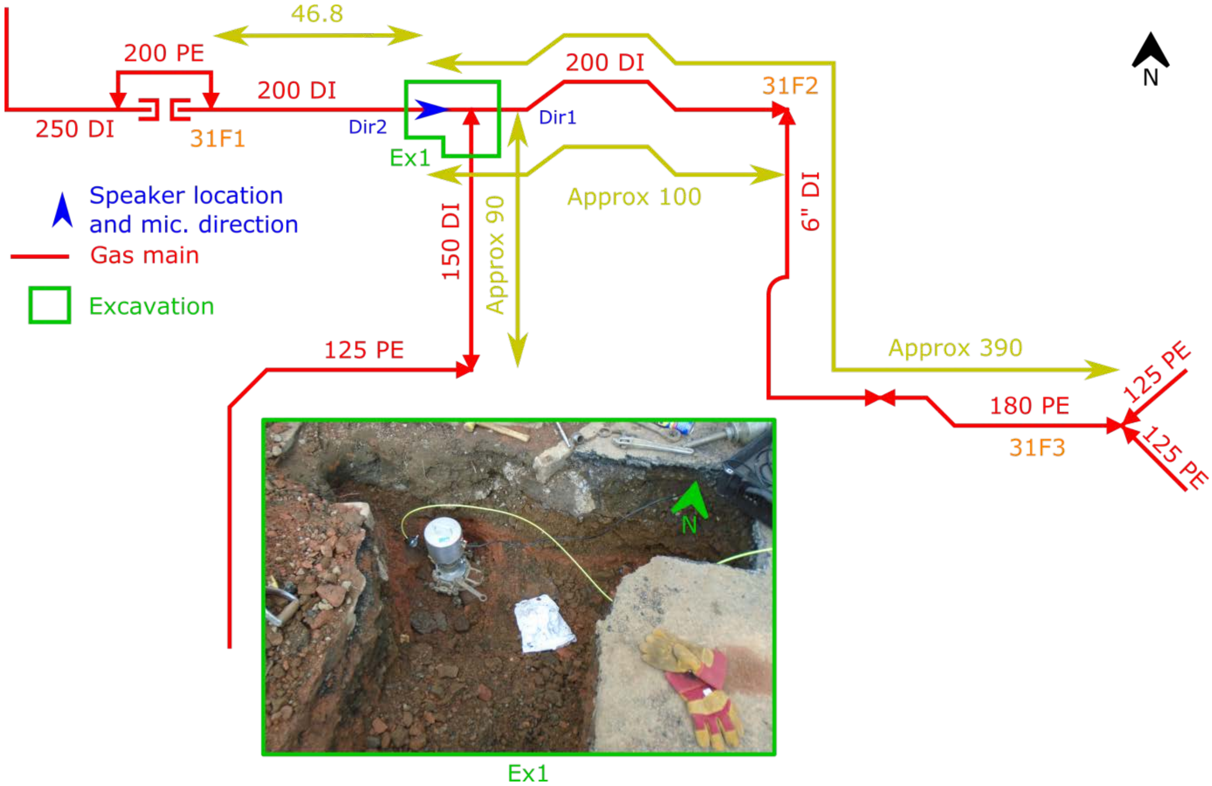
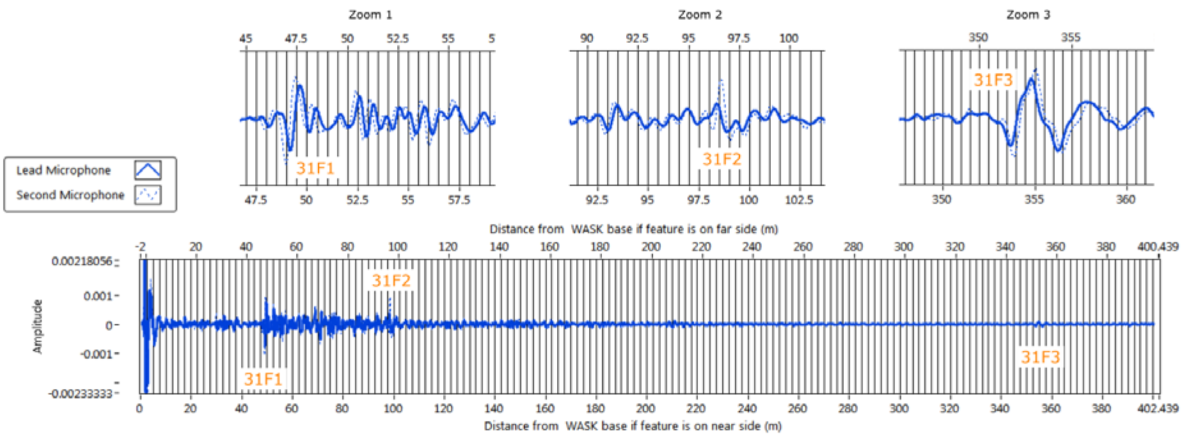


Figure 043



Feature code	Features detected	Direction	Distance	Confirmed	Location error
31F1	tee/expansion	Dir 2	47.2 m	Found with camera at 46.8 m	+0.9 %
31F2	blockage/reduction	Dir 1	98.4 m	Reduction from 200 mm to 6" present on maps	N/A
31F3	tee/expansion/siphon	Dir 1	354.2 m	reduction to 125 mm and tee nearby on maps	N/A

Figure 044

Notes: SGN operatives requested the use of the Acoustek® system to test an area for blockages following a water ingress problem. From a single location the Acoustek® system was able to confirm that approximately 500 m of gas main was clear of obstructions. Figure 043 gives the site layout and Figure 044 shows plots from the Acoustek® software and presents the table of features detected by the Acoustek® equipment. The Acoustek® system detected a pipe feature (31F3 in Figures 043 and 044) at 354.2 m. unfortunately this feature could not be fully confirmed: gas maps show a branch nearby but the distance estimated from the map is ≈ 390 m.

Appendix 1

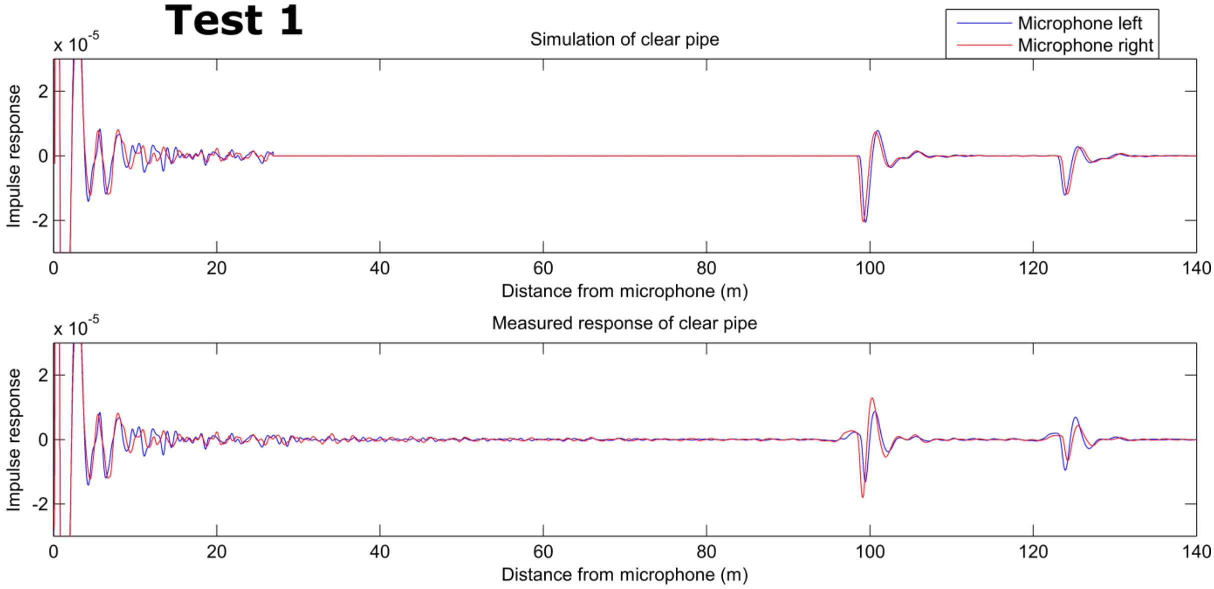


Figure 004

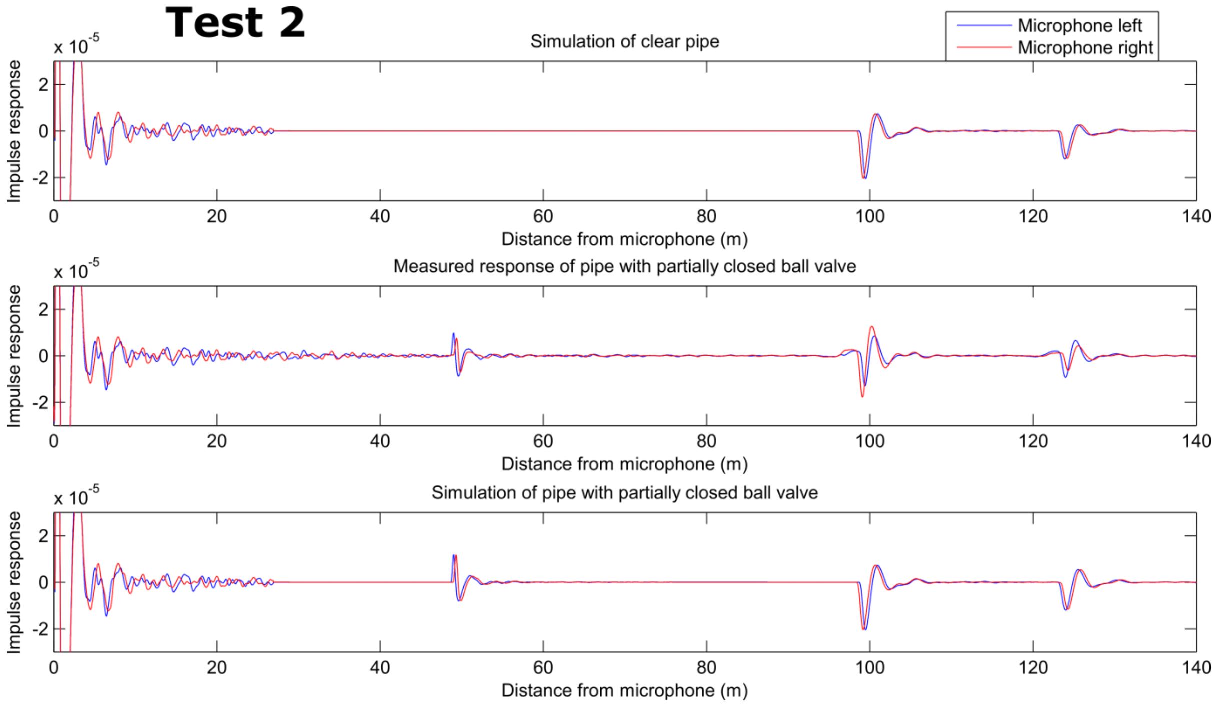


Figure 005

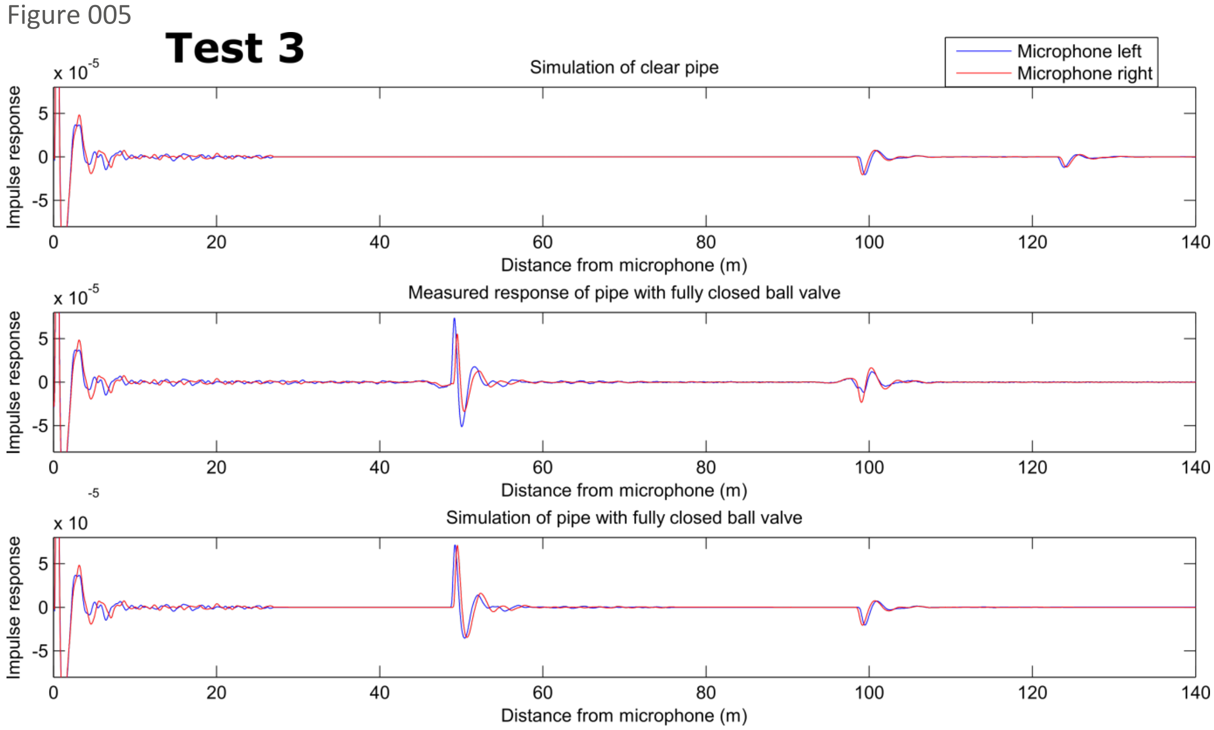


Figure 006

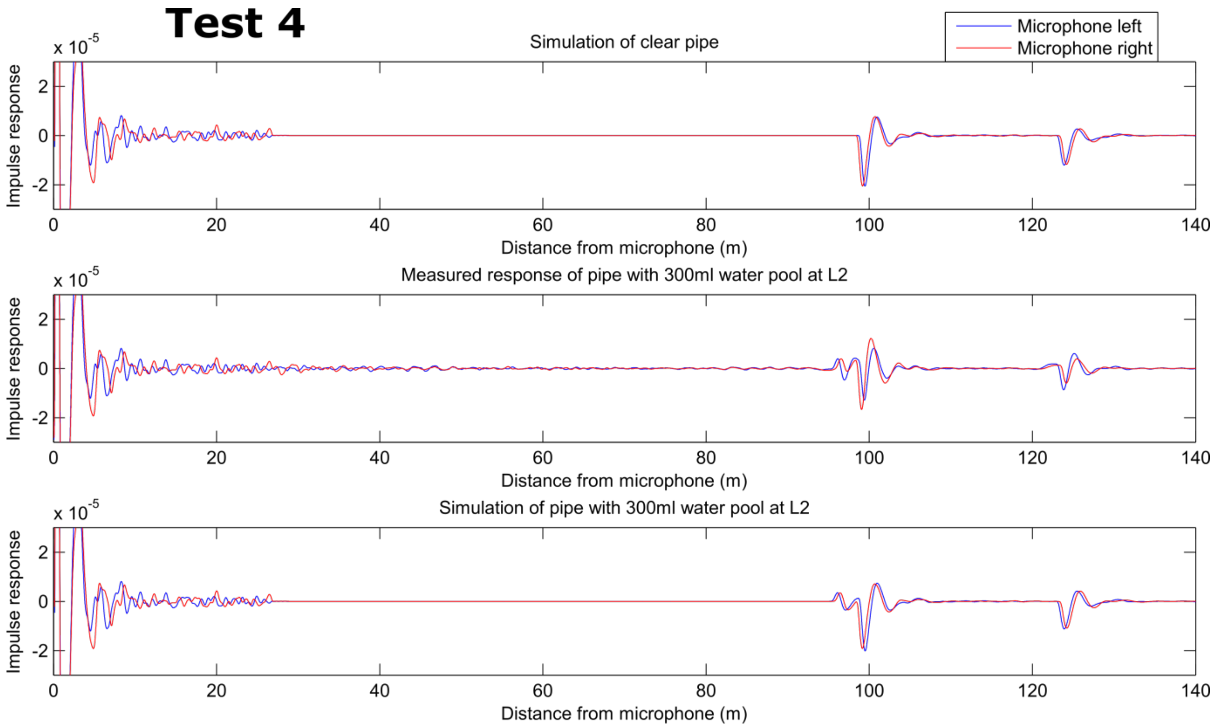


Figure 007

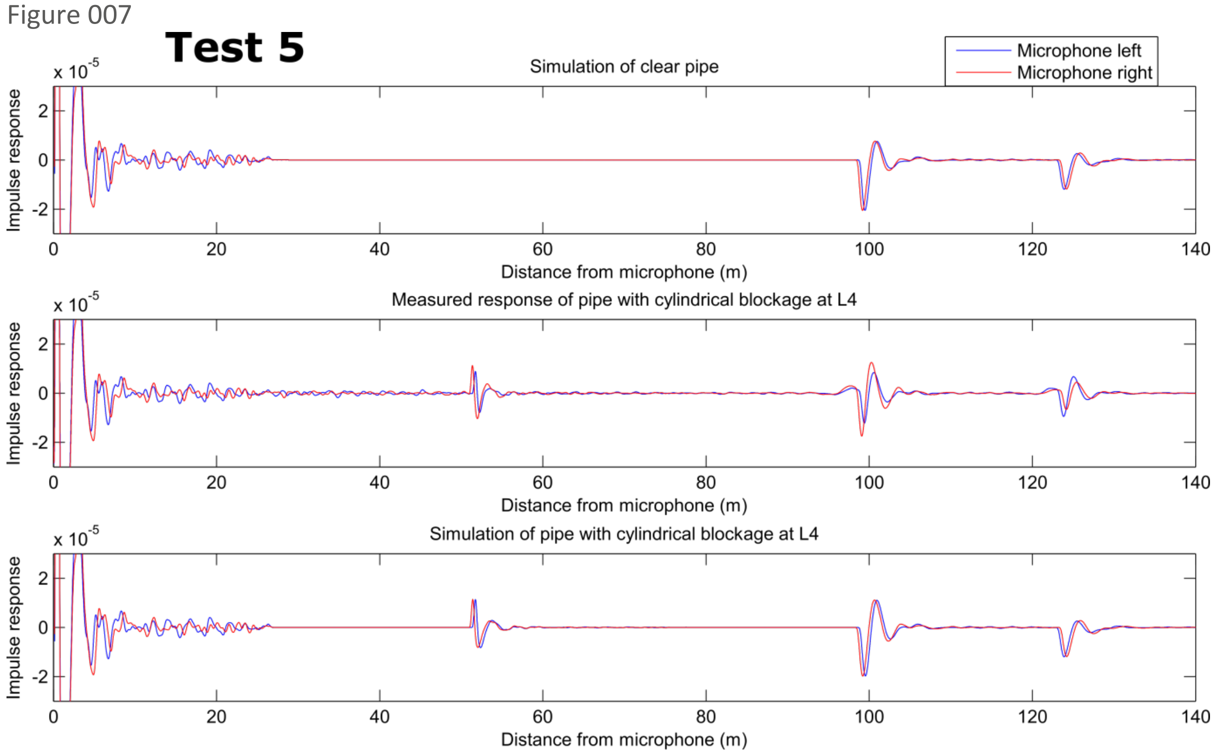


Figure 008

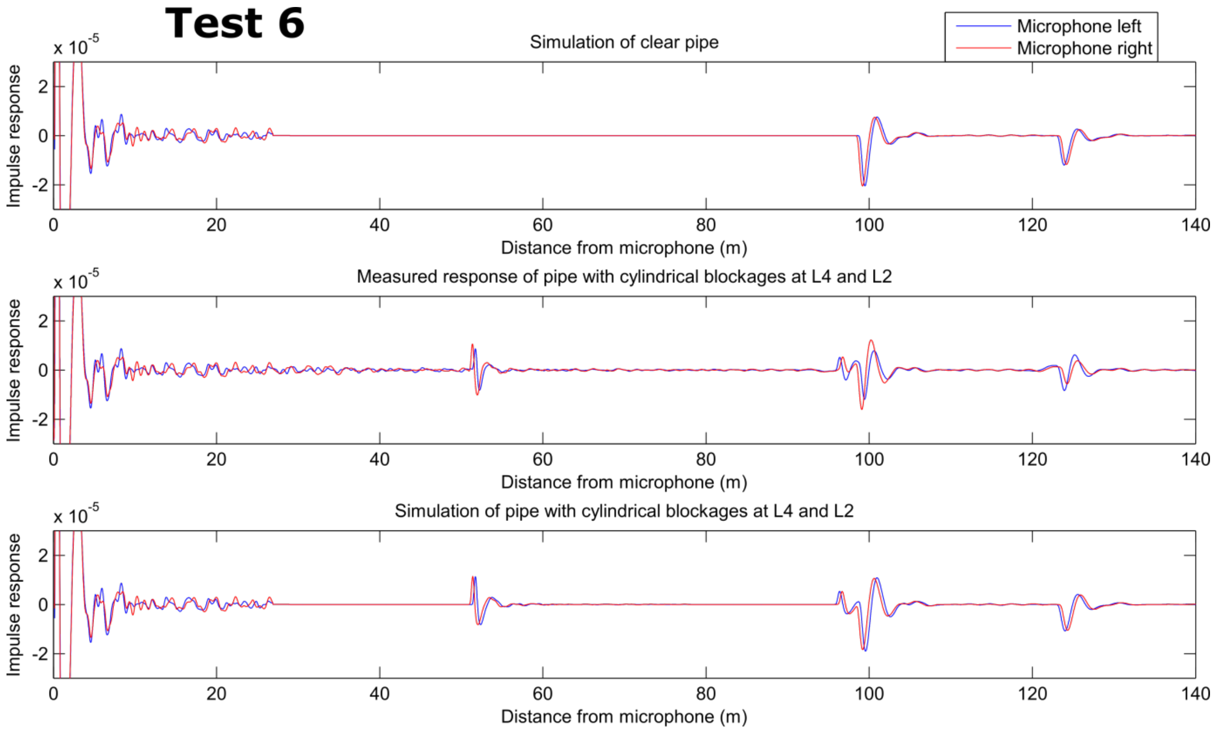


Figure 009

Appendix 2 Dead Field Trial Results Greenock

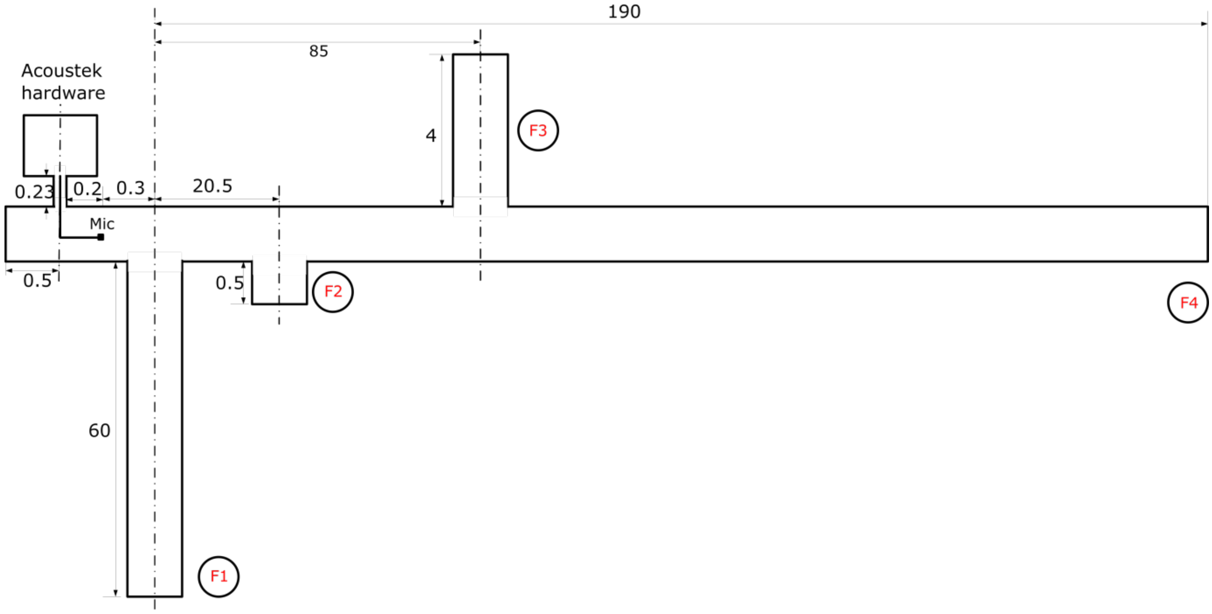


Figure 010

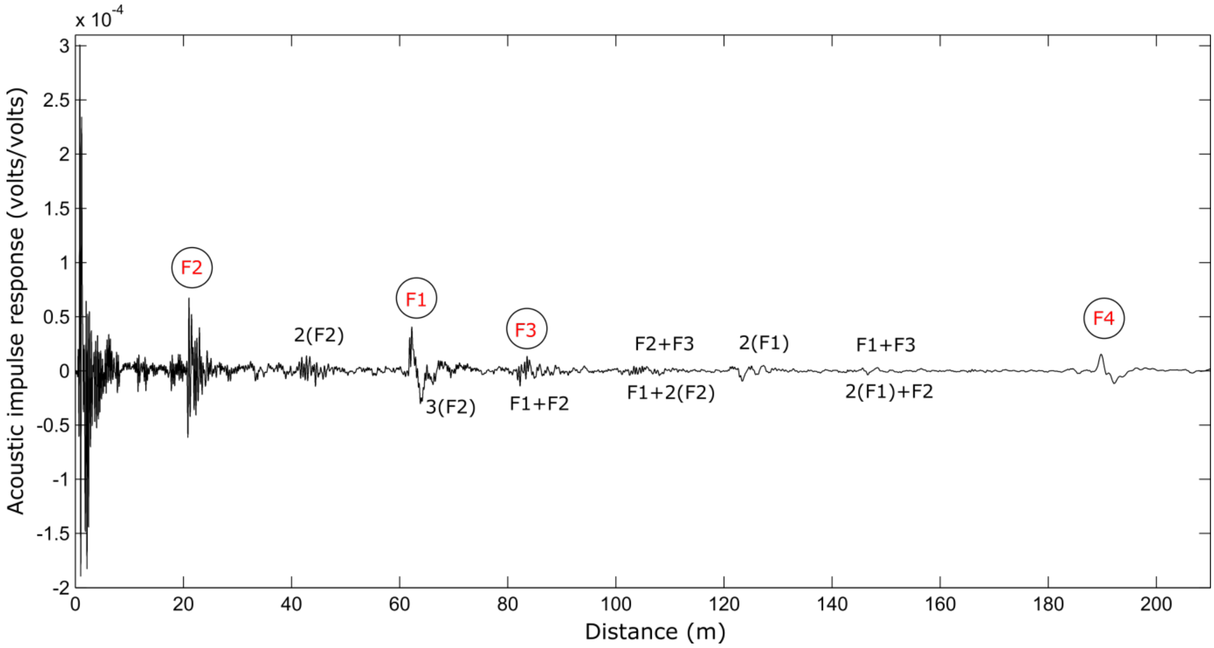


Figure 011

Appendix 3 G23 Field Trial Documentation

Project Risk Register and Mitigation

Scoring Key: 16-25 | 10-15 | 1-9

Ref No	Risk	Business Risk	Inherent Risk: Likelihood	Inherent Risk: Impact	Inherent Risk: Score	Controls & Mitigation	Owner	By When	Residual Risk: Likelihood	Residual Risk: Impact	Residual Risk: Score	Status
1	Acourtek equipment ignites escaping gas resulting in an explosion, fire, injury or loss of life. Damage to third party property, vehicles or other structures.	SGN/Public	2	8	16	1. Only trained and competent Team Managers and Repair Teams will be authorised to use this equipment. All operatives to wear PAMS throughout the operation. 2. Competent personnel must remain onsite throughout complete operation. 3. Must ensure that users fully comply with the method statement conditions, these are mandatory and specify that equipment is located a minimum of 5 Metres from any detected gas reading, in a safety zone. This is the same requirement for non intrinsic camera survey equipment. Equipment housing and gland system has been fully tested and certificated prior to use in live environment.	Alex Stewart / Alex Gardiner / Tom Neavyn	During training and competency assessments.	1	8	8	
2	Manual Handling. Injury sustained to users.	SGN/Public	2	7	14	1. Trained and competent Team Managers and Repair Teams. 2. Must ensure that users fully comply with the method Statement conditions which are mandatory. 3. A full risk assessment will be carried out to assess the lift before attempting to move the equipment 4. Weights on both units should be clearly marked and Operatives made aware.	Alex Stewart / Alex Gardiner / Tom Neavyn	During training and competency assessments.	1	7	7	
3	Trip hazard from cables. Major injuries	Public	2	7	14	Provision of a barriered work area to prevent access to members of the public during operations and until it is safe for them to regain access. Where requires cable mats etc should be used to minimise the possibility of any trip hazards.	Alex Stewart / Alex Gardiner / Tom Neavyn	During training and competency assessments.	1	7	7	
4	Cuts and Grazes from sharp edges or protusions	Public utility	2	5	10	All equipment should be inspected prior to use. Any sharp edges should be identified and reported on completion of work. All appropriate PPE (Overalls, hard hat, protective eyewear, gloves, protective footwear etc.) MUST be worn throughout the course of the operation.	Alex Stewart / Alex Gardiner / Tom Neavyn	At the design stage	1	4	4	
5	Electrical Shock	SGN/Public	2	7	14	All electrical equipment to be checked and certified safe prior to use.	Alex Stewart / Alex Gardiner / Tom Neavyn	During training and competency assessments.	1	7	7	
6	Electrical Overheating due to moisture ingress and debris.	SGN/Public	2	7	14	All equipment should be inspected prior to use. Any faults identified should be rectified before equipment is used onsite. Electrical equipment should only be connected and disconnected in a dry clean environment.	Alex Stewart / Alex Gardiner / Tom Neavyn	Off and onsite during operation	1	7	7	

Acoustek Method Statement

1. Check all of Acoustek assembly for damage, misuse or breakage and purge tap valve is closed. Ensure location of Acoustek case is a minimum of 5 metres from any gaseous area. The area MUST be checked with a gascoseeker to ensure it is gas free. Before drilling the main the system should be fully assembled and tested to 100mbar for 15 minutes.
2. Check the insertion base WASK mounting is clean and free from contamination and liberally coated in grease (M494 silicon grease). Check the O-ring is fitted correctly.
3. Fit the Insertion base assembly onto the WASK base. Ensuring the bayonet fittings are fully engaged.
4. Check the Cam-lock engagement male and female are clean and free from contamination and liberally coated with grease.
5. Fit the Speaker enclosure onto the Insertion base via the Cam-lock engagement.
6. Ensure the Insertion base adapter and mating insertion base screw hole are clean and free from contamination, the O-ring is seated correctly and liberally coated with grease.
7. Screw the Insertion base adapter onto the Insertion base.
8. Ensure the Cable insertion system is clean and free from contamination, the O-ring is seated correctly and liberally coated with grease. Check the purge tap is closed.
9. Screw the Cable insertion system onto the Insertion base adapter.
10. Fit cable gland stack onto the Microphone cable without grease to ensure that grease does not come into contact with the Microphone apertures.
11. Once the cable glands are fitted clean and free from contamination, liberally coated with grease.
12. Fit a coloured tape or heatshrink to the microphone cable above the glad stack to be used as an indication of when the microphones are completely extracted.
13. Insert cable and cable glands into the insertion system.
14. Check all fittings are tight and correctly seated.
15. Connect the purge tap on the Speaker Enclosure to a gascoseeker.
16. Open the speaker enclosure purge tap. Open WASK Base gate valve and purge through the purge tap until two readings > 90% GIA are achieved on the gascoseeker. Close purge tap.
17. Connect the Cable insertion system purge tap to the gascoseeker.
18. Open the Cable insertion system purge tap. Purge through the purge tap until two readings > 90% GIA are achieved on the gascoseeker. Close purge tap. Check enclosure and gland system for soundness using leak detection fluid.
19. Push microphone cable through the WASK base into the main at a controlled speed ensuring it is correctly positioned.
20. The system can now be powered up and acoustic survey at detailed by Acoustek carried out.
21. Once survey is completed disconnect power supply and ensure system is fully powered down and electrically isolated. Carefully withdraw the microphone cable back out of the insertion system until the indication tape/heatshrink is visible.
22. Close the WASK base gate valve.

23. Open the purge tap on the cable insertion system and vent system.
24. Open the purge tap on the speaker enclosure and vent system.
25. Unscrew the gland stack and remove cable from cable insertion system.
26. Unscrew the cable insertion system from the insertion base adapter.
27. Unscrew insertion base adapter.
28. Unlock the Camlocks and remove the Speaker enclosure from the insertion base.
29. Remove the Insertion base assembly from the WASK base bayonet fitting.

Acoustek® EIC Survey procedure - Software version 7.2

1 Taking measurements

1. Open the measurement and analysis Peli case.
2. Turn on laptop (Figure 1).
3. Connect USB cable from Peli case front panel to the laptop (Figure 1).
4. Connect six pin microphone cable plug (yellow cable) to the front panel socket labelled “microphone” (Figure 1).
5. Connect three pin speaker cable plug (black cable) to the front panel socket labelled “speaker” (Figure 1).
6. Switch the green button on the front panel, labelled “power” to turn the box on (Figure 1).
7. Check the box charge - when fully charged the voltage should read between 12.1 and 12.4 (Figure 1).
8. Check cable connections match Figure 1.
9. On the desktop double click the icon labelled “EIC SOFTWARE”.
10. In the MEASURE tab check the speed of sound, test length and insert length are correctly set for the current test. Insert length should ideally be 1m (Figure 2).
11. In the MEASURE tab set the folder to save results in. It is good practice to include the street address of the excavation in the folder name, for example a folder name might be: “Sterling road 31” (Figure 2).

Figure 1 – Taking Measurements – steps 2 to 7 and correct Peli front panel cable connections

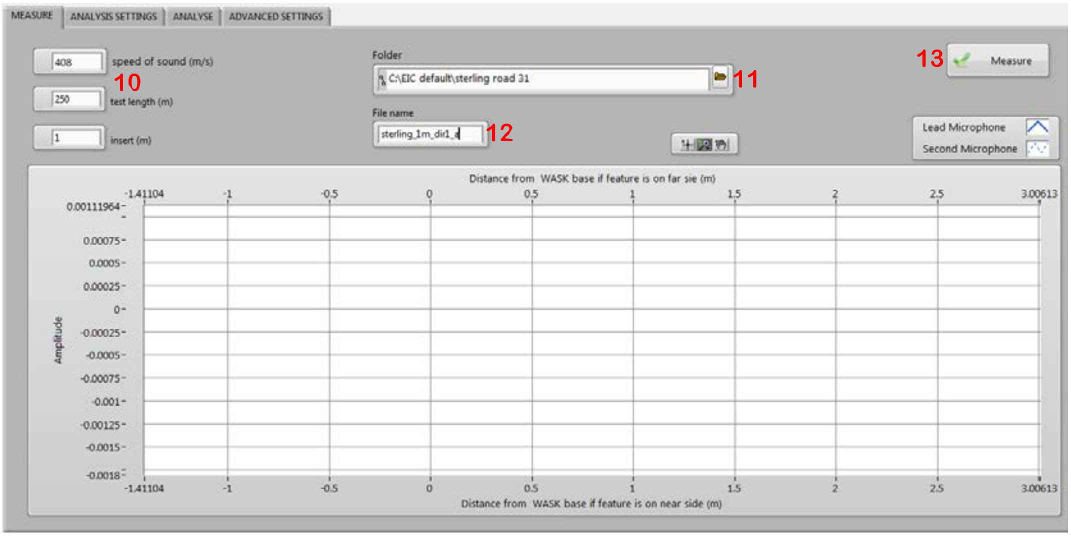


Figure 2: Taking measurements - steps 10 to 13

12. In the MEASURE tab set the file name for the current test. It is good practice to include the insert length and the direction of the lead microphone in the file name for future reference, an example file name is "sterling_1m_dir1_a" (Figure 2).

13. A measurement may now be taken by pressing the “Measure” button in the top right corner. If a file with the same name already exists in the specified folder a dialogue box will appear giving you the option of overwriting the file or cancelling the measurement (Figure 2).

14. System will now measure for around 30 seconds and the result is plotted on the graph in the MEASURE tab

15. Further measurements may be taken by repeating steps 12 to 14. It is good practice to check the named folder to ensure that the files have been success- fully recorded.

16. Once all required measurements have been taken, turn off the box power by switching the green button on the front panel to the off position.

17. Unplug the speaker cable, the microphone cable and both ends of the USB cable.

18. Close the software.

19. Shutdown the laptop.

20. Close the Peli case.

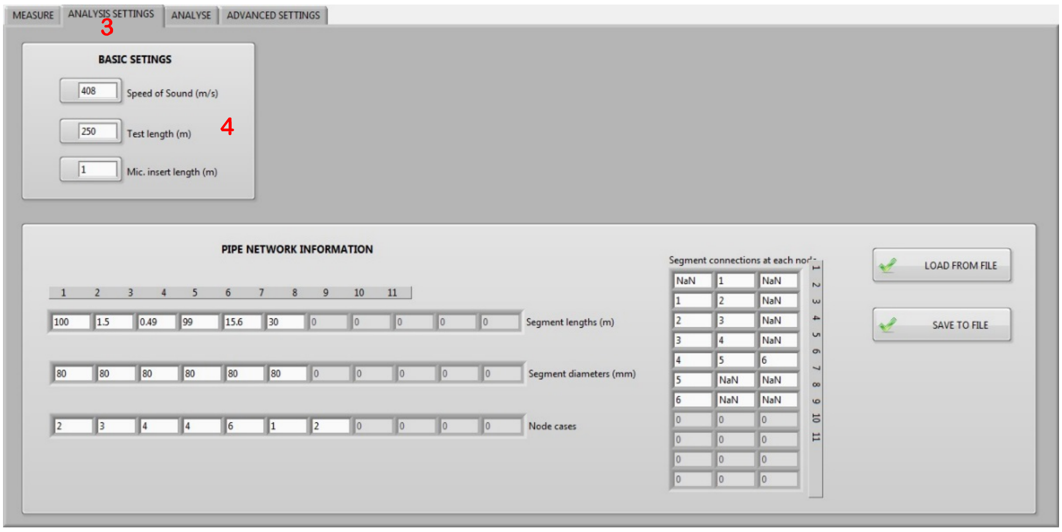


Figure 3 – Loading results - steps 3 and 4

2 Loading results

To load results only the laptop and measurement files are required.

1. Turn on laptop.

2. On the desktop double click the icon labeled “EIC SOFTWARE”.

3. Go to the “ANALYSIS SETTINGS” tab (Figure 3).

4. In the “BASIC SETTINGS” box set the speed of sound, test length and insert length that apply to the test result to be loaded (Figure 3).

5. Go to the “ANALYSE” tab (Figure 4).

6. Click the “LOAD RESULT” button (Figure 4).

7. Select the file to be loaded and press “OK”.

8. Repeat steps 3 to 7 to load more results.

9. Close the software.

10. Shutdown the laptop.

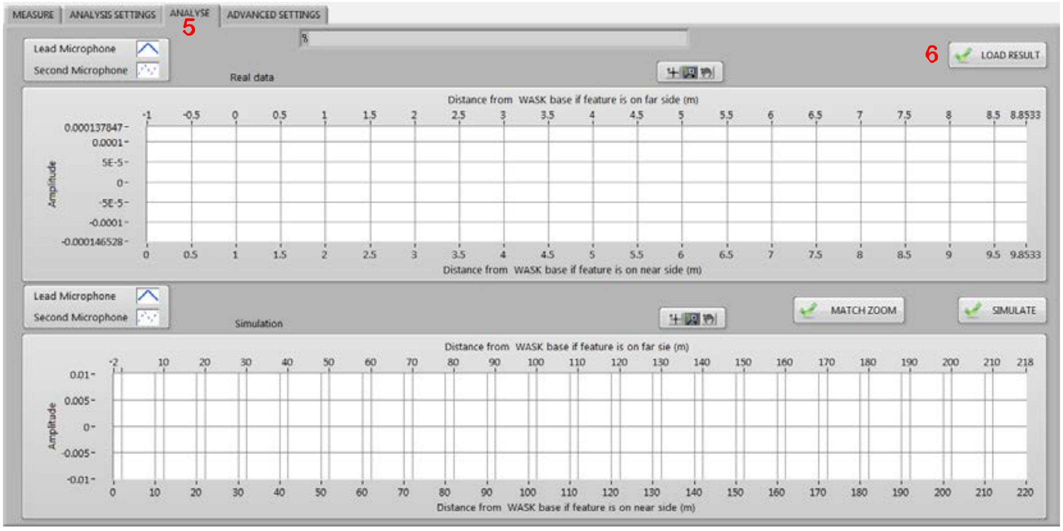


Figure 4 Loading Results – steps 5 and 6

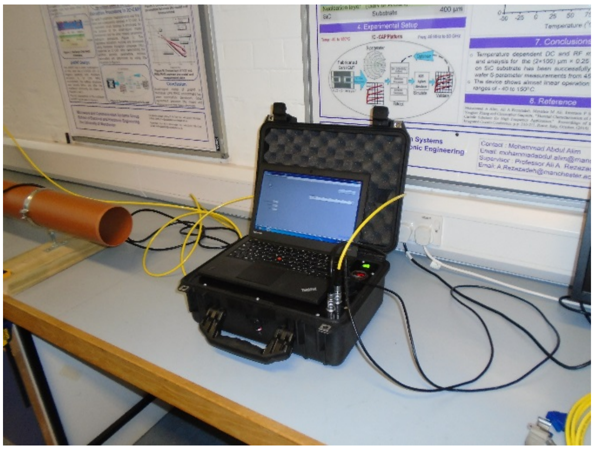
PROPOSAL FORM

Part 1 of 2 – (To be completed by the Proposer / Originator)

Proposer Details	
Name of Proposer	Alex Stewart
Job Title of Proposer	Project Manager
Office / Depot Location	Glasgow
SGN Senior Manager Sponsor	Angus McIntosh
Specialist Advisor (if applicable)	
Date	02/11/2015

Proposal Details	
How was the subject identified?	Joint NIA project through EIC.
Is this proposal essential, desirable or supporting an existing product or process?	This is a desirable product which would assist Operations in location and mapping of pipe networks.
Describe the product /equipment / technique **in detail** (photos/diagrams should be attached as supplemental information)	The technology used in the Method uses sound waves (Acoustic Pulse Reflectometry or APR) to identify the location and nature of a feature of interest in a pipe. The sound wave (typically a sweeping frequency) is injected into the pipeline under investigation. The ultrasound waves are reflected back to the instrument and by using advanced signal processing techniques the nature and location of a wide range of pipe features can be determined (essentially the same general technique used by bats and sonar). In terms of the speaker output, it sends out a repeated sine sweep from 20Hz to 1500Hz The amplifier power output is about 1 watt during this sweep. The system is battery powered by a 12v 8Ah battery pack. The power consumption of the system is about half an amp (6 watts). Speaker unit weighs 11.4kg, launch tube 0.8kg and adaptor for WASk base 2.5kg. Peli case 11.4kg
Would significant training be required to support this proposal?	Operatives would be trained as part of the field trial process. The most critical part of the training being the results interpretation. To assist in this the equipment and results system has added features to simulate potential results based on perceived pipe configurations. We have also requested additional assistance with interpretation including auto scaling.

Are there financial / safety / environmental benefits or risks involved in the proposal?	If the equipment proves to be successful there would be both financial and environmental benefits. The bulk of these would be a reduction in the excavation numbers and sizes of excavations required to identify and locate pipe features. These savings would be more accurately quantified during the field trial, with potential cost benefits being captured as part of the trial output.
What is the estimated cost of adoption?	The cost of adoption will, primarily, be based on equipment costs at the end of the project. It is anticipated the unit costs figure should be > £5,000 per unit although this would be finalised after completion of the trials.
What impact on existing procedures would adoption of the product/process have?	Impact on exiting procedures would, hopefully be, a reduction in the number of excavations required to accurately locate water or other pipeline features (valves, size changes, offtakes etc.) It is anticipated that the equipment would be used in tandem with existing CCTV inspection either on Emergency work or as part of planned pre survey work on mains replacement type work. It can survey longer lengths than existing CCTV and could, therefore further reduce the requirement for excavation that would be required if only using CCTV.



PROPOSAL FORM

Part 2 of 2 – (To be completed by the Project Manager / Evaluation Group)

SGN Approval	
Has Part 1 of the Proposal Form provided sufficient information?	Yes/No
Is a Field Trial required?	Yes/No

Field Trial Details	
Project Manager	Alex Stewart
Business Sponsor	John Lobban
Review Group members (ensure a good cross section of experience and all relevant areas of the business represented)	Alex Stewart
	Bob Hipkiss
	Guys Bertrand
	G Paver / A Nicholas
Field Trial Coordinator	Alex Gardiner / Tom Neavyn
Engineering Policy approval to proceed?	Yes/No
Engineering Policy Manager Signature	
Commencement Date	dd/mm/yyyy
Target Completion Date	dd/mm/yyyy

Final Approval	
Field Trial results reviewed?	Yes/No
Acceptable Results	Yes/No
Date	dd/mm/yyyy

Date of Approval by SGN Engineering Policy?	dd/mm/yyyy
Date approval captured on Product Register Database?	dd/mm/yyyy
Date Manufacturer advised of Approval?	dd/mm/yyyy
Date Procurement advised of Approval?	dd/mm/yyyy
Date of Implementation?	dd/mm/yyyy

FIELD TRIAL DATA CAPTURE FORM

Product on Field Trial	**Acoustek**
Product Description	**Accoustic pipe inspection system**
Depot	
Location	
Date	
Field Trial Number	**(e.g. 1 of 5)**

Trial Terms of reference

Field trial of Acoustek inspection system. It is anticipated that this equipment should minimise the number of excavations required to carry out internal surveys of pipes to identify blockages, size changes, valves, siphons, offtakes etc over a much longer distance than can be covered by CCTV from a single excavation. As part of the trial success of location of pipe features and accuracy should be recorded and confirmed using existing techniques and an assumed saving on number of excavations should be recorded based on the accuracy of the location of the features identified.

Field Trial Description

Complete a detailed description regarding the operation of the product, observations, limitations, performance versus expected performance.

Conclude with a summary regarding the product suitability and any suggestions for refinement or improvements, and performance versus the success criteria.

1. *Was the output from the survey comparable with the visual inspection completed? Y/N*
2. *Were there any significant differences in lengths measured between the two surveys Y/N*
3. *Did the Acoustek survey highlight anything not shown on our records Y/N*
4. *How many excavations were required to complete the visual inspection?*

Include photographs and capture video if possible.											
Scoring vs. Success Criteria											
Scoring system against previously determined relevant criteria. Amend as required.											
Performance	*1*	*2*	*3*	*4*	*5*	*Safety*	*1*	*2*	*3*	*4*	*5*
Ease of use	*1*	*2*	*3*	*4*	*5*	*Accuracy*	*1*	*2*	*3*	*4*	*5*
Manual Handling	*1*	*2*	*3*	*4*	*5*		*1*	*2*	*3*	*4*	*5*