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Guest COMMENT

Dr Oleg Aksyutin

Deputy Chairman of the Management Committee of Gazprom and CEO of South Stream Transport BV, Russia

When we talk about the TurkStream project, people usually question the political difficulties that we faced. We had South Stream – the predecessor of TurkStream – cancelled under political pressure. At that stage, our pipes were already delivered in Bulgaria and our pipelay vessel entered the Black Sea to kick-off the construction campaign. It was not easy for our team to find an alternative route and to deliver the project. We are proud of the perseverance of our team who never gave up.

We are convinced that one of the reasons why we stayed together during the difficult phase is because our experts enjoyed the technical challenges we faced on the project. Being a Doctor of Technological Sciences, I indeed prefer to talk about these technical feats.

> "WE GENERATED MANY NEW INSIGHTS IN MATERIALS CHARACTERISTICS AND BEHAVIOUR, PIPELINE DESIGN, SEABED INTERACTION..."

TurkStream is characterised by its significant water depths and relatively large outside diameter of the pipeline. The depth along our route exceeded 2200 m. By all standards, this is extreme for any pipeline. As we installed a pipeline with a 32 in. diameter, TurkStream is in fact a world first. By comparison, other existing pipelines in the same diameter range are installed up to a depth of 1400 m. Surely, those other projects do not have a length of over 930 km like TurkStream.

For the industry to be able to manufacture the line pipe to the project specification, we needed a complete materials development programme. Together with our partners in the industry, we successfully pushed the limits of technology by executing a programme that was effectively the largest qualification programme in the industry's history up to that moment.

One of the results of our extensive programme is that we used thermal ageing during the production process to recover the collapse resistance of the pipe. This way, the project could reliably extend the fabrication factor (alpha-fab) from the DNV standard value of 0.85 to a project specific value of 1.00, bringing the required wall thickness down within the manufacturing capabilities of leading pipe mills.

The project was further complicated by the anoxic nature of the deepwater section, with associated high H_2S content. This placed further demands on the materials specification. One might think that the complexity ends there, but it does not. Especially along the Russian continental shelf break, we had to lay the pipeline along steep slopes, reaching close to 40°.

Of course, we defined all the technical specifications before we started the pipelay campaign. Doing the job is something else. That is where *Pioneering Spirit*, the largest construction vessel in the world, did her magic.

I would not define the Black Sea as the roughest sea of the world. Still, it is far from being easy to lay a pipe at 2 km water depth while encountering 6 m high waves and wind speeds in excess of 40 knots.

Even under these circumstances, *Pioneering Spirit* was capable to safely continue the pipelay campaign. We even set a record, laying 6.3 km in one day. On just one occasion in the 15 months that the vessel laid pipe for TurkSteam, we needed to lay down the pipe due to weather conditions. Just to be clear: we did not avoid the more difficult months in the winter. Even stronger, the final touch to the project, the last offshore welds – the so-called above water tie-ins – were performed in the winter months in order for the project to be completed on time.

When we look back at the entire project, we realise how we stepped into the various unknowns. The prize is that we generated many new insights in materials characteristics and behaviour, pipeline design, seabed interaction, manufacturing processes and construction. The scientific value and experience for future pipeline projects is priceless. Each of the individual characteristics of TurkStream would be enough to classify a project as 'challenging'. All combined they really made our project 'extreme'.

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COMMENT

EXTREME IS A HURDLE, NOT A BARRIER

Quickly giving thought to the word 'extreme', one may think of a challenging outdoor adventure – such as the Marathon des Sables – or perhaps an incredibly hot chilli – like the Carolina Reaper – or maybe a threat of danger and risk to life or society – such as a pandemic or a terrorist organisation.

In the pipeline industry, extreme is quite normal for a pipeliner. Pipelines can run for vast distances, often through remote, uncharted locations where climatic and geological factors require both foresight and the capacity to react quickly and effectively on demand. Equally, extreme situations can surround local opposition to projects, thieves stealing crude and natural gas, and governments setting policies and changing regulations during a project's development.

The Nord Stream projects – both 1 and 2 – have faced an ongoing battle regarding the EU's Gas Directive amendment, which was passed on 23 May 2019. Discussed in the Extreme 2019 editor's comment, it was highlighted how if Nord Stream 2 fails in its bid for derogation, then it would have to apply EU rules mandating that its only shareholder cannot be both the owner of the pipeline and the shipper of the gas, and that other companies shall be entitled to access the final section of the pipeline. Flash forward to the present, and Nord Stream 2 has, as of 20 May 2020, lost its court case against the Gas Directive changes – the EU's General Court rejected Nord Stream 2's attempt to annul the directive as inadmissible.

It has been argued by the gas project that if the new obligations are complied with, then Gazprom (the owner) would be forced to either sell the pipeline in its entirety to Germany (from Russia) or completely restructure the organisation, at a heavy financial cost. There is the option to appeal the EU General Court's decision and also challenge any exemption decision by BNetzA (the German regulator) by claiming the amendments to the Gas Directive were invalid. 14 June is the deadline for any appeal to BNetzA and 30 August to file an appeal against the court's decision. There has been confirmation, however, that both legal decisions have not impacted Nord Stream 2's construction works. In fact, the only progress that has been interrupted has been a result of the US imposing sanctions on companies providing pipelaying vessels for the project – thus Allseas suspended pipelaying in the project's Danish section.

20 May was a day of extreme polars; on the one hand, Nord Stream 2's bid for derogation was denied, but on the other hand the Nord Stream Pipeline was granted derogation from the application of the primary provisions of the Gas Directive. Having transported over 345 billion m^3 of natural gas since the first line was commissioned in November 2011, the project involved complex logistics and numerous feats of engineering firsts. Overcoming the extremes has resulted in the efficient transport of natural gas and the fulfilling of an important role by securing Europe's energy supply.

> "THE PROJECT INVOLVED COMPLEX LOGISTICS AND NUMEROUS FEATS OF ENGINEERING FIRSTS"

During recent months as a pandemic has battered the globe, leaving no corner untouched, people have been facing extreme challenges, whether it be social, financial, mental, etc. However, many have risen to the occasion and turned a darkness into light, with people setting themselves extreme challenges for the greater good. This has included people running marathon distances around their apartment balconies to setting almost-impossible targets. One such example is Captain Tom Moore, who at 99 years old, on the eve of his centenary year, raised £33 million for the UK's National Health Service by walking, with the aid of his walking frame, 100 laps of his garden in a charitable quest.

Evidence is clear that the extreme can be overcome, it just requires a splash of ingenuity, a heap of perseverance, and unfettered focus. Please read on through *World Pipelines*' special magazine for some tales from extreme pipeline jobsites – whether it be in the deserts of Kuwait, the outback of Australia or the jungles of Myanmar, we have it all covered.

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WORLD PIPELINES

SURVIVAL IN THE DESERT

Matteo Dondeo, Euro Pipeline Equipment S.p.A., Italy, discusses the key features of equipment used for a challenging pipelaying operation in the deserts of Kuwait.

This year marks the 25th anniversary of activity for Euro Pipeline Equipment S.p.A., and this article looks back at the many projects the company has carried out. Since 2015, the company has changed its approach to the market, developing into an active pipeline equipment manufacturer in serving oil and gas sectors across the globe, from Mexico to Argentina, Europe to the Middle East, and North Africa to Russia.

The entire range of products from pipelayers to bending machines, from pay welders to vacuum lifts, has benefitted from thorough design improvements – introducing the use of suppliers like Caterpillar, Yanmar, Sauer Danfoss, Bosch Rexroth, Fassi, Bonfiglioli, Berko and many others. This has been a key focus of Euro Pipeline Equipment, together with the build-up of its rental service.

In less than 36 months, 41 pipelayers (98 t) have been manufactured and proposed to the market; however, nowadays this is not enough. Clients require a real integrated service with a range of options, from the possibility of choosing the simple

cold rental of the equipment, up to the turnkey solution of rental with maintenance and operators.

As a result of this flexibility, the availability of a rental fleet, and financing solutions in case of purchase of equipment, more than 200 pieces of pipeline equipment and accessories manufactured by Euro Pipeline have been used by pipeline contractors across the world. One of the most recent challenges has been the New Refinery Pipeline project under development in Kuwait.

Case study: Kuwait

The protagonist of this project is the pipelayer Performer 980, chosen by Alghanim International due to its patented technology that allows a containerised shipment. One of the key aspects of this project is the extreme conditions, in which 20 pipelayers and a bending machine from Euro Pipeline's rental fleet have been working for almost two years.

With environmental temperatures up to 52°C, constant winds and desert sand, the pipelayers have been working in laydown, welding and tie-in crews without any major breakdown thanks to the specific design of the component, and the regular maintenance carried out on-site by Euro Pipeline technicians.

This particular contract, on top of the harsh conditions, foresees a full-service including mobilisation of the equipment; rental; maintenance with technicians on-site; supply of parts, consumables, and lubricants; and also locally hired operators. In terms of Euro Pipeline's history, this is the rental project most similar to a subcontract.

Figure 1. Performer 980 laying pipe in Kuwait.

Figure 2. Part of the Performer fleet in Alghanim's project yard.

The Performer 980, a 98 t hydrostatic pipelayer of the last generation in terms of heavy equipment, can be equipped with a Tier 3A engine, or Tier IV f-Stage V engine for those locations in which emissions are required to comply with the most stringent regulations. As standard it comes with Bosch hydrostatic transmission that allows counter-rotation of the tracks, to aid handling on-site.

The most important feature of the Euro Pipeline Performer is the patented system that allows operators to dismantle the left and right tracks; in this way, the pipelayers can be shipped via standard open top container, resulting in cost and time savings since special transport authorisations are not required.

The Euro Pipeline solution for modular pipelayers is designed to be easy-to-use and effective. Thanks to a dedicated console, the operator can control four stabiliser legs hydraulically actuated that lift the equipment from the ground. Once the pipelayer is lifted in a safe position, another set of controls activate a pin and hook system that allows the disengagement of the left and right tracks. Counterweight as a package, boom and accessories are then disassembled. The full operation cycle is carried out in a couple of hours, and requires an operator and several helpers together with a small crane to handle the parts. Each pipelayer fits into two 40 ft plus one 20 ft open top containers.

In order to provide the best working conditions for operators and maximise efficiency on-site, all the Performers have been equipped with a fully enclosed cabin with air conditioning and a digital display to continuously monitor the working parameters of the pipelayer. All the controls feature ergonomic multi-function joysticks that are designed to enable precise operation of the tracks and winches.

A fully integrated electronic package

All the Performer pipelayers are equipped, as standard, with an anti-tipping system and load monitoring for safe operations in any conditions, including challenges that present themselves, such as steep slopes.

It works by measuring the boom angle and the hook load, providing a continuous feedback to the CPU. If the combination of load and angle is over a pre-set curve, the anti-tipping system disengages the boom and/or the hook in order to avoid a dangerous situation for the operator.

A graphic chart is also reported on the screen for the operator, and a traffic light allows line inspectors to evaluate in real-time that all the equipment is operating in a safe way.

It is possible to easily adjust (within certain ranges and always on the safe side of the operation) the intervention of the anti-tipping system in order to best fit the specific site requirements, such as the depth of the trench or increased tolerance for the operator manoeuvres. The operator can also intervene autonomously as a result of a free fall push button, in order to free the load and prevent tipping. An electronic boom kick-out completes the electronic package, to prevent boom bending in case of incorrect operation.

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Fleet management

The entire fleet of Euro Pipeline pipelayers is equipped with a fleet management system based on GPS technology, designed to ensure constant data communication in the most remote areas. The system allows access via a dedicated website to a map-integrated control panel, which is able to show the vital parameters of each piece of equipment.

The first section is dedicated to the actual data such as working hours, working status, pipe load, boom angle, equipment inclination, engine rpm, AdBLue level (where applicable), load monitoring status, and battery voltage. The second one is the diagnostic section reporting CPU errors, engine errors, and encoder status. The third section shows the actual position of each piece of equipment on a map. Data logging is also available as a standard feature, reporting the historical data of all the previously mentioned parameters.

This makes it suitable for efficient supervision of the equipment in order to maximise use on-site, minimising idle time, and controlling proper maintenance operations.

Figure 3. Euro Pipeline's 22-36 bending machine and mandrel ready for bending.

Figure 4. Performer 980 working in harsh conditions with desert sand and temperatures up to 52˚C.

Pipe bending machines

The second family of equipment used on the Kuwait project is Euro Pipeline's pipe bending machine. The PBM-22-36 model is a hydraulic cold bending machine that has been used by Alghanim for bending pipes ranging between 24 - 36 in. in diameter.

The rental includes all the bending sets and the hydraulic wedge mandrels that are fed directly by the PTO of the bending machine, without any need for external hydraulic units or a pneumatic mandrel that requires an additional compressor. It is powered with a Yanmar 4TNV98 engine with 85 HP, enough for bending pipes up to 36 in. with relevant thickness. Specific air filters and anti-sand barriers have been used in the Kuwaiti application of the bending machine to reduce maintenance on-site.

The hydraulic system is based on a twin pump (main and service) able to pump hydraulic oil up to 250 bar; together with generous cylinders and the proper bending set geometry, the bending machine can bend up to X80 pipe. Also, in the case of double joint pipe, the 8000 kg hydraulic worm gear winch can easily handle 24 m on the urethane-coated supporting rollers of the machine. Particular care has been taken with the design of the bending set, and it is available bare or with polyurethane lining for fusion bonded expoy (FBE) coated pipes.

The pipe bending machine is also up-to-date with the latest HSE regulations; an operator protection grid, anti-slippery operator platform, safety winch counter frame, ergonomic winch blocking control, and engine positioning far from the operator are standard on each piece of equipment.

The Euro Pipeline pipe bending machine is available in seven models according to the pipe size, and can cover pipes from 4 - 60 in., and from X52 up to X100 steel grades. The bending machine package can be integrated with the full range of hydraulic wedge mandrels, from the easy 6 in. spindle mandrels up to the 60 in. double motor mandrels.

A range of conditions

In contrast to the conditions in Kuwait, there are arctic environments in Russia and Kazakhstan where pipeline projects are found. As a result, Euro Pipeline Equipment has developed a winterised version of its bending machines and pipelayers, including webasto, engine space heaters, dedicated electrical plant, dedicated lubricants, use of special steel resistant at -40˚C , proper heat treatments, and a closed, insulated operator cabin for safe and comfortable conditions.

Euro Pipeline relies on a network of sales managers and agents covering almost all of the countries in the oil and gas market; wherever the project is, the company is structured in order to provide full service. This is also carried out through partnerships with local companies, as in the case of the Kuwait project, for the best results in terms of project achievement.

Construction in all weathers

Lisa Perreault, SCAIP S.p.A., Italy, explores a range of pipeline construction equipment designed for use in challenging and extreme environments.

SCAIP S.p.A., located in Parma, Italy, has been engineering and manufacturing products for the pipeline, industrial, and agricultural industries for over 60 years. The company's machinery and equipment are working around the world, including North America, South America, Russia, Asia, the Middle East, and Australia. As a result of collaboration with both Italian and foreign pipeline companies, SCAIP has been involved

Figure 1. SPB 36-48 operating in freezing conditions in Manning, Canada.

Figure 2. SPB 36-48 in the Andes Mountains, Peru.

Figure 3. SWM-50 operating in the Apennine Mountains, Italy.

Figure 4. SPD-350EHD operating in the New Mexico, US desert.

in providing greater security and comfort for operators, compliance with environmental issues, and more user-friendly operation of the machines.

The company's aim is to not only offer standard products such as pipelayers and pipe benders, but also to offer solutions that are customised to the specific requirements of operators.

SCAIP has recently provided several machines that are designed to work efficiently in conditions of extreme temperature and terrain. These machines have been utilised in desert conditions with temperatures approaching 48°C, and arctic conditions with temperatures near -37°C. Examples of these extreme variations in terrain and climate where SCAIP's machines have been utilised include Siberia (Russia), Arizona (US), Canada, Saudi Arabia, Australia and Germany, to name a few. The company prides itself in incorporating the latest technological advances in electrical and hydraulic systems that are assimilated into its line of equipment.

The fleet of equipment

SCAIP's bending machine line has been utilised in some very extreme temperatures and locations. From working in freezing temperatures in Alberta, Canada, to South American countries such as Peru at the top of the Andes Mountains, the Mexican desert, and the Italian landscape in winter.

The SCAIP bending machines can be ordered with or without enclosed cabins. These enclosed cabins include air conditioning and heating systems. A winterisation kit is available that includes an insulated motor containment, the enclosed cabin with a heating system, and various programmable warmers for cold weather fluids. The entire line of SCAIP bending machines include CAT engines as standard; however, other engine options are also available. All bending machine models have the options for operating hydraulic mandrels or pneumatic mandrels directly powered from the bending machine, with self-propelled mandrels also available.

A new SCAIP product related for use in extreme terrains is the stationary winch SWM-50. These are designed for assistance in winching equipment and other pipeline-related items up a steep incline, by the use of a winch platform that is anchored to the top of the steep incline. This particular unit has a 215 HP engine with a weight of 28 660 lbs. The SWM-50 has a primary maximum pull of 110 230 lbs and a wire rope diameter of 1.26 in.

SCAIP's SPD padding machine line also has several incorporated features that allow the customer to choose a machine to successfully operate in an extreme terrain and climate. All SPD padding machine models are hydrostatically driven, which gives the operator a full range of speeds, and are designed to be efficient and controllable on steep grades. The new


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Figure 5. SPX 660 in the Amazon rainforest, Peru.

C9.3B CAT engine on the SPD-350EHD model is coupled with an oversized radiator to allow operations in high-temperature climates such as Saudi Arabia, Australia, Africa, and the desert states in the US. The SPD-250EVO model includes a C7.1 CAT engine that incorporates an oversized radiator, and the SPD-450EVO model includes a C13B CAT engine also with an oversized radiator. This engine/radiator set-up is designed to allow the machines to work in extremely warm temperatures without the engine overheating. The escalator system contains features that allow the operator to vary escalator speeds and shaker system speeds in order to adjust for conditions in the material being processed.

Coping with difficult terrain

In extremely steep terrain, the shaker/screen system allows the operator to adjust the angle of screen inclination to allow the fine material to fall through the screen, thus capturing the maximum amount of fine material for the padding operation. The new cabin design includes an ergonomic operator seat, as well as an air conditioning and heating system. The new style cabin moves and rotates to allow the operator to view the padding operation when working the machine on either side of the trench, thus allowing the operator to make small adjustments to the functions and providing the required speeds dependent upon terrain and material conditions.

The SPD-160EVO padding machine is a design which is not self-loading, but is loaded with material normally from an excavator. It can be utilised in extremely steep terrain by means of a winch line assisting the stability and movement of the machine. A remote-control system allows the operator to adjust the functions of all padding machine models without being located near the machine. This added safety feature is important when operating in steep terrain or unfavourable climate conditions. Another safety feature is cameras that are installed in strategic locations to assist the operator in observing critical areas of the machine. The 250EVO, 350EHD, and 450EVO have two digital screens installed in the cabin: one screen for machine functions and one screen for the observation cameras.

SCAIP's SPX pipelayer line has engine options from Tier 3 to Tier 4 final (Stage V) that allow the customer to choose an engine that will conform to the extreme terrain and climate in which their project may be located. The SPX pipelayer line also has a fully digital screen that allows the operator to easily view the operational functions of the machine at any time and visualise important information from the anti-tipping system (ATP®). The track controls include a single joystick for general movement of the machine, and also include a right and left track lever so that the operator can make fine track movements and adjustments when on steep terrain, or when moving the pipe into a tie-in position. The proprietary ATP allows the operator to visually see the weight on the hook at any given time, and also observe the position of the boom overhang. A boom kick-out switch, which stops the boom from contacting the A-frame, is also incorporated into the machine safety system. A coloured graph screen on the monitor shows the inclination of the actual machine, and will disengage the movement of the machine if positioned on too steep of an angle based on the internal programming. Another coloured graph on the monitor shows the outlay position of the boom and weight on the hook, and will also disengage the hook/boom operation if the parameters exceed the internal programme. The SPX pipelayer line has an open ROPS for the machine, or there is the option of a fully enclosed cabin. Air conditioning and heating are both standard with the enclosed cabin option.

The '03 models, which include the SPX-603, SPX803 and SPX903, are designed to enable the customer to remove all of the major components such as the boom, ROPS-FOPS, counterweight rack, A-frame, and both tracks (in the case of the SPX903, the tracks can be retracted to reach 3 m width) for easier transportation in locations and countries where road permits, etc. are extremely limited.

SCAIP recognises that technological development has become increasingly important in recent years, specifically in order to improve the safety of products in working environments, as well to reduce their environmental impact. The opportunity to develop ideas that can meet customer requests is important to continue this advancement, and SCAIP continues to apply this to its range of products.

ANCHORS MAKE BUOYANCY A THING OF THE PAST

Jeff Curnick, Platipus Anchors Limited, UK, explains the application of percussion driven earth anchors as a solution for pipeline buoyancy in a range of challenging locations.

Buoyancy has always been an issue when a pipeline is constructed within a saturated environment, such as rivers, floodplains, or areas with a high ground water table (Figure 4). Over the last century, pipeline owners, designers and contractors have utilised various

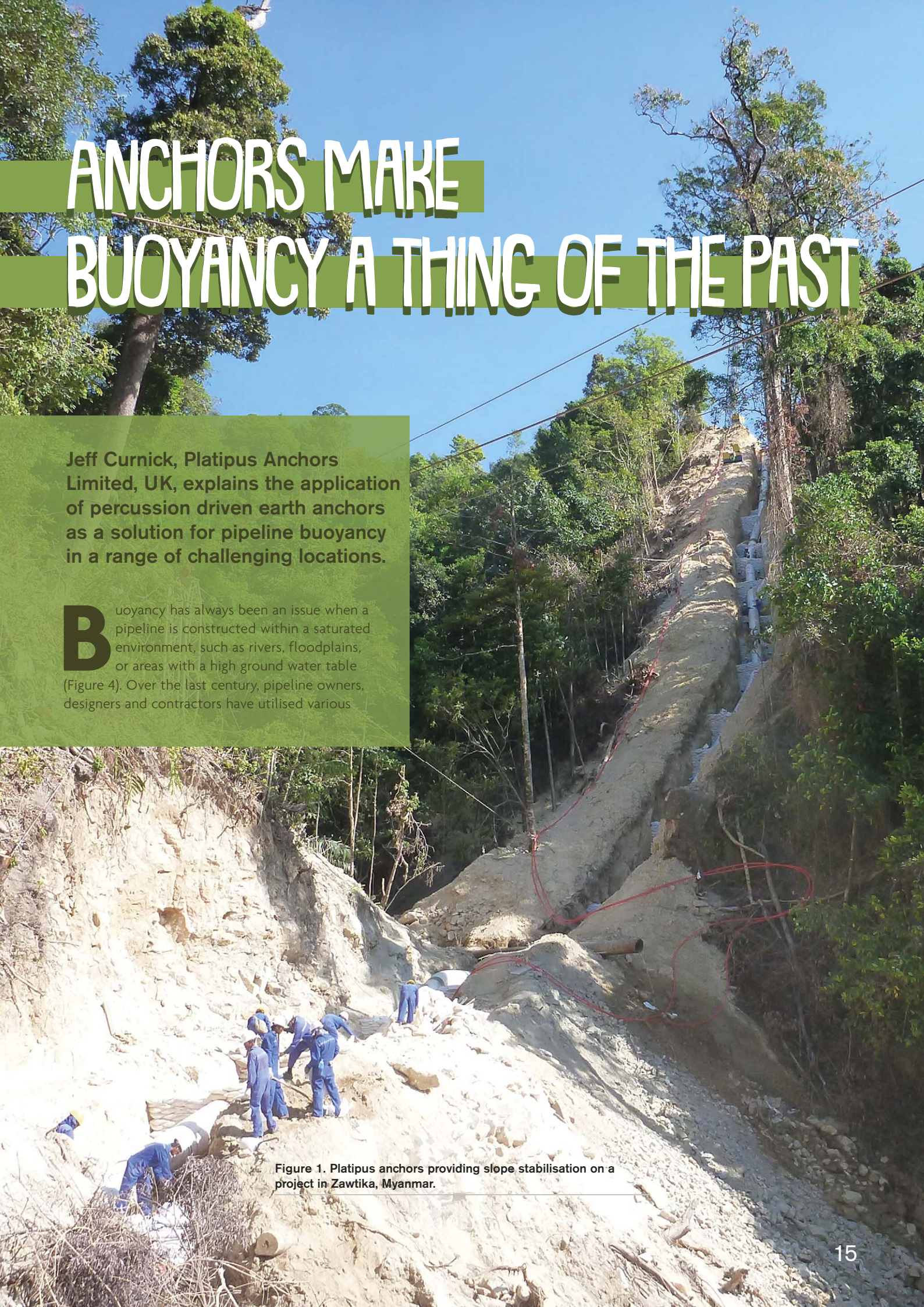

Figure 1. Platipus anchors providing slope stabilisation on a project in Zawtika, Myanmar.

methods to counteract floatation, starting with simple pipeline weighting that consisted of two cast iron halves bolted together around the pipe. This was later replaced by concrete set-on weights and geotextile saddle bags. All these methods provided their own challenges, particularly with the transportation of heavy materials to remote locations and the time and resources it took to implement, especially when today's modern equipment was not available. It was not until the 1980s that significant progress was made in pipeline buoyancy control technology with the introduction of ground anchors as an economical and effective alternative to traditional methods.

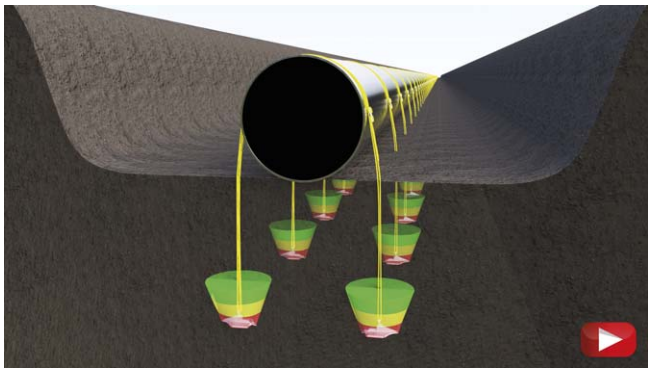

Figure 2. **Installation guide of a typical Platipus pipeline anchoring system.**

Figure 3. **Typical frustum of soil in granular soil.**

Figure 4. **Installed pipeline in submerged conditions anchored by the Platipus systems on the TAP project in Albania.**

An earth anchoring system

Platipus® has over 35 years of experience in the design, manufacture and supply of Percussion Driven Earth Anchors (PDEA®) for a wide variety of market sectors. The PDEA is a modern and versatile device that can be rapidly deployed in most displaceable ground conditions. It offers a lightweight, corrosion-resistant anchor that can be driven from ground level using conventional equipment. It is designed to create minimal disturbance in the soil during installation, can be stressed to an exact holding capacity, and made fully operational immediately. As a completely dry system it also has minimal environmental impact.

Pipeline anchor system specifications can vary depending on the diameter of the pipe, length of each pipe section, local soil conditions (including ground water table), structural integrity of the pipe, if the pipe is being installed in fresh or saline water, and the reinstatement of backfill material. Typically, the anchor head is manufactured from aluminium alloy or spheroidal graphite cast iron and is connected to a webbing strap. The system is then put into service by using a buckle and tensioning device. Anchor system sets are spaced along the pipeline, at calculated distances, through areas that require anti-buoyancy measures or stabilisation from other external forces. The installation of a typical pipeline anchoring system can be seen in the animation in Figure 2.

Stress distribution and bearing capacity

The stress distribution in front of a loaded anchor can be modelled using traditional foundation theory. The ultimate performance of an anchor within the soil is defined by the load at which the stress concentration immediately in front of the anchor exceeds the bearing capacity of the soil. Factors that will affect the ultimate performance of the anchor include shear angle/undrained shear strength of the soil, size of the anchor, depth of installation, and submerged conditions.

PDEAs perform well in granular soils, displaying short load lock and extension characteristics, a broad frustum of soil immediately in front of the anchor, and extremely high loads (Figure 3).

Stiff cohesive soils, such as boulder clays, can also give impressive results. However, weaker cohesive soils, such as soft alluvial clays, can result in longer load lock and extension distances and a smaller frustum of soil in front of the anchor. Consequently, these conditions require a larger size of anchor and, if possible, a deeper driven depth to achieve design loads.

Advantages of the anchoring system

- Standard 2 t (20 kN) and 10 t (100 kN) pipe kits are suitable for small and large diameter pipelines.

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- High-performance anchors are designed to provide significant cost savings over traditional concrete set-on and saddle bag weights.
- Anchor installation can be completed before or after the pipe is laid using standard on-site equipment.
- Each anchor system can be proof tested and verified immediately upon installation.

Figure 5. Platipus pipeline anchor system being tensioned on the TAP project in Albania.

Figure 6. Anchor installation guide for a typical slope stabilisation application.

Figure 7. Platipus system to prevent uplift used in combination with foundation on the Cirebon 2 project, Indonesia.

- Application-designed webbing can provide fast tensioning with no damage to the pipe or corrosion coating.
- Flexible anchor selection for varying soil conditions.
- No cathodic protection is required.
- Technical guidance and support at all stages of the design and installation process.
- Low mobilisation costs and minimal environmental impact.
- Lightweight products and installation equipment make them ideal for extreme or challenging locations.

Platipus pipeline anchor systems have been used on challenging projects in extreme locations all over the world, as outlined in the following case studies.

Trans Adriatic Pipeline – Albania and Greece

This is a well-known and documented project transporting natural gas across Albania and Greece over a full onshore length of 770 km (478 miles). Platipus Anchors was the selected supplier for all anti-buoyancy control measures as required in the low-lying areas of the pipeline with extremely high ground water table. This resulted in fully submerged soil conditions that posed many challenges in preventing uplift to the 1200 mm (48 in.) and 900 mm (36 in.) diameter steel pipes.

The worst-case soil conditions, as identified by the in-depth soil investigation reports, were soft to firm clays with an undrained shear strength of approximately 49 kN/m^2. A full analysis of these conditions was carried out by the Platipus geotechnical team and used to calculate the theoretical anchor loads. An evaluation of the results, compared to the supplied uplift forces, resulted in the B8 anchor being specified with a design load of 50 kN per anchor (or 100 kN per anchor set) and installed to an average depth of 9 m below pipe invert level.

Weighing approximately 8 kg each, the B8 anchors were an ideal solution in the extremely remote areas of Albania with limited road access. From an installation perspective, after full on-site training by Platipus Anchors, readily available existing plant 30 t excavators were used to install the anchors to the required depths and proof tested to the specified loads. Finally, the webbing strap supplied with each set of anchors was ideal for placing over the steel pipe as no cathodic protection was required (Figure 5).

Zawtika onshore pipeline project II – Myanmar

This 6 km long pipeline project, completed in 2014, was characterised by complex ground and terrain conditions such as tropical forests on sandy soil and steep slopes that needed to be crossed. After the successful completion, a

number of the steep-sided slopes were identified as being potentially unstable and needed to be remedied to prevent any future damage to the now operational pipeline.

By this time there was extremely limited road access to the site and no machinery left in the remote area (Figure 1). Any proposed solution had to be suitable for installation by hand-held equipment only. While not a buoyancy control application, Platipus Anchors can cover a wide range of applications, with erosion control and slope stability being an industry standard.

Armed with Platipus S8 anchors weighing only a few kilograms each, portable hydraulic hammers and 100 kN hydraulic stressing equipment, the installation teams were able to get anchors into position on the slopes for installation to the specified 4 m depth. Laid out in a diamond grid pattern and installed beyond the theoretical failure plane identified in the slope analyses design, each anchor was proof tested to an exact holding capacity of 40 kN – providing global stability to each section of slope where required. Anchor installation for a typical slope stabilisation application is illustrated in Figure 6.

Cirebon 2 – Indonesia

The 1000 MW coal power plant, being constructed in the coastal region of northern West Java, Indonesia with poor soil and potential flooded working conditions, posed several challenges for the installation of the various pipework required.

The most challenging of these was the 4000 mm (157 in.) diameter circulating water pipes which had the potential to sink or float due to the soft clay soil and extremely high ground water levels.

Part of the designed solution was to implement a concrete base placed on piles to provide foundation support to the large diameter pipes. Platipus Anchors was then tasked with providing a system to prevent the uplift in combination with the foundation (Figure 7).

The solution was a large 75 mm wide webbing strap, with a 150 kN breaking load, placed over the pipe at set spacings and secured to pre-cast eyebolts using full stainless steel accessories for added corrosion protection. With only basic tensioning tooling required, this solution provided the installation team with a simple means of securing the pipeline without the need for any additional machinery on-site.

Summary

As pipeline infrastructure continues to expand globally, often through challenging and remote terrain, the need for lightweight, effective and economical solutions to counteract pipeline buoyancy and support other associated applications is vital.

The PDEA system provided by Platipus has been designed to be a beneficial solution for pipeline stakeholders needing to overcome the aforementioned challenges and achieve their objectives. WP

COVER STORY

Christoph Ludescher, LCS Cable Cranes, Austria, describes the technical capabilities of the cable crane system for use in pipelaying in inaccessible areas.

Figure 1. Cable crane systems can be equipped with curves to follow any specific terrain. The picture shows a pipe being transported along a 12˚ curve.

KING OF THE SLOPES

When it comes to laying pipes in inaccessible areas, most pipeline contractors are confronted with the challenge of how to lay the pipes in the steep terrain. For this purpose, cable crane systems can provide an efficient solution. Pipes, construction material, and equipment can be easily transported over all kinds of territory and positioned precisely at any point along the track. This method has been used successfully for several years.

The first cable crane system ever used in connection with a major pipeline construction was a simple build 'tower and cable construction' which was installed and operated for the Trans-Alaska Pipeline project in 1977. One of the last sections of the project was a 45° steep slope at Thompson Pass with a length of approximately 850 m. With the help of the cable crane system it was possible to lay the 48 in. and 24 m long pipes.

The methodology has essentially been the same since 1977, but it has been significantly improved and refined in terms of safety,

efficiency, quality, and with respect to the environmental impact.

Work method

A cable crane system consists of a strong wire rope which is tensioned, in mountainous terrain, from a point in the valley to a point at the mountain top, with several towers and special ropeway components. Furthermore, the system is equipped with a crane unit that is mounted on the track rope. Loads can be lowered and lifted with the crane unit's two independently controllable winding devices. The crane unit itself is pulled up and down along the track rope with a haul rope which is wound on a winch. The winch is located at the top station.

Figure 2. **Transport of 48 in. pipes in up to 30° inclined terrain for a pipeline project in Greece.**

Figure 3. **Easy transportation of padding material for filling up the trenches. Due to the two independent lifting systems of the crane unit the bulk can be adjusted as required.**

For the construction of a pipeline in steep terrain by means of a cable crane system, the following workflow can be realised in an easy and safe manner:

- Installation of the pipeline exactly along the pipeline centre line.
- Transportation of a spider excavator into the steep slope for trenching.
- Transportation of the pipes and construction equipment to the intended location.
- Precise positioning of the pipe into the inclined trench.
- Holding the pipes steadily during the welding operations.
- Transportation of padding material and filling of the trench.
- Reinstatement of the right-of-way (ROW) where the pipeline has been constructed.

Construction challenges and how to handle them

Various challenges can arise during the planning and construction of a pipeline that need to be solved. Generally, these challenges are particularly demanding in sections that are difficult to access – such as mountainous areas, steep slopes, and inaccessible terrain – with a conventional means of transport. The following key challenges have to be considered when it comes to the laying of pipes.

The terrain

The terrain and landscape may impact the length of the pipeline and the way the pipes are laid. Areas with large differences in altitude, mountains or swampy terrain can make it difficult to find a pipeline route. Some contractors may choose to make an expensive detour or build many kilometres of access roads to avoid certain inconveniences.

The cost-efficient alternative method to overcome these challenging terrains is the use of a cable crane system. With such a system the pipes, construction material, and machinery can be transported in mid-air to the intended location. The ropeway runs directly above the ROW and can load and unload goods at any point along the track. An advantage of a cable crane system is that it is flexible and can be installed at a range of unanticipated locations and in sections of up to 3000 m. Furthermore, pipes can be positioned easily and safely in slopes with an inclination of up to 70°.

By using a cable crane system, pipelines can follow direct routes and contractors do not have to lay several additional kilometres of pipeline to avoid tough terrain. Consequently, savings can be made on costs and resources.

Transportation of pipes

Efficient material planning and a working supply chain are crucial for every pipeline construction project. When a construction site is in an area with limited access for excavators, drilling equipment and sidebooms, the logistics department faces a considerable challenge. The solution is a cable crane system that can easily and safely transport large pipes and construction material to exactly where they are needed. Additionally, the system can be used to move all kinds of machinery, e.g. excavators, to any place along the track where civil works or trenching works shall be performed. Loads of up to 20 t and more can be lifted and unloaded along the ropeway route.

Laying and welding of pipes

Not only the transport, but also the laying of pipes in a steep and critical slope can be solved with a cable crane system. For proper erection of a pipeline, an exact working procedure during positioning, welding, and other installation steps is important. In areas with a high inclination, working with traditional methods such as sidebooms, large welding equipment, and sandblasting is largely impossible. The cable crane system makes pipelaying at the exact intended position and welding in steep and hazardous terrain uncomplicated. Since each crane unit of a cable crane system has two independently controllable winding devices, the pipes can be perfectly lifted and lowered into the terrain to fit in the trench. For the following welding works, the cable crane holds the pipe steadily in place. The pipe is fixed with a welding clamp, just as it would be done in flat terrain, ready to start the welding process (Figure 4).

In relation with the sandblasting and coating, a special platform can be attached to the cable crane system and be transported above the welded section. The tasks are then performed from this platform, which is hanging above the pipe.

Padding material

The laid pipes need to be stabilised with sandbags or foam and covered with padding material to guarantee a fixed positioning. Depending on the inclination of the terrain, the use of sandbags and padding material might not be sufficient. Anchors, net fixations, and other protection may be required as well. Transport of the required filling material to the intended location represents another challenge. When using a cable crane system, the solution is as simple as attaching a transport bucket to the crane unit. The bucket is filled with padding material at the loading station with the help of a truck or an excavator. Afterwards, the bucket is positioned with the cable crane to the place where it is needed (Figure 3). The crane operator adjusts the bucket to the inclination of the terrain by using the two independent lifting systems of the crane unit and empties it as planned.

Figure 4. **Precise positioning of the pipe for welding purposes.**

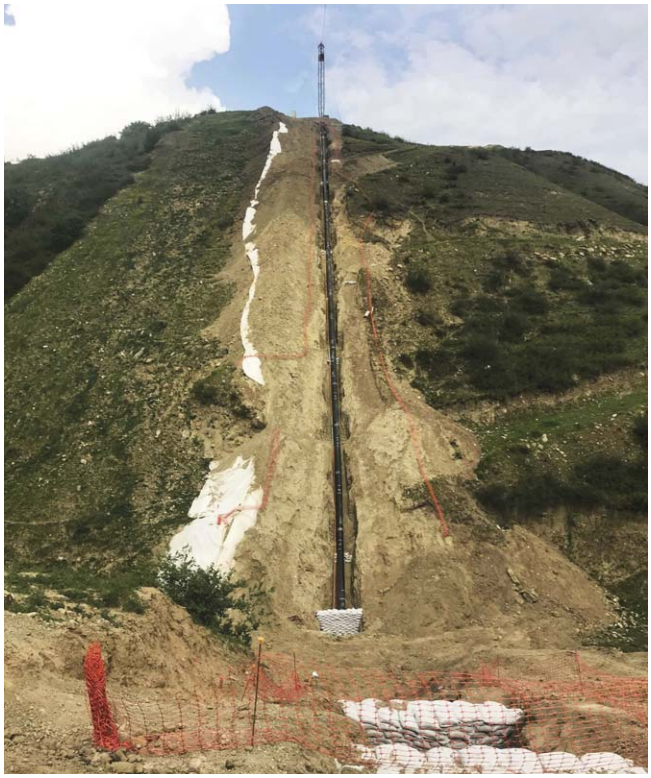

Figure 5. **Cable crane systems require a smaller ROW than traditional methods, which means the environmental impact is reduced.**

Environmental sustainability

Pipelines are often built over long distances, some of which are subject to various environmental requirements. When a route crosses a critical section, the area is not just difficult to overcome, but also surrounded by untouched nature. In this case, you have the option to build more construction roads to access the slope, or to build an alternative route to bypass this section. Apart from the environmental issues that have to be considered, in both cases the construction

Figure 6. A reinstated steep slope by means of a cable crane system and spider excavators after the pipeline construction has been finished.

Figure 7. Case study in Papua New Guinea, where two cable crane systems are installed on different steep slope sections.

time will be increased. A cable crane system is designed to offer a more time-efficient and environmentally sound solution than alternative options. A ropeway is only erected temporarily in order to lay the pipe along the ROW, and due to a smaller ROW – just 8 m instead of 30 m with traditional methods – the environmental impact is also reduced. After finishing the construction work, the slope is reinstated with the help of the cable crane system. Finally, the system is dismantled and the foundations and anchors for the towers removed.

Considering all these aspects, the application of a cable crane system is a proven alternative for efficient and safe pipeline construction in tough terrain and under difficult conditions.

Case study – pipeline construction with a cable crane system in Papua New Guinea

LCS has been commissioned to provide two cable crane systems in order to build a 600 m long section of a pipeline in the jungle of Papua New Guinea. There are several challenges to be considered: the area where the pipeline shall be laid is in a remote and environmentally sensitive region, and the track includes a steep section with an inclination of up to 30°.

With the ropeway system, it is possible to find a direct line of the pipeline through the difficult terrain and construct it without building long access roads. Thereby, the environmental impact can be kept to a minimum – an important aspect for the customer.

Based on its longstanding experience in providing customised solutions, LCS designed two systems for the project, one of which has two curve support towers, to overcome the steep section. These systems are installed, operated, and dismantled on two different steep slope sections. This allows the transport of all of the material for the construction work and the triple joints (pipe length of 36 m) to the exact welding location along the track. The pipe will then be kept in position until welding is completed. Subsequently, the laying of pipes, welding, and padding can be performed easily as well as in a safe manner.

Technical information of the cable crane systems

The two cable crane systems are designed with four towers each: one system has a straight line, the other has two curve towers. Each system is equipped with a crane unit with a payload of 6 t. The crane units have a double hoist unit. This means that the system can be operated in tandem mode, so when operated in this mode, the hoists of the crane unit can be lowered to each side independently. With this technique, the pipes and material can be positioned precisely in inclined terrain.

The maximum rope speed of each system is 4.5 m/s when fully loaded with the 14 in. triple joints and other construction material. One system is powered by a 350 HP diesel-hydraulic winch and the other system is powered by a 260 HP diesel-hydraulic winch.


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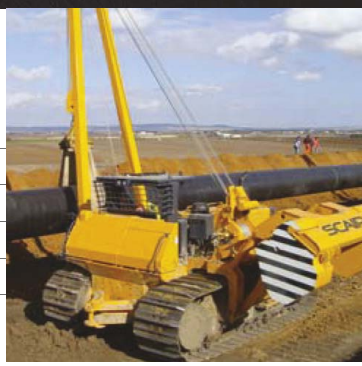
Operating weight (lb)	44,095	68,345	91.492	123.500	138,890
Net flyweel power (hp)	202	250	375	416	440
Travel speed (mph)	5.6	5.4	5.1	5	5.6

All models comply with engine EPA CARB Tire 4 final (or Tier 3 on request)



SPD PADDING MACHINE

MODEL	SPD-150	Restyling SPD-160 EVO	Restyling SPD-250 EVO	Restyling SPD-350 EHD	Restyling SPD-450 EVO
Screening area (ft²)	25	56	30	52	86
Operating weight (lb)	26,455	55,115	66,140	85,980	119,050
Net flyweel power (hp)	142	225	250	375	440

All models comply with engine EPA CARB Tire 4 final (or Tier 3 on request)

SRT-SFT CRAWLER TRACTOR

MODEL	SRT -155	SRT-180	SFT-155	SFT-180	New SRT-155RD	New SRT-180RD
Payload (lb)	13,230	22,050	13,230	22,050	13,230	22,050
Operating weight (lb)	20,945	27,650	19,620	26,455	25,355	33,070
Net flyweel power (hp)	202	225	202	225	202	225
Travel speed (mph)	4.6	5.0	3.7	3.7	4.6	5.0
Type	Rubber tracks	Rubber tracks	Steel tracks	Steel tracks	Rotating dumper Rubber tracks	Rotating dumper Rubber tracks

All models comply with engine EPA CARB Tire 4 final (or Tier 3 on request)

SPD PADDING MACHINE

MODEL	SPB-6.20	SPB -16.30	SPB-22.36	SPB-32.42	SPB-36.48	Restyling SPB-48.60 SL
Operating weight (lb)	13,225	40,785	59,525	95,900	149,900	182,985
Net flyweel power (hp)	62	142	142	225	225	225

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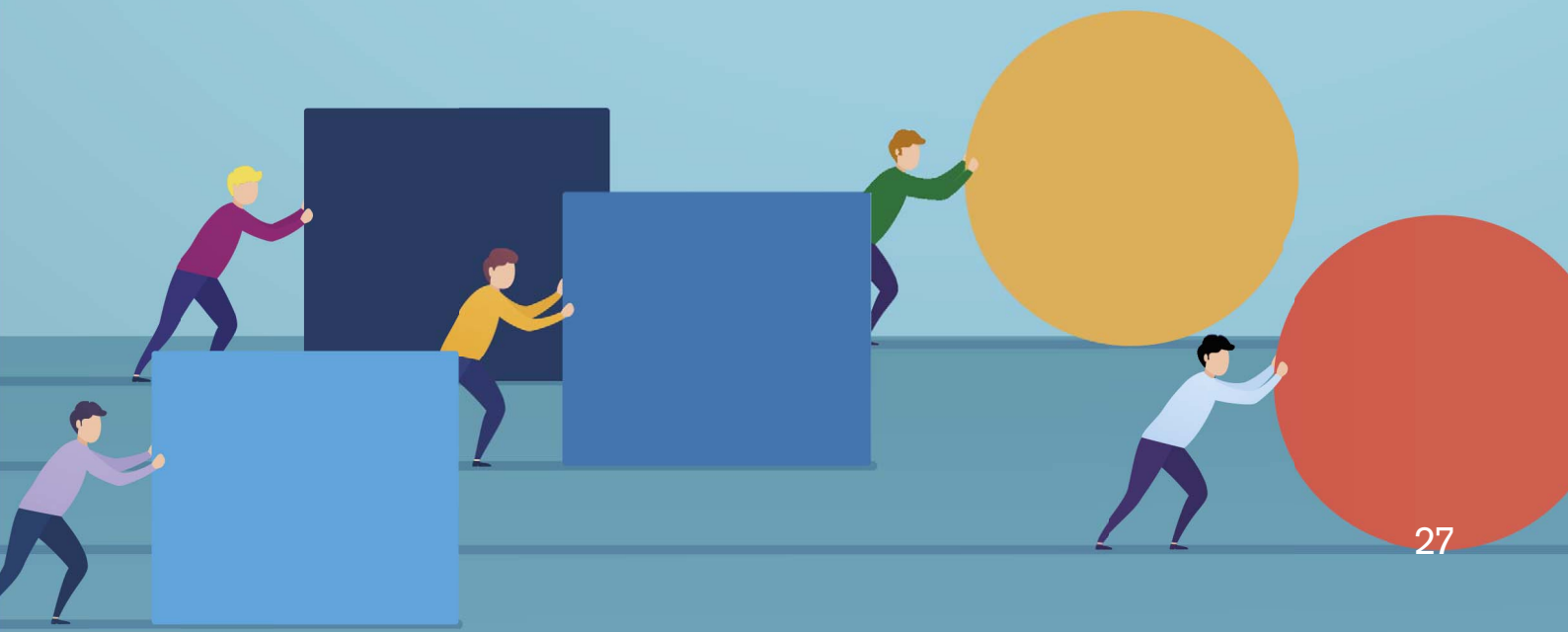
Strategy for success

Jules Rawles, SSI Group, UK, explains how the right planning for operations in high risk or remote locations can open up a wider range of opportunities for pipeline construction.

Health and safety of personnel are key to successful operations, and constructing pipelines requires great attention to all aspects of health and safety, including reducing risks for employees. Are these two principles compatible with pipeline construction and operations in higher risk, austere, and remote locations? SSI Group believes they can be, by following the five steps outlined in the following article. SSI's aim is to help companies to pursue commercial prospects in places where the threats and risks demand a deliberate risk management response. What happens when a company's commercial strategy involves



countries better known for their challenging environments than their commercial opportunities?

Such opportunities might be rejected without due consideration of the potential rewards, unless a structured approach to security and medical risk management is taken. Fortunately, it is possible to assess and manage these risks.

This article will explain the five key steps in addressing security and medical risks in remote, austere, or high threat environments. Following these steps can help new business opportunities not only become feasible, but a reality.

Gathering information

There is a great deal of reliable information available on the internet free of charge. The objective at this stage is simply to learn about the region and the country where the business opportunity has arisen.

Governments invest a lot of money in intelligence, and some of this information is made available to the public in the form of advisory services. Consequently, the British Foreign & Commonwealth's Travel Advice Service, and US Department of State Travel Advisories, are good places to start.

Many think-tanks produce indices measuring security and supporting reports that can be very informative. The Fund for Peace's Fragile State Index and the Institute for Economics & Peace's Global Peace Index are two noteworthy examples.

Finally, there is also the option to commission a report from a security risk consultancy, but at this stage – unless time is limited – this is often not necessary.

Framing the problem

This is a critical stage, the importance of which is frequently underestimated; however, it is key to ask the right questions in order to arrive at the right solution. Companies should take the time to clearly identify what the problem is that needs to be solved.

In simple terms, hazards are the threat to things that are valued. So, when framing the problem, this is a good place to start; it is important to identify the most valuable resources and capabilities of a business in the context of the commercial opportunity that has arisen.

Engaging with experts across the business will allow for a full understanding of how it will operate in the region where this potential opportunity exists. While doing so, companies should resist the temptation to jump to conclusions about what people, resource, or capability is the most valuable.

The problem has been correctly framed when it can be stated in a sentence or two that encompasses related sub-problems. There should be broad agreement among stakeholders that the statement does indeed encapsulate the problem.

An example of a such a statement would be: "How can continuity of operations, including the supply of essential materials, be maintained without stockpiling too many assets in the high threat area?", or "How can people remain working in this austere environment in the same physically and mentally healthy condition, as if they were working in normal conditions?"

Analysing the risks

With the knowledge of how it intends to operate, and which resources and capabilities are most valuable, a company should have the basis for understanding and analysing the security and medical risks. This can be undertaken by the company itself or a consultancy.

This is where the effort expended in gathering information pays off, as the more detail that is available, the better the quality of the analysis. Local, in-country agents can be particularly helpful in answering specific questions that arise during analysis, but it is important to cross reference recommendations.

A rational and analytical method is the best approach to take. Intuitively, a company may know that assets need to be protected, but it is only by applying a structured methodology that the detail necessary for the next stage can be achieved.

Counter-intuitively, the analysis of risk can actually soften the perception of it. This is why this stage should be conducted with representation from across the company, as the process and conclusions can reduce anxiety and increase support.

Also, it is crucial to consider risk from 'the other side of the hill.' Sometimes an asset has a value to others that is different to the value one company places on that asset – e.g. a truckload of pipe can be stolen but the £500 000 precision tool left behind. Equally the 'key status' of personnel is not always within 'management'; the On-site Manager will most likely have a deputy, should he/she become ill or unable to work a shift. However, the 'key person' may be a plant or precision tool operator, and that person may not have a deputy. Protection of the key assets and personnel is not always obvious.

Developing solutions

At the end of the previous stage, three or four security risks should have been identified that need to be managed. The seriousness of these risks is determined by the extent they can be mitigated, and this depends on the solutions that are developed and implemented.

Orthodox risk management strategies are a perfectly suitable point of departure for developing solutions; however, a limited understanding of what is possible can restrict the process.

To illustrate, a road may pass through a dangerous area but that does not mean movement through it is impossible or unwise. It is also often better to use alternatives such as light aircraft or fast offshore vessels to move people and material in relative safety.

On other occasions, solutions can be extremely simple. Renting and securing a villa or complex in a suburban or rural location is frequently much more cost-effective than the alternative of paying for hotel rooms in a nominally more 'secure' city centre location.

Implementing and evaluating

A security and medical risk mitigation plan will only be as effective as the diligence with which it is implemented. This

responsibility cannot be outsourced. Security and medical risk management must become part of the company's culture when operating in austere, remote, and high threat environments.

Perhaps the key task during implementation is assurance. Ensuring that assets are being protected as planned, resources are held at readiness as stated, and security officers and medical staff are briefed, exercised and competent are all assurance activities.

No matter how much information is gathered, how skillfully the problem is framed, how much time is spent analysing threats, and how comprehensively the mitigation of risks is planned, a company can never be fully informed and therefore risk can never be fully eliminated.

Consequently, both the assumptions made in formulating the security and medical risk management plan, and the current situation in which it is being implemented, must be continuously evaluated. This ensures that the response to risks remains appropriate.

One final recommendation is to conduct contingency planning and to periodically test/exercise the readiness to execute the plans that result. Going through this process can develop a culture of preparedness and greatly increase the resilience of the business.

Case study

By following a comprehensive risk management strategy in assessing the risks and complexities of working in a hostile, remote and austere environment, Global Marine Group was able to successfully carry out a project both onshore and offshore in Somalia.

This involved the *C.S. Sovereign* transiting the high risk area, best known recently for pirate activity. The port of Bosaso is on the northern tip of the Horn of Africa, where the *C.S. Sovereign* was then laying offshore, as well as engineers and technicians working and living onshore for several weeks.

"SSI RM led us through these risk management steps, enabling us to not only be comfortable with the post-mitigation risk, but also to bid competitively and win a project that we may otherwise not have bid on," said Robert Twell, Company Security Officer and Marine Manager, Global Marine Group.

Global Marine Group then went on to complete the security plan that was successfully implemented in-country. This complex plan involved deploying medics, travel managers and protection officers; chartering private planes; using accommodation complexes; liaising with local governors, national coast guard and police, as well as continually monitoring the security situation and adapting the plan accordingly.

"The project went so smoothly that it finished ahead of schedule with no security incidents," said Twell.

Conclusion

Jules Rawles, Director of SSI RM, states that "there are lots of commercial opportunities in countries with medical and security challenges, but risks can be analysed, understood and mitigated especially in the oil and gas sector. My advice is not to reject these opportunities without first going through the five steps outlined." WP

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OVERCOMING THE OUTBACK

Frank Tudor, Jemena, Australia, addresses the challenges of developing gas pipeline infrastructure across vast distances, difficult terrains and climates, such as in Australia.

The Australian outback is everything you think it is. As the books and films depict, it is hot, dry, and there is red earth as far as the eye can see. At more than 6 million km^2, to some people it is a whole lot of nothing, but to others it is a land rich in history, culture, and opportunity.

And it is in this remote, inhospitable, and demanding environment that energy infrastructure company Jemena has not only achieved one feat of engineering, but wants to do more.

Figure 1. The Australian outback; red earth, blue skies.

Weathering the weather

According to the Australian Bureau of Meteorology, the mean maximum temperature at the Tennant Creek post office, in the Northern Territory (NT), is 32.2°C, with temperatures in summer comfortably above 36°C. That said, it is not uncommon for temperatures to be well over 40°C.

Conversely, in the 'wet' season, cyclones can dump enough rain to cause widespread damage and flooding.

Figure 2. **More than 33 000 lengths of pipe were used to construct the Northern Gas Pipeline.**

Figure 3. **Jemena MD Frank Tudor (centre) officially opens the NGP at Mount Isa with MPs and key stakeholders.**

Figure 4. **It took approximately 17 months to construct the 622 km NGP.**

"There's no doubt, the climate of the outback is a challenge. It tests you all year round, which means increased levels of planning to ensure people's safety," said Frank Tudor, Jemena's Managing Director.

"When we constructed the Northern Gas Pipeline between Tennant Creek in the Northern Territory and Mount Isa in Queensland, it required a high level of planning to overcome the local climate and environment, strong leadership and excellent co-ordination to ensure the health and welfare of a large workforce. We had to do additional things that so-called business-as-usual infrastructure projects just don't require, such as building access tracks, erecting multiple remote camps, establishing sustainable sources of water, and managing complicated logistics for our local and fly in/fly out staff."

Land of plenty

Australia is considered a land of plenty. It is a country blessed with natural resources for both export and internal consumption. However, these resources are often found in the country's most isolated areas, and therefore the investment to extract and transport them is prohibitive.

This has contributed to high energy prices for Australian industrial and commercial customers, which threatens jobs and negatively impacts the economy, especially for those industries that use gas as a feedstock.

There are impacts for households and small businesses too. The cost of living in Australia is already high enough without high energy costs hitting the pocket.

"We know Australians want to use gas, and the research says we have huge reserves of it, but it's hard to get to, a long way from where we need it, and expensive to transport. Financially and logistically we're facing a huge challenge," said Tudor.

In early 2019, Jemena delivered on its promise to construct the Northern Gas Pipeline (NGP) and now transports up to 85.3 million ft^3/d (90 TJ/d) of gas, across 622 km – which is approximately the distance from Edinburgh, Scotland to London, England.

"Construction of the Northern Gas Pipeline was challenging because of the remoteness of the area, and the transportation and management of crews and materials in harsh climatic conditions, across vast distances. We did it largely thanks to the support from the local community and in the knowledge that commercial and residential customers are crying out for more gas," Tudor said.

"The NGP proved we have the know-how, experience, and commitment to successfully complete a demanding project and we are confident we can expand and extend the NGP, in what could result in a pipeline network more than 2000 km long, potentially creating 4000 jobs.

"If the potential of the Beetaloo Basin is realised, we could be supplying beyond 663.6 million ft^3/d (700 TJ/d) of gas, which is enough to meet the average daily gas needs of Sydney, Brisbane, and Adelaide combined. It is thought the Northern Territory has enough gas reserves to meet Australia's future supply needs for the next 200 years or more.

"Not only would this benefit high demand areas across the eastern states, but it would also have a considerable positive impact on the Northern Territory economy," Tudor said.

Infrastructure investment

According to the Australian Government's Geoscience Australia, the Beetaloo natural gas basin in the NT contains approximately 169 trillion ft³ (178 200 PJ) of undiscovered shale gas. Not only would its development bring huge benefit to Australia, but, as the first major shale basin in the Asia-Pacific region, it could support development across many countries in the area.

"The research is positive and suggests this country is sitting on exactly what we need to continue to support the energy demands of business and homes, secure our energy future, and deliver national and international opportunities. What we need to kick start this is targeted investment," said Tudor.

The idea of a Northern Gas Pipeline was the brainchild of the NT government. The NT government sought from market proposals to connect the vast gas reserves in the NT to the east coast. It required significant capital investment from the private sector – in this case Jemena, and the proposal was the Tennant Creek to Mount Isa connection. While investing in the NGP made sense, it also involved a level of risk.

For a while Jemena had just a single foundation customer, which meant approximately 70% of the pipeline's capacity remained uncontracted at the time the final investment decision was made. By the time the NGP was officially opened, in December 2018, it was 80% contracted.

"Our AUS$800 million investment in the NGP was not a gamble, but it was a bold decision by our shareholders and stakeholders who considered not short-term gains, but long-term investment in Australia's energy infrastructure.

"Now we need support from local jurisdictions to ensure market confidence to drive future investment. It is absolutely necessary that political and policy certainty across State and Federal governments is provided.

"This would give our industry the platform it needs to commit to greater investment. Without political agreement, the investment we so desperately need to ensure the future of Australia's energy markets, and ultimately the industries and livelihoods they underpin, is at risk," said Tudor.

Planning and consultation

While the upstream gas companies explore for gas in the Beetaloo Basin and across northern Australia, Jemena is enacting its Northern Growth Strategy, with planning and preliminary work ahead of any future pipeline construction. In addition to route planning, this also includes significant consultation with traditional owners, landowners, and the community.

The business is modelling a number of scenarios, depending on when and where fields open up, to construct a series of connected pipelines to move gas from the north to the east of the country. The NGP is the backbone of a four-step approach to the Northern Growth Strategy.

Stages one and two have been completed. These include the construction of the NGP and acquisition of the Darling Downs Pipeline, a crucial step in providing a platform for greater connectivity around Surat Bowen Basins.

It is early days in stage three, with Jemena entering a Memorandum of Understanding with Australian Stock Exchange (ASX) listed Galilee Energy Limited, which could see an anticipated 189 million ft³ (200 TJ) of gas delivered from Queensland's Galilee Basin to the east coast domestic market. Galilee Energy is currently flowing gas from its pilot well. The AUS$600 million project would result in a 585 km pipeline from Longreach (approximately 650 km southeast of Mount Isa) to Jemena's Queensland Gas Pipeline near Injune (approximately 550 km north west of Brisbane). It would

Figure 5. As each individual length of pipe was welded, the vision of the NGP was realised.

Figure 6. Unloading and stringing pipeline near Mount Isa.

include two compressor stations, two mainline valves, and two scraper stations.

The fourth and final section – stage four – would be the all-important last piece of the jigsaw, including the link between Tennant Creek and the Beetaloo Basin. Pipeline costs and length will be determined by where and when the gas is sourced.

Indigenous and community engagement

"In addition to the pipeline construction itself, one of the things we are most proud of about the NGP was the level of local support," said Tudor.

"We have great respect for the traditional owners of the land and we acknowledge the significant role Indigenous communities, landholders, and local communities played in supporting the pre-approvals and construction. It was good to be able to give back by ensuring jobs, training, contracts, and community support was provided for local communities and businesses."

The planning, construction, and commissioning of the NGP created more than 1100 jobs, of which (through Jemena's Local First approach) approximately 830 jobs were secured by people from communities surrounding the route, including 268 jobs for Indigenous people.

More than 260 contracts, worth in excess of AUS$52 million, were awarded to local businesses, with more than AUS$4 million invested in training and development opportunities.

Jemena's commitment to the community was recognised with awards from the NT government Chief Minister's Local Content Award and the Federal government's Significant Investment Award. However, Tudor says that while it is nice to be recognised, it is the local community who deserve the plaudits.

"We could not have achieved construction of the NGP without the local community, and we have developed a number of relationships with the community as a result. These projects are nation building for the economy and, just as importantly, life-changing for local businesses and people. To have their support and to experience working closely with local contractors, suppliers and individuals, has been rewarding."

Table 1. Jemena's Northern Growth Strategy

Stage	Activity	Status
Stage 1	Construct the Northern Gas Pipeline.	Completed
Stage 2	Acquire the Darling Downs Pipeline.	Completed
Stage 3	Construct new pipeline connecting Queensland's Galilee Basin to the Darling Downs Pipelines.	MoU
Stage 4	Final connections including between Tennant Creek and the Beetaloo Basin.	Recommended

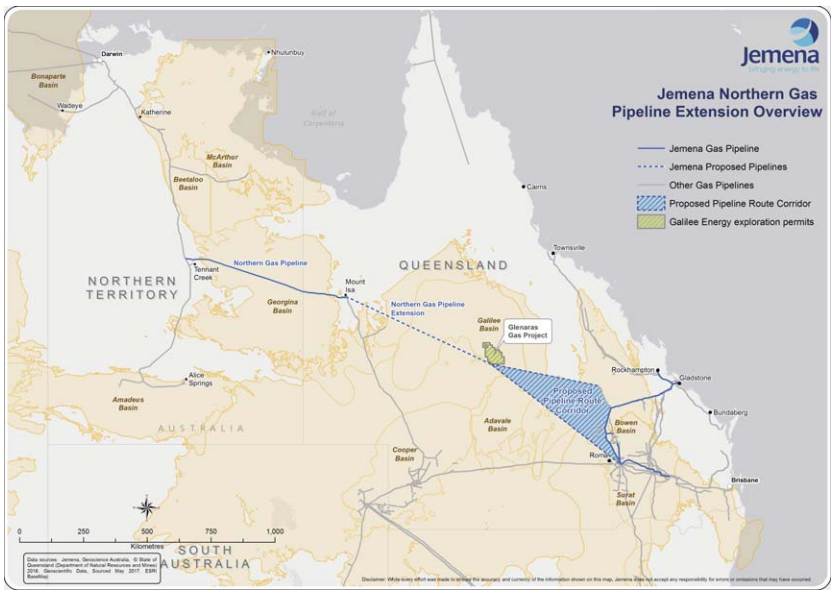

Figure 7. Map of Jemena's Northern Growth Strategy.

Pipeline for the future

"We know gas has a future in Australia, as our customers have told us they want to continue to use it in their industries and homes. However, in addition to meeting the demands of the current customer base, it will be important for the Australian gas industry to convey to users how gas supports renewable energy in Australia's future energy mix.

"We see a future where gas has a real role to play as a reliable, low carbon and affordable fuel source. Our Northern Growth Strategy is designed to support Australia's green ambitions and contribute to reducing the nation's carbon footprint. Gas has around half the carbon intensity of other fossil fuels and international experience tells us that it can accelerate a shift from coal, which in the US helped lower carbon emissions to levels not seen since the 1990s.

"By unlocking gas reserves in northern Australia, and having the capability to transport it from remote regions to areas of high demand, we will not only be supporting livelihoods, but also supporting environmental demand.

"The quicker we can access, extract and move the gas, the better for everyone. Now is the time for politicians and policy makers to see gas as a viable solution to the energy trilemma of affordability, reliability and sustainability, and to support national energy security.

"As a business, we feel privileged to have had the opportunity to build the Northern Gas Pipeline. We can't wait to get back on the ground and continue our work in northern Australia, and continue to enjoy the red dirt and blue skies," said Tudor.

Note

The units of measurement have been converted from terajoules to ft^3 using a conversion of 1 TJ = 948 000 ft^3. This figure has been rounded up for ease of understanding.

COMPLETING THE UNIMAGINABLE

Joel Bailer and Matt Fournier, United Piping Inc., USA, detail a pipeline relocation project in the US where conditions were challenging and the job was large and complex.

Oil and gas contractors are often challenged with completing projects in adverse, extreme conditions. What might seem an unworkable environment to the average person is simply another challenge to overcome to many contractors. When asking a superintendent or project manager their interpretation on extreme environments, several things might come to mind depending on the location or the environment.

Jobs can be difficult because of many factors, from the terrain to the distance to the project site, but every week men and women step up to support across all aspects of the job. While superintendents may think they have seen it all and are equipped to prepare their team, the reality is that each new project often holds unpredictable conditions and must be treated as a brand new challenge. It is not by coincidence or bad planning that so many pipeline projects are undertaken in extreme conditions. In fact, it is almost to be expected. Given the fact that many of these projects connect oil and gas supplies to markets, and that hydrocarbon deposits tend to be concentrated in a few locations, the most efficient and safest way to transport them is often along a line that was not drawn with comfort and

Figure 1. A 2.25 mile ice road through an expansive wetland was maintained at 24 - 40 in. of frost and ice.

convenience of installation in mind. Additionally, timelines are often dictated by limited windows of opportunity that frequently do not align with preferred seasonal weather. Working around protected wildlife species and their migration and nesting habits can also lead to less than optimal working conditions.

Tackling challenges as a team

Creating a plan of success and having a properly trained team that you trust is imperative to safely executing any project. It takes a team that has the skills and mindset to push through conditions that are cold, hot, dusty, and just plain miserable. An initial meeting with the team is necessary to lay out all the risks and the steps to be taken to mitigate the hazards. Fortunately, most workers have learned from experience what to do and how to keep everyone on the team safe.

Whilst many people are fortunate to be working in an ergonomic chair and desks, these workers are donning multiple layers to protect themselves from harsh weather conditions. We tend to complain when our office gets too cold, but these workers could have a master's degree in winter survival.

Challenges unrelated to field workers constantly arise during projects as well. As can be imagined, sub-zero temperatures tend to make a working environment difficult. Getting a piece of equipment to start can take almost all day, as well as the skill of a good mechanic. The small challenges that arise daily force everyone to push themselves to stay productive and motivated to get the job done.

Figure 2. Crews worked 24 hours a day to install sheet piling and welding/stringing the replacement section in sub-zero temperatures.

Figure 3. The project surpassed 105 000 hours, worked with more than 150 employees and zero lost-time injuries.

Experience in the extreme

United Piping Inc. (UPI), an oil and gas general contractor based in Duluth, Minnesota (US), is no stranger to extreme projects and challenges. Recently, the company's team completed a challenging pipeline relocation project in northern Minnesota. Located along the shoreline of Nushka Lake in Cass County and the Leech Lake Reservation, the pipeline had shifted from its original position since installation. This required the team of contractors to relocate the segment of pipe as part of the company's ongoing maintenance programme.

In total, the project required 14 permits acquired over a 10-month period, with an extensive public, government, and tribal affairs outreach plan. The project team worked diligently to select the remediation method most favourable to stakeholders for a long-term solution to a 1250 ft span that had deflected as much as 27.5 ft into Nushka Lake. Key options reviewed included a 2.25 mile pipe replacement, 0.75 mile pipe replacement, horizontal directional drill, and a smaller 1200 ft pipe replacement.

UPI knew that its general contracting services were going to be substantial. Services included site clearing and preparation – consisting of construction of an ice road, preparing the new piping, as well as excavation and removal of the old piping. Project work also included tie-ins, hydrotesting, field coating, internal cleaning, caliper and gauging of the new pipe, and site restoration.

Construction activities in the wetland could not run into another year, which created a tight construction schedule for the crews. One of the most challenging aspects of staying true to the schedule was the 2.25 mile ice road through an expansive wetland that was maintained at 24 - 40 in. of frost and ice. The temporary workspace spanned across nearly 40 acres, with approximately ¼ of that requiring tree clearing prior to pipeline work commencing. Crews worked 24 hours a day to install sheet piling and welding/stringing the replacement section in sub-zero temperatures. A 90 hour outage was scheduled during which a 9.3 mile nitrogen purge was executed for the tie-in of the replacement segment.

The project was unique and challenging in many aspects to UPI, and the project's success was not easily achieved. The crew had to work on the removal of the existing 3200 ft pipeline and challenging tie-in to the existing line in less than ideal conditions. The crew relied heavily on Mother Nature for the success of the job in a swampy area, as well as the construction of an ice road. Man-hours spent on the project surpassed 105 000 hours, with more than 150 employees working on the project.

The most impressive statistic about this job, or any project, is that it was completed with zero lost-time injuries. In sub-zero conditions, dealing with ice, frozen equipment, slick surfaces and bulky cold-weather gear, pipe segments were dug up, cut out and hauled off. New pipe was welded, placed in the trench and covered. This went on around the clock, and yet the team

remained committed to the safety of themselves and the community around them.

In addition to the main scope of the replacement installation, the project also included full workscopes at two separate mainline valves approximately 4.5 miles on either direction. These included excavation, fitting installation, and site set-up for nitrogen injection and blowdown. The team also improved the upstream mainline valve location to bring it into compliance, full installation of pressure and temperature transmitters, as well as the removal of an obsolete crossover valve at the completion of the project.

The single, most important key to achieving success on a project like this is pre-planning. The team had a thorough and comprehensive plan that was then executed well and ensured success. Unusual as it may sound, having a plan to deal with the 'unplanned' is a very important component. How will you respond in the event that the unexpected happens? Simply knowing how your team will react and ensuring that plan is communicated to all levels of the team will be crucial to safety and project success.

Why rise to the challenge?

In 1962, standing outside in the scorching Houston, Texas summer at Rice University's football stadium, President John F. Kennedy delivered his famous speech challenging Americans to go to the moon. One of the most quoted lines from that speech is about why people choose to undertake difficult challenges under extreme conditions. According to Kennedy, we choose to do these things "not because they are easy, but because they are hard," and because the goal is important to us all.

Pipeliners probably understand what Kennedy meant in that speech more than most. Of course, everyone has their own idea of what extreme is. For some it might be ice roads, for others it might be a three hour drive to the project site every morning, or a jobsite situated in a swamp full of snakes and mosquitoes. For crew members, the end of a tough job marks a high accomplishment and level of pride. They have worked in conditions that most would not even attempt to face, let alone work long, physically demanding hours in.

These pipeline projects are crucial to keeping utilities and businesses in operation, and ultimately providing the power that drives the economies of many countries. Pipeliners, more than most, understand the importance of managing the risks of extreme environments in order to accomplish the job.

Like Kennedy's space race challenge, once a pipeline project has been started you cannot simply decide the conditions are too hostile and stop. As a retired pipeliner once said, "We never installed a U-turn. We just kept going until the job was done." Moreover, the project must not only be completed, but must operate reliably and safely for years in that same tough environment. This requires an attention to detail and quality which is all the more impressive when considering the distractions of a hostile environment.

Regardless of how the extreme is measured, the pipeline industry has a culture and history of assessing the challenges, finding ways to overcome them, and sharing their knowledge for future crews.

These jobs are not easy, and pipeline work can challenge crews in unimaginable ways. However, like the saying goes: if it was easy, everyone would do it.

THE PASSAGE TO THE FINISH LINE

Josh Mitchell, T.D. Williamson, USA, explains the role of pig passage indicators, and the impact of installation procedures on their performance.

Pig passage indicators are the sentries of the pipeline maintenance world. Permanent devices either welded or strapped to the pipe's exterior, they monitor and deliver the news that a cleaning, batching, gauging or other pig has passed predetermined locations inside the pipe. As the pig travels past each point, it trips a mechanism inside the pipe that triggers a visual indicator atop it – a flag, electrical signal or a combination of both. By all appearances, the pig is staying the course: it is not stuck, stalled or lost along the way. Pig passage indicators have also traditionally been used to signal that a pig has left the launcher or made it to the receiver. This eliminates guesswork and saves the time and expense associated with depressurising and emptying the trap to check on the pig's whereabouts.

However, sometimes it seems like the pig indicator is not doing its job. The pig passes the trip point but nothing happens. No flag pops up and no signal flashes on. Without this cue – and in the absence of pig tracking equipment, which is a different type of technology altogether – it is very difficult to know what is happening inside the pipeline until the pig or tool arrives safely at the receiver.

Under those circumstances, operators might start to think that pig indicators are unreliable, or simply do not work. However, this is not the case. The fact is, pig passage indicators are rugged, durable and dependable workhorses. Almost every piggable pipeline in the world has at least one, and for the most part they operate exactly as they should.

There is one caveat, however. Pig passage indicators have to be installed and maintained correctly to perform correctly. Proper installation ensures reliability and avoids failure in all types of equipment, from putting batteries in a flashlight to hooking up the complex turbines used in power generation. There is no reason pig passage indicators should be any different. Yet installation is sometimes an afterthought, especially during new pipeline construction.

Installation

Whether the pipeline is above or underground, installing a pig passage indicator is a job best left to the experts. So-called 'intrusive' pig indicator models require certified hot tapping and plugging (HT&P) personnel to tap the pipe and install a fitting – or pipe nipple – onto it so the trigger mechanism can be inserted into the line. Even installing a non-intrusive pig passage indicator, the kind that uses high-strength, rare earth magnets to trip the trigger, should be carried out by a skilled pipeline professional. Installing either type of indicator onto an underground pipe is an even more complex process that requires connecting an extended unit that keeps the flag and electrical switch above the surface.

Unfortunately, during new pipeline construction, contractors who do not know much about pig passage indicators often carry out the installation. If they do not know how to confirm that the indicator matches line diameter and wall thickness of the installation site, or they overlook manufacturer instructions, they can make mistakes that can affect functionality from the start.

For example, the TDW PIG-SIG® V has two parts, as shown in Figure 1. One is a plug assembly that screws into the fitting (nipple) that is welded onto and seals the pipe. The other is the indicator assembly, which sits on top of the plug assembly and the fitting. Opposing magnets enable the plug assembly to interact with the indicator assembly, avoiding additional potential leak paths and simplifying installation.

Contractors often incorrectly assume that pig passage indicators incorporate NPT connections, which are commonly found on threaded pipes and fittings, and overtighten

the connection. In addition, they sometimes do not realise that hydrotest dirt and debris are clogging the threads and preventing them from engaging fully. Although clogged threads are avoidable – plugs can be installed to prevent debris from building up during hydrotesting, and there are also tools to clean the threads – if material remains in the threads, it can prevent the trigger mechanism from fitting properly into the pipe nipple. When that happens, the trigger will not protrude far enough into the pipe for the pig to interact with it, meaning there will be no signal when it passes.

However, even more concerning is the question of whether the unengaged threads are preventing the indicator from holding pipeline pressure. Because no one wants to find out the hard way, the only means for avoiding risk is through correct installation.

Installation problems are not the only issue that can affect pig indicator performance. Pipeline conditions such as excessive ferrous debris can also cause malfunctions, as can the lack of adequate and timely maintenance, which can lead to the indicator working only sporadically before it fails completely.

Figure 1. The TDW PIG-SIG® V with flag and electrical indicator. The plug and indicator assemblies interact via opposing magnets.

Figure 2. Left: A magnet equipped with a filter pack. Right: A magnet without one. The filter pack provided a barrier against ferrous debris building up on the magnet itself. Without a filter pack, ferrous debris on and around the magnet kept the pig passage indicator from operating as designed.

There is nothing wrong with the equipment; it simply has not been cared for.

Just like all equipment, pig indicators have an expected useful life. When that is exceeded, the trigger mechanism might stop working. With so many variables in play, pinpointing the true cause of any operational hiccup is difficult – and wondering if the equipment itself was defective all along becomes the default response.

Improved pump station protection

Installation issues and pipeline conditions were at the root of multiple PIG-SIG V malfunctions near pump stations along two natural gas lines in Oklahoma (US).

In recent years, installing indicators at pump stations has become an increasingly popular way to protect both assets and throughput, especially as the pump stations themselves have become more advanced. No longer dependent on manual operations, today's pump stations are prime examples of digital transformation at work, with smart controls replacing manpower – an advantage particularly in remote locations.

A pig moving through a pump station is a routine but serious operation, so typically there is at least one indicator at each of the station's incoming and outgoing sides. As the pig travels toward the station, the indicator gives the automated system enough time to idle the pumps and switch the mainline valves, allowing the pig to pass safely without having to stop. After the pig passes the mainline valve, it trips the outgoing pig indicator, signalling that the valves can return to their normal positions, the pump can be realigned to pipeline flow, and normal operations can be resumed.

When an incoming indicator does not work, it is possible that the pig will hit the valve; however, that might be the least of the problems. If there is only a single suction line feeding from the main line to the pump station, the pig could block the line. Under extreme circumstances such as guide bar failure, the pig could be sucked into the pump and cause considerable damage. Fortunately, many pump stations are designed with at least two suction lines; if a pig is pulled into one, the issue is typically limited to lost production until personnel can manually switch the valves and allow the pig to pass.

If an outgoing indication malfunctions, it generally creates less havoc. That is because modern pump stations are equipped with timers that realign the pump back to pipeline flow even if the indicator is not working. However, that means there is no actual confirmation the pig has travelled out of the station. Proof then relies on one of two things: either the pig tripping an indicator farther down the line, or checking flow speed and pressure upstream and downstream of the pig. If those things are unchanged, it suggests the pig is still travelling through the pipeline. However, if the pig is still between the suction and discharge tees there will not be any indication of flow or pressure changes, and it may be necessary to redo a pump passage sequence to force flow through the pipeline and push the pig past the station.

Ferrous build-up

In Oklahoma, the operator had a third-party crew mount TDW PIG-SIG V pig passage indicators between multiple pump

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stations. Their weatherproof, tight-seal, corrosion-resistant construction is designed to make the PIG-SIG V resilient to even the toughest conditions. They also have fewer parts than other indicators, which means they are considered easy to install. However, when a number of units malfunctioned, an investigation uncovered very different installation-related problems.

In one case, the plug assembly was unscrewed from the set depth by nearly ¼ in., meaning the trigger did not protrude far enough into the pipe to interact with and detect the pig. TDW technicians removed and examined the plug, but could not determine why it had not been installed to the designated depth. The technicians tried to install a new plug, but could not get it to the correct depth, either. It was only when they ran a twist drill through the tap to ensure it was the right size for the application that they discovered the actual problem: the hole in the pipe was undersized. Redrilling the hole enabled them to install the new plug and restore the indicator's function.

At another location, parts had been removed. TDW installed new indicator assemblies, provided instruction about how to correctly adjust them, reviewed all of the troubleshooting techniques, and completed a system check.

Of more widespread concern, however, was the fact that there was ferrous build-up on the tops of a number of indicator magnets. This was unanticipated given that the line was clean and the operator believed there was no ferrous debris in it.

Ferrous debris in a pipeline is never a good thing, and it is easy to understand how it can affect component performance. Even a small amount of build-up on an indicator magnet can lessen its ability to identify the passage of a magnet-equipped pig. If the accumulation atop the magnet is significant enough, it can reduce the trigger's range of motion and eventually cause the equipment to fail, as seen in Figure 2.

As it turned out, ferrous debris was the underlying cause of malfunction in all but one of the remaining indicators. That indicator was installed on a line transporting refined products including gasoline, and had been equipped with a filter pack to prevent ferrous debris from reaching the magnet. Originally, PIG-SIG Vs did not have filter packs; they were added as an improvement in response to ferrous build-up.

Over the course of two days, a crew of two TDW technicians replaced all of the damaged assemblies at five locations. Other TDW representatives and the customer were also on-site. Confirmed results show that the locations where equipment was replaced continue to perform as intended.

Since TDW completed the work repairing or replacing the pig passage indicators, the company has made the filter pack standard on all non-extended models. The upgrade is part of the company's continuous goal of improving product function and reliability. Yet even enhancements cannot ensure a piece of pipeline equipment will perform to high standards unless all the components are in place, installed correctly, and maintained adequately.

THE RIGHT SELECTION

Michael Beller and Carlos Enrique Sabido Ponce, ROSEN Group, Germany, **discuss the factors to be considered when choosing ILI tools for challenging pipeline inspections.**

Our society depends on high-pressure pipelines to transport the oil, oil-related products and gas required by industry and consumers. They form essential 'lifelines' to ensure secure transportation, supplies, and availability across the energy industry.

High-pressure steel pipelines must be operated safely, efficiently, and in compliance with regulations. Consequently, ensuring their mechanical integrity is of paramount importance, and confirming safe maximum allowable operating pressure (MAOP) is part of the equation.

An important element of an optimised maintenance process is having a complete understanding of the mechanical integrity of a given pipeline or pipeline network. Any threats such as dents, metal loss, cracks, or the effects of geohazards that may affect the safe operating pressure of the pipeline must be identified, assessed, and understood.[1]

ILI tools and their mission

Modern inline inspection (ILI) tools provide the means to inspect pipelines for the presence of those threats. Today, there is a vast range of highly specialised ILI tools for very specific tasks. From an engineering perspective, ILI tools are mechatronic systems. One part of such a system addresses detecting, sizing, and locating defects potentially present in the pipeline wall. In order to reliably assess the fitness for purpose, data on safety-relevant features and defects must be collected, analysed, and turned into useful information. This is where sensor technology and the

non-destructive principles utilised are of critical importance. The strengths and weaknesses of the physical principle utilised must be understood, as they affect detection thresholds, accuracy, and confidence levels. The other part of the system is the propulsion technology required for taking that sensor technology to where it needs to go. Different types of propulsion methodologies are applied in modern tools to move them through the pipeline to be inspected.

ILI tools, also referred to as intelligent pigs, have been used for more than 50 years. The tools initially available were free-swimming tools inserted and pumped through the pipelines. However, not all pipelines are the same; thus, not all pipelines were suitable for the typical tool designs of those days. Eventually, pipelines were distinguished into piggable pipelines, which could be inspected with those free-swimming tools, and unpiggable pipelines, which could not. The term 'unpiggable' soon became misleading, however, because tools did become available to inspect many pipelines that had originally been called unpiggable. It became clear that the unpiggable pipelines had to be further differentiated into pipelines that could actually be inspected from the inside (although not by using the traditional designs) and those that can truly only be inspected from the outside. The term 'challenging pipelines' was introduced for the former and eventually replaced by the term 'difficult-to-inspect' (DTI) pipelines.

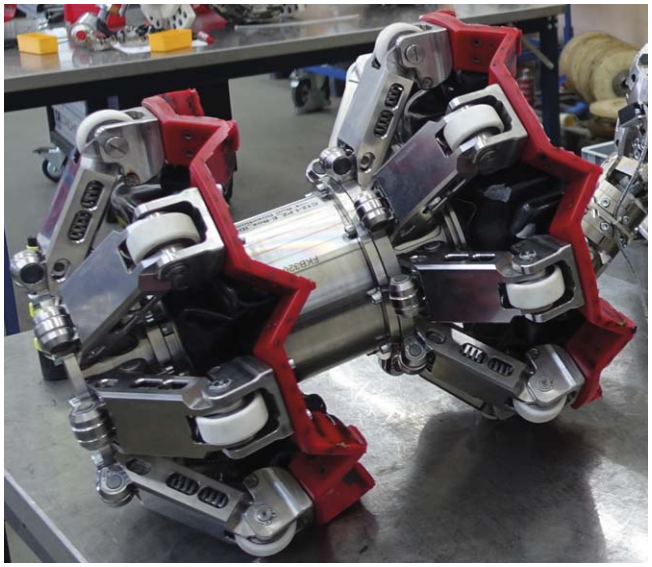

Figure 1. A sealing element of the 12 in. × 16 in. inspection system.

Figure 2. Loading lines only have one launch-receive site, which makes BIDI ILI necessary.

The major differences between traditional and DTI pipelines with respect to inspection were discussed in detail in a paper published in 2015.[2] Tables 1 and 2 are taken from that article.

Table 1 shows an overview of the typical types of defect found in high-pressure pipelines, while Table 2 provides an overview of the inspection technologies most commonly applied in ILI tools – for traditional pipelines as well as for DTI pipelines. Further technologies have been introduced or are on the horizon.

The big difference between any two given pipelines lies in getting the sensor technology to where it needs to go. This addresses the operational aspects of an inspection project. There are more than 2 million km of high-pressure transmission pipelines in the world.[3] Reliable estimates put the total length of DTI pipelines at approximately 1.5 million km just in the upstream and midstream sector, with many more in the downstream sector.

Traditional vs difficult-to-inspect pipelines

There is no set boundary between DTI pipelines and traditional pipelines. Technical and operational challenges form a moving boundary. Take coverage, for instance: the early generation of tools could only travel a very limited distance compared to current tools. Today, an inspection of an offshore pipeline with a length of over 1000 km is possible. The same line in the 1960s would have presented an insurmountable challenge. Furthermore, traditional tools can now negotiate pipe geometries that were impassable only 40 years ago. Many other examples could be found where a pipeline formerly regarded as DTI is now considered a traditional pipeline.

However, new challenges can also arise. One example is lower operating pressures in gas lines due to depleting fields. There are transmission and production lines today that are operating at significantly lower pressures than in their earlier life. This also impacts ILI tools; especially in a gas environment, they require a minimum operating as well as a differential pressure to ensure a 'smooth ride'. This is necessary, less for the tool mechanics but more so for the data quality and the ability to analyse the data collected.

The inspection of DTI pipelines has become an important and growing segment in the ILI industry, with many articles published and special conferences hosted to cover this field.

As discussed in one article, there are three major issues that must be considered in order to classify a pipeline as traditional or DTI: accessibility, negotiability, and propulsion.[2] The extensive experience gained over the years in solving challenges for DTI pipelines, however, has led to further examination of the definition of characteristics that contribute to this classification. Therefore, the aspects that determine a pipeline to be DTI have been revised to the following characteristics: pipeline design, operating conditions, and medium characteristics. All these aspects and their combination will determine the level of complexity of the challenge at hand. Additionally, there is yet another element defining the complexity of an ILI – the competence of the personnel.

These are not sensor or measuring-related items; instead, they are all related to the operational environment during the inspection. Any tool used inside a pipeline must somehow be introduced into the line and successfully retrieved again. The tools must successfully negotiate the line even in the presence of 'operational obstacles', such as unbarred tees or complex arrangements of bends. Tools must also be able to collect data successfully if operational pressures and/or temperatures are outside the range that is suitable for traditional ILI tools. Last but not least, the question of how the tool can be propelled through the pipeline it is supposed to inspect must be answered. Can it be pumped? Is it possible to use a tool in a unidirectional configuration or does it need to be bidirectional? Maybe pumping is not possible, and the tool may need a tether or cable to be moved. On some occasions, tools may need their own drive unit. In that case, crawler or robotic tools present a solution. The three aforementioned classes of propulsion means have become established to date. All come with their own specific advantages and disadvantages. They must therefore not be seen in competition but as complementary in providing inspection solutions for DTI pipelines.

For all those reasons, choosing the most suitable and effective solution for a given inspection requirement is not trivial and requires a good understanding of the advantages and disadvantages of the non-destructive testing and propulsion technologies available. Table 3 addresses these issues, and can be used for initial guidance when selecting the tool.

There are currently three classes or types of ILI solutions for DTI pipelines. Specialty free-swimming tools are pumped through the line like traditional ILI tools. These special tools are, however, modified or completely redesigned compared to their traditional counterparts. Tethered tools use a cable or tether for data transfer and/or energy supply to power tool movement. Finally, robotic tools incorporate their own drive unit. Table 3 covers various characteristics of these different tool categories.

Compared to free-swimming tools, tethered tools are limited in range by the length of the cable used and the number of bends they must negotiate. Robotic tools are limited in range by their battery capacity. The inspection speed of the specialty free-swimming tools is in the same range as traditional ILI tools: somewhere between 1 m/s and 5 m/s, depending on the technology used and the specific application. Tethered tools move much slower, and the same applies to robotic tools. Online inspection, i.e. inspection during normal pipeline operations, is only possible with free-swimming tools. For tethered or robotic tools, pipelines usually have to be taken out of normal operation. Tethered tools can be stopped in a controlled manner and data can be collected in a stationary mode, enabling, for example, time-of-flight diffraction (TOFD) crack measurement. Compared to free-swimming tools, tethered and robotic tools are limited in their pressure capabilities.

The remainder of the article will briefly introduce three case studies presenting ILI solutions for challenging pipelines, picking up on the issues discussed earlier. The first addresses a gas pipeline with a low operating pressure, which makes it unsuitable for an inspection with a traditional ILI tool. The second introduces a tethered solution to highlight the advantages of using this approach for the given inspection challenge. The third introduces a tool with its own drive unit.

Case study one: free-swimming solution

The first case study focuses on an inspection success for a set of 12 in. × 16 in. multi-diameter natural gas distribution pipelines with operating pressures of less than 27.57 bar (400 psig). Furthermore, the pipe tallies revealed several critical features in regard to ILI tool operations. These included, for example, high-degree bends, back-to-back bends, 1.5D or tighter bend combinations, miter bends, and more. Therefore, ROSEN decided to customise inspection tools for this particular set of multi-diameter pipelines. The parameters defined as a basis for tool customisation included:

- Natural gas as the medium.
- 1.5D 90° back-to-back bend passage capability in 12 in. nominal pipe.
- The ability to pass a 10° mitered bend in 12 in. nominal pipe.
- The ability to operate in pressures as low as 17.23 bar (250 psig).
- The ability to pass an unbarred full-bore tee.
- A goal of having a maximum differential pressure of 3.44 bar (50 psig) across the inspection tools while passing all design pipeline feature configurations.

Two separate inspection tools were to be developed, one for metal loss and one for geometry. Because of the gaseous medium, magnetic flux leakage (MFL) technology was chosen as the inspection technology for metal loss. Eddy current technology, combined with caliper arms, was chosen as the technology for measuring the pipeline geometry. To reduce friction, wheels were added to the sensor carriers of the two tools and to the pull units. Additionally, the sensor units and pull units were designed so that they could collapse and expand in order to maintain the inner diameter of the pipeline.

In addition to applying a specialised heavy-duty cleaning programme, which included liquid cleaning with a diesel-

Table 1. Overview of types of anomalies and flaws in pipelines

Major categories of features	Sub-categories	Examples
Geometric anomalies	Diameter changes Pipeline position	• Dents • Out-of-roundness • Pipeline movement
Metal loss	Wall loss without corrosion	• Gouging
	Wall loss due to corrosion	• General corrosion • Localised corrosion • Pitting
Material separation	Laminations Cracks	• Laminations • Fatigue cracks • Hook cracks • Stress corrosion cracking

detergent mixture, the operator agreed to raise the pressure slightly, where possible, in order improve the run behaviour of the tool and minimise speed excursions.

The inspection results from the first 12 in. × 16 in. multi-diameter pipeline with the new solution showed a greatly improved run behaviour compared to what was achieved during previous inspection attempts in the same pipelines. During a previous attempt with a standard 12 in. × 18 in. MFL tool, a large speed excursion had occurred at the transition from the 16 in. section to the 12 in. section.

Case study two: tethered solution

An operator approached ROSEN to develop a new inspection solution to apply proven ILI technology to well casing pipes. The operator had general concerns about the integrity of the casing pipes in addition to the known unstable environmental conditions, which included a sinking cavern ceiling. However, with the downhole inspection solutions available on the market, these concerns had yet to be explored with the necessary precision.

The pipelines in question had a diameter of 13 3⁄8 in. and varied in length from 800 m to 1500 m. The pipe sections were connected via threaded couplings, which also varied in both diameter and length. The task was to detect and size corrosion and metal loss features on the pipe wall, and measure the opening width of the threaded couplings.

Metal loss and threaded couplings with their corresponding defects are characterised by wall thickness. Therefore, high-resolution MFL technology was preferred for this inspection. High-resolution data collection was possible due to a concept that was developed to combine strong magnetisation with a unique low-friction magnetiser and sensor suspension system. Through this, the powerful magnetic tool could be deployed safely into the pipe casings.

The ultra-compact and lightweight tool design was capable of bidirectional movement and supported by a gravity-based wireline operation. Thanks to this wireline connection, clear monitoring during the inspection process was possible, including monitoring the tool's progress and identifying any potential obstacles, helping to ensure the best possible data collection and provide high-resolution results.

Table 2. Overview of inspection technologies applied in ILI tools

Method	Application	Main mission
MFL	• Axial magnetisation • Circumferential magnetisation • Spiral magnetisation	Metal loss inspection
UT	• Piezo-electric – vertical beam • Piezo-electric – angled beam	Metal loss inspection and wall thickness measurement Crack inspection
EMAT	• Electro-magnetic acoustic transmission; different wave types possible	Depending on configuration: metal loss inspection or crack inspection
EC	• Traditional EC • Magnetic-bias EC	Complementary technology used for metal loss inspection or ID/OD differentiation Metal loss inspection for special materials and pipe configurations

Table 3. The characteristics of the three different ILI tool categories

	Specialty free-swimming	Tethered	Robotic
Range	↑	↓	↓
Inspection speed	↑	↓	↓
Online inspection	Yes	No	No
Stationary inspection	No	Yes	With limitations
Real-time data availability	No	Yes	With limitations
Pressure capabilities	↑	↓	→

Case study three: robotic solution

ROSEN was approached by the operator of a 10 in. subsea vent line to identify the presence of any internal or external corrosion. Vent lines were not designed to be internally inspected, and up to that point, a successful ILI of vent lines had not taken place. Several challenges were identified that needed to be assessed in order to allow for a successful ILI, including:

- No conventional access for ILI tools.
- Pipeline accessible only from main platform.
- No or very low flow and pressure.
- No previous inspection knowledge.
- Cleanliness unknown.

The most viable solutions for a successful inspection would therefore need to include low-friction technology, bidirectional and self-propulsion capabilities, and the ability to cope with moderate amounts of debris. As a result, a sophisticated 10 in. robotic propulsion unit was developed. The solution included specialised cam driving components that provided an increase in pull force capabilities, allowing for the utilisation of extensively tested high-resolution MFL technologies. Furthermore, the design contained both vertical and horizontal bidirectional movement capabilities and distance tracking, all of which were critical for this application.

To ensure zero risk, various fail-safe measures were implemented. These entailed visual and sensor monitoring to allow for the safe approach of possible deformations and tees, as well as onboard power storage and monitoring. Additionally, a tethered retrieval unit was installed to ensure that the tool could be pulled out in the event of failure. The cams on the propulsion module were programmed to collapse into 'fail-safe mode' in the event of a limited power supply, allowing for the tool to be easily removed from the pipeline if necessary.

During the inspection, the robotic propulsion unit functioned properly and was able to manoeuvre in and out of the pipeline as expected, successfully negotiating the 645 m section of pipe without the need to utilise the retrieval contingency. Throughout the inspection, all functional components and communication remained fully operational, and the data collected met all reporting requirements.

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The sky is the limit

Dmitry Glinkin, Transneft Diascan, Russia, describes the diversity of factors that can affect the quality of inline inspections, ranging from terrain to temperatures.

Extreme temperatures, precipitation, high humidity, marshy or sandy terrain – the operating conditions of pipelines are often far from ideal and have special requirements both for the organisation of inline inspection (ILI) and for elements of the design of the equipment used. Neglect of these factors can significantly affect the quality and objectivity of the

inspection, to such an extent that not only the accuracy of the examination results due to distortion of the inspection data can be reduced, but also its complete loss can occur. The quality of ILI results is influenced more by parameters and modes of pumping medium (liquid or gas) in which the inspection tool works, than by external factors.

There is a concept of 'operational limits', which fixes the maximum allowable parameters of the environment surrounding the inspection equipment. The use of the inspection equipment in conditions exceeding these parameters can lead to both a decrease in the quality of inspection results and failure of the flaw detector equipment. But there are situations when inspection has to be carried out in extreme conditions, with the operational limits of the diagnostic equipment going beyond the boundaries. What factors are worth considering? How can the possible impact of external factors be assessed, and its consequences reduced?

Figure 1. Preparation of the geometry tool at an underwater crossing of the Ust-Ilimsk reservoir. Pictured is P. Sherman, a technician of the profilermetry department of the Ufa branch of Transneft Diascan.

Figure 2. Marker installation at Neryungri, Russia.

At the limit

Tools for ILI are made in a sealed design and are designed to work under high external pressure, so any types of precipitation cannot have a negative effect on them. On the other hand, extremely high and low temperatures are able to exert a significant influence on the mechanical parts and components of ILI equipment, affecting the mechanical properties of polymeric materials widely used in the design of the tools, primarily on their elasticity.

Product transportation through pipelines is carried out mainly at positive temperatures, and given that ILI tools are designed to operate at negative temperatures (down to -15°C), the influence of a lower temperature inside the pipeline can be excluded from consideration. On the contrary, extremely low air temperatures outside the pipeline have a significant impact on the preparation of equipment for launching, and the process of putting an ILI tool into the pipeline. A decrease in elasticity and, as a consequence, an increase in the hardness and brittleness of the elements of the tool made of polymeric materials, can increase the risk of their damage or destruction upon external exposure. This is especially critical for flexible polyurethane products designed to transfer loads and external electrical cables of ILI tools. Overcoming these negative factors is achieved by a set of measures, starting with the right choice of materials and design solutions when designing inspection equipment, and ending with the development of special measures for placing the ILI tool into the pipeline. This is in addition to their clear and co-ordinated implementation by specialists performing these works.

Exposure to high medium temperatures can also seriously affect the operation of inspection equipment. For example, the speed of sound in the medium depends on its temperature, and change of the latter affects the parameters of the input of the probe pulse of ultrasonic inspection devices into the object under control. Incorrect operating modes of the inspection system can lead to a delay or failure to record the echo signal during the registration time specified by the on-board algorithms of the device. For the tools that have a magnetic measuring system, with an increase in the medium temperature, the magnetic field created by the permanent magnets is weakened and, as a result, the ability to detect defects decreases.

In addition, exceeding the maximum allowable medium parameters for an ILI tool can negatively affect the structural elements and electronic components of the device. In particular, under such conditions there is a decrease in the ability of elastic structural elements made of polyurethane to remain stable under load. The deformation of these elements during movement is possible (the so-called

'subsidence' of the ILI device) and, as a result, the formation of product overflows, which can slow down the movement of the tool or stop it completely. On-board electronic equipment of an ILI tool exposed to external temperature exceeding the allowable value for a given equipment may malfunction or completely fail.

In each specific case of the upcoming operation of the ILI tool at elevated temperatures, a qualified assessment of its impact on the operation of the equipment should be carried out and appropriate measures should be taken to stop any negative consequences. These measures for the complexity of their implementation can vary widely: from estimating the time of exposure of the tool to elevated temperatures and calculating the dynamics of an increase in the temperature of its elements during the run, changing the on-board operation algorithms and settings of the measuring systems, to significant redesign, and – in extreme cases – the development of special equipment for operation in high temperatures.

Aside from extreme temperatures, other factors may also affect inspection activities, for example, the nature of the area where the pipeline runs. It is important to note that various climatic zones, soil types, water obstacles, and other external environmental conditions do not affect the inspection tool itself. However, the main problems arise in the process of the inspection equipment transportation and its further tracking in areas located in swamps, taiga, rocky or weakly bearing soils. In these cases, it is necessary to use special all-terrain vehicles or air transport for the delivery of equipment and personnel. Often, inspection work at such sites has to be carried out in winter, when it is possible to travel along the pipeline.

Assess and adapt

One of the most important tasks for ILI specialists is to adequately assess the conditions for work and perform the necessary preparatory procedures. When considering extremely low temperatures, the pumping product temperature is usually higher than the ambient temperature, so the easiest and most effective way after placing the ILI tool in the trap would be to fill the launcher with the pumping product in order to raise the temperature of the tool elements.

A more serious problem is the high temperature of the pumping product, when its reduction is not possible. Special measures are required to eliminate the effects of high temperatures on structural elements and electronic components of the inspection device. For example, for operation at elevated temperatures, a preliminary change in the operating parameters of the ultrasonic measuring channel is possible to account for propagation velocity of ultrasound in a medium with elevated temperature.

Regardless of whether the inspection is carried out under normal or extreme conditions, almost every

section under examination has its own characteristics, and adaptation of the equipment to one degree or another is necessary before each run. This is largely related to the features of the pipeline. To ensure the maximum accuracy of the inspection results, each pipeline section is subject to analysis before an inspection run, even if this section is not examined for the first time.

In extreme conditions, where there are cases of exceeding operational limits, it is imperative to perform an analysis of conditions for carrying out inspection work, as well as, if necessary, an experimental simulation of the impact of these conditions on equipment elements. This allows the operator to properly configure the measuring systems and predict the influence of external factors on the process of obtaining reliable inspection data.

Put into practice

Transneft Diascan's experience includes many projects that have been undertaken in the most difficult climatic, geographical, and natural conditions. From 2007 to 2012, the company took part in the implementation of a large-scale project for the construction of the Eastern Siberia - Pacific Ocean (ESPO) oil trunk pipeline. Participation in the project was a real maturity test. All the experience gained by the Transneft Diascan specialists over previous years was utilised.

The ESPO oil trunk pipeline was built by Transneft in accordance with a decree from the Government of Russia to transport oil from fields in Eastern and Western Siberia to oil refineries in the Russian Far East and markets in the Asia-Pacific region.

According to the official Transneft website, pursuant to the initial plans, the project was supposed to be completed by 2030; however, due to the high demand for supplies from oil companies in this area, Transneft decided to complete the work in record time – ahead by more than 10 years.

When carrying out inspection work on sections of the ESPO pipeline under construction, the Transneft Diascan specialists encountered a number of difficulties. The lack of roads and electricity in many areas; swamps; deserted taiga; active seismicity; extremely low temperatures in winter and other external factors, required the use of special technical solutions during ILI.

Initially, inspection work on the ESPO pipeline was carried out only in the warm season; water served as the medium for the movement of ILI tools along the constructed sections of the pipeline. In some areas, due to difficult geographical conditions (taiga, swamps, etc.) and a busy construction schedule, it was decided to conduct inline geometry inspection in winter, while compressed air was supposed to be the driving medium. To this end, Transneft Diascan's design department finalised the design of the geometry tools, allowing this project to be implemented.

In addition, since pipes with a diameter of 1067 mm were used for the first time in Russia for the construction of a trunk pipeline, Transneft Diascan specialists had to adapt all available inspection tools to the specified size. This included geometry tools, as well as magnetic, ultrasonic, and combined flaw detectors.

The early onset of cold weather and the need to run inspection equipment in cold weather also necessitated the adaptation of inspection devices. Especially for working at ESPO, the company's designers developed inspection equipment in the configuration for pipelines using compressed air. As a result, for the first time in its practice, Transneft Diascan at ESPO successfully applied the technology of running geometry and magnetic inspection tools in air for inspection at low temperatures.

Also at the ESPO pipeline for the first time, an inspection survey of the pipeline was carried out with a combined magnetic-ultrasonic inspection tool during the filling of the pipeline with oil.

The problem of lack of electricity was solved by using gasoline and diesel generators available as part of inspection systems. During the inspection run, the ILI tool tracking along the pipeline and over small rivers was carried out on all-terrain vehicles. Equipment and personnel were transported by air and barges along the rivers, and by motor transport in places of country roads.

During the construction of the ESPO pipeline, the pace of inspection and its timing in the practice of Transneft Diascan were unprecedented. For example, in 2010, the company's specialists inspected more than 50 000 km of pipelines. Of these, 9000 km were inspected as part of the first stage of the ESPO project. Up to this point, not a single inspection company in the world had carried out such a volume of work in such a short time.

Figure 3. Difficult conditions for the transportation of inspection tools during the construction of the ESPO pipeline.

HARNESSING THE POWER OF NATURE

Mohamed Fourati, Saft Batteries, France, describes the use of impressed current cathodic protection on remote pipelines where reliable electricity sources are unavailable.

Many countries legally compel plant and site owners to apply cathodic protection to gas pipelines, tanks, vessels, and wellhead casings to prevent corrosion attack. Many remote and off-grid sites do not have access to reliable electricity sources, making the cathodic protection system challenging. This article takes a closer look at the capabilities of impressed current cathodic protection (ICCP) when powered by solar or wind-powered systems with batteries, mains, or diesel generators.

First applied to a bridge deck in 1973, ICCP is widely used to control the corrosion of steel structures in oil and gas, offshore wind farms, marine and ports industries. By protecting assets such as buried pipelines from natural deterioration, it not only guards safety and process continuity, but also protects the environment by reducing the risk of leaks.

ICCP instils confidence and efficiency, as operators apply it to provide a constant trace current to delay the corrosion rate. ICCP is particularly reassuring for operators in remote and off-grid sites, where inspection and maintenance of vital assets can often be a complex and protracted process.

The process of impressed current cathodic protection

Corrosion takes place through a natural electrochemical reaction. ICCP works on the principle of overcoming the naturally occurring galvanic current with an opposing current, where the current is 'impressed' or forced by a power supply.

This supply must be able to deliver direct current (DC) as a constant trickle via anodes in the ground, with current flowing towards a cathode embedded in the structure that is being protected. The DC power ensures that the current always moves in the right direction to prevent or slow down the oxidation of steel structures.

Depending on the level of current applied, some ICCP systems can extend asset life indefinitely as they reduce the corrosion rate to near zero. A single system can be used over a wide range of soil and water resistivity. It can protect approximately 50 km of pipeline

in a desert (where moisture levels are low), or 100 m for structures immersed in seawater.

ICCP is primarily aimed at structures where protective current and life requirements are high, such as pipelines. For small structures such as the hull of a ship, an alternative is galvanic cathodic protection – which uses a sacrificial anode – and has a higher electrochemical potential than the steel structure, therefore corroding before the hull does. This would not be economic at the scale of a pipeline. As a result of this, in many countries ICCP is a legal requirement, most notably for gas lines.

While some systems can be switched off for several months without posing a significant risk, it is better to have a constant and reliable supply of current. Various methods of powering ICCP exist and some are outlined here.

Mains power

The grid powers the vast majority of ICCP systems. These include an AC-DC rectifier to receive AC power from the grid and provide a constant current and voltage DC output. A cathode connects the AC-DC rectifier electrically to the structure that needs protection.

Whilst mains power systems provide high reliability and a low risk of outages, they can only be specified at sites where there is existing grid infrastructure or where a grid connection is possible with a modest investment. This rules out mains-powered ICCP for pipelines that run for hundreds of kilometres through remote terrain.

Figure 1. One of the ICCP stations on the Hassi R'Mel pipeline in Algeria.

Figure 2. A single station can protect 50 km of desert pipeline.

Renewable energy

As renewable energy does not consume fuel, it has the advantage of low operating costs that can be offset against the comparatively high installation cost. Energy sources include solar photovoltaic panels (PV) or wind turbines to generate power.

The use of PV panels is well established, having been used for almost 30 years in ICCP installations. Unlike mains power or wind turbines, there is no need for an AC-DC rectifier because they generate DC power directly, which is an added benefit. The downside, however, is that supply is inconsistent – if the sun does not shine or the wind does not blow, power drops out and corrosion resumes.

To counter this, many operators integrate a battery system to store renewable energy that can be used when required. Wind-powered systems charge batteries on windy days and solar-powered systems charge the batteries during the day, and can ensure a constant unbroken supply of current for the ICCP system.

The cost of adding a battery system is significantly less than the value of the infrastructure that the ICCP protects, so it is well worth the investment. However, operators need to undertake some homework before deciding on a battery. Not all batteries can withstand the robust environment of a remote or off-grid site, where varied and extreme temperatures may impact performance and lifetime.

Diesel genset

For remote sites that have no access to a grid, a more traditional option is a diesel genset, as this can provide power either intermittently or continuously. While relatively inexpensive to procure, operational costs are high as technicians need to visit frequently to refuel, inspect, and maintain the genset. Another logistical challenge can be the need for specialised maintenance at remote sites, when a qualified technician has to visit to supply and fit spare parts.

Lifecycle cost analysis for ICCP

Evaluating total cost of ownership (TCO) of each option is imperative before deciding on a solution for a particular site. Apart from purchasing cost, asset ownership also brings installation, operational and maintenance costs – all of which can be substantial. In addition, it is often possible to claw back the value to salvaged materials at the end of an asset's life. Consequently, for many kinds of assets, TCO analysis finds a significant difference between purchase price and total lifecycle costs.

Site surveys, engineering design and specification, site delivery, installation and commissioning, make up the initial cost. Each ICCP installation will have highly specific requirements, and this will influence both the initial purchase price and operational costs. A typical system for a pipeline might draw 1 Amp at 5 - 10 V, while systems for well casings will draw 15 - 20 Amps at a similar voltage.

The current drawn for any installation depends on the soil resistivity and moisture levels on land; the salinity of water for subsea installations; level of rainfall or humidity; and the degree of protection required. All of these represent a wide variety of specifications. Operational costs include the cost of fuel or power from the grid, as well as site visits by certified technicians over the lifetime of the installation. For remote sites, these can be time-consuming and costly.

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Transformer rectifier units are typically the least costly option if mains power is available. This option, however, is impractical for operators of oil and gas pipelines that run through uninhabited regions. The remaining options are diesel gensets and solar PV or wind power. However, the high cost of fuel and its transportation make hybrid renewable power supplies a significantly more attractive option, as outlined below.

Case study: protecting a 1650 km long pipeline in an arid landscape

Located approximately 550 km south of Algiers in the Sahara Desert, the 1650 km long Hassi R'Mel gas field pipeline is one where operators have adopted an ICCP system powered by solar PV and battery systems. The pipeline stretches from the remote Hassi R'Mel gas field in Algeria to the Qued Saf-Saf on the Tunisian border, and feeds into Transmed's supply link that flows from Tunisia to Italy to provide Europe with gas. The gas field currently represents ¼ of Algeria's total gas output.

In 2018, Spie Oil & Gas Services installed an ICCP system that is powered by solar PV in combination with Saft nickel technology battery systems, to ensure an uninterrupted 100 W power supply to protect the pipeline's integrity. The equipment has been installed at 34 stations along the pipeline where energy drawn from the solar panels is stored.

During the day, the panels generate electricity to meet the demands of ICCP, run SCADA systems, and charge the batteries. At night and on overcast days, the batteries kick in to maintain a continuous power supply. The batteries are sized to provide up to five days of power to ensure the pipeline is protected at all times – even in the unlikely event of extended cloudy weather.

Important considerations for engineers in remote sites

Engineers who specify batteries for remote sites, where a maintenance call-out can be costly and resource-intensive, need to be mindful of certain factors before placing an order. Batteries at such sites need to be robust enough to withstand the extreme temperatures of the desert climate and the mechanical stresses of transportation to the site.

Operators typically want to utilise batteries that have a proven track record and demonstrated reliability in similar operating environments.

Temperature has a significant impact on battery performance and life expectancy, and is an important consideration when selecting battery technology and sizing batteries. Nickel-technology batteries have a reputation for robustness, reliability and service life, and are better able to withstand extreme temperatures than lead-acid technology.

Although lead-acid batteries have a lower purchase cost, their lifetime is limited and deteriorates even faster in hot climates. A lead-acid battery system designed to provide five days of autonomy lasts 10 - 11 years at 25°C, or 5 - 6 years at 35°C. But in real application, the end user is obliged to replace lead-acid batteries during the second year of operating. In comparison, nickel batteries last up to 20 years.

Sunica+ (a nickel battery designed by Saft for PV cycling application) needs less maintenance over the installation's lifetime, hence it has been a well-used solution for ICCP pipeline projects in Algeria and the Middle East over the last 15 years. This attribute impacts TCO significantly and should therefore be a deciding factor when selecting a battery system.

POWER TO THE PROJECT

Alex De Valukhoff, Managing Director Eurasia and Global Sector Lead, Oil and Gas, Aggreko, Russia, explores the use of specialist power generation and temperature control equipment to ensure the smooth delivery of a project.

Pipelines can be remote, extremely vast, and they can face tight pressures associated with cost and timings. Even if you navigate these, as with any oil and gas project, issues can crop up which can be complex to fix if the right systems are not already in place.

Often these issues are the first of their kind, which makes them tricky to navigate. Acting fast, with flexibility and a clear understanding of a customer's demands and pressures, are all key to ensuring the smooth delivery and running of a project. This article addresses three project case studies that have faced hurdles that threatened to prevent the smooth completion of the projects.

Powering a pipeline running across two continents

Aggreko has worked on some of the largest and most challenging pipeline projects in the world, including the construction and commissioning of an intercontinental gas pipeline centred in Azerbaijan.

The pipeline, which runs across two continents spanning a total of six countries, delivers an alternative source of energy to millions of people. However, the distances, environmental conditions, and remote nature of the route provided numerous challenges during the course of its set-up.

Having been brought in from day one, Aggreko provided camp power, welding power, power on compression stations during turbine installation, and load banks for compressor station commissioning. All of the power solutions that the company used were modular, which enabled flexibility and the delivery of power to the customers when and where they needed it. Flexibility was particularly crucial for this project due to its vast nature, because it also meant that the team, and ultimately the power source, could move across borders with ease.

Additionally, Aggreko's remote monitoring systems were implemented to enable technicians to track the performance of each piece of equipment remotely, which not only ensured that power outages were avoided, but ultimately reduced the manpower required to cover the fleet.

Such a system is key when you are working within tight remits – both financially and physically – as not only does it reduce people on the ground, but on this occasion, it also lowered the travel time of technicians. As a result, this reduced the risk of road traffic incidents in some very remote areas – something that can often be overlooked in these scenarios.

Figure 1. An example of equipment cooling water for a hydrotest.

Figure 2. Aggreko pipelines can be found in remote locations.

Testing the water

As with many energy projects, timings are critical to the delivery of pipelines. One of the biggest challenges for pipeline construction companies is minimising the time it takes to cool the test water. Test water temperature must be stabilised and cooled to the pipeline's organic temperature before the actual pressurisation part of the test can be initiated. The pipeline must then be drained and dried to complete the commissioning process.

This is an important, but lengthy process. In fact, it can take up to 10 days for this water to stabilise to an acceptable temperature. Speeding up the testing process is beneficial for customers across the world, as time spent waiting for test water to stabilise can often result in unnecessarily high costs.

A water cooling system at work

The lengthy process of stabilising test water temperature was a pressure faced by an Aggreko customer when commissioning 4600 ft of newly constructed pipeline in Texas, US, due to the tight timeframe that was planned.

When Aggreko was brought in, the water was stored on the surface in eight fracturing tanks, and its temperature needed to be reduced from 43°C to 21°C before flooding and pressurising the pipeline. Once this was completed, the water needed to be returned back into the tanks, and the full length of pipeline dried according to stringent specifications.

Utilising a 400 t chiller and a 1 MW diesel generator, Aggreko engineered and installed a water cooling system that brought the temperature of the water in the tanks down to 15°C in just five hours.

The cooled water was flooded into the pipeline to accelerate the completion of pressurisation testing – cutting days off the production schedule and reducing

associated project crew costs. A diesel air compressor located on the opposite end of the pipeline then provided 100% oil-free air to push the test water back into the tanks.

Aggreko then used the same air compressor to dry the pipeline by pushing eight cleaning inspection gauges, or pigs, through the line. To perform the final step of removing moisture from the piping system, engineers deployed a low-amperage desiccant dryer to reduce residual moisture to the required low levels.

Previously, this pipeline construction company had not used a mechanical cooling system, instead choosing to let the water cool organically in the pipeline. But as a result of this solution, the customer was able to knock off a large amount of time, as well as cost, traditionally associated with this effort.

Running into unexpected difficulties

Not all issues can be anticipated, however; sometimes pipelines face issues that would never have been considered. It is essential that power providers can adapt to these sudden changes, and, most importantly, act fast.

This is exactly what happened when a Gulf Coast oil platform needed help in reducing gas temperatures flowing into its pipeline. The increase in temperature, which was at 48.5°C and could not go over 48.9°C, was largely being led by the unusually high surrounding temperatures and increased flow which resulted from a third well being brought online.

To temporarily mitigate the impact of the temperature rise, Aggreko's customer was scaling back flow, but an alternative solution was needed to ensure the site's capacity was not reduced long-term.

Aggreko had never seen an issue like this before, but it did not let this stop the progress. In seven days Aggreko had completed the assessment, design, and project installation.

The company's solution was to install a closed-loop chiller water system which ran through the exchanger to drop the temperature of the gas. To achieve this the system included:

- Four 200 t explosion-proof chillers.
- Two explosion-proof pumps.
- One 3000 Amps I-line panel with breakers.
- One 3000 Amps circuit breaker.
- Chiller hose, fittings and cable as required.

The implemented system allowed the customer to increase flowrates by more than 50%, while maintaining a gas temperature of 42.2°C.

The quick mobilisation and resolution was essential for the pipeline being able to run constantly and efficiently.

Figure 3. A cooling system in action.

Figure 4. Aggreko's engineers developing a pipeline project.

Lower cost, lower risk, and more flexibility

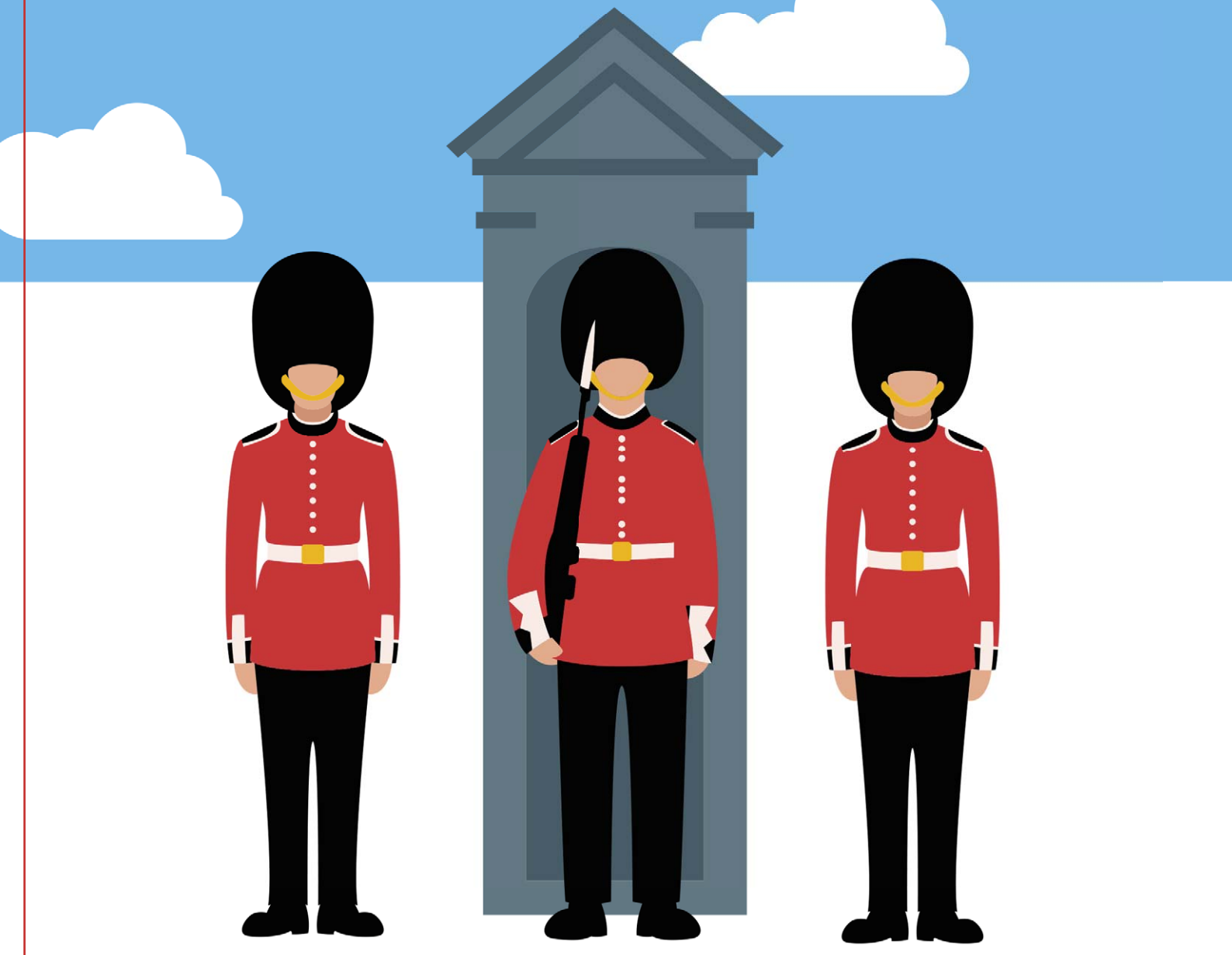
Like many oil and gas projects, pipelines can face hurdles in their commissioning, implementation, and running phase. It is important to ensure that the right team and partners are in place to help you act quickly, efficiently, and with new tools and techniques to manage these scenarios.

This is often why rental power is seen as a go-to option when it comes to developing and running pipeline projects. With more and more oil and gas companies looking to reduce their costs and capital investment, renting specialist power generation and temperature control equipment is often the preferred option. Not only is it often a lower cost, lower risk, and more flexible option than buying equipment, it can also avoid the time-consuming process involved with getting CAPEX sign-off, and instead, use operational or maintenance budgets.

Flexibility is also key to these projects, as they can be hired on a long or short-term basis and can be scaled up or down with very short lead times, to meet varying power requirements.

As Aggreko has learnt with some of the discussed projects, the crucial factor is always having the right team and equipment. With this, operators can develop ways to manage issues that they may never have seen before and give the project the best chance of success.

More than a security guard



Stuart Large, Fotech, UK, outlines the consequences of inadequate pipeline protection and how DAS technology can assist in predicting and preventing unwanted activity.

Threats to pipelines are considered to be on the rise. In a report published in 2019, the US Congressional Research Service positioned pipeline protection as a significant contributor to ensuring national security, stating that "Ongoing threats against the nation's natural gas, oil, and refined product pipelines have heightened concerns about the security risks."

With over 2.4 million miles of pipelines running across the country, this is not a situation the US can afford to take lightly. The fuels being transported through these pipes provide a crucial energy source, but they are also volatile and dangerous materials. If not secured adequately, there could be catastrophic consequences.

Potential soft targets

A fear of terrorism is well founded. Due to their remote nature, pipelines are difficult to monitor, and are seen as possible soft targets for extremist groups and violent political regimes.

In May 2019, drone attacks caused damage to a major pipeline that stretches for hundreds of miles across Saudi Arabia, leading to rising political tensions throughout the region. These threats are a particular problem in nations that rely heavily on a single industry. In Nigeria, terrorist attacks on pipelines caused oil production to drop by 36% in 2016, reducing government revenue by a significant 50%. Security issues do not appear to be abating – with theft costing Nigeria as many as 22 million bbls of oil in the first half of 2019.

The impacts of these incidents are wide-ranging. Every industry downstream from oil suppliers have their supplies affected. At its worst, this can lead to a rise in inflation, increased living costs, and a fall in employment.

A vicious cycle

Oil pipelines are a huge source of revenue for many countries, and are typically underpinned by investment from financial institutions worldwide. However, the frequency of threats may alarm investors and cause them to move to 'safer' markets, if they feel commodities can easily become compromised.

Unfortunately, this can contribute to a vicious cycle, with developing nations kept even further adrift from global economic networks because of perceived instability – which in turn leads to further attacks due to a lack of infrastructure. This illustrates just how damaging attacks on pipelines can be. It is not just the immediate physical dangers and lost revenue, but the ripple effects throughout the entire international community.

Clearly, threat prevention is more vital than ever, and traditional methods are proving insufficient. It is incredibly difficult for guards alone to adequately monitor pipelines, because of the large area they span. Supporting technologies such as aerial surveillance, closed-circuit television (CCTV), and ground radars also have limitations, as they only provide localised visibility of potential dangers.

Real-time, reliable data is required that covers the entire length of pipelines and can provide protection around the clock, such as distributed acoustic sensing technology (DAS).

The technical details

DAS is a photonic sensing technology that converts standard communications fibre into a linear array of discrete vibration sensors.

Activities such as people hot-tapping pipelines, leaks, perimeter intrusions, moving vehicles, industrial operations, failing mechanical components, and many more, all generate vibrations with distinct acoustic characteristics.

DAS technology monitors these vibrations, and if supported by the right software it can accurately detect, classify, and report on the vibration events – locating the position of each event to within a few metres.

DAS is an advanced variant of an optical time domain reflectometer (OTDR) that monitors the coherent Rayleigh backscatter noise signature in a fibre optic cable as pulsed light is sent into the fibre. The coherent Rayleigh noise generates fine structure in the backscatter signature of the fibre cable. DAS focuses on the Raleigh component to increase its prominence in the backscatter trace.

The technology is optimised to measure small changes in the coherent Rayleigh noise structure that occur from pulse to pulse. Since the coherent Rayleigh noise structure is generated interferometrically within the fibre by the relative locations and strengths of local scattering centres intrinsic to the structure of the glass, very small physical (acoustic or vibration) disturbances at a point in the fibre can make detectable changes in the interferometric signal.

Pipeline security

DAS operates with standard telecommunications-grade optical fibres. These optical fibres can be installed whilst an asset is being built, with DAS in mind (e.g. a pipeline), or retrospectively on existing telecommunications infrastructure – such as the ubiquitous fibre networks in urban areas. DAS uses optical fibres as the 'sensor', the DAS itself being the interrogator of the returning backscatter signal.

By using DAS, a sensor is used that is immune to EM or RF interface – it is also inert and requires no power along the entire length beyond the DAS interrogator. Furthermore, depending on the quality of fibre (among other environmental attributes), 50 km of optical fibre can be monitored by one interrogator on a single channel. As a result, a DAS monitoring solution can often be installed more quickly than some traditional monitoring technologies and at lower deployment expense, therefore resulting in a considerable reduction in through life and maintenance costs.

For pipeline security, DAS and Fotech's LivePIPE platform harnesses the latest photonics, advanced artificial intelligence, and edge computing to detect, classify, and alarm on security and integrity events with confidence.

The technology is designed to allow users to prevent criminal activity, malicious attacks or accidental damage; detect and locate leaks at the earliest possible stage; and track and monitor pigs during maintenance activities. Fotech systems are already monitoring thousands of kilometres of assets, accumulating millions of operational hours in 27 countries.

The LivePIPE platform taps into the fibre optic network running along an operator's pipelines – it is designed to provide uninterrupted and real-time feedback of activities occurring along the pipeline's entire span. Fotech's dual-channel photonic technology is designed to allow operators to monitor more of their network with less; expand the protection of the pipeline with ease; and be confident with a pipeline management platform proven with customers around the globe.

Figure 1. LivePIPE is designed to provide uninterrupted and real-time feedback of activities occurring along the pipeline's entire span from one central point.

Figure 2. Field engineer working on a site acceptance test in South America.

Human error

It is not only external threats that can have extreme consequences when it comes securing a pipeline. Simple human error can potentially be just as disastrous, and in this way DAS recently demonstrated its value in South America.

During the site acceptance test of a LivePIPE solution on a pipeline prone to hot tapping and theft, an unexpected signal was detected at a location in the rainforest.

The client initially considered it a false alarm, because of the remote, seemingly inaccessible, position of this section of pipeline and the fact there had been no notifications of planned work in the area.

However, acting decisively, Fotech's engineers insisted that a visit should be made to the site as the detected vibrations had all the characteristics of human activity. This was absolutely crucial. At the site, a seismic team were discovered drilling holes in the ground ready for explosives, as part of their exploration activities. Their GPS navigation had malfunctioned due to the influence of the tree canopy and taken them a significant distance away from their intended location.

Through the intervention – directed by the LivePIPE technology – the drilling was stopped and subsequent detonation of explosives close to the pipeline prevented, averting what would have been a very serious and dangerous incident.

A strategic partner

There is no doubt that pipelines are inherently difficult assets to monitor because of the vast expanse of land they cover and the remote areas in which they are often located.

For pipelines in the most inaccessible terrains – whether that is in a jungle, a desert, or over mountains – surveillance can be extremely challenging. Indeed, large sections of pipeline might be entirely unmonitored and extremely vulnerable to accidental damage (as was fortunately prevented in South America), or even terrorist threats as a result.

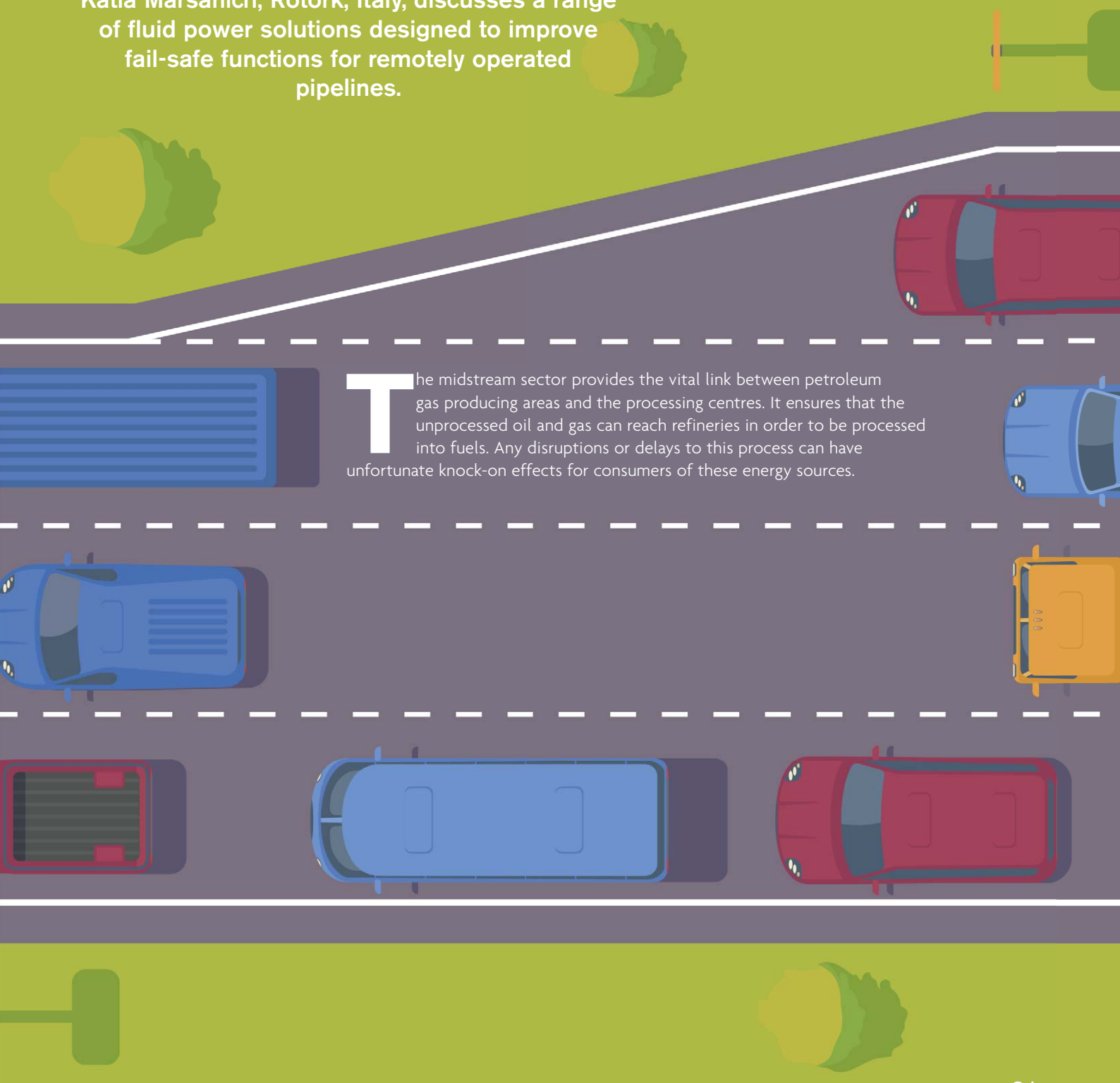
However, DAS technology is designed to give operators the means to achieve comprehensive monitoring and threat detection – even in the most remote locations. By effectively providing an invisible 'smart barrier' along the entire length of the pipeline, DAS can detect potential threats and help direct an operator's response wherever it occurs.

DAS can serve as a strategic partner in the fight against terrorism and theft on pipelines, alerting security personnel to the exact location of an incident and enabling the swift resolution of any potential problems. Moreover, after an incident, post-acquisition analysis of DAS data can highlight activity associated with scouting missions or reconnaissance. This additional insight shows the value of DAS – not only helping to tighten security monitoring processes, but also providing new, previously impossible, methods to predict and pre-emptively prevent attacks or criminal activity.

With social, political, and economic progress at stake if pipelines are not fully secured, it is time for operators to turn to solutions, such as DAS, to ensure severe consequences are avoided.

KEEP IT MOVING

Katia Marsanich, Rotork, Italy, discusses a range of fluid power solutions designed to improve fail-safe functions for remotely operated pipelines.



The midstream sector provides the vital link between petroleum gas producing areas and the processing centres. It ensures that the unprocessed oil and gas can reach refineries in order to be processed into fuels. Any disruptions or delays to this process can have unfortunate knock-on effects for consumers of these energy sources.

Diverse fluid power solutions can be applied to the midstream sector in order to ensure pipelines continue to run safely and reliably. Pneumatic actuators, high-pressure pneumatic actuators, electronic line break (ELB) and electro-hydraulic actuators each provide solutions with their own benefits.

Low-pressure pneumatic actuators

Rotork's GP pneumatic low-pressure actuators include spring return fail-safe functionality. This is a simple and reliable fail-safe solution, as it does not depend on an external power source. The actuators are also available in a double-acting configuration, where air is supplied to both sides of the piston. In either configuration, the maximum torque and operating speed are not an issue.

These actuators are appropriate for use on both gas and oil pipelines, and can be equipped with a wide variety of customised control systems to develop any logic type function such as emergency shutdown (ESD), partial stroke (PST), redundancy, fast stroke, and modulating control. They are, however, dependent upon on-site compressors and are therefore not ideal for remote area installation. Some of the largest models can weigh up to 9 t, and are suitable for valve sizes from 20 in. - 68 in.

More than 80 of these actuators were installed on a natural gas pipeline in India. The actuators operate buried service ball valves to perform ESD functions along the length of the 30 in. diameter, 879 km pipeline, which runs from a 5 million tpy capacity LNG import terminal on India's south-west coast.

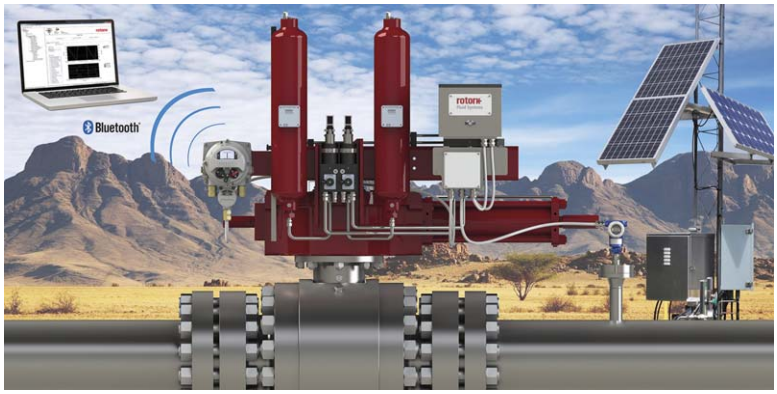


Figure 1. Gas-over-oil actuator with electronic line break.

Figure 2. Rotork's third generation Skilmatic SI3 self-contained electro-hydraulic valve actuator.

High-pressure pneumatic actuators

High-pressure pneumatic actuators are designed for large valves requiring high torque. Even if pipeline gas pressure is the fluid motive power, they never require a pressure reduction system. Unlike their low-pressure counterparts, they are ideal for remote area installations as they do not depend upon an on-site compressor.

Since they are specifically designed for gas pipelines, alternative power sources such as bottled nitrogen must be applied for liquid pipelines. As a result of the double-acting configuration, the system is only pressurised during the valve stroke. They are also able to provide a wide range of high-pressure control logic options.

There are two high-pressure pneumatic actuation solutions: gas-over-oil (GO) and high-pressure gas (HPG).

A solution for every site

GO and HPG actuators use the pressure of gas flowing through the valve as the fluid motive power for the actuator itself. Intelligent pipeline pressure monitor solutions can provide early detection of pipeline breaks, and allow the automatic closure of the actuator in the event of a break being detected. Electro-hydraulic actuators can be an alternative to GO or HPG, where the pipeline gas cannot be employed. Actuators help control almost everything that happens in a petrochemical plant, so they are vital for the safe operation and maintenance of every plant.

Gas-over-oil actuators

The working principle of GO is using the pipeline gas pressure to stroke a hydraulic double-acting actuator. The system is a hybrid one, made up of a double-acting hydraulic actuator controlled by a pneumatic circuit, a gas block, and solenoid valves with a manual override. The gas will meet and push the oil into two gas/oil tanks, hence the name gas-over-oil.

GO actuators, fitted with ELBs, provide line break monitoring and protection services on remotely installed valves on a natural gas pipeline in China. They enable the operator to monitor the running condition of the pipeline and the position status of the valves.

High-pressure gas actuators

In a high-pressure gas actuator, the pipeline gas is sent directly into the actuator's cylinder chamber, avoiding the use of gas/oil tanks. The system is controlled by the same pneumatic circuit, gas block and solenoid valves as in GO actuators, and is provided with a hydraulic manual override.

Over 100 Rotork HPG actuators have been installed on one of Brazil's largest natural gas pipelines. The pipeline has a capacity for over 4 million m^3/d, and its construction enabled a fundamental improvement in the use of clean energy products, as natural gas was now able to be supplied in place of diesel or oil fuel, which had been used previously.

Typical control options and accessories

Both the GO and HPG actuators use a double-acting configuration. In the event of damage to the pipeline, four possible logic options can be chosen:

- Electric emergency shutdown (ESD): This is the solution applicable in installations with a dedicated electrical signal from the control room. This signal is used to automatically close the valve in the event of an emergency. An ESD solenoid valve is then installed in the system, and in the event of loss of signal, the actuator moves to one end of stroke.

- Low pressure close: This is a pneumatic solution applied when there is a risk of sudden pipeline damage (which would cause a drop in pressure). A low-pressure sensor then allows for the automatic closing of the valve after pressure drops below a predefined set point. A high differential open inhibit allows for the automatic inhibition of opening when the difference of pressure from upstream to downstream exceeds a predetermined set point. It avoids eventual shock waves in the pipeline due to the valve reopening.

- Electronic line break (ELB): This is an electric device designed for use with GO actuators. It continuously monitors pipeline pressure and can provide automatic valve movement to a predetermined emergency position. It stores a comprehensive data logger and can be programmed to perform a set of functionalities covering not only line break, but also low pressure close, high differential open inhibit, ESD and partial stroke. The Rotork Bluetooth® Setting Tool can be used to configure the ELB and to retrieve data from it. Close, open, and stay put are all configurable as fail positions.

- Pneumatic line break: This is a pneumatic solution applied when there is a risk of relatively small damage to the pipeline, which would cause a pressure decrease over time. Like the ELB, it allows an automatic close in the event of the pressure drop rate becoming higher than a predetermined set point.

Electro-hydraulic actuators

Electro-hydraulic actuators combine the simplicity of electrical operation with the precision of hydraulic control and the reliability of spring return fail-safe. They are

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designed to provide a self-contained solution which is for remote locations. A solar powered option is also available.

Designed for safety-critical application, they are suitable for both oil and gas pipelines. Built-in diagnostics, partial stroke testing (PST), and fieldbus communications are all available for use with electro-hydraulic actuators. These actuators are designed to provide reduced installation and maintenance costs, and consume less power than other models.

Rotork's SI electro-hydraulic actuators are installed with an integral control module and an integral hydraulic power unit (oil reservoir, pump and motor). An LCD screen can be used to monitor hydraulic pressure settings, position limits, controls, indication functions, alarms and a data log, which is all readily available to the operator. Local operation also allows for local/remote configuration as well as open/close function through the use of simple selectors.

The control module is responsible for driving the logic function of the actuator. It provides a two-position control as well as ESD control with PST capabilities. Non-intrusive access is granted with the Rotork Bluetooth Setting Tool, with an infrared option also available.

The control module manages the PST by de-energising each bleed solenoid valve in sequence, to allow the valve to move to the required position and then return to its original position. The percentage of valve movement can be configured by the end user. PST can also be initiated locally with a handheld setting tool, remotely via the control room or via a network card. A pass/fail log on the LCD display records the results of the PST, and the results of the last 25 PSTs can also be accessed. A trend overlay allows the operator to compare the results of the test to the results when the actuator was initially commissioned.

Additionally, the SI actuators allow for customisation of the ESD function, based on plant needs. For applications where the loss of mains power is considered a part of the safety-instrumented system, the SI is offered as fail-safe on either loss of power or ESD signal. If the application uses an unreliable mains power supply, it can alternatively be configured for fail-safe only in the event of loss of ESD signal. It is also possible to have a second ESD input by using an additional ESD option card, which means the SI is able to operate two shutdown systems. An optional manual reset can also be included.

SI actuators have been installed in automated and unattended pump stations on two major pipelines in China. They are designed to provide isolating and fail-safe ESD functions. By providing fast and accurate valve movement in one direction and reliable mechanical spring return movement in the fail-safe direction, they are able to isolate sections of the pipelines in the event of a potential emergency. WP

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