TURNKEY SOLUTIONS FOR NON-INTRUSIVE PIG MONITORING

By William Louden, Online Electronics Limited

Introduction

All Oil & Gas pipelines in operation require some form of routine maintenance primarily the removal of wax and scale deposits. The complexity of inspecting pipelines differs greatly between projects with some lines rendering pigging operations impractical due to the nature of their design. Pipelines such as these are often branded ‘unpiggable’.

The routine pigging of standard ‘piggable’ lines can also present several challenging obstacles that are often difficult to predict prior to launch. It is of paramount importance to monitor the progress of pigs transiting a pipeline. For many projects it is essential to know when a pig has left the launcher and arrived at the receiver. This allows for timely activation of valves to allow successful pig passage. Operators often require pre-warning of a pig approaching the receiver to save the cost of having staff remain at the site for the duration of a pigging operation.

The risk of a pig becoming lost or stuck is a concern attributable to all inspection operations. Until located and released, lost or stuck pigs can result in extensive down time and significant extra expense. For this reason pigs are frequently monitored passing points in a pipeline where a section is deemed to pose a risk to a pig becoming stuck; such as a valve, launcher, steep incline or sharp bend where the velocity of a pig is likely to be impeded. This strikes true for all sizes and locations of pipeline, regardless of onshore, subsea, buried lines, wall thickness or any other geometric or operational challenge ‘piggable’ pipelines may present.

Often, particularly for long and complex pipelines, it is necessary to monitor pig passage from a remote location and as such effective company-wide data communication is vital.

The following discussion will focus on such common obstacles to routine pigging operations and how turnkey solutions can be implemented by addressing the options available to a specific project and responding with the correct combination of technology. Case studies will be referenced to illustrate how these challenges are addressed in practice, and how product applications have succeeded in affirming operators with the desired confirmation(s) as to the success of an internal inspection job.

The operations discussed will not be exhaustive of all plausible applications, but rather a method that was applied to solve a particular problem. As such there may be cases discussed where additional technology – either supplied by Online Electronics Ltd. (OEL) or otherwise – was also implemented during the project for additional confirmation, but for the purpose of this discussion the focus will be on technology driven directly towards the provision of a solution. This structure will help illustrate how (theoretically) any of these problems could occur during the same job and hence how contingency can be achieved for all such instances despite differing project conditions.

Signalling Pig Launch

On almost all pigging operations operators will want certain confirmation that the pig has been successfully launched, navigated past the first and subsequent valves and has eventually left the launch site. Only after all of these events have been assured can a successful pig launch be confirmed. The scale of the launch site and number of valves within its proximity will determine how many pig signallers are to be installed.

Regardless of the complexity of these operations, there are always benefits with the use of non-intrusive technology. Traditional mechanical signallers necessitate a permanent installation at strategically selected points on the line. Mechanical signallers function by way of intrusion of a probe into the interior of the pipeline so at time of passage the physical impact of a pig connecting with the probe will cause it to retract, which in turn will cause the unit to signal. The application of this type of signalling means that units are prone to wear due to the frequency of occasions at which a pig will connect with the probe. When mounted on 'live lines' these signallers can entail costly and difficult maintenance with regards to the servicing of faulty units.

OEL designs and supplies a range of non-intrusive magnetic signallers which can be attached to any point in a pipeline, including major barrels (such as a launcher or receiver barrel). Mounting mechanical signallers on major barrels has traditionally been unreliable as it has been found that the probe was unable to consistently make contact with the pig due to the large diameter of the pipe.

Magnetic Signaller on a Launcher Barrel

Installation is quick and simple with no associated down time as the units can be simply strapped onto the pipe wall whilst the pipeline is in operation. Since the units can be battery-powered, it is also possible to directly replace any signaller with no hard wiring necessary. Any number of signallers can be attached to a pipeline and can be monitored by operators in real-time or the information can be communicated to a remote location, a function that will be discussed in greater detail in later sections.

The simple installation process means that units can be placed on the pipeline either permanently or temporarily to confirm safe passage through valves (or other critical points in the line). Pig passage through the initial sequence of valves at a launching terminal is a process which needs to be diligently monitored. It is of upmost importance to confirm when the pig has successfully left the launcher. If a pig becomes stalled at a valve within the launcher and this has not been confirmed, operators will have no method of determining the location of the pig. Therefore a pig locating operation would need to be undertaken for a potentially great distance of pipeline.

OEL Magnetic Signaller (MAGSIG®)

The OEL MAGSIG® Pig Detector monitors the level of magnetic flux perpendicular to the surface on which it is mounted. The MAGSIG® monitors changes in magnetic flux on the pipeline whilst keeping track of the 'ambient' level of flux which is always present due to the earth's magnetic field as well as the possible self-magnetism of the pipeline itself. The unit is set with a threshold level of flux (milli-Gauss) and if a sudden change in the measured flux is detected above this threshold the unit indicates the detection of a pig. As such the pig needs to be mounted with magnets of sufficient strength to breach the threshold level of flux that has been set.

The setting of the threshold level of flux at which the detection is initiated is important. The MAGSIG® detects the presence of a change in magnetic flux, but is not configured to be able to innately gauge what level of magnetic flux it is required to detect. The actual level, monitored on the outside of the pipeline, is determined by a number of factors:

- Pipe wall thickness
- Pipeline material (mild steel, stainless steel, etc.)
- Strength of magnets used on pig
- Orientation of magnets on the pig
- Speed of pig
- Distance the magnets are from the inside wall of the pipeline

External 'magnetic noise' also affects the sensitivity selected as setting too low a threshold (highly sensitive) may mean that the unit picks up stray magnetic flux in the surroundings of the pipeline from passing vehicles, electric valves, etc.

Through many years of designing and manufacturing magnetic pig detection equipment OEL has found that threshold levels between 15 – 35 milli-Gauss have been reliable in use. Tests done on standard schedule mild steel pipelines have shown that with strong magnets, mounted correctly, flux readings 10 – 20 times this level have been present on the outside wall of the pipeline.

By using easy-to-install signallers which can be positioned anywhere along a pipeline, launch operations can be monitored with multiple confirmations that the pig has successfully navigated and left the launching terminal.

Magnetic Signalling Subsea: Monitoring from Vessel

In order to monitor pig passage subsea the indication from a signaller can be:

- Monitored by a diver or ROV in real-time (on the signaller display)
- Transmitted topside via an ROV communications umbilical (utilising an RS232 interface)
- Autonomously transmitted topside utilising acoustic technology which can be accomplished by interfacing an acoustic pinger with the signaller

The project discussed will be the pipeline between Statoil's Heimdal platform to Marathon's Brae platform which incorporated an ROV monitoring the signaller display (as seen below). An explanation will also be given with regards to how an acoustic interface could have been implemented and the potential benefits this method provides.

The Heimdal to Brae pipeline is an 8" 116km long line in 120m water depth buried in a trench of 0.9m. Pig monitoring was a very important aspect of this job due to the quantity of wax present in the line having caused pigs to become stuck on previous runs. OEL was approached to assure successful monitoring of the inaugural pig run of a High Friction Jetting Pig which was designed to be able to loosen and remove all wax deposits in one run. Such an operation had never before been undertaken and as such there was no real method of ensuring the pig would complete its run without fault.

4000SD Unit above Buried Line at Heimdal to Brae Pipeline (Detected Pig Passage)

The buried line raised speculation with operators as to the ability of a signaller being able to detect a pig from a metre above the pipe. OEL advocated the use of their subsea magnetic signaller, the 4000SD. This works in the same way as the topside MAGSIG® model but is designed specifically for subsea usage in depths of up to 3000m. Since the unit measures changes in magnetic flux and not an absolute value it posed no difficulty to configure the unit to detect the pig at the metre distance from the pipe.

OEL operators duly ensured that the magnet packs mounted on the pig were strong enough for the change in flux to be detected over such a distance. The pig design had already been approved by this point, meaning that OEL had to assimilate magnets of necessary strength to be mounted on the pig with no option to alter any parts of the pig design. The ability to adapt to a given pig configuration evidenced the flexibility of magnet strengths available to operators utilising magnetic signalling methods, without the requirement of additional time and expense associated with design modifications.

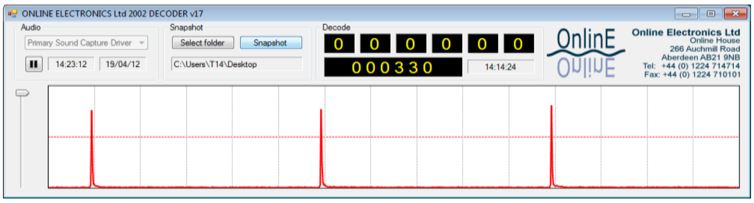
As shown in the image above, the 4000SD correctly signalled pig passage at eight locations along the pipeline and so monitoring of the High Friction Jetting Pig was a success.

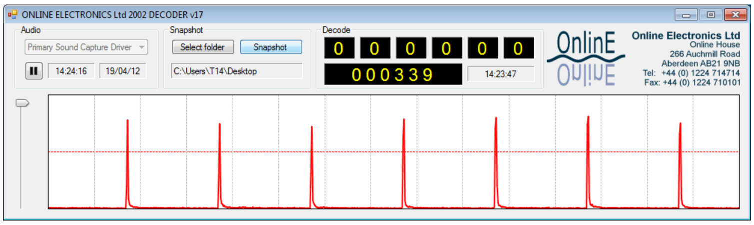
There is another method available for subsea pig signalling that does not require an ROV to monitor the display nor transmit information offering a potential cost reduction in vessel utilisation. This involves a signaller being interfaced with an OEL 1260 Acoustic Smart Pinger to transmit the signaller data topside once a pig passes the unit.

The pinger will usually be configured to operate on a dual rate. This involves a pinger continuously pulsing at the background ping rate to confirm successful data transmission until such time a pig passes the signaller, after which the pinger will start to ping at a faster rate to indicate confirmation of pig passage.

Usually the background ping rate will be set at a very low level in order to preserve battery life (around 1 ping every 5 seconds). The ping rate to confirm pig passage will be quicker as the unit is not likely to be in operation for as much time after pig passage has been indicated (standard rate is around 1 ping per second). The pinger operating at its standard ping rate will function for around 80 days and can transmit signals topside at distances of up to 8km. This means the vessel does not need to stand by above the signaller to await pig passage when other operations could be undertaken during the pig run. When the pig is estimated to transit the signaller the vessel simply has to sail back to within range to confirm if the pig has passed.

The pulses emitted by the pinger are received topside utilising an OEL 2001 topside receiver. The signals received can then be interpreted using dedicated Audioscope software offered by OEL. Audioscope is a multifunctional platform that displays waveforms received by either electromagnetic or acoustic pulses. The display is easily understood and is particularly useful for differentiating between coded transmissions, as would be the case when identifying the difference between ping rates.





Two Audioscope displays showing the background ping rate (top) and confirmation of pig passage (bottom). Note: the difference in the ping rate is clearly observable and simple to interpret

Remote Pig Monitoring

It is not always possible for operators to have staff on location to oversee information provided by signallers. This is often the case for pipelines which span great distances, lines in remote areas or simply to reduce the costs associated with having staff remain on site during lengthy pigging applications. For projects like these it is imperative to have an effective method of communicating the data received to operator locations to either warn of imminent pig receipt at a terminal or to track a pig path along a pipeline. Both of these outcomes will be addressed with reference to BP's Central Area Transmission System (CATS) project's pig receipt operations and pig tracking on Aleyeska Pipeline Company's Trans-Alaska Pipeline System (TAPS) project respectively.

CATS

The CATS pipeline begins at a riser platform adjacent to the BG operated Everest Gas Field in the Central North Sea and transports gas 404km to the CATS processing terminal in Teeside on the North-Eastern coast of England. BP required to know when the pig had transited the offshore section and reached a beach valve station in order to provide pre-warning of arrival at the main terminal (the pig is known to take around half an hour to transit from the beach valve station to the receiving terminal). It was requested that this be done remotely to save the expense of having staff overnight at the beach site awaiting pig passage in order to give the terminal advance notice to allow receipt of the pig. It is important to ensure the valve is left open for as short a time as possible.

The operators requested a minimum of three confirmations that the pig had passed before accepting the legitimacy of signals received. BP already had signallers on site to enable two confirmations of pig passage but no method available to communicate this information remotely. Since the pig had already been equipped with an ATEX 3001X electromagnetic transmitter for locating purposes and the valve station was certified as an ATEX zone it made sense for OEL to advocate the use of their Electromagnetic 3003X ATEX antenna and 3002X ATEX Receiver for signalling purposes. The antenna picks up the signal from the transmitter as it passes its position on the line and then transmits this information to the receiver. The receiver was connected to a GSM link which was configured to send a text message to operators' phones at the time of pig passage.

Pipeline in pit at beach valve station with 3003X antenna strapped to the pipe wall. A cable connected to the antenna transmits signals received to the 3002X Receiver at the pit's surface.

OEL's GSM link can be interfaced to any signalling apparatus and offers very simple installation and operation. The unit is a small battery-powered box that can last extensive periods of time without being replaced (up to 5 years battery life). Each box is fully user-programmable storing up to 4 phone numbers to contact at the time of a pig signal being received and any number of boxes can be used in conjunction on a single network. Each GSM unit can be linked to up to 6 signalling devices at any one time. Pig signalling can be communicated to mobile devices at any location worldwide providing there is mobile network coverage in the area.

During operation the 3002X began to show activity sometime before pig passage. Pig passage was confirmed by the 3002X system at 16:11. During this time the 3002X continuously monitored the signal slowly increasing until it had reached its maximum level during pig passage, at which time the GSM link triggered and contacted operators' mobiles. Pig arrival was also confirmed by other signallers on the line. Triggering of the GSM link provided operators with adequate remote pre-warning allowing sufficient contingency time for preparations to be made at the receiver terminal.

TAPS

The Trans-Alaska Pipeline System (TAPS) runs for 1250km, commencing at Prudhoe Bay and covering great distances of rural terrain at points elevated to heights up to 1445m and eventually terminating at Valdez, the northernmost ice-free point in America. TAPS requires two pigs per week to be pumped through the line for cleaning purposes. The operator needs to monitor pig passage at each valve station in the line for the entire distance, some of which are in very remote locations and are rarely visited by workers. Previously this was done utilising flowmeters at certain valve stations, however, this method did not provide full coverage and was unreliable.

Since this project is now an ageing operation there is evidence of low flow rates and an increase in wax content in the pipeline which raises concerns towards the likelihood of a pig becoming stuck during its run. Therefore the tracking of these pigs is of upmost importance. If a pig does become stuck or lost it will need to be retrieved as quickly as possible so as to avoid down time which in turn could affect the whole of Alaska's domestic oil production.

Project conditions for pigging the TAPS lines presented several difficulties. The most evident obstacle to pig monitoring was the depth at which the lines were buried. Due to the excessively cold temperatures the lines were buried in up to 9m depth for vast stretches of pipeline (over 600km). This was to ensure that product flow would not freeze during operation as a result of Alaska's predominantly permafrost terrain.

Since the pigs were already equipped with electromagnetic transmitters for locating purposes, OEL designed a special antenna and receiver utilising electromagnetic technology. The 3004E antenna, located above ground, was designed to withstand acutely cold temperatures and enable the detection of signals at 9m pipeline burial depth and then relay these signals to the 3002E receiver located within a valve station on the line. The function of the 3002E receiver was to allow transmission of these signals to operators at remote locations.

The 3002E facilitated a direct link to the Company's SCADA network which was already in place for remotely operating valves. This method allows operators to monitor pigs passing each point in the line from any location where there is access to the Company network, usually, these transmissions are monitored from the Company headquarters in Anchorage. This project now implements a full range of remote EM antennae and receivers strategically placed at pump and valve stations for the length of the pipeline.

Aleyeska Pipeline's Trans-Alaska Pipeline System

3004E Antenna attached to the pipe wall at TAPS
(same antenna design was used at points on the line buried at 9m depth)

3002E Receiver mounted at remote valve station monitoring cabin

Pig Receipt Indication

Indicating pig receipt is an integral part of any pigging operation. There are many aspects to consider:

- Advance warning of when the pig is due to arrive
- Multiple confirmations by different pig signalling technologies
- Absolute confirmation and location of pig in the receiver
- Determination of any debris in front of the pig
- How far the pig is from the receiver door

This section will describe the functionality of OEL's Ultrasonic ID5000 (Active) Pig Signaller in relation to BP's Kinneil project.

ID5000 Active Ultrasonic Pig Signaller (ID 5000A)

The ID5000A is attached to a pipeline with the main purpose of signalling pig passage by sending a high frequency ultrasonic pulse through a liquid pipeline medium several times a second. This pulse stream effectively creates an ultrasonic 'sound beam' across the pipeline by reflecting off the opposite pipe wall. Once this beam is broken pig detection is indicated.

There are extended uses of the ID5000A applicable to operations where a pig or plug has become stuck or deliberately stopped. The unit can profile the interior of a pipe utilising the principle of 'time of flight' measurement which is essentially the measurement of time it takes between the ultrasonic pulse being emitted and an echo received. This principle allows the unit to provide physical measurements of the internal features of the pipeline and objects in it. Therefore the unit can be used for functions such as:

- Measuring the internal pipe diameter
- Measuring the distance between the pipe wall to the pig body
- Providing a profile of debris or wax found within the pipeline
- Functioning as a permanently fixed wax monitoring tool so that future pigging can be determined as and when needed

Debris profiling allows operators to gauge for any cleaning requirements in an 'empty' pipe or assess how much debris would need to be removed that has been pushed in front of a pig before the pig can be retrieved.

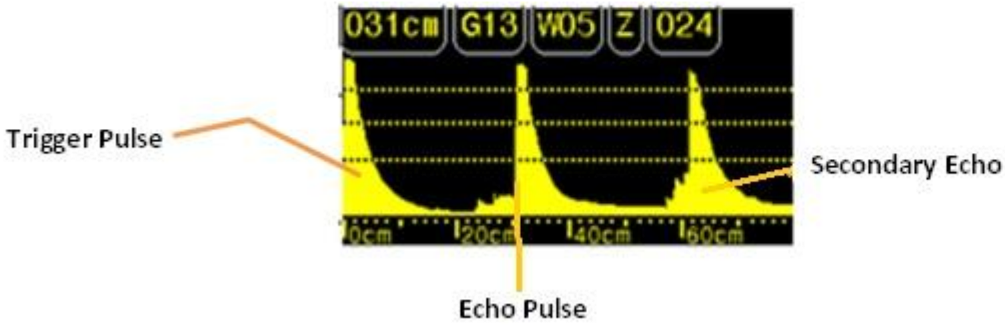
This functionality eliminates the need for any isotope/radioactive/x-ray type non-intrusive NDT measurements.

Using the id5000a allows:

- Immediate physical measurements of the pipeline's internal features. No need for offsite processing
- Profile of a pig or debris situated within the line can be established
- Does not require the creation of restricted zones of operation for personnel
- Completely portable and can be installed on any liquid pipeline by a trained operator

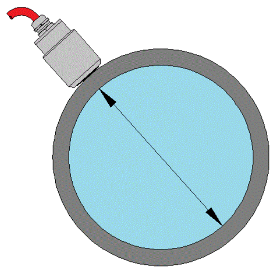
By viewing the live display (below) a visual representation of the pulses can be analysed to give an accurate indication of any object within the pipe, such as discs on a hard bodied pig or foam pig. If the 'spikes' shown at 31cm (in this example) disappear then there is no reflection from the back wall and so the unit will signal the detection of a pig.

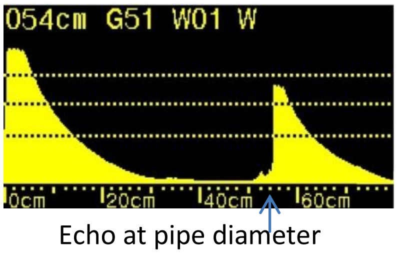
'Live' OLED display on id5000a



Clear pipe

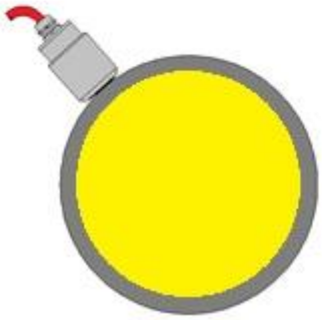
When pipe is clear a reading of the full Internal Diameter is given:

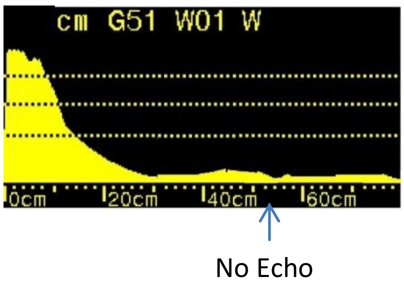




Pig or discs (no echo)

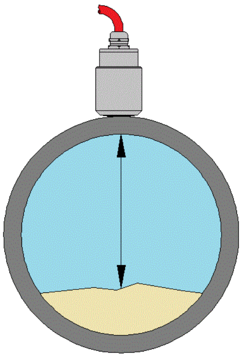
When a pig is present in the line the signal is completely blocked, so when there is a zero (or thereabouts) reading of the internal diameter of the line the presence of a pig can be confirmed:

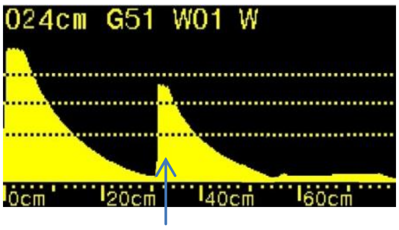




Pig body or debris (echo at 25cm)

When placed at the 12 o'clock position the sensor will give a measurement of the clear space above any debris that has collected at the bottom of the pipeline allowing for a calculation of the 'settled debris' in the line:





Echo at pig body or debris

Tests undertaken on a GEL slug to demonstrate the different waveforms displayed when the pipe is clear and when the signal is blocked by the GEL slug within the pipe

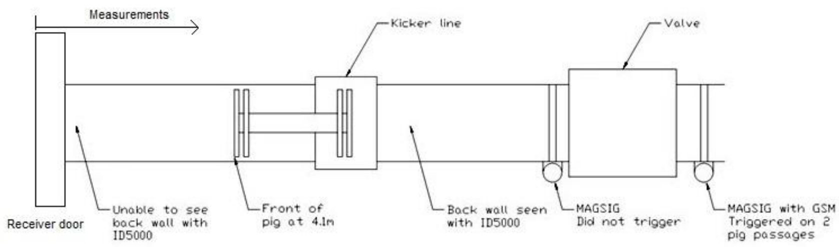
Test Kinneil

Kinneil is a BP-operated terminal at the delivery end of the Forties Pipeline System which a is 36" pipeline that transports crude oil 384km from the Central North Sea towards Grangemouth refinery, located under 3km from Kinneil. For pigging operations at Kinneil, BP required 3 confirmations of the pig having been successfully received and hence sitting stationary in the receiver.

Two MAGSIG® units were placed before and after the isolation/pigging valve at the receiver to indicate when the pig had entered the receiver. Further confirmation of pig receipt was to be confirmed by indicating the presence of a stationary pig in the receiver first by a 3003X antenna and 3002X receiver (again the pig was equipped with electromagnetic transmitter) and finally utilising the ID5000A.

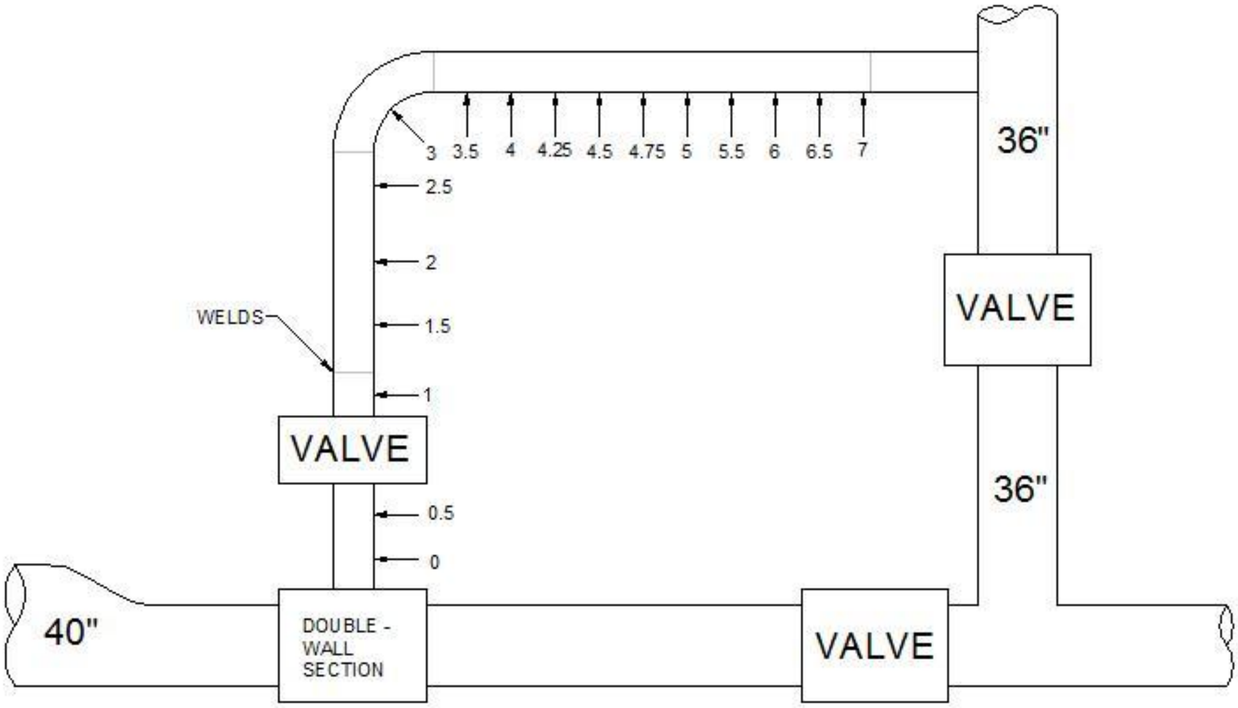
At the time of pig arrival, the MAGSIG® situated before the valve triggered to indicate passage but there was no indication from the unit positioned after the valve. From this information operators were able to deduce that the pig had stopped in the valve. In order to push the pig through the valve the bypass valve at the receiver was closed further. The additional force of line flow that was previously diverted through the bypass valve and now along the main flowline was sufficient to propel the pig through the valve and into the receiver barrel which was confirmed by the triggering of the second MAGSIG® unit. The 3003X antenna was then used to scan the receiver barrel and detected a pulsing signal from the transmitter, the ‘null point’ of which was 4.2m from the receiver door.

The ID5000A was then used on the receiver barrel and the front end of the pig was detected at 4.1m, a short distance from the kicker line in the receiver barrel. At 5.9m, the ID5000A got a response at 40cm depth displaying part of the pig body. There were now three confirmations that the pig had cleared the isolation valve and had stuck in the receiver. The unit took a reading behind the pig which confirmed the line as clear, giving a profile consistent with the pipeline’s internal diameter. From the readings of the front of the pig and behind the pig, operators were able to deduce that part of the pig had stopped at the ‘kicker line’ exit point. The ID5000A received no signal when moved from 4.1m along the receiver barrel indicating that there must be a large build-up of debris in the line which had been pushed in front of the pig.



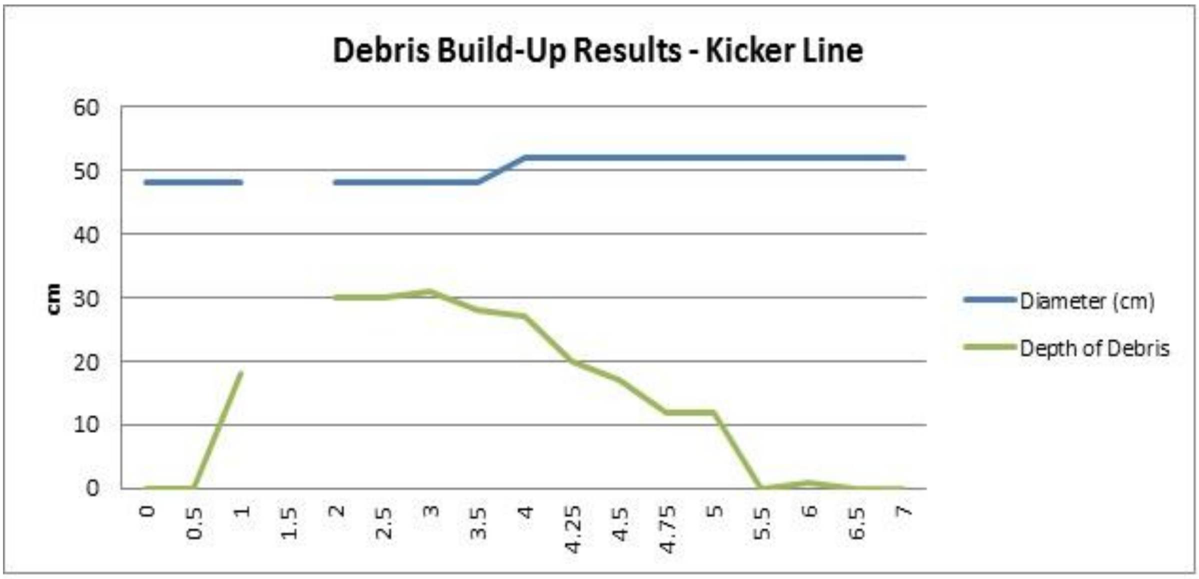
By being able to profile the debris in front of the pig and the clear line behind the pig, OEL was able to indicate the exact pig location with three confirmations that the pig had entered the receiver and was stuck 4.1m from the receiver door at the kicker line. At this point operators had all the information necessary to open the receiver door, clear out the debris and retrieve the pig.

Due to the volume of debris present in the receiver BP requested if OEL could conduct a profile of the debris build-up through the kicker line. The drawing below shows the receiver layout.



Surveyed positions along 'kicker line' at 0.5m intervals

The kicker line was inspected at 17 different points each 0.5m apart. Data points were taken both horizontally on the pipe to determine pipeline diameter and vertically to determine the level of debris settled at the bottom. The kicker line was found to be free of debris for the first 0.5m of the line. An OEL operator was unable to find a signal at the one metre mark due to lack of access. Large amounts of debris were recorded up until the 5. 5m mark at which point the level of debris was significantly reduced.



Conclusion

As observed, there are many potential obstructions to monitoring pig navigation on routine pigging operations. This paper aims to show that many of these challenges are surmountable given the necessary ‘know how’ of pipeline operators and the deployment of the correct combination of technology. It is evident that often many issues can be resolved through utilising the same technology in a different manner or altering what equipment is used in conjunction with a particular signaller and/or receiver.

The aim of this paper was to show that by altering the configuration of various acoustic, electromagnetic, magnetic and ultrasonic technologies the following challenges could be overcome:

- Successful Pig Launch indication with minimum down-time or servicing requirements
- Ability to monitor pig passage subsea without the requirement of an ROV or diver with improved vessel utilisation
- Remote monitoring of pig passage for various applications, such as buried lines, ATEX zones and rural locations
- Successful Pig Receipt Indication
- Solutions towards identifying the location of a pig at its estimated arrival time.

Demonstration of how complex technologies can be used intuitively and with ease to solve an array of problems has been emphasised with reference to a variety of major projects illustrating the success of such methods.