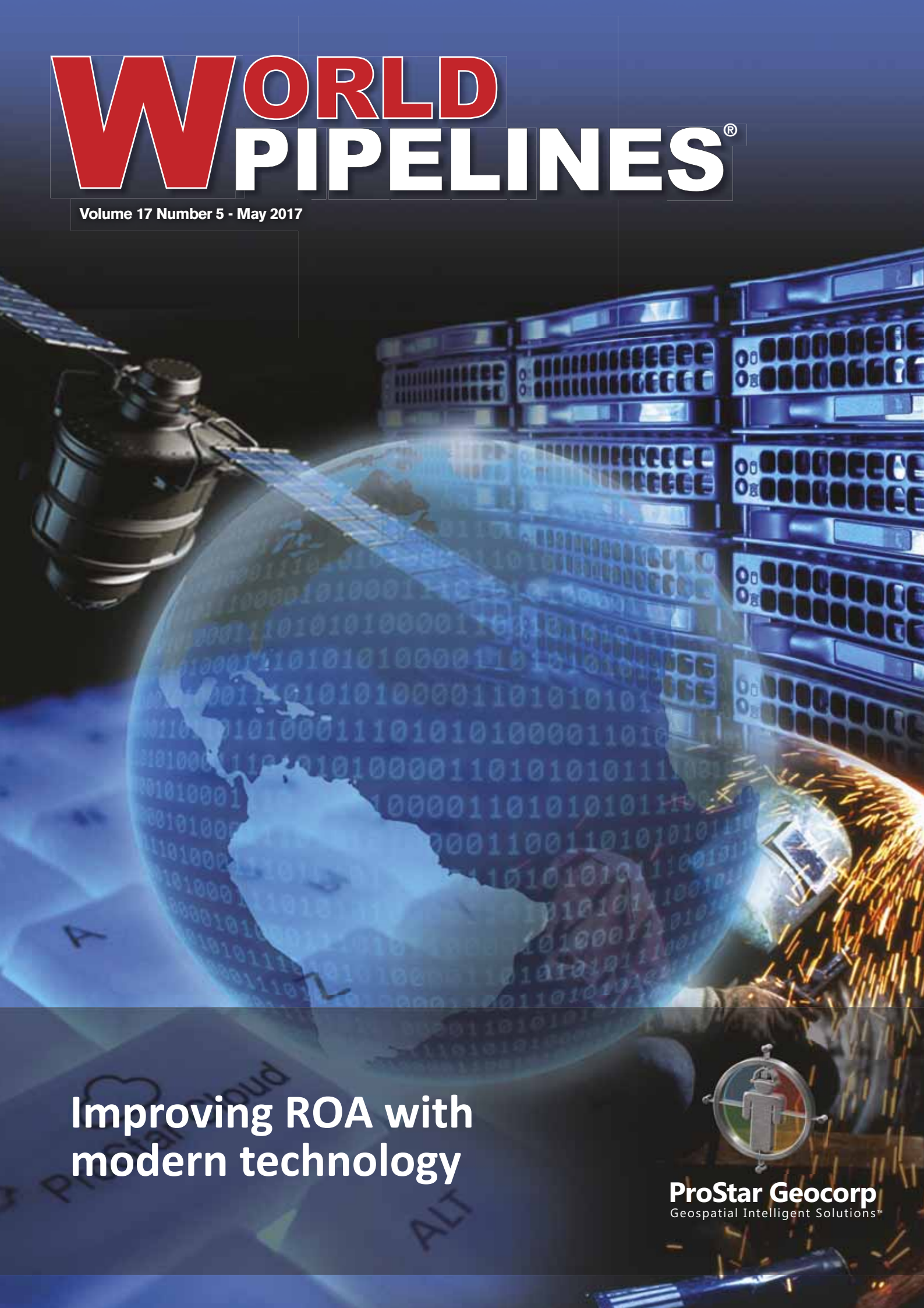
WORLD PIPELINES®

Volume 17 Number 5 - May 2017



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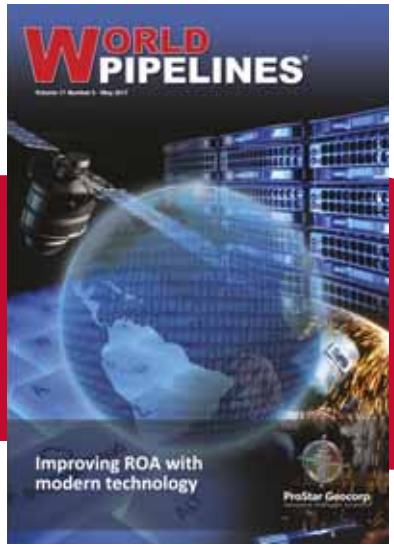

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WORLD PIPELINES

EUROPE: A NEW HOPE?

With the temperature slowly picking up as we move further into spring in the Northern Hemisphere, many will soon be turning their thoughts to relaxing holidays and long weekends away. With its variable climates and broad offerings, one popular tourist destination is Europe. Yet, it's not all sunshine and smiles for the continent – Europe is suffering as its oil and gas sector faces challenging market conditions.

At present, it is attempting to retain its position as a powerful trading region. However, although growing wary of its dependency on Russian natural gas, Europe is still a consumer in need of mass energy imports.

The continent receives its natural gas predominantly through pipelines from Russia's 32.3 trillion m^3 of reserves. The country is expected to continue exporting similar volumes of gas to Europe as in 2016, especially with the European Commission's (EC) decision to increase the gas supply from Russian energy giant, Gazprom, to 80% through Germany's OPAL pipeline. The OPAL pipeline connects to Gazprom's Nord Stream export line, which transports natural gas from Russia to Europe via the Baltic Sea. In 2016, Gazprom reported that Nord Stream delivered 43.8 billion m^3 of gas to European customers.

> DESPITE TOUGH ECONOMIC CONDITIONS, EUROPE DOES HAVE OPTIONS. PROJECTS ARE ADVANCING WITH NEW ONES ON THE HORIZON

While many applaud the EC's verdict, there are some who openly oppose the increased gas flow. Off the back of this decision, Ukraine's Naftogaz Ukrainy has filed a lawsuit against the EC. The company is currently seeking to terminate Russia's increased flow from Nord Stream through the OPAL line, stating that the approval was made without consultations with Ukraine.

Similarly, both Poland and Lithuania have joined Ukraine in protesting the EC's decision, citing the European Union's (EU) dependency on Russian gas as their main reason for this. With this newly granted increase in gas flow to Europe, the EU's reliance on Russia for natural gas will grow, which could potentially threaten the region's energy security.

Despite Europe's overall gas consumption decreasing, there has been a surge in the region's import dependency due to its diminishing domestic production, caused mainly by the shutdown of numerous North Sea fields.

However, this might be set to change. By 2020, the North Sea is expected to begin operations on 22 crude oil projects and eight natural gas projects. A GlobalData report[1] published in March stated that the North Sea had seen improvements during the market downturn over the past few years. For instance, 10 additional fields are expected to begin production in the North Sea between 2021 - 2023.

So, it appears that, despite tough economic conditions, Europe does have options. Projects are advancing with new ones on the horizon. For instance, Independent Oil and Gas plc has recently signed a sale and purchase agreement for the acquisition of the recently decommissioned Thames gas pipeline, which is located in the southern North Sea. The pipeline will provide a proposed export route for the company's southern North Sea assets.

The Trans Anatolian natural gas pipeline (TANAP), which transports Caspian natural gas to Turkey and Europe, is advancing rapidly. TANAP recently received its delivery of pipes from Turkey's Toscelik Spiral Boru ahead of schedule, and Sermiax has completed its welding operations for the project too.

In Greece, construction operations for the Trans Adriatic pipeline (TAP) project have been making headway. The project is currently on schedule, with construction advancing through two of the three northern Greek regions that TAP will cross: eastern Macedonia-Thrace and central Macedonia.

And finally, Gazprom's Nord Stream 2 and TurkStream pipelines are steadily progressing. In February, Allseas was awarded a contract for Nord Stream 2's offshore pipelay work through the Baltic Sea. Similarly, South Stream Transport B.V. and Allseas have been contracted for the construction of the second string of TurkStream's offshore section, which delivers Russian natural gas to Turkish and European customers.

This month's regional report discusses Europe's need for extensive oil and gas imports, and considers the region's economic climate and ongoing pipeline projects. Turn to p.12 for a more in-depth account.

1. https://www.globaldata.com/store/report/gdge0169mar--h1-2017-production-and-capital-expenditure-outlook-for-key-planned-upstream-projects-in-north-sea-norway-to-lead-in-crude-oil-production/?utm_source=email&utm_medium=pr&utm_campaign=170411a_gd_og_pr_h1_north_sea_oil&utm_nooveride=1

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World News

Nord Stream 2 begins EIA procedure

Nord Stream 2 AG, the developer of the Nord Stream 2 pipeline project, has started an environmental impact assessment (EIA) procedure in Russia. The relevant project documents, including the terms of reference and the EIA programme, were disclosed for public discussion and consultation as the first phase of the EIA procedure.

In addition to the required documents, the company also published the reports prepared by independent environmental consultants that provided a comparative environmental assessment of the route options for the Russian section of the Nord Stream 2 pipeline. The reports present the results of the comprehensive analysis of various technical, environmental, social and economic factors.

Based on the analysis of the route and landfall options, the Narva Bay route in the Kingisepp District of the Leningrad region has been defined as the preferred option due to its smaller overall environmental and social impacts. The final decision on the Russian landfall will be made by the Russian environmental authorities.

In the next phase, Nord Stream 2 AG will carry out the EIA in line with the terms of reference and present the draft EIA report for public consultation. The EIA procedure is the main condition for obtaining the required permits to build the new pipeline through the Baltic Sea. The EIA includes analysis of hydrometeorological, geological, biological, social, economic and other conditions, as well as nature protected areas, rare species, vulnerable habitats and other factors. The EIA assesses all potential environmental and social impacts from the planned activities and describes environmental protection measures.

Simon Bonnell, Head of Permitting, Nord Stream 2 AG, commented: "On top of compliance with Russian law, Nord Stream 2 AG, as a responsible developer of a major infrastructure project, has committed to applying best practices and adhering to international environmental and social standards. We are aware of our responsibility to preserve the conservation value of all sensitive areas to be traversed by Nord Stream 2. Our experts are developing optimal technical solutions and a comprehensive biodiversity conservation plan. As a next step, we will discuss our proposals with the expert community and relevant authorities." WP

PennEast pipeline update

New Jersey Conservation Foundation (NJ Conservation) and Stony Brook-Millstone Watershed Association has called upon the New Jersey Department of Environmental Protection (NJDEP) to reject applications for a freshwater wetlands individual permit and water quality certificate (that were recently filed by the PennEast Pipeline Company. Is has been reported that the pipeline company does not have the legal authority to make the request.

"By submitting this permit application, PennEast is asking NJDEP to ignore its own regulations in a rush to damage our land, pollute our air and water, and put our families at risk," said Tom Gilbert, Campaign Director, NJ Conservation. "NJDEP must reject PennEast's latest attempt to steamroll its unneeded pipeline over New Jersey's environmental protection laws."

Similarly, on 9 April, HALT PennEast – a group of landowners along the pipeline's path and other concerned citizens – were joined by other groups in a massive display of opposition. The focal point of their protest was the Federal Energy Regulatory Commission's (FERC) decision to issue a final environmental impact statement (EIS) for the pipeline.

According to the groups, the final EIS simply repeated the unfounded conclusions of its previously issued draft EIS: that the project would not cause significant adverse environmental impacts.

Lawyers at Eastern Environmental Law Center and Columbia Environmental Law Clinic are prepared to bring PennEast to the courts should the project plow forward. They stated that the final EIS by no means constitutes a final approval of the project, and added that – for the pipeline to be approved – FERC must still consider whether there is any true public need for the project prior to issuing a certificate.

The 120 mile, 36 in. dia. pipeline will transport natural gas from northeastern Pennsylvania to New Jersey. The project, which is expected to begin construction in 2018 pending regulatory approval, will reduce energy costs and create jobs in the region. WP

Energy East and Eastern Mainline to be reviewed concurrently

A National Energy Board (NEB) hearing panel will review Canada's Energy East and Eastern Mainline pipeline projects concurrently. After reviewing comments from 11 groups and individuals, the hearing panel said that the two project applications are closely interrelated and would be most efficiently assessed through a co-ordinated approach.

The proposed Energy East is a 4500 km pipeline that would carry 1.1 million bpd of crude oil from Alberta and Saskatchewan, to refineries in eastern Canada and a marine terminal in New Brunswick.

The proposed Eastern Mainline would see the construction of approximately 279 km of new gas pipeline and related components, beginning near Markham (Ontario) and finishing near Brouseville (Ontario). In its application, TransCanada – the company behind the project – indicated that this project was conditional upon the approval of the Energy East pipeline project.

While the two applications will be considered together with a single hearing record, the hearing panel will issue separate lists of issues and carry out individual environmental assessments for each project. When appropriate, the hearing panel will issue documents or hold oral sessions specific to each application. The panel will also issue two separate recommendation reports to the Federal Cabinet at the end of the review.

According to the NEB, information regarding the next steps of the hearing process will be released soon. WP

World News

INBRIEF

USA

On 7 February, a Hilcorp Alaska underwater natural gas pipeline began leaking in Cook Inlet. As of 13 April, the pipeline has been repaired. While the pipeline repair operations were delayed for weeks due to icy weather conditions, on 8 April, the company was able to begin repair of the line.

Russia

During a meeting on 11 April, Russia and China discussed both countries' co-operation in the gas sector, specifically the projects for Russian gas supplies to China, including via the Power of Siberia pipeline.

Turkey

Onshore and offshore pipeline welding company, Serimax, has successfully completed its welding scope for the Trans Anatolian natural gas pipeline (TANAP) project.

USA

US Vice President, Mike Pence, recently met with Alaska Gasline Development Corporation (AGDC) to discuss its Alaska LNG project. Advancing the development and construction of a North Slope natural gas pipeline and LNG export terminal is AGDC's top priority.

UK

Wood Group has won a front end engineering design contract by Premier Oil for the delivery to the Tolmount offshore field development in the North Sea. Wood Group will provide topsides, pipeline, flow assurance and subsea engineering knowledge for Premier Oil's Tolmount offshore assets and export pipeline.

USA

Enterprise Products Partners L.P. (Enterprise) has announced the construction of a new 571 mile pipeline to transport growing volumes of natural gas liquids (NGL) from the Permian Basin to Enterprise's NGL fractionation and storage complex in Mont Belvieu (Texas).

EastMed construction on the horizon

Following discussions with European energy ministers, Israel has made a deal with Italy, Greece and Cyprus for the construction of the Eastern Mediterranean (EastMed) subsea natural gas pipeline, which would connect Israel to Europe. The countries have agreed to support and continue pursuing the development of the pipeline project.

The document was signed on 3 April by the energy ministers of the four respective countries, along with the participation of the European Commissioner for Climate Action and Energy, Miguel Arias Canete.

Feasibility studies have been completed and the parties hope to develop a full plan for development by the end of the year.

Construction of the EastMed pipeline is estimated to cost US$6.2 billion and is expected to take approximately eight years to complete. The parties have targeted 2025 for the project's completion.

It is set to be one of the longest underwater gas pipelines in the world, connecting fields offshore Israel to Italy, Greece and Cyprus.

The EastMed pipeline is reportedly backed by the European Union, as it would help reduce European dependence on Russian energy sources. WP

Cano Limon-Covenas pipeline reopens

Ecopetrol has restarted Columbia's second largest oil pipeline; the 485 mile (780 km) Cano Limon-Covenas. This comes after a series of approximately 30 bomb attacks forced the company to halt the transportation of crude oil through the pipeline for seven weeks, as of 15 February.

In March, Ecopetrol claimed that the attacks have led to a reduction of 893 000 bbls of oil production so far this year. Meanwhile, military sources have reportedly attributed the attacks to the National Liberation Army rebels.

With the pipeline reopening, production at the Cano Limon and Caricare fields is also expected to resume soon. US-based Occidental Petroleum Corp – the company that operates the fields – suspended output from the field in early March due to the attacks. In normal operating conditions, the fields produce approximately 52 000 bpd, and the pipeline has a capacity of up to 210 000 bpd.

The Cano Limon-Covenas pipeline came online in 1986. According to Ecopetrol, attacks against the pipeline have left 751 victims, of which 167 were killed, over the last 17 years. Moreover, since it opened, the pipeline has been out of service about 10.4 years, or 30% of its life. WP

TAP project progresses in Greece

Construction in Greece for the Trans Adriatic pipeline (TAP) is advancing according to schedule. It has been 10 months since the Inauguration Ceremony was held in May 2016, and construction has significantly progressed in two of the three northern Greek prefectures to be traversed by the pipeline: eastern Macedonia-Thrace and central Macedonia.

As of the end of March, out of the approximately 550 km of pipeline in total to be built on Greek soil, TAP's contractors have already received 66% of the total 32 000 line pipes to be used for the construction of the pipeline's Greek section. The contractors have also cleared and graded 260 km of the project's route, strung 217 km of pipeline and welded 184 km of the mainline. At the same time, 154 km of trench has been opened, 119 km of pipeline has been lowered into the trench, 97 km of pipeline has been backfilled and 18 km of land is being reinstated.

Commenting on the timely progress of construction, TAP's Country Manager for Greece, Rikard Scoufias, stated: "I would like to congratulate all engineering, procurement and construction (EPC) contractors for the effectiveness and quality of their work, and kindly thank local communities and competent authorities for their collaboration."

As construction progresses, the project's direct benefits for the country, its economy and local communities, are also becoming more evident.

Two out of the five EPC contractors operating on TAP are Greek companies, namely TERNA S.A. in a joint venture with Renco S.p.A., and J&P AVAX in a joint venture with Bonatti S.p.A., while AKTOR has been selected by French contractor Spiecapag as its subcontractor. Also, TAP has awarded CORINTH PIPEWORKS S.A. one of two major contracts for the procurement of line pipes. WP

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World News

Events DIARY

13 - 15 June 2017
Global Petroleum Show
Calgary, Canada
https://globalpetroleumshow.com/

9 - 13 July 2017
22nd World Petroleum Congress
Istanbul, Turkey
https://www.worldpipelines.com/events/22nd-world-petroleum-congress/

10 - 11 August 2017
The 2nd IndoAIM 2017
Jakarta, Indonesia
http://indoaim.com/

5 - 8 September 2017
SPE Offshore Europe
Aberdeen, Scotland
http://www.offshore-europe.co.uk/

17 - 19 September 2017
Pipeline-Pipe-Sewer Technology Conference and Exhibition (PPST)
Cairo, Egypt
https://www.pipelinepipesewer.com/

25 - 29 September 2017
IPLOCA 2017 Convention
Mexico City, Mexico
http://www.iploca.com

24 - 26 October 2017
LAGCOE 2017
Lafayette, USA
http://www.lagcoe.com/home-expo

13 - 16 November 2017
ADIPEC
Abu Dhabi, UAE
https://www.adipec.com/

Thames gas pipeline acquired

Independent Oil and Gas plc (IOG) has signed a sale and purchase agreement for the acquisition of the recently decommissioned Thames gas pipeline, which is located in the southern North Sea. IOG is set to purchase the pipeline from Perenco UK Limited, Tullow Oil SK Limited and Centrica Resources Limited. The pipeline will provide a proposed export route for IOG's southern North Sea assets. The company intends to export gas from IOG's Blythe and Vulcan Satellite hubs once they are in production.

These hubs will require an estimated maximum throughput of approximately 150 million ft^3/d, which is well within the pipeline's anticipated capacity. The company, therefore, expects the pipeline to have sufficient capacity to accommodate the export of gas from the Harvey discovery, subject to its successful appraisal.

Upon completion of the acquisition, IOG will undertake an intelligent pigging inspection to ensure the pipeline's integrity for safe reuse. WIOG Chief Executive, Mark Routh, and Deputy Chief Executive, Andrew Hockey, will outline the company's plans at the East of England Energy Group southern North Sea rejuvenation special interest group in Norwich on 1 June.

IOG previously acquired most of its southern North Sea gas assets at low cost because they were considered stranded without a viable export route.

Pipeline expansion project for Enable

Enable Midstream Partners, LP (Enable) has announced that its wholly-owned subsidiary, Enable Gas Transmission, LLC (EGT), has entered into a 205 000 dth/d natural gas transportation agreement with Newfield Exploration Company (Newfield), a top producer in the growing SCOOP and STACK plays.

The 10 year contract is associated with EGT's recently announced Cana and STACK Expansion project, and is expected to start at an initial capacity of 45 000 dth/d in early 2018, growing to the full 205 000 dth/d of contracted capacity by 4Q18.

"We are pleased to provide Newfield with a timely, cost-effective and flexible natural gas transportation solution out of the Anadarko Basin with access to premium markets," said Rod Sailor, Enable's President and CEO.

NEB amends pipeline safety advisory

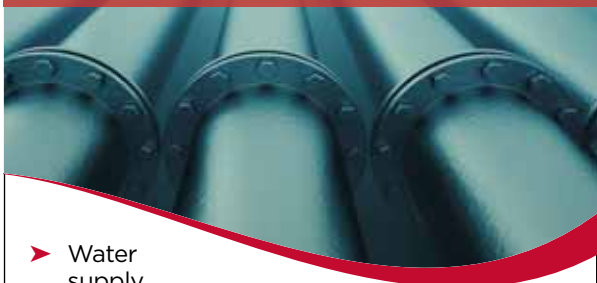
The National Energy Board (NEB) has expanded the scope of a previous safety advisory and draft order regarding the quality assurance of pipeline materials.

In February 2016, the NEB issued two safety advisories and an order, which required NEB-regulated companies to identify and report on purchased and installed pipeline components that contain material properties that do not meet standard associations' requirements. Recently the NEB has become aware of additional quality issues associated with pipeline fittings.

In order to continue to ensure the safety of NEB regulated pipelines and facilities, the NEB has issued an amended safety advisory and order. The amended advisory will expand the scope of the previous advisory by naming additional manufacturers whose components did not meet requirements. The draft order will require NEB-regulated companies to identify components fitting this description, confirm they are safe, and take appropriate mitigation measures.

The NEB is concerned about these manufacturing issues but stresses that there is no immediate risk to the public or the environment. No incidents have been reported on NEB-regulated pipelines that relate to the use of these materials.

News Highlights



- Water supply concerns cause Northern Access pipeline permit denial
- FERC issues environmental assessment for Millennium's Eastern pipeline
- Lloyd's Register to conduct pipeline inspection
- SkyX develops UAV drones to service oil and gas pipelines

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Contract News

Ienos and BP confirm Forties pipeline deal

Ineos has agreed to pay up to US$250 million for BP's Forties pipeline system (FPS) and the associated Kinneil terminal in the UK North Sea. This deal will see Ineos assume responsibility for transporting approximately 40% of the UK's oil and gas production.

Ineos will pay US$125 million up front to BP, with the remaining US$125 million potentially maturing over seven years under an 'earn-out' arrangement, based on unspecified performance targets.

Ineos already controls the 10 million t (201 000 bpd) Grangemouth refining and petrochemical complex near Edinburgh, which receives approximately 20% of the oil currently pumped through the FPS. BP's CEO, Bob Dudley, argued that recoupling FPS and Grangemouth would enable Ineos to achieve "greater efficiencies" to ensure the pipeline had a "long term future."

The St. Fergus-to-Cruden Bay pipeline for natural gas liquids (NGLs) and the Cruden Bay terminal were also included in the transaction.

These assets should help Ineos reduce the overheads associated with transporting feedstock to the Fife ethylene plant, which was designed to use NGLs extracted from the North Sea.

Ineos is on a push to create an integrated energy business model that includes upstream, midstream and downstream assets. The firm purchased the Breagh and Clipper South fields in the southern North Sea in October 2015, taking control of around 2.85 billion m^3/y of gas production. Elsewhere, Ineos is looking to develop shale gas production from English assets purchased from iGas, also in October 2015, in a deal that made the company the UK's third biggest shale player.

The company also announced in 2014 that it would spend up to US$1 billion on developing UK shale projects to yield feedstock for its downstream facilities. This strategy saw the company agree to purchase Engie's UK shale portfolio for an undisclosed sum in late March. WP

Shawcor awarded Thai pipe coating contract

Marubeni-Itochu Tubulars Asia Pte Ltd., a 100% subsidiary of Marubeni-Itochu Steel Inc., has awarded Shawcor Ltd.'s pipe coating division a contract in excess of CAN$40 million to provide internal lining and three-layer polyethylene anti-corrosion pipeline coatings for Thailand's Fifth transmission pipeline project.

The Fifth transmission pipeline project is owned by PTT Public Company Limited, a Thai state enterprise company. The pipeline will run through eight provinces in Thailand, and is aimed at reducing risks to electrical power security and easing the delivery of gas from the LNG Terminal in Rayong to the western region.

Shawcor will execute the contract in its coating facilities in Malaysia. Work is expected to commence in 4Q17 and be completed by 4Q18. WP

Enbridge and NDT Global partner in R&D pipeline project

Enbridge Inc. (Enbridge) and NDT Global have partnered in a multi year research and development (R&D) project to advance innovation in pipeline inspection technology and, ultimately, drive pipeline safety and reliability to a new level.

The multi year collaboration agreement focuses on the development of a new generation of inspection tool that is targeted to even further improve pipe crack assessment. Enbridge and NDT Global have already been working together for 15 years on pipeline inspections and are at the forefront of the industry in advancing crack assessment with high resolution ultrasonic inspections. This joint investment will bring added innovation and a new technology capability to the existing integrity management programmes.

Walter Kresic, Enbridge's Vice President Pipeline Integrity of Enbridge Pipelines Inc., stated: "We believe this next generation project with NDT Global will build on the industry leading tools and technology we already use, and further enhance our ability to inspect, monitor and prioritise cracking threats in pipelines."

Mario Lemme, CEO of NDT Global, commented: "We are delighted to collaborate closely with Enbridge on this initiative, which offers a real opportunity to make a breakthrough in crack assessment capability."

The scope of the new project is aimed at evolving existing inline inspection performance. An important step in this R&D programme will be to prove the equipment capability by conducting test runs within the Enbridge pipelines in Canada and the US. WP

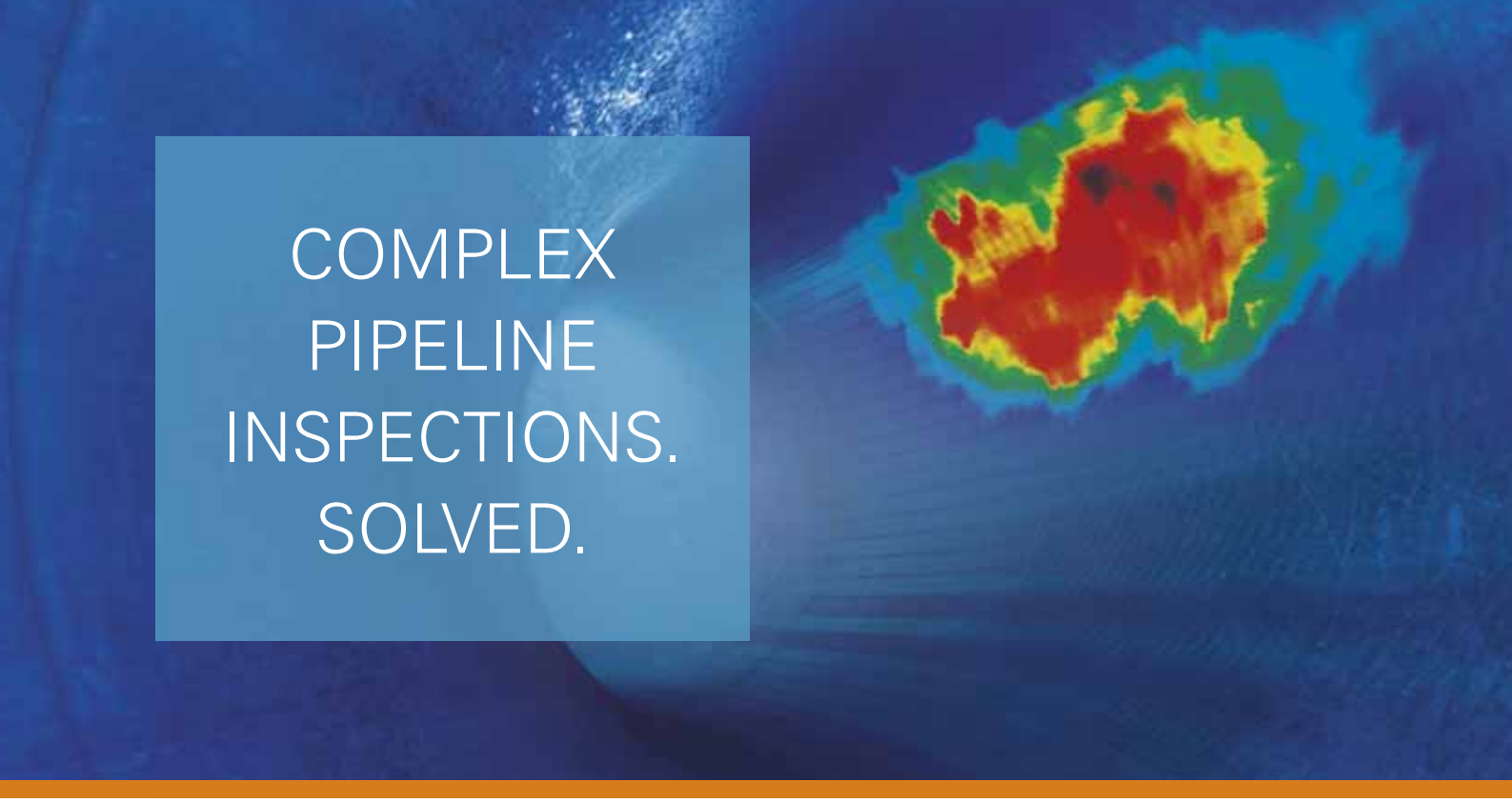
Kinder Morgan and DCP sign agreement for Gulf Coast Express pipeline

Kinder Morgan Texas Pipeline LLC – a subsidiary of Kinder Morgan, Inc. (KMI) – and DCP Midstream, LP (DCP), have signed a Letter of Intent for DCP to participate in the development of the proposed Gulf Coast Express pipeline project, which will provide an outlet for increased natural gas production from the Permian Basin to growing markets along the Texas Gulf Coast. The project is designed to transport up to 1 700 000 dth/d of natural gas through approximately 430 miles of 42 in. pipeline, from the Waha (Texas) area to Agua Dulce (Texas). The pipeline is expected to be in service by 2H19, subject to shipper commitments.

A non-binding open season for firm natural gas transportation is currently in process. It is anticipated that DCP will be a partner and shipper on the pipeline, while KMI will build and operate the line.

Kinder Morgan Natural Gas Midstream President, Duane Kokinda, said: "We believe DCP's strong Permian position, when combined with the downstream market connectivity of Kinder Morgan's Texas intrastate network, creates a valuable project for both producers and markets. [...] In addition to DCP's role as partner and shipper on the Gulf Coast Express pipeline, we are pleased with the tremendous level of interest in our project during this open season."

It is anticipated that natural gas supply will be sourced into the project from multiple locations, including existing receipt points along KMI's Texas pipeline and El Paso pipeline in the Permian Basin, a proposed interconnection with the Trans-Pecos pipeline, and additional interconnections to both intrastate and interstate pipeline systems in the Waha area. WP



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CHALLENGE CONVENTION

Europe is a major energy consumer, requiring vast oil and gas imports. Typically, this should result in extensive pipeline activities. However, Europe's current economy has branded this unrealistic for the remaining decade. **Dr. Hooman Peimani** reflects on the region's economic climate and summarises its ongoing pipeline projects.

Europe is no longer the world's largest energy consumer, as its annual consumption secures its rank as the third, after the Asia-Pacific region and North America. Yet, it is a major energy consumer in need of extensive imports, in particular, for oil and gas. This is a factor that should result in considerable pipeline activities. However, apart from many small pipeline construction and repair projects, there has only been a small number of major projects in 2016 and early 2017, mainly geared to gas imports from Eurasia, as the European fossil energy reserves are inadequate and depleting rapidly.

Despite various sources of tension between the European Union (EU) and Russia, along with the well-known EU policy of decreasing the regional grouping's dependency on Russia for a significant portion of its annual oil and gas demand, the continuity of Nord Stream 2 with the support of the EU 'heavy weights' suggests the unrealistic nature of this policy. This is due to the absence of alternative long term oil and gas suppliers to Russia, caused mainly by Brussels' foreign policy. This policy excludes Iran as a supplier for strategic considerations, notwithstanding it having the world's largest conventional gas reserves (34 trillion m^3) and third largest conventional oil deposits (157.8 bbls), as reported by BP in 2016.

The other EU supplier (Azerbaijan), whose exports to the EU will increase once the under-construction Trans Adriatic pipeline (TAP) is operational in 2020, cannot substitute Russia because of its small gas reserves (1.1 trillion m^3) and limited production capacity (18.2 billion m^3/y). Comparably, Russia holds 32.3 trillion m^3 of gas reserves and a production capacity of 573.3 billion m^3. The ongoing development of its Shah Deniz 2 gas project will only add around 16 billion m^3/y to its export capacity at that time.

Demographic factors, namely low/negative birth rates (depending on countries) and ageing populations, have put a 'natural' cap on Europe's energy consumption. Decreasing economic activities owing to the continent's loss of its industrial and economic preeminence to Asia (now the world's largest economy) and North America, has been translated into a lowering demand for energy. The recession of the late last decade continued into the first half of the current decade and contributed to Europe's lowering energy demand as well. However, the ongoing recovery rate is too small to result in a significant surge in energy consumption.

It is too early to assess the impact of Brexit on the continent's economic health to make any prediction on its effect on the European energy consumption, although it is highly unlikely to change Europe's lowering energy demand. In absence of any firm evidence, the continental economic growth in the foreseeable future cannot be sustainably high enough to compensate for years of negative and low growth rates, with the effect of shrinking the European GDP as a whole. This is evident in the European Commission's (EC) winter projections of 1.8% for the EU region in 2017 and 2018.

Various uncertainties about the individual EU countries' economic performance raise doubt about achieving such growth rate in the projected period. Needless to say, a major boost in European pipeline activities is not realistic for the remaining decade should the current economic climate continue, as reflected in the following summary of the major European pipeline projects.

Nord Stream 2

The Nord Stream 2 pipeline project has been advancing since it surfaced on 4 September 2015 as a project to double the existing Nord Stream gas pipeline system's capacity by 2019. Towards that end, Austria's OMV, Germany's E.ON and BASF/Wintershall, France's ENGIE and Royal Dutch Shell signed an agreement with Gazprom to construct a new pipeline system within the framework of a joint venture (JV); the New European Pipeline AG. Gazprom's share is 51% while others have a share of 10% each, excluding ENGIE (9%).

Mirroring the existing Nord Stream, Nord Stream 2 will supply Germany with 55 billion m^3/y of Russian gas via twin offshore pipelines (each 27.5 billion m^3/y; 1200 km) buried under the Baltic Sea's seabed.

Apart from its obvious importance as a large pipeline project and its role of consolidating Russia's energy supplying role to the EU, the project's significance is reflected in its continuity with the participation of the heavy weight EU countries (Germany, France and the UK) despite Brussels' opposition, which reveals the trio prioritising their national interests over those of the EU. Brussels and Washington's (USA) strong opposition to Nord Stream 2 for strategic reasons, comes as a result of their ties with Moscow being on a downward track. This is due to a range of issues, including Ukraine and Syria. Additionally, the clearly stated opposition of 10 EU countries (Estonia, Latvia, Lithuania, Poland, the Czech Republic, Greece, Hungary, Bulgaria, Romania and Slovakia) in November 2015 has failed to stop it, at least up to this date.

Gazprom's 18 May 2016 announcement demonstrated the company's confidence in the pipeline's commissioning before late 2019, which was backed by major reported developments by Nord Stream 2 AG. They include the start of pipe delivery for laying on 22 September 2016 by OMK, one of the project's three pipe suppliers. The pipes were subsequently transported by rail from its mill in Vyksa (Russia) to the coating plant in Kotka (Finland), where almost half of the required pipes will be coated. These pipes are set to be produced by Russian suppliers OMK and Chelpipe. Chelpipe started its pipe delivery on 23 September 2016. The remaining required pipes will be produced by Germany's EUROPIPE GmbH and will be coated in Mukran (Germany), whose delivery of its first supplies for coatings started on 27 October 2016.

The pipeline project further progressed on 9 December 2016, as Nord Stream 2 AG and Allseas signed a Letter of Intent. The signing declared that Allseas was to undertake offshore pipelay works for the first line, while providing the option for the company to lay the second line. However, on 22 February 2017, Nord Stream 2 AG finalised the agreement with Allseas by awarding it a contract for laying both offshore pipelines through the Baltic Sea, to be undertaken in 2018 and 2019, a development described by Henning Kothe, Chief Project Officer of Nord Stream 2 AG, as "another key milestone for Nord Stream 2."

Eugal

The German transmission system operator, Gascade – a JV of BASF and Gazprom – is planning to construct a pipeline system for the distribution of Nord Stream 2 gas. As explained in its February 2017 statement, only about 4 billion m^3/y of the gas (55 billion m^3/y) would pass through the existing North European gas pipeline, which carries Nord Stream gas. For the remaining gas (about 51 billion m^3/y), Gascade has planned to construct a 485 km twin pipe transmission system; the Eugal. The line is set to carry gas from Germany's

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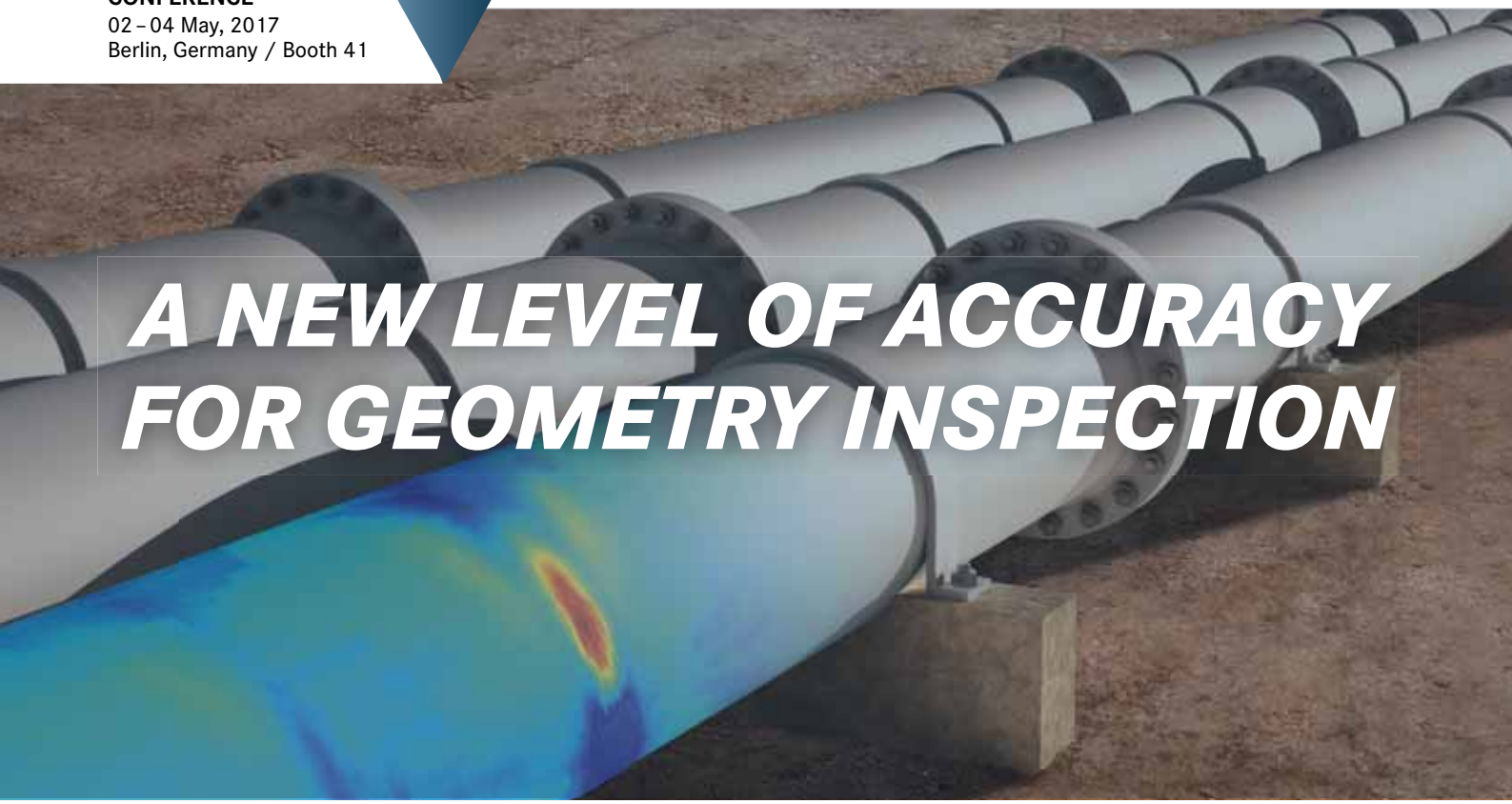

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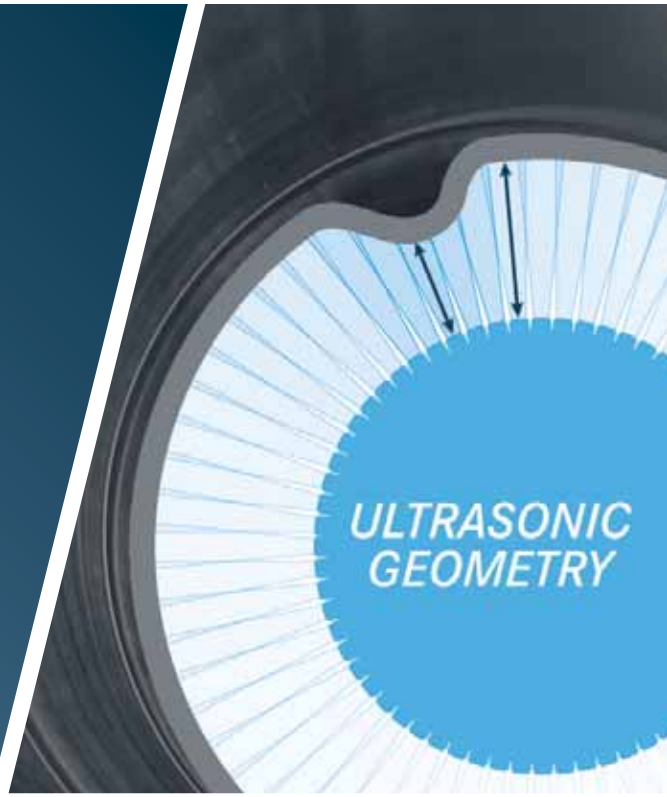

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Greifswald on the Baltic Sea where the Nord Stream 2 ends, through Mecklenburg-Vorpommern and Brandenburg to southern Saxony, before crossing the German-Czech border from where gas would pass through the existing transmission system across the Czech and Slovak Republics to the Baumgarten hub in eastern Austria. Much of the latter's capacity is expected to be free for such transmission thanks to Gazprom's declining gas exports via Ukraine. The Eugal is still in its early stages according to Gascade, which hopes for Nord Stream 2 gas to start flowing via its first pipeline in late 2019. Provided securing the required approval by 2018, its first line will be built from around mid 2018 to the end of 2019, while its second line will be built in subsections, from mid 2018 to the end of 2020.

TAP

TAP's construction for transferring Azerbaijan's Shah Deniz 2 gas to Europe has continued uninterrupted since it began on 19 May 2016. Selected by the Shah Deniz consortium on 28 June 2013 as the pipeline for such purpose over its rival Nabucco, the 878 km pipeline has since enjoyed Brussels' blessing, which designated it as an EU Project of Common Interest. Once completed, TAP will help the EU meet its gas requirements, diversify its gas suppliers and decrease its reliance on Russian gas for its growing gas imports, thanks to its depleting gas reserves. Provided the availability of supply and demand, its initial annual capacity of 10 billion m^3 could be increased to 20 billion m^3 by adding two extra compressor stations. Also, the pipeline's 'physical reverse flow' feature will allow gas from Italy to be diverted to southeast Europe should the need arise.

The construction of TAP's feeder – the 1850 km, 16 billion m^3/y Trans Anatolian pipeline (TANAP) – is well underway to feed the pipeline with 10 billion m^3/y of Shah Deniz 2 gas, leaving the remaining gas (6 billion m^3) for Turkey's consumption.

TAP's onshore and offshore segments will cross northern Greece, Albania and the Adriatic Sea, to come ashore in southern Italy. With the length of approximately 773 km, its 48 in. onshore section starts near Greece's Kipoi on the Greek-Turkish border, where it will connect with TANAP. TAP will continue onshore, crossing northern Greece, before continuing onwards east to west through Albania to the Adriatic coast. The length of its Greece, Albania and Italy segments are 550 km, 215 km and 8 km, respectively.

On 4 March 2016, contracts were awarded for the engineering, procurement and construction (EPC) of its Greek and Albanian segments, divided into five lots (three lots in Greece and two lots in Albania). Of these, contracts for two lots in northern Greece (approximately 360 km) were awarded to a JV comprised of Italy's Bonatti S.p.A and Greece's J&P AVAX S.A, to connect Kavala and Ieropigi (Albanian border).

France's SPIECAPAG was awarded the EPC contract for a lot in Greece (185 km) connecting Kipoi and Kavala, and for two lots in Albania (215km) linking Bilisht to Topoje. This company will also construct the pipeline river crossing at the Greek-Turkish border where TAP and TANAP will be connected.

Beginning near Fier (Albania), TAP's offshore section (105 km; 36 in.) will cross the Adriatic Sea and connect with Italy's gas transportation network in the Puglia region. The deepest point of the pipeline below sea level will be 820 m in the Adriatic Sea's strait of Ontranto. Saipem S.p.A was awarded the contract for this section's engineering, procurement, construction and installation on 14 April 2016.

Honeywell SRL of Italy was selected on 16 December 2016 for the engineering, procurement and installation of TAP's supervisory control and data acquisition telecommunications and security systems.

Kick starting the project, the construction of TAP's Greek section began on 19 May 2016 near Kipoi, while that of the Albanian section started on 30 September 2016 close to Fier. The date for constructing its Italian section is not yet certain given the local opposition to the removal of old olive trees from its path in Italy's Puglia region, in addition to TAP meeting other conditions such as "measures to preserve the natural environment and wildlife habitats – on land and at sea," as reported by Reuters in March 2017.

TAP is the undertaking of BP (20%), SOCAR (20%), Snam S.p.A. (20%), Fluxys (19%), Enagás (16%) and Axpo (5%). The pipeline is scheduled to be operational in 2020 and, according to TAP's Albania Country Manager, Shkelqim Bozgo, in March 2017, the pipeline's cost is was estimated to be approximately €4.5 billion.

Balticconnector

As a proposed gas pipeline between Estonia and Finland, the Balticconnector (7.2 million m^3/d) will connect the gas grids of these countries and link the Finnish gas grid to the EU supply network through Estonia.

Having received the EC's priority status to receive financial assistance, the project to connect Paldiski (Estonia) and Ingå (Finland) became a JV of Estonia's Elering AS and Finland's Baltic Connector Oy, for which an agreement was signed between the EC and the two companies on 22 December 2015. This was meant to increase energy security in the Baltic Sea region.

The project's feasibility study was completed in 2007 and followed by an offshore front end engineering and design in 2015 when its offshore environmental impact report was approved, leading to its seabed surveys set to be completed in 2017. Provided its construction starts in 2018 as planned, the pipeline (150 km; 500 mm dia.), consisting of a Finnish onshore section (22 km), an offshore section on the Gulf of Finland's seabed (81 km) and an Estonian onshore section (47 km), will be operational in 2020. To allow for its full capacity utilisation, the Estonia-Latvia gas connection will be modified. Promoted by Elering AS, the project will upgrade the interconnection gas pipeline between the two countries by installing a compressor station and a new metering station in Estonia.

Estonia and Finland will equally divide the Balticconnector's construction cost, estimated at €250 million (US$282.95 million), of which 75% will be funded by the EC as per its 15 July 2016 announcement. The EC will also fund 50% of the associated Estonia-Latvia gas connection modification project.

Elizabeth Nicholson, Matthew Bechberger and Patrick Yaremko, Cathodic Technology Ltd, Canada, review the process of developing a new cathodic protection survey instrument from concept to market.

Notes from a Napkin in Shanghai

As any equipment manufacturer will recognise, a demand or need for something is the first essential ingredient of any new product. After a successful NACE conference in 2011, staff from Cathodic Technology Ltd (Cath-Tech) were talking with its distributor from Beijing, SANO Technologies (Sano). Conversing in a hotel lobby, Sano highlighted the need for an easy to use cathodic protection (CP) data logger for performing routine test station surveys that could eliminate the need for handwritten field notes, provide the pipeline operator with more accurate and detailed data, as well as document when and where the readings were taken for regulatory compliance concerns.

During the discussion, notes were hastily made on napkins and other papers as the concept of what would be the CorrReader was thought out. A clear understanding of the customers' data requirements, cost considerations and existing technologies available was given initial consideration. Being in the oil and gas pipeline integrity instrumentation business for over 40 years, developing a specialised automated handheld CP instrument was fitting for Cath-Tech.

Requirements

Across the world, oil and gas pipelines must log critical CP data on a regular basis as part of their pipeline integrity management programme. Logging includes complex surveys such as close interval potential surveys (CIPS), direct current voltage gradient surveys (DCVG) and inline inspection, as well as regular monitoring of rectifiers, bonds and test stations. Test station surveys are still being performed globally with a regular digital voltmeter (DVM), such as a Fluke and a handwritten notebook.

To improve this, the new instrument needed to be a purpose built, handheld, outdoor device for performing regular test station surveys. It would be easy to use so that personnel with little to no training (for example, local landowners, students or interns) can acquire high quality data. Concurrently, the instrument needed to protect previously inputted data to prevent an untrained user from disrupting the records. Low cost is also required to get the equipment into the hands of many surveyors simultaneously. By allowing many technicians to have an instrument of their own, travel costs for dedicated survey workers and shipping costs for equipment are reduced.

Handwritten readings and notes can easily introduce human errors when recording data and later transcribing to a computer file. Integrated electronic logging satisfies regulatory compliance requirements and ensures that precise location and time data are captured. Electronic files are much easier to transmit, copy to multiple recipients, store and backup securely. Using commercially available MicroSD cards, the technician can simply swap the cards if a local computer for downloading the information is not available. The new instrument is programmed, charged and downloaded through a standard USB interface.

The CorrReader CP instrument has been designed to perform interrupted or polarised surveys. Interrupting the source of CP on a structure allows the surveyor to measure the polarised potential. Without interruption, the surveyor reads both the pipeline potential and errors from any other potentials in the ground. If the survey is performed with a normal DVM, readings are often

inaccurate due to imprecise timing. During an interrupted survey, there can be leftover capacitance or inductance due to the length of pipe and the nature of the coating on it. This causes spikes in the pipe-to-soil potential that are included in the reading on a DVM. Modern CIPS instruments improve accuracy by using the GPS system to delay the reading to a moment when the potential has stabilised, thus, recording an accurate pipe-to-soil potential.

Another emerging factor in the management of oil and gas pipeline integrity is monitoring of alternating current (AC) interference. It has been proven that induced AC on structures can cause corrosion and failures. Cath-Tech's instrument was designed to measure AC and direct current (DC) for each reading. Since the instrument is synchronised with the interruption cycle, it records separate 'off' and 'on' readings. Survey systems, such as CIPS, are unable to measure AC accurately as the long trailing wire will pick up AC current through induction and distort any readings. By developing a purpose built and easy to use instrument, these issues were addressed.

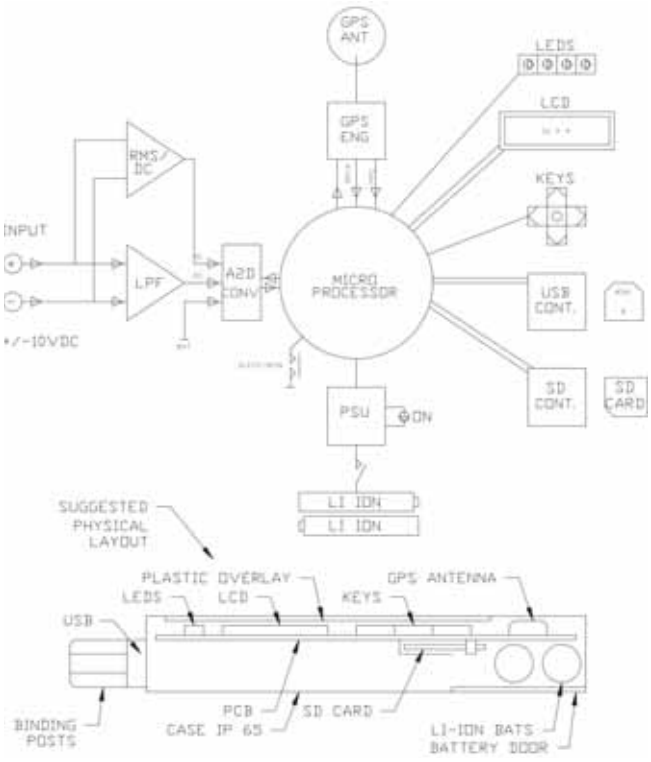


Figure 1. CorrReader block diagram schematic.

Figure 2. A field trial in Canada.

Development

The development team reviewed the requirements of NACE SP0207, section four and researched other CP survey instruments to investigate what features are necessary to obtain accurate readings. The circuitry was designed with a 10 mΩ input impedance and a -80 dB AC filter to ensure that DC readings are accurate with no imposed AC. It also uses an internal GPS module to synchronise with current interrupters and obtain the true off and on potentials. User configured measurement delays also ensure that accurate readings are obtained by waiting for any inductive or capacitive spikes to clear prior to measurement. Finally, the ability to enter comments at the time of measurement makes it easy to identify and organise data during an analysis.

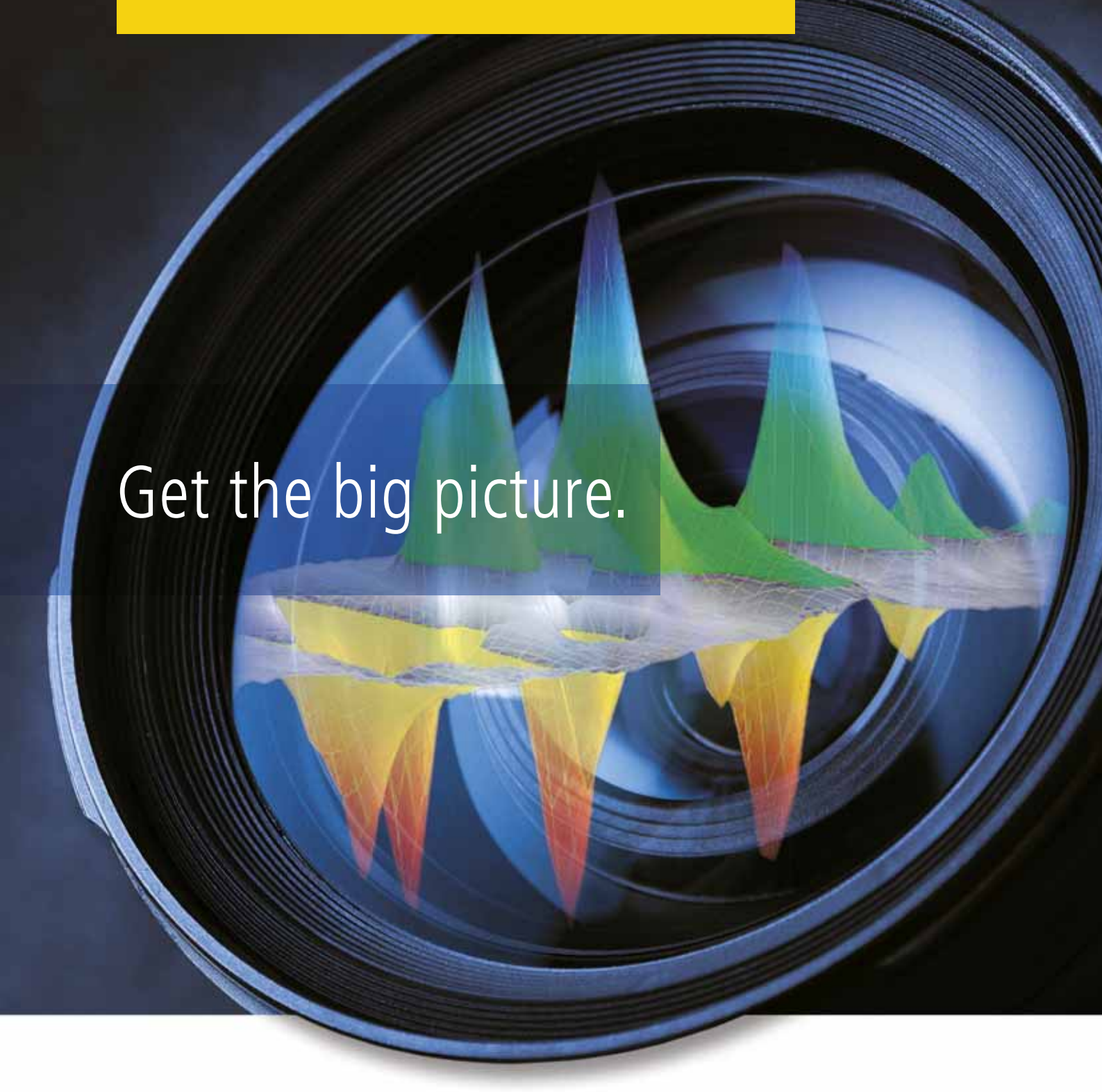
The CorrReader is configured using a parameter file when it is connected to a computer via USB. The settings available are:

- Cycle time: 1 sec. minimum and 6 min. maximum.
- Off time: adjustable in 10 msec. increments.
- Starting level: can be configured for the cycle to have the on or the off first.
- On/off measurement delays: separate configurable delays for the on and off reading times.
- Local time offset: the UTC time offset can be entered to correct the GPS time to match local time.
- Number of readings: can be configured to record a 'batch' of 1 - 20 readings across multiple cycles to capture useful data.

The CorrReader has integrated error-checking to ensure that the user has configured the cycle on/off times and delay times correctly. When the user presses the 'Power' button, the unit starts up, checks the settings, obtains the GPS signal and begins to display voltage values without needing any additional action from the user. The user can then view the values in real time on the screen and press 'Enter' if and when they want to record the reading. After the reading is recorded to memory, the user has the option of entering any comments (location ID) using the arrow keys and on-screen keyboard.

When in the field, the instrument records the following data:

- DC off and on (±10 V, 0.1 mV precision).
- AC off and on (100 V, 0.1 V precision).
- Local time and date.
- GPS co-ordinates, number of satellites, position dilution of precision and altitude.
- User-entered comments, such as test point name or location ID.



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The data is stored in a plain text .csv file, making it easy to import into any oil and gas pipeline information management database and is Pipeline Open Data Standard compatible. No special software is required to compare the data from the CorrReader with previous surveys. The file header also contains information on the settings that were used to obtain the readings, such as cycle time and measurement delay. Therfore, the operator can ensure consistent data collection over time. The instrument was also designed to accept firmware updates, permitting upgrades to units that are already in the field.

Testing

The CorrReader went through numerous tests both in a laboratory and in the field prior to its commercial launch. Throughout its development, the team worked closely with its production and field teams to confirm that the instrument was reading and recording accurately and to design for ease of production. The laboratory testing included AC rejection, filter settling time, battery consumption and GPS lock time.

There were two main opportunities for field testing. One was local with Cath-Tech staff, the other in China with Sano Technologies.

Cath-Tech staff went to a local ski resort during the off season and used CP to protect underground water and air pipes. This was an isolated system that was free of external influences, with easy access to rectifiers and no hazardous product involved. Staff interrupted four rectifiers with a cycle of 200 msec. off, 800 msec. on for a total cycle time of 1 sec. They then walked along the pipelines and took readings at snow machine hydrants. The instrument obtained an effective GPS lock and recorded valid on and off readings.

Figure 3. A field trial in China.

Figure 4. A graph comparing the CorrReader with a stationary data logger during a field trial in China.

Once Cath-Tech's development staff were satisfied with the operation and accuracy of the instrument, units were sent to Sano in China for evaluation and testing. The testing yielded some successful data and highlighted further work to be done. Issues with certain cycle times were exposed and these required software modification. The source of the problem turned out to be a software bug that would synchronise with the pulse per second from the GPS properly, but would not correctly locate the 'top of the minute' to match the cycle patterns with the interrupters. This was easily resolved in the software once the correct diagnosis has been made.

A watertight external USB port was added as a response to feedback and an option was added in the software to allow the technician configuring the instrument to override the measurement delay with their preferred value. If there is no delay value input, then the instrument calculates a value based on the off and on cycle times.

A sample of the data taken from the tests in China, which compared the CorrReader with a GPS-synchronised stationary data logger, is shown in Figure 4.

In order to keep the cost low, the development team also considered production challenges. Wherever possible, standardised off-the-shelf components were used, as this saves both time and cost. The electronics were designed to fit on one side of a printed circuit board and plug directly into the LCD screen. Minimising the separate subassemblies, as well as reducing custom components and wiring have made the assembly production more streamlined and efficient. Attention was also paid to the lifespan of the components chosen with a planned production life of seven years.

The CorrReader was submitted to an independent laboratory and tested for dust and water ingress. It successfully passed IP6X and IPX5 testing giving it a rating of IP65. It was also subjected to a 1 m drop test, which was also passed.

Conclusions

Since its release on the market, many companies have successfully utilised the CorrReader in their daily pipeline monitoring activities. The combination of accurately timed readings, electronic data recording and GPS location are ideal features for this. The integration of GPS and configurable delay times ensure that the reading is taken in synchronisation with the interrupters and without any distortion from induction spikes. It is important to obtain accurate instant off potentials, which can then be directly compared to data taken in a similar manner during a close interval survey.

If an oil and gas pipeline operator or government oversight auditor questions the validity of the data, the surveyor can use it to prove that they were present at that site, and validate that company protocols were followed. With no need to handwrite or transcribe data into a database, a major source of human error is eliminated.

COATING SOLUTIONS FOR MICROTUNNELLING

Pascal Collet and Wim Kardux, RKT International B.V, the Netherlands, outline a method of protecting coated steel pipes during special pipeline construction works.

The design, construction and operation of oil and gas pipelines are decided by a wide network of figures in order to comply with the law. For instance, the Energy Industry Act from the International Energy Agency contributes to the technical security of energy facilities and to the construction of an integrated, efficient and competitive market. Regulations for sectors such as high pressure gas pipelines, along with technical rules (including codes of practice and national/international standards), are standardised through this network of industry professionals. All of the above elements serve as a legal basis and framework for pipelines construction and operation.

Integrity of the pipe coating

Managing the integrity of coated pipes during their production and construction requires key processes. The pipes must be monitored and controlled during each stage of the process, from application of the coating, through to storage, hauling, handling and transportation. Moreover, if the pipe is being constructed through open trench work, additional steps are required, such as laying and lowering-in the trench and backfilling.

Special civil works and associated coating design

In uncommon and challenging conditions and environments, pipelines that cross traffic routes and railways, large rivers/canals, nature reserves and landscape protection areas have additional technical rules and instructions. These must be respected in order to maintain the integrity of coated steel pipes. Alongside total or temporary blocking allowing for an open trench, trenchless crossing solutions have been developed, including impact ramming and thrust boring; horizontal directional drilling (HDD); microtunnelling; and direct pipe techniques.

Of course, these different techniques influence the design of the external pipe coating differently. Where stress is severe, the coating must be thicker. For instance, when considering a different thickness of the external coating or its structure, HDD and direct pipe techniques can be applied.

The design also applies to the field joint coating where specific coating systems are implemented, such as PUPP lining®, in order to comply with the specific mechanical stress that can affect the external coatings during operations.

When microtunnelling, external pipe coatings must be protected from abrasion and possible mechanical damage due to the inner layer of the cement casing.

Microtunnelling operations

Today, external casing insulators that are used to protect external pipe coatings can be installed into the microtunnel. These are standardised products that are designed and manufactured to be mechanically fixed onto coated pipes. Generally speaking, they are moulded by injection from high density polyethylene (HDPE) materials that are chosen due to their minimal coefficient of friction.

To fasten the insulators firmly onto the carrier pipe, steel straps are used to prevent slippage or looseness and to stop them from sliding along the pipe. Occasionally, rubber plates are attached to the inner wall of the insulator in order to enhance the coating's protection.

As far as installation is concerned, the generally agreed procedure is to space these casing insulators 2.5 - 5 m apart, with one casing insulator installed at either end of the pipe. The standard size of the spacers is 100 - 150 mm in width. They have relatively standardised heights, varying from 35 - 55 mm.

In specific cases where the linear weight of the steel pipes is high (approximately 700 kg/m), mechanical HDPE based casing insulators cannot be chosen as the compression strength is too high. For such circumstances, insulators on sleds and wheels may be an option. This highlights the technical limits of HDPE casing insulators in extreme conditions.

Even in less severe conditions, coated pipe damages were reported when using such casing spacers. External pipe coatings were harmed, which led to spot repairs and replacement of some pipe sections. The damages were caused by several different factors, including insulator sliding, unlocking of the bolts and blowout of the insulator. As a result, some gas operators have decided to ban the use of such spacers for pipe diameters of over 30 in.

The abovementioned situation highlights the technical limitations of using HDPE casing insulators based on relative standard solutions. The above is particularly the case with large pipe diameters.

Thinking differently

An approach was developed to address this issue and to introduce new solutions to both pipeline contractors and associated industry professionals, such as microtunnel contractors. The approach taken was to develop a fine-tuned performing solution that is adapted to each of the following objectives with cost control:

- A versatile solution.
- Optimised performance.
- Guarantee during operations.

With regards to providing a versatile solution, it was decided that rather than a standard product, it would be best to sell

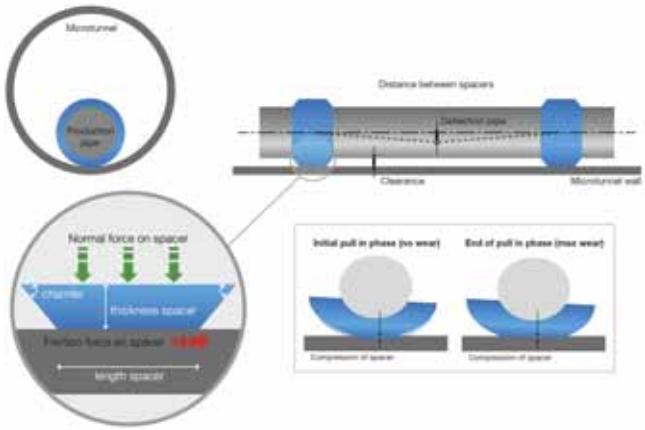

Figure 1. Forces applied on the spacers.

Figure 2. Performance of the spacer after harsh test conditions.

Figure 3. Installation of the pipeline into the casing.

fine-tuned solutions that are tailored to the environment that was submitted by the client. This led to the development of a products and services package, which was supported by a strong design engineer and innovative computer modelling.

To develop a solution with optimised performance, it was important to take the environment (such as the casing design), the microtunnel length, the friction coefficient and the characteristics of the pipeline (pipe diameter and wall thickness) into account.

As an example, in one instance, casing conditions were set in the EN1594 norm, relative to the operational prescriptions for gas pipelines with a pressure of over 16 bar. The insulators had to be spaced and calculated based on a water-filled pipe. From these external parameters and additional potential client requirements (such as safety factors), a methodic approach was implemented in order to identify all of the potential stresses that the spacers would have to support during the pipe's installation into the casing.

Therefore, material selection began by taking different requirements into account. These requirements included adhesion on the pipe coating, mechanical properties (tensile and compression strengths, shear resistance, hardness) and abrasion resistance. A material application process made the spacer void-free, in order to guarantee its performance.

The materials were tested extensively, both in a laboratory and at a pilot scale to assess behaviour. Figure 2 illustrates the adhesion of the spacer and the material resistance after pulling a three layer PE (3LPE) coated pipe on an uneven cement surface for few hundred metres, applying a normal force corresponding to a pipe linear weight of 2000 kg/m with a 48 in. steel pipe section.

Using the microtunnelling conditions, the characteristics of the steel pipe and the properties of the spacer material, a software to model the stresses applied and to anticipate the behaviour of the spacer for designing the spacers themselves, was developed. The different identified stresses were calculated by modelling, thus determining the size of the spacers for a given situation.

Real test results were compared against a satisfactory correlation. The results gave confidence in the approach and they allowed experts to predict and recommend the most suitable and adapted spacers for a given configuration.

Fine-tuned spacers

The process of developing a product with an associated design tool was presented to pipeline contractors who could be supported by this unique software. Pipeline contractors take part in the process of designing the spacer by sharing the microtunnelling conditions and pipe characteristics. Of course, safety in terms of the wear of the spacer is an input. In turn, the PUPP spacer has been created.

Using the design specifications, spacers are designed and sized in terms of width and thickness, along with the distance between two spacers. The dimension of the spacers is determined individually for each project. This flexible approach allows the size of the spacers to be optimised for greater performance, with cost control and without oversizing the spacers.

Furthermore, these spacers are manufactured offline. The approach is driven by a close relationship with pipeline contractors, who have a large input in the production of the spacers onsite.

Case study

These spacers were selected by some of the pipeline contractors working on the 300 km Arc de Dierrey gas transmission pipeline (France), operated by GRTgaz. The microtunnelling technique was selected for important crossings, such as at the Oise River and at a heavy traffic highway between Paris and northern France. The pipeline had a wall thickness of 17 mm.

The spacers were designed by modelling. For this project, unique spacers with of 800 mm in width and 40 mm in thickness were designed. It was decided that the distance between each spacer should be 6 m. According to these specifications, every spacer was produced offline, with high productivity on the construction site of the pipeline contractor.

The spacer equipped pipes were available onsite and were ready for microtunnelling operations. The feedback provided by the pipeline contractor after the installation into the casing was positive thanks to the efficiency of the spacer for protecting the 3LPE coated pipe. The wear observed after pulling the pipe confirmed the wear that was calculated by the model.

By combining material science and civil work constraints, this approach addressed those specifically involved in microtunnelling operations by providing a customised and optimised case by case solution. The solution is versatile and adaptable to a wide range of pipe diameters and microtunnel lengths. Additionally, the economical factors are not compromised when using this offline process with a high throughput.

Remedies

TO MAINTAIN PIPELINE INTEGRITY

Pipeline coating failures can jeopardise pipeline integrity, resulting in leaks and, in some cases, ruptures caused by metal loss and stress corrosion cracking. **Jim Banach, Specialty Polymer Coatings, Inc., Canada,** discusses how to ensure pipeline integrity with high performance coatings.

In many countries, hydrocarbons are transported by way of buried pipelines. In North America, crude oil and some of its refined products are shipped mainly by pipelines and, as of late, increasingly by rail. This switch to rail transportation has been, in part, a result of opposition to the construction of new pipelines that transport hydrocarbons. Unfortunately, there have been many incidents of train derailments where tanker cars carrying hydrocarbons have caused environmental damage. Additionally, in 2013, a train derailment in Lac-Mégantic (Canada), resulted in the deaths of 47 people. The 74 tank cars that derailed were carrying crude oil.

Opponents, both environmental and political, cite the many incidents of pipeline leaks or ruptures that have resulted in catastrophic environmental damage to lakes and rivers, as well as being a potential danger to the people living near a pipeline right-of-way. One of the main causes of pipeline failure is corrosion, and corrosion is preventable.

A combination of cathodic protection (CP) and coatings are used to prevent external corrosion on buried and submerged pipelines. Coatings are the primary source of protection for a pipeline and are supplemented by the use of CP. Coating failure exacerbates any attempt to maintain pipeline integrity. Adding additional CP to compensate for coating failure is difficult at best, and may not be effective in preventing corrosion.

Coatings for pipeline corrosion protection

Pipelines that have been built over the last 30 years are generally coated with fusion bonded epoxy (FBE), three layer polyethylene (3LPE), three layer polypropylene (3LPP), liquid epoxy and urethane, extruded polyethylene (PE)

and cold applied tapes. The coatings that were used in the 1960s - 1980s included coal tar enamels, asphalt enamels, cold applied tapes, wax and mastics.

Only general reference will be made to specific coating types when discussing coating attributes and why coatings fail in this article. Moreover, coating attributes and limitations will be stated throughout. They are given as a general guideline for coating selection for new pipelines, and also to consider what may be happening to an existing coating.

Coatings are mandated for newly constructed pipelines the energy industry. Many of the aforementioned coating systems would not be approved for new construction based on past performance.

Whether stipulated or not, in construction permits, pipeline coatings should possess the following properties:

- Electrically isolate the external surfaces of the pipeline from its environment.
- Have sufficient adhesion to resist under film migration of electrolytes.
- Be sufficiently ductile to resist cracking.
- Resist damage due to normal handling and soil stress.
- Be compatible with CP.
- Resist deterioration due to the environment and service temperature.

Why coatings fail

Werner[1] defines coating failure as follows: "A buried pipeline coating has exceeded its useful life when adequate CP can no longer be economically maintained." All coatings will deteriorate with time, some more than others. The rate and amount of deterioration depends upon the coating, pipeline operating temperature and environment. Generally, coatings fail as a result of poor surface preparation, wrong choice and/or improper application.

Surface preparation

Most of today's high performance coatings require a near-white blast cleaned surface with a sharp peak to valley profile of at least 1.5 mm. Additionally, prior to blast cleaning, the pipe surface should be free of soluble salts, principally chlorides and sulfates. If present, these salts would need to be removed prior to application.

Table 1. Maximum pipeline operating temperature for coating systems

Coating system	Temperature range
Coal tar and asphalt enamels	45°C
PE tapes	30°C
3LPE	80 - 100°C
3LPP	90 - 120°C
FBE	80 - 110°C
Liquid epoxy	80 - 150°C
Liquid urethane	50 - 65°C

Epoxy coatings (liquid and FBE) are the coating of choice for most large diameter (greater than 304 mm) pipeline systems. These epoxies are used as the primary coating system or in combination with PE or polypropylene. Epoxies can absorb moisture. When a semipermeable membrane separates a solution of different concentrations, the water permeates from the concentrated solution to the dilute solution. This is known as osmosis. The application of CP will facilitate osmosis, resulting in a process called electro-osmosis. The presence of dissolved salts on a pipe surface may result in an osmotic pressure build up and disbond the coating (usually observed as blisters). These areas of disbonded coating require increased CP current.

Any coating would benefit from a properly prepared surface, even those that call for a power wire brushed surface, as was the practice for asphalt, coal tar enamels, mastics and tapes.

Poor surface preparation results in reduced adhesion of the coating to the pipe surface. Loss of adhesion can occur from forces applied during construction, while in operation and from chemical interaction.

Wrong choice of coating

Pipeline operating temperature

When selecting a pipeline coating, the system's operating temperature must be taken into consideration and must account for excursions above the initial design. A pipeline's maximum operating temperature must be considered during the selection of a coating. Table 1 provides some general guidelines for coatings based on pipeline operating temperatures.

Soil stress

Mechanical forces in clay soils can cause coating damage to tapes, mastics, coal tar and asphalt enamels through abrasion as a result of pipe movement. Even with a blast-cleaned surface, these coatings do not exhibit sufficient adhesion to resist soil stress and soil loading.

Epoxies, three layer systems and extruded PE are not affected by soil stress or soil loading.

Piping installed by horizontal directional drilling (HDD) should be coated with an abrasion resistant coating, such as an epoxy or urethane to prevent damage during installation. Coal tar and asphalt enamels, tapes and mastics are not abrasion resistant coatings and would undergo extensive damage if used for HDD.

Improper application

Inspect, inspect, inspect. This cannot be stressed enough. Inspection of the coating should be done at all stages of the coating process by qualified personnel. If a pipeline coating fails in service, the integrity of the pipeline will be compromised.

Coating influence on pipeline integrity

CP

In the oil and gas industry, CP is a requirement for corrosion protection in order to maintain the integrity of a buried or submerged pipeline. CP is an electrochemical technique in which a flux of electrons is sent into a metal. This increases the negative charge at the metal surface and, in the case of a pipeline,

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retains the Fe^{++} cations in the metal, thus, preventing oxidation and corrosion. In practical terms, a current is sent through an electrolyte from the anode to the cathode (pipeline).

Coatings are the primary source of corrosion protection for a pipeline. CP provides corrosion protection at coating holidays. Generally, pipeline systems are protected using impressed current CP (ICCP) from remote ground beds (buried anodes) that are powered by a rectifier.

For an effective coating system, CP is relatively inexpensive. The length of pipeline that can be protected from a remote ICCP varies with the efficiency of the coating, diameter of the pipeline, and somewhat less with the soil resistivity.

The CP system changes the potential of the buried pipe's surface by providing sufficient current density to the coating holidays. The required current density is determined when the pipeline potential reaches -0.85 V vs a saturated copper-copper sulfate electrode. The effective reach of one remote system is determined by the following attenuation equation:

$$E_x = E_0 e^{(-\alpha x)}$$

Where:

- E_x = the pipeline potential in volts at a distance 'x' along the pipeline from the remote ground bed.
- E_0 = the pipeline potential in volts at the location of the ICCP.
- x = the distance along the pipeline (graph shows both directions from centre point).
- α = the attenuation constant and is equal to $\sqrt{R_s/R_L}$.
- R_S = longitudinal resistance per unit length of the pipeline.
- R_L = pipeline leakage resistance.

Figure 1 illustrates an attenuation curve for pipeline potential against distance along a pipeline from a remote ICCP.

As the pipeline leakage resistance decreases, caused by coating deterioration, the distance that can be protected from a remote ICCP also decreases. For example, a 914 mm dia. pipeline with a coating efficiency of 99.99% (0.01% bare) would require a remote ICCP every 50 km. In this case, 'x' would equal 25 km. The longitudinal resistance of the pipeline would be the limiting factor for distance reached from a remote ICCP, provided the coating has the efficiency as stated heretofore.

A coating with a bare area of 3 - 10% would require more closely spaced ICCP systems. Where the coating is deemed to be more than 30% bare, a continuous ICCP system would be required. The examples given assume a soil resistivity in the range of 1000 - 20 000 Ωcm. No actual distances have been calculated for each example, as the purpose of the discussion is to show that CP cannot be relied upon to provide adequate corrosion protection for a pipeline when its coating undergoes substantial deterioration. Additional CP is not just a matter of pumping more current out of a remote ground bed to compensate for increased current demand as the coating deteriorates.

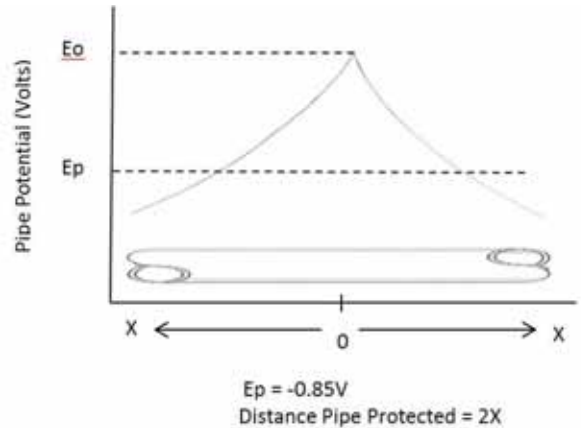

Figure 1. Distance of pipe protected using ICCP remote system.

Cathodic disbonding

For an impressed current CP system, current flowing to the pipeline produces a reduction reaction of water, according to the following:

$$H_2O \rightarrow H^+ + OH^-$$

The hydrogen ion (H^+) is discharged at the cathode (pipe surface) to form a polarisation film of nascent hydrogen.

$$H^+ + e^- \rightarrow H$$

Hydroxyl groups (OH^-) that form at the pipe surface at coating holidays create an alkaline environment and are the primary cause of cathodic disbondment. An example of cathodic disbondment on a FBE coated pipeline is shown in Figure 2.

According to Neal[2], sufficient research has been done to show that disbonding at coating holidays on all pipeline coatings are due to alkaline conditions caused by CP, and it is one of the primary changes observed in buried pipeline coatings. Cathodic disbonding tests, although severe, will show which coatings are most affected by CP. Generally, epoxy and epoxy-primed coating systems show the best resistance of any coating system to cathodic disbonding.

A study by Papavinasam and Revie[3] ranked coating failure modes in polymeric pipeline coatings (epoxies). They concluded that electrochemical changes in polymeric coatings (one such change is water absorption) may be considered a coating failure

Figure 2. Cathodic disbonding of FBE.

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and not all changes affect the ability of a coating to protect the pipeline. The coating protects the pipeline and, when it fails, the CP system acts as a backup. Only after both mechanisms fail would the pipeline become susceptible to corrosion.

Additionally, Neal concluded that FBE coatings will absorb moisture, are transparent to CP current and are an oxygen barrier. These combined properties allow the formation of a protective magnetite layer. The outcome is a stable current demand and an economical CP system.

Stress corrosion cracking

Stress corrosion cracking (SCC) in pipelines, known as environmentally assisted cracking, can cause catastrophic failure of a pipeline. Two SCC types have been identified; near neutral pH SCC and high pH SCC (classical).

Neutral pH SCC occurs in alternate wet-dry soils and soils that disbond or damage coatings. Insufficient CP is one contributor with the potential range for this type of SCC between -760 mV to -790 mV ($Cu/CuSO_4$).

High pH SCC occurs typically within 20 km downstream of a compressor station or pump station. The potential range for this type of SCC is between -600 mV to -750 mV ($Cu/CuSO_4$).

In 1995, the National Energy Board of Canada[4] (NEB) held an inquiry into SCC on Canadian oil and gas pipelines. In its report filed in 1996, the NEB stated that most of the SCC-related failures occurred on pipelines coated with PE tape. The report stated that some PE tapes are prone to disbonding because of tenting created by the tape, which occurs between the pipe surface on spiral welds and long seams welds. Also, disbondment occurs where the tape is overlapped between successive wraps of tape, or where soil stress has caused the coating to move or wrinkle (Figure 3).

Due to the high electrical insulating property of PE and the relatively long path under the disbonded tape, sufficient CP current cannot reach the pipe to prevent corrosion. This is called shielding. When shielding does occur it can result in pitting corrosion. Of greater concern, as a result of shielding, is extensive general corrosion or the formation of an environment susceptible to SCC. These two scenarios could lead to catastrophic failure of the pipeline.

Classical SCC failures have been reported in Canada and in many countries on pipelines coated with tape, asphalt and coal tar. Importantly, no SCC has been found on any pipeline coated with FBE or liquid epoxy. FBE has been used on pipelines since the 1970s, and liquid epoxy since the 1980s.

Figure 3. Tape coating with tenting at 9 o'clock position.

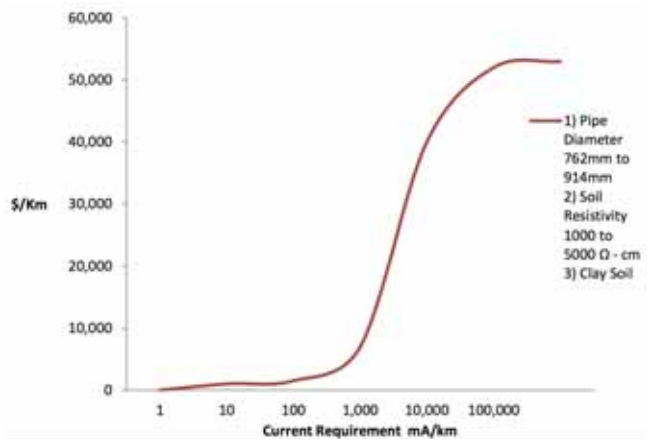

Figure 4. CP costs as a function of coating performance.

Maintaining pipeline integrity

Both CP and coatings are required to maintain pipeline integrity. Many of the older 'low adhesion' coatings deteriorate over time to the point of total ineffectiveness. Industry experience has shown that this has happened with mastics, asphalt enamels, tapes and, to an extent, coal tar enamels.

Figure 4 illustrates how costs for CP can accelerate as coating deteriorates.[5] Current requirements per kilometre have been calculated for a pipeline with a 714 - 914 mm dia. and a current density of 10 mA/m^2. Initially, current requirements are low. At 30% coating deterioration, the curve ascends almost vertically. Where it flattens again, the pipeline is essentially bare. With more than 30% coating failure, an ICCP system may not provide adequate current distribution, as seen from the attenuation curve. A distributed ICCP system may be required at a substantial cost increase over a remote system, and would require anodes located adjacent to the pipeline and parallel to it. The length of pipeline that an ICCP remote system would protect in the example given is approximately 10 - 150 m. As the coating fails, additional power would be required as well as more anodes, feeder cables and current control systems. Cost can escalate an order or magnitude (or greater to change) from a remote ICCP system to a distributed one.

Figure 5. Pipeline coating rehabilitation.

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An additional cost associated with coating failure and the use of distributed ICCP is monitoring. For an efficient coating system, pipe potentials measured at aboveground test stations would give a good indication of the level of corrosion protection. Such is not the case for a pipeline protected with a distributed ICCP. Here, a continuous over-the-line potential survey would be required at a cost greater than an order of magnitude over a test lead survey.

In the presence of shielding, over-the-line potential surveys are suspect in their ability to accurately assess the status of corrosion protection of a pipeline. Other costlier methods, such as pigging, hydrostatic testing or discrete excavations, would be needed.

Regardless of the integrity assessment method used, remedial programmes will be required if corrosion is found.

Remedial options are generally limited to additional CP, recoating, pipe replacement or a combination of the aforementioned choices. The cost of pipe replacement is known. As a comparison, the cost of recoating is about 50 - 80% of the cost of pipe replacement, depending upon the severity of corrosion found and the amount of pipe replacement associated with it. Coating rehabilitation of a transmission pipeline is shown in Figure 5.

In the case of a disbonded coating causing shielding, additional CP would not be an effective option. Thus, the only alternatives are rehabilitation by recoating, pigging or pipe replacement. If SCC is suspected, a planned integrity programme checking for crack colonies at selected bell hole excavations, pigging and hydrostatic testing may be required.

Conclusion

Pipelines are an intrinsically safe method of transporting hydrocarbons. However, the integrity of a pipeline must be sacrosanct. An effective pipeline coating is essential to maintain the integrity of a buried or submerged pipeline. CP is used as a supplemental system to prevent corrosion of a pipeline at coating defects. Where a coating undergoes substantial deterioration, CP becomes onerous to apply and maintain and, in some cases, may not be effective.

Remedial measures to maintain pipeline integrity when the coating fails include additional CP, recoating and pipe replacement. All of these measures can be expensive. If SCC is detected, remedial measures include pigging, bell hole excavations at discrete locations to examine the pipe surface for SCC, periodic hydrostatic testing and pipe replacement. Costs could exceed replacement costs of the suspect pipe.

An effective coating system reduces maintenance costs and eliminates expensive remedial measures.

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Improving ROA with MODERN TECHNOLOGY

Page Tucker, Peter Forster and Carl Lashua (ProStar, USA), discuss improving return on assets with enterprise geospatial intelligence software for the midstream oil and gas industry.

Today, many asset-centric industries, including the oil and gas midstream sector, are facing uncertainty in the current tumultuous global market. To be more competitive and, in some cases, to survive, they must adopt new methods in order to reduce costs and improve operational efficiencies. The primary focus is to improve overall return on assets (ROA) by employing more modern technologies. Midstream companies have traditionally relied heavily on multiple legacy systems of record to manage their assets and remain regulatory compliant, including enterprise resource planning (ERP), computer-aided design (CAD) and geographic information system (GIS). The challenge is that these systems are often fragmented and disparate, creating operational inefficiencies and data silos that are incapable of sharing information. Midstream operators need to consider the adoption of cloud and mobile technologies that are inherently designed

Figure 1. Use of icons to depict events assists in depicting precise locations.

Figure 2. Selecting the icon on the map opens a view/edit dialogue for the user.

and proven to improve all phases of the asset lifecycle, including planning, construction, operations and maintenance, compliance and public safety.

Major industries throughout the world are now leveraging cloud and mobile technologies to create business value throughout their enterprise, and this trend is only going to increase. Companies like Microsoft, Amazon, IBM and Google are betting heavily on being able to support and capitalise on this migration to cloud and mobile technologies.

For midstream oil and gas companies, the challenge to successfully adopt modern technologies will be in change management, including current business culture, integration with legacy operational systems and business processes.

An asset-centric solution

To address these challenges, ProStar Geocorp – a US-based company – has developed Transparent Earth®, a native cloud and mobile solution designed specifically for asset-centric companies. Transparent Earth is a Geospatial Intelligence Software as a Service (GaaS®) that seamlessly connects with on-premise systems of record, mobile devices and the Internet of Things (IoT) to create an interoperable, connected and holistic enterprise system. Transparent Earth provides geospatial intelligence, robust reporting and analytics, and machine learning, where the system is capable of predicting and detecting changes or events that impact business operations.

Adopting cloud and mobile innovations, such as Transparent Earth, will help midstream companies become more competitive by empowering them to work more efficiently and productively with real time access to critical asset data and connectivity throughout the enterprise. Whether planning, designing or monitoring assets from the office, or installing, inspecting or managing the integrity of assets in the field, cloud and mobile applications in combination with geospatial intelligence and real time visualisation provides insight into what, when and how work must be performed. This results in better resource utilisation during the entire asset lifecycle. Now, 3D visualisation, predictive analytics and geospatial intelligence can be realised to ensure the right information gets into the hands of the right users, in the right format and at the right time. This, in turn, will make for better information, better decisions and better outcomes.

"Innovation through the cloud, mobile and IoT is occurring everywhere and at warp speed, including in the energy industry," said Vishnu Arunachalam, Chief Technology Officer at Attunix. "We have seen this first-hand in many industries, and the rate of commoditisation creates real challenges along with real opportunities. We are pleased to combine our expertise and services with ProStar's technology to quickly integrate and deliver effective solutions to the energy industry with the greatest impact."

Oil and gas company case studies

Transparent Earth improves all phases of the asset lifecycle for oil and gas companies through asset data aggregation and the delivery of more precise and readily available information. This is achieved by integrating modern technologies with the company's disparate legacy operational systems using the ProStar hybrid cloud platform, creating data standardisation across various departments. This enables the sharing and visualisation of critical information, which provides personnel with easy access to qualified asset data, including precise and pedigreed geospatial locations and associated metadata. Now, for the first time, office and field workers can leverage the power of predictive analysis as well as the direct monitoring of assets, processes and events through geospatial intelligence and machine-to-machine communication.

Large midstream company

Recently, SemGroup Corporation, a US-based company that specialises in crude oil gathering, transportation, storage and marketing, recognised significant business value using ProStar's Transparent Earth. The system could be used to digitally document and record the complete end-to-end workflow process of a construction project, including tallying the pipe, stringing, bending, welding and inspecting the pipeline. The PointMan mobile app allowed field staff to work efficiently on complex issues onsite, leading to early alerts and efficient front line corrective action. The project data collected during pipeline construction was readily available to the operations and maintenance department. Since a single view of the data is used for construction, operation and maintenance, and

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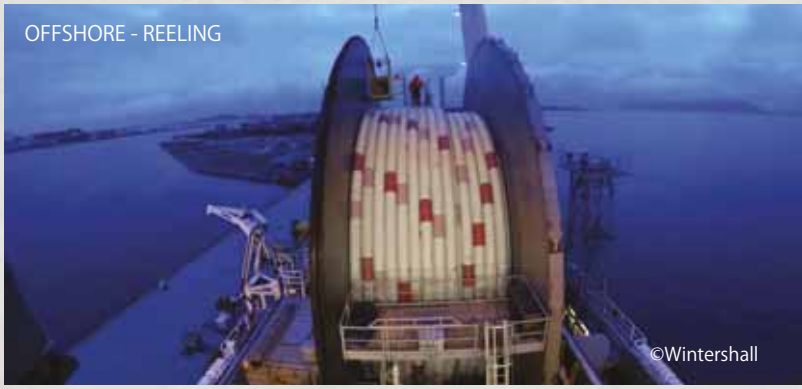

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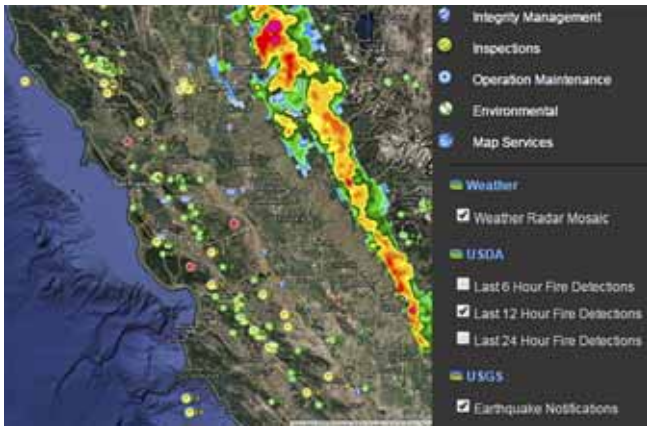


Figure 3. Streaming earthquake notifications, weather and fire hazard information.

Figure 4. Tablets are ruggedised for field use in extreme conditions.

as the location data is captured with precision and pedigree, confidence in the data is extremely high.

"Using ProStar's Solution for new construction we were able to commission the project in just a few days after completion opposed to several months," says Cheryl Janicek, GIS/Engineering/Pipeline Integrity, SemGroup.

The SemGroup implementation of Transparent Earth was completed in a relatively short period of time, required very little capital on the part of the company, delivered immediate return on investment and provided an interoperable enterprise platform to achieve long term benefits. The cloud subscription model minimises business and IT investment, operational risks and leverages ongoing product enhancements and innovations through ever-greening.

Large transmission company

ProStar is currently working with one of the world's largest pipeline transmission companies, deploying Transparent Earth to improve its asset management lifecycle and business practices. The ProStar solution provides geospatial intelligence and real time visualisation of linear asset data from multiple source systems seamlessly and securely, to both field and office personnel where and when it is most needed.

Transparent Earth provides the ability to share internal asset systems data, as well as IoT data from systems such as NOAA and the USGS across the enterprise, using OGC® open web feature service (WFS) and web map service (WMS) standards. This provides the ability to trigger geospatially intelligent event-driven workflows and notifications. The cloud software deployment enabled easier connectivity and conflation of data from multiple data sources. This includes data from ERP, GIS and CAD systems, such as environmental, earthquake, weather and landowner information so that this can be displayed on a laptop, desktop or mobile device.

The PointMan mobile app, developed using Microsoft Xamarin for Visual Studio, allows field personnel to capture the asset's precise geospatial location, bind any transaction record and submit the data back to the enterprise through the cloud. This improves the availability, timeliness and quality of asset data. PointMan captures asset data in accordance with both the ASCE 38-02 and CSA S250-11 mapping standards. By using Pipeline Open Data Standards and other open data standards, PointMan provides the ability to capture and share precise and pedigreed data that can be trusted to meet industry standards in order to make informed business decisions with confidence.

Other modules deployed on Transparent Earth that leverage geospatial context and improve ROA include patrols, stakeholder contact and land acquisition.

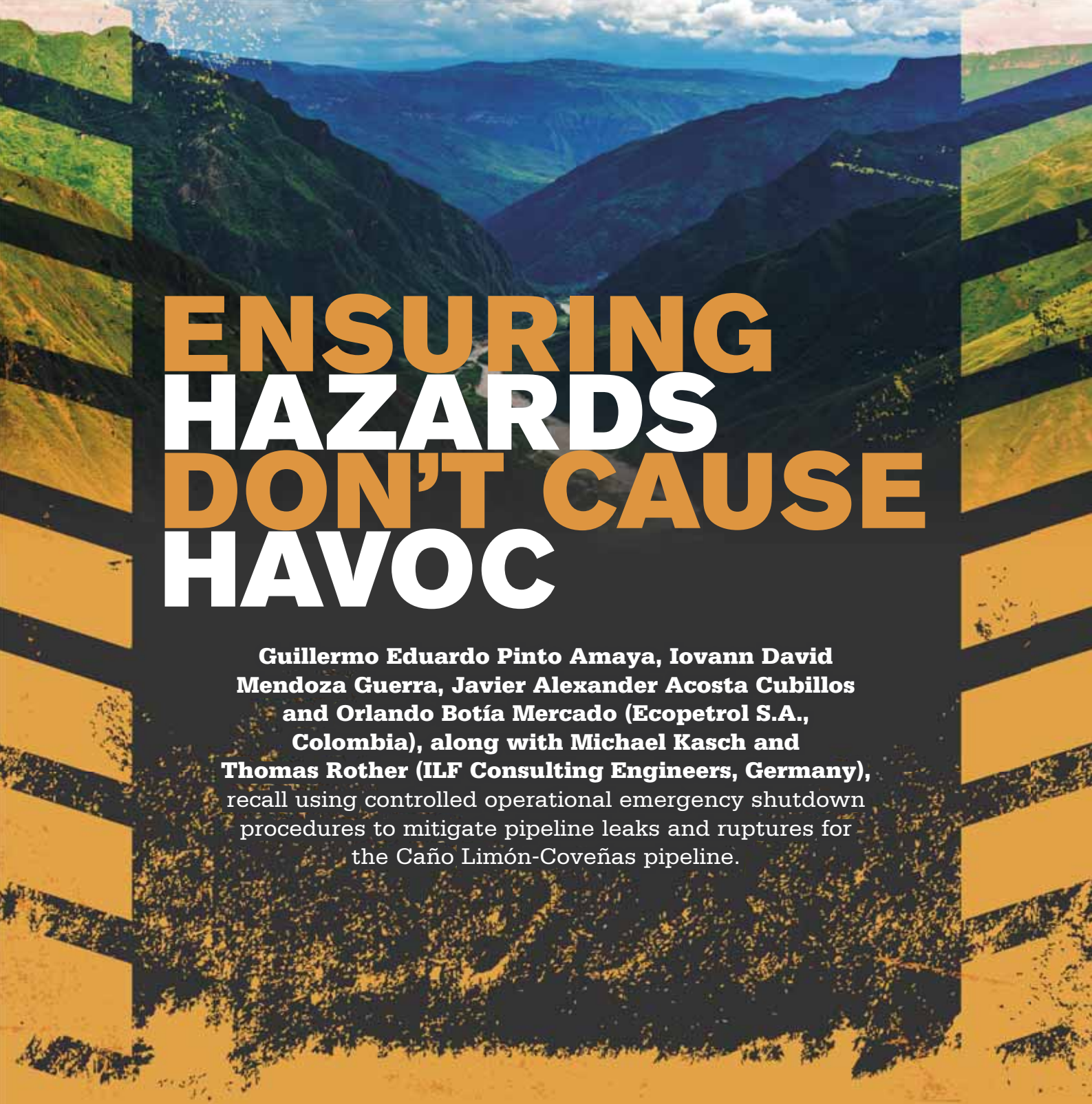
"We are excited to support Xamarin Premier Partner Attunix in their work with ProStar. The decision to leverage Microsoft's Azure and Xamarin Technology for Transparent Earth and PointMan, shows their commitment to developing best in class mobile cloud energy solutions," stated Greg Urquhart, Senior Director, Xamarin Partners and Alliances.

Conclusion

"We focused on system interoperability, data aggregation and data provenance to improve the entire asset management lifecycle," explained Carl Lashua, ProStar's Chief Operating Officer. Using Transparent Earth, the company's GaaS office workers and field personnel can now easily access, display, qualify and share asset-centric data to identify and rectify any discrepancies.

ProStar's solution is designed as a hybrid cloud running on Microsoft Azure, and leverages web services and open data standards to enable information integration and process integration across multiple systems. This approach eliminates data silos, creates a fully integrated enterprise system and makes access to critical information easier, faster and more precise. The hybrid cloud also enables seamless connectivity and conflation of data from other off-premise systems, including public domains and the IoT. This means that company enterprise data from customer relationship management, ERP, GIS and CAD, and external data sources (such as environmental, weather, geological and landowners) can be displayed and visualised in a single system and single conflated map view. For any asset-centric company that is trying to become more efficient, streamlined and regulatory compliant, this approach offers the solution.

ProStar is currently exploring other markets, including the public sector, where cloud computing, enterprise mobility and geospatial intelligence drive forward-thinking, citizen-centric programmes. "Our GaaS architecture allows us to easily expand into other verticals, as other market sectors that are asset-centric explore and embrace cloud solutions," stated Page Tucker, ProStar's CEO and President.



ENSURING HAZARDS DON'T CAUSE HAVOC

Guillermo Eduardo Pinto Amaya, Iovann David Mendoza Guerra, Javier Alexander Acosta Cubillos and Orlando Botía Mercado (Ecopetrol S.A., Colombia), along with Michael Kasch and Thomas Rother (ILF Consulting Engineers, Germany), recall using controlled operational emergency shutdown procedures to mitigate pipeline leaks and ruptures for the Caño Limón-Coveñas pipeline.

Ecopetrol S.A. (Ecopetrol) operates a complex pipeline network across Colombia. The company aims to protect people and the environment from potential hazards. Based on the results of oil spill quantity calculations, Ecopetrol had defined high consequence areas (HCAs) and effective measures to mitigate potential emergencies for its Caño Limón-Coveñas pipeline. ILF Consulting Engineers (ILF) was requested to reassess a 93 km pipeline section between Toledo and Oripaya in order to develop controlled operational emergency shutdown (COESD) procedures and numerically verify these utilising a hydraulic pipeline model.

As this article outlines, Ecopetrol worked alongside ILF on a joint project, performing a 'segmentation study' for the section under evaluation.

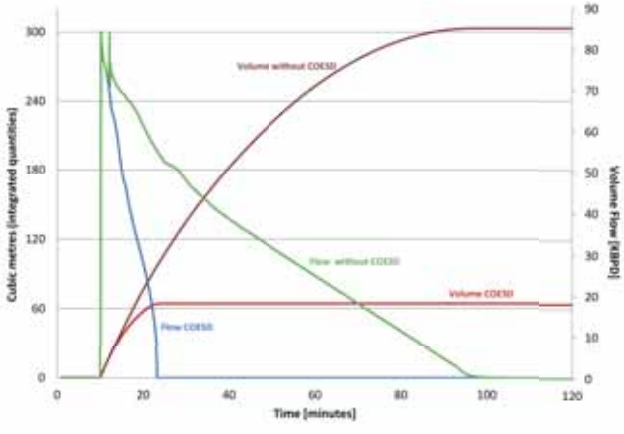


Figure 1. An example of the spill volumes on a downhill section of pipeline with a 2 in. leak hole.

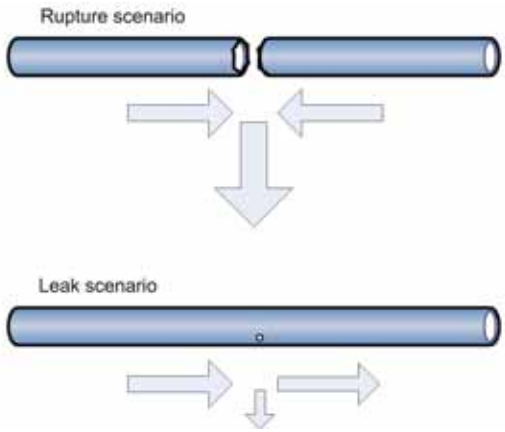


Figure 2. A comparison of rupture vs leak scenario immediately after an incident.

Background

Starting near the city of Arauca, the Columbian Caño Limón-Coveñas pipeline runs close to the country's border with Venezuela, through Norte de Santander Department, before it turns off to the west near the city of Tibú. It then continues to the Coveñas terminal station on the Caribbean coast. The pipeline transports crude oil across a total length of approximately 771 km.

Ecopetrol's pipelines and facilities (such as valves and pumps) are remotely controlled from regional control centres by certified personnel. All of the control centres along the Caño Limón-Coveñas pipeline are connected to assigned pipeline stations through a reliable telecommunication system.

In previous years, Ecopetrol has suffered ruptures and oil theft (due to illegal tapping) on its pipelines. Quite often, these attacks have caused large leaks or ruptures and, in the worst case, full bore ruptures have been caused. Full bore ruptures lead to substantial oil spills, with some of them contaminating the water supply of nearby towns and cities and causing the pipeline to shutdown. Fast detection of such leaks or ruptures and immediate execution of optimised emergency response measures are indispensable preconditions for keeping the total oil spill quantities to a minimum. After such an incident, pipeline operation can only be resumed after having the pipeline repaired, which is often a several day challenge.

The segmentation study undertaken by Ecopetrol and ILF was between the pipeline's Toledo pumping station to its Oripaya pipeline station. This section of the pipeline runs as an 18 in. underground line through mainly mountainous areas. It crosses two major mountain peaks; one being around 2800 m high and the other approximately 1700 m high. Segmentation valves are installed along the pipeline in such a way that the potential oil spill quantities can be substantially limited by co-ordinated shutdown of pumping stations and isolation of the leak.

Due to the pronounced topography of the Caño Limón-Coveñas route in the Norte de Santander region, optimal emergency response measures vary from location to location. The investigated section between Toledo and Oripaya are divided into 15 subsections for individual emergency response, each with their own COESD procedures. These subsections are determined by the location of existing segmentation valves and by pronounced topographical features. As soon as the pipeline operator has detected and confirmed a leak or rupture and its location, the optimal emergency response for that situation and pipeline section is initiated and executed.

The segmentation study

Ecopetrol and ILF's segmentation study was executed between December 2015 and March 2016. The task included an initial 'as-built' review and evaluation report. Hydraulic calculations were performed to confirm the potential oil spill volume profile in the addressed section. The 'as-built' report was completed by site visits to different types of pipeline stations. The next major task was to develop and calibrate a hydraulic model (DNV GL SPS; formerly known as STONER® pipeline simulator) for the entire Caño Limón-Coveñas pipeline. The ultimate aim of the segmentation study was to elaborate, optimise, define and verify emergency response measures for the specific local conditions along the pipeline section.

The initial review of 'as-built' documentation included the pipeline itself and its stations, the redundant telecommunication network, as well as the local and remote control facilities (based on a supervisory control and data acquisition system). A key focus of this was the current placement and maintenance status of segmentation valves as their reliability is essential for when responding to emergency situations, such as leak isolation.

HCAs are pipeline sections where a potential oil spill would either release large volumes or where a leak of any size would have a severe impact on the population and environment.

As stated previously, using DNV GL SPS, a hydraulic model was developed for the Caño Limón-Coveñas pipeline for further internal use by Ecopetrol. The model was calibrated against real process snapshots. A calibrated hydraulic model can be used for various engineering tasks, 'what-if' analyses, forecast calculations, operator training and, as it has been used in the segmentation study, to verify the effectiveness of

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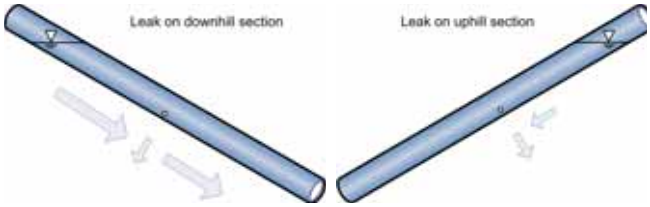

Figure 3. Typical leak scenarios on downhill and uphill sections when applying COESD procedures.

Table 1. An example of COESD procedures for one of the pipeline sections

Step number	Response action
1	Initiate shutdown of all upstream pumping stations (Caño Limón, Banadia and Samoré) immediately.
2	Shut down the Toledo pumping station immediately.
3	Close SVS2 (Iscalá Norte) immediately.
3R*	Close SVS2 and SVS3 (Puerto Colombia) immediately.
4	Inform the Orú pumping station about the shutdown.
4R*	Initiate the shutdown and blocking of the Orú pumping station immediately - skip steps 5 and 6.
5	Open the trend display for pressure reading at Puerto Colombia and open the hydraulic display. Monitor both displays. The Orú pumping station should be kept in operation until either the pipe at the leak location is empty (when pressure reading at Puerto Colombia shows constant average value) or when column separation occurs at Alto de Morretones.
6	If one of the conditions in step 5 is met, close SVS4 (El Caney) and SVS3 (Puerto Colombia) before initiating shutdown and blocking of pumping station Orú (to be executed at Orú).
7	Close the Oripaya main line block valve.

* Steps 3R and 4R are to be used instead of steps 3 and 4 if a rupture occurs.

emergency response actions by transient hydraulic simulation. Figure 1 is an example in which the total spill volume was reduced by approximately 80%, from around 300 m^3 (brown curve) down to approximately 60 m^3 (red curve) when following the defined COESD procedures. The blue and green curves show the leak volume flowrates in kilo barrels per day (1 kilo barrel per day = 6.625 m^3/hr) with and without applied COESD procedures.

As part of the segmentation study, individual COESD procedures were specified for all 15 subsections between Toledo and Oripaya. These were identified specifically with respect to emergency response to leaks and ruptures. Based on the findings of the 'as-built' review, recommendations for potential improvements and additional requirements for the implementation of the COESD procedures were highlighted.

COESD procedures

The primary idea behind the concept of COESD is to expedite the pressure reduction at the leak opening down to atmospheric pressure by co-ordinated measures both upstream and downstream of the leak. This, therefore, implies that it is not necessarily recommendable to shut down the entire pipeline and close all segmentation valves immediately after a leak has occurred.

Common to all leak and rupture incidents is the need to immediately shut down the pipeline upstream of the leak. This is done by shutting down pump stations and closing main line block valves (segmentation valves) to reduce and, finally, stop further flow towards the leak. All of the following response measures depend on the local conditions at the leak's location, such as topography and pressure, as well as whether it is a leak or a rupture.

While the most effective local response actions need to be investigated in detail, in general, it can be stated that:

- If a rupture occurs, the pipeline splits up into hydraulically independent parts upstream and downstream of the rupture. Since the pipeline cannot be operated any longer, the best emergency response in this case is to immediately shut down the pipeline upstream, which includes closure of the next available block valve upstream of the leak, and close the next available downstream block valve to prevent potential backflow from downstream. The leaking pipeline section is isolated.
- If a leak occurs on an uphill section, the pipeline should be shut down upstream. This involves closure of the next available block valve upstream of the leak, and closure of the next available downstream block valve to prevent backflow.
- If a leak occurs on a downhill or flat section, the next available block valve upstream of the leak should be shut down. Additionally, if possible, the pipeline should be kept running downstream to expedite pressure reduction at the leak location. This may be accomplished by keeping downstream pumping stations in operation until the leak runs dry or by draining the pipe into downstream tanks.

COESD procedures include these general response measures. However, the remaining specific response actions and mitigation measures have to be defined individually in relation to the pipeline system being addressed, as well as individually for each pipeline section. COESD procedures will also differ for leaks and ruptures. An example of this is given in Table 1.

The differentiation between a leak and a rupture is, on the one hand, related to the ratio of leak rate and normal operational flowrate in the pipeline. Typical definitions of ruptures mention 20% or more of normal throughput. On the other hand, in the case of a rupture, it is no longer possible to maintain substantial flow downstream of the rupture. More likely is backflow from downstream due to the initially pressurised pipeline. Figure 2 illustrates the two distinct situations. It is clearly visible from Figure 2 that, in a case of a rupture occurring, there is no longer any hydraulic coupling between the upstream and the downstream part of the pipeline. The emergency response measures on the

upstream and downstream sides are, therefore, independent of each other. When a rupture occurs, it is best to reduce and eventually stop further flow towards the leak from either side as fast as possible.

The situation is different for leaks. When a leak occurs, there is substantial flow downstream of the leak and the pipeline is still operable. Shutdown upstream of the leak and closure of upstream valves reduces and finally stops further flow towards the location of the leak. Depending on the average slope around the location of the leak, the COESD procedures differ. On a flat or mainly downhill section, draining of the pipeline can be expedited by maintaining the downstream flow until the leak runs dry. Figure 1 shows such a situation. On uphill sections, it depends on the specific details of the pipeline system (such as elevation profile and the available facilities) as to whether there is further potential to expedite draining of the line after shutdown upstream. ILF has developed individual COESD procedures with quite different solutions for various important pipeline systems.

Summary

Fast leak or rupture detection, along with a co-ordinated emergency response, will most effectively reduce total spill quantity. This requires sensitive and reliable leak and rupture detection systems. Moreover, it is essential to reliably detect and locate a leak as fast as possible, particularly for ruptures.

COESD procedures provide valuable support for the operating personnel. They specify the sequence and chronology of the mitigation measures that should be executed. It is important to have defined leak and rupture response procedures in place to be followed by operators in control centres and by maintenance personnel. Emergencies are uneasy situations so having effective COESD procedures means that operators and maintenance teams should be relieved from difficult decisions.

If a huge sudden leak or full bore rupture occurs, there is no potential for optimising the leak response procedures. The COESD procedure for such situations is to shut down the pipeline and close the next available upstream and downstream valves as fast as possible to isolate the leaking pipeline section.

The COESD concept is most effective for reduce the total spill volume on flat and downhill sections, on which pressure reduction can be expedited by maintaining the downstream flow until the leak runs dry. On uphill slope sections, how to best respond to leaks depends on several factors and on the upstream and downstream facilities that are available.

Acknowledgements

Tipiel S.A., the people of the Caño Limón O&M department, the people of the Toledo and Oripaya plants, and the people of Ecopetrol.

Sound the alarm

Håkan Hansson, Axis Communications, Sweden, explains how security guard callouts can be reduced by adding network audio to video surveillance.

Protecting and securing pipelines poses a number challenges. Be it illegal trespassing, vandalism, copper theft or even sabotage, security systems need to be able to not only alert to incidents, but also to enable operators to identify the type, scope and severity of an incident so that the proper action can be taken. Traditional security system components – such as microwave barriers, motion and trampling sensors – all require a second confirmation level in order to clearly identify an incident and to exclude the possibility of a false alarm. Pipeline perimeters are sometimes not easy to clearly define and to cordon off. This is especially true for pipelines in remote

locations. Wildlife and weather conditions can trigger false sensor alarms.

Remote video surveillance monitoring with audio talk down capabilities is proving to be a very effective and powerful combination for protecting remote and isolated pipelines. Consisting of extremely valuable assets that are remotely located and often difficult to secure, they continue to be targets for sabotage, attacks and organised threats. Pipelines require constant protection; alarm monitoring services and security guard companies increasingly substitute manned guards with video surveillance and centralised control centres, which monitor the feeds. Therefore, there is a growing need to be able to address and respond to incidents immediately from a remote location.

Network audio enables an effective way to intervene directly at the scene of an incident. When video surveillance cameras or perimeter detection devices identify a breach of the perimeter or people loitering, an alarm message is displayed in the control centre. This can either automatically trigger a pre-recorded audio message to be played back at the scene of the incident, or the operator can quickly assess the situation from video footage and live feeds before responding by speaking through a microphone. The operator can also talk directly to the perpetrators at the scene of the incident before deciding whether to dispatch a security team. This adds an important human element to the security solution even if there are no guards in the vicinity, and can potentially de-escalate a situation without placing personnel in danger.

Network audio enables proactive video surveillance

If operators are able to speak directly to those that triggered an alarm or show suspicious behaviour, this makes a great difference compared to only being able to record their actions on video. Network audio can be used to communicate warnings, orders or requests from a remote control centre location directly to people trespassing, loitering or otherwise needing to be addressed. For instance, if a person in a video surveillance camera's field of view demonstrates suspicious behaviour or is seen to be entering a restricted area, an operator in the remotely located control centre can send a verbal warning to the person. In a situation where a person has been injured, being able to remotely communicate with and notify the victim that help is on the way can greatly help with managing the incident.

Security services company, Securitas, is using network audio to make its video surveillance services more effective. The company is offering cloud-based remote video surveillance (security as a service). This approach reduces the cost compared to security guards patrolling customer premises. By adding network audio to video surveillance cameras, Securitas can offer its customers real time security services at competitive price points, as security guards are only sent out if and when needed. Besides the cost savings, network audio also enables the company to effectively address incidents by immediately communicating in a de-escalating and deterring manner.

"Horn speakers allow our operators to immediately intervene when video analytics alerts us of trespassing at customer sites," says Lars Kämpe, Business Development Manager at Securitas. The company equips virtually all of its outdoor perimeter protection installations with loudspeakers. "Normally, a trespasser will flee the scene when notified of his detection. This saves cost for our customers due to reduced damages and also no unnecessary callouts."

Easier to install than analogue speakers

Audio talk down is a function that is supported by most video management software solutions (VMS), either by allowing the operator to speak directly by pressing a button

Figure 1. An example of a security guard callout at a power plant.

Figure 2. An example of a security guard callout at telephone tower.

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in the video view or by automatically playing back pre-recorded audio messages on different previously defined triggers. This native VMS integration makes it easy to add audio talk down to a video surveillance system. Many network cameras come equipped with onboard audio capability. If there is external power available, an amplifier and analogue speaker can be connected to the audio output of the camera.

Adding network audio functionality to video surveillance systems is even easier as network horn speakers can be added. Network horn speakers provide a simple to install and complete paging solution in a single unit. With Power over Ethernet (PoE), the unit gets power and connection over a single network cable, just like a network camera does. This means you do not need an external power supply or any additional equipment.

In a network audio system, every horn speaker is individually addressable providing great flexibility and scalability. Integration with other systems is made very simple with IP-based technology. Network horn speakers can be integrated directly into the VMS or into a standard voice over internet protocol phone system using session initiation protocol.

Smart functionality with network audio

Network horn speakers allow operators to monitor the connection and status of each unit at all times. This is not possible with analogue speakers. Operators would not be sure an analogue speaker is operational at any given time or that its volume or sound quality are sufficient. Multiple locations can easily be integrated and managed centrally. For securing and protecting pipelines, it is all a matter of network. Network horn speakers feature a built-in microphone and onboard analytics allowing for automatic self-checks to ensure the sound quality is always optimal. The microphone can also be used to listen in on the scene or for automatic intelligent detection of aggression, gun shots, explosions or vandalism.

"Securitas has worked with analogue loudspeakers until now," says Kämpe. "With analogue loudspeakers, there is always an uncertainty since there is no way to remotely detect if they are actually working correctly. Network horn speakers allow us to remotely monitor the heartbeat of the speaker and check the sound quality. The speakers also support PoE, which makes them easier to install and lowers installation costs. It also gives us the possibility to use pre-recorded messages."

Network horn speakers are a simple yet extremely effective addition to video surveillance systems. They allow remote operators to directly address people and deter unwanted activity. Security guard callouts can be reduced and incidents are better managed by being able to communicate with those present at the scene from any location and at any given time.

Get it clean, keep it clean

Bob Long, U.S. Water, talks about eliminating under deposit corrosion and preventing downtime in pipelines.

Ensuring the integrity of pipeline assets not only protects systems from environmental catastrophes, but also maximises profitability and improves the final product. Millions of dollars are wasted each year on traditional internal corrosion programmes. Even with a preventative programme in place, pipelines may still suffer from corrosion. Ineffectively treating corrosion can result in unscheduled downtime, expensive waste disposal, increased operating costs and even safety and environmental concerns caused by pipeline rupture.

A new integrated approach to pipeline integrity management combines industry best practices to achieve and maintain a clean pipeline and, as a result, the best business outcomes.

Financial impact

Deposits, microbiological activity and corrosion are all inextricably linked in their effect on pipeline safety, asset integrity, reliability and transport efficiency. In addition to the fines and cleanup costs associated with these issues, a loss in asset integrity can have other direct economic consequences, such as unscheduled downtime, waste disposal, increased operating costs and pipeline rupture. In the end, it all translates to environmental stewardship, human safety and financial performance.

In 2000, a southern US operators' natural gas pipeline exploded in southeast New Mexico. In addition to the irreparable cost of 12 fatalities, the operator endured costs of almost US$1 million in property damage and US$15.5 million in civil penalty. According to a National Transportation Safety Board, the cause of the 50 year old pipeline explosion was severe internal corrosion and a reduction in pipe wall thickness.

Figure 1. A pipeline before cleaning.

Figure 2. A pipeline getting bare metal clean.

Introduced in 2015, the Pipeline and Hazardous Materials Safety Administration's (PHMSA) regulated Pipeline Modernisation and Consumer Protection Act requires gas pipeline facilities to follow best practice guidelines to identify and classify high risk pipeline infrastructure and leaks for repair or replacement. Inline inspections (ILI) are used by PHMSA to identify pipeline wall loss based on pitting corrosion rates. This data is then used to predict general wall pipe loss and develop any repair or replacement plans needed prior to leak or environmental disaster. Clean pipeline systems ensure accurate ILI data.

Identify the root cause

There are a variety of variables and events that impact a pipeline's internal corrosion situation. Identifying the root cause of the corrosion is the first step in remediation. Corrosion sites may be made up of many things, such as sulfate reducing bacteria, dissimilar metal from corrosion by-product or paraffin deposits. It can be the result of a collection of corrosion building on itself throughout the line, the introduction of other chemical treatments or water into the line, or can even be caused by ineffective operations. Sample testing throughout the line is a common practice to pinpoint the location of system corrosion and identify the exact corrosion mechanisms and by-products.

A best practice is to simulate the worst possible corrosion scenario in a pipeline. Discussions with pipeline owners and operators about their unique circumstances can help to identify unfavourable conditions. Using testing and monitoring in an environment that mimics the worst possible scenario for each pipeline asset allows for implementation of a programme that can virtually eliminate corrosion throughout the system and protect the entire pipeline.

Most internal corrosion failures are due to under deposit (iron sulfide) and microbiological corrosion, which typically forms along the bottom of the pipeline. The National Association of Corrosion Engineers (NACE) Standard, SP0106-2006 Item No. 21111, is to place corrosion coupons in a water drop at the bottom of the line for sampling. The water drops act as a collection site for solids and waste, and simulate low spots where sludge and water typically build up within a line. The fluids inside the water drop and the coupon itself can then be used for further testing. NACE recommends utilising the worst pit on the coupon to accurately measure its depth to calculate the pitting corrosion rate in mils per year.

Millipore™ slipstream testing is another form of testing used to determine solids in crude oil/natural gas/condensate flowrates and can be conducted at a variety of locations throughout the line to identify which pipeline or inlet is carrying the debris. The Millipore is weighted prior to the slipstream test and again after the test. The difference in weight is then used to estimate the level of debris present at that point of the line. Debris samples can also be sent to an

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analytical lab to conduct a deposit analysis and identify the debris' exact elemental breakdown. These tests help determine the root cause or source of the debris.

Once the content of the debris has been identified, a chemical programme to clean the system can be recommended. A soak test on collected deposits is conducted to select the most efficient cleaner, solvent or dispersant based on a pipeline's unique line and operation concerns. Follow up testing and monitoring is used to identify when the system is clean. Remediation of under deposit corrosion cleans the pits and allows the protection film to adhere to the bare metal pipe wall to protect the line.

Get it clean and keep it clean

The standard industry pipeline treatment method is to apply a corrosion inhibitor directly over the debris. Once the level of bacteria has reached 1000 col/ml or above, it is common to batch treat with biocide to kill bacteria in an effort to stop microbiologically induced corrosion. Often, a pigging treatment will follow the chemical programme in an effort to remove most of the build up inside the line.

Corrosion inhibitors work best when they are able to attach to bare metal clean pipelines and create a barrier film to protect against dissolved acid gases under deposit and corrosion sites. Equally, a biocide treatment is most effective when it is able to reach the sessile bacteria hiding underneath the protective deposit corrosion. If the chemical programme application does not address the sessile colonies, corrosion is still able to cause pitting damage to the pipeline. Dry pigging the pipeline without dissolving the debris removes the major build up but smears the debris into pits and around the pipe. Adding a filming corrosion inhibitor after dry pigging would be similar to waxing a car prior to washing it.

A paradigm shift in pipeline treatment programmes is spreading throughout the industry. This integrated approach combines a custom chemistry treatment with a mechanical pigging programme to get pipelines bare metal clean. Innovative chemistries combining filming amines with cleaners, scale inhibitors, oxygen scavengers etc. are inserted into the line to remove the debris from the pipe wall and pits. Once suspended in the system, a pig can be used to fluidise and move the debris to the end of the line. To ensure the system is bare metal clean, chemical batch treating and brush pigging is done in intervals until the pig comes out of the system clean (Figure 1 and 2).

Once the pipeline is bare metal clean, a combined approach of monitoring technology and automated chemical injection systems can be used to optimise the chemical and inhibitor programme to keep the system clean. Sampling and testing can again be utilised to determine the system's ideal chemical programme, ensuring operators are not over or under-treating the system while continuing to remove and prevent sessile bacteria attachment. This method prevents corrosion and corrosion by-product from depositing further down the line.

Installing corrosion coupons and using solids monitoring and Millipore testing are proactive options to continue to measure a programme's effectiveness throughout the line. Installing an atomiser, fast-stroking pumps and pulsation dampers into the pumping system are also recommended to establish a consistent chemical stream and treatment. Chemical pumps typically stroke in intervals of 5 - 30 sec. to feed chemical into a gas pipeline. This results in up to 30 sec. of untreated gas in-between strokes, but fast-stroking pumps are able to stroke every 2 - 3 sec. An atomiser will 'fog' gas into the system as a fine mist allowing it to easily blend with the product and move down the pipeline. Adding a pulsation damper will minimise inconsistent treatment if a fast stroking pump is not possible. Integrating these tools allows operators to make adjustments quickly to the inhibitor rates if needed to ensure a clean stream of process fluids and gas.

Investing in real time monitoring, i.e. corrosion monitoring, helps determine producer upsets and identify intermittent corrosion issues. A properly implemented monitoring programme will generate large amounts of data, manually or automatically via instrumentation or physical measurements. Data, or key performance indicators (KPIs), not utilised or visualised to show programme effects and process improvement opportunities are considered 'dark data'. All too often data it is collected and deposited in a logbook, never to be seen again. Transforming data into information and getting it into the hands of people who need it, when they need it, in the form that they need it, has arrived. These KPI data logs can then be used as an investigation tool to identify the specific event that caused a spike in corrosion rates, or digitally processed and translated to alarms and trends that can be visualised and acted upon before they create a serious problem.

Heat guns and infrared cameras (heat and IR imaging) are other great investigation tools used to read the vessel/tank levels and solids content. Fluid levels and sludge can be identified before, during and after cleaning projects. This allows for treatment without downtime for vessel entry and improves operations and crew safety.

In addition to optimising chemical programmes and implementing monitoring technology, maintenance

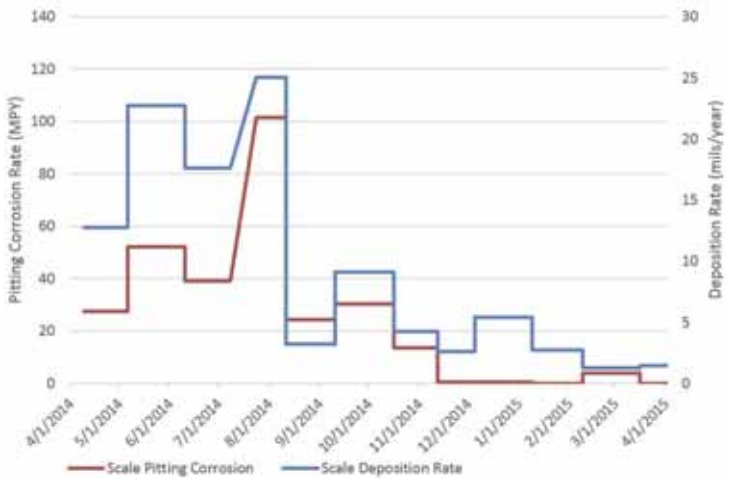

Figure 3. Deposition vs pitting corrosion.

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pigging should also be conducted frequently. It is beneficial to work with a pigging company and operators in order to determine process and frequency, such as the type of pig to use, when to replace a pig or when to transition to a more aggressive pigging programme. A customised chemical and pigging programme is like having the right cleaning solution with the right mop, sponge or brush. These techniques work synergistically together, providing better results than pigging or chemical treatments alone.

Proven results

In 2012, a crude oil pipeline operator's ILI predicted a line repair would be needed in 2016 due to the rate of pipe wall loss caused by under deposit corrosion. The line began utilising the integrated approach outlined in this paper, combining testing, monitoring and pipeline chemistry. In 2016, the verification inspection dig revealed no additional anomaly wall loss over the past four years. The programme stopped the corrosion build up and an internal inspection verified the pits at the bottom of the pipe were bare metal clean.

In 2014, a 36 in. sour crude line in a high consequence area was experiencing under deposit corrosion and severe pitting. Use of this integrated approach, cleaned up the line and lowered deposition rate, resulting in the elimination of under deposit corrosion (Figure 3).

An additional benefit to this approach includes reduced energy costs. Clean lines reduce drag and, therefore, reduce the energy required to move crude or gas. After another operator began using the integrated 'get it clean, keep it clean' approach, their results showed a 50% reduction in kilowatt hours per barrel energy costs from start until the line was clean. This is a financial reduction of over US$1 million. After subtracting annual programme costs, the operator was saving approximately US$995 000/y over the original programme cost. The operator's ILI run on the line found no additional corrosion five years after implementing the integrated solution.

Advancements in testing capabilities, chemistries and data management technologies have given operators the tools needed to develop a complete integrated approach for corrosion control and pipeline integrity, to get it clean and keep it clean. Integrity teams are able to identify the root cause of the corrosion issues, clean the system up (risk mitigation) and keep the system clean with a transparent maintenance plan. Combining chemical, equipment and automation in this integrated approach can result in reduced operating costs, increased profitability, and decreased personnel and environmental risks.

CAPTURING CRITICAL DATA

Jason Rossback, Trimble, USA, explores the role of data in keeping pipeline infrastructure safe and sustainable.

While moving oil, gas or petroleum over land via a pipeline is the most economical method of transportation today, the environmental impact when accidents occur can be catastrophic. This risk has driven an increase in regulations and resulted in more mandatory tasks being required during the construction of a pipeline. In addition, operators are increasingly mandated to provide more pipeline data, showing what is in the ground, precisely where it is located, where it was made, who manufactured it, who welded it, etc. Added to this information are questions about who should record that data, how it should be collected, when it should be collected and how to easily access the data when required.

Data collection can be a cumbersome job. However, today there are solutions that can improve the efficiency of collecting data to ensure that it is accurate, collected in a timely manner and will not impede on the progress of construction. Some solutions are manual, while others incorporate data in electronic form through guided workflows that ensure data integrity and regulatory compliance.

Why more data?

With 36% of pipeline failures being caused by material or weld failures, these are the most common instigators.[1] The second leading cause is corrosion at 24%, followed by excavation damage at 14%. While some of the causes mentioned cannot be completely eliminated, they can be greatly reduced by knowing where the pipeline assets are located in the ground, how the pipe was constructed (e.g. using an anti-corrosion coating) and where the critical failure points are located.

The age of the pipeline infrastructure will often dictate when new pipelines need to be installed. Over 50% of the pipelines that are currently in service in the US were constructed in the 1950s and 1960s. Some of the issues with this infrastructure come as a result of a lack of data relating to the pipelines' precise position and where the material was manufactured. In the process of updating pipeline infrastructure, data needs to be recorded accurately to better ensure safety over the life of a pipeline.

Often, ageing pipelines are not an issue if the pipeline operator has sound pipeline integrity management programmes. It is important for the operator to have a good understanding of the infrastructure and the environment in which it has been deployed to ensure that its integrity management programme is successful. However, accurate data capture at the point of installation is even more critical.

To monitor the health of this ageing infrastructure, there are many tracking systems that collect data about pipeline leak and spill failures. This data can be important when analysing the root cause of failures. If it is determined that a particular type of material from a certain manufacturer was faulty, corrective actions can be taken to eliminate future integrity issues.

The answer should be evident: the importance of recording informative data during the pipeline construction process is key to reducing and preventing future issues. This changes the role of the surveyor during pipeline construction. Why a surveyor? Typically, the surveyor is the last person to 'touch' the pipeline assets before a dozer covers it in dirt. Since a surveyor's primary role is to record the accurate position of an underground asset, it makes sense to store all of the important data that was captured. This helps to ensure the integrity of both the data and the pipeline.

Figure 1. Keystone Surveying and Mapping, Inc. (KSM) working on a final tie-in on a 50 mile pipeline project.

One method that has been reluctantly but necessarily deployed in the past is manually recording data, during which a surveying crew member would log information in a field book. This information consisted of the data stenciled on the pipes and welds, which included location information (typically, the horizontal stationing on an alignment) and other pertinent data. At the close of day, the handwritten notes would be entered into a computer to get the appropriate data into the system of record, which, of course, introduced error possibilities that could ultimately produce bad data.

The amount of data that can be captured is significant and poses challenges to survey crews across the industry. Surveyors are now asked to collect more information or help ensure the pipeline has been constructed in accordance with the parameters defined by regulations, building code and the

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operator's design, to name a few. Some of the key information that is needed is:

- The location of welds, bends, valves and connectors.
- Information about the pipeline material (e.g. material, coating).
- Other pipe characteristics (e.g. length of a joint, outside and inside diameter).
- Depth of cover – how far under the surface is the pipeline?
- Relative position of a joint, valve and bend to a weld.
- How the pipe was welded, who welded it and who inspected it?
- How a bend was made – was it prefabricated or was it bent in the field?

Keys to accurate data

Ensuring pipeline data is accurately captured has proven to be a big challenge over the years. However, as more data becomes available electronically, this problem is reduced significantly. For example, when pipeline materials are delivered to a job, a manifest (inventory list) is usually provided. While this was a paper copy in the past, today, the data can be accessed electronically so the risk of inaccuracies is minimised.

An important factor to ensure that data is accurately captured is to enable all data to be recorded in the same place, rather than being scattered over multiple mediums, i.e. field books and proprietary databases on data collectors, as well as spreadsheets on computers. This makes many operational tasks easier as status reports can be generated quicker. Ultimately, the final deliverables can be submitted in various file formats to the parties needing the data.

Figure 2. Pipeline module also works with locating fabrication.

Another key is to ensure that regulations, including legal right-of-ways (ROWs) and safety concerns are met. Quite often a pipeline route may be alongside protected wetlands, private property or other areas that must be avoided for legal reasons. Safety risks may potentially arise if a portion of the pipeline is installed in the wrong spot, both during construction and years later. Therefore, it is important that an effective system offers the surveyor situational awareness to assist with sound decision making.

The processes that a surveyor implements when working on a pipeline construction job may vary from region to region, but each are fundamentally implemented in the same way. These processes include:

- Topographical survey prior to any construction.
- Collecting or validating inventory information in the field or in the pipe yard (often referred to as the tally process).
- Recording the relative position of welds and bends to pipe joints.
- Recording the as-built information of the pipeline assets once they are put into the ground and, most importantly, before they are covered with dirt.

Topographical surveys

Topographical surveys, or 'topos', are the 'bread and butter' work of surveyors. They involve using a survey grade global navigation satellite system (GNSS) receiver or a total station to measure the corridor where the pipeline is to be installed. Most modern surveying systems support this workflow. However, the data captured here can be very useful throughout a pipeline construction job if it is recorded correctly.

The tally process

The tally process is key to ensuring that the inventory going into the ground is what the operator thinks it should be. The surveyor obtains an electronic manifest, typically a comma separated values file with all of the data, and must confirm that the data is correct. For example, a pipe joint may be 40 ft long on the manifest but, in reality, it is only 38 ft. Data validation helps to ensure that the final deliverable is accurate.

The tally data should also live throughout the pipeline construction process since it will probably be adjusted. An example of this is when a pipe joint needs to be shortened and, what was once a 40 ft pipe is now a 25 ft pipe. Surveyors may not notice this discrepancy until the joints have been welded together. Therefore, it is important to be able to adjust the data throughout the workflow.

Weld mapping

Weld mapping is when things get interesting. The pipeline section may not be in the ground yet so recording the relative position of a weld to the connected joints is relatively easy.

This allows the surveyor to associate an upstream and downstream pipe joint with a weld and, if the system works efficiently, the attributes collected or validated during the tally will flow into this process.

As-built asset measurement

Finally, the as-built measurement of the assets in the ground should tie the recorded data together. The surveyor typically performs this task with a GNSS receiver by obtaining centimetre precision within three dimensions of the asset. In addition to the actual location of the asset, the system should record data about the inventory going into the ground, including depth of cover, whether it crosses another pipeline and other critical information that could impact operational integrity. Recording where the assets are located is also important because it tells the surveyor if the pipeline is in the wrong place.

Midstream application

Choosing the most suitable products is key to the success of pipeline construction. Trimble® builds surveying and mapping solutions and, approximately four years ago the company developed a software solution for the construction of transmission pipelines. The solution, Trimble Access Pipelines, was released two years ago and provides surveyors working on pipeline construction projects with a streamlined data collection application integrating key functions to ease the workload of the surveyor.

KSM specialises in midstream oil and gas activities in the Marcellus and Utica basins, using geospatial solutions to do so. In the past, the company has used Trimble Access™ software with Trimble R8 GNSS receivers to maintain a data dictionary and collect most data in Microsoft Excel spreadsheets. However, KSM recently transitioned to the Trimble Access Pipelines module, which incorporates the workflows discussed above, as well as other features and utilities, to help streamline the surveyor's role in pipeline construction.

KSM did not choose Trimble Access Pipelines due to field collection issues. While the company had a data dictionary and was collecting most of its pipeline data electronically, the company simply did not have connectivity with the data. Therefore, it chose to use Trimble Access Pipelines due to its data processing capabilities.

The results have been impressive for KSM. The turnaround time on deliverables has been greatly reduced and KSM can provide data for hydrotests, final pipe footages, wall thickness footages, tally reports, a number of CAD welds, a number of drain tiles, KMZ files and alignment sheets before the contractor has left the ROW.

"Using the pipeline module has freed up the time spent going through the reports to clean up errors since many of the errors are caught in the field," Keith Higgins, PLS and CEO of KSM, commented.

Regulations may ebb and flow, but they will never go away. Having access to both spatial and asset information is critical in keeping pipeline infrastructure safe and sustainable for years to come. Ensuring this data can be captured efficiently and accurately will ultimately reduce costs and keep pipelines running safely for years to come. WP

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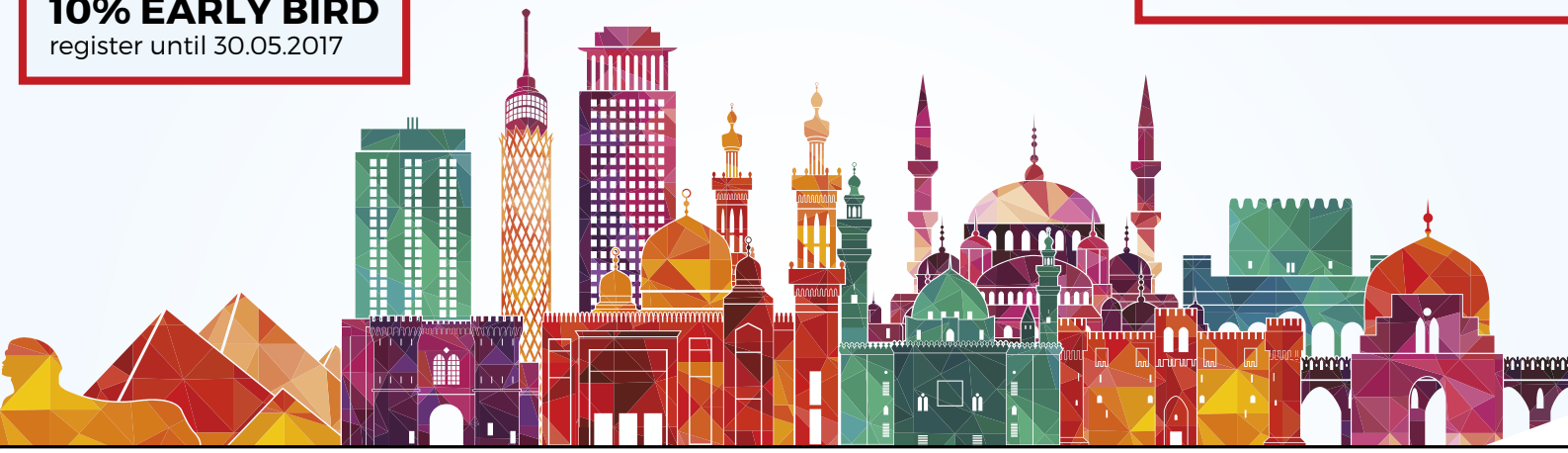

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Nicholas J. Clough and James McGinty, Orbital Gas Systems, USA,
introduce an alternative way of measuring pipeline gas properties.

Providing an ACCURATE MEASUREMENT

Natural gas that enters into or moves between networks must be metered for volume and calorific value (CV). Since countries have national regulations in place for the provision of natural gas, appropriate levels of accuracy in CV measurement must be maintained. Traditionally, gas chromatographs (GC) have been used and approved for this purpose, calculating CV from full compositional analysis (ISO 6976). Separation of the sample gas into individual components within a GC takes several minutes to complete, meaning that a full analysis is slow, with accuracy depending on regular and expensive calibration, as well as ongoing maintenance.

Historically, this slow response was not a problem when gas quality in networks was relatively stable. However, recently, several countries have experienced a significant shift from utilising a single source of indigenous natural gas, towards multiple sources of gas from new interconnector pipelines, shipped LNG and unconventional gas, such as biomethane. Many countries are now net importers of natural gas, which has resulted in greater variation in gas quality within networks.

An alternative to traditional GC

The GasPT® gas properties transmitter is a fast response inferential CV determining device, which has been developed to provide accurate and rapid measurement of gas properties. With this transmitter, users can monitor and accurately meter both transmission and distribution gas pipes with varying gas quality. The device measures speed of sound, thermal conductivity and carbon dioxide.

ISO 6976, an international standard, then used to calculate the gas sample CV. In addition to gross and net CV output, the GasPT gas properties transmitter also provides outputs of gas compressibility, density and several other natural gas parameters. The transmitter's sensor units have been integrated with Orbital's VE Technology sample probe and gas conditioning to provide high pressure gas sampling, filtering, preheating, pressure and flow control. The integrated analysis (GasPTi) compiles a sample cycle from probe tip to data output in less than 10 sec. The hydrocarbon equivalence that is built into the GasPTi inferencing mechanism ensures that the higher hydrocarbons C4+ are accounted for in the composition.

Advantages over the traditional GC method

The advantages of GasPTi over traditional GC include fast response, low cost of installation and ongoing costs, ease of installation and use, no field calibration required, very low maintenance and no requirement for carrier gas. These benefits can also convert into the other advantages for the operator, including lower purchase price, as well as reduced footprint, civil works, technician visits and gas emissions.

Figure 1. GasPTi mounted on a pipeline.

Table 1. Performance improvements over time for GasPTi

	April		May		June		July	
	GC	GasPT	GC	GasPT	GC	GasPT	GC	GasPT
Sample time	240	2	240	2	240	2	240	2
Analysis time	240	8	240	8	240	8	240	8
Error	0.05	0.2	0.05	0.2	0.05	0.2	0.05	0.2
Average error	38.774	38.772	38.98	38.981	39.682	39.681	39.237	39.237
Average CV	0.001	-0.001	-0.001	0.0	0.001	0.0	0.0	0.0
Maximum error	0.26	-0.09	0.77	0.19	0.18	-0.16	0.51	-0.16
Root mean square	0.021	0.01	0.033	0.011	0.017	0.011	0.026	0.009

The tool that is used for the abovementioned alternative can be mounted directly on the pipeline sample probe (Figure 1) to minimise sample tubing length and lag time. Alternatively, a post mounted system can be provided and installed alongside the pipeline if there is an existing sampling point. The post mounted option can be configured with a retractable probe if the pipeline operator needs to withdraw the sample probe from the pipeline for maintenance or online inspection activities. If a gas test is required to validate the GasPTi, a sample gas bottle can be incorporated into the enclosure and test validation can be operated remotely.

Addressing gas sampling uncertainty

Highly accurate gas analysis is pointless without having satisfactory gas sampling and conditioning prior to the analyser. Long gas sample lines contain threaded fittings, areas of stagnant gas (dead legs) and potential for condensate formation, all of which alter the composition or identity of the sample gas. Ideally, gas sample lines should be short, contain as few fittings and components as possible and should not have any areas of expansion or reduction in volume where recirculation could cause stagnant gas build up. When designing and developing VE Technology, these problems were taken into consideration and addressed.

Helical strakes on the external surface of the sample probes reduce the vortex shedding effect and eliminate probe vibration. An aerodynamic probe tip prevents the formation of aerosols and reduces the entrainment of particulates into the sample line. Total electropolishing of all internal wetted surface areas (including fittings and components) prevents chemical and physical interaction altering fresh sample gas.

In addition to the probe, the principles of VE Technology have been incorporated into a gas conditioning system (a VE conditioning unit and analyser interface module), which provides gas filtering to 0.4 µm, gas preheating prior to pressure reduction with flow and pressure control prior to gas sample supply to an analyser. Gas sample preheating is required to ensure that there is no liquid dropout during the pressure reduction (associated with the Joule Thomson Effect), as this alters the sample identity. Pressure is controlled in the form of a backpressure regulator, which is situated in a fast flow loop outside of the live sample pathway, in order to minimise components in the live gas sample flow path.

For metering installations, the International Organisation of Legal Metrology (OIML) has over 60 member states worldwide, including 27 European countries, and recommends a Class A instrument with CV error of less than 0.5% (approximately 0.2 MJ/m^3). The American Gas Association Report No.5 is widely used across North America, the Far East and the Middle East, which also recommends a CV uncertainty level of less than 0.5%. GasPTi has approval from the NMi under recommendations of the European OIML R 140 'Measuring systems for gaseous fuel' as a Class A instrument for CV measurement.

There are several areas of uncertainty that should be considered when metering natural gas in high pressure pipelines. The GasPTi is a simple option that does not require calibration or

carrier gases and can be mounted directly on a pipeline without additional housings on the plant, thus requiring little equipment compared to GC. This gives a very fast response of typically less than 10 sec. for a T90 step change from sample probe tip to data output. This compares with several minutes response time for a traditional GC installation.

Independent uncertainty analysis has shown GasPTi to be more accurate than traditional GCs over a timed period with changing CV conditions.[1] Over time, this will convert into significant performance improvements for the GasPTi, as can be seen in Table 1. This is based on four months of real CV data from a UK gas network and shows the GC with a much slower cycle time that results in RMS errors up to three times that of GasPTi.

The slow response of traditional GC means that further errors can occur on the metering system. A volumetric flowmeter, such as an ultrasonic or turbine meter, will output data almost instantaneously. However, the delay of several minutes in gas analysis by the GC means that there is a mismatch in the CV data. If flow or CV are changing rapidly, there will be errors in the overall energy flow accounting. Volume correction could be affected as the calculation in density and compressibility will also be mismatched with the flow data. Finally, there are ultrasonic meters that use the gas composition to calculate and cross-check the sample gas speed of sound and this could be mismatched.

Conclusion

The GasPTi gas properties transmitter has many advantages for metering systems on high pressure gas pipelines, including natural gas transmission lines. While traditional GC analysers may have issues with speed of response when gas quality varies in the pipeline, GasPTi with VE Technology provides continuous gas sampling, conditioning and analysis to give rapid and accurate CV data without the need for carrier gas or calibration gas.

GasPTi will provide a gas composition, which can be fed to a flow computer if required or will calculate all the gas physical properties from ISO 6976 in the same way as a GC. This modern solution has met performance criteria set by international standards (European OIML R140 and US AGA Report No.5) and safety standards (ATEX, IECEx and CSA) for use in Zone 1 hazardous areas. It is a lower cost solution than GCs for online gas quality CV measurement, which can be deployed more widely for fiscal metering systems across gas transmission and distribution networks and for custody transfer on downstream end use.

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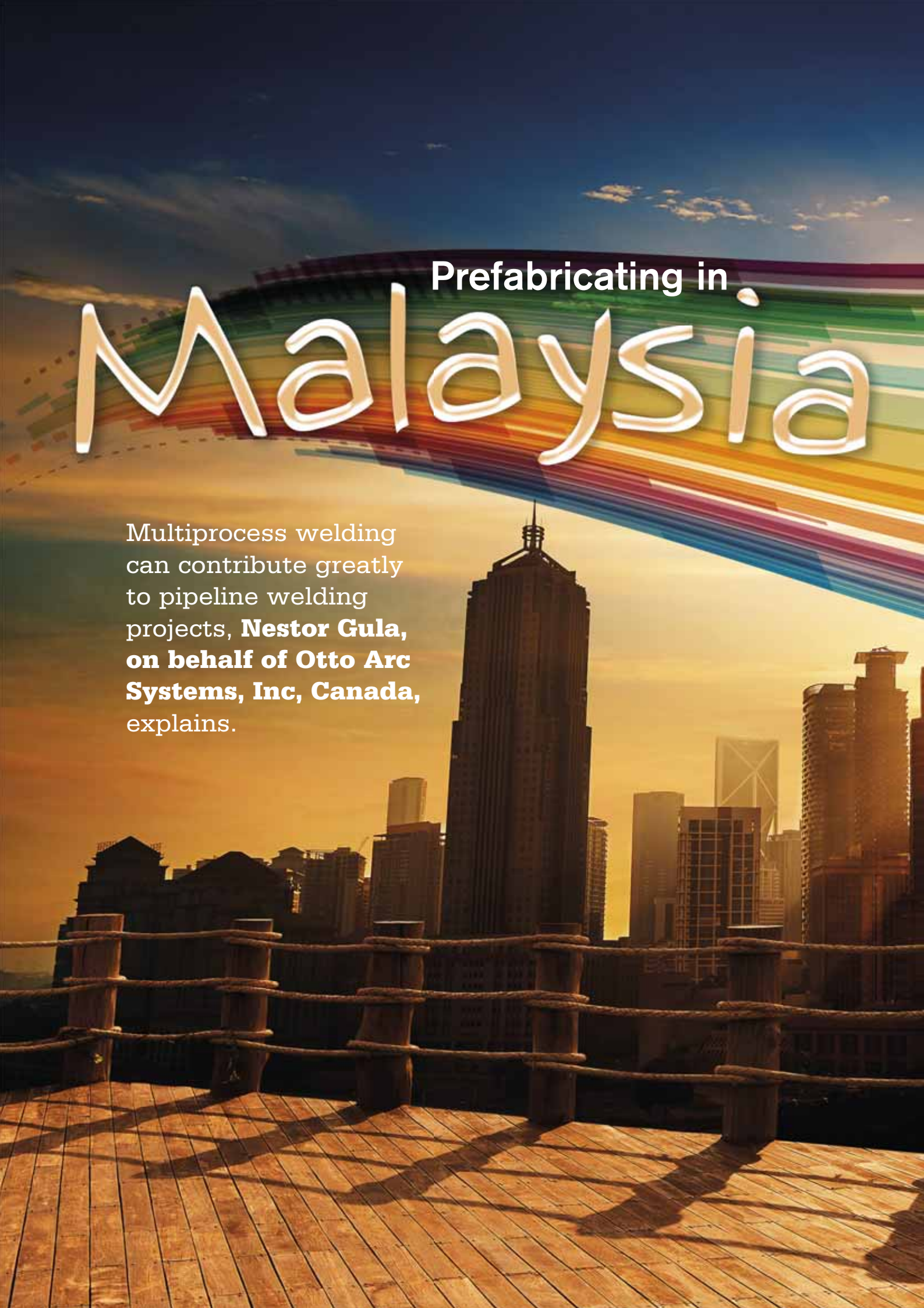

Prefabricating in Malaysia

Multiprocess welding can contribute greatly to pipeline welding projects, **Nestor Gula, on behalf of Otto Arc Systems, Inc, Canada,** explains.

With approximately 4 billion bbls of oil in proven reserves and another 39 trillion ft^3 of natural gas reserves, Malaysia has a definite presence in the world's energy market. These considerable assets fall largely under the purview of Malaysia's government-owned oil and gas company, Petroliam Nasional Berhad (Petronas).

Responding to increased demand and global competition, in 2011, Petronas and the Malaysian government, launched

Figure 1. One of the smaller open headstock pipe spool welding stations welding a flange to a pipe.

Figure 2. The pipe spool prefabrication workshop in Malaysia, with the fit-up stations shown.

a US$27 billion refinery and petrochemical integrated development (RAPID) project with the aim of modernising and expanding the country's presence in the petrochemical market. Ultimately, this project will include a 300 000 bpd oil refinery, a petrochemical complex with a production capacity of 7.7 million t, a co-generation plant, an LNG regasification terminal, an air separation unit, a raw water supply project, a liquid bulk terminal, and other central and shared utilities and facilities.

Notably, while this article uses the RAPID project outlined above as a case study, Otto Arc Systems, Inc.'s (Otto Arc) pipe spool system is also applicable to oil and gas transmission pipelines.

In April 2014, Petronas finalised the RAPID project and it officially got underway. Expected to be complete by 2019 and touted to employ approximately 70 000 workers during its construction, the refinery project is also set to generate 4000 new jobs once it is finished. On 28 February, Saudi Aramco bought a US$7 billion stake in the RAPID project.

Two participants involved in this project are Otto Arc (California, USA) and its Chinese partner, Huaheng Welding Co. Ltd (Huaheng Welding). The companies were tasked with setting up a pipe spool prefabrication project for the RAPID programme, with their scope of work consisting of two production lines to cover both exotic and non-exotic pipe prefabrication for pipes with outside diameters of 2 - 24 in. One of the production lines was for carbon steel and the other was for stainless steel. Meanwhile, a separate line was set up for fit-ups of 24 - 60 in. dia. pipe. The total value of the project was US$4.2 million.

Otto Arc and Huaheng Welding took on the project at the end of 2015 and handed it over to the end user by mid 2016. While the project is on track for preparation of peak production volume, it is not in high efficiency mode yet due to the low production volume that is currently required. The project was then taken over and will now be run by Huaheng Welding.

This is the third project requiring a pipe spool prefabrication system of this kind that Otto Arc has set up – the previous two were in Singapore and Thailand. Otto Arc's pipe spool welding systems were designed with oil and gas transmissions pipelines in mind. Similarly to the pipes in the abovementioned project, many of these transmission pipelines are prefabricated in shops before being installed in the field.

With each project having different pipe, flange and elbow assembly stations, as well as different welding stations, the systems are custom-made to the specifications of the client in each project. In addition, different transmission pipelines have different requirements, such as backflow preventers and set up valves. The company's pipe spool system is automated to create pipe segments efficiently and without defects. The equipment used cuts the pipe to length, bevels it and adds the flanges or other fixtures as needed for the project. The finished pipe spools are then shipped to the installation site, which in the case study was the refinery that is part of the RAPID programme.

Welding everything onsite would be very difficult. Otto Arc and Huaheng Welding built a prefabrication shop for one of the contractors that is located in the industrial town of Pasir Gudang (Malaysia). Although it is not currently running at full capacity, in theory, it will reach

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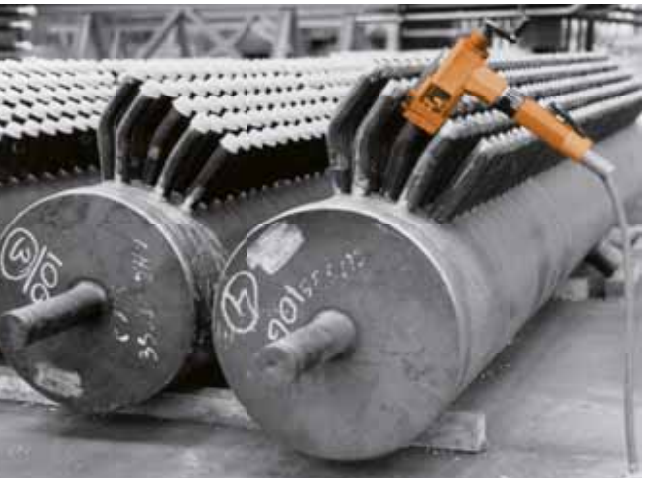

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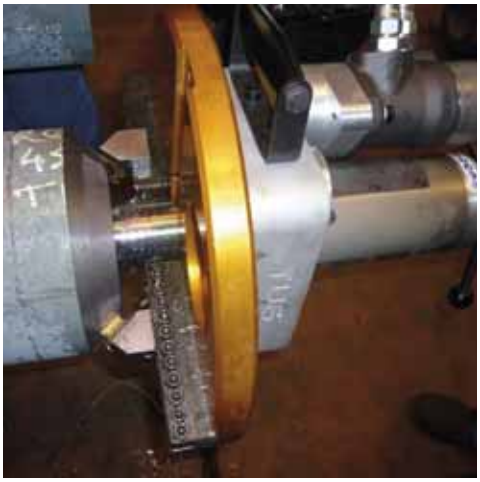

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800 000 in. dia./y for shift production. Therefore, rather than bringing all of the small components and the machines that are required onsite, some of the welding work is completed on the shop floor. Since performing its services onsite would not be practical, the company's Malaysian distributor, HH Automation BHD SDN was contracted to provide prefabrication services for the RAPID project.

Huaheng Welding developed a high speed integrated cutting and bevelling process system for the RAPID project. Included in its system was an automated length measurement function that covers pipes of up to 14 in. dia. For larger diameter pipes that have an outer diameter of 8 - 24 in., cutting can be accomplished using a band saw. Beveling is completed using a CNC end beveling machine.

Otto Arc customised the band saw machine with self-aligned clamping features for the convenience of automating pipe conveying on the conveyor system during the RAPID programme. Band saws are used to cut and trim the pipe, thus, avoiding inadvertently heat treating the steel, which would occur if plasma cutting was used.

A very smooth surface is required when welding pipe during the completion of fit-ups. When hot cutting is used for carbon steel, the cut surface needs to be ground clean to prepare the surface for bevelling, fitting and welding. Since hot cutting does not always result in a clean cut, sometimes it is preferable to use cold cutting. For fitting, the system automatically deploys a lathe-like tool to get the bevel.

Combining welding methods

Otto Arc's pipe spool welding system combines gas metal arc welding (GMAW) and gas tungsten arc welding (GTAW) into one package in order to achieve defect free pipe welding. The automated GTAW was first introduced with a solid core cold wire process for root pass welding on the machine. It was optional to select a low heat input GMAW process for root pass welding using the same machine. The company has since introduced an auto-switch function for GTAW/GMAW process change – including polarity changes, water cooling changes, shielding gas changes, as well as wire feeding changes – with just the press of a button.

Generally, if you want to use the same power source for two processes, such as tungsten inert gas (TIG) and metal inert gas (MIG), generally, you have to plugout the cables, switch over the polarity and change the wire feeder, etc. However, this is not necessary with Otto Arc's system, as it is preset and all of the necessary changes will be made automatically once the button is clicked.

The abovementioned system enhances automated multiprocess welding power source technology and allows for true multiprocess welding without the cumbersome and time consuming process of manually switching cabling when changing between GTAW and GMAW.

Concurrently, Huaheng Welding has developed an open headstock pipe spool welding station with a fully process programmable welding procedure schedule to save on labour costs during complex welding projects. Onsite welding quality control is enhanced due to the reliability of the station. The company's open headstock pipe spool welding station brings high efficiency welding output and reliable performance regardless of the skill level of the workers. It allows for a productive pipe prefabrication line and is both efficient and user friendly.

Figure 3. A machine using positioning welding for welding a large diameter pipe. The system uses both TIG and MIG to create defect free welds.

Conclusion

With a high productivity pipe prefabrication line and a highly efficient, user-friendly fit-up and welding system, as previously mentioned, this combined welding system is applicable to oil and gas transmission pipeline projects.

With regards to the RAPID project, Otto Arc and Huaheng Welding have found that productivity on the programme has increased greatly, from a maximum of 20 - 25 in. per manpower per 8 hr shift, to at least 80 - 100 in. with much lower (almost zero) defect rate. This occurred with just six months of experience with Otto Arc's welding system after it was installed in its workshop in Malaysia, which was installed to compensate for the lack of high skilled welders in the workforce and reduce costs. It allows for a productive pipe prefabrication line and is both efficient and accessible for users.

Sustaining safe welding operations

Borja Saíz Sánchez (Newtesol, Spain) and Jürgen Krüger (Polysoude, France)

explain how weld overlay of components can help to guarantee zero defect manufacturing of pipes.

Modern oil and gas pipelines are assembled specifically for the energy industry. Pipeline systems include manufactured line pipe and further components, such as flanges, fittings and branch pieces (tees). In order to absorb induced mechanical stresses, most of these parts consist of high strength low alloy steel. If increased corrosion resistance is required, the interior can be reinforced by a corrosion resistant alloy (CRA) coating.

CRAs are a group of materials, such as austenitic and martensitic stainless steels, as well as nickel-based and titanium-based alloys. There are two distinct types of CRA line

pipe, CRA-lined steel pipe and clad pipe. A pipe is referred to as CRA-lined steel pipe if the outer host and the inner CRA segment are joined together by a mechanical bond. This kind of pipe is manufactured by industrial mass production. For clad pipe, the connection between the outer host and CRA is established by a metallurgical bond.

Figure 1. TIG^{er} weld overlay installation using the bicathode TIG process for a 12 m pipe.

Figure 2. The connection of flanges and valves is carried out during prefabrication.

Figure 3. Reconstruction of the sealing face of a flange by a circular weld.

Applicable on standard steel pipes, internal CRA cladding can advantageously be carried out by overlay welding. During this process, horizontally positioned pipes are rotated around their longitudinal axis while torches with wire feeding devices attached are mounted at the end of a welding lance and guided along the inner wall.

Polysoude SAS (Polysoude) has developed a bicathode tungsten inert gas/gas tungsten arc welding (TIG/GTAW) cladding process, named TIG^{er}. The process ensures a particularly smooth surface on the corrosion-resistant layer, low dilution rates and reliable metallurgical bonding between the deposit and substrate. Using two separate current supplied tungsten electrodes that are situated next to each other in a specially designed welding torch, the process results in a combined arc that offers unique features with high deposition rates of CRA alloys without any loss in quality.

For CRA cladding pipe lengths of up to 2 m, as well as flanges, valves and similar rotation symmetric workpieces, the advantages of the TIG^{er} technology can be exploited. To enable fast prepositioning, the torch is mounted on a column and boom device before fine positioning and moving in the direction of the different axes is carried out by means of particular slides. The workpiece itself is fixed to a turning gear, turntable or positioner. Movement of the torch and rotation of the workpiece must occur in exact synchronisation with the progress of the weld cycle so that control of the whole process can be embedded into the power source.

Standard steel pipes tend to be delivered in lengths of 6 m or 12 m. To minimise onsite butt welding operations, tubes are often joined together directly onsite instead. The connection of flanges and valves is carried out during the prefabrication stage of a project as much as possible. While the design of the joints must guarantee an uninterrupted CRA layer on the inner wall of the pipe, the characteristics of the deposit (especially its corrosion resistance) should not be compromised by welding operations.

Manufacturing customised CRA clad pipe

Nuevas Tecnologías de Soldadura S.L.U. (Newtesol) manufactures customised CRA clad pipe with different types of welding connectors, flanges and other components. The company's scope covers the acceptance of an order to the packaging and shipping of finished parts.

To decide whether a project is inside its scope, a customer's specifications have to be analysed and compared to the available resources: personnel, equipment (machinery/tools), experience and capacities. Once an order is placed, the technical details of the production have to be decided, with the related fabrication drawings and work instructions being issued. Accurate purchase specifications, including welding qualification procedures with destructive and non-destructive testing, the approval and issue of welding process specifications (WPS), final tests, painting, packaging, marking and shipping of the goods have to be prepared. Moreover, the provision of primary products and appropriate welding material must be ensured and the necessary auxiliary operations have to be planned and organised.

Weld overlay case study

In the following case, a 16 in. API 5L X60 PSL2 line pipe was purchased as a standard product. Having successfully passed an incoming goods inspection, the line pipe was released for processing.

With a wall thickness of 12.7 mm, this line pipe is made of carbon steel and agreed for 'sour service'. Additional protection against corrosion and wear was achieved by applying an internal INC 625 coating, which was composed of two layers and had a total thickness of 3 mm and realised by weld overlay with Polysoude's TIG^{er} technology.

Cladding process samples were taken during the welding qualification procedure, including a cross section of the base material underneath the coating and the deposit of the two CRA layers. The results of chemical analyses at a distance of 2 mm from the base material showed that the iron content of the exterior layer of the coating remained far below the specified limit.

As required by the American Society of Mechanical Engineers, further testing took place. Tests included bend tests, dye penetrant examinations, hardness measurements and corrosion resistance determinations, each of which the pipe passed without objection. This then meant that the final WPS could be issued. All welding operations must be preceded by a positive material identification or filler material conformity test.

The weld overlay process

To compensate for the longitudinal shrinkage that is caused by the weld overlay operation, the pipes are cut with an over length of 2%. A supplementary add on is fitted onto each side of the pipe to allow for the final end preparation of the groove for subsequent butt welding. A clean surface on the interior of the pipes, which is essential, is achieved by undertaking a sandblasting operation immediately before the cladding process.

The equipment that is required for weld overlay is designed for pipe lengths of 6 - 12 m. The pipe must be positioned horizontally on non-motor-powered supports and clamped by the chucks of a height-adjustable hollow shaft positioner, which can be used on pipes of 5 - 39 in. A welding lance with bicathode torches mounted on it is then guided through the pipe until the torches arrive at the opposite end. The weld cycle begins with the ignition of the first torch and the welding lance is pulled out at a controlled speed, while the positioner rotates the pipe synchronously. As result of these combined movements, a first layer of CRA is deposited inside the pipe. The second torch starts the cladding process of the second layer when it arrives at the start of the already deposited first layer.

The two torches are arranged one behind the other. This functional construction allows the two layers of the coating to be deposited in one single pass of the welding lance. TIG^{er} technology guarantees accurate quality of the deposit with a strong bond between the coating and base material. Boosted

Figure 4. Butt welding the flange with a J-preparation of the parts.

with hot wire welding technology, welding speeds of 700 - 900 mm/min. and deposition rates of 3 - 3.5 kg/hr per torch can be reached, meaning a total deposit of 7 kg/hr.

Flanges are purchased as forged parts. For cladding, flanges are clamped on a turntable, which generates the rotation of the workpiece. Meanwhile, the movement of the bicathode torch comes from a column and boom device. In combination with hot wire feeding, TIG^{er} technology allows for fast welding speeds and enhanced deposition rates.

The sealing face of a flange has to be built up by a circular weld. The offset can be continuous or performed in step over mode after each revolution of the workpiece. In every case, to get a regular deposition at a constant linear welding speed, the rotational speed must be increased in line with the reduction of the rotation diameter. Precise control of rotational speed is offered by a special feature of the implemented software, meaning that unproblematic programming of an adequate welding cycle becomes possible.

Cladding connecting tubes and pipes can be carried out with a positioner, column and boom device. TIG^{er} technology is applicable on horizontally or upright positioned cylindrical workpieces. To ensure that the coatings are of a sufficient thickness, electromagnetic test methods are applied from the clad side and the unaffected integrity of the second layer is determined by a 100% dye penetrant test.

Realisation: butt welding operations

Welding flanges to connecting pipes can also be carried out using a turntable, column and boom device. Hot wire TIG welding involves a J-preparation of the parts, where the collars consist of the clad coating. ERNiCrMo-3 (DIN W. No. 2.4856) can be used as a filler material to ensure that high quality wire is delivered with low iron content and a residue-free surface, leading to limited ferrite in the weld, better feeding characteristics at high speed and, during production, less or no interruptions for maintenance. The above filler metal is also qualified for welding of joints between dissimilar materials.

Particular attention has to be paid to the preparation of workpieces. As mechanised welding is quite sensitive to thickness differences of the collar, bevelling must not exceed the specified tolerances. Moreover, weld joints have to be perfectly aligned inside. Gaps between the collars cause perforation and are not allowed at all.

Cleanliness is another imperative prerequisite for obtaining high quality welds. The machined extremities of the workpieces have to be deburred and any remaining oil, grease or other contaminants (such as contaminants from dye penetrant tests) must be removed with a compatible solvent.

To avoid oxidation or heat tinting on the inside of the weld and on the heat affected zone, while welding the root pass and the following two filler passes, the interior of the workpieces must be flooded with backing gas. The oxygen content of the argon flow should be constantly monitored and welding operations can begin if values of less than 10 ppm of oxygen are attained.

As specified in the WPS, the welding parameters are programmed and stored in the command unit of the power source. The torch with the tungsten electrode has to be positioned in the welding groove by means of a remote controlled pendant before the welding cycle can begin. The welding operation itself is carried out automatically, with all of the necessary functions and movements being initiated and monitored by a control unit. Arc voltage control is used to keep the distance between the workpiece and the tungsten electrode constant, such that the root pass, filler passes and cap pass can be welded without interruption. Torch oscillation generates a cyclic movement perpendicular to the welding direction. This allows the width of the welding seam to be altered as required by the specifications.

Radiographic testing and hydrostatic tests are applied to finalise the quality controls, while painting and packaging of the workpieces is carried out as required by the customer.

Conclusion

The use of CRA clad pipe is an economic way of enabling the sustainable and safe operation of oil and gas pipelines. Both mechanised TIG welding and cladding using the TIG^{er} technology are beneficial for the production of customised CRA line pipe. After a period of thorough planning, the primary products and welding materials must be purchased, experienced and trained personnel made available, WPS approved and issued, ensuring that the welding equipment guarantees joints and coatings that meet the strictest specifications and quality requirements. The service life of pipelines extends over decades and, as experience shows, little or any maintenance tends to be provided during this time.

World Pipelines' Steels Q&A!

World Pipelines **invited steels and pipeline materials experts to discuss the following:**

- Fabrication challenges associated with line pipe.
- Development and production of high strength steels.
- Ensuring the integrity of structural welds in pipeline steels.
- Pipeline steels in harsh climates.
- A relevant and recent project where companies' pipeline steels have been supplied.

Read on to see what they said:

Evraz North America, Canada

Fabrication challenges associated with line pipe

From the perspective of a pipe producer, pipeline design is increasingly moving towards pipes with thicker walls. This is partially a due to an increased design for stakeholder influence, where thicker walls are desirable for additional comfort with regards to pipeline safety.

Gas pipelines that carry large volumes at higher pressures (such as emerging pipeline requirements for transmission to LNG terminals) will require pipes with thicker walls. However, these pipes also require specific attention in the steelmaking process, to ensure that coils and plates meet all of the necessary requirements.

Welding thicker walled pipe necessitates additional time and effort to be spent on field welding efforts. Both Evraz North America (Evraz) and other capable pipe producers are experienced in welding thicker walled pipes. Once proper welding setup, adjustments and testing procedures have been performed, fabrication is not an ongoing challenge for larger pipe volumes.

Developing and producing high strength steels

Reducing variability and tightening tolerances of pipe properties (such as yield strength) are key areas of recent advancement. Evraz is the only vertically integrated producer of large diameter line pipe in North America, controlling all processes from scrap to finished coated pipe. The company performs research and development (R&D) work at a dedicated R&D centre. Here, pipeline metallurgies are tested, from initial scrap and alloy composition, through steelmaking and pipe forming.

Figure 1. A pipe staged in the Evraz Spiral 'Mill 5'. A new building was constructed for two-step welding and another for pipe coating through a joint venture with Wasco Energy.

Evraz works closely with its customers on pipe specifications. Exceeding minimum standards and regulatory recommendations is critical to delivering the safest and highest quality pipe possible.

Ensuring the integrity of structural welds in pipeline steels

A number of tests and controls are in place to ensure the integrity of pipeline welds. Additionally, no piece of pipe is released without several tests being conducted on it first.

For electric resistance welding and helically submerged arc welding, inline weld monitoring and testing is performed while the welding activity is taking place, to identify any issues prior to further pipe processing. Non-destructive testing is performed by hydrotesting to ensure adequate flow pressures can be met for each piece of pipe. Full pipe ultrasonic testing is also performed on each piece of pipe.

Pipeline steels in harsh climates

Pipeline companies must conduct rigorous analyses to ensure that the correct pipe is used for the terrain. They must also determine the specifications needed to meet the demands that are associated with that terrain.

Evraz is working towards providing pipeline steels that can be used in extremely low temperatures, of down to -60°C, as part of its new steelmaking upgrades. Rigorous requirements and pipe tolerances are likely to increase in importance in the future, as regulators continue to weigh in on ensuring that pipelines are technically advanced given their terrain and location.

Pipeline steels project

Evraz recently supplied the Keystone XL project with 36 in. dia. X70 grade line pipe. Made in Saskatchewan (Canada) from 100% Canadian steel, the pipe was produced to supply both Canadian and US portions of the route. The company also supplied pipe for use on the Cushing extension portion of the project, which has been installed and is operational.

As per a TransCanada report that was created in 2012, Evraz's pipe accounts for 24% of the US portion of the project.

Vallourec, France

Fabrication challenges associated with line pipe

Generally speaking, there are three main fabrication challenges associated with line pipe – producing the material properties, geometrical tolerances and quality assurance. Mastering these challenges results in product integrity, ease of jointing and enhanced product characteristics, which are needed for the installation and operation of a pipeline.

One question reflecting these fabrication challenges associated with line pipe is: how do you know whether a pipe is corrosion resistant?

Operating a pipeline in sour service conditions requires an optimised hardness profile. The pipe needs to combine a moderate hardness with adequate strength. Consequently, both R&D and production teams need to manage and balance opposing properties.

Developing and producing high strength steels

High strength steels are typically understood as having a yield strength of higher than 555 MPa (80 ksi), such as the API-5L Grade X80. High strength steel comes down to one material characteristic; microstructure. For seamless line pipe, microstructure is the result of a carefully chosen alloying concept and optimised heat treatment.

In order to control chemical composition and heat treatment, it is necessary to have qualified steel suppliers with controlled processes and product properties. Otherwise, it is not possible to get the predictable and repeatable raw material quality that is required by Vallourec to produce the pipe properties demanded by its customers.

The right prematerial alone does not suffice to make a high strength pipe. At Vallourec, steels of X80 and above are the result of carefully controlled heat treatment parameters and cooling conditions (quench and tempering).

Ensuring the integrity of structural welds in pipeline steels

For the purpose of this Q&A, Vallourec understands structural welds as being girth welds that connect seamless pipes.

The foundation of sound welds is the quality of the base material (here, steel pipes). The integrity of a weld depends on the weld concept (including acceptance criteria), which needs to fit the project and be executed properly by a capable welder. Ensuring that the pipeline is welded correctly will depend, to a large extent, on a welder's ability to detect non-conformities by non-destructive examination, as per the acceptance criteria being used.

Vallourec is positioned to offer both pipes and welds. The company brings both together and comes up with new ideas for facilitating weld integrity, for instance, in the domain of dimensional tolerances.

Tighter diameter and wall thickness tolerances make it easier to align pipes during welding. Vallourec offers two optional solutions for facilitating the integrity of structural welds, depending on the specification being used: CleverScan (a welding solution) and PURE (a pipe solution). Additionally, the company has created weld methods calibrated to pipe metallurgy to ensure that post-welded heat treatment is either robust and simple or is avoided all together. All this simplifies the jointing process, which helps improve the structural integrity of pipeline welds.

Pipeline steels in harsh climates

Harsh climates impose several challenges. Amongst others, jointing becomes more difficult. Imagine welding a pipeline in a snow storm, wearing winter clothing and gloves or, alternatively, in a desert at 50°C while operating welding equipment.

In the case of low temperatures, steel needs to be safe against brittle fracture. Tough pipeline steel changes to become brittle at low temperatures. By controlling the microstructure of the pipes, this shift in material properties can be moved to temperatures as low as -50°C. However, in combination with customers' rising material requirements, ductility may be a tough nut to crack.

Pipeline steels project

Vallourec delivered 16 000 t of steel pipe to a miscible gas injection project in the Middle East. As part of this injection line pipe project, a highly corrosive gas (a media containing H_2S and CO_2) is injected into the ground to more than 3000 m (3 km) depth in order to produce oil as part of an elaborate oil recovery programme.

The company has created steel that is strong and tough at low temperatures, yet easily weldable and corrosion resistant. These lines connect the compressors to the injection wells on top of the field.

The largest lines have a 20 in. outside diameter and have wall thicknesses of above 50 mm, manufactured in grade X65QS. Due to the high pressure and extreme corrosion risk, prequalification, ongoing technical exchange and rigorous quality controls were in place to deliver the products to the customer.

Vallourec overcame the logistical challenges of hydrotesting for its customer, applying coatings and delivering these 5.6 t pipes to an installation site that is located in the desert.

Never left to CHANCE

The selection of a wall thickness is never left to chance in the pipeline industry. During the design phase of pipeline projects, the characteristics of wall thickness must be carefully studied and determined in order to avoid any complications and unnecessary costs.

The importance of determining wall thickness for pipelines

Subsea pipelines are known to have wall thicknesses of up to 75 mm (2.953 in.). However, why is that much steel needed for an oil and gas pipeline?

Pipes are subject to high mechanical, thermal and chemical temperatures or pressures, depending on the type of fluid they transport, especially at depths of over 2 km (1.24 miles). A pipe's working condition must be calculated by design engineers and the result must align with applicable codes.

The design and operation of gathering, transmission and distribution pipeline systems tend to be governed by codes, standards and regulations. If there are no codes or standards that specifically apply to oil and gas production facilities, the design engineer may select one of the industry codes or standards as the basis of design. The engineer must also verify whether the particular country in which the project is located has regulations, codes and standards (ASME, ANSI, ISO, DIN) that apply to facilities and/or pipelines.

Pipeline wall thicknesses must be strategically determined to prevent potential setbacks from occurring. With this in mind, **Nadia Reicher, Protem, France,** explores the use of large and heavy walled pipes in the oil and gas industry.

Figure 1. A compound bevel made with a high speed bevelling bench, Protem BB3-16.

Once the inner diameter of the piping segment has been determined, the pipe wall thickness must be calculated. There are many factors that affect the pipe wall thickness requirement, such as:

- Maximum and working pressures.
- Maximum and working temperatures.
- Chemical properties of the fluid.
- Fluid velocity.
- Pipe material and grade.
- The safety factor or code design application.

Wall thickness formula

The basic formula for determining pipe wall thickness is the general hoop stress formula for thin wall cylinders, which is stated as:

$$t = \frac{Pd_o}{2(H_s + P)}$$

In the above equation: H_s = hoop stress in pipe wall (psi); t = pipe wall thickness (in.); P = internal pressure of the pipe (psi); d_o = outside diameter of pipe (in.).

As an example, an underwater gas pipeline will use 39 mm wall thickness pipes (approximately 1.54 in.) of high quality material with additional plastic coatings. The pressure would be considerable at 2 km (1.24 miles) depths, on the order of 20 MPa or 200 atmospheres. The pipe needs to be thick enough to withstand these high pressures.

Depth is an important consideration when determining the wall thickness of tubes. However, another parameter must also be taken into account; the installation method. Different methods, such as J-lay, S-lay and reel lay, may cause fatigue in pipe sections. Thus, correct wall thickness must be determined in consideration of consequences.

The material grade specified for pipes with a wall thickness of less than 30 mm (1.181 in.) is usually X-60 or X-65 for high pressure pipelines or deepwater applications. Higher grades can be selected in special cases. Lower grades, such as X-42, X-52 or X-56, can be selected in shallow water or for low pressure, large diameter pipelines to reduce material costs.

Bevelling heavy walled pipes

When the wall thickness increases on the parts to be welded and exceeds 20 mm (0.787 in.), the quantity of weld metal that needs to be deposited in the weld bead also increases in similar proportions. To avoid welding operations that are too long and costly from a labour and consumables point of view, preparations for welding joints with thicknesses of over 20 mm are made using bevels that allow the total volume of the bevel to be reduced.

Double angle V grooves

The first solution for reducing the size of the bevel is to change the groove angle. An initial angle of either 30° or 37.5° (or up to 45°) is combined with a second angle that is generally 5 - 15°. The first angle must be maintained to ensure that the groove does not become too narrow and prevent the welder from making the root pass. Double angle V grooves are also known as 'compound V grooves'.

Just like single V grooves, these preparations require a land of 0.5 - 1.5 mm wide and an opening between the parts of 0.5 - 1 mm.

The potential savings in terms of bevel volume increase in proportion to the wall thickness of the pipe to be welded. Consequently, savings will be over 35% on a 30 mm (1.181 in.) thick pipe.

Single and double angle J grooves

The second solution for significantly reducing the volume of the bevel and, in turn, the amount of weld metal is the J groove preparation. Single angle J grooves are comprised of an angle that tends to be 5 - 20°, a groove radius and an increase in the land. The latter element makes the root pass easier to do by giving the welder better access to the land.

For cases with very thick walls, compound angle J grooves can be made. The first angle tends to be made at 20° and the second at 5°. Both J or compound J grooves are usually welded with either a very small or a zero opening between the parts.

From the point of view of geometry, bevels must be perfect to avoid cracking and other problems. As well as providing the accuracy to be guaranteed for this type of preparation, the machine that is used must also be capable of machining thick walled pipes rapidly in order to meet the production speeds that are required by manufacturers.

Narrow gap preparation

A variation on this type of bevel is narrow gap preparation. This is used more and more in the oil industry due to the increase in pipe wall thicknesses and the high production rates that need

Figure 2. A pipe beveller with axial stroke, Protem US40.

Figure 3. Producing a bevel onsite at the end of a pipe for an onshore pipeline.

to be maintained. The technique generally involves making a single or compound angle J bevel, with an opening as narrow as possible. This also allows for a substantial reduction in the amount of weld metal used and an increase in productivity as a result of the decrease in welding times. For thicknesses of over 50 mm (1.968 in.), the productivity factor can be over five times higher than on a weld made with a traditional bevel.

Even so, many constraints can be found when using this technique. Two of them have a direct impact on the weld preparation process. Firstly, bevel geometry and the opening between the parts must be controlled with utmost accuracy. This is because the opening between the parts does not give the welder access to the bevel root. As a result, the whole weld, including the root pass, must be done using an automatic process. Automatic processes cannot accept any faults in alignment or irregularities in land width, contrary to the welder, who is capable of adjusting the position of his torch for compensating geometric faults in the groove.

The grade of the materials to be welded is the second factor that must be taken into account. Every type of material possesses different shrinkage characteristics. Therefore, bevel geometry (the opening angle) must be studied before for each grade. The higher the shrinkage level of a material after welding, the more the angle has to be open so as to prevent any cracks from appearing during solidification. A variation of a few tenths of a degree in the angle is liable to have a direct impact on the occurrence or absence of cracking, especially when welding nickel-based alloys.

These types of constraints require long and costly preliminary studies. Therefore, they need to be accompanied by a perfectly controlled bevel machining process. The description of the welding procedure resulting from preliminary studies requires lands to be accurate to 1 mm (0.039 in.), for angles to be accurate to 1° and for the parts to be welded to be aligned perfectly so as to avoid possible welding defects. Therefore, the equipment used for making the bevel must be capable of guaranteeing reliable repeatable preparations under all conditions.

Performing a bevel with heavy wall thicknesses

Pipe facing machines

Many techniques exist for producing a bevel. The most commonly used method for wall thicknesses of less than 50 mm is a frontal facing process. For the oil and gas industry, pipe facing machines tend to be used. The PROTEM PFM-HSB can achieve perfect weld preparations on pipes with a wall thickness of up to 2 in.

For wall thicknesses of over 50 mm, another approach can be used to create bevels. Instead of performing the bevel with frontal machining, bevels or compound bevels are created using a copying cam. Radial movement is controlled using a copying cam, which allows the machinist to easily perform bevelling jobs on wall thicknesses of up to 4 in. The tool holder is also equipped with carbide tips.

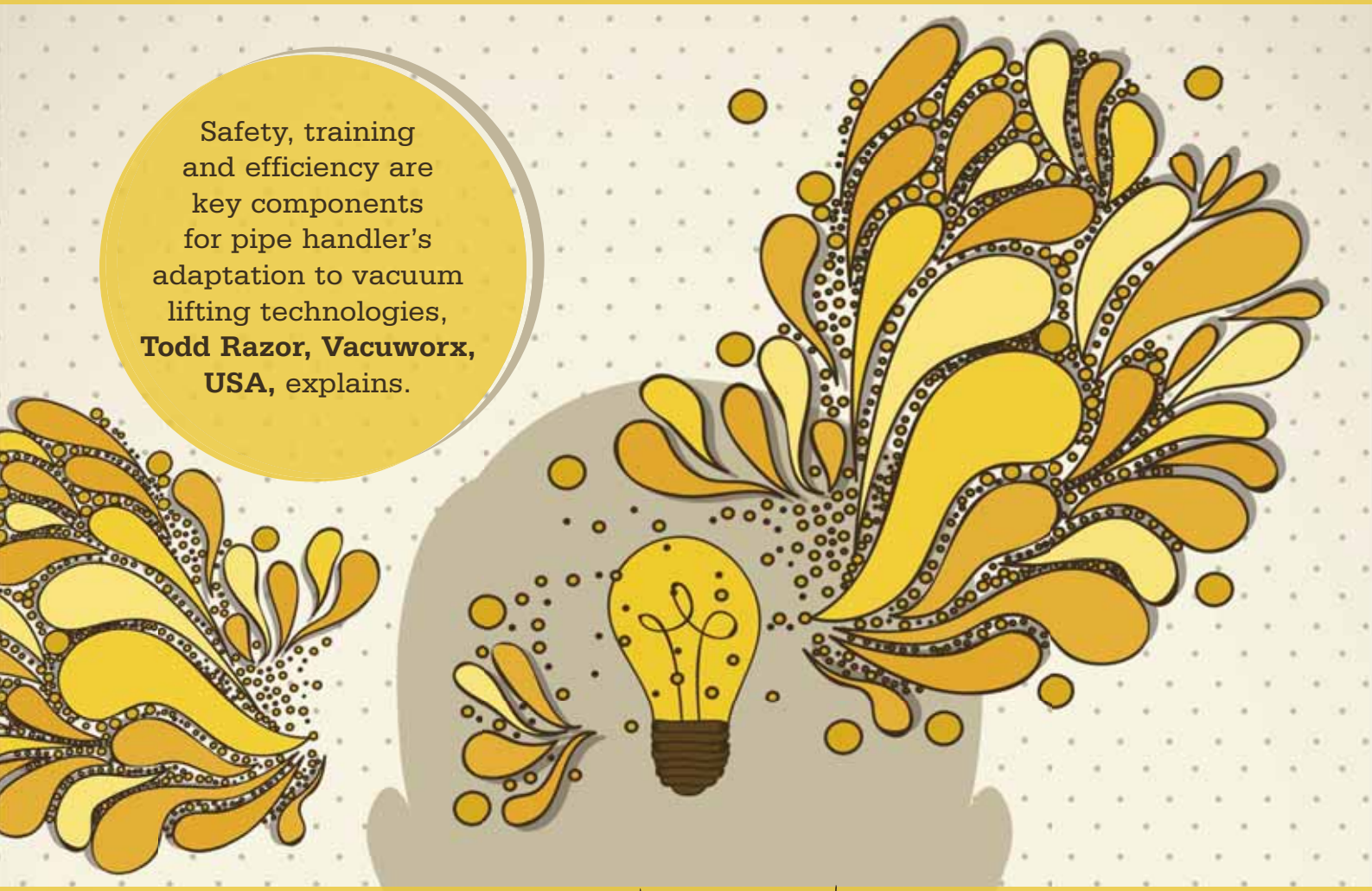
Protem offers a high speed pipe facing machine with an outside clamping system and copying carriage. The carriage, which is mounted on the tool holder plate, is driven with hydraulic radial movement. With this machine you can perform end preps of 6 - 14 in. with wall thicknesses of up to 60 mm (2.362 in.).

Another transportable machine, which performs custom bevels of 24 - 59 in. on wall thicknesses up to a 4 in. wall pipe, is the US600-R. This machine performs any type of weld preparation, such as an I bevel, J bevel, V bevel or compound bevel, with accuracy and repeatability, on any type of material, whether it be carbon steel, stainless steel, alloy, Inconel, duplex or super duplex.

Copying carriage technology

Protem has a full range of pipe cutting and bevelling clamshell machines, from 2 - 58 in. That are designed for construction, maintenance and dismantling projects. Protem's TTNG machines can perform bevels on pipes with wall thicknesses of up to 4 in. The process steps for machining extreme wall thicknesses involve making a straight cut on the pipe and setting up a copying carriage to perform J bevels or compound bevels.

Safety, training and efficiency are key components for pipe handler's adaptation to vacuum lifting technologies, **Todd Razor, Vacuworx, USA,** explains.



KEEPING AN OPEN MIND

The ability to embrace change while holding onto the fundamentals plays a key role in overcoming operational challenges, as they relate to the safe and efficient handling of heavy duty materials that are used for oil and gas pipeline projects.

At Dun Transportation & Stringing Inc. (Dun), a focus on safety and productivity is propelling the outlook of a pipeline contracting company that emphasises adaptation to contemporary solutions in the large diameter pipe handling field as a means of staying ahead of the curve.

Over 15 years ago, Dun traded a series of cranes, hooks, cables and spreader bars for a system that can achieve critical lifts and orchestrate precise movement of materials without the need for traditional rigging equipment. The company's process of moving away from cranes and wheel loaders in favour of vacuum lifting began with an understanding that the successful integration of a new solution requires a balance of technology, training, support and accountability.

Dun's switch to vacuum lifting has led to a long-standing relationship with Vacuworx. The two companies have collaborated during various stages of researching and developing the original line of RC Series vacuum pipe handing systems. Working together to address specific application needs in the field, Dun mounts its Vacuworx lifting devices on steel track excavators, as opposed to a rubber tired or crawler-type cranes for greater versatility and better handling on rough terrain.

The principal components of a vacuum lifting system include a pump, reservoir and sealed pad assembly. The power source drives the vacuum pump, which maintains a constant

vacuum in the pressure reservoir. A specially formulated pad seal on the vacuum pad is used to cover the pipe or other material that is to be lifted in order to create the necessary suction. When activated, the system pulls a vacuum between the pad and object to be lifted, providing a powerful positive seal.

Putting safety first

Dun's fleet of equipment includes some 85 trucks, 10 dozers, 10 excavators and more than 40 vacuum lifters. Prior to using vacuum lifters, Dun had 20 cranes for handling pipe. However, the company's Vice President, Matt Muirhead, made a case for focusing on safety first, followed by efficiency, when unearthing contemporary solutions for pipe lifting equipment.

Muirhead suggested that if you are loading and unloading faster (which a vacuum lifting allows for) then fewer trucks and humans need to be involved in the process. The vacuum lifter is versatile enough to pick up and turn pipes in any direction. Therefore, using a vacuum lifter means that people can be taken out of places where they should not, or do not, have to be. Whether it is in a pipe yard or along a right-of-way, this translates into less risk and higher productivity.

Figure 1. A Vacuworx RC Series lifter operating on a CAT excavator offers a safe way to handle large diameter pipe.

Figure 2. Vacuum lifting has allowed Dun to reduce the amount of manpower it requires.

Eliminating the need for additional tagline operators mitigates exposure to risk by acting as both a preventative safety measure and a performance enhancer, which helps to protect the bottom line.

The International Pipe Line & Offshore Contractors Association (IPLOCA), which represents nearly 250 industry players across the world, reported on 1180 safety incidents in 2014. Of those, 19% were attributed to lifting operations, with falling objects and collisions with obstacles being listed as primary culprits.

According to the IPLOCA report, eight workers lost their lives on pipeline projects in 2014 and 284 work injury cases resulted in an employee not being able to conduct normal duties after the day of the incident. The association also recorded that there were over 10 000 'near misses' during the course of 2014.

Through the use of vacuum lifting, Dun has significantly reduced the amount of necessary manpower in recent years. Typically, when using a crane or spreader bar, two people would be required on each end holding a tagline. With vacuum lifting, some of the hazards relating to crawling on top of trucks, trailers or rail cars and other exposures are automatically eliminated from the equation.

Dun utilises vacuum lifting systems to achieve all of its lifts. On both organisational and operational levels, buy-in was based on a culture of being open to new ideas and technologies, as well as new types and ways of running pieces of equipment.

Figure 3. Dun unloaded, hauled and racked nearly 1700 miles of 42 in. dia. coated steel pipe for the Rockies Express pipeline.

"You cannot focus on one way of handling pipe or building a pipeline," Muirhead commented. "Companies have got to adapt their cultures from a safety and training perspective as new requirements or policy changes are rolled out."

In action

From Alabama, to Nevada, to South Dakota and virtually every state in between, Dun has worked across the US over the past two decades to complete dozens of large diameter pipe handling jobs in the 36 - 42 in. (914 - 1066 mm) dia. range.

The company has recently worked on natural gas pipeline construction projects for Enbridge Inc., including the offloading of rail cars, and racking or stringing of nearly 1200 miles (1931 km) of pipe in the past three years alone.

In December 2016, Dun completed an offloading project for 150 miles (241 km) of 36 in. (914 mm) dia. pipe as part of Enbridge's Line 3 replacement project; a crude oil infrastructure maintenance job consisting of 1031 miles (1659 km) from Hardisty (Canada) to Superior (USA). By replacing the existing 34 in. (864 mm) dia. pipeline along most of Line 3's route, Enbridge intends to transport Canadian crude oil to the US through the restoration of historical operating capabilities to 760 000 bpd.

The total cost of the project, including the proposed pipeline and associated facilities that are to be constructed both north and south of the US-Canada international border, was estimated at US$7.5 billion. Responsible for offloading and staging a total of 337 miles (542 km) of pipe in US states, North Dakota and Minnesota, Dun was expected to resume activity there in March 2017.

One of the most ambitious application associated with Dun's use of vacuum lifting equipment to date is unloading, hauling and racking almost 1700 miles (2735 km) of pipe lengths for the Rockies Express pipeline in the US.

Between December 2006 and July 2009, Dun employed up to 12 crews and 20 vacuum lifting systems – Vacuworx RC Series lifters hosted by and operated along with Caterpillar 345 and 365 excavators – at a time. After co-ordinating the procurement of pipe stock from four regional locations, Dun proceeded with an array of material handling tasks, from offloading barges, ships, trucks and railcars, to hauling product, managing inventories and building and maintaining pipe yards.

Stretching from northwestern Colorado to eastern Ohio, the Rockies Express pipeline has a long haul design capacity of 1.8 billion ft^3/d of natural gas. After becoming fully operational in November 2009, this pipeline is widely regarded among the largest pipeline construction jobs that have been completed in the US. Dun lifted and handled a total of approximately 115 000 pieces of 42 in. (1066 mm) dia. coated steel pipe lengths with various wall thicknesses as part of a 30 month campaign.

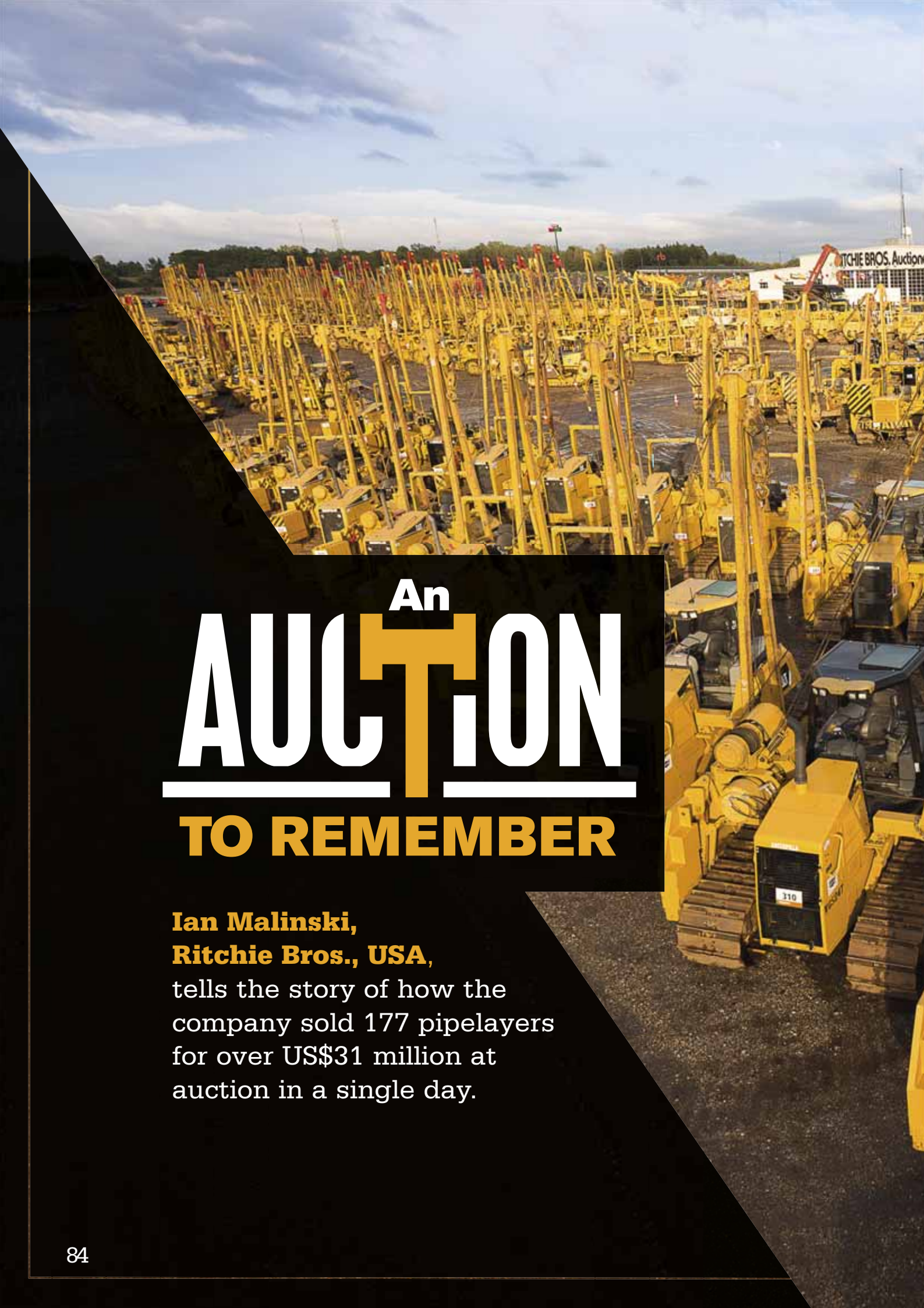
Keeping up with innovation

Since 1945, Dun has handled over 73 000 miles (117 482 km) of pipe, with diameters of up to 48 in. (1219 mm). Whether operating in the more controlled environment of a pipe yard or battling otherwise unforgiving conditions in the field, training and preparedness are key to shortening unloading and loading cycle times, and helping to ensure that materials arrive on time and without incident.

"You have people in the industry who have been doing it [pipe handling] the same way for 60 years," Muirhead stated. "You have got to surround yourself with alternative ideas, take the good ones when you have specific needs and be willing to change with the times."

The mindset of companies that provide material handling services must align with modern schools of thought that emphasise a systems-thinking approach to handling and the supply chain, likewise encompassing operational issues such as scheduling, transportation and inventory management. Dun has embraced technology, which has been a smart investment for the company. For example, it only took approximately a year of using the vacuum lifting system to realise that cranes would become an antiquated way of handling pipe.

Companies have to be able to absorb all of that and find what works best for them. They must make their company as efficient as possible and get their employees on board.



An AUCTION TO REMEMBER

Ian Malinski, Ritchie Bros., USA, tells the story of how the company sold 177 pipelayers for over US$31 million at auction in a single day.

Figure 1. More than 177 pipelayers were sold for over US$31 million in Columbus on 28 - 29 September 2016.

It is not often that you see 177 crawler pipelayers sell in a single auction, but that is exactly what happened on 28 - 29 September 2016 at Ritchie Bros.' largest ever, two day auction in the US, held in Columbus (Ohio). The massive selection of pipelayers included 15 Caterpillar 583T crawler pipelayers that sold for a combined US$7.62 million, 14 Caterpillar 594H crawler pipelayers that sold for a combined US$3.795 million, and five 2008 Caterpillar 572R series II crawler pipelayers that sold for a combined US$1.725 million. In total, 177 pipelayers were sold at auction for a staggering US$31 million.

Ritchie Bros. has been in the auction business for close to 60 years. Starting out as a family-owned and operated auction house in Canada in 1958, the company is currently one of the world's largest sellers of used equipment for the oil and gas, construction,

transportation, agriculture, mining and forestry industries, to name a few. The company conducts more than 300 auctions each year, selling US$4.3 billion of equipment in 2016, but rarely has it held an auction like the one in Columbus this past September.

The auction

The two main consignors for this massive auction just so happened to be two of the longest running contractors in the US: Sheehan Pipeline, a company that has been in business for over 100 years; and Oliver Pipeline & Equipment Inc. (Oliver Pipe & Equipment), which has been in business for more than 85 years. Similarly, both companies were looking to sell their entire fleets.

The grandfather of David Oliver, Owner of Oliver Pipe & Equipment, started the Oliver Pipe & Equipment company in the 1930s and, over the decades, it has grown from trucking leasing, to pipe and heavy equipment leasing. Additionally, it now also has one of the largest equipment fleets in the US. However, without a younger generation to succeed him and having recently refurbished his inventory 'bumper to bumper' over the last year, Oliver thought it was right time to call Ritchie Bros.

Figure 2. Equipment in the Columbus auction came from over 265 owners, including Sheehan Pipeline and Oliver Pipe & Equipment.

He explained: "I have had a long relationship with my Ritchie Bros. reps, and they knew it was a hard decision for me. With the reputation of Ritchie Bros., you feel comfortable placing it in an auction and getting the best return. [...] I decided that it was the best route."

With the big names of Sheehan Pipeline and Oliver Pipe & Equipment on board, dozens of other equipment owners began consigning their equipment to the auction, including Cross Country Pipeline Supply Company Inc.

By the time the auction was set to begin, more than 3400 equipment items had been listed to be sold for over 265 owners. Beside the massive selection of pipelayers, the two day Columbus auction also featured 135 excavators, 110 dozers, more than 235 truck tractors, over 210 trailers, and much more. Every item was to be sold unreserved, with no minimum bids or reserve prices.

As a result of the vast equipment selection, the auction attracted bidders from all around the world.

More than 3600 bidders from 52 countries registered to bid in the auction, in excess of 2500 online. As a result, this surpassed the previous Columbus attendance record by 36%. Approximately 91% of the equipment was purchased by US domestic buyers, including 21% being purchased solely by Ohio buyers. International buyers purchased approximately 9% of the equipment, from countries as far away as Singapore, South Africa and the Netherlands.

Andrew Stednitz, Vice President of Ritchie Bros., stated: "This was a truly unique event. Even with the

Figure 3. Equipment was driven in front of an audience of bidders who were seated in an auction theatre. The Columbus auction site is one of over 40 sites owned by Ritchie Bros. around the world.

Table 1. Ritchie Bros.'s Columbus auction statistics

Total gross auction proceeds	Over US$76 million
Amount sold to online bidders	Over US$26 million
Total registered bidders	Over 3600
Registered online bidders	Over 2500
Total lots sold	Over 3400
Number of sellers	Over 265

current state of the oil and gas market, we reached the right buyers from around the world, due to our extensive marketing. This was not just a Columbus auction; this was a global event. We attracted equipment from consignors across the US, marketed it to the world, generated strong demand and pricing, and achieved record results."

After all the items were sold, the auction had generated in excess of US$76 million in gross auction proceeds, making it Ritchie Bros.' biggest two day auction ever conducted in the US.

The following highlights the specific equipment sales that took place at the auction in Columbus:

- 15 Caterpillar 583T crawler pipelayers sold for a combined US$7.62 million.
- 14 Caterpillar 594H crawler pipelayers sold for a combined US$3.795 million.
- Five 2008 Caterpillar 572R series II crawler pipelayers sold for a combined US$1.725 million.
- Two 2008 Caterpillar 587T crawler pipelayers sold for a combined US$1.4 million.
- Eight 2012 Caterpillar D8T crawler tractors sold for a combined US$2.58 million.
- Three Caterpillar D7E crawler tractors sold for a combined US$860 000.

"We have been selling and renting equipment to pipeline contractors for 35 years," said John James, President of Cross Country Pipeline Supply. "We were looking to liquidate some of our surplus equipment. We talked to Ritchie Bros. and their competition, but felt that Ritchie Bros. was the best route because of their expertise in marketing to people within our industry. Turnout at the auction was great and, overall, we ended up with better results than we expected."

Over 70 pipelayers available at upcoming auctions

As of 1 March, Ritchie Bros. has already held 11 auctions in 2017. The company held a two day auction in Houston (Texas), which took place on 15 - 16 February, where more than 4400 items were sold at a US$42 million auction, and a five day mega auction in Orlando (Florida) on 20 - 24 February, where 10 000 items were sold for over US$188 million. The Orlando auction attracted a record 10 400 people from 88 countries to register to bid in person or online.

The company currently has more than 70 pipelayers in its current inventory, which will be sold in its auctions in the US, Canada, Mexico, Spain, France, Dubai and New Zealand.

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