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Volume 24 Number 8 - August 2024

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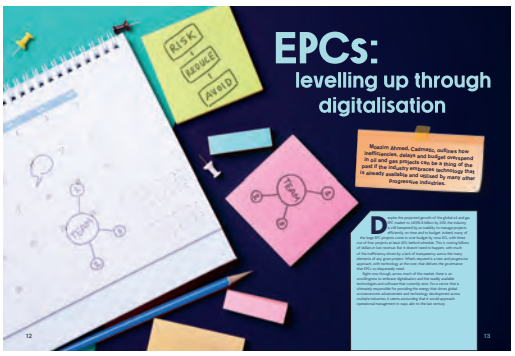

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ON THIS MONTH'S COVER

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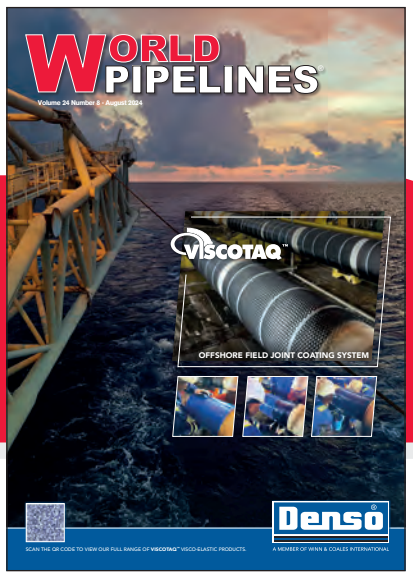
Winn & Coales International Ltd. has specialised in the manufacture and supply of corrosion prevention and sealing products for over 90 years. The front cover application showcases the innovative Viscotaq™ Offshore Field Joint Coating system's application to 3300 field joints on two new offshore gas pipelines constructed for a leading oil and gas supplier in Malaysia.



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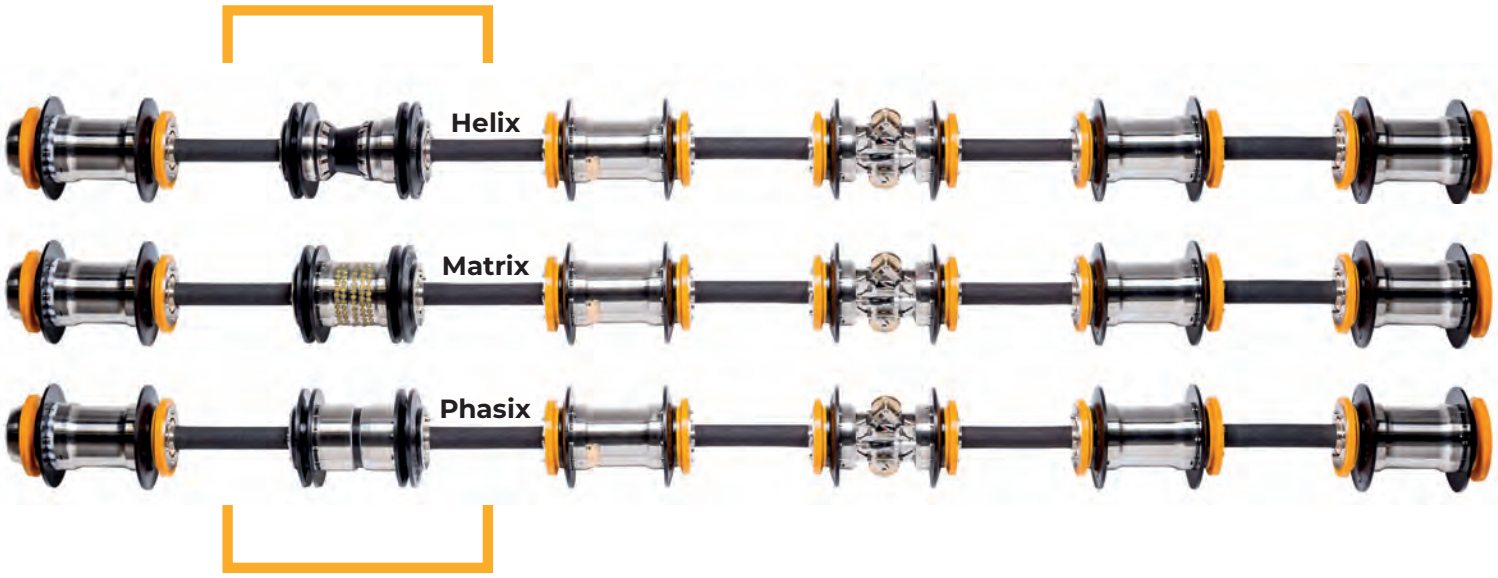

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GUEST COMMENT

ALAN THOMAS
CEO, AMPP

An often overlooked or misunderstood component of sustainability is effective corrosion management, which is fundamentally the antithesis of sustainability – it signifies the relentless deterioration of assets, opposing the principles of longevity and resource efficiency.

The annual cost of corrosion in the oil and gas sector is over US$1.372 billion in the US alone, according to the Association for Materials Protection and Performance (AMPP). Research led by Gerald S. Frankel, an AMPP member and professor at The Ohio State University, sheds light on the environmental impact of steel production, responsible for about 27% of carbon emissions from the global manufacturing sector. Specifically, corroded steel replacement accounted for 1.6 - 3.4% of global carbon emissions in 2021, with projections indicating these figures could rise significantly by 2030 if current trends continue.

These figures highlight the extensive environmental impact of corrosion and the potential for transformative change. AMPP's global initiatives to standardise corrosion-resistant materials have sparked innovations extending asset life and enhancing sustainability, demonstrating international cooperation's power in promoting sustainable industry practices.

By establishing rigorous standards and providing advanced education on corrosion prevention and control, AMPP empowers organisations to enhance their infrastructure's corrosion management, asset integrity and longevity while minimising environmental impact.

For instance, the recently updated AMPP standard SP0169-2024 focuses on controlling external corrosion on underground or submerged metallic piping systems. This standard, which includes comprehensive procedures for designing, installing, operating, and maintaining deep anode systems for impressed current cathodic protection (ICCP), helps the industry avoid premature replacements and reduce the environmental footprint of new material production and old infrastructure disposal. Notably, AMPP's recent Guide 21569-2024 aligns with the latest PHMSA regulations, highlighting our ongoing commitment to enhance operational sustainability through advanced corrosion control methodologies.

Moreover, AMPP's educational initiatives equip professionals with the skills to implement these standards effectively. AMPP educates tens of thousands of professionals annually through certification programmes, workshops, and seminars, ensuring the workforce is well-versed in the latest corrosion control technologies and strategies. This education drives innovation and efficiency, which are critical components of sustainable practices.

AMPP also provides a platform for industry stakeholders worldwide to share knowledge and best practices. This global network is essential as corrosion challenges go beyond national borders, and cooperative international efforts are necessary to address them effectively.

Addressing corrosion is both an operational necessity and a strategic imperative linked to national and global security. The oil and gas industry is crucial to the global energy supply, and disruptions due to infrastructure failures can lead to widespread economic instability and security risks. Therefore, robust corrosion management practices are vital to ensure a reliable energy supply.

As we advance, industry leaders must advocate for and adopt sustainable practices, including rigorous corrosion management. Doing so, we safeguard our assets and contribute to the broader global sustainability and security goals. AMPP's role in this journey is indispensable, providing the standards, education, and collaboration needed to turn the tide against corrosion.

We urge all oil and gas industry stakeholders, from operators to regulators, to actively engage with AMPP's initiatives. Adopt our standards, participate in our educational programmes, and contribute to our collaborative efforts, like our work with PHMSA to influence and shape regulations that govern corrosion control standards in the oil and gas industry. Join us in embracing change with AMPP because every step toward better corrosion management is a step toward a more sustainable and secure world.

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WORLD PIPELINES®

SENIOR EDITOR Elizabeth Corner
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In early July, Hurricane Beryl barrelled out of the Atlantic, to cause chaos in the Caribbean, and then the US Gulf Coast. Beryl is the earliest category 5 hurricane on record in the Atlantic basin. It moved through Jamaica, Grenada, St. Vincent and the Grenadines, before making landfall near the coastal town of Matagorda, Texas, with maximum sustained winds of 80 mph. The storm was downgraded to a tropical storm a few hours after landfall.

Oil ports were closed across a 200 mile stretch of the Texas coast, and vessel traffic was halted. Enbridge activated emergency plans for assets under threat, and Shell and Chevron stopped production and evacuated staff from their Gulf of Mexico offshore platforms.

"Since the storm...threaded the needle between the two major production hubs in Corpus Christi and Houston, it seems that the threat of regional supply disruptions has passed," said fuel marketer TAC Energy, noting that only Phillips 66's Sweeny, Texas, facility was in the immediate path of the storm."[1] But Beryl knocked out the power grid in its wake: more than 2.6 million Texas power customers went without electricity for days in the summer heat.

There may be more, and worse, to come: National Oceanic and Atmospheric Administration (NOAA) National Weather Service forecasters at the Climate Prediction Centre have predicted above-normal hurricane activity in the Atlantic basin this year. NOAA's outlook for the 2024 Atlantic hurricane season, which spans from 1 June to 30 November, predicts an 85% chance of an above-normal season, a 10% chance of a near-normal season and a 5% chance of a below-normal season. NOAA has announced new tools for hurricane analysis and forecasting this year, along with some enhanced communications for the 2024 season, and system upgrades for its observation activities.

NOAA has long been a pioneer in the use of AI. In the 1980s, NOAA was one of the first organisations to employ AI to analyse satellite data and improve weather forecasting models. In 2020, Congress passed the National AI Initiative Act, which codified the mandate for NOAA's pioneering coordination of AI application across climate, ocean, earth, and space sciences. At NOAA's Centre for Artificial Intelligence (NCAI), data scientists work to accelerate the AI-readiness and public cloud accessibility of NOAA data.

Cognitive tools can help oil and gas, and pipeline, operators create best practices for hurricane preparedness, to protect continuity of supply and avoid delays. An increasing number of companies are using AI and mapping data in their modelling scenarios, and in supply chain management.

Two of our keynote articles this month focus on how AI can elevate pipeline project management. Cadmatic explains how digitalisation, ML and AI can help with EPC scheduling (p. 12); and Garrison Haning, Safety Radar (p. 18) outlines how AI can improve workplace safety for pipeline operations.

NOAA's Climate Prediction Centre will update its 2024 Atlantic seasonal outlook in early August, prior to the historical peak of the season. Also out in August is our inaugural *Americas* issue, covering pipeline activity and trends in North America, Central America, Latin America, the Caribbean and South America. This special issue will offer insight into the unique challenges and opportunities for the pipeline sector in the Americas.

1. https://www.reuters.com/business/energy/texas-energy-industry-braces-beryl-storm-gathers-strength-2024-07-08/

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WORLD NEWS

Rystad Energy: End of Ukraine gas transit sets the stage for LNG and pipeline diversions

The European Union (EU) targets a ban on Russian fuel imports by 2027. However, nearly half of Russia's pipeline gas supplies to Europe and Moldova are still passing through Ukraine, totalling 13.7 billion m^3 in 2023.

As the EU discusses the possibility of involving Azerbaijan in a future transit deal, the current five year gas transit agreement between Russia and Ukraine is set to expire by the end of 2024, leading to concerns about the future flow of these gas volumes. Rystad Energy predicts that Russia's gas will need to be rerouted to Europe through alternative paths, requiring an additional 7.2 billion m^3/yr of LNG to replace the gas transiting Ukraine. Supply disruptions may occur sooner than initially expected, as indicated by the Austrian company OMV's market warning in May.

Slovakia, Austria and Moldova are the European nations most dependent on transit volumes, importing about 3.2 billion m^3, 5.7 billion m^3 and 2.0 billion m^3, respectively, in 2023. Last year, Russian gas passing through Ukraine supplied EU countries via entry points in Slovakia and Moldova. Moldova is adjusting its supply while having agreed with Ukraine on a continuous flow of Russian gas until the end of 2025, largely supplied to the pro-Russia separatist region of Transnistria. In 2023, the country imported 74% of its gas through Ukraine and, for the first time, received gas from Romania and the south through reverse flows via the Trans-Balkan pipeline. Italy's energy company Eni and Hungary also imported Russian gas through Ukraine, while Slovenia and Croatia have been smaller takers of Russian gas via Ukraine.

Halting Russian gas pipeline flows via Ukraine would significantly impact countries relying on these volumes. For example, when the transit extension expires after 2025, Moldova would need to reroute its 2 billion m^3 supplied via Ukraine, possibly through reverse flows of the Trans-Balkan pipeline. To reach Moldova, Russian gas could use the Isaccea entry point between Romania and Ukraine, but a transit agreement for the short 25 km distance through Ukraine would be required. The Trans-Balkan pipeline has been operated in reverse flow since the end of 2022, with 0.54 billion m^3 of gas entering Moldova via Ukraine from Romania through the Isaccea entry point in 2023. Additionally, gas from the Southern Gas Corridor in Azerbaijan, as well as from Turkish and Greek LNG import terminals, can reach Moldova via the south. When the Russia-Ukraine transit agreement ceases, the only alternative supply routes for Central and East European countries would be the Balkan Stream and the Horgos entry point between Serbia and Hungary.

"Russian producer Gazprom and European importers are keen on continuous supplies via Ukraine, while Ukrainian officials deny any intention for a renewed agreement with Russia. Without Azerbaijan or another third party transiting the gas following a swap deal with Russia, the EU will require about 7.2 billion m^3 of gas to be sourced from the LNG market. Terminals in Poland, Germany, Lithuania and Italy could forward these volumes to the most affected counties, such as Slovakia and Austria," says Christoph Halser, Gas & LNG Analyst at Rystad Energy.

Rystad Energy forecasts potential changes to the 2023 gas balance for affected countries under the assumption of 50% and 0% flow of gas via Ukraine and capacity limitations at relevant entry point alternatives. Without Russian gas, Slovakia would find itself at the end of the flow chain, requiring about 4 billion m^3 of gas delivered through the Lanzhot entry point from Czechia. With additional regasification capacity in Poland only available in 2025, a zero-flow scenario may even entail reverse flows from Austria into Slovakia.

Austria, the largest offtaker of Russian gas in 2023, would pivot towards increasing imports from Germany via the Oberkappel entry point, expected to operate at a maximum annual capacity of 8 billion m^3. However, for Rystad Energy's baseline year of 2023, the import capacity at Oberkappel will not be sufficient to close the 8.53 billion m^3 import gap. Without short-term capacity adjustments, gas transits to Hungary would decline, and outflows to Italy would be stopped. If all Russian gas flows via Ukraine were to cease, Austria would need to import up to 2.5 billion m^3 from Italy via the Arnoldstein-Tarvisio crossing point.

Italy has several options to replace Russian gas pipelines and has largely achieved independence from the Ukrainian transit. However, the country would be required to source about 3.75 billion m^3 for Slovakia and Austria. These additional supplies could come from the Ravenna floating storage and regasification unit (FSRU) – 5 billion m^3/yr from 2025 – and 1.23 billion m^3 from pipeline supplies through Tunisia.

Hungary would face large challenges in case of a complete halt of Russian gas flow through Ukraine. Assuming Moldova is supplied via the south, capacity via the Trans-Balkan pipeline from Romania would be fully allocated, halting inflows from Romania. Furthermore, Austria would be unable to forward gas to Hungary, while Croatia won't have additional regasification capacity available before 2025. Hungary would have to rely solely on increased gas flow through the TurkStream pipeline, whereby the Horgos entry point would be required to operate continuously at its maximum capacity of 9 billion m^3/yr. Alternatively, if Austria could source sufficient LNG from Italy, Hungary could receive additional gas through reverse flows at the Mosonmagyarovar entry point from Austria.

Central and Eastern European countries are preparing for a possible halt in the Ukraine gas transit and have joined forces to create a Vertical Gas Corridor under the EU's Central and South Eastern Europe Energy Connectivity Initiative (CESEC). This year, on 19 January, an MoU was signed in Athens involving EU energy commissioner Kadri Simson and the Transmission System Operators (TSOs) from Greece, Bulgaria, Romania, Hungary, Slovakia, Ukraine and Moldova. The corridor would utilise existing infrastructure in Ukraine and Moldova and enable LNG imports from Greece and Turkey to reach Slovakia, Hungary and possibly Poland.

Furthermore, Turkey's transmission system operator BOTAS and Bulgaria's operator Bulgartransgaz signed an agreement in January 2024 to increase gas entry capacity at the Strandzha 1 entry point, enabling increased gas flows from Azerbaijan and the Caspian Sea region into Europe. This expansion could aid in raising Azerbaijan's EU gas exports from 13 billion m^3 to 20 billion m^3/yr by 2027 and, in the long run, potentially transport Iranian gas through the Solidarity Ring Initiative.

WORLD NEWS

IN BRIEF

USA
The ADCC Pipeline entered commercial service on 1 July 2024, and is capable of providing approximately 1.7 billion ft^3/d of natural gas transportation capacity to the Cheniere Corpus Christi liquefaction facility from markets on Whistler Pipeline's Agua Dulce Header in South Texas

CANADA
Wolf Midstream has announced a CAN$1 billion (US$730 million) final investment decision (FID) to proceed with the NGL North Phase Two expansion project. The project aims to enhance the NGL production capacity of the existing NGL North System in Alberta, which began operations in 2023.

NORWAY
Norwegian oil and gas company Vår Energi has announced a 12 year extension to its natural gas sales agreement with Italy's Eni. The renewed deal will see Vår Energi deliver up to a total of 5 billion m^3 of natural gas to Eni from 2024 to 2036.

USA
Energy Transfer LP has announced the completion of its previously announced acquisition of WTG Midstream Holdings LLC (WTG).

UK & CANADA
Voyis, a leading provider of ocean imaging solutions, is thrilled to announce its latest venture, the OASIS Project. Funded by Canada's Ocean Supercluster's UK Collaborative Ocean Innovation Solutions programme, in partnership with Innovate UK, this initiative aims to revolutionise marine environmental surveys through the collaboration of Canadian and UK ocean technology experts.

THAILAND
Sulzer is meeting growing demand from critical energy markets in APAC by opening a new service centre in Rayong, Thailand.

Engie to partner with Macquarie in Mexican pipeline project

French energy company Engie has agreed to partner with Australian infrastructure investor Macquarie Asset Management to expand the Mayakan natural gas pipeline in Mexico, the two companies said in a statement on Thursday 11 July 2024, according to Reuters.

The project aims to accelerate the energy transition of the region and will reduce carbon footprint by up to 7.4 million tpy of CO_2 equivalent, the companies said.

The partnership involves Macquarie acquiring a 50% stake for US$360 million in the construction of a 700 km natural gas pipeline in the Yucatán Peninsula, according to a source with knowledge of the deal.

The enterprise value of the project will be up to US$3 billion at completion and the two companies will share the governance of the company running the asset, known as Mayakan System, the person said.

The new pipeline will double the natural gas transportation capacity for the Yucatán Peninsula and will pass through the states of Chiapas, Tabasco, Campeche and Yucatán.

Mexican state power utility CFE in November 2022 signed an agreement with Engie to expand the Mayakan gas pipeline in the Yucatan Peninsula.

BofA Securities and Sumitomo Mitsui Banking Corporation acted as financial advisers to Engie, while Rothschild advised Macquarie.

Germany could import up to 100 TWh of green hydrogen via pipelines by 2035, study shows

Reuters reports that Germany could cover up to 100 terawatt-hours (TWh) of its annual energy needs with imports of green hydrogen via pipelines from neighbouring countries by the mid-2030s, covering a significant share of its projected demand, a study showed.

Berlin is seeking to expand the use of hydrogen as an energy source to cut greenhouse emissions for highly polluting industrial sectors that cannot be electrified, such as steel and chemicals, and cut dependency on imported fossil fuel.

Produced using solar and wind power, green hydrogen is a pillar of Germany's planned energy transition. The study by Berlin-based Agora Energiewende and Agora Industry think tanks said that by 2035 hydrogen could cover 11.2% of the country's projected 894 TWh total energy demand.

But Germany will need to import around 50 - 70% of its hydrogen due to its limited renewable energy resources.

Currently, Germany uses around 55 - 60 TWh of hydrogen per year but it is produced almost exclusively from fossil fuels, data by the economy ministry showed.

The study said that by 2030 Germany could produce 11 TWh of hydrogen and import about 17 TWh of green and some 15 TWh of blue hydrogen, produced from natural gas, via pipelines. That would cover less than half of Germany's total hydrogen demand projected to reach 95 TWh to 130 TWh by the end of the decade.

However, by leveraging existing natural gas infrastructure in Europe, Germany could boost pipeline imports to between 60 TWh and 100 TWh by 2035, the study said.

"To achieve climate neutrality, Germany needs a secure and cost-effective supply of renewable hydrogen. Pipeline imports from Europe play a crucial role in this," Simon Mueller, Agora Energiewende Director, said in statement.

To reach this imports potential, Germany will need a financing model and will have to move quickly with agreements on cost-sharing among involved countries, Mueller said.

Hydrogen producers and pipeline operators will also need assurances about future hydrogen demand from Germany, Mueller added.

The study examined five potential hydrogen pipeline corridors to Germany, considering factors such as production potential, political support, and technical complexity.

Promising corridors include imports from Denmark and Norway via the North Sea, and potentially from Sweden and Finland via the Baltic Sea in a later stage due to the distance and technical complexity, it added.

In the long term, pipelines from Southern Europe and North Africa, especially Spain and Tunisia, can play a significant role, in addition to possible imports from the United Kingdom, Portugal, Algeria, Greece, and Ukraine.

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CONTRACT NEWS

EVENTS DIARY

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Stavanger, Norway
www.ons.no

9 - 13 September 2024
IPLOCA convention
Sorrento, Italy
www.iploca.com/events/annual-convention

17 - 20 September 2024
Gastech 2024
Houston, USA
www.gastechevent.com

24 - 26 September 2024
International Pipeline Conference & Expo (IPE) 2024
Calgary, Canada
www.internationalpipelineexposition.com

23 - 24 October 2024
Hydrogen Technology Expo Europe 2024
Hamburg, Germany
www.hydrogen-worldexpo.com

23 - 24 October 2024
Carbon Capture Technology Expo Europe 2024
Hamburg, Germany
https://www.carboncapture-expo.com

23 - 24 October 2024
Subsea Pipeline Technology (SPT) 2024
London, UK
https://sptcongress.com

4 - 7 November 2024
ADIPEC 2024
Abu Dhabi, UAE
www.adipec.com/visit/registration

20 November 2024
Global Hydrogen Conference 2024
ONLINE
www.accelevents.com/e/ghc2024

Woodside Energy awards Trion offshore project to Corinth Pipeworks

Corinth Pipeworks has been awarded a significant contract by Woodside Energy, as operator of the Trion deepwater field, to manufacture and supply approximately 118 km of high frequency welded (HFW) steel pipes.

The Trion field is located in the Perdido Fold Belt in Mexican waters of the Gulf of Mexico. Situated approximately 180 km off the Mexican coastline and 30 km south of the US-Mexico maritime border, Trion is poised to be the first production site from Mexico's deep water with potential for future discoveries to be tied back to Trion's facilities. Trion is an alliance between Woodside Petróleo Operaciones de México, S. de R.L. de C.V. (60%, Operator) and Pemex Exploración y Producción (40%, non-Operator).

The development involves a wet tree subsea system connected to an infield floating production unit (FPU), which will be linked to a floating storage and offloading (FSO) unit, ensuring efficient ex-traction and processing of the resources.

The scope of supply also includes the application of external coating and concrete weight coating (CWC).

ADNOC Gas awards US$550 million contracts for UAE gas pipelines

ADNOC Gas plc has announced the award of EPC contracts for the next phase of the UAE sales gas pipeline network enhancement ESTIDAMA project. Separately, ownership of ESTIDAMA is being transferred from ADNOC Gas to ADNOC, thereby significantly optimising ADNOC Gas's capital efficiency.

The EPC contracts are worth a combined US$550 million (AED2 billion) and were awarded to NMDC Energy P.J.S.C and Galfar Engineering & Contracting W.L.L Emirates. Approximately 70% of the contracts' value is expected to flow back into the UAE economy through ADNOC's In-Country Value (ICV) programme, supporting local economic growth and diversification.

ESTIDAMA will extend the UAE's natural gas pipeline network operated by ADNOC Gas from approximately 3200 km to over 3500 km.

Ramco Norway secures long-term OCTG contract with Equinor

Ramco Norway, specialists in the preparation, inspection, surface treatment, and preservation of OCTG (oil country tubular goods), has secured a long-term contract with Equinor.

"Ramco Norway has been awarded 80% of the volume of oil and gas pipes running from Equinor at Fjord Base in Florø to the Norwegian Continental Shelf (NCS). From Sandnessjøen and Hammerfest, we have been allocated 100% of the volume. This means we are establishing a new department at Polarbase in Hammerfest, a supply base for oil and gas activities in the Barents Sea.

"It's strategically important for us to be close to the Barents Sea, where the growth will occur," CEO Arild Moe emphasised.

THE MIDSTREAM UPDATE

- GlobalData: Permian Basin shale production to remain strong
- bp sees global oil demand peaking next year
- AMPP announces new Chair of the AMPP Board of Directors
- Hedge funds make rival takeover bid for Martin Midstream
- Engie to partner with Macquarie in Mexican pipeline project
- GlobalData on the future of oil and gas in a Labour parliament
- Elevation Midstream and ARB Midstream subsidiary merge

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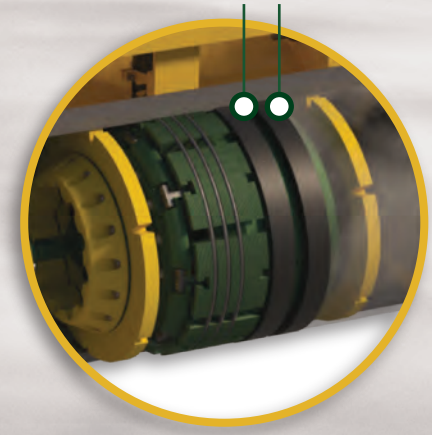

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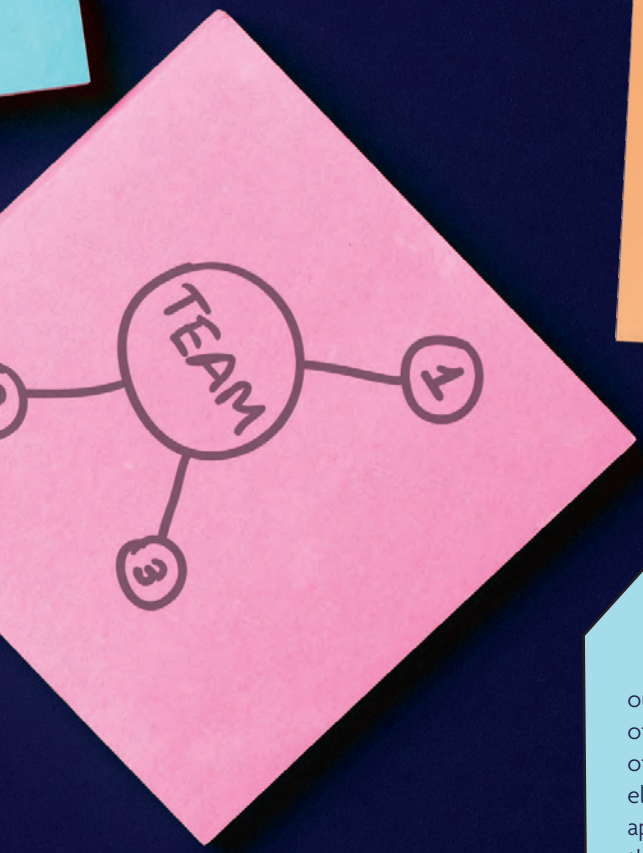
EPCs: levelling up through digitalisation



Moazim Ahmed, Cadmatic, outlines how inefficiencies, delays and budget overspend in oil and gas projects can be a thing of the past if the industry embraces technology that is already available and utilised by many other progressive industries.

Despite the projected growth of the global oil and gas EPC market to US$92.8 billion by 2031, the industry is still hampered by an inability to manage projects efficiently, on time and to budget. Indeed, many of the large EPC projects come in over budget by circa 10%, with three out of four projects at least 40% behind schedule. This is costing billions of dollars in lost revenue. But it doesn't need to happen, with much of the inefficiency driven by a lack of transparency across the many elements of any given project. What's required is a new and progressive approach, with technology at the core, that delivers the governance that EPCs so desperately need.

Right now though, across much of the market, there is an unwillingness to embrace digitalisation and the readily available technologies and software that currently exist. For a sector that is ultimately responsible for providing the energy that drives global socioeconomic advancement and technology development across multiple industries, it seems astounding that it would approach operational management in ways akin to the last century.

No one is suggesting that EPCs should turn to machine learning and artificial intelligence overnight. Although this kind of technology will play an increasingly significant role in aspects such as the performance optimisation of operations, modernising maintenance practices as well as streamlining data management, documentation and supply chains, for example. What we are talking about is fundamentally more basic, and it is centred around the limitations of the widely used scheduling systems that the majority of EPCs use.

Limitations of current software

Clearly, these software solutions are the main database for any given project, and nothing happens without them. And they are very good at what they are designed for; creating project schedules on a very large scale. However, they also have certain limitations in relation to some important areas of functionality and capability. Essentially, in terms of schedulling levels for large projects, they stop at EPC Level 4. So, while they are essential from a strategic planning perspective, they can't accurately calculate and support a project's progress or provide an immediate comparative analysis with the project baseline. They can't show the methodology for calculating progress at all levels in a transparent and verifiable way, especially with projects involving thousands of activities. They also lack easily understandable visual interfaces with focused, selective, and user-definable views of how a project is developing in line with the schedule. Fundamentally, they don't deal with the actual deliverables or how they are been executed.

What is of most concern, is that once the software has developed the schedule for a project, any inevitable changes, necessary updates or activity developments within the project, are mostly conducted via Excel workbooks. Site managers, planners and other key stakeholders fill in their activities on a daily basis and share them accordingly. When there are literally thousands of contractors working on a project at any given time, using multiple workbooks and having to manually input multiple datasets and information is not just monotonous, but also hugely time consuming.

The direct impact of this means that many EPC companies do not have the required level of insight or information to influence the right decision making and they spend a significant amount of time on non-optimal activities. EPC projects are hugely complex with multiple phases and thousands of activities that need careful scheduling and management. They require software that delivers unprecedented detail, and transparency that brings data to life, fuelling collaboration and communication to ensure projects remain on schedule and to plan. Without this, EPCs, in essence, are often 'operating blind' when it comes to planning activities. They don't have the information on whether some of the previous steps have been completed – which need to be – to commence the next activity.

This means wasted time and money in planning and preparing for activities that you can't begin. It is the result of operating in an analogue way in a digital world.

Scheduling a project differently

To overcome this, a small minority of progressive EPCs are increasingly using advanced project management software (project level 5 and 6), integrating and overlaying it into their scheduling platform. By utilising 3D modelling, it enables them to visualise, analyse, estimate and report on the progress of a project; essentially adding a clear layer of comprehension, understanding and transparency beyond what they have had before, improving visibility and eliminating those blind spots. This is particularly important when many of the people involved in a project may not be engineers with a deep technical knowledge. 3D modelling simplifies the process, brings a project to life in an intuitive way, where a picture is worth a thousand words, and conveys much more information than just tables of data. This is critical, particularly for the C-suite level of an organisation, where they don't want or need to go into the minutiae of detail on a specific project, but they do want overarching oversight on how developments are progressing and where issues or challenges might be occurring.

Project management software, such as CADMATIC Projects is a good example of this. Launched by Cadmatic in 2023, it helps EPCs to establish a framework for measuring and comparing progress to the project baseline; analysing how activities are developing in real-time on the ground. This assists project managers in micromanaging projects, identifying critical paths and potential bottlenecks, as well providing early warning signs of any problems, so that they can proactively take action to correct and intervene at an early stage to keep the project on track.

As well as more transparency, the increased visibility also creates a level of accountability as everyone can see what each stakeholder should be doing. This inspires collaboration and shared ownership in working towards the same goal. On top of this, it can also track progress at a real-time level against the budget that has been assigned to deliver the project; often a project may be at 50% complete in terms of time and on schedule, but 70% of the budget may have already been spent, which leads to unanticipated cost increases and overspend. Fundamentally, as well as ensuring efficiency, allocating resources effectively and reducing waste (both in terms of time and materials), this type of software provides project managers with a complete overview of the entire health of a project and levels of insight and detail that ensures optimal decision making. The software also keeps past data on the performance of all contractors, not just in terms of cost, but also quality. It analyses their efficiency levels, as well as the quality of products and services. It provides invaluable data and learnings that can be taken onto the next project to ensure further efficiencies and optimal performance.

Digital transformation with CCC

This concept is the heart of 'digital transformation'. Where, at a human level, technology is taken and used as a tool to think differently about a process, to push boundaries beyond the routine or status quo and to use data and intelligence to adapt and evolve. It is for this reason that Consolidated Contractors International Company (CCC), one of the world's largest construction companies recently partnered with Cadmatic to implement CADMATIC Projects to enhance efficiencies and performance within its operations.

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Figure 1. CADMATIC Projects transforms thousands of activities into summarised and detailed progress reports using a consistent weighting system.

Figure 2. CADMATIC Projects aids informed decisions and ensures effective resource allocation to meet deadlines and budgets.

Zahi Ghantous, CCC's Vice President for Project Support with responsibility for supporting all projects from inception and transition to completion in various technical processes, approached Cadmatic because they knew that they needed to better embrace digitalisation.

"Engineering and construction are rather 'laid back' industries that have not caught up with or embraced technology like other sectors such as manufacturing or production. We therefore wanted to better understand and introduce technologies and digital solutions available into our organisation to better serve our needs, help us improve our performance and to empower our project management teams, both onsite and at HQ to execute often very complex large-scale projects efficiently, on time and on budget."

Understandably, CCC wanted to ensure that it was using the right product, was supported in the right way, and working with like-minded people.

Cadmatic therefore ran a pilot simulation for CCC on a past, medium-sized project, which involved up to 5000 separate activities, demonstrating how CADMATIC Projects would have performed and managed the project. Starting from scratch, the Cadmatic team exported all data from the scheduling tool and imported it into the Projects software, creating the structure and linking the activities with the items in the 3D model, simulating costs and updates on progress over the length of the 12 month project (delivered by Cadmatic in just one month). The pilot demonstrated all the levels of functionality within the software and simulated all the outputs such as generating all the necessary reports on budgets, time and progress, showcasing the level of detail and transparency that the technology can provide. The success of the project has resulted in a formal agreement and Cadmatic is now working with CCC on a real-world megaproject, which is currently under construction.

Harnessing digitalisation for project management of the future

Fundamentally, there is excitement to explore new horizons in project management through the collaboration with CCC, where there is immense potential in leveraging Digital Twin Technology to revolutionise project efficiency. Partnering with CCC, as a recognised leader in the industry, demonstrates the opportunity to usher in a new era of streamlined project management, harnessing the power of digitalisation to enhance decision-making, optimise resource allocation, and ensure the seamless execution of complex initiatives. It is about creating a future where the integration of cutting-edge technology transforms the way projects are approached, setting new standards for excellence.

As the transition towards new sources of energy continues at pace, EPCs within the oil and gas market will also need to adapt and evolve. This is not just related to seizing new opportunities in renewables, decommissioning projects or supporting oil and gas companies in meeting the current demand for hydrocarbons from burgeoning industries and economies. It also means embracing new ways of working and being open to new ideas and new innovations. Technology and digitalisation are key components of this; driving efficiencies, ensuring projects remain on time and to budget and in improving the whole operational performance. Those that do will thrive and seize the opportunities that change always brings.

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Garrison Haning, Co-Founder & CEO, Safety Radar, USA, walks us through ways to integrate AI into pipeline operations.

Imagine this: it's 7:35 am on a Saturday morning in October. You're getting ready to take your family to the kids' soccer match. The car is loaded, the snacks are packed, and you have everything you need for the five hours of fun that you've been looking forward to all week.

Then, as you're locking the door to your house and heading for the car, your phone rings. The caller ID says it's a 1-800 number and likely SPAM, but you know better: that phone number is from your company's emergency contact centre.

Before you even answer, you know that your weekend plans are done. The call is for a Code Red emergency; somewhere across your company's operating footprint, a pipeline has been struck, and for the coming days or weeks, you'll be on the team trying to clean up the catastrophe; a catastrophe that may have been mitigated by using AI.

Unfortunately, this scene is too common, and anyone who has worked in the pipeline industry for more than a few years has likely been involved in fixing the consequences of a line strike. When the stakes are so high, the pipeline industry needs to embrace the best, most effective tools for mitigating risk. And the good news is that there are many ways to implement AI in your organisation's safety programme to decrease damages, keep your team safe, all while decreasing the cost of your One Call and safety programmes in the process.

Line strikes are as dangerous as ever

The pipeline safety industry is certainly on an impressive trajectory and in many ways continues to become safer every year. This ongoing commitment to safety is fuelled by cutting-edge technologies such as electronic positive response (EPR) systems, robust regulatory enhancements, and comprehensive education initiatives, ensuring our pipelines are safer than ever before.

However, despite these efforts, pipeline strikes remain a critical concern, costing the US an estimated US$30 billion annually.

WORKPLACE SAFETY AND THE AI OPPORTUNITY

Figure 1. **Safety Radar in the field: members of the Safety Radar team (Garrison Haning, CEO, and Mike Sixmisth, Director of Safety), applying their technology for customers in the drilling industry.**

The 2022 DIRT Report indicates that the number of damages per million dollars of construction spending increased by 12.35% from 2021 to 2022, highlighting the persistent nature of these incidents. Major root causes, such as failure to notify the one call centre/811 and improper excavation practices, continue to drive these damages, underscoring the need for ongoing vigilance and improvement in damage prevention strategies.

AI can help

One Call tickets will always need human involvement, but AI thrives in scenarios where data and context matter. For example, a typical company's ticketing process might involve multiple employees evaluating factors like the type of dig to be done, what assets are in the excavation area, the track record of the excavator conducting the work, and the potential impact should a line strike occur.

While decisions like whether a proposed excavation is close to company assets are easy enough for a human to determine, AI can consider the excavator's history, the type of dig and past incidents from such excavation, and potential consequences if something goes wrong in just a few seconds, all while making these determinations with datasets consisting of decades of data and tens of millions of data points.

Better yet, AI can provide a recommendation regarding how to proceed with line marking, whether to have a company employee present for the dig, its confidence in its recommendations, and can provide references to company documentation and data to support such its contention, in less time than it takes a person to read the original One Call ticket.

In fact, based on my company's research, AI and humans working together can cut nearly four-fifths of the time necessary to evaluate One Call tickets. This time saving supports decreasing costs and decreasing margin for error.

But more importantly, the time savings allow for pipeline operators to respond to tickets faster, removing one more unnecessary excuse for One Call violators: "I didn't call because I thought you would take too long to get back to me."

Figure 2. **Examples of some of the visualisations that AI can power to track risk by specific factors in real-time.**

Greater opportunities ahead

Line strikes are just one important hazard that AI can help mitigate, but equally important is protecting pipeline workers in the field. Near misses, good catches, incident reports, job safety analyses, and even work orders for upcoming projects provide insight into where the next accident could occur.

With so many safety departments already stretched thin, if reports ultimately need to go through a safety team member to be triaged and analysed for trends, the necessity to review data can become overwhelming.

Using AI to analyse this data as it enters the reporting system yields life-saving results. By analysing incoming

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Figure 3. Garrison Haning, Co-Founder and CEO of Safety Radar, on the job in the Permian Basin, supporting energy production operations.

data, considering past information in a company's safety management system, industry datasets, and company safety protocols, AI acts as the 24/7/365 digital safety team member to spot changing risk signatures in real-time. By analysing hazard reports and near misses and good catches coming in from the field, AI can extract underlying causes, serious injury and fatality exposure, and much more. In seconds, it can compare regions, operating divisions, and project types, can provide benchmarks, and can call out when deviations begin to occur.

The same type of AI platform can also look at incoming work orders and assist the field in tasks like populating JSAs with recommendations about hazards they may encounter and how to mitigate them, based on actual data from hundreds of thousands of industry and company data points.

The experience of a good hand in the pipeline industry is invaluable, but if a crew is inexperienced, AI can provide the continuity and insight to call out hazards and mitigations that have otherwise been overlooked.

So what now?

The first question my firm is often asked by customers is "AI sounds great, but we don't know anything about it. How do we even begin?" The shortest answer I can give is: "just start." Whether you're a publicly traded firm or a small, privately held operation, the best thing any organisation can do to start gaining the benefit of AI is to set the intention to try it, and start working towards that goal.

There's plenty of AI doomerism in the media, but for practical purposes, much of it is actually irrelevant to your organisation. Here are a few simple steps you can take to start onboarding this valuable teammate:

Start today

Set the intention to experiment with AI and communicate that within your team. Simply put, if you set it as a goal within the organisation, you're on the path. Whether you establish a task force, talk about it in your meetings, incorporate reading about it into your professional development, or begin talking to vendors about how they can help your organisation apply it to solve problems, the best thing you can do is start.

Consider pain points

Look across your organisation for pain points and things that people want to improve. Is there a manual process that happens (or should happen) on a regular basis? AI can be a great teammate for augmenting these efforts. Are there data streams that could yield critical insights if only they were consistently reviewed and/or considered in the larger context of other information? This is where AI thrives. Pick a few key issues where you're lacking solutions, and consider them through the lens of AI to explore new approaches.

Work with a multidisciplinary team

Regardless of background, AI experience (or lack of AI experience), no one person or team in your company fully understands the scope of AI or the best applications for it. If you truly want to benefit from it, bring multiple stakeholders into the decision-making process. People from across the company will yield opportunities and provide solutions that you never could have foreseen. But one important caveat: don't let a multi-disciplinary team lead to death by committee. Everyone will have insights and concerns, but at the end of the day, someone needs to make the decision about what you'll try and what you won't.

Talk with startups

While big tech service providers offer processes and scale, most of them came about in the time before AI. As a result, they often struggle to incorporate it into their operations. The concept of technological debt is real; if a service provider's infrastructure was built before AI, they'll likely have to change and rebuild significantly before they're capable of effectively leveraging it. Like the name implies, startups are younger companies, and as a result, many built their technology with AI in mind from the outset. Coupling this with the fact that they're nimbler is a great combination for your organisation to find a responsive partner in getting you the services you need.

Start with something approachable

Instead of setting out to automate some proprietary, complex process that requires integration with multiple company systems, conduct limited pilots using static data. For example, instead of trying to use AI to turn valves or execute emergency shutdown procedures from the company control room, instead try using it on a large static dataset of past incident reports to detect serious injury and fatality exposure or causal factors from past incidents. If you're impressed with the insights, incorporate additional analyses. Eventually, you can tackle integrating it with your live safety management system to track this information in real time. As an aside, this is a great reason to introduce AI to your organisation via safety management; while safety data is sensitive, using it to train your AI won't give away any proprietary information, and the benefits of applying it can be realised very quickly. As you build your organisation's AI chops here, you can expand those learnings to other aspects of your operation.

After-action reviews

Don't let any pilot conclude without conducting an after-action review. What you learn from each pilot will be invaluable and as you move out of the pilot stage and into the long-term application of AI in your organisation, keeping track of your learnings ensure that you're building something progressively versus starting over each time and shooting for the moon.

Iterate

Like anything worth doing, the biggest benefits come from AI when you try different approaches. Pick different scopes, apply AI to different problems, keep what worked well and move away from what didn't. Using concepts like the OODA loop here is a great approach; observe, orient, decide, act, and repeat. You'll get immeasurably better over time.

AI will never replace humans. Instead, it should be viewed as a teammate. There are things it's good at and things it's not. But in the pipeline industry, using this technology isn't just about using something new; it's about creating a safer and more efficient business. By integrating AI into the safety team, companies can significantly reduce the frequency and impact of incidents, including line strikes. And the journey down this path starts with a commitment to adapt and grow; a commitment already at the core of our industry.

About the author

Garrison Haning is the Co-Founder and CEO of Safety Radar, a workplace safety tech company managing operational risks through AI. Garrison is a Major in the US Army Reserves who began his career in safety as a First Cavalry Division Platoon Leader deployed to Iraq. He has also worked in government and external affairs for a publicly-traded oil and gas exploration company in Tulsa, OK, where watching the devastation caused by deaths from easily preventable accidents drove him to co-found Safety Radar.

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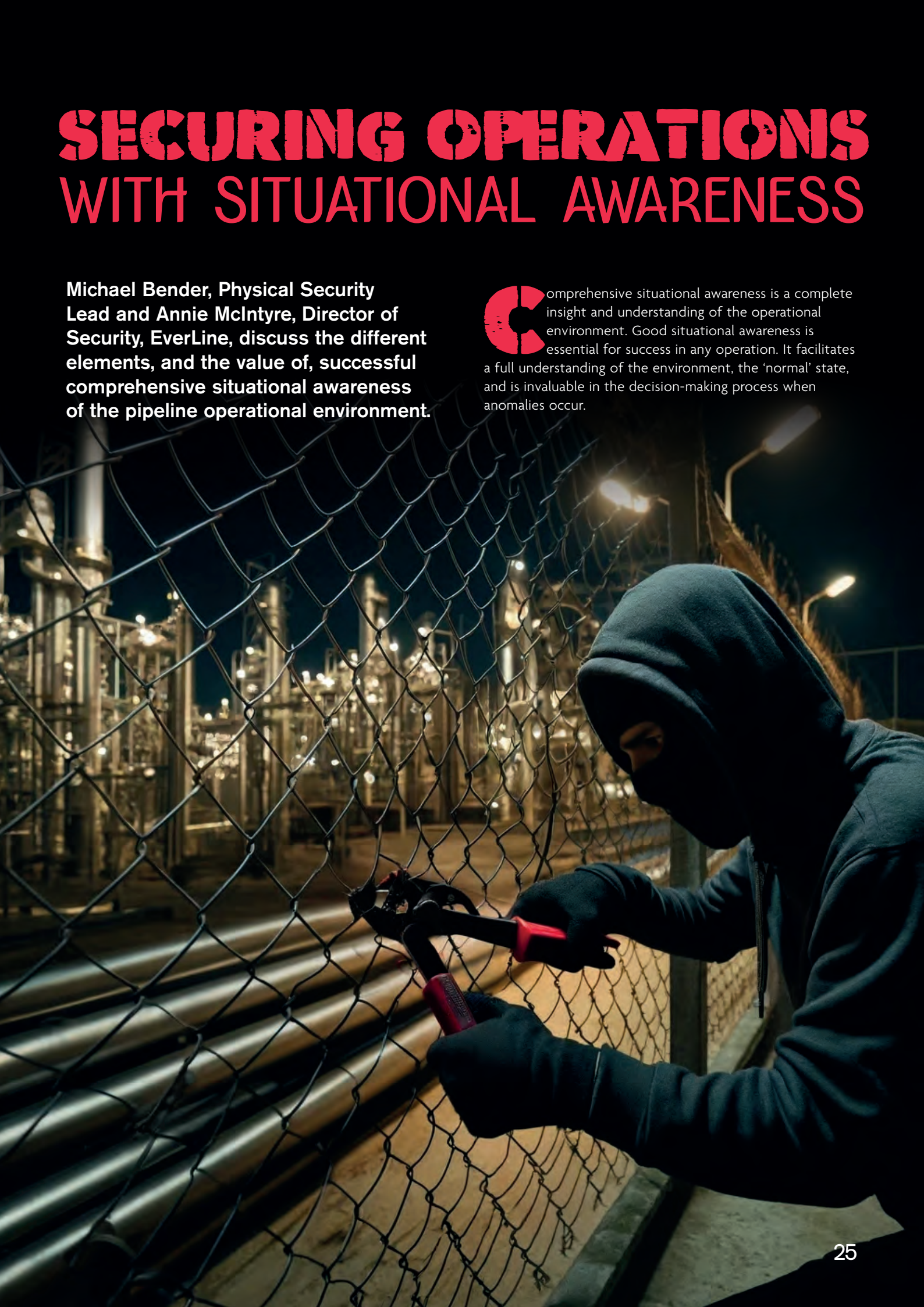
SECURING OPERATIONS WITH SITUATIONAL AWARENESS

Michael Bender, Physical Security Lead and Annie McIntyre, Director of Security, EverLine, discuss the different elements, and the value of, successful comprehensive situational awareness of the pipeline operational environment.

Comprehensive situational awareness is a complete insight and understanding of the operational environment. Good situational awareness is essential for success in any operation. It facilitates a full understanding of the environment, the 'normal' state, and is invaluable in the decision-making process when anomalies occur.



Managing a life-safety-critical operation and remaining stable and secure requires full situational awareness. Without awareness, the decision-making process often fails. In times of crisis, that process includes identifying the current operating state, gathering information, analysing multiple courses of action, conducting a risk assessment, and choosing and executing the best course of action. Given the criticality of pipeline operations, making the wrong decision can have disastrous consequences. This article examines the elements and benefits of successful comprehensive situational awareness.

The elements of situational awareness

Situational awareness is multifaceted and requires interpreting data and observations into a single conclusion. Typically, in the operational environment, we utilise situational awareness to assess the current state of stability and security. Given the emerging threats and increased regulations, situational awareness is critical. Moreover, it is an expectation by insurers, regulators, partners, and shareholders. Accurately knowing the details of your operation is simply doing your due diligence.

Situational awareness can be composed of several elements. Various sensors, monitors, and human observations serve as data inputs. Tools and technologies that provide nearly every detail of your current operating state can be deployed. It is easy to see that managing the sheer volume of details can be a challenge. One concept is to organise the data into cyber and physical data. Cyber would include operating states and alarms handled by control systems, as well as infrastructure tools such as network and system security monitoring tools on your operational network. Physical monitoring includes site sensors and surveillance.

While separate organisational departments often manage these functions, obtaining and analysing this data from a structural view can be significantly advantageous. This may occur within a control room or a security operations centre (SOC).

Cyber monitoring of the operational technology (OT) environment is essential to maintaining secure and stable operations, particularly for operators within the national critical infrastructure. Numerous technologies exist that monitor for anomalies on the network and across systems. These tools can include various monitoring capabilities, data collectors, and artificial intelligence. Continuous monitoring allows asset owners to react to potential threats and abnormalities and choose the best course of action to mitigate through effective decision-making. Cyber monitoring in the OT environment has advanced significantly in the past decade. It can provide a view into network and system behaviours far beyond a human user's ability to surveil the digital landscape.

Physical security monitoring also provides asset owners with better situational awareness by allowing them to surveil, record, track, and identify potential threats and security vulnerabilities within their environment.

Video surveillance and recording is essential to establishing a strong physical security posture. Being able to capture images and video allows the asset owner to have visibility in and around buildings, assets, and the perimeter. Video surveillance tools include closed circuit (CCTV) and Internet protocol (IP) cameras. These camera systems can be capable of Pan-Tilt-Zoom (PTZ), Infra-red (IR), night vision, and facial recognition. Comprehensive video surveillance systems store recorded images and video using either a digital video recorder (DVR) or a network video recorder (NVR). The DVR captures analog footage and converts it to digital format compared to an NVR, which records digital footage. These systems can also have video analytics software that allows the system to learn 'normal' behaviour and determine when the actions of individuals are suspicious or 'abnormal'. Upon discovering suspicious behaviour, the system can alert monitoring personnel to the activity.

Access control systems can track employees' ingress and egress by recording identification numbers, names, and when and where they gained access or exited. These systems can also be programmed to limit access throughout different areas of the building.

Surveillance tools

Various types of sensors, including motion, glass break, intrusion detection, water, temperature, humidity, smoke, fire, ballistic, and blast detection, are valuable tools in securing sites and assets and provide useful input for accurate situational awareness.

Motion sensors commonly deployed are often Passive Infra-red (PIR) or microwave. PIR detects heat and is most used in corridors, entryways, and small to medium-sized rooms. Microwave sensors function like radar or sonar by emitting microwaves and detecting and measuring the time it takes for the waves to return to the sensor. Microwave sensors are best used in large rooms or warehouses with little to no movement so as not to trigger false alarms. Sensors can be used to trigger lighting, cameras, or alarms after regular business hours.

Glass break sensors measure sound vibrations that occur when a window is broken and will trigger an alarm. Intrusion detection sensors are small in size and typically mounted on doors, windows, and cabinets. They can also be mounted on several rack cabinets as an added level of security. Physical sensors are often low-cost and significantly contribute to situational awareness in areas with limited observation.

Given the longstanding risks of shooting pipeline assets and the recent trends in shooting electrical transformers, ballistic detection is becoming highly valuable. Ballistic and blast detection uses a network of acoustic sensors that detect gunshots or an explosion and can determine the exact location or point of origin. This type of situational awareness can not only save asset owners time in their response to an incident but also more accurately direct first responders to the incident or offender's precise location.

A variety of tools and technologies exist to collect inputs that form a situational awareness picture. Correlating cyber and physical inputs has significant value, presenting an asset owner with a comprehensive view. For example, coordinated, multi-faceted adversary attacks may use physical distractions while conducting a cyber-attack or the opposite. If there are gaps in the situational picture, or monitoring is

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the responsibility of disparate groups in the organisation, communication can be slow, costing valuable time in responding to an incident or threat.

When establishing a complete situational awareness view, several factors and challenges should be considered. From a cyber standpoint, monitoring core OT assets generally exists on the OT network, which, if implemented correctly, does not openly connect to business or internet-facing networks. Physical monitoring sensors may not exist on the same OT network, meaning data correlation in a single view may be challenging or require careful selection of tools and network configuration.

Reaching a comprehensive view may require analysing data from disparate systems and tools, some of which may be legacy in nature. Migration and integration of these systems require planning. Simply put, new and old technology do not always work well together and can adversely affect optimal performance. These can be solved through careful planning and analysis, as well as clearly established lines of communication, data, or human communication.

The more significant challenge for many operational organisations is the need for human resources and available time to establish and maintain technology and continually monitor the collective view. Some options include careful configuration of alerting mechanisms, reducing the need for constant viewing, or utilising third-party monitoring services. If monitoring services are obtained from a third-party, those entities must understand the criticality and processes within the operational environment. Standard monitoring of a business or enterprise network can be significantly different than an operational network. However, third-party monitoring can be an attractive and cost-effective solution to 24 x 7 x 365 coverage.

The bottom line is, if an asset owner wishes to monitor both cyber and physical landscapes, they must carefully configure and maximise technology as well as plan for human resources to engage and manage it. Staff must also be trained in incident response, decision-making in times of crises, forensics, and so forth. This can make outsourced services attractive.

Threats are both cyber and physical, but no single tool accomplishes unified cyber-physical monitoring. It is important to select tools and processes that best fit your operation and provide the view you need.

The 'why' and the benefits

Threats to operations of all kinds continue to evolve. Full situational awareness is imperative, coupled with the regulatory and stakeholder expectation that asset owners have a comprehensive view of their networks, systems, and site. Being prepared, being able to speak to the current state of operations, and equally being able to respond quickly is simply being diligent and a good steward of life-safety processes. As regulations frequently change and become more stringent, companies may struggle to stay current and audit-ready. Maintaining this full view and ability to respond also assists in obtaining insurance and, perhaps, a better premium.

In tough market times, it can be challenging for asset owners to find or establish a budget for preparedness. The return on that investment is simply that nothing terrible happens each day, and operations remain stable. Reaction to an incident often prompts a situational awareness budget, but at that point, the cost of an incident far outweighs any preparedness cost. Incident costs can be significant and have lasting consequences.

Threats are real, and as the saying goes, "it's not a matter of if it happens, but when it happens." The evidence is all around us. Situational awareness, coupled with effective security measures, illustrates diligence and preparedness. It also lays the foundation for quick reaction, quarantine, and recovery. Tangible costs and safety incidents are undoubtedly well-known. Still, a loss of investor trust, increased insurance premiums, mounting fines, negative press, and loss of reputation and customers can be difficult for an organisation to understand until it is in that situation.

Cyber-physical monitoring in unified view has substantial benefits, including the value of coverage at remote or unmanned sites. This allows an asset to understand if an anomaly is a technical glitch, communication issue, security issue, or wholly separate threat, such as weather. Incident response at remote sites can be dangerous for employees. With no vision into what is causing the issue (pump failure, drop in pressure, loss of power, changes in flowrate, etc.), a responding employee may fall victim to anything from eco-terrorism to opportunistic attacks. Many remote sites only have cyber monitoring capabilities and lack surveillance assets. Remote sites with CCTV or IP camera monitoring would offer situational awareness to a responding employee. Before arriving at the site, the employee would have visual confirmation that the site is or is not secure; if not, local law enforcement could be dispatched to clear and secure the area before the responding employee gains access to the site. Providing a view into remote operations sets the scene for responding staff, ensuring their safety and ability to react quickly without triage. A unified view decreases response times as there would be no need to gather or receive information from two separate sources, thus overcoming current response time challenges.

There are many benefits to comprehensive situational awareness. Coupled with suitable security measures, both cyber and physical, and incident response planning, the ability to be resilient and live through a crisis becomes readily achievable. A unified view allows asset owners to have a visual of their networks via cyber monitoring, and physical security enhances the safety of employees and the protection of core digital assets. We live in a technical age where vast amounts of data are at our fingertips. Operational environments should be no different; an asset owner should be able to see and react to the current state of operations, whether from a safety or security, cyber or physical standpoint. Decisions should flow from confidence in the situational data; ultimately, the asset owner can be fully aware.

An asset owner that has reached their desired security posture and achieved comprehensive situational awareness ultimately provides the safest work environment for employees with stable, secure operations.

REVOLUSIONISING PIPELINE

Jyoti Singh and Shubhendu Tripathi, MarketsandMarkets, India, explore advanced inspection and monitoring techniques that are paving the way for safer energy infrastructure.

In the pursuit of enhancing safety measures and ensuring the integrity of energy infrastructure, the realm of pipeline inspection and monitoring has witnessed a ground-breaking revolution. With advanced techniques and technologies at their disposal, experts have pioneered a new era of safeguarding pipelines, significantly reducing the risk of potential hazards. Pipeline inspection and monitoring have emerged as paramount practices in the energy sector. Implementing cutting-edge methodologies, such as robotic inspection tools and intelligent monitoring systems, has enabled the thorough assessment of pipeline conditions. By utilising these technologies, operators can identify and address issues proactively, preventing leaks, ruptures, or other potential failures. This paradigm shift has instilled confidence in stakeholders as pipeline safety becomes a top priority. Integrating artificial intelligence and machine learning algorithms empowered operators to analyse vast amounts of data, identify patterns, and predict potential failures. This proactive approach saves valuable time, enhances operational efficiency, and reduces maintenance costs.

Besides, remote monitoring systems emerged as a game-changer in the pipeline industry. Real-time data acquisition and continuous monitoring enables operators to promptly detect anomalies, changes in pressure, or temperature variations. By closely monitoring pipeline conditions, operators can swiftly respond to emergencies, minimising environmental impact and ensuring the safety of nearby communities.

In conclusion, advanced inspection and monitoring techniques have revolutionised pipeline safety. These technologies have ushered in a new era of enhanced infrastructure integrity and public protection, with their ability to identify issues and swiftly respond to emergencies. Embracing these innovative practices, the energy sector demonstrates its commitment to safety and reinforces its position as a responsible steward of critical resources.

Magnetic flux leakage and ultrasonic technology

Different technologies are used to inspect and monitor pipelines: ultrasonic, pigs, magnetic flux leakage, smart ball, fibre optic technology, and others such as beta-foil technology and LEO technology. Magnetic flux inspection services offer a non-destructive testing technique for detecting pipeline corrosion, surface pitting,

cracks, and weld defects. This method provides valuable information about the pipe wall's condition by scanning its circumference and length.

By using magnetic flux leakage technology, it is possible to identify the remaining wall thickness, depth, and the precise location of metal loss caused by deterioration mechanisms – particularly in steel/ferrous pipes. Ultrasonic leak detection is a superior technology for pipeline inspection and monitoring; it accurately identifies leaks by analysing pipeline variations and capturing emitted noise. Its exceptional sensitivity enables early detection of even the smallest leaks in oil and gas pipelines, preventing costly damages and environmental risks. Using sensor devices placed outside the pipe, the non-intrusive method minimises disruption and damage. With versatility across pipeline materials and conditions, ultrasonic technology ensures high accuracy in leak detection. Real-time data analysis allows operators to respond swiftly to leaks, ensuring uninterrupted pipeline operation. Overall, ultrasonic

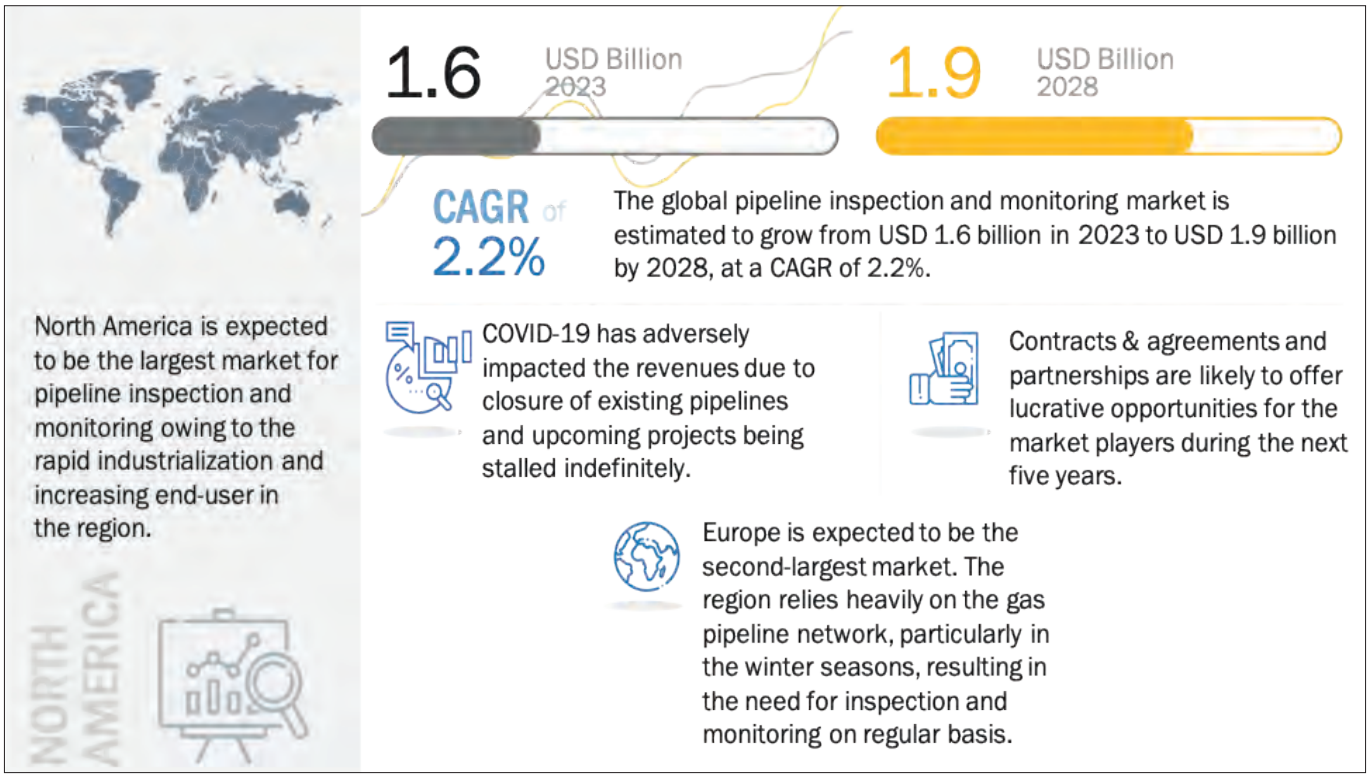

Figure 1. **Pipeline inspection and monitoring market trends, 2023 - 2030.**

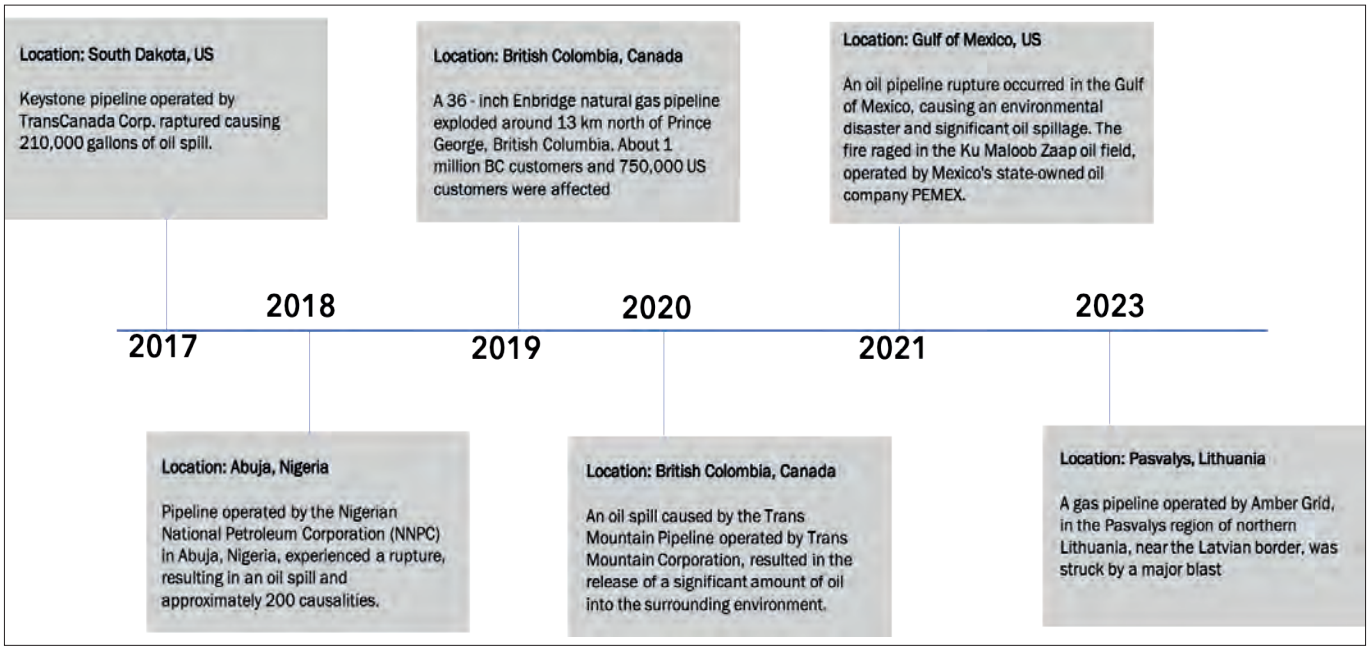

Figure 2. **Major pipeline incidents reported between 2017 - 2023.**

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leak detection technology offers precise, non-intrusive, and proactive capabilities, safeguarding the integrity and safety of pipelines while mitigating risks.

Regulatory framework is evolving

The regulatory framework surrounding pipeline inspection and monitoring has evolved significantly to adapt to changing industry needs and enhance safety standards. Governments and regulatory bodies worldwide are placing greater emphasis on pipeline integrity and the prevention of incidents. This includes developing and implementing more stringent regulations, bars, and guidelines governing pipeline inspection and monitoring practices. Additionally, there is an increasing focus on risk-based approaches, incorporating advanced technologies and data-driven methodologies to assess and manage pipeline integrity. The evolving regulatory framework aims to foster a proactive and systematic approach to pipeline safety, ensuring continuous improvement and reducing the potential for pipeline failures and environmental impacts.

Market outlook

The global pipeline inspection and monitoring market is projected to grow from an estimated US$1622 million in 2023 to US$1889 million by 2030, at a CAGR of 2.2%. Owing to the increasing demand from end user industries, the global pipeline inspection and monitoring market is expected to have significant potential for future growth. The market growth is positive, but it is important to note that this industry is still emerging with substantial challenges. Still, success will depend on a few factors, including technological advancements, government support, and market demand. Any technological breakthrough in this market will likely lead to a significantly higher growth rate than projected. The rising expenditure of most oil and gas companies for pipeline infrastructure, network monitoring, and an increase in leakage accidents will likely drive the pipeline inspection and monitoring market. Likewise, increasing oil and gas demand in developing countries and the augmented demand for pipeline monitoring due to improved pipeline infrastructure offer excellent opportunities to this market.

Siemens AG (US), Honeywell International Inc. (US), Huawei Technologies Co. Ltd. (China), BAE Systems (UK), and TransCanada PipeLines Limited (Canada) are some of the key players in the pipeline inspection and monitoring market. These companies account for significant shares due to their extensive product portfolio, wide geographical presence, and solid customer base. These market players are ranked according to their revenues, product offerings, customer bases, and geographical presence.

Pipeline inspection and monitoring potential

Pipeline inspection and monitoring techniques vary across regions like North America, Asia Pacific (APAC), Europe, South America, the Middle East, and Africa. In North America, where extensive pipeline networks exist, regulatory frameworks emphasise integrity management programmes. APAC faces challenges from huge distances, diverse terrain, and rapid industrialisation. Europe focuses on stringent safety regulations and the use of advanced technologies. South America grapples with environmental concerns, while the Middle East and Africa (MEA) tackle desert conditions and security considerations. Tailoring inspection strategies to these regional nuances is essential for effective pipeline maintenance and safety.

By location

Pipeline inspection and monitoring techniques consider location-specific details to ensure adequate maintenance and safety. For instance, coastal areas are prone to corrosive saltwater exposure, therefore special attention is given to corrosion prevention measures. In regions with seismic activity, advanced inspection methods are employed to assess pipeline integrity and withstand potential earthquakes. Areas with extreme temperatures, such as arctic regions or desert environments, require specialised monitoring to prevent thermal stress or permafrost-related issues. Urban locations demand meticulous planning to minimise disruptions to existing infrastructure during inspections. Considering these, location-specific factors allow for tailored approaches that address the unique challenges and ensure the reliability and longevity of pipeline systems.

By region

North America accounted for the largest share, followed by APAC, Europe, and MEA of the pipeline inspection and monitoring market 2022 - 2030. However, the pipeline inspection and monitoring market in APAC and MEA is poised for substantial growth as companies in these regions adopt new technology solutions to enhance the security and robustness of their pipeline infrastructure operations. This heightened focus on monitoring critical infrastructures, including pipeline networks, is driven by the need for secure and efficient operations in various industries. The increasing security breaches targeting large-scale pipeline infrastructure are a notable trend shaping the market. This leads to rising demand for advanced security and monitoring solutions to safeguard pipelines from vulnerabilities.

Key barriers and challenges

The pipeline inspection and monitoring market faces various barriers and challenges hindering its growth and effectiveness. One major challenge is the vast network of existing pipelines, making inspecting and monitoring them comprehensively difficult. Additionally, ageing infrastructure, remote locations, and harsh environmental conditions hinder accessibility. Furthermore, the high cost of advanced inspection technologies and the need for more skilled personnel in operating and maintaining them add to the challenges. To overcome these barriers, collaboration between stakeholders is crucial. Governments, pipeline operators, and technology providers need to work together to develop efficient inspection and monitoring strategies. Investment in research and development can lead to cost-effective solutions and innovations tailored to address specific challenges. Training programmes and partnerships can help bridge the skills gap by educating and empowering personnel to utilise advanced technologies. Embracing digitalisation and remote monitoring techniques can improve accessibility and reduce the need for physical inspections in remote areas. By proactively addressing these barriers and fostering collaboration, the pipeline inspection and monitoring market can thrive, ensuring safer and more reliable energy infrastructure.

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Pipeline construction SHOWCASE

Cappline B.V., the Netherlands

Cappline B.V. is a young company specialising in welding solutions and pipeline construction equipment, mainly for the onshore pipeline industry. With our extensive expertise and commitment to excellence, we have established ourselves as a trusted partner for companies worldwide in a very short time. Our mission is to provide innovative, reliable, and efficient solutions that meet the unique needs of our clients.

One of our key features is the CAPP-Crawler and its zero-emission design. Traditional welding equipment often relies on fossil fuels, contributing to air pollution and carbon emissions. In contrast, our CAPP-Crawler is battery powered, significantly reducing cost and its environmental footprint.

With this innovative solution, we are proud to lead the way in promoting eco-friendly practices in the pipeline welding industry.

The CAPP-Crawler is more than just an environmentally conscious choice; it is also a versatile and efficient tool for pipeline welding. Designed with the needs of welders in mind, this state-of-the-art equipment carrier offers exceptional mobility and manoeuvrability, enabling seamless navigation through challenging terrains and tight spaces. Its rugged construction ensures durability and reliability, even in the harshest working conditions.

At Cappline we prioritise safety and adhere to stringent safety protocols in all our operations. We understand the importance of maintaining a safe working environment, not only for our personnel but also for our clients and the communities we serve.

We pride ourselves on our ability to provide customised solutions that meet the unique requirements of each client. Our team works closely with our clients to understand their specific needs, project goals, and budget constraints. This collaborative approach enables us to tailor our services to deliver the best outcomes, ensuring client satisfaction at every stage of the project.

Projects update

After months of dedicated effort, the team at Cappline is thrilled to announce the successful completion of the CAPP-Crawler project. This innovative welding equipment carrier represents a significant leap forward in pipeline construction technology, embodying our commitment to sustainability and efficiency.

The CAPP-Crawler is designed to meet the needs of modern pipeline projects, particularly those involving smaller diameter pipelines where manual welding is typically used. One of its standout features is its zero-emission design, achieved through battery power, which significantly reduces both costs and environmental impact compared to traditional fossil fuel-powered equipment.

Vietz Pipeline Equipment Manufacture in Germany further developed the CAPP-Crawler for Cappline, equipping it with an advanced electrical hydraulic system, providing exceptional mobility and manoeuvrability. The vehicle is remote-controlled, further enhancing its operational efficiency and safety on-site. The design minimises downtime with fewer parts than conventional vehicles, ensuring reliability and low maintenance costs.

By replacing the need for boom trucks and additional drivers, the CAPP-Crawler not only cuts operational costs but also delivers a quick return on investment. It's a testament to our innovative approach, designed to support eco-friendly practices in the welding industry and push the boundaries of what's possible in pipeline equipment.

We are incredibly proud of this achievement and excited to see the positive impact the CAPP-Crawler will have on our clients' projects. At Cappline B.V. we remain committed to developing cutting-edge solutions that drive success and sustainability in the pipeline industry.

Figure 1. Cappline B.V. office.

Figure 2. CAPP-Crawler, battery powered equipment carrier.

Pipeline construction SHOWCASE

Michels Corporation, USA

Established in 1959 in the Midwestern United States, Michels is an international leader in energy and infrastructure construction. Through organic growth, strategic acquisitions and an understanding of our customers' current and future needs, Michels has expanded into the civil, energy, energy transition and renewables, foundations, marine, transportation, and water and wastewater industries.

Our core values of safety, environment, dedication, teamwork, integrity, social responsibility, and sustainable operations guide our actions, regardless of the type of work being performed.

The Michels Family of Companies builds solutions for safe, modern infrastructure throughout the world. Our engineering, procurement and construction services are supported by 8000 people, 17000 pieces of heavy equipment, more than 50 offices in the US, and operations in Canada, Australia, and Europe. In 2024, Michels was named the 34th largest contractor on the Engineering News-Record (ENR) Top 400 list.

Figure 1. Michels Pipeline constructed 134 miles of 42 in. pipeline to deliver natural gas from supply basins in the Haynesville shale play in northeast Louisiana to liquid natural gas terminals along the Gulf Coast.

Figure 2. During peak construction operations, approximately 1000 Michels people worked on the massive pipeline project in northeast Louisiana.

As a member of the Michels Family of Companies, Michels Pipeline, Inc. is a leading mainline pipeline, fabrication, facilities, and integrity, maintenance, and repair contractor. We partner with our customers to nurture transmission systems from initial planning through decommissioning. Our full-service construction services support traditional and renewable resources. We design, build, maintain and expand all aspects of critical networks.

Beyond serving society by providing the means to move life-sustaining resources from generation plants through distribution to endpoint users, we pledge to work responsibly and respectfully with regard to the environment.

Project highlight

Michels constructed 134 miles of 42 in. pipeline to deliver natural gas from supply basins in the Haynesville shale play in northeast Louisiana to liquid natural gas terminals along the Gulf Coast. Construction was done on an aggressive schedule. During peak construction operations, approximately 1000 people worked on the project.

Michels Pipeline, Inc. was supported by Michels Trenchless, Inc., which completed nine horizontal directional drills (HDD) totalling approximately 4 miles. The crossings include interstates, bayous, marshes, and rivers between Shreveport and Lake Charles. Michels Construction, Inc.'s foundation group installed sheet piles to assist with trench support and dewatering.

FOCUS ON EXCAVATION

Eneida Hoxha, Tesmec, Italy, writes about sustainable solutions for pipeline trenching.

In the evolving landscape of oil and gas infrastructure, Tesmec stands as a global leader in advanced excavation solutions. The company's commitment to cutting-edge technology, sustainability, and an impressive project portfolio has made it a pivotal player in shaping the future of rock trenching and surface mining. With a deep understanding of client needs, particularly regarding varying soil characteristics, Tesmec delivers fast and sustainable solutions across five primary systems: pipeline excavation; heavy civil works; network laying; surface mining; and earthworks. These solutions ensure that Tesmec trenchers can address a wide array of trenching scenarios, providing tailored responses to meet specific project requirements.

Comprehensive trenching solutions

Tesmec's product lineup includes three main types of trenchers: Rock Saw, Chainsaw, and Rock Hawg. Each is designed to tackle

Figure 1. 1675 EVO Chainsawin use in Chile.

distinct excavation challenges, ensuring highly specialised solutions for various projects.

The Chainsaw Trenchers are well-suited for projects involving water conduits, utilities, pipelines, and cable ducts in residential areas or near existing infrastructure. They offer exceptional performance in hard and abrasive rock conditions, providing precise and efficient excavation. By utilising Chainsaw Trenchers, operators can reduce the number of machines needed on-site, lower operating costs, and minimise environmental disruption. This makes them invaluable for urban infrastructure projects.

Advanced Chainsaw Trenchers: meeting the demands of oil and gas pipeline projects

Chainsaw Trenchers from Tesmec are at the forefront of meeting the rigorous demands of oil and gas pipeline projects. Their design and functionality are tailored to ensure precise trenching in challenging conditions, particularly in hard and abrasive rocks. These trenchers can excavate trenches to significant depths and widths, making them suitable for large diameter pipelines and complex project requirements.

The advanced features of Tesmec Chainsaw Trenchers include:

- High cutting precision: Equipped with state-of-the-art cutting systems that ensure precise trench dimensions, reducing the need for rework.
- Durability and reliability: Built to withstand harsh working conditions, these trenchers deliver consistent performance and require minimal maintenance.
- Efficiency: The design allows for rapid trenching, significantly reducing project timelines and associated costs.
- Environmental considerations: By minimising the number of machines on-site and reducing material waste, these trenchers help lower the environmental impact of pipeline projects.

Local support and comprehensive services

Tesmec's global presence is reinforced by a network of subsidiaries that offer trenchers, consulting services, project management, after-sales support, rental, and fleet management. This local presence ensures the availability of up-to-date spare parts and experienced staff, enabling prompt and efficient service. Tesmec supports its clients at every stage, from pre-acquisition consultation to continuous post-sale and spare part support. The company also provides on-site supervision and comprehensive operation and maintenance (O&M) packages to maximise machine efficiency.

Commitment to safety and efficiency

Safety is a fundamental priority at Tesmec. By reducing the number of machines and personnel required on construction sites, Tesmec trenchers enhance both safety and productivity. Tesmec trenchers minimise environmental impact by controlling dust, noise, and vibrations. These machines allow for precise excavation, reducing the amount of material extracted and focusing action only on the necessary areas. By consolidating multiple operational steps into a single process, Tesmec trenchers limit the number of personnel on construction sites, improving safety and operational efficiency.

Environmental sustainability

Tesmec is deeply committed to environmental sustainability, developing technologies that ensure fewer machines are needed on jobsites, thereby reducing CO_2 emissions and fuel consumption. For example, the Tesmec Rock Hawg significantly reduces emissions and fuel use by replacing multiple conventional machines. Tesmec surface miners operate with minimal environmental impact, generating low levels of dust and noise, negligible vibrations, and conserving water. The 1875 EVO, Tesmec's largest trencher, offers high production performance while reducing environmental emissions. Additionally, the material extracted during excavation can be repurposed to cover the excavated area, promoting environmental conservation.

Figure 2. 1675 EVO Chainsaw for a gas pipeline project in France.


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Cutting-edge technological innovations

Tesmec continuously advances its technology to meet the evolving demands of the construction industry. The company's trenchers are equipped with state-of-the-art technologies, including:

- Detection and mapping solutions: Enabling 3D mapping of below and above-ground structures.
- TrenchTronic: Automatic trenching and self-diagnostic technology that enhances ease of use and productivity.
- TrenchIntel: A 3D-GPS automatic guidance system that precisely controls machine steering, trajectory, and trenching depth.
- Re.M: Remote monitoring and reporting technology for real-time performance insights.
- Smart Tracker: An as-built data recorder that collects data during trenching, reducing survey time and costs.

Figure 3. 1675 Chainsaw in South Africa.

Cost-effectiveness and reliability

Tesmec offers significant cost-effectiveness through the use of fewer machines, resulting in savings on tool costs, fuel, and personnel. The reliability and quality of Tesmec trenchers minimise maintenance needs and downtime. High-quality, original spare parts ensure longer service life and less frequent maintenance.

The future of excavation

Tesmec is set to revolutionise the oil and gas industry with the launch of the 1875XL EVO, a groundbreaking 950 HP chainsaw trencher. Designed for large diameter pipelines and challenging hard rock soils, the 1875XL EVO sets new industry standards with trench depths up to 732 cm and widths up to 213 cm. This trencher's enhanced power and advanced hydraulics boost operational efficiency and streamline digging processes. Key features of the 1875XL EVO include:

- Productivity: Maximise output with the 1875XL EVO tractor and chainsaw, featuring adjustable stabilisers, crumbshoe, and cross conveyor system.
- Technology: Enhance excavation efficiency and fleet monitoring with TrenchTronic and Re.M.
- Safety in cab: Enjoy a pressurised cab with air conditioning, heating, sound suppression, ROPS, and security locks.

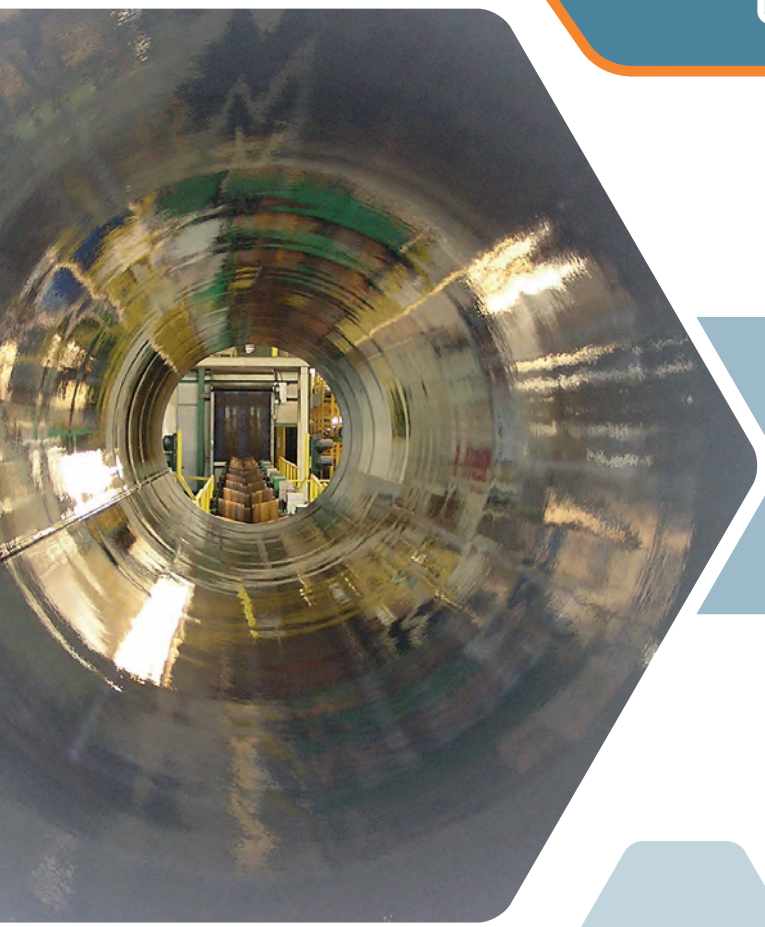
Supporting ambitious projects

The 1875XL EVO is ideally suited for large-scale projects like Saudi Aramco's Master Gas System Phase 3, which aims to convert power plants from oil to natural gas. This initiative will add over 3000 km of pipeline, contributing to Saudi Arabia's cleaner energy mix and net-zero emission goals. The 1875XL EVO's ability to economically trench in hard rock and achieve maximum productivity underpins its role in such transformative projects.

Conclusion

Tesmec's innovative excavation technology is reshaping the oil and gas infrastructure industry. By combining efficiency, flexibility, reliability, and speed, Tesmec trenchers significantly reduce operating costs and environmental impact. With a commitment to safety, sustainability, and technological innovation, Tesmec is not only meeting the evolving needs of its clients but also leading the way in sustainable and efficient excavation solutions. The launch of the 1875XL EVO marks a new chapter in Tesmec's mission to support ambitious projects worldwide, ensuring a future where infrastructure development is both economically and environmentally sustainable.

TIBCHEMICALS



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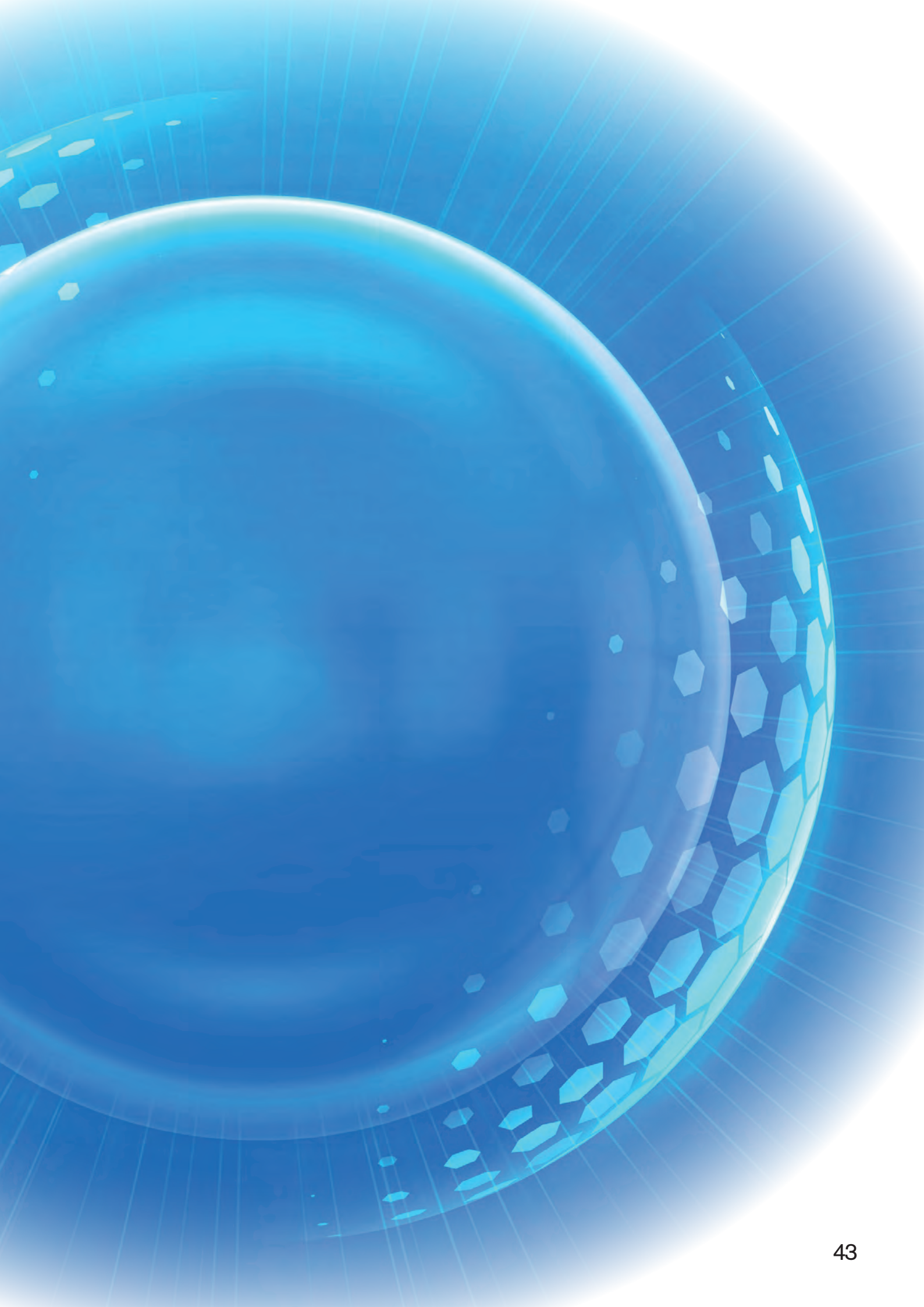
INVESTIGATING ISOLATION FAILURES

Ahmed Wahba Mahgoub, Usman Shahzad, and Ghalib Al-Houtan, Saudi Aramco, Saudi Arabia, discuss the effects of isolation failures in CP performance.

Pipelines are used worldwide to transport a variety of resources such as oil, gas, water, chemicals, etc., which are either found naturally or produced in different sectors of industry. These pipelines are composed of piping systems that are usually welded line pipes and spool pieces of standard or custom lengths. Most of the times flanged connections are considered, for reasons including connection to valves, pumps, plants and many other facilities.

During the design of a cathodic protection (CP) system for an oil/gas plant, electrical isolation is a crucial consideration. While isolating a single pipeline segment from point A to point B is relatively simple using either an isolating flange (IF) or isolating joint (IJ) which requires careful construction, monitoring and maintenance practices, the reality observed is very different. Usually oil/gas plant piping networks greatly complicate the practical expectation of isolation. Although everything above ground in an oil/gas plant is required by regulations to be grounded, it is typical to find CP systems designed based on electrical isolation of the buried piping. Even if isolation is accomplished during plant construction, maintaining it during the facility's life is practically very challenging.



Investigating the failure of IJ

IJ is a costly isolation system and hence its use is limited in the oil and gas industry compared to IF. The failure of IJ has been investigated for different scenarios. In a discussion of the results of IJ failure analysis, it was demonstrated that the most credible corrosion mechanism was internal stray current, caused by CP applied to the pipeline.[1] Other sources provide a sound basis on the stray current corrosion risks associated with IJ failure, with experimental testing using a large-scale experimental model of an IJ.[2] Some illustrate how the IJ failure can significantly impact the CP operation.[3] In turn, this may jeopardise the CP effectiveness and stray current control, maintenance and monitoring endeavours; thus increasing the risk for AC/DC corrosion, as a consequence.

This article focuses on the failure of IF, although the effect on CP is similar regardless of the type of isolation system used. The insulation effectiveness of isolating appurtenances is of paramount importance in CP systems; this article aims to further the investigation and to evaluate the consequences of faulty IF on CP performance.

Generally, pipeline systems are kept intact by using flange isolation kits to electrically isolate and seal flanges. They lessen corrosion brought on by galvanic activity or when used in conjunction with a CP system by preventing metal-to-metal contact. These kits consist of gaskets, nonconductive sleeves and washers. The gaskets separate flanges in metallic piping systems, while the sleeves and washers prevent electricity from flowing across connections. However, improper specification, manufacturing defects and incorrect installation can cause failure in these kits.

Table 1. Pipeline details

Pipeline details	Pipeline length (km)
PL-1 (30 in. pipeline from NGL to GOSP-2)	12.4
PL-2 (36 in. pipeline from GOSP-2 to NGL)	13.2
PL-3 (36 in. pipeline from GOSP-1 to NGL)	37.2
PL-4 (44 in. pipeline from GOSP-4 to NGL)	23.6
PL-5 (44 in. pipeline from NGL to GOSP-4)	22.8

Table 2. Current across the IF

Pipeline	DC current at IF (A)	DC current at IF (A)		
	NGL plant	GOSP-1	GOSP-2	GOSP-4
PL-1	+5.8	-	+1.5	-
PL-2	+37.7	-	+5.3	-
PL-3	+32.5	+6.3	-	-
PL-4	+1.1	-	-	+0.48
PL-5	+2.3			+0.16

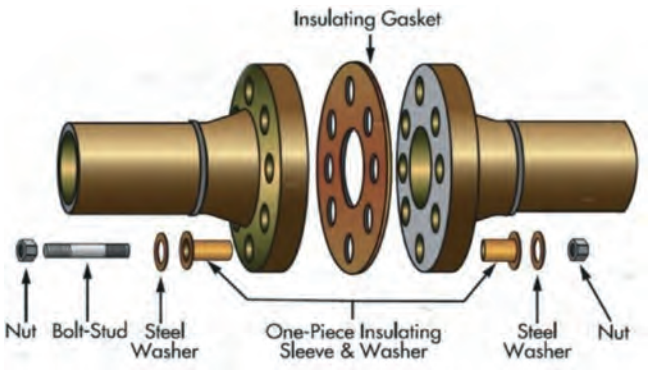


Figure 1. Sample of flange insulating gasket kit.

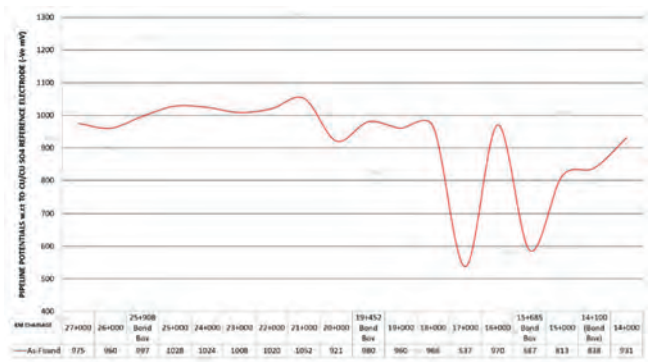


Figure 2. Sample of as-found potential (PL-3).

IF failure considerations

Many of the issues with IF are caused by utilising materials other than those specified. These issues appear to be far more widespread than most people realise. Many failures have happened as a result of materials considered which did not satisfy the design criteria.

Flange isolation kits are critical components in pipeline operations. These kits consist of a gasket that both seals and electrically insolates the pipe joint, together with sleeves and washers to isolate the fasteners.[4] Gasket quality has a significant impact on performance, as does the design of the sealing element itself.

Gasket, sleeve, and washer failures can be reduced considerably by specifying higher grade products in new installations, and ensuring that the product being used is the same as the one specified. In addition, the specifics of gasket material should be documented for each flange, so that new gaskets introduced into the system can be evaluated for their compatibility with different media or electrolytes in the line. Specifications for flange isolation kit sleeve material frequently call for the sleeve to be full length, an undefined measure for which there is no known industry standard. A better specification would require the minimum standard length of the sleeve to extend at least halfway into the back-up steel washers. Figure 1 explains the typical detail of a flange insulating gasket kit.

Moreover, field fabricated isolating flanges could be rendered ineffective by over torqueing and improper alignment, inadequate coating internally and externally, improper selection of gaskets, sleeves, and washers, etc. A detailed approach in how to evaluate IF assemblies is illustrated in "Simple Approach to Pipeline Electrical Isolation" by Joseph L.Pikas.[5] Moreover, the electrical isolation facilities field test is explained in NACE SP0286.[6]

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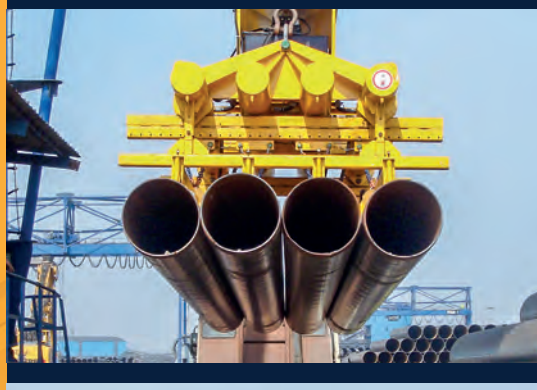

SUXXESION

The plant operation experience suggests that in the event of an IF electrical failure, a thorough investigation should take place. The type of defects found in the isolating flange depend on whether it is shorted across the main isolating gasket or whether it is a sleeve or washer that is cracked or broken. This investigation entails decisions that would reflect either on immediate IF replacement actions or on other peripheral measures to reinforce the effectiveness of the CP system (should the IF replacement be deferred for practical or cost related matters).

Case study

A case study of a CP system for five interconnected pipelines will be illustrated: all pipelines were connected between gas oil separation plants (GOSP) and natural gas liquids (NGL) plants, electrically isolated from both ends by IF and externally coated by fusion bonded epoxy (FBE). The lengths of the pipelines are listed in Table 1.

Table 3. Current pick-up by foreign structures through IFs

Pipeline	DC current across IF located inside NGL plant (A)		DC current pick-up by foreign structures (A) (ON-OFF)
	TR unit ON condition	TR unit OFF condition	
PL-1	+5.81	+4.2	+1.6
PL-2	+37.7	+11.1	+26.6
PL-3	+32.5	+5.7	+26.7
PL-4	+1.1	+0.6	+0.9
PL-5	+2.3	+1.9	+0.3
Current (Foreign Structures) (A)			+56.1

Table 4. Electrical isolation status of IFs

Pipeline	IF location			
	NGL plant	GOSP-1	GOSP-2	GOSP-4
PL-1	FAILED	-	FAILED	-
PL-2	FAILED	-	FAILED	-
PL-3	FAILED	FAILED	-	-
PL-4	FAILED	-	-	PASS
PL-5	FAILED			PASS

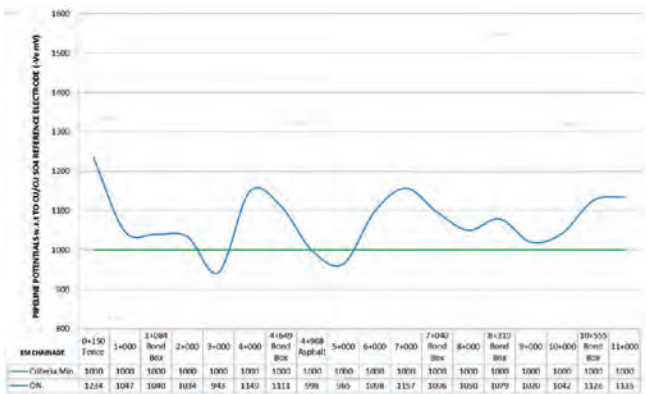

Figure 3. Sample of ON potential (PL-5).

The interconnection pipelines achieved the mechanical completion certificate in 2016. As-found pipe to soil potential (PSP) measurements were completed after the mechanical completion and prior to the permanent impressed current cathodic protection (ICCP) system energisation/ commissioning. Figure 2 depicts a sample of the PL-3 as-found potentials. The measured as-found potentials were slightly more negative than usual native potentials; this was due to existing pipelines and temporary magnesium anodes being connected to the proposed pipelines via bond boxes and test stations.

The permanent ICCP system was designed to achieve the proper protection criteria based on company and international standards and transformer rectifier (TR) is rated for 100 V/100 Amps DC.[7,8,9] The amount of CP current required was limited to protect the pipelines and achieve the optimum level of polarisation based on the accepted criteria. Commissioning for the CP system was attempted at the end of 2016. According to a preliminary CP commissioning report, ON measured PSP does not meet the commissioning criteria (CP commissioning criteria is CP ON potential shall be more negative than -1000 mV and less negative than or equal to -2500 mV) and was prone to commissioning failure. Figure 3 illustrates a sample of the PL-5 ON measured PSP.

Furthermore, the report investigated locations of prolonged and low CP ON measured PSP that are often (but not always) related with chain-age around the NGL as explained below:

- The ON PSP of the PL-1 is ranging from -903 mV to -1314 mV w.r.t Cu/Cuso4 Reference Electrode (CSE). Based on the ON PSP profile, more than 63% of the observed potentials were less than -1000 mV w.r.t CSE, indicating a commissioning failure due to not meeting the criteria.

- The ON potential of the PL-2 is ranging from -926 mV to -1272 mV w.r.t CSE. More than 58% of the identified potentials were less than -1000 mV w.r.t CSE, indicating that commissioning was not successful based on the ON PSP profile and commissioning criteria.

- The ON potential of the PL-3 is ranging from -865 mV to -1328 mV w.r.t CSE. Based on the ON PSP profile, more than 52% of the observed potentials were less than -1000 mV w.r.t CSE, indicating a commissioning failure.

- The ON potential of the PL-4 is ranging from -1013 mV to -1447 mV w.r.t CSE. The ON potentials recorded were more negative than -1000mV.

- The ON potential of the PL-5 is ranging from -993 mV to -1248 mV w.r.t CSE. More than 71% of the identified potentials were less than -1000 mV w.r.t CSE, indicating that commissioning was not successful based on the ON PSP profile and commissioning criteria.

The IF's integrity was tested by measuring the current across the IF using a swain meter. Table 2 shows the location of the IFs and current values measured when the CP System

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was turned on and all existing pipelines were connected. +ve sign means current coming from plant side to pipeline and -ve sign means current coming from pipeline to plant side.

Table 3 shows the current across the IFs placed inside NGL plants, as well as the current picked up by plant piping's and system grounding (foreign structures), when all existing pipelines were connected.

Observations

The measured current values of PL-1 by swain meter for the IF inside GOSP-2 was 5.81 A, as this current is passing across the IF, indicating IF failure as electrically short. Similarly, the measured current by swain meter for the IF located inside the GOSP-2 plant was 1.52 A, indicating IF failure as electrically short.

The measured current values of PL-2 by swain meter for the IF inside the NGL plant was 37.7 A, as this current is passing across the IF, indicating IF failure as electrically short. Similarly, the measured current by swain meter for the IF located inside the GOSP-2 plant was 5.22 A, indicating IF failure as electrically short.

The measured current of PL-3 by swain meter for the IF located inside the NGL plant was 32.50 A, as this current is passing through the IF, indicating IF failure as electrically short. Similarly, the measured current by swain meter for the IF located inside the GOSP-1 plant was 6.32 A, indicating IF failure as electrically short.

The measured current of PL-4 by swain meter for the IF located inside the NGL plant was 1.1 A, as this current is passing through the IF, indicating IF failure as electrically short. While, the measured current by swain meter for the IF located inside the GOSP-4 plant was 0.48 A, indicating IF as electrically isolated.

The measured current of pipeline PL-5 by swain meter for IF located inside NGL plant was 2.24 A, as this current is passing through the IF, indicating IF failure as electrically short. While, the measured current by swain meter for the IF located inside the GOSP-4 plant was 0.16 A, indicating IF as electrically isolated. Table 4 summarises the IF location and electrical isolation status.

The total current pick-up by foreign structures is 70 A, considering total current through IFs and bonding current. Hence, the rectifier output has been set at 85 A for CP system commissioning. As a result, the total current picked up by newly commissioned pipelines from its own new CP system is only 15 A. Since then, a maximum current of 82% has been picked up by foreign structures from the new CP system, while only 18% has been picked up by commissioned pipelines. As a result, commissioned pipelines are not receiving the required current to meet protection criteria at all points.

The pipeline's CP system design basis was based on complete electrical isolation; the existing CP current leakage condition between the pipelines and the NGL/GOSPs has resulted in an ICCP that is insufficiently sized to achieve protected potentials on the intended assets. Swain clamp readings with the CP system turned on show a large drain of CP current to the plant side of the GOSPs, particularly in the NGL plant. The CP current returns to the CP system's negative drain point via an unexplained pathway across most IFs.

Discussion

Leaving an electrically failed IF in service can have serious implications. This is due to the fact that by leaving a shorted IF (or an IF with reduced insulation properties), important questions about whether peripheral measures would be sufficient to maintain CP effectiveness are raised. Such peripheral measures may include, for example, the installation of DC decoupler systems or the installation of additional CP systems. These are, of course, subject to sound reasoning, which clearly justifies that the CP effectiveness is not jeopardised by the IF failure, and thus the IF replacement can be postponed. However, the need to replace the failed IFs cannot be averted at all occasions. For instance, the replacement can be become an immediate necessity when there is a gas leak through the insulation.

In this particular situation, most of IFs are found defective; it may not be possible to make repairs without taking the line out of service. In today's competitive environment, this makes it an impossible task. Based on that, a remedial CP solution is mandatory to achieve the company's CP commissioning criteria.

The proposed CP solution should consider the following pre-existing conditions:

- Existing and installed CP systems for the interconnecting pipelines.
- Existing interconnecting pipelines and IF arrangements.
- Existing grounded facilities on plant side for both NGL and GOSPs.
- Existing CP system installations for both NGL and GOSPs.

The CP solution should also consider and mitigate the following project risks:

- Limitations of the existing CP System for interconnecting pipelines.
- Possible internal electrolytic bridging by the CP currents across the IFs due to conductive internal product.
- Excessive current drainage of CP system on the plant side (grounding and/or buried services) at NGL and all GOSPs.

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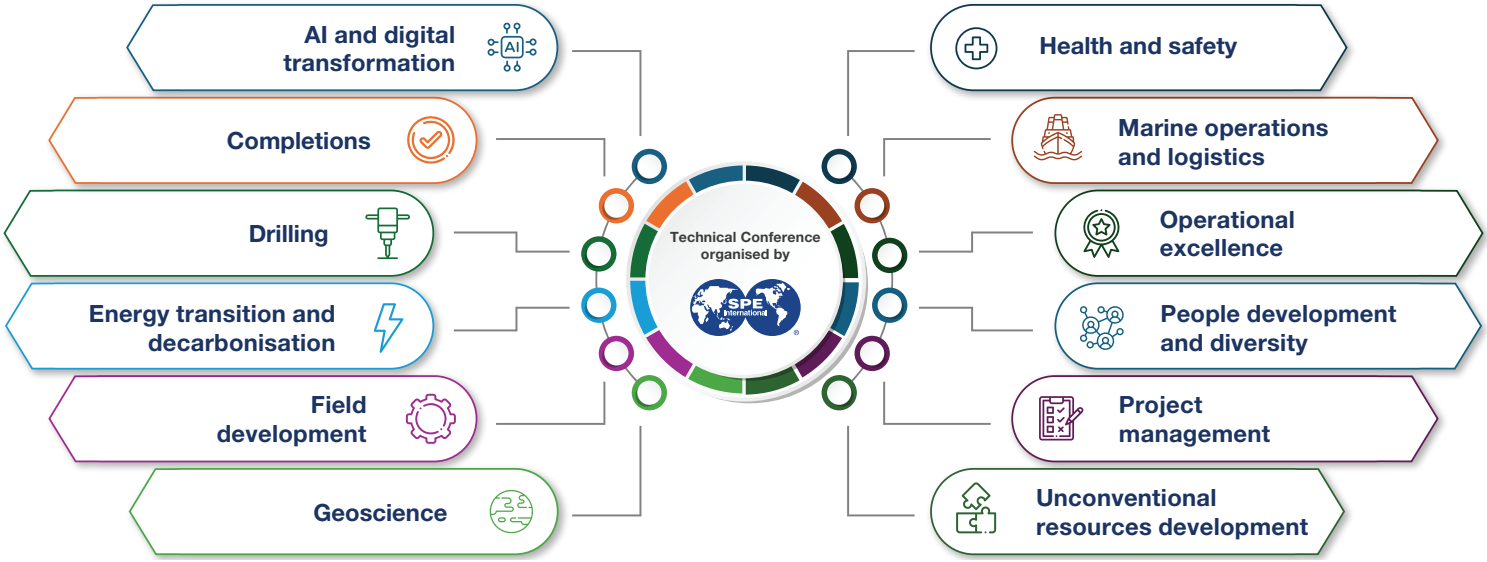

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A DEEP DIVE INTO INTERNAL CORROSION

Henry Osabohien, Ph.D., ADNOC Onshore, Abu Dhabi, UAE, explores the causes of internal corrosion in gas flow lines and how to prevent it, through chemical treatment and corrosion monitoring locations and methods.

Corrosion can be described as the deterioration of materials, especially metals, by chemical interactions with their environment.[1] It can be classified into different categories based on the materials, environment, or morphology of the corrosion damage. Metals corrode due to the natural consequence of their temporary existence in metallic form. As shown in Figure 1, the more energy required to bring about the change of a metal from its natural state to its metallic form, the more reactive the metal will be to its environment or the more inclined it is to corrode. The most common form of corrosion is rusting, which occurs when iron combines with oxygen and water.

In oil and gas production, the flowline serves as the initial pipeline system that connects to the wellhead. As shown in Figure 2, the flowline carries the total produced fluids (e.g., oil, gas, and production water) from the well to the first piece of production equipment, typically a production separator. Gas flowlines transport both associated and non-associated gases to production equipment. Associated gas is produced from crude oil extraction. It contains methane, ethane, and hydrocarbons, while non-associated gas is a natural gas found in a natural reservoir and does

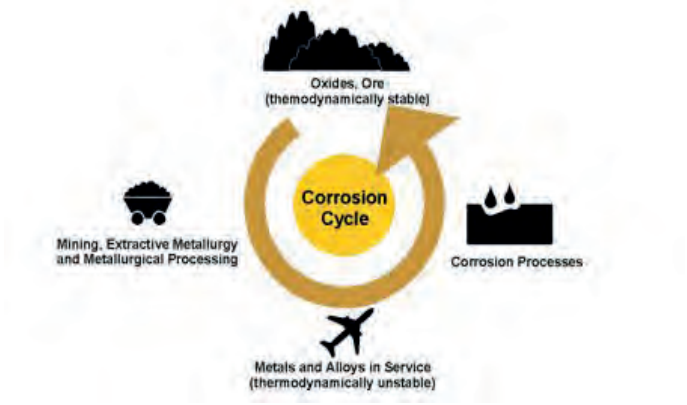

Figure 1. Corrosion cycle.

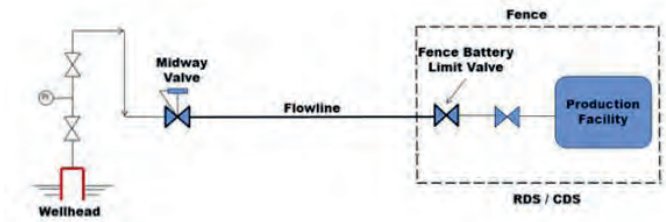

Figure 2. Schematics of flowlines.

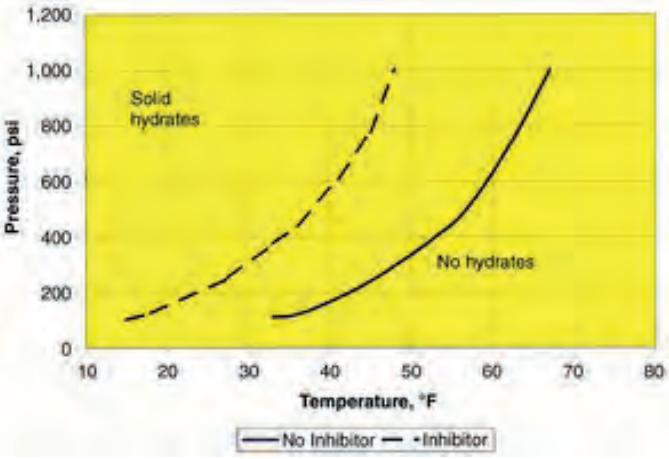

Figure 3. Effect of inhibitors on hydrate prevention.

Table 1. Guidelines for selection of internal corrosion monitoring locations for different gas systems

S/N	Asset	System
1	Well site piping	Downstream of choke valve i.e. downstream of the first bend
2	Flowlines	i. Inlet to mainline, trunkline, or plant ii. Pig launcher bypass line iii. Inlet to plant and downstream of the pig receiver
3	Main oil lines/ trunklines, transfer lines	Downstream of the pig receiver
4	Separators and scrubbers	At the gas outlet stream, especially at the cooler outlet

not contain crude oil. Water, dissolved ions (e.g., Cl- and Ca2+), and acid gases (e.g., CO_2 and H_2S) are frequently found in the gases passing through flowlines. Severe corrosion of the inner wall of steel pipes happens when temperature, pressure, and stress are combined. The primary element affecting natural gas flowline integrity is internal corrosion. In addition to weakening pipes and thick walls, it might cause leaking incidents. When gas flowlines burst, it not only results in significant financial loss but also pollutes the environment.

Causes of corrosion in gas flowlines

Water, oxygen, and dissolved ions

Water, oxygen, and dissolved gases are major factors influencing corrosion, otherwise referred to as rusting. Rusting occurs in flowlines made of carbon steel, stainless steel, and other alloys containing iron. It is an electrochemical process that starts with the flow of electrons from iron to oxygen.[2] Iron acts as the reducing agent by donating electrons, whereas oxygen acts as the oxidising agent by accepting electrons. The primary reaction involves the reduction of oxygen.[2]

$$O_2 + 4e^- + 2H_2O \rightarrow 4OH^-$$

Acidity strongly influences this process because it forms hydroxide ions. Indeed, at low pH, oxygen accelerates the corrosion of most metals. The oxidation of iron provides the electrons for the aforementioned reaction, which is described as follows:[2]

$$Fe \rightarrow Fe^{2+} + 2e^-$$

The following redox reaction, which is critical to rust formation, also occurs in water:

$$4Fe^{2+} + O_2 \rightarrow 4Fe^{3+} + 2O^{2-}$$

In addition, the following multistep acid-base reactions affect the course of rust formation:

$$Fe^{2+} + 2H_2O \rightleftharpoons Fe(OH)_2 + 2H^+$$

$$Fe^{3+} + 3H_2O \rightleftharpoons Fe(OH)_3 + 3H^+$$

The following dehydration equilibria:

$$Fe(OH)_2 \rightleftharpoons FeO + H_2O$$

$$Fe(OH)_3 \rightleftharpoons FeO(OH) + H_2O$$

$$2FeO(OH) \rightleftharpoons Fe_2O_3 + H_2O$$

The equations above demonstrate that the presence of water and oxygen determines the formation of corrosion products. When there is a low amount of dissolved oxygen, minerals that contain iron (II) are more likely to form, such as FeO and black lodestone or magnetite (Fe_3O_4). Ferric materials with the nominal formula $Fe(OH)_{3-x}O_{x/2}$ are preferred in environments with high oxygen concentrations. Rust undergoes a transformation over time, which is a result of the gradual progress of solid reactions. In addition, the existence of other ions, such as Ca^{2+}, serves as electrolytes to accelerate the process of rust formation or react with iron hydroxides and oxides to produce various Ca, Fe, O, and OH compounds, so influencing these intricate processes. In a laboratory setting, a ferroxyl indicator solution can be used to detect the initiation of rust formation. The solution is capable of detecting both Fe^{2+} ions and hydroxyl ions. The presence of Fe^{2+} ions is represented by blue patches, while the presence of hydroxyl ions is indicated by pink patches.

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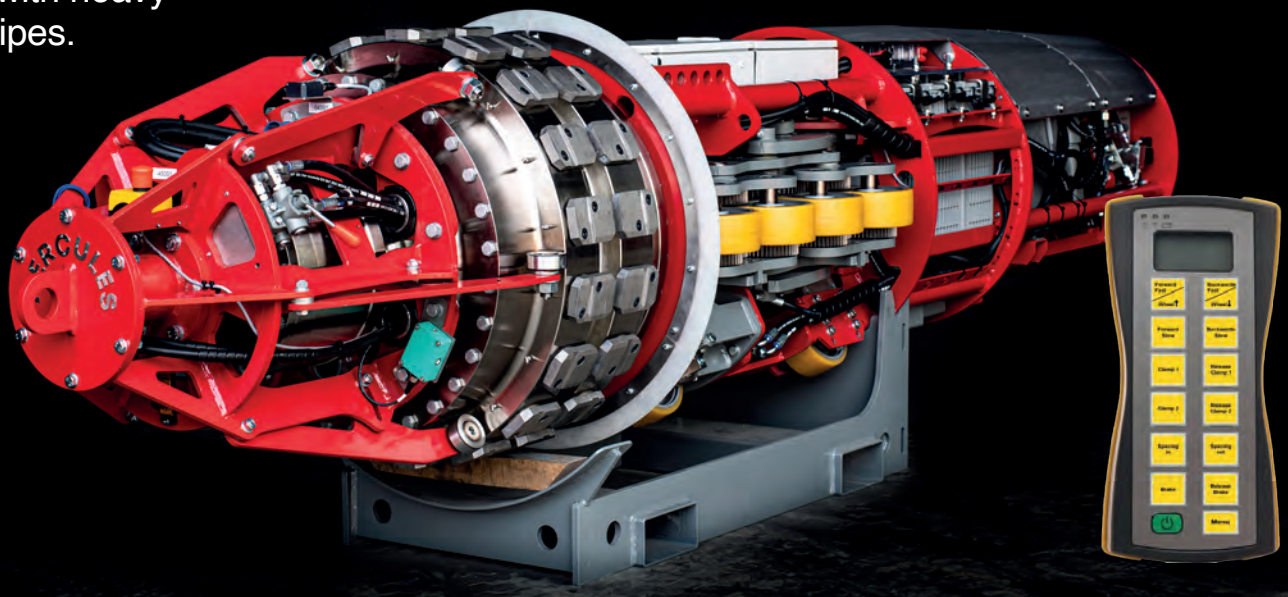

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Carbon dioxide

Carbon dioxide undergoes dissolution in water, resulting in the formation of carbonic acid. This process leads to a reduction in the pH of the water and an increase in its corrosive nature. Corrosion that occurs when there is dissolved carbon dioxide is commonly known as sweet corrosion.[3]

$CO_2 + H_2O \rightleftharpoons H_2CO_3$ (carbonic acid)

$Fe + H_2CO_3 \rightarrow FeCO_3 + H_2$ (Iron carbonate)

The solubility of carbon dioxide is determined by the temperature, pressure, and water composition. Elevated pressure, decreased temperature, or decreased water salinity all enhance the solubility of CO_2, resulting in a decrease in pH. Several dissolved minerals act as buffers in the water, reducing the impact of the previously described alterations on pH lowering.

The corrosiveness of a system can be predicted by utilising the partial pressure of carbon dioxide as a measure. The subsequent equation calculates the partial pressure of carbon dioxide:

CO_2 partial pressure (psi) = total pressure of gas (psi) x mole fraction of CO_2 in gas

Empirical evidence suggests that when an electrolyte is present, corrosion rates can be significantly accelerated when the partial pressure exceeds 30 psi. Partial pressures ranging from 7 psi to 30 psi can also lead to elevated corrosion rates. Even pressures below 7 psi can still result in corrosion rates that are classified as low to moderate.

Hydrogen sulphide

Hydrogen sulphide exhibits solubility in water under typical pressures and temperatures encountered in oilfield activities. When dissolved, it acts as a mild acid and tends to induce pitting. Attack due to the presence of dissolved hydrogen sulphide is referred to as sour corrosion.[4]

The steel's general corrosion reaction is:

$H_2S(aq) + Fe \rightarrow FeS + H_2$

The iron sulphide that is formed typically sticks to the surface as a black scale and acts as a cathode for the steel. This, when combined with water, leads to localised and severe corrosion in the form of deep pitting. Nevertheless, in certain cases, a thin layer of iron sulphide scale may have a relatively low permeability, thereby impeding the corrosion process, provided that the scale is not removed by erosion or any other means.

Sulphate-reducing bacteria (SRB) can produce hydrogen sulphide. These bacteria facilitate corrosion by thriving in oxygen-deprived environments and converting sulphate ions into hydrogen sulphide. The absence of oxygen in the area beneath a bacterial colony creates a situation where the majority of the electrolyte acts as a differential aeration cell. In this environment, the bacteria can generate hydrogen sulphide, which can lead to significant localised corrosion.

Under specific pressure and temperature circumstances, the hydrogen generated by the corrosion reaction can permeate into the metallic structure, leading to the weakening and subsequent formation of cracks in vulnerable metals.

Table 2. Monitoring methods for different gas assets

S/N	Corrosion monitoring	Sour gas	Wet hydrocarbon gas
1	Weight loss corrosion coupons	Recommended	Recommended
2	Process parameters/sampling and analysis	Recommended	Recommended
3	Electrical resistance probes	Optional	Recommended
4	New generation ER probes	Optional	Recommended
5	LPR probes	Not applicable	Not applicable
6	Galvanic probes	Not applicable	Not applicable
7	Bio probes	Recommended	Not applicable
8	Fixed UT	Recommended	Recommended
9	Hydrogen probes	Recommended	Optional

Chloride ion

Water is the most prevalent electrolyte in associated gas production, and chloride ions are the most frequently occurring ions in the solution. The chloride ion and its concentration have a major effect on the corrosion reactions, as noted below:

- Higher concentrations of chloride ions elevate the conductivity of the solution, thereby enabling the corrosion currents to be comparatively greater.
- Chloride anions, which are negatively charged ions, readily undergo reactions with cations such as Fe^{2+} when they enter the solution at the anode of a corrosion cell. Consequently, these processes diminish polarisation by facilitating the entry of more cations into the solution, thereby augmenting the conductivity of the electrolyte.
- A higher concentration of chloride ions enhances the vulnerability of austenitic stainless steels to pitting and cracking.

Physical variables

When developing and executing a corrosion control programme, it is essential to take into account the factors of temperature, pressure, and velocity. The effective use of inhibitors and cathodic protection as approaches for controlling corrosion is highly contingent upon these characteristics.[7] The relationship between temperature and pressure is interconnected, and the corrosiveness of a system is additionally affected by velocity.

Different forms of corrosion may exist in gas flowlines.

- Uniform corrosion.
- Pitting corrosion.
- Bimetallic corrosion.
- Flow-enhanced corrosion (erosion corrosion).
- Cavitation corrosion.
- Intergranular corrosion.
- Hydrogen-induced failures.
- Sulphide stress cracking (SSC).
- Stress corrosion cracking (SCC).
- Microbiologically influenced corrosion (MIC).
- Acid corrosion.

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Prevention of internal corrosion in gas flowlines

Chemical treatment

Chemical treatments are deployed for the control of corrosion and scale, to reduce flow assurance risks, to improve gas production and injection, and to ensure compliance with export quality.[6] Monitoring the performance of production chemicals is required at regular intervals to assess their efficiency as well as optimise the injection dosage.

Periodic testing, verification, and optimisation of each application shall be carried out in the field, and findings shall be reported. Once chemicals are tested and evaluated for performance, the results of the test or analysis are tracked against the acceptance criteria and the key performance indicators.

Types of chemical treatments:

Corrosion inhibitors

Corrosion inhibition can be described as the application of substances, often in low quantities, to prevent or minimise the corrosion of metals in aggressive media.[8] It entails forming a coating (passivation layer) that prevents contact between the corrosive materials and the metal. These substances used for this process are referred to as inhibitors.

The effectiveness of corrosion inhibitors depends on the composition of the fluid, the quantity of water, and the flow regime. Inhibitors are synthetic or naturally occurring chemicals classified either as organic or inorganic; as oxidants or non-oxidants; or as anodic or cathodic.

Biocides

Biocides are also known as disinfectants, preservatives, sterile and anti-microbial agents, and antiseptics. The strict definition of 'biocide' is that it will kill living cells. Whether it can successfully 'kill' depends upon several variables, not least the dose (i.e. the concentration of biocide) and the time it is in contact with microorganisms. Most biocides also serve as biostatic agents. That is, at concentrations lower than those required to kill, the biocide inhibits cell growth while it is present. Upon removal of the chemical, the bacteria will resume their growth. At doses lower than biostatic, the biocide can even become a source of nutrition and therefore encourage growth.

In oilfield operations, it is usually necessary to dose the system, either periodically or continuously, with biocides that prevent microorganisms from growing or kill them outright. In the oilfield, glutaraldehyde (glut) and tetrakis-hydroxymethyl-phosphonium (THPS) are the most commonly used non-oxidising organic biocides, with smaller amounts of formaldehyde and acrolein.

Hydrate inhibitors

Natural gas hydrates are crystalline solids that occur when water and natural gas mix under high pressure and low temperatures. This phenomenon can manifest in both gas and condensate wells, as well as in oil wells. The distribution and magnitude of hydrate deposits in a well are subject to variation and are influenced by design, operating regime, fluid composition, geothermal gradient in the well, and other considerations.

Hydrate inhibitors are employed to regulate the creation of hydrates in gas flowlines.[9] They can be categorised as environmental, kinetic, and thermodynamic inhibitors.

A conceptually straightforward and environmentally inhibiting method involves drying the gas before cooling. This process involves the adsorption of substances onto silica gel, the cooling and condensation of vapours, the absorption of water into alcohols, or the adsorption of substances onto hygroscopic salts.

The predominant approach for managing gas hydrates has been through the use of 'thermodynamic inhibition'. There are multiple options available:

- Applying heat to the gas.
- Reducing the pressure in the system.
- Introducing salt solutions into the system.
- Administering alcohol or glycol by injection.

An approach to supplying heat to the area where hydrate formation occurs involves utilising electrical-resistance heating through wires that are linked to a transformer. An alternative is to position the choke in a suitably high-temperature region of the manufacturing system. The addition of salts, particularly $CaCl_2$, decreases the production of hydrates by reducing the chemical reactivity of water and decreasing the ability of gas to dissolve in water. Currently, there is a growing trend towards using the last option, which involves shifting from methanol to ethylene glycols. This transition is motivated by concerns related to health, safety, and the environment (HSE). Figure 3 demonstrates the overall impact of these inhibitors. This results in the hydrate-formation curve moving towards lower temperatures, supposedly outside the PT production area, instead of completely resolving the issue. It is feasible to accurately calculate the phase diagram for gases, water, methanol, or glycols. The primary limitation of this inhibitory approach is the substantial amount of methanol or glycol needed. This has a significant effect on both the expenses associated with operations and the management of the transportation of resources, especially in the case of wells and pipelines located offshore.

In response to these issues, researchers have been exploring the use of kinetic hydrate inhibitors, which are low-dose compounds that hinder the formation of hydrate nuclei or the clumping together of nuclei into larger crystals, also known as 'threshold hydrate inhibitors'.

Other chemicals

- Oxygen scavengers.
- H_2S scavengers.
- Scale inhibitors, among others.

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Corrosion monitoring

Corrosion monitoring is the systematic evaluation and prediction of corrosion tendencies in operational plants and equipment.

Selection of corrosion monitoring locations

There are no fixed rules for the selection of corrosion monitoring locations. Before defining locations, the first task is to identify areas susceptible to corrosion. When identifying the most suitable monitoring locations, experience from similar operations is often the most useful information to utilise. Inspection and maintenance reports will also provide information on areas of each system that are vulnerable to corrosion. If inspection or monitoring data is already available for the asset, an assessment of the data and the locations can aid in the decision-making process for future monitoring locations. Table 1 states the guidelines for the selection of internal corrosion monitoring sites.

Factors to consider when deciding on suitable corrosion monitoring locations and orientations include:[5]

- Corrosion risk assessment.
- Location of the corrosive attack.
- Mode of attack.
- Flow effects.
- Process conditions.
- The chemical injected and the injected location.
- Periods of upset conditions.
- Material type.

Selection of corrosion monitoring methods

Having identified the most appropriate corrosion monitoring locations, it is equally important to select the correct corrosion monitoring methods (i.e. the equipment types and techniques). The method to be applied should be selected to provide useful, accurate, and reliable information, taking into account the environmental conditions, actual and predicted corrosion mechanisms, technical and economic feasibility of the application (including data acquisition costs), and health and safety considerations.

There are no set rules for selecting corrosion monitoring methods. Operating conditions can vary considerably, and each available method provides a limited range of information. Therefore, it is recommended to apply multiple corrosion monitoring methods in a single system to enhance the confidence and confirmation of the collected data, given the frequent occurrence of errors within corrosion monitoring systems.

Generally, any corrosion monitoring scheme should include, as a minimum, three primary methods:

- Corrosion coupons.
- Fluid sampling and analysis.
- Other methods (such as traditional ER, new generation ER, LPR, galvanic probe, or fixed UT).

Note that the second method comprises offline sampling and analysis and, hence, does not require any specialist facilities.

The selection of the third method will be dependent on the particular process or asset type and the expected corrosion rate or morphology. In addition to the three primary methods, consideration can be given to incorporating one or more additional secondary monitoring systems. These would normally be deployed in addition to (and not to replace) any of the primary methods unless it was not physically possible to use a primary method.

Such secondary monitoring systems could comprise:

- Bacterial monitoring (bio-probes).
- Hydrogen monitoring (intrusive or non-intrusive).
- New developing or experimental techniques.

Except for bio-probes, the secondary methods may be considered experimental, and hence, if these are selected, there is unlikely to be reliable operational experience of their performance.

Weight loss coupons are highly recommended in all media because the coupons are cheap and easily applied, they are made of similar material to a vessel or pipeline for comparison.

Conclusion

Gas flowlines are generally susceptible to internal corrosion due to the presence of water, acid gases (such as CO_2 and H_2S), and dissolved ions (such as Cl^- and Ca^{2+}) in the transported fluid. The rate of internal corrosion increases with a decrease in temperature and increases with an increase in pressure and stress. Microorganisms are also great contributors to internal corrosion, and care must be taken to keep the number of microorganisms particularly sulphate-reducing bacteria (SRB), present in the flowline below 10 colonies/mL. Proper corrosion control methods must be deployed and optimised to keep the rate of corrosion of the flowlines below 1 mpy (0.025 mm/yr), though subject to the design life of the flowline.

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Ian Kinnear, Product Manager, GPT Industries, addresses the impacts of hydrogen sulphide, particularly on corrosion and electrical bridging, and provides solutions to these challenges.

THE SOURING

Hydrogen sulphide (H_2S) has become an increasingly concerning issue in oil and gas pipelines around the world. Also known as sour gas, H_2S is highly toxic, explosive, and corrosive, posing significant safety and infrastructure risks.

Where is H_2S coming from?

H_2S naturally occurs in some reservoirs as a component of raw natural gas and crude oil. Additionally, it can be introduced into pipelines through microbial metabolism of sulfur-containing compounds. The oil industry is accessing more challenging reservoirs, with many containing higher levels of H_2S than traditional resources. Operators are also maximising efficiencies by processing and transporting multi-phase mixtures with heightened H_2S concentrations rather than constructing dedicated natural gas pipelines. These factors mean pipelines are transporting more sour gas than ever before.

Impacts on pipeline integrity

Corrosion is the primary threat H_2S introduces to pipeline integrity. When moisture condenses on pipe walls, H_2S reacts with the steel, producing various iron sulphide corrosion products. At higher concentrations, H_2S corrosion can lead to pitting and cracking, which severely undermine pipe strength.

Another emerging issue exacerbated by the presence of H_2S is electrical bridging across pipeline isolation joints. Isolation joints strategically installed at certain points along the pipeline are designed to control electrical current flow from cathodic protection (CP) systems. Stray current leakage reduces CP system effectiveness, wasting power while leaving unprotected pipe segments vulnerable to accelerated corrosion.


OF PIPELINES

Figure 1. An extreme case of iron sulphide or better known as black powder, build up inside of a pipeline.

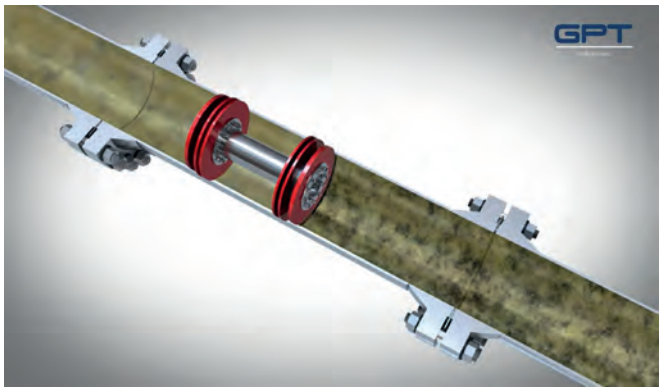

Figure 2. An example of an inline inspection tool running down the pipeline which may push hot tappings or debris across the flange face.

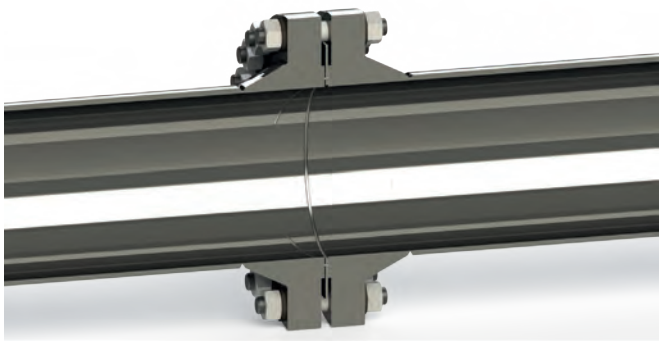

Figure 3. The flange connection, where electrical bridging can take place if built up occurs.

Electrical bridging explained

Electrical bridging occurs when an electrically conductive material, often iron sulphide corrosion products, spans the isolation joint to create a current pathway between pipe segments. This provides an easier path for CP current to flow than the intended circuit through the soil back to the rectifier. When bridging happens, CP systems continue pushing current through now-connected sections rather than forcing it to disperse into the ground. This can often be seen by what are called travelling shorts. Travelling shorts occur as a pipeline cleaning pig goes down the line and deposits this iron sulphide at the flange interfaces. When this occurs, you will see a shorts travel down the line as the pig does, being isolated before but potentially no longer after.

Iron sulphide, known in industry as black powder, readily precipitates from H_2S-tainted condensate within pipelines. Over time, iron sulphide deposition can completely mask isolation joint gaskets. Its extreme conductivity enables sustained electrical connectivity between flanges, bypassing the isolation joint's function. The iron sulphide sludge apparent in Figure 1 illustrates the severity this bridging phenomenon can attain.

Similarly, errant metal shavings from hot tapping or debris from inline inspection tool runs may lodge across isolation joints. Welding spatter can also introduce metallic bridging paths. However, iron sulphide from H_2S-influenced corrosion tends to cause the most persistent, widespread bridging problems over the long term.

Effects of uncontrolled bridging

When designing a piping system, isolation is always put in place for a specific reason. There are several different reasons why isolation would be used, with each of these causing a benefit in terms of corrosion mitigation, safety, protection, cost or a combination of all these. When systems experience electrical bridging, isolation across the bolted flange assembly is no longer maintained, resulting in the opposite effect than what was designed for.

If there is no longer isolation being present between the flanges, a number of direct effects can take place. The first is that there is a significantly higher potential for increased rates of corrosion. Isolation is typically used in conjunction with corrosion prevention methods, and a loss in isolation can mitigate these corrosion preventions. In addition to this, there can be potential large expense losses in capital and operational spend. Wasted cathodic protection current and unnecessary rectifier operation drives up expenses while potentially failing to adequately protect all assets. Large amounts of time and resource also typically then needs to be spent to troubleshoot and provide solutions, which many times comes at the expense of downtime to the system.

In addition to these, isolation can be a means of mitigating stray current. With a loss in isolation, stray current can promote disbondment of protective coatings from pipe surfaces, enabling under film corrosion. If pipe structures are no longer protected as a result of isolation being lost due to electrical bridging, localised corrosion damage can occur, resulting in pitting, cracking, and wall loss in the pipe. Over time, this can cause leaks or ruptures in the pipeline, leading to multitudes of issues in this regard.

Seeking solutions

Left unaddressed, electrical bridging will over time lead to the challenges discussed above, which can be incredibly costly for the system. Fortunately, improved isolation joint technologies can help combat bridging.

Monolithic isolation joints (MIJs) with internal coatings substantially extend the effective isolating distance, impeding electrical bridging. Instead of using a bolted flange assembly with a flange isolation kit, a monolithic isolation joint welds directly into the pipeline and provides the same electrical isolation capabilities. When the MIJ is internally coated, the effective isolating distance becomes that of the joint itself, as opposed to being the width of the isolation gasket in a flange isolation kit. The coating increases the amount of distance that bridging would have to span in order for isolation to be lost. However, not every system can utilise the MIJ design. In these cases, flange isolation kits will still need to be used.

When utilising a gasket in these applications, the first consideration that must be taken is ensuring that the gasket ID at least matches the pipe bore. The reason for this is because if the gasket ID is larger than the pipe bore, this will allow for there to be a gap between the flanges. This gap creates a perfect place for conductive media to build up between the flange faces and create an electrical bridge. In the most challenging cases, a slight protrusion of the gasket ID into the pipe bore has also been successful, to again effectively increase the isolation distance where build up can occur.

Gasket enhancements have also been made specific to overcoming challenges that come from electrical bridging. Utilising a gasket with a PTFE inner diameter seal has proven to provide benefits in terms of electrical bridging. The ID seal allows for the only material to come in contact with the media to be PTFE, which creates a non-stick surface to prevent build up at the gasket and flange face, where isolation could be lost. The ID seal also ensures that the metal core of the isolation gasket is no longer exposed, as it typically would be in higher pressure models.

This increases isolation efficiency by again increasing the effective isolating distance, whereas previously the metal core exposed made this distance short. Strategically recessing or protruding the gasket ID relative to the pipe inner wall controls the potential for deposit accumulation at flange faces.

The example above illustrates how a PTFE-sealed Evolution gasket successfully maintained electrical isolation where previous metallic cored gaskets had repeatedly failed. Its non-stick PTFE ID seal prevented bridging deposit adhesion even with highly conductive produced water.

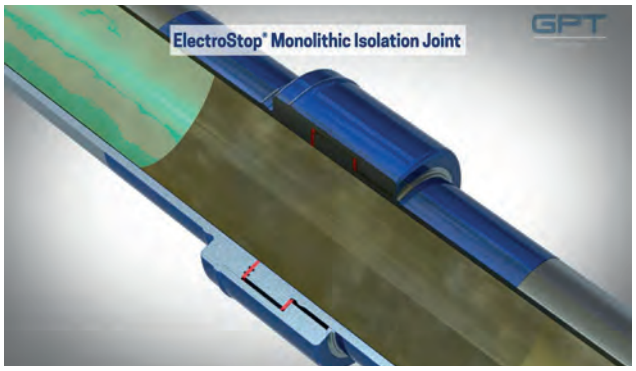

Figure 4. An internally coated GPT monolithic isolation joint, which provides the longest effective isolating distance.

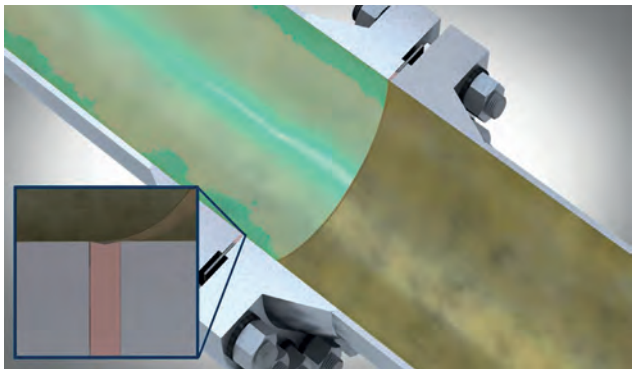

Figure 5. GPT Evolution gasket, utilising a reinforced PTFE ID seal, used specifically to combat electrical bridging challenges.

You can't manage what you don't measure

In addition to providing solutions that can help mitigate electrical bridging from taking place, remote monitoring can provide solutions towards ensuring the isolation is being maintained where it is designed to be. When electrical bridging takes place, the isolation flange will pass isolation tests when installed, but likely fail isolation at some time when in service. Without monitoring, there is no way for operators to know exactly when this isolation failure occurs and on what flanges it is taking place. By using remote monitoring, there can be a constant view to ensure that the flange is indeed isolating or be able to track any changes that may occur. If isolation is lost, an alarm will be sent highlighting this so the operator is aware to proceed. This remote monitoring of isolation will keep the health of the pipeline where it needs to be, instead of simply assuming the system is working as intended.

Looking ahead

Specification of properly configured, bridging-resistant isolation products plus accurate remote monitoring of the system will become increasingly necessary to manage growing H_2S-related pipeline integrity risks. As reservoirs sour and throughputs rise, H_2S is fast transforming from an occasional nuisance into a pervasive, potent pipeline threat, and along with this comes the challenges with electrical bridging as well. Adopting the latest isolation technologies, monitoring technologies and corrosion prevention strategies will prove essential to safely transport production, protect infrastructure investments, and avoid catastrophic failures.

Combatting casing failure

Jonathan Loomis, Cathodic Protection Specialist and Senior Corrosion Engineer, Farwest Corrosion Control, USA, discusses the galvanic anode protection of (coated) pipeline casings.

In the early days of pipeline installations (and even sometimes today), pipelines were installed bare, i.e. with no external coating system. Therefore, due to the large surface area of pipe exposed to the earth, impressed current cathodic protection (CP) systems

Figure 1. Example of a carrier pipeline and casing lead wire installation.

were required due to the inordinate amount of CP current needed to protect them; levels that just could not feasibly be provided by sacrificial anodes. Modern pipeline coatings have improved tremendously in terms of effectiveness and longevity over earlier coal tar epoxy and mastic coatings. Pipelines are now routinely provided with an external, high-quality, long-lasting dielectric coating. Due to the minimal surface area exposed to the soil these coated pipelines are often cathodically protected with sacrificial anodes. However, engineers outside the CP industry have the misconception that sacrificial anodes can easily protect a bare steel casing.

Casings are intended to provide either structural support for loads above a pipeline or to collect and vent releases aboveground and away from the underground (or suspended, in the case of bridges) crossings. When pipelines were provided with dielectric coatings, the CP industry realised that casings needed to remain bare to pick up applied CP current and transfer it internally to the carrier pipe inside the casing. For this transfer of current to occur, there must be a conductive liquid medium, which is assumed to accumulate from repeated cyclic air exchange through the casing vents in the day-night and seasonal temperature variations. Warmer air containing moisture will enter the casing vents and condense on the cooler casing or pipe surfaces, eventually accumulating to an unknown level.

After 30 years in the ground, many or most of those bare casings are structurally compromised by general corrosion, pitting corrosion, or other corrosion mechanisms. This article is intended to start a conversation on how we, as an industry, can best address the growing requirement to protect new pipe casings using sacrificial anodes.

This author has seen an ever-increasing aspiration by engineering firms to design sacrificial anode CP for bare steel casings. Such systems, especially for large diameter or long casings, can require up to and beyond 100 sacrificial anodes to provide the current required to protect the bare steel casing (see example below). Such a quantity of anodes is initially very costly and often impractical from both an allowable physical footprint requirement and a budgetary constraint. To provide an economically feasible sacrificial anode CP system, we must reduce the bare steel surface area of the casing. This is typically accomplished by providing a dielectric coating; therefore, as discussed above, sacrificial anodes can be a viable and cost-effective option when a dielectric coating is provided on the casing.

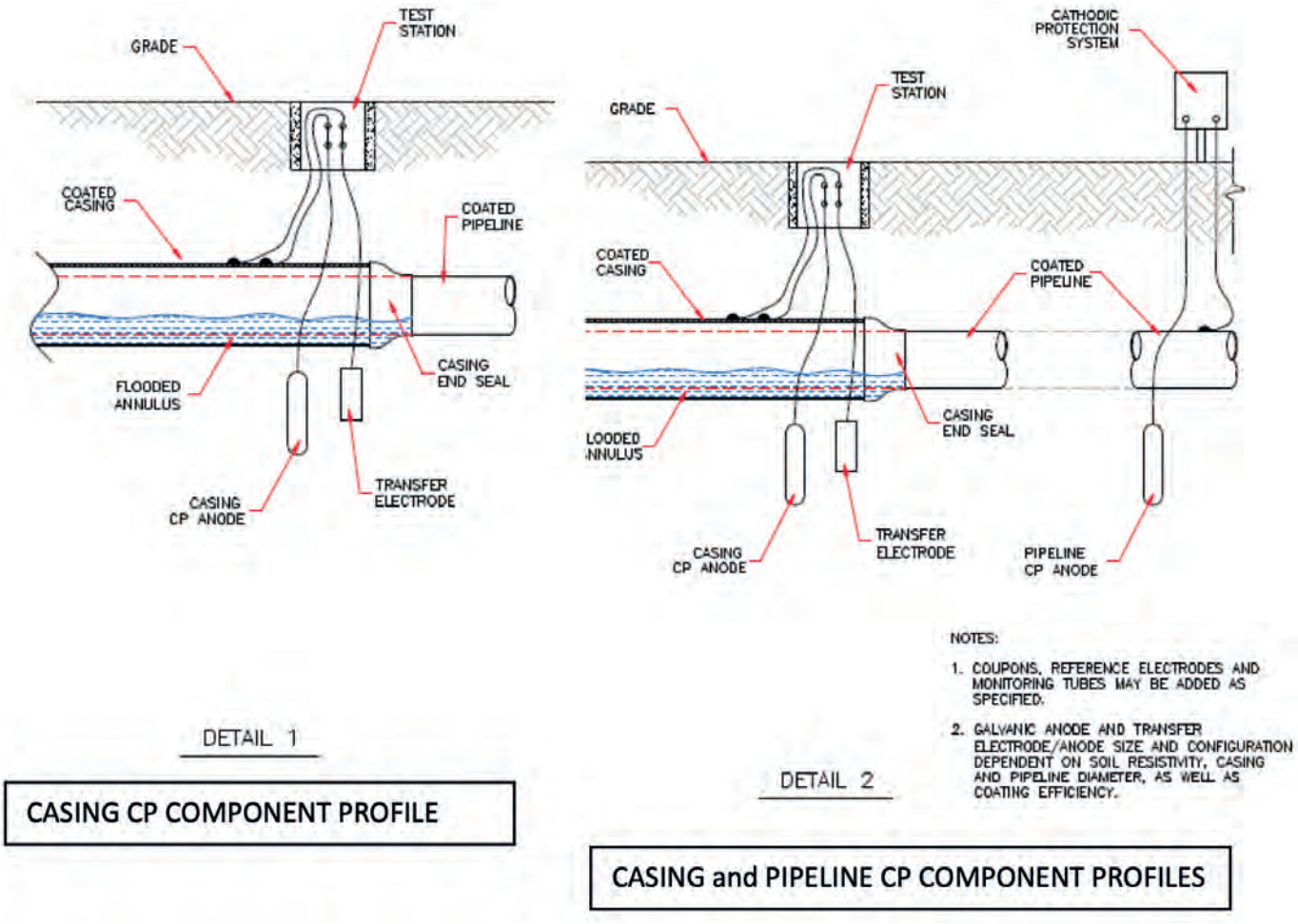

Figure 2. Standard drawings for CP components on cased pipelines.

Unintended consequences

What about the CP current needed to protect the internal carrier pipe? A coated casing provides a dielectric barrier for transferring CP current from the soil to the carrier pipe. A mechanism must be found to allow CP current to pass through the casing and to the pipe surface.

A proposed solution

What is needed is not necessarily a means to pass current directly through the casing from one side to the other but an adequate bare metallic surface area to collect the CP current. In this discussion, we shall refer to the 'bare metallic surface area' as a 'transfer electrode', which is a bare metallic surface (electrode) provided to pick up DC current from a pipeline CP system and transfer it to the coated casing. This would allow a metallic path to protect the carrier pipe in the flooded annulus. Casings with no internal flooding will have neither a complete circuit nor a need for cathodic protection of the carrier pipe. The wiring to accomplish this would typically be passed through an above-ground test station (see Detail 1 in Figure 2).

Design considerations

To satisfy both requirements, it is necessary to provide sufficient bare surface on the transfer electrode to collect adequate current and transfer it to the coated carrier pipe.

For this discussion, a factor of five times the expected equivalent CP current requirement of the coated pipeline inside the casing is offered for consideration. For example, if 1 mA of protective CP current is expected to be required to protect an equivalent 1 ft^2 total assumed coating holiday inside the casing annulus, then a 5 ft long bare transfer electrode would be the estimated target size to pick up the necessary current for transfer to the casing and use as needed inside the casing.

In practice, small- to mid-size pipes and casings will require a small bare steel transfer electrode, sized to receive enough CP to transfer current to the assumed coating holidays in the carrier pipe in a flooded casing annulus. In contrast, larger diameter pipes and casings with longer lengths will require a more robust transfer system.

Case study

A 100 ft long, 12 in. diameter (12.75 in. OD) coated casing installed in an open trench contains a newly installed 6 in. carrier pipe with an assumed 99.9% coating efficiency. The carrier pipe has an OD of 6.625 in. by 100 ft long. The total surface area calculates to 0.17 ft^2 of bare surface. At a conservative factor of five, the minimum requirement for a CP transfer electrode would be 0.9 ft^2, rounded to 1 ft^2.

Using a standardised 4 in. (4.5 in.) pipe diameter by 1 ft long and the same calculation procedure for this bare

Figure 3. Carrier pipeline and casing prior to backfill, with lead wires routed to test station conduit.

ground yields approximately 1 ft^2 of bare surface area, making this an acceptable size for the transfer electrode.

The bare CP collector surface area of 1 ft^2 would require 1 mA of CP current in a 5000 ohm-cm environment. This current would come from the pipeline CP system, as the pipeline CP system would be connected to the casing. In fact, the casing and transfer electrode would remain invisible to the pipeline CP system.

To protect the surface area of a 12 in. (12.75 in. OD) casing coated with a 99.9% efficient coating would require 0.3338 ft^2 x 1.0 mA/ft^2 = 1 mA (rounded up). Therefore, protecting a 100m ft long casing plus a 5 ft^2 bare transfer electrode, 1 + 5 = 6 mA of CP current would be required. In 5000 ohm-cm soil, one-each, 18 lb zinc anode would be able to protect both structures with over 7 mA/anode theoretically available for horizontal or vertical installation at 5 ft depth. In soils of various aggressiveness, the current density and required total current to protect the pipe and the transfer electrode could be adjusted accordingly, leading to larger or smaller transfer electrode sizes and casing CP anode sizes and quantities.

The equations used to determine theoretical anode current output are:
Dwight's single vertical anode equation:

$$Rv = \frac{0.0521\rho}{L} \times [\ln(\frac{8L}{d}) - 1]$$

and Sunde's multiple vertical anode equation:

$$R_a = \frac{0.00521(\rho)}{(N)(L)}\left[Ln\left(\frac{8L}{D}\right) - 1 + \frac{2L}{S}Ln(0.656N)\right]$$

Where:
ρ = soil resistivity in Ohm-cm
L = anode length in ft
N = number of anodes
d and D = anode diameter in ft
S = twice depth of anode burial in ft

If additional pipe coating deterioration is assumed, the transfer electrode size can be increased accordingly. Likewise, if the coated casing is installed by jack-and-bore or other push-or-pull technologies, the casing coating damage may well approach 5% or more.

The galvanic CP system can, therefore, be used on a coated casing to protect the coated casing and bare transfer electrode simultaneously. At the same time, the pipeline CP system puts out current to protect the direct-buried pipeline and pipe in the casing annulus if they are flooded to any extent.

Important considerations

Cathodic protection

Since protecting a carrier pipe in a casing annulus is, in effect, an interference function, the same constraints apply. That is, the structure receiving the CP (the casing) must be at a lower protection level than the interfering current (carrier pipeline CP system). For this reason, it is best to use zinc anodes for the casing CP system and even to provide individual anode leads or an anode junction box to allow a manual adjustment of the number of zinc anodes in use to decrease the protection level if the local carrier pipe CP levels are on the lower side (see Detail 2 in Figure 2).

Cost vs. other technologies

Both 'vapour phase inhibitors' (VPIs) and 'wax casing filler' require products to be installed within the annulus of the casing. VPIs require routine replenishment of inhibitors. Depending on the annulus volume, it may be an easy decision to select one technology over another. If another technology is selected, the casing may be provided with a quality coating and independently protected using a CP system of choice.

Conclusion

Where casing vents are not allowed to be sealed (so VPI cannot be considered), or wax-type inhibitor fillings are not allowed, this article offers one more tool to the arsenal of weapons for consideration to combat casing failure by corrosion while protecting the carrier pipe in the annulus.

Acknowledgements

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- John Rettig – CP Specialist, VP of Services, Farwest Corrosion Control.
- Michael Schifferle, CP-2 - Bakersfield Engineering Manager, Farwest Corrosion Control.

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Beyond current

PIPE DREAMS

Pipeline integrity is paramount in the oil and gas sector to ensure the safe transportation of hydrocarbons from production sites to processing facilities, and eventually to end consumers. Maintaining pipeline integrity involves a comprehensive approach that includes regular inspection, monitoring, and maintenance activities to mitigate the risk of leaks, corrosion, and other potential failures that could result in environmental damage, safety hazards, and economic losses.

Non-destructive testing (NDT) plays a crucial role in assessing the integrity of pipelines without causing damage to the structures being inspected. NDT techniques utilise various physical principles to detect defects, anomalies, and weaknesses in pipelines, allowing operators to take corrective actions before failures occur.

The selection of NDT techniques for pipeline integrity assessment depends on various factors including pipeline material, diameter, location, environmental conditions, and regulatory requirements. By utilising a combination of NDT techniques, operators can effectively identify and mitigate potential threats to pipeline integrity, ensuring safe and reliable operations in the oil and gas sector.

Advantages of phased array ultrasonic testing

Weld inspection

In recent years, phased array ultrasonic testing (PAUT) has emerged as a preferred method for weld inspection in pipelines, offering numerous advantages over traditional radiographic testing (RT).

TO REALITY

Gareth Mugford, Product Manager, Eddyfi Technologies, outlines how phased array ultrasonic testing offers precision in pipeline integrity assessments.

Figure 1. Anisotropic coarse-grain structure in austenitic materials.

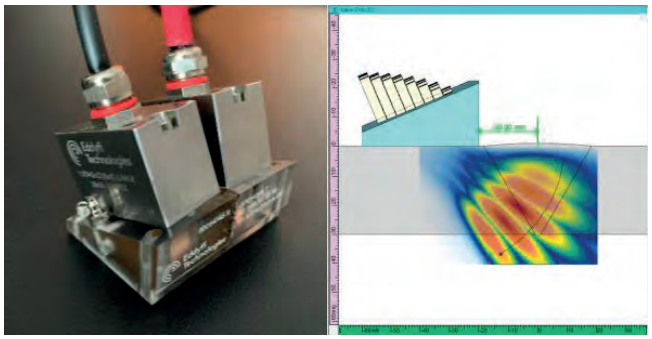

Figure 2. Dual Matrix Array (DMA) probe and beam simulation.

Figure 3. Eddyfi Technologies A10 linear array probe.

- Safety and environmental concerns: PAUT eliminates the need for radiation, addressing safety concerns associated with RT. By utilising sound waves instead of radiation, PAUT ensures the safety of technicians and the environment, making it an environmentally friendly and sustainable option.

- Enhanced efficiency: PAUT offers faster and more efficient testing compared to RT. With the ability to automate the testing process and provide real-time feedback, PAUT significantly reduces testing time and associated costs. This efficiency is particularly beneficial for large-scale pipeline projects where time is of the essence.

- Superior resolution and accuracy: PAUT provides superior resolution and accuracy, detecting smaller flaws and providing detailed information about their size, nature, and location. This high level of accuracy ensures thorough inspection, reducing the risk of undetected defects and potential pipeline failures.

- Versatility: PAUT is highly versatile and can be used on a wide range of materials and structures, including those with complex geometries or variable thickness. This versatility makes PAUT suitable for various pipeline configurations, ensuring comprehensive inspection coverage.

- Digital data management: PAUT generates digital data that can be easily stored, reviewed, and shared. This facilitates seamless communication and collaboration among stakeholders, enhancing transparency and efficiency in the inspection process.

Austenitic stainless-steel inspection

PAUT offers a solution for the challenges posed by inspecting austenitic stainless-steel welds. Austenitic materials possess an anisotropic coarse-grain structure, causing specific behaviours of the ultrasonic beam, such as high attenuation, significant grain noise, and beam distortion. Traditional inspection methods struggle to provide accurate results due to these characteristics.

To overcome these challenges, Eddyfi Technologies offers specialised packages tailored for austenitic weld inspection. These packages enhance flaw detection and characterisation, ensuring highly optimised solutions for various applications.

For effective inspection of stainless steel and dissimilar metal welds, low-frequency Dual 2D Matrix Array (DMA) probes are typically used. These probes generate longitudinal waves that propagate well through coarse-grain austenitic material. Additionally, advanced focusing techniques like Full Matrix Capture (FMC) and Plane Wave Imaging (PWI) firing can optimise image resolution, improving flaw detection capabilities.

Linear array probes are still valuable for inspecting fine-grain base material and the heat-affected zone (HAZ). These probes are typically chosen with a slightly lower frequency than those used for carbon steel welds.

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Encoded examinations, facilitated by manually encoded, semi-encoded, or fully motorised scanners, ensure thorough coverage of welds. Data storage enables ongoing asset monitoring, while offline analysis enhances inspection reliability for challenging austenitic weld configurations. Advantages of using a scanner provides constant and smooth encoding capability, ensuring 100% coverage of the accessible weld, a high probability of detection (POD), accurate positioning and sizing.

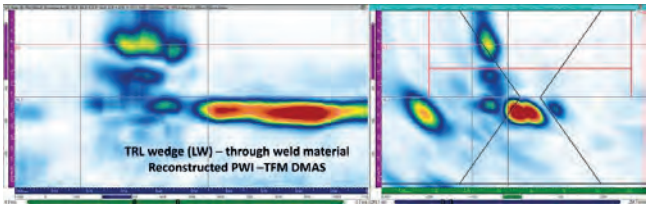

Figure 4. Indications imaged with advanced focusing technique.

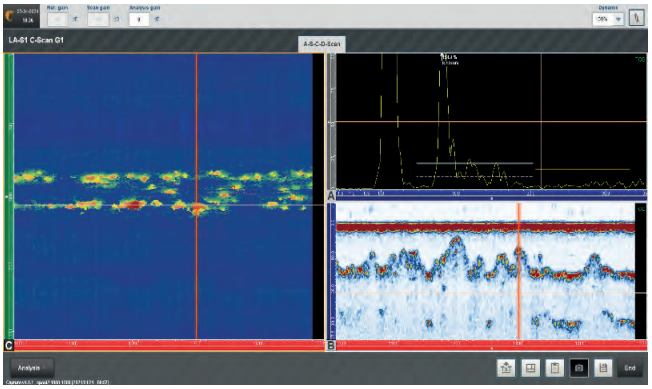

Figure 5. Phased Array Corrosion Mapping 2D data map.

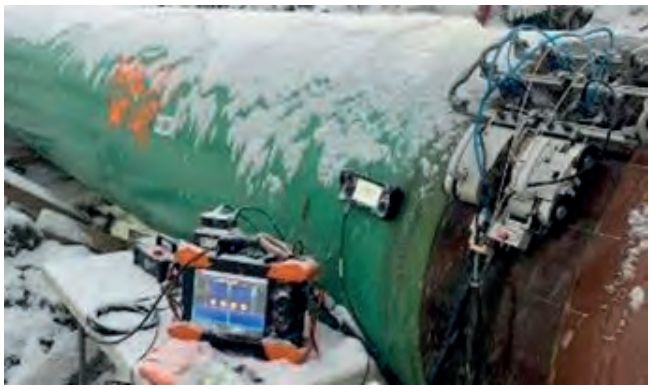

Figure 6. Turnkey automated inspection solution.

Figure 7. Semi-automated solution.

Corrosion mapping

Corrosion mapping is a critical aspect of asset integrity management, particularly in industries reliant on carbon steel structures like pipelines. The non-intrusive technique is typically utilised on the external surface of a test component, providing a 2D map representing the condition and visually highlighting variations in material thickness due to material loss, graphically portrayed as an easy to interpret picture. The data sets are fully recordable which carries a wealth of benefits such as offline analysis, repeatability; thus, improving accuracy for repeat surveys and auditable data; suiting compliance within industry regulations. Each of these benefits helps to control the exclusion of human error and as a result increased POD and accuracy of results.

PAUT emerges as a robust solution for this purpose, offering several advantages over traditional methods. PAUT's advanced ultrasonic technology enables high-resolution imaging of internal surfaces, allowing for precise mapping of corrosion features, such as localised pitting and wall thinning. This detailed assessment helps operators prioritise maintenance efforts effectively, mitigating the risk of catastrophic failures. Moreover, PAUT's flexible probe configurations accommodate various pipeline geometries, ensuring thorough corrosion mapping even in complex environments. Real-time data analysis capabilities empower technicians to interpret inspection results promptly, facilitating timely decision-making regarding further maintenance activities. Additionally, by integrating PAUT data with corrosion modelling techniques, operators can assess corrosion rates and predict future degradation trends, enabling proactive maintenance strategies. Long-term monitoring capabilities further enhance PAUT's utility, allowing for continuous assessment of asset integrity and the validation of mitigation measures over time.

Carbon steel inspection

In the realm of carbon steel inspection, PAUT stands out as a versatile and effective technique. Carbon steel components, prone to various defects including weld discontinuities and corrosion, demand thorough evaluation to ensure structural integrity. PAUT excels in detecting both internal and external defects in carbon steel welds, providing comprehensive inspection coverage. Its flexible beam steering and focusing capabilities enable adaptation to variations in thickness and complex weld geometries, ensuring accurate defect detection across diverse configurations. Moreover, PAUT's sensitivity to corrosion-related anomalies facilitates proactive monitoring and evaluation, crucial for preventing corrosion-induced failures. In industries where downtime is costly, PAUT offers significant advantages in terms of inspection speed and data analysis, enabling efficient decision-making and timely identification of defects. Furthermore, PAUT's integration with advanced inspection techniques such as time-of-flight-diffraction (TOFD) enhances defect detection and characterisation, providing a holistic understanding of weld quality and integrity. Overall, PAUT emerges as an ideal choice for carbon steel inspection, offering versatility, accuracy, and efficiency in detecting and mitigating structural defects.

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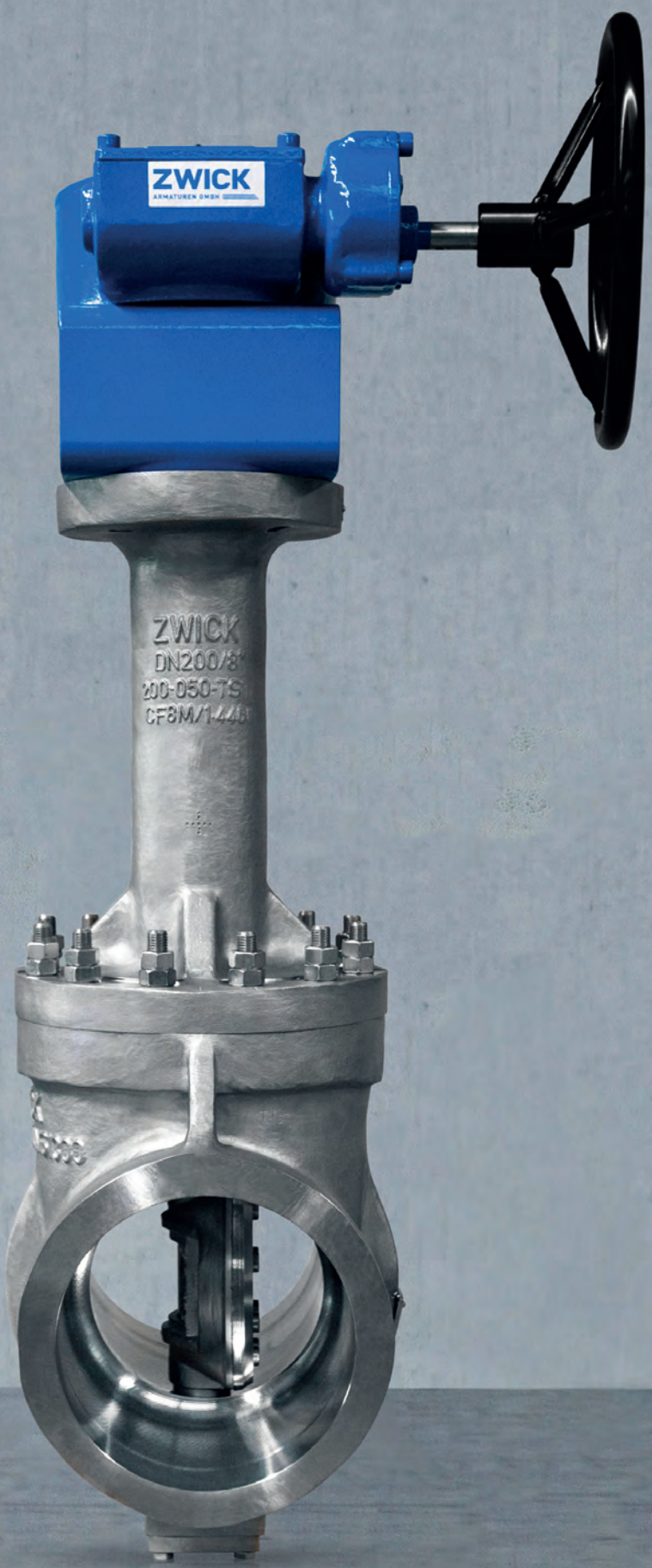

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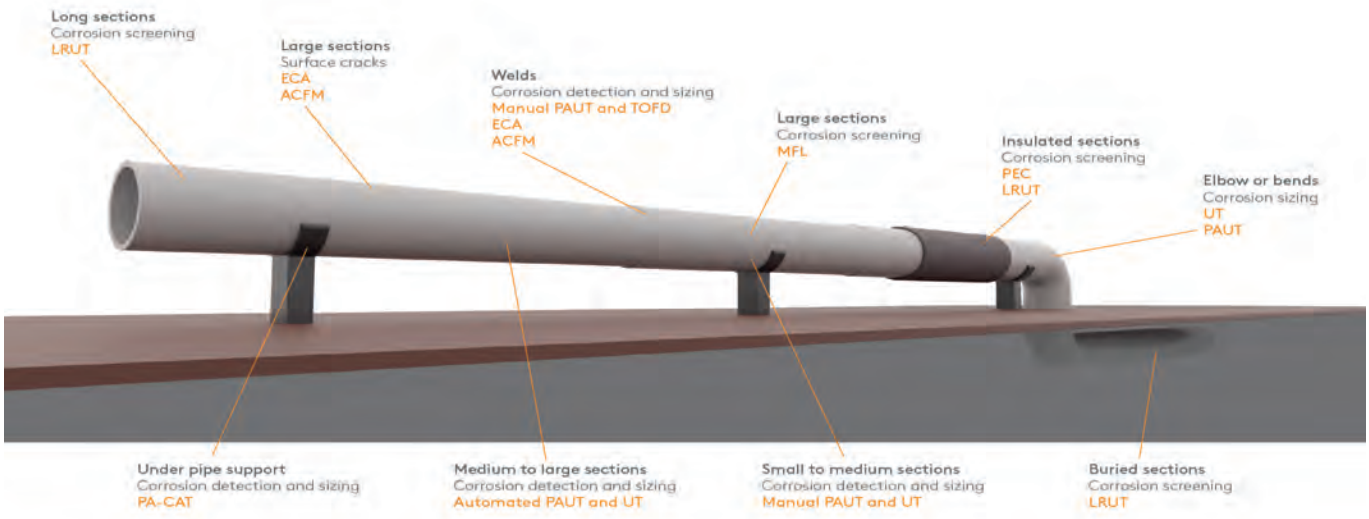


TECHNOLOGY	LOCATION	CORROSION	CRACKS	QUANTITATIVE	QUALITATIVE
Long Range Ultrasonics (LRUT)	ID/OD	●		●	
Magnetic Flux Leakage (MFL)	ID/OD	●		●	
Automated Phased Array Ultrasonics (PAUT) and Ultrasonics (UT)	ID/OD	●	●	●	●
Manual Phased Array Ultrasonics (PAUT) and Ultrasonics (UT)	ID/OD	●	●		●
Pulsed Eddy Current (PEC)	OD	●		●	
Eddy Current Array (ECA)	OD		●	●	●
Alternating Current Field Measurement (ACFM)	OD		●		●

Figure 8. Eddyfi Technologies provides a diverse portfolio of advanced inspection equipment to address pipeline integrity assessments.

A full circle approach with PAUT for pipeline lifetime assessments

PAUT serves distinct purposes in both pipeline manufacturing and in-service assessments. In the realm of pipeline fabrication, PAUT plays a pivotal role in quality assurance processes, ensuring the integrity of welds by detecting various defects such as lack of fusion, porosity, and incomplete penetration. Its integration into automated inspection setups enables high-throughput assessment without compromising accuracy, facilitating efficient production schedules. Calibration and optimisation of PAUT systems during fabrication are essential to tailor inspection parameters to meet specific pipeline requirements. Moreover, comprehensive documentation generated during this phase serves as crucial quality control records. Conversely, during in-service assessments, PAUT is deployed for routine inspections to monitor the pipeline's condition over time. Challenges such as accessing buried or subsea pipelines necessitate specialised equipment and deployment strategies. PAUT data contributes to risk-based inspection approaches, guiding the frequency and intensity of assessments based on the likelihood and consequences of failure. Additionally, real-time monitoring and integration with other inspection data provide a comprehensive understanding of the pipeline's health during operation.

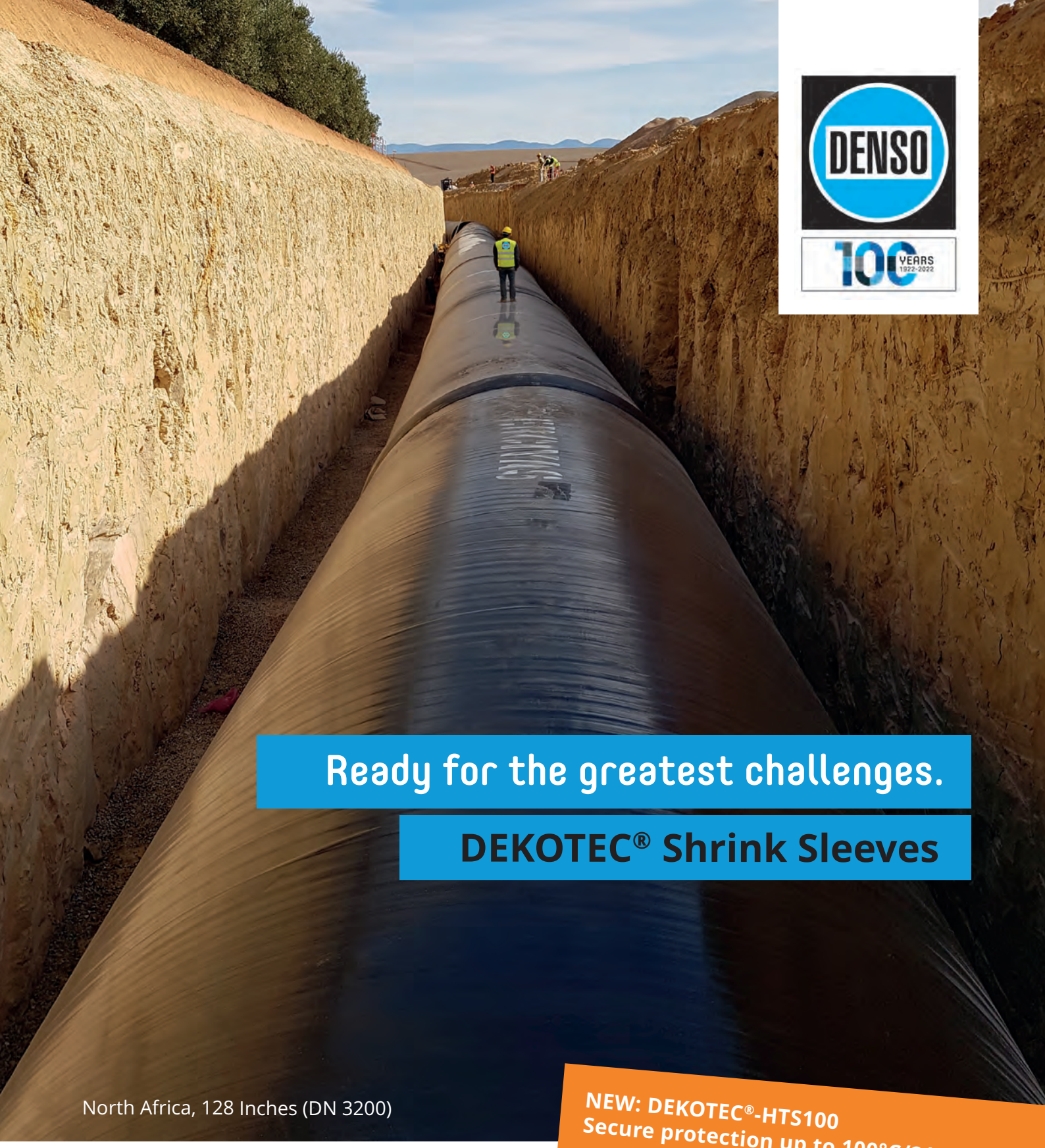
Thus, while the principles of PAUT remain consistent, its application varies significantly between pipeline manufacturing and in-service assessments, reflecting the diverse contexts and objectives of each phase.

Choose the right systems for comprehensive, cost-effective pipeline integrity assessment

In conclusion, PAUT represents a significant advancement in pipeline integrity assessment. Its numerous advantages, including improved safety, efficiency, accuracy, and versatility, make it a preferred choice for various inspection tasks such as weld inspection and corrosion mapping across different materials.

PAUT's adaptability to different materials, configurations, and environmental conditions makes it highly valuable in the oil and gas sector. By integrating PAUT data with predictive modelling and real-time monitoring, operators can proactively manage pipeline integrity, reducing risks and ensuring continued safe operation.

Eddyfi Technologies offers a range of NDT solutions, including PAUT, to meet diverse inspection needs. As technology evolves, PAUT will continue to play a crucial role in maintaining pipeline integrity, offering a practical and effective solution for ensuring the safety and reliability of energy infrastructure.



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DEFINING DEPTH SIZING PERFORMANCE

Abdullahi Atto, Lukas Klinge, and Stefan Bauer, ROSEN Group, Germany, offer an introduction to the extended depth sizing of UT crack inspection and show the performance validation.

The depth sizing of the ultrasound crack detection (UTCD) is generally based on the signal amplitude of the ultrasound echo reflected by the linear anomaly in the pipe wall and received back by the transducer (pulse-echo technique). The larger the reflecting anomaly surface (depth), the stronger the received signal.

Conventional UTCD depth sizing was originally based on depth classes and only limited to up to 4 mm depth because of the direct corner-echo signal saturation. Anomalies with a signal amplitude saturation were classified as 'depth ≥ 4 mm' without discrete depth sizing.

Recently, the UTCD technology has been further improved, especially regarding depth sizing. An 'extended depth sizing' approach using an indirect echo allows continuous depth sizing for anomalies above 4 mm depth.

The extended depth sizing for crack-like anomalies, has been made available recently for large diameter ILI tools. For small diameter pipelines (OD ≤ 12 in.) additional challenges to the measurement performance had to be considered and addressed by the inspection tool design, before an extended depth sizing can be provided in a robust and reliable manner.

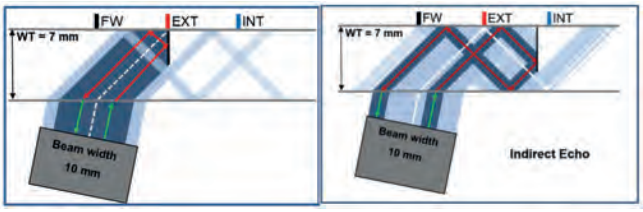

Figure 1. Sketch showing the specular shear wave reflection angles of direct (left) and indirect echo (right).

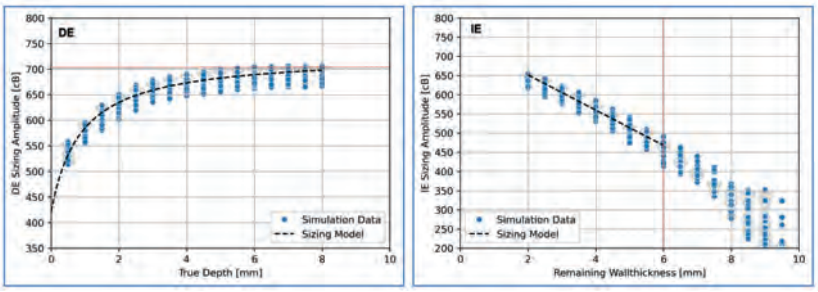

Figure 2. The DE amplitude distribution (left) shows an amplitude saturation level (about 70 dB) for anomalies above 4 mm depth. The IE amplitude distribution (right) shows an amplitude saturation and a linear correlation between amplitudes and depths for anomalies with a remaining WT of up to 6 mm.

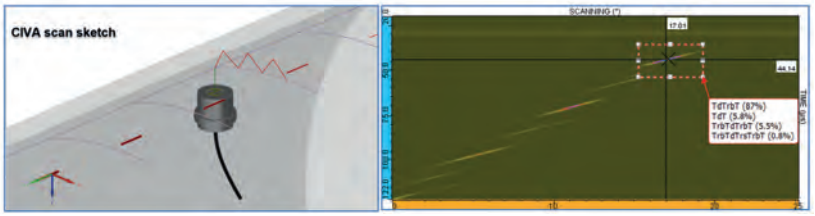

Figure 3. CIVATM simulation sketch of UTCD pipe measurement (left) and B-scan of the measurement data (right).

Extended depth sizing

The conventional UTCD depth sizing uses corner echo directly reflected over the closest pipe wall surface. The direct corner echo is usually the strongest signal and can be easily and robustly identified in the gathered data. The deeper the anomaly the stronger the 'direct echo' (DE) – but only up to a certain amplitude saturation level. Therefore, depth sizing based on DE cannot be applied to anomalies deeper than 4 mm.

A deeper part of a linear anomaly can indirectly reflect a part of the shear wave beam over the pipe surface opposite to the anomaly wall surface. External anomalies reflect the indirect echo over the internal wall surface whereas internal anomalies reflect IE over the external surface. The shear wave reflection over the opposite pipe wall surface is designated as 'indirect echo' (IE).

The deeper an anomaly and the smaller the remaining wall thickness (WT), the stronger the indirect echo. Hence, the depth of anomalies deeper than 4 mm can be discretely sized according to IE amplitudes.

IE amplitudes are generally weaker than DE and cannot reach the amplitude saturation threshold. See Figure 1 for an illustration of DE and IE.

The UTCD extended depth sizing is based on a combination of DE and IE amplitudes (see Figure 2):

- Linear anomalies with a depth of up to 2 mm can only be sized by DE.
- Linear anomalies with a depth between 2 mm and 4 mm can be sized by both DE and IE.
- Linear anomalies with depths above 4 mm can only be sized by indirect echo approach (IE).
- Indirect echo sizing can be reliably applied if the anomaly remaining WT is not larger than 6 mm.

Table 1. Overview of the test anomaly populations and number of test runs per pipeline diameter

Nominal OD (in.)	Number of notches			Number of test runs	Total of anomalies in features lists
	External	Internal	Total		
6	453	450	903	24	21672
8	817	532	1349	24	32376
10	202	200	402	12	4824
12	100	100	200	12	2400
	1572	1282	2854	72	61272

Performance qualification

According to API 1163, the UTCD performance qualification applies a comprehensive approach consisting of four stages for each of the included pipeline diameters:[1]

- UT simulation is based on the essential variables of the UTCD tool and operational conditions.
- Laboratory measurement of pipe coupons with test anomalies by applying ILI tool components.
- Full-scale pump test consisting of repetitive UTCD runs in a test loop with a large test population.
- Recent and future field validation results will also be added to the performance qualification.

UT simulation

CIVA™ is a renowned simulation, processing, and analysis software for non-destructive testing (NDT). It is widely used in different industries for research, design, and qualification studies.

ROSEN applied UT simulation during the development phase for design, improvements, and comparison of different measurement system configurations. The simulation results are compared to and qualified with the results of high-resolution laboratory measurements applying the ILI tool components and configurations.

UT simulation is also applied for the performance qualification process:

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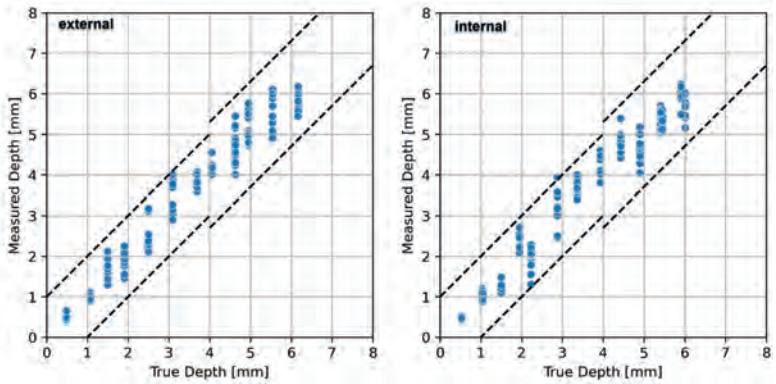

Figure 4. Unity Plots of the 6 in. UT-C performance qualification with extended depth sizing (full scale pump test).

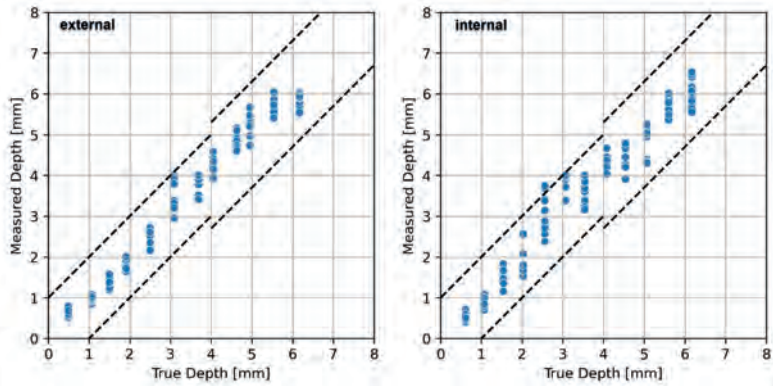

Figure 5. Unity Plots of the 8 in. UT-C performance qualification with extended depth sizing (full scale pump test).

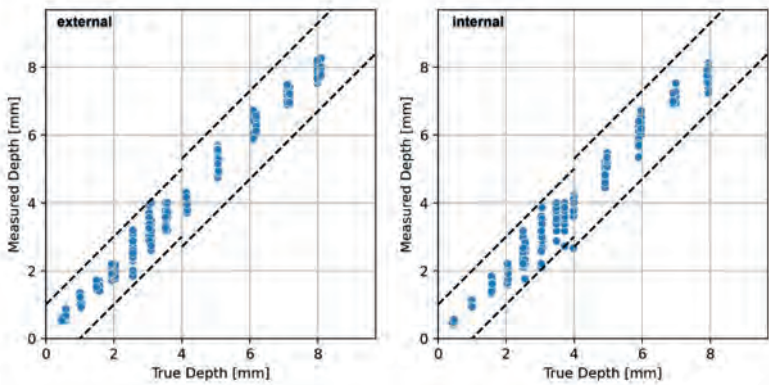

Figure 6. Unity Plots of the 10 in. UT-C performance qualification with extended depth sizing (full scale pump test).

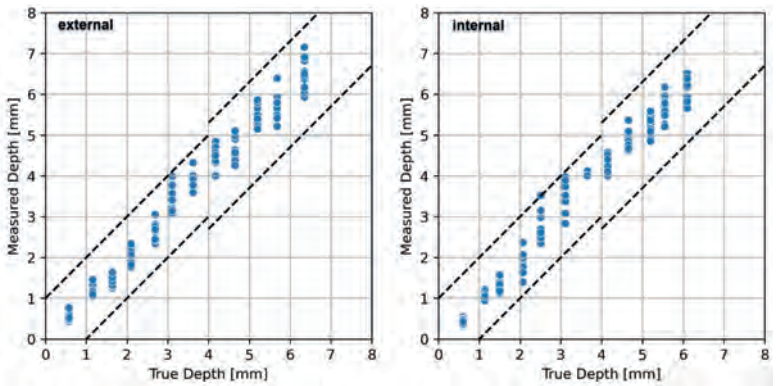

Figure 7. Unity Plots of the 12 in. UT-C performance qualification with extended depth sizing (full scale pump test).

- The configuration of the UTCD measurement system and the main pipe parameters are configured in the simulation.
- Dimensions and shapes of the test anomalies are configured for the pump test spools.
- A novel approach of an ILI tool-like data sampling method is used for the UT simulation so that the gathered data corresponds to the resolution of a random UTCD inspection or pump test run.

The depth sizing model based on the CIVA simulation results and qualified through corresponding laboratory tests is applied to the performance qualification process of the pump tests. For each pipeline diameter and WT, the UT simulation data is used to train the depth sizing model, and the pump test results are used as test data for the performance qualification process.

This qualification approach has the main advantage of avoiding a bias occurring if the same pump test data is used for both sizing model training and testing the performance qualification. Eventual deviations of individual test anomalies and irregular pipe geometries of some test spools will also not influence the depth sizing model.

Full scale UTCD pump test

To create a representative database for each pipeline diameter, one or two full-scale pump test series, each consisting of twelve repetitive UTCD runs, are performed in a test loop with a large population of linear test anomalies:

- Test spools with nominal WTs between 4 mm and 13 mm are used for each pipeline diameter.
- As linear test anomalies, notches with a depth of 0.5 mm to 80% of the nominal WT are manufactured into the external and internal surfaces of both pipe body and longitudinal seam welds.
- The verified anomaly dimensions are used for the comparison with the ILI anomaly dimensions measured by the UT-C tools for the purpose of performance assessment.

Table 1 shows an overview of the test anomaly populations and the number of test runs for each pipeline diameter from 6 - 12 in.

After data processing and the related data quality check, the pump tests were deemed as successful. The gathered inspection data of the pump test runs were handed over to the data analysis team. Since the data analysis team had no information about the actual/design dimensions of

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the test anomalies, 'blind' data analysis was performed as follows:

- An 'automated feature search' (AFS) was applied to the inspection data to create 'feature boxes'.
- The data analysis team classified each feature and checked the amplitude values and lengths.
- A senior data analyst performed a quality assessment and validated the analysis results.

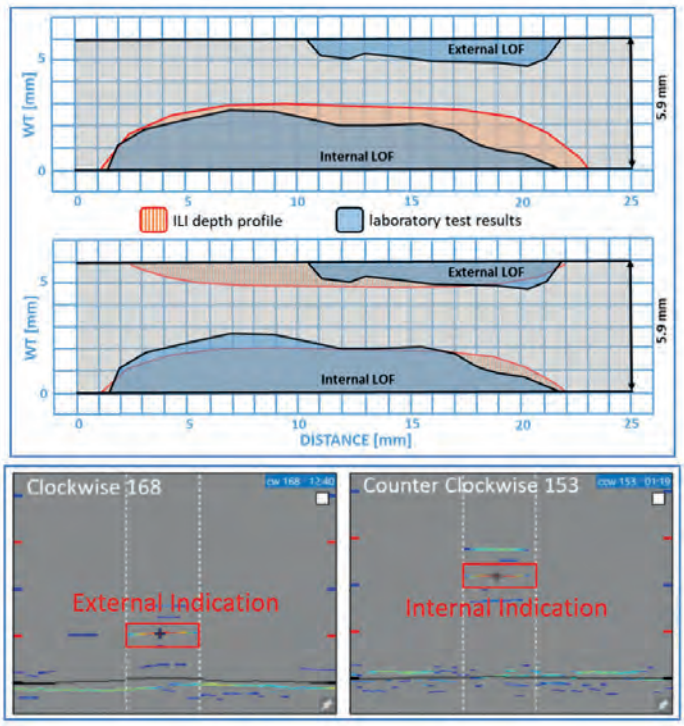

Figure 8. Comparison of depth profile of stacked LOF between UT-C inspection data and destructive metallurgical test.

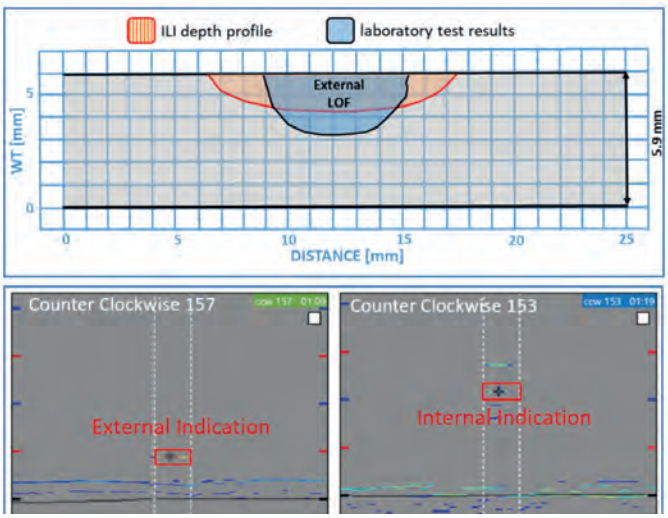

Figure 9. Comparison of depth profile of stacked LOF between UT-C inspection data and destructive metallurgical test.

The final feature lists have been handed over to a different analysis team to correlate the ILI results with the actual test anomaly dimensions and to assess the performance capabilities.

Performance qualification of extended depth sizing

An extended depth sizing based on both DE and IE amplitudes was applied for the performance qualification of small diameter UT-C tools (6 - 12 in.) based on a full-scale pump test.

The results of the performance qualification can be summarised as follows:

- All linear test anomalies with a length ≥ 20 mm and a depth ≥ 1.0 mm were detected by the ILI tools and identified during the data analysis. Additionally, more than 95% of the test anomalies with dimensions below the specified detection thresholds were also detected (depths below 1 mm, lengths below 20 mm).
- Depth sizing accuracy ≤ 1.0 mm is calculated for test anomalies of up to 4 mm depth.
- Depth sizing accuracy ≤ 1.3 mm is calculated for test anomalies with depths above 4 mm.
- The extended depth sizing is only valid for anomalies with a remaining WT of up to 6 mm.

Confidence levels significantly above 90% were calculated for POD and depth sizing accuracies.

Figures 4 to Figure 7 show the results of the full-scale performance qualification pump tests as depth unity plots of 6, 8, 10, and 12 in. UT-C tools.

Field validation

The new generation of UTCD small diameter tools with 5 mm circumferential resolution was recently introduced. Therefore, only a limited number of field validation results are meanwhile available. Results of two field validation measurements of lack of fusion (LOF) in ERW longitudinal seam weld are included as examples in this article.

The reported flaws were detected during a baseline survey of an 8 in. pipeline of a nom WT = 5.9 mm. The anomaly locations were first verified in the field and then cut out for destructive testing and laboratory measurement. The destructive testing with anomaly profile measurement has accurately revealed the actual length and depth profile of the anomalies. Two of the three verified anomalies have lengths significantly shorter than the specified minimum length threshold of 20 mm.

The first reported anomaly consists of two overlapping stacked LOF anomalies at the external and internal pipe surfaces. The pair of stacked LOF anomalies are identified by the UT-C data analysis and reported as one internal anomaly (Figure 8):

- The similarity in length and profile between the main internal signal and the overlapping external

signal suggests that the external indication would be an indirect echo caused by the internal anomaly. Therefore, the anomaly was reported as 3.1 mm deep to the indirect echo sizing.

- The destructive testing has revealed that the major anomaly is at the internal pipe surface and has a length of 18.9 mm and a peak depth of 2.85 mm. The minor part of the stacked LOF is at the external surface and has a length of only 11.5 mm and a peak depth of 1.2 mm.

The second validated anomaly is significantly shorter than the specified minimum length for detection and sizing of the UT-C Performance Specification. The anomaly has been reported as 1.9 mm deep (DE sizing) and 11 mm long. The destructive testing revealed a length of only 6.2 mm long with a peak depth of 2.8 mm.

Conclusion

As part of the extended depth sizing to apply discrete depth sizing to linear anomalies deeper than 4 mm, ROSEN has implemented further improvements of the essential variables influencing the depth sizing performance of small diameter UTCD tools:

- UTCD transducers are optimised/tailored for the specific challenges of small diameter pipelines and implemented to UT-C tools of 6 - 12 in. nominal OD.
- Circumferential resolution of the small diameter UT-C tools is enhanced from 7 - 5 mm sensor spacing.
- Depth sizing methodology is improved with the application of CIVA modelling and lab testing.
- A detailed full-scale pump test with a large population of test anomalies is performed to validate and qualify the UTCD performance specification.

Extensive performance qualification tests have proven a clear improvement in the reliability and accuracy of the UTCD depth sizing in general and particularly in small-diameter UT-C tools.

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2. ATTO, ABDULLAHI et al., 'Continuous Depth Sizing of ILI Ultrasonic Crack', International Pipeline Conference Sep 2016, Calgary, Paper IPC2016-64409, 2016.
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PIPELINES, PARTNERSHIP AND PREVENTIVE MAINTENANCE

Edward Belsley, Valve Aftermarket Engineer for Celeros Flow Technology, considers the technological and human factors involved in servicing pipeline equipment effectively.

Pipelines are amazing pieces of infrastructure. Designed to carry essential liquids and gases from their point of origin, through processing and refining, and on to the customer, pipelines often cover vast distances and pass through demanding environments that range from icy tundra to baking deserts.

In engineering terms, pipelines can be surprisingly complex. Their long, linear nature requires equipment in the form of pumps, valves, and other control devices to ensure that their contents flow continuously at the desired rate, pressure, and temperature. Maintaining all this equipment to achieve optimal performance over the pipeline's lifetime is critical to avoiding supply disruption and environmental impacts.

However, the remote nature of pipelines, coupled with extreme operating environments and the often-aggressive properties of the substances they are transporting, can create some specific servicing and maintenance challenges. Let's take pipeline valves as our example.

Figure 1. Pipeline valves like this one will spend most of their service life in one position – either open or closed.

Figure 2. **Replacing the valve seat, gate, and stem every 10 years as a precaution is good practice.**

Maintenance indicators

Pipeline valves often sit in one position – either open or closed – for most of their service life. While they may not be required to operate very often, regular maintenance is still necessary, because you don't want to find out that a valve is not functioning properly at the critical moment! This is why regulatory organisations such as the DoT in the US recommend an annual inspection, including actuator testing.

A preventive maintenance regime involving planned, routine actions therefore aids compliance and can prevent equipment failures or performance degradation. For example, consumables such as O-rings become brittle over time, reducing efficacy and even leading to breakages. Basic maintenance includes changing the soft goods when the valve is opened as part of regular maintenance schedules. A further recommendation is that operators replace the valve seat, gate and stem as a precaution over a 10 year cycle for good actor valves: clearly, bad actors would require earlier intervention to determine and correct the cause of the problem.

Sediment may build up in the bottom of the valve body over time, particularly in dirty services, and this adversely affects valve operation. Left unchecked, sediment buildup can prevent the gate from fully travelling and therefore have an adverse effect on the functional capability of the valve. On electrically actuated valves, operators will experience an increase in torque or thrust requirements because the actuator is having to compensate. Left unresolved, sediment build-up therefore results in higher energy costs.

Scratches and gouges on the valve stem are indicative of internal damage to the stem and packing, but it does require removal of the yoke to confirm the cause. While this involves some time and cost, it is far preferable to a complete rebuild, which will result if the damage is left unchecked. Full replacement of the top works to incorporate a two-piece stem rather than a single piece can be a good investment because this makes it easier to swap out damaged parts and meet actuation requirements. Whether the valve is welded in or buried, this approach can extend valve life without the need for complete replacement.

Leakage is another common indicator that a valve needs attention. Units can leak either through the valve body itself (internal leakage) or through the packing (packing leakage). Leaking valves are not cheap to repair, particularly if they are weld-in valves that must be repaired in situ during planned outages. If a valve is leaking internally, it will not shut off completely. The consequences of internal leakage include product losses, product contamination if mixing occurs, and environmental impact. Meanwhile, packing leakages can often be temporarily mitigated by injecting packing compound, but this is not a substitute for proper replacement.

One preventive measure is the CFT-Green Valve Packing System, developed to reduce fugitive emissions across pipelines and provides a safe and efficient sealing solution for valves. Stationary loaded packing seal solutions are traditionally used to control fugitive emissions, but this type of packing gradually wears and fatigues, thereby requiring regular adjustment. The CFT-Green uses a spring-loaded mechanism to ensure a tight and robust seal even under extreme conditions, which eliminates the need for packing tightness intervention during the seal's lifetime. It is also able to accommodate slight misalignments or deformations in the valve stem or body, which further helps to prevent leaks and reduce the need for frequent maintenance or repair. Simple to retrofit, the CFT-Green is a good choice for critical valves that are not used for extended periods of time in remote and inaccessible locations.

Prevention not cure

Preventive maintenance is clearly essential to ensure optimal performance, prevent leaks, minimise downtime, and extend the lifespan of your valves, but what does best practice look like?

Regular visual inspections should be undertaken to check valves for signs of wear, corrosion, or damage. Check for leaks around valve seals, flanges, and connections and address any leakage promptly. Also tighten any loose bolts and replace damaged gaskets as part of your maintenance regime.

Keeping all moving parts well-lubricated is also good preventive maintenance, because it reduces friction and ensures smooth operation. Lubrication type and frequency will be dependent on the manufacturer, so always check the guidelines.

Cleaning valves will remove build-up of dirt and debris, while periodically flushing the pipeline will also help to prevent sediment accumulating and affecting valve performance.

Visual checks should be followed up with periodic testing of valves under actual operating conditions. This will ensure

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that the valves open and close smoothly without sticking or excessive force. Pressure testing can also be applied to check that valves can handle system pressures without leaking.

Finally, good valve maintenance should be underpinned with accurate record keeping. This includes keeping maintenance logs that contain details of all valve maintenance activities, including inspection dates, repairs, and replacements. Valves should also be clearly labelled so they are easy to identify during maintenance.

Balancing act

In an ideal world, preventive maintenance would mean that a valve never fails unexpectedly and that it meets or exceeds its original design life. But, as any pipeline operator knows, the reality is quite different. An unexpected valve failure or malfunction will arise at some point, and this triggers the need for reactive maintenance which essentially involves an unplanned intervention for emergency repairs. The amount of downtime this requires is largely dependent upon the availability of qualified personnel and replacement parts.

Budgetary constraints, regulatory requirements, operating environments and personnel availability all have an influence on maintenance decisions. Pipeline operators must therefore strike a balance between preventive and reactive maintenance. Deciding factors may include the criticality of a valve: for example, giving emergency shutdown valves more preventive attention than non-critical valves.

Risk assessments to evaluate the consequences of failure (safety, environmental, financial) will help to determine the appropriate strategy. Decisions should be further informed using historical data, reliability analysis, and cost-benefit assessments to guide the choice. The aim is to develop an effective and practical maintenance strategy that uses preventive maintenance to reduce risks and reactive maintenance to resolve unforeseen issues promptly.

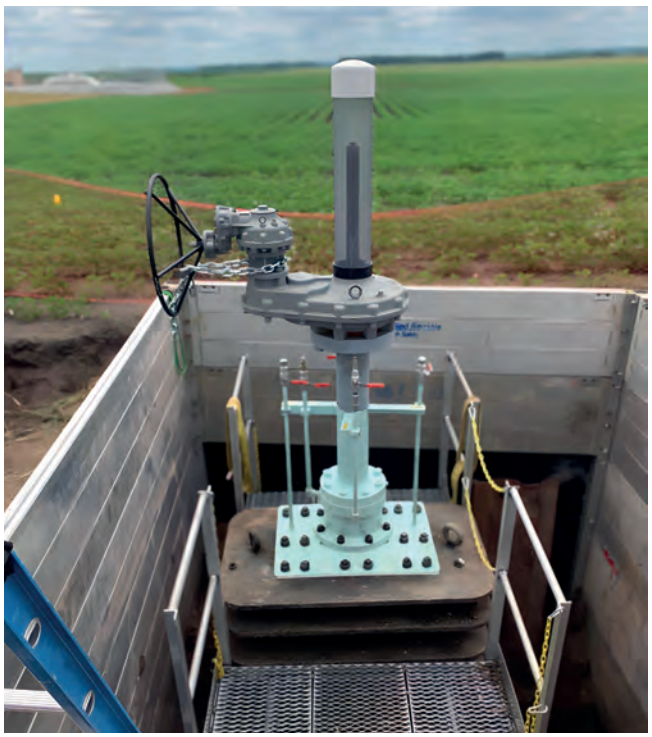

Figure 3. Celeros FT's valve conversion kit adapts pipeline valves from crude oil to carbon dioxide.

Outsourcing maintenance

For some pipeline operators, establishing their own in-house valve maintenance resources may not be practical or cost effective, in which case a valve maintenance partner is required. While the cost benefits of outsourcing maintenance are a key factor, successful selection should consider many different aspects. Remember that choosing the right valve maintenance partner directly impacts the safety, efficiency, and environmental performance of your pipeline system.

- Expertise: Fundamentally, a maintenance partner should have extensive experience in valve maintenance and repair. A partner will be required to resolve anything from field issues to developing a new technical solution to a problem, to ensure they offer complete lifecycle services. For example, Celeros Flow Technology covers everything from managing installed equipment through to parts supply and engineered replacement parts – not only for our own M&J Valve and Copes-Vulcan brands, but for third party valves as well. We also have specific materials technology expertise that means we can advise on the metals and coatings for your valve application.

- Accreditation: Your valve partner must understand and uphold all relevant industry standards such as API 6D, safety regulations, and environmental requirements. Establish their credentials by verifying their safety protocols, training programmes, and adherence to occupational health guidelines. Also check out their quality control processes to see whether they perform thorough inspections, testing, and validation after maintenance work.

- Responsiveness: Evaluate their responsiveness to emergencies and routine maintenance requests. Do they have the geographic coverage and ability to serve your pipeline network effectively? They should also have access to a wide range of spare parts for different valve types and brands that will ensure timely repairs and minimise downtime. Also check their emergency response capability. A reliable partner should have a well-defined emergency plan and be available 24/7.

- Flexibility: Every pipeline system is unique. A good partner should be flexible and offer customised maintenance solutions based on your specific needs. Avoid one-size-fits-all contracts and find a partner who understands the priorities of your business and the intricacies of your pipeline system.

- Value for money: When comparing pricing structures and service packages, consider both short-term costs and long-term value. As well as hard costs, assess the overall benefits that the partnership might bring. For example, Celeros Flow Technology can undertake inventory management, and conducts customer training programmes led by qualified and experienced technicians.

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- Commitment: Outsourcing may be attractive financially, but it is also an investment in time and relationships. This payback improves with a long-term partnership. Look for a partner with a track record of building successful partnerships and who is committed to your pipeline's success and growth. Another key indicator is their investment in testing and technology, as well as the continued professional development of their own team.

Partnership in action

Knowing you can call on additional expertise in moments of need can be extremely helpful. In one recent example, Celeros Flow Technology was able to resolve a serious valve maintenance challenge for a customer to keep their schedule on track.

The customer had experienced a critical valve failure and required an emergency turnaround. The valve dated from the 1970s and the spare parts required were obsolete. There was no time to use laser scanning and reverse engineering techniques to reconstruct spares, which typically requires a six to eight week lead-in. The customer had tried ordering equivalent components for a new valve, but these did not fit the old model. Combining its OEM valves expertise and its aftermarket engineering skills, Celeros Flow Technology was able to modify the modern components to fit the obsolete valve and restore performance. This rapid response and quality engineered solution meant that the valve was brought back on-line within the 12 hour maintenance window.

New maintenance challenges

The advent of new processes, increasingly stringent environmental regulations, and changes in market demand continue to raise new maintenance challenges for pipeline operators. For example, the energy transition is driving a major shift from hydrocarbon-based fuels to more sustainable alternatives, including biofuels like green hydrogen, as well as the development of carbon capture and storage (CCS). Achieving the energy transition will be reliant on large-scale adaptation of existing pipeline networks to accommodate the alterations in pressure, temperature, flowrates, and corrosive properties associated with these new fuels.

Celeros Flow Technology has the application knowledge and technical expertise to deliver fully customised flow control solutions that respond to the diverse process challenges of transitioning from fossil fuels to renewable resources. One example is our valve conversion kit for adapting pipeline valves from carrying crude oil to carbon dioxide.

Our valve maintenance services keep leakage and emissions to a minimum, as well as significantly lowering energy consumption, ensuring that pipeline valves continue to function efficiently throughout their design life. As both an OEM valve manufacturer and aftermarket engineering experts, we have a unique ability to augment operational parameters or modify performance to accommodate new feedstocks as they emerge – adding value at every stage of the lifecycle to improve overall efficiency and lower carbon intensity.

TAKING BACK CONTROL OF OT

Bernard Montel, Technical Director and Security Strategist, Tenable, UK, describes the new threats facing operational technology, and how to tackle them in a holistic, proactive manner.

The world is addicted to operational technology (OT), even if most don't realise it. In the upstream, midstream and downstream sectors, OT is no longer confined to the production plant and distribution network, but integrated across the whole infrastructure – within the office environment through smart appliances, heating, ventilation, and air conditioning (HVAC) controls, across the physical estate monitoring gated access and badge scanners, powering security cameras, lift controllers and more. And it's not just OT that's crossing borders as a large percentage of the OT environment is actually made up of IT devices, such as network switches, Windows running HMIs and more.

The result of this convergence is that threats that originate in IT systems can quickly spread to OT environments, or vice versa. This leads to expensive downtime with increasingly harmful consequences, or even potentially life threatening results. This expanded attack surface security teams need to defend.

Accidental (on purpose) conversion

Due to their critical nature, most OT devices deployed within engineering environments, such as programmable logic controllers (PLCs), human machine interfaces (HMIs) and supervisory control and data acquisition systems (SCADA), were not designed to be public-facing and internet-accessible. However, a shift in working practices to optimise production, drive innovation and increase efficiency, has seen the provisioning of remote access within these sensitive environments. This includes cellular modems, 4G/5G, dial-up, or dedicated internet lines, which are being used to monitor and access equipment.

This leaves these OT devices discoverable via the internet and they're being fingerprinted and indexed by search engines, such as Shodan. This allows a variety of users, including security researchers and threat actors, to search for and obtain information about them. And we're seeing this exposure abused by threat actors.

It's important to recognise that whatever is visible on the internet is likely to be the first point threat actors will target. OT devices are increasingly a target for attack by a variety of threat actors, such as ransomware groups and affiliates, hacktivists and nation-state cyber criminals linked to Iran and China.

Who's responsible?

Traditionally, any software intended to interact with OT equipment was the responsibility of the Operations team – whether at the plant/site level, at the regional level, or the corporate level. This is still the case for a lot of organisations, but there has been a recent shift in ownership of OT security software buying decisions, from OT Operations to IT Security.

IT security leaders are now challenged with managing the risks that come with digital transformation, where integrating diverse digital ecosystems under one umbrella can help drive down costs. But this also exposes organisations to new security threats. This is particularly critical as digital environments become more connected, and IT and IoT/IIoT products increasingly interact with the internet and cloud.

The challenge for CISOs and InfoSec teams tasked with securing these connected environments is they often have no idea where to start, or how to gain visibility into what assets they have and where risks hide. The issue is that most OT security solutions only focus on OT devices, creating blind spots from undetected IT/IoT assets in the OT domain. Transversely, traditional IT security solutions cannot run within an OT environment without causing disruption or safety concerns.

Today's security programs need to have comprehensive asset visibility from corporate IT to industrial OT environments.

Tenable and Thales

Tenable recently disclosed that it has joined the line up of solutions used to run real world simulations in Thales Cyber Range, a simulation and virtualisation platform for training, testing, exercising and R&D.

Thales describes itself as an engineering company that is also engaged in consultancy. This gives Thales a great insight; it can not only secure systems for UK organisations, but also provides the knowledge of how to build and integrate them.

Thales first opened the National Digital Exploitation Centre in January 2019, in an effort to secure OT. Over the years the site has evolved to become a research and development centre for OT security and also expanded with additional projects and equipment to become the Thales ICS Lab. The site now hosts a 'cyber range' testing facility and education centre which helps visitors understand OT environments and the impact that equipment can simultaneously have on physical safety and cybersecurity.

The cyber lab is a virtualised supercomputer that blends together physical and computing technology combined with a simulated control room and Security Operations Centre (SOC). Cyberattack simulations and exercises can be run against typical 'real world' scenarios – be it a power plant or manufacturing line, to determine and understand the implications in a controlled setting.

And that's where Tenable comes in, providing holistic visibility into assets across IT and OT environments. Tenable OT Security is an industrial security solution for the modern industrial enterprise that identifies assets in the OT environment, communicates risk, prioritises action and enables IT and OT security teams to work better together.

Visitors to the Ebbw Vale campus will be able to test Tenable's comprehensive set of security tools and reports in a virtualised environment, whether upstream, midstream or downstream. This allows them to experience how Tenable OT Security provides unmatched visibility across IT and OT security operations to deliver deep situational awareness across all global sites and their respective assets – from Windows servers to PLC backplanes – in a single interface.

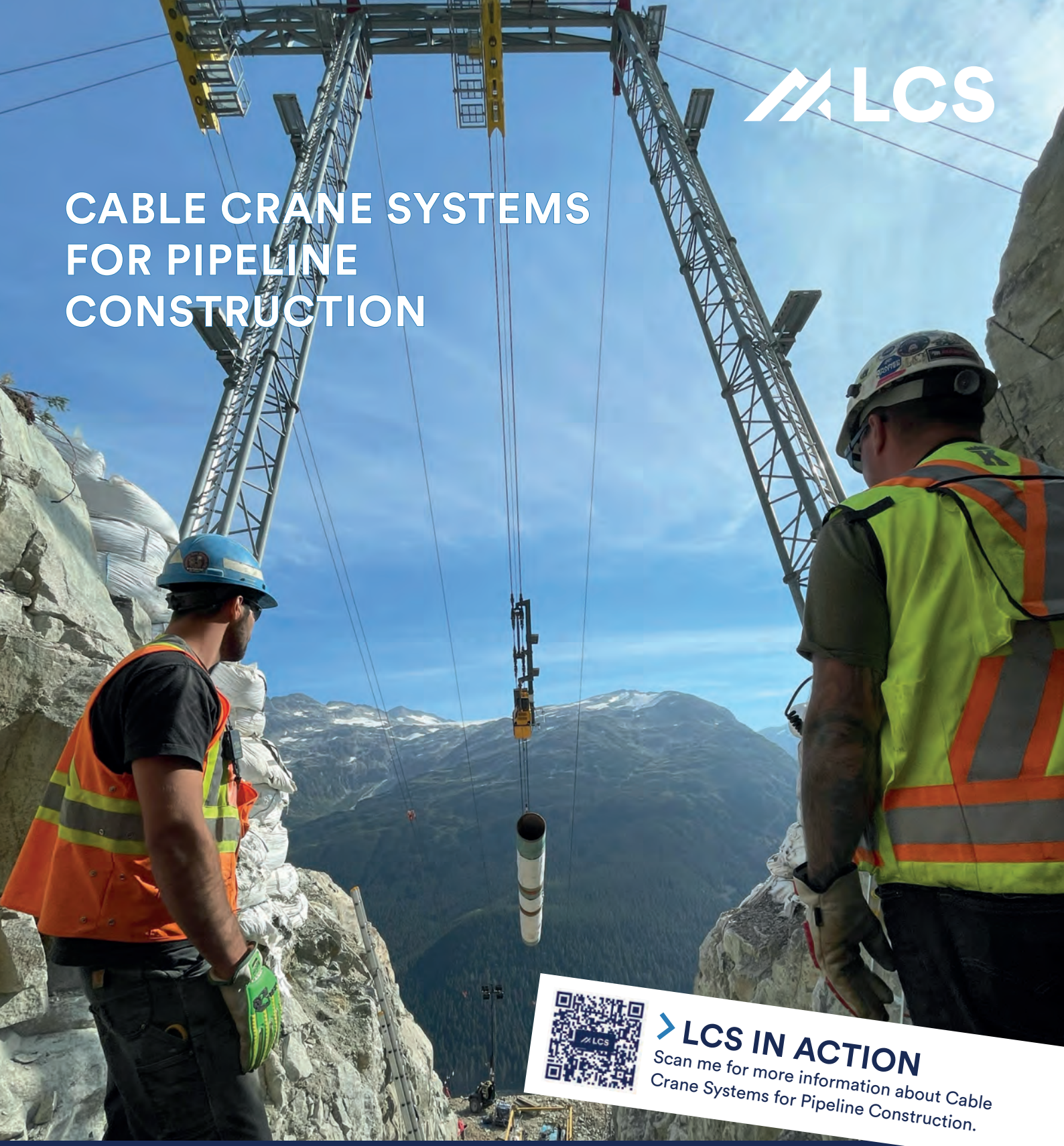
Take back control

True cybersecurity requires complete and holistic understanding of the risks that exist within the entire infrastructure. A preventative approach in cybersecurity, covering both sides of the house (IT and OT) is paramount to eliminate many of the core risks associated with the new trends and challenges that are present. When threat actors evaluate a company's attack surface, they're probing for the right toxic combination of vulnerabilities, misconfigurations and identity privileges.

The most effective action to protect OT devices is to disconnect internet-accessible OT devices, unless they were designed to be enabled for such access. Given that this is not always practical, if such devices do require remote access, it's critical that they are properly configured behind firewalls and isolated from business critical networks. In order to do this it's imperative to gain full visibility into the environment – of IT and OT assets, IoT, building management systems, and everything in between, the interdependencies that exist for critical functionality, and determine where weaknesses and vulnerabilities exist.

With that intelligence, security teams then need to identify where weaknesses, vulnerabilities and misconfigurations (changes made by humans in error or by malicious malware) exist and prioritise those assets that could become possible attack paths. With OT permeating every aspect of the digital ecosystem, the number of vulnerabilities has surged due to the increased attack surface created by these connected environments. From this stance, steps can be taken to remediate the risks where possible, or monitor the assets related to the risk for deviations that could be indicators for attacks.

Gaining this broad visibility can be difficult, challenging security teams to conduct analysis, interpret the findings and identify



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what steps to take to reduce risk as quickly as possible. AI has the potential to address this. It can be used by cybersecurity professionals to search for patterns, explain what they're finding in the simplest language possible, and decide what actions to take to reduce cyber risk. AI is being harnessed by defenders to power preventative security solutions that cut through complexity to provide the concise guidance defenders need to stay ahead of attackers and prevent successful attacks. Harnessing the power of AI enables security teams to work faster, search faster, analyse faster and ultimately make decisions faster.

Additional steps to bolster security practices are:

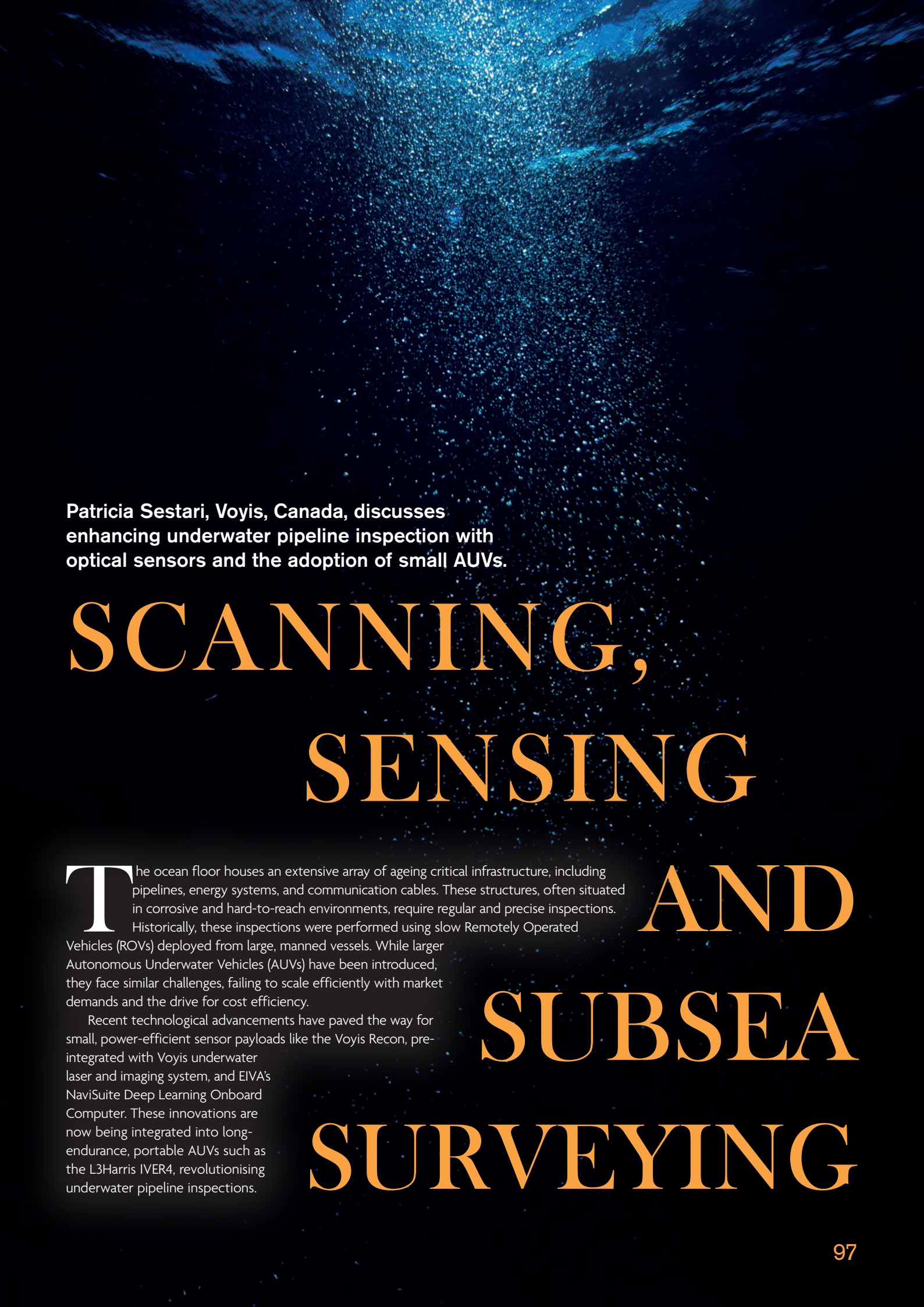
- Limit administrator access and ensure accounts have only the required permissions.
- Use strong, unique passwords for accounts and ensure all default-passwords have been changed.
- Enable multi factor authentication (MFA) on accounts where possible.
- Standardise on a secure remote access platform for OT with audit and logging capabilities to ensure access is being utilised properly.
- Create a baseline of all the configurations of OT and IoT devices, monitor for changes, and determine if these are made intentionally or not, by a human or if potentially malware.

Organisations should also implement a strong continuity plan, such as backup and recovery, for the inevitable attack – such as ransomware. Companies that backup often and regularly, and test their backups to verify their integrity, have confidence that they can isolate the incident and restore operations in the shortest amount of time as possible.

Additionally, establishing incident response plans, practising and reviewing those plans once or twice a year ensures that stakeholders – executives, engineers and security personnel – are ready to respond. Tabletop exercises should evaluate the impact on operations if different combinations of equipment are unavailable and as well as communication plans for shareholders, employees and customers in the event of an attack.

Taking security to the next level requires investment in OT security, which, as previously mentioned, has lagged behind its IT counterpart. When considering return on investment, this reality is flipped. For every dollar spent on OT security, organisations get more than what they get with a dollar in IT security investment. OT investments buy down risk much more so than IT security.

On a daily basis, threat actors find creative ways to disrupt businesses through non-traditional paths. Risk doesn't begin or end at IT, nor ignore OT. Strong security best practice is about understanding what is critical for the business to function, whether that's systems or data, then address the risks these systems face first. Doing so means the vast majority of attack paths will be closed off, preventing compromise, malware infiltration and/or exfiltration of data.



Patricia Sestari, Voyis, Canada, discusses enhancing underwater pipeline inspection with optical sensors and the adoption of small AUVs.

SCANNING, SENSING AND SUBSEA SURVEYING

The ocean floor houses an extensive array of ageing critical infrastructure, including pipelines, energy systems, and communication cables. These structures, often situated in corrosive and hard-to-reach environments, require regular and precise inspections. Historically, these inspections were performed using slow Remotely Operated Vehicles (ROVs) deployed from large, manned vessels. While larger Autonomous Underwater Vehicles (AUVs) have been introduced, they face similar challenges, failing to scale efficiently with market demands and the drive for cost efficiency.

Recent technological advancements have paved the way for small, power-efficient sensor payloads like the Voyis Recon, pre-integrated with Voyis underwater laser and imaging system, and EIVA's NaviSuite Deep Learning Onboard Computer. These innovations are now being integrated into long-endurance, portable AUVs such as the L3Harris IVER4, revolutionising underwater pipeline inspections.

Figure 1. Voyis Recon AUV Payload for the IVER4 AUV.

Figure 2. Pipeline 3D laser model captured with Voyis Insight Laser Scanner.

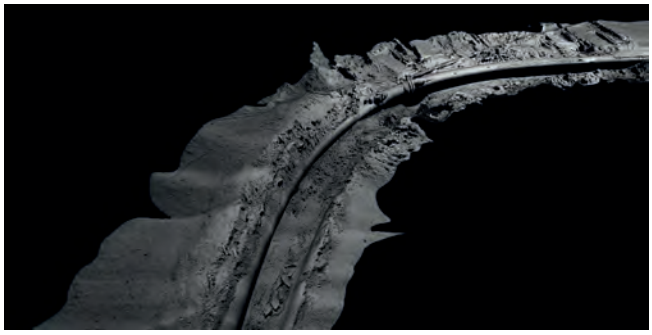


Figure 3. Pipeline 3D model created with Voyis underwater optical sensors.

Evolution of underwater inspections

The offshore survey industry has transitioned from manual, tethered ROV operations to automated surveys with large AUVs. Traditional surveys relied on manual sonar data review and low-resolution video, whereas modern surveys utilise automated defect detection with 3D laser data and high-resolution still images. Voyis played a crucial role in this shift, starting in 2014 with the delivery of the first dynamic subsea laser scanner on a large HUGIN AUV, and continuing in 2018 with the first long-range still imaging solution for the Norwegian Navy's HUGIN fleet. These advancements have significantly reduced inspection costs, enhanced AUV capabilities, and provided higher quality, quantifiable data for better decision-making.

Technological integration

The Voyis Recon AUV Payload is a pre-integrated system designed to enhance the speed and quality of remote decision-making processes for surveying subsea assets. It delivers high-resolution data on pipeline and anode conditions, processed in real-time using machine learning algorithms. This innovation reduces or eliminates the need for personnel to operate in hazardous marine environments.

Integrating sensors into AUVs involves more than merely attaching equipment. Factors such as hydrodynamics, ballasting, and size requirements must be considered. The Voyis Recon AUV Payload is designed to improve capabilities without compromising the platform's size, weight, and power (SWaP) limitations. This pre-integrated payload combines Voyis' underwater laser scanner and imaging systems, simplifying integration and enabling the capture of exceptional optical data at high speeds.

Challenges and innovations in autonomous underwater inspections

Historically, the offshore industry employed large work-class ROVs for survey work, relying on direct connections to surface vessel personnel. This setup led to the development of larger sensors, offline processing servers onboard the vessel, and the need for operators for sensor control and data review.

The rise of autonomous solutions and resident robotics has shifted the paradigm. Complete surveys can now be conducted with minimal surface interaction, forcing sensor manufacturers to prioritise onboard data enhancement capabilities. With the advent of autonomous systems, data review can no longer occur simultaneously with survey operations. Instead, the complete survey dataset is downloaded after vessel recovery, significantly increasing data analysis time.

EIVA has responded to this challenge by developing onboard data processing and anomaly detection services, enabling analysis during the survey. This approach reduces the overall survey time and enhances the efficiency of underwater inspections.

The role of small AUVs in pipeline inspections

The adoption of AUVs initially focused on integrating large, high-power sensors, which restricted state-of-the-art survey capabilities to sizable AUVs. While some survey companies developed exclusive data automation capabilities for pipeline inspection, a comprehensive onboard data processing chain remains largely unavailable to the broader market. The high procurement costs and expensive deployment infrastructure of large AUV platforms have hindered widespread adoption, emphasising the need for portable AUV solutions.

Small AUVs, such as L3Harris's IVER4, present a transformative opportunity for the market by addressing several key challenges and offering numerous benefits. Small AUVs are significantly less expensive to procure and operate than their larger counterparts. Their reduced size and weight enable deployment from smaller, less costly vessels, cutting operational expenses. Additionally, their lower power consumption translates to extended mission durations without frequent recharging, further reducing costs.

The compact form factor of small AUVs allows for greater maneuverability in confined or complex underwater environments. This capability is particularly valuable for

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inspecting pipelines in areas that are difficult to reach with larger AUVs or ROVs. Their ability to navigate close to subsea structures enables detailed inspections, improving data accuracy and completeness.

Small AUVs can be quickly mobilised and deployed, offering a rapid response to inspection needs. Their ease of deployment reduces the time required to begin surveys, allowing for more frequent and timely inspections. This rapid turnaround is crucial for identifying and addressing potential issues before they escalate, ensuring the continued integrity of underwater infrastructure.

Small AUVs equipped with onboard processing capabilities can analyse data in real-time during the survey. This real-time processing allows for immediate identification of defects or anomalies, reducing the need for extensive post-mission data analysis. Consequently, decision-making processes are accelerated, enabling quicker implementation of corrective actions.

Optical sensors: enhancing underwater pipeline inspections

Optical sensors play a pivotal role in the advancement of underwater pipeline inspections, offering unprecedented detail and accuracy in data collection. Two critical components of these optical systems are the underwater laser scanner and the high-resolution stills camera. Together, they provide a comprehensive solution for detailed inspection and analysis, driving the evolution of underwater survey techniques.

The Voyis Insight underwater laser scanner revolutionises subsea inspections by delivering high-resolution 3D data of underwater structures. This technology works by projecting laser lines onto the target surface and capturing the reflected light to construct detailed 3D models. The laser scanner generates precise 3D point clouds that accurately represent the underwater environment, which is crucial for detecting small defects, such as cracks, corrosion, and deformations in pipelines that might be missed by traditional sonar systems. Integrated with real-time data processing capabilities, the laser scanner provides immediate feedback during inspections, enabling operators to identify and address issues on the spot, thus reducing the need for extensive post-mission analysis and expediting decision-making processes. Its ability to capture detailed 3D data over wide areas ensures comprehensive coverage of pipeline infrastructure, which is essential for maintaining the integrity and safety of underwater assets. Additionally, the 3D models generated by the laser scanner offer quantifiable measurements, facilitating precise assessments of pipeline conditions and supporting informed maintenance and repair strategies.

Complementing the laser scanner, the high-resolution Observer Imaging System captures detailed visual imagery of underwater structures. This camera incorporates advanced features such as real-time image enhancement, colour correction, even illumination, and image blur correction. Real-time image enhancement techniques improve the clarity and quality of underwater photographs by correcting colour distortion caused by water absorption and scattering, producing true-to-life images that accurately represent the inspected structures. Ensuring even illumination across the image field eliminates shadows and highlights, providing consistent lighting conditions, which is particularly important for capturing high-quality images in low-light or turbid water environments. Advanced algorithms correct motion-induced blur, ensuring sharp and clear images even when the AUV is in motion, which is essential for obtaining reliable data during dynamic survey operations. The high-resolution images captured by the stills camera are instrumental in creating photogrammetry models, which use overlapping photographs to generate accurate 3D reconstructions of underwater structures. The precise colour-corrected, evenly illuminated, and blur-free images enhance the quality of these models, providing detailed visualisations for inspection and analysis.

Integrating the data from both the underwater laser scanner and the high-resolution stills camera offers a synergistic approach to pipeline inspections. The laser scanner provides precise 3D geometric data, while the stills camera adds high-quality visual context. This combination delivers a comprehensive understanding of the pipeline's condition, enabling accurate identification and characterisation of defects, which is critical for early detection and preventive maintenance of subsea infrastructure. The integration of quantifiable 3D data with high-quality visual imagery supports informed decision-making processes, allowing operators to assess the severity and extent of defects with greater confidence and prioritise repairs and maintenance activities effectively. Furthermore, the synergy between laser-scanned 3D data and high-resolution images enhances the accuracy and detail of photogrammetry models. These models provide a valuable tool for visualising and analysing the pipeline's condition, supporting comprehensive inspection reports and maintenance planning.

Combining wide-area and high-resolution sensors

One core challenge in subsea data gathering is balancing coverage and resolution. The Recon payloads address this by combining wide-area sidescan sonar with high-resolution optical sensors (lasers and cameras). This combination is ideal for detecting and reacquiring targets using a single payload. Acoustic sonar data first detects objects of interest, and optical sensors then provide clear identification of the target.

The integration of small, power-efficient sensor payloads into portable AUVs represents a significant advancement in underwater pipeline inspections. The Voyis Recon AUV Payload, with its combination of high-resolution optical sensors and real-time data processing capabilities, exemplifies this progress. By reducing reliance on large, manned vessels and enabling high-quality, automated inspections, these innovations promise to enhance the efficiency, safety, and cost-effectiveness of underwater infrastructure inspections. As the offshore survey industry continues to evolve, the adoption of portable AUV solutions will play a crucial role in meeting the growing demands for accurate and timely underwater inspections.

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REIMAGINING UNDERWATER INSPECTION

Ibtesam Hasan, Fugro (Middle East), discusses leveraging AI and remote technologies to redefine subsea asset inspection.

ROV underwater inspection of oil and gas assets such as platforms, rigs and pipelines has been around for nearly half a century, and it has served the industry well, providing valuable data and contributing significantly to the industry's maintenance and safety practices.

In the oil and gas industry, where subsea infrastructure plays a pivotal role in energy production, ensuring the integrity and safety of assets is paramount. Traditional methods of performing subsea inspection and handling data have often been fraught with challenges, including time-consuming historical trend analysis and cumbersome access to critical data. Analogue or decentralised data storage has made it difficult to fully utilise data to take advantage of risk based inspection (RBI) and latest technology such as artificial intelligence (AI).

The problem is that typically one ROV inspection generates terabytes of data for every campaign. The data gathered during an ROV inspection campaign includes still photos of the features, video log, survey parameters, cathodic protection field gradient log, flooded member detection ultrasonic thickness measurement readings etc. The asset owners typically receive one paper-based report for each asset, commonly spread over hundreds of pages with photos and tables of anomalies and notable features identified during the inspection. The video reports produced and submitted can have over 200 hours of video footage for every 100 km of pipeline inspected. The video report is processed in proprietary software, and a viewer is provided to the asset owner to ease the process of asset integrity management.

Let's take a look at some of the recent technologies developed and deployed by Fugro that are enhancing the data gathered during the ROV inspection and play a part in Fugro's transformative approach to reimagining the ROV

Figure 1. Fugro *Blue Essence*® is a next-generation autonomous, uncrewed vessel, transforming the way subsea surveys are conducted.

Figure 2. The transition to remote operations for offshore projects is evolving and Fugro's remote operations centres are innovating and reimagining the way we work.

underwater inspection. Fugro's emphasis on map, monitor, and model has led to the development of several groundbreaking technologies, from hardware to digital deliverables, that have the potential to revolutionise data collection, analysis, storage, access, and utilisation.

What has changed in ROV inspection?

For most of history, the change in ROV inspection was evolutionary, i.e. video records changed from VHS to portable hard drives. The COVID-19 pandemic changed the way business was conducted, and the offshore industry was no exception. Previously, subsea inspection data management has been characterised by manual processes, paper-based reports, and disparate data storage systems. This approach not only hampers operational efficiency but also poses challenges in accessing and analysing historical data.

Additionally, the use of proprietary software for data recording adds complexity and cost to the process, hindering seamless collaboration among stakeholders, especially in a world where travel across the border is becoming increasingly difficult and experts who were flown in for a campaign are no longer accessible.

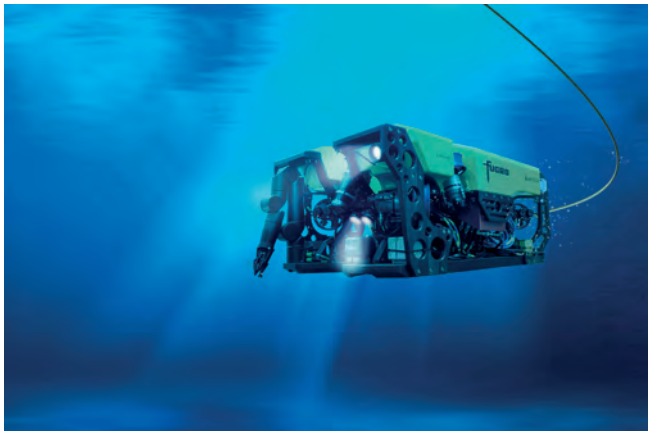

Figure 3. Fugro *Blue Volta*® is an advanced electric remotely operated vehicle, designed for integration and deployment from an uncrewed surface vessel, to perform remote inspection and light intervention tasks for offshore projects.

Asset owners and operating companies are increasingly joining the net-zero pledge and actively reducing CO_2 emissions from operational activities. This has led to the development of low-carbon inspection solutions such as unmanned surface vessels (USVs) with ROVs, faster inspection speeds, and remote operations to minimise flights and improve offshore health, safety, and environment (HSE).

The advent of new technologies such as 3D photogrammetry and the use of AI to detect features means a lot more data needs to be collected, processed, and centrally accessible than ever before. This also created a need for integrating new technologies into asset management systems.

What can we achieve by reimaging the ROV inspection?

The primary goal of the new development was to meet sustainability targets while enhancing operational efficiency by using advanced technology. By leveraging advanced technologies and software solutions tailored for the industry, operators aim to streamline data collection, analysis, and reporting processes. This will not only save time and resources but also provide decision-makers with instant access to comprehensive historical data and digital twins of subsea assets.

Environmental and sustainability advantages

The introduction of USVs that are equipped with ROVs can significantly reduce the carbon footprint of the ROV inspection spread. Since there is no need for crew onboard, the USVs can be much smaller in size compared to a DP2 vessel. The fuel consumption of these vessels per day is in litres as opposed to tons for DP2 vessels. The smaller size offers other advantages such as speed, endurance and faster mobilisation, which help with reducing the total duration of the inspection campaign.

Impacts on operational efficiency

Modernisation is expected to have a profound impact on operational efficiency by automating data collection processes and facilitating real-time monitoring of subsea assets. This will enable operators to conduct more comprehensive inspections, leading to early detection of integrity issues and minimising downtime. Moreover, the ability to instantly access digital twins of assets will empower decision-makers to make informed choices and optimise maintenance strategies.

Collaboration and communication

The adoption of modern communication technologies will facilitate collaboration and communication among stakeholders involved in subsea inspection projects. By providing secure access to standardised data and digital twins, operators can foster cross-functional collaboration between engineering, operations, and maintenance teams. This will enable faster decision-making, improved problem-solving, and enhanced coordination of inspection campaigns.

Cost savings

The transition to digitalised subsea inspection data offers significant cost savings and revenue opportunities for operators. By reducing the need for manual labour and

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paper-based reporting, modernisation will lower operational costs and improve resource allocation. Furthermore, improved asset management and risk-based inspection models will enhance operational reliability, potentially leading to increased production and revenue generation.

Training AI models for the future

The importance of a dataset in training an AI model cannot be overstated. A large database of historical data will enable an accurate AI model that can transform the analysis of underwater inspection data from days to minutes. In order to build a comprehensive dataset for supervised learning of AI model the data needs to be of good quality, annotated, uniformly labelled, and representative of real-world maximum scenarios.

How to achieve transformation of ROV inspection?

Introducing new innovations to ROV inspection is no easy task as it involves considerable investment, research, and development in new hardware and software that can be operated reliably for a remote operation centre. Achieving sustainability while improving efficiency means that Fugro had to start from scratch and completely reimagine the way ROV inspection data is acquired, processed and delivered to the client. The process resulted in the creation of a new ROV with sensors, data-gathering software and a cloud-based engagement platform to access Geo-data.

The first step in Fugro's journey to modernisation was to develop unmanned surface vessels and a new class of ROV that can be launched and operated from a remote operations centre (ROC) without sending personnel offshore.

The Blue Essence® USV fleet forms part of Fugro's remote and autonomous operations programme to deliver market-leading Geo-data insights to its clients with improved efficiency, safety and sustainability. Thanks to the vessels' economical design and optimised fuel system, the USVs eliminate carbon emissions by 95% versus conventional vessels and can spend up to two weeks at sea without refuelling. Fitted with an electric remotely operated vehicle (ROV) that is equipped with a completely redesigned cathodic protection monitoring system (Fugro CP+) and multibeam echo sounder, it can perform ROV inspection twice as fast as the conventional approach.

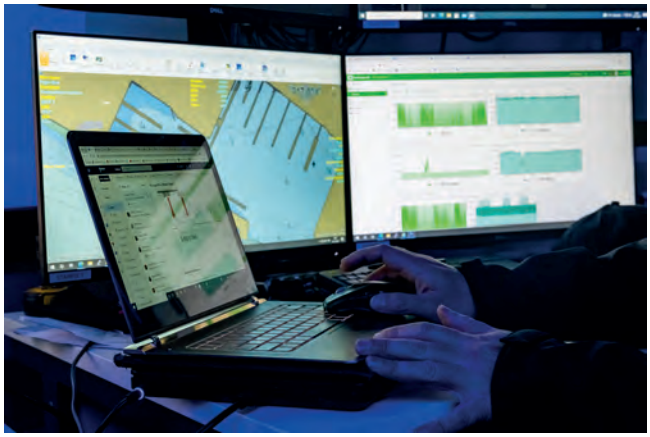

Figure 4. Fugro ROC provides clients with real-time data, enabling informed decision-making based on the collected data.

Remote operations centres (ROC)

To support USV operations worldwide, Fugro has set up nine state-of-the-art ROCs based on bespoke robotic control architecture. The advanced ROCs allow Fugro to operate the USV and eROV over large distances with minimal latency and high reliability. The ability to remove personnel from the offshore environment significantly reduces health and safety risks and creates the opportunity to build a more localised and diversified workforce onshore.

State-of-the-art cloud processing of data

Sense-suite® provides state-of-the-art cloud processing of data generated when inspecting marine assets, and enables rapid decision making. The Sense.Suite includes:

- Sense Pipeline: a unique software service that executes and delivers remote subsea pipeline inspection.
- Sense Structures: plan, execute and publish results of a live structure inspection campaign from any location.
- Digital twin: Fugro's eROV onboard USV is natively equipped with in-house design CamBlock cameras that can capture a photorealistic point cloud of the asset.

Cloud-hosted, web-based geo-data engagement platform

VirGeo® is a cloud-hosted, web-based geo-data engagement platform for accessing geospatial data and documents throughout an asset's life cycle. VirGeo provides a single source of information for the project team by allowing users to access Geo-data at any time, from any location in a simple way: a website. Within a singular interface, VirGeo provides a clear overview of the various types of geo-data visualised in a spatial context (i.e. on a map) and linked with associated documents hosted in Fugro's document management system.

Advisory

Remote operations and cloud-based deliverables have made it easy to tap into 2000+ geo-data and subject matter experts in Fugro, both during the inspection campaign and after the data has been gathered. ROC-based operations mean that our and the client's experts can join the inspection without the need to travel and stay onboard a vessel.

Conclusion

In conclusion, modernising subsea inspection data holds immense promise for the oil and gas industry. It offers a pathway to enhanced operational efficiency, sustainability, improved safety, and cost savings. By leveraging advanced technologies and software solutions, operators can unlock new levels of insight, reliability, and sustainability in their subsea operations.

About the author

Ibtesam is a chartered metallurgy and materials engineer with over two decades of experience and currently works as a SME for I&M service line at Fugro in the Middle East office.

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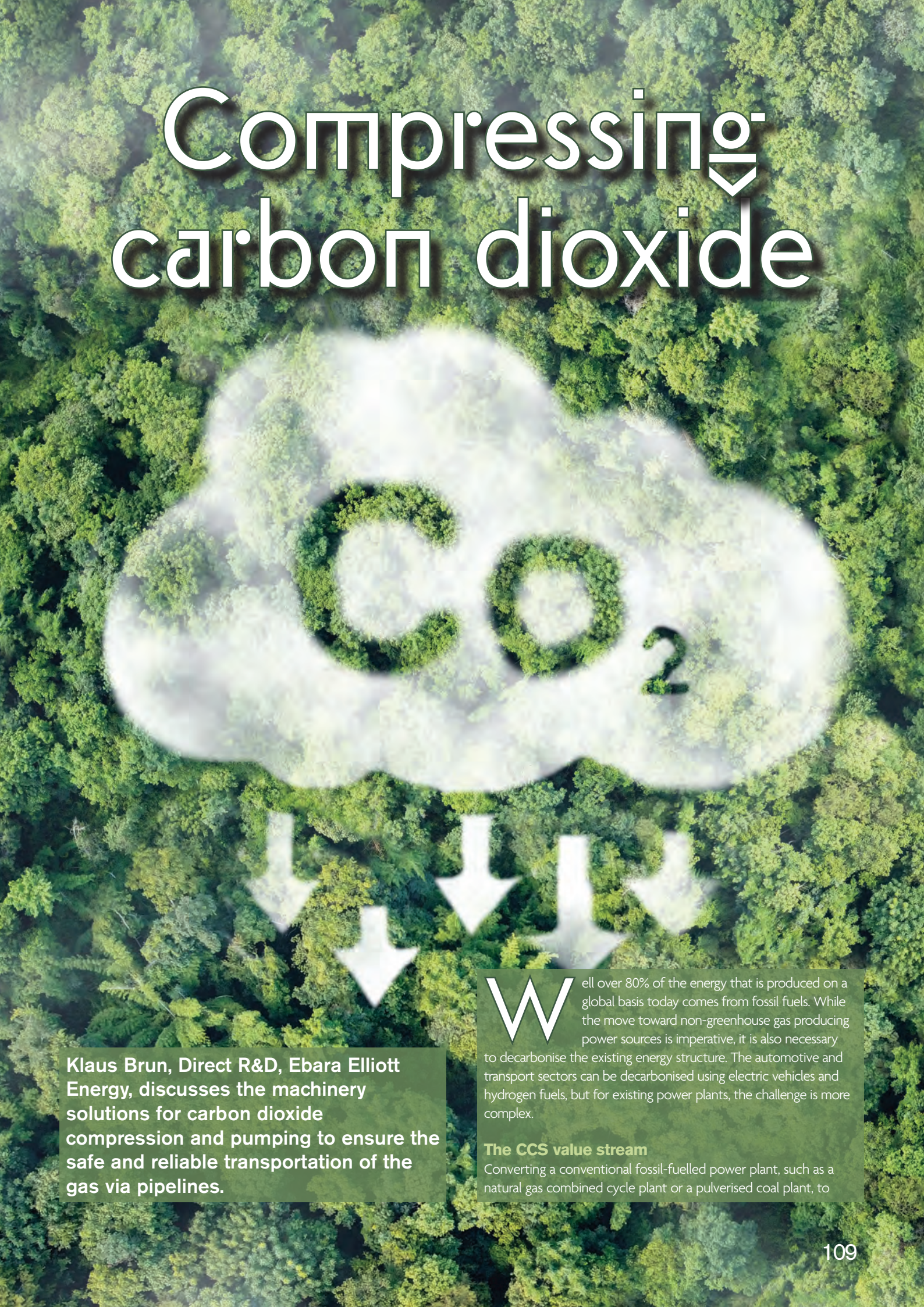
Compressing carbon dioxide



Klaus Brun, Direct R&D, Ebara Elliott Energy, discusses the machinery solutions for carbon dioxide compression and pumping to ensure the safe and reliable transportation of the gas via pipelines.

Well over 80% of the energy that is produced on a global basis today comes from fossil fuels. While the move toward non-greenhouse gas producing power sources is imperative, it is also necessary to decarbonise the existing energy structure. The automotive and transport sectors can be decarbonised using electric vehicles and hydrogen fuels, but for existing power plants, the challenge is more complex.

The CCS value stream

Converting a conventional fossil-fuelled power plant, such as a natural gas combined cycle plant or a pulverised coal plant, to

eliminate carbon emission requires the installation of carbon capture and sequestration (CCS) technologies. This means capturing the fossil fuel's carbon either pre-combustion through the local production of hydrogen using reforming or gasification processes, or post-combustion, through separation of the exhaust carbon dioxide emissions from the plant's flue gas. Both of these carbon capture technologies have been demonstrated, are technically viable, and both processes produce carbon dioxide at relatively low pressures. Once captured, the carbon dioxide must then be transported via pipeline to a suitable geological sequestration site and injected into the formation for long term storage.

The CCS value stream requires three different compression services:

- Compression of the low-pressure plant carbon dioxide emissions into a pipeline.
- Recompression of this gas along the pipeline for transport.
- Compression of the pipeline carbon dioxide gas into a geological formation at the appropriate reservoir pressure.

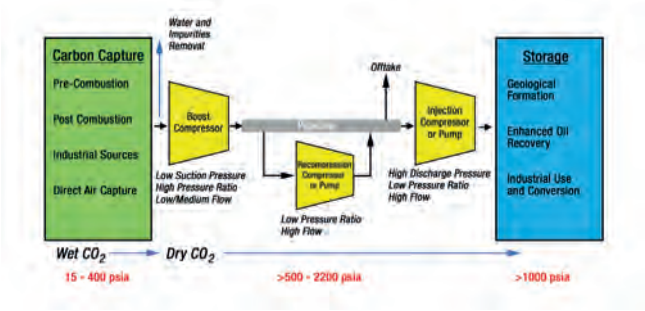


Figure 1. Carbon dioxide value stream for capture and sequestration.

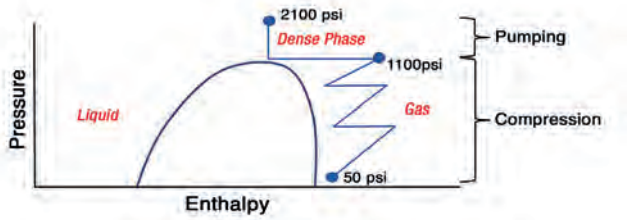


Figure 2. Compression process for low pressure plant exhaust carbon dioxide to pipeline transport.

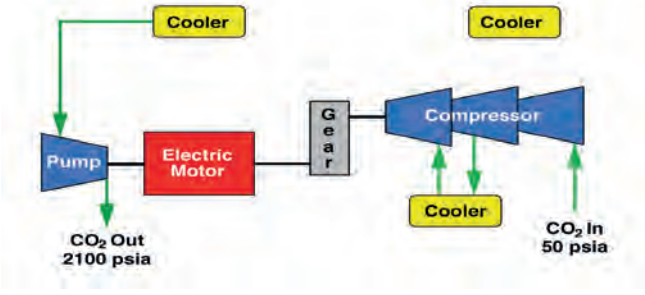


Figure 3. Hybrid compressor and dense phase pump mounted on a single shaft.

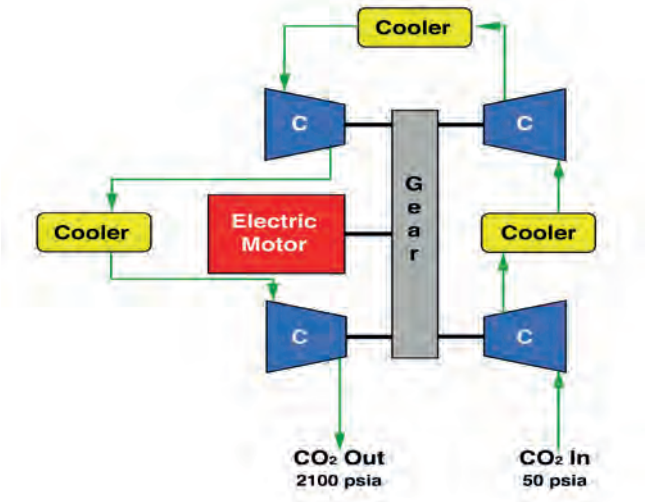


Figure 4. Integrally geared centrifugal compressor with intercooling.

CCS processes

The pressure of carbon dioxide gas from the separation process depends on the type of separation process used, and can vary from slightly above atmospheric to several hundred psi. There is also significant uncertainty about the geological formation injection pressure since it strongly depends on the type of formation and its depth of injection. However, a generally accepted rule is that for every kilometre of depth of injection, about 1150 psi of gas pressure is required. Since many of the geological formations currently under consideration are relatively shallow, injection pressures between 1500 to 2500 psi are expected to dominate initially. For this reason, a typical CCS pressure application requires carbon dioxide to be compressed from below 50 psia to somewhere above 2000 psia.

Regardless of the sequestration injection pressure, it is a generally accepted industry convention that in pipelines, carbon dioxide should be transported as a supercritical fluid above 2100 psi. At 2100 psi, carbon dioxide is well above its critical point in a supercritical state for almost all ambient temperatures. Liquefied gases in a dense phase share some physical properties of liquids, such that they have a very low compressibility, and also, some gas fluids have low viscosity and will expand in space to fill voids. The advantage of transporting carbon dioxide at supercritical pressures is that its density does not change much with pressure, and from a thermodynamic perspective, it is basically pumped rather than compressed. This significantly reduces the power demand for the compression stations along a carbon dioxide pipeline.

Since carbon dioxide is a very heavy gas, it is relatively easy to compress. This means that for a given head, the pressure ratio per compressor impeller stage is high. But because of the high pressure ratio per stage, carbon dioxide also has a significant specific volume decrease with pressure, and a very high heat of compression. Consequently, carbon dioxide will heat up when compressed, which requires stage intercooling to maintain the gas temperature at reasonable levels so as to not damage the seals and bearings of the compressor. Furthermore, because of its rapid density change with pressure, there is a significant reduction in flow volume that requires a wide range of aerodynamic high-to-low flow compression stages. The optimal thermodynamic path for carbon dioxide maximises intercooling to maintain the

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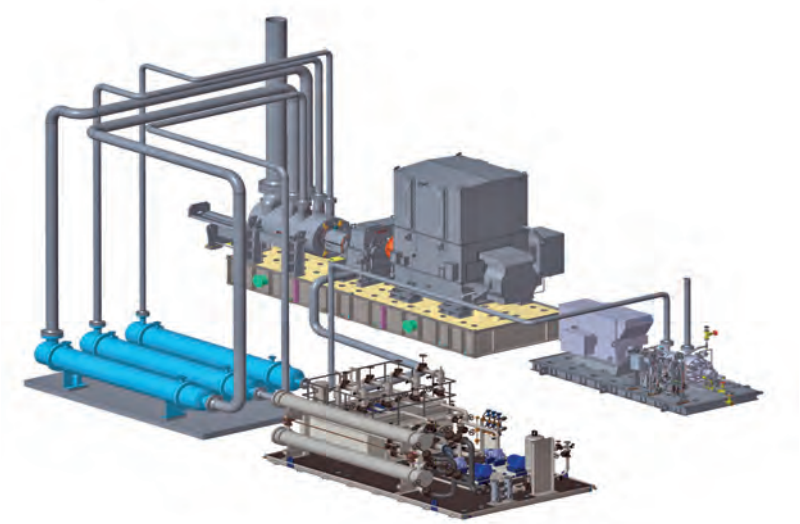

Figure 5. Layout of carbon dioxide hybrid compressor-pump.

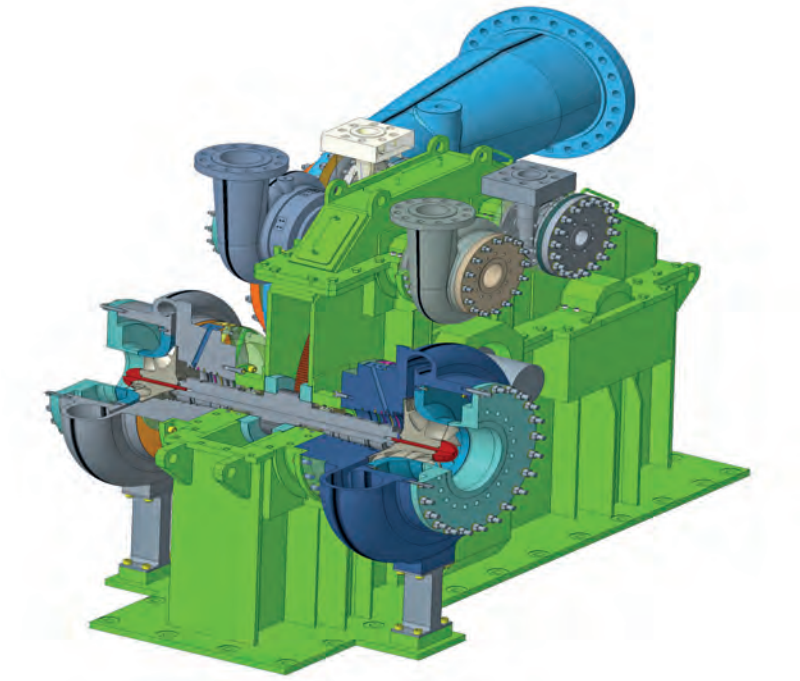

Figure 6. Integrally geared centrifugal compressor without the intercooler shown.

process gas temperature as near as possible to isothermal. This compression path can be seen in Figure 2 on a pressure-enthalpy diagram with three intercooling steps. Clearly, more intercooling will reduce compression power requirements and increase the efficiency of this process.

Compression options for CCS

The types of compressors that are usually considered for high pressure ratio carbon sequestration CO_2 applications are reciprocating, screw, centrifugal barrel, and integrally geared. Above the critical point, a dense phase pump can also be used instead of a compressor. Since both reciprocating and screw compressors are severely flow limited, they cannot be practically used for large-scale power plant carbon sequestration applications. The remaining technology options all rely on proven centrifugal compressor or pump impellers but use different layouts and stage arrangements, as shown in Figures 3 and 4.

Figure 3 shows a hybrid compressor-pump option where the carbon dioxide is compressed to above the critical point using a barrel compressor, and then pumped to the desired injection pressure using a dense phase pump. It should be noted that the compressor and pump do not necessarily have to be on the same shaft and two separate driver motors could be used instead. Figure 4 shows a typical integrally geared centrifugal compressor arrangement which provides for the potential of intercooling between all individual compression stages. This arrangement, albeit mechanically more complex, will usually have a higher overall process efficiency.

The actual implementation of these compression options into practice is shown in Figures 5 and 6 for the hybrid compressor-pump and integrally geared compressor arrangements, respectively. Specifically, these figures show schematics of the possible centrifugal compressor configurations to compress carbon from about 50 psia to 2100 psi, from carbon separation into pipeline header for transport or geological storage injection. Here the hybrid compressor-pump uses a single barrel compressor with two intercooling stages (requiring a total of six compressor nozzles), a discharge cooler, and a dense phase pump driven by a separate motor (Figure 5). The integrally geared compressor shown has six to eight impellers that are overhung mounted on the gear pinions, with all pinions driven by a single bull gear (Figure 6).

Conclusion

Several machinery solutions for carbon dioxide compression and pumping are commercially available and have been field demonstrated. These options all have some advantages and disadvantages. A final decision on which of these options is the most appropriate solution for a given carbon capture application must be decided based on a careful engineering analysis, and very much depends on the detailed application and site-specific requirements.

For large-scale industrial carbon dioxide transport and sequestration, the most favourable solution appears to be either a conventional barrel compressor in combination with a dense phase pump, or an integrally geared centrifugal compressor. While the integrally geared compressor will usually provide for the highest process efficiency, the conventional barrel compressor-pump tends to be more rugged and scalable. Regardless, when properly applied, engineered, and implemented, both compression solutions usually provide cost effective, safe, reliable, and operationally flexible solutions for carbon dioxide transport and sequestration applications.

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Bridging the green skills gap

IACS, UK, shares insights from key personnel about the company's efforts in creating the next generation of highly skilled pipeline inspectors and supporting the green transition through hydrogen training.

"Our industry has never been more exciting!" comments Ross Hewitt, CEO of IACS. "We are operating at a time of significant investment in the infrastructure for utilities as energy supply chains look to extend and upgrade. The changes that will develop over the next five years are exponential.

"As a business that has provided pipeline inspectors, products and services into the energy sector for over 25 years, we feel very fortunate to be playing a role in this global energy transition as we move towards net-zero. Supporting this ambition is not without its challenges. There are lots of roles to fill, yet we are operating in an industry struggling to recruit the right people with the right skills due to a critical shortage.

"Over the coming years, there will be an unprecedented demand for professional pipeline inspectors who are equipped to support the green agenda and the evolving knowledge demanded by the energy market. Recognising this, IACS Ltd has devised a way to efficiently and quickly scale up the number of candidates attracted to, entering and excelling in pipeline inspection."

Dedicating resources to training and education

Ross explains: "IACS has a rich heritage of investing in people. We nurture our contractors and colleagues, and instil an approach that is focused on quality and safety, which is vital as our engineers have a huge responsibility.

"In 2023 we made a commitment to put the time and attention into future-proofing our business and workforce. We made a multi-million-pound investment in people and skills development, which started with the launch of

The apprenticeship

The 16 month apprenticeship offers a starting salary from £28 000. Each apprentice will achieve performance-related salary incentives as they gain individual certifications awarded by TWI. On successful completion of the apprenticeship, permanent roles with IACS Ltd will be offered.

Figure 1. Ross Hewitt, CEO of IACS Ltd, is joined by Andy Burnham, Greater Manchester Mayor, as he welcomes the second cohort of apprentices onto the pioneering 'Practitioner in Pipelines for Hydrogen & Utilities' Apprenticeship at Hopwood Hall College and University Centre in Middleton.

Figure 2. Rachael Burns, Head of Partnerships in Education at Hydrogen Safe, Julia Heap, Principal and CEO at Hopwood Hall College and University Centre, Laura Hewitt, Director at IACS Training and Education and Heather Claxton, Associate Director and Group Regional Manager, UKEUS at TWI represent an innovative partnership between education, industry and specialist skills providers.

the IACS Training and Education subsidiary and the 'Practitioner in Pipelines for Hydrogen and Utilities' Apprenticeship."

Through IACS Training and Education, the company focuses on bespoke training programmes to help existing inspectors progress within the industry and has also launched an apprenticeship. Together, this will help to meet the urgent, global demand for the provision of specialist inspection, quality assurance, asset examination and auditing services – whether offshore, operating in the energy transmission or renewable energy industries.

To complement its contractor model, which IACS will continue to operate and expand, the business prioritised the development of the pioneering 'Practitioner in Pipelines for Hydrogen and Utilities' Apprenticeship, which includes the UK's first Ofqual registered qualification in hydrogen safety.

Laura Hewitt, Director at IACS Training and Education explains: "Our vision for the 'Practitioner in Pipelines for Hydrogen and Utilities' apprenticeship is simple. Our aim is to develop highly skilled tradesmen and women who will confidently contribute to, and have a long and fulfilling career within, the evolving energy sector.

"To achieve this, the apprenticeship is employer-led and has been created through an innovative partnership with education, industry and specialist skills providers. Our enhanced curriculum combines classroom learning and on-site experience to deliver soft skills alongside real life, practical knowledge."

Innovative partnerships

Partners supporting the apprenticeship are Hopwood Hall College and University Centre, TWI and Hydrogen Safe.

Julia Heap, Principal and CEO at Hopwood Hall College and University Centre, comments: "This pioneering partnership is a brilliant example of how collaborative innovation can make a big impact. By bringing together diverse knowledge, skills, resources and experience, we have been able to solve a skills challenge. Providing the right training in our world-class facilities means that we are perfectly positioned to deliver the highly skilled, well-paid, green workforce of the future."

Derived from the Construction Support Technician apprenticeship standard, the apprenticeship will yield recognised qualifications and certifications from training and examinations delivered by TWI, Hydrogen Safe and the Energy and Utility Skills Register (EUSR). Bespoke course features include welding, coating and painting inspection and non-destructive testing.

The 16 month apprenticeship offers a starting salary from £28 000. Each apprentice will achieve performance-related salary incentives as they gain individual certifications awarded by TWI. On successful completion of the apprenticeship permanent roles with IACS Ltd will be offered.

Industry specific

Extending beyond technical proficiency, the bespoke programme also encompasses essential aspects of the industry, Michael Michlovsky, Technical Director at IACS Ltd explains: "We must ensure that our apprentices are ready for the challenges and responsibilities they will face. To support this, we focus on nine key areas – health and safety, quality, procurement, documentation, relationship management in construction, project management, technology in construction, surveying methods and construction principles."

Hydrogen safety

The programme also includes a qualification in hydrogen awareness, to ensure apprentices can work confidently and safely with hydrogen. To enhance the learning, this is delivered through an immersive, multi-sensory training experience that provides access to working environments using content that is created using 3D cameras, 360° video and AI rendered imagery.

CEO and Founder of Hydrogen Safe, Andy Lord, comments: "IACS has taken a bold step with the launch of a dedicated

training division. What's more, it has proven to be an industry leading business that is attracting talent and equipping its workforce with the skills they need to embrace the transition to green energy.

"We are very pleased to play our part in this revolutionary apprenticeship programme. Having launched the UK's first registered qualifications in hydrogen safety, delegates can be assured that they will gain the skills they need today and also the knowledge they will need for tomorrow.

"This is just the start of an exciting journey and one that will provide opportunity, jobs and economic stability to those that get involved."

Educating future talent

To date, IACS has welcomed two cohorts, with 22 apprentices now enrolled on the Practitioner in Pipelines for Hydrogen and Utilities' Apprenticeship, which launched in September 2023. IACS will start to recruit for its third cohort in the autumn of 2024 and the company holds the ambition for this programme to run for many years. Attracting a diverse mix of apprentices; four females are already part of the programme, Laura explains: "Educating prospective apprentices about the role is imperative. After all, a pipeline inspector is not traditionally on the top ten list of careers.

"We do operate in a niche market, and it is difficult to get started in. You are often in challenging conditions and environments, and it doesn't suit everyone. Individuals need to understand this if they are to succeed and excel in our industry.

Figure 3. Week three of the Practitioner in Pipelines for Hydrogen and Utilities' Apprenticeship and apprentices receive hands on experience.

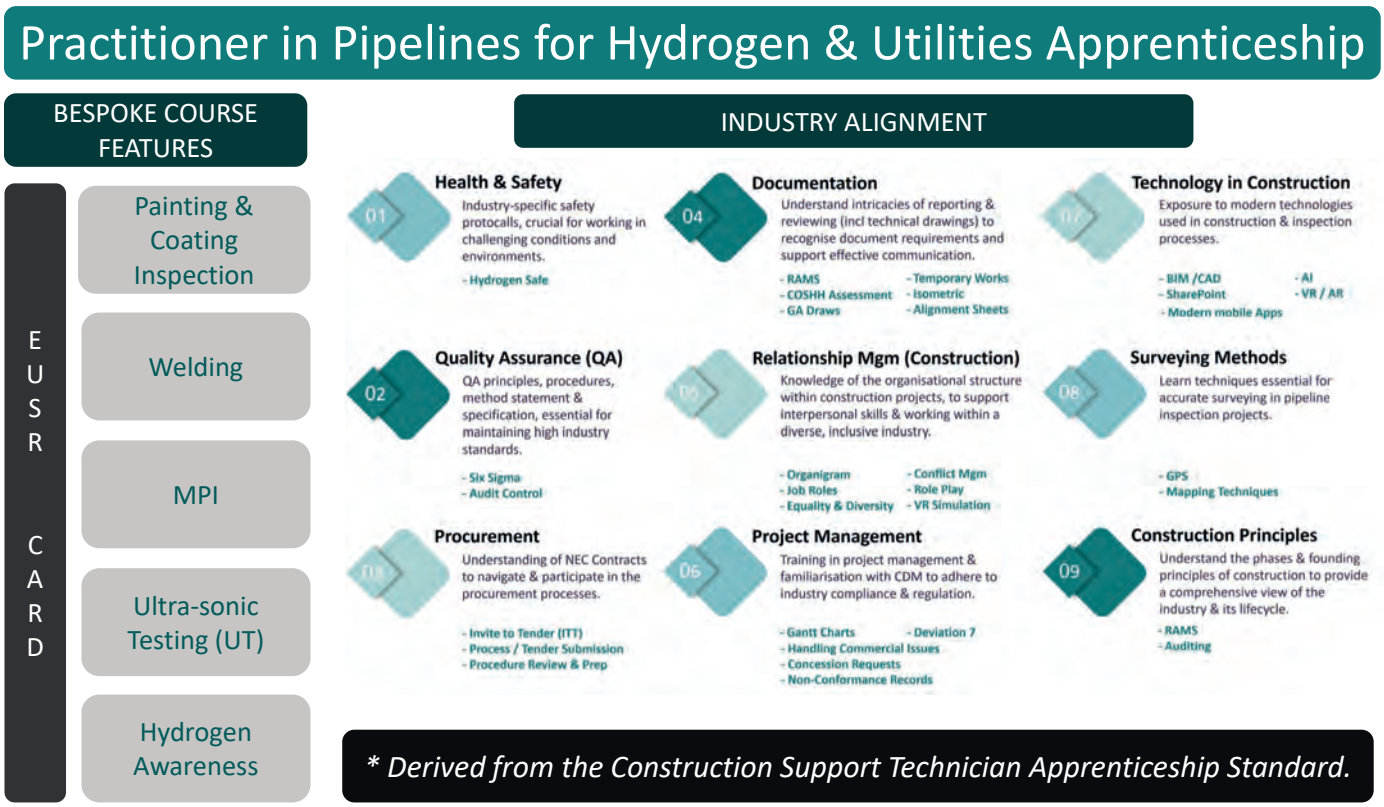

Figure 4. **Aligning the 'Practitioner in Pipelines for Hydrogen & Utilities' apprenticeship with the industry.**

"We started this journey with no preconceived ideas about our apprentices, but it is no secret that our industry is male-dominated, and we relished the opportunity to try and change this. Working with Hopwood Hall College and University Centre has really helped us attract a diverse group of apprentices.

Kayleigh Hill from Cheshire started the IACS apprenticeship in September 2023. Previously a Criminology university student, she realised that this wasn't the career she was hoping for and more importantly, neither was this way of study.

Kayleigh explains: "Criminology wasn't for me! I wanted a career that would challenge me and allow me to grow and thrive. I met the IACS team at a job fair in Anfield and was keen to understand more about a role I'd never heard of, never mind considered.

"The more I learnt about the role and its potential, the more I liked it.

"There was no doubt that it was going to be challenging and that I was going to be outside of my comfort zone, after all this is a highly skilled apprenticeship. But with structured learning, study combined with experience, support, mentoring and an endless list of future opportunities, I knew that it was the right decision."

Almost one year on and Kayleigh is one of nine apprentices from cohort one that is already active on live sites having studied, passed and gained their inspecton qualifications. Importantly she is loving her apprenticeship, she adds: "I love this way of learning. You study and then you are on site shadowing and everything that you have covered makes sense ready for your tests and examination. I have received so much help and support, not just from the IACS team and Hopwood Hall College, but the other apprentices too. We are such a diverse group, with varying skills and experiences that there is always someone that can help."

Stephen Fitchett was a Fabricator Welder for 14 years before he joined the IACS team as an apprentice, he recognised that this apprenticeship could be the step he needed to progress his career in an industry that he knew well.

Stephen, like Kayleigh, has been on the programme for nearly 12 months, he explains: "I had been a welder for 14 years but within the role I held, my career progression was limited. When I met the IACS team and found out about the position it met my brief perfectly. It's certainly been intense, and in some ways challenging, but this has all been outweighed by how rewarding this apprenticeship is and will be."

Supporting the green transition

Michael Michlovsky adds: "This is the first time that anyone from within our sector has done anything like this. We want to create new jobs in the inspection industry for pipelines, for hydrogen and to meet the needs that will come from a transition to green energy.

"By working with the right partners and attracting a diverse mix of apprentices, we are playing a small role in changing the perception of the industry, and in doing this, it will help to attract a wider and more inclusive team of professionals."

By 2027 hundreds of apprentices will have completed or be part-way through the 'Practitioner in Pipelines for Hydrogen and Utilities Apprenticeship. Qualified in non-destructive testing skills, each individual will support quality control and product reliability which is vital for energy and utilities. They will have also developed the skills specifically designed to equip them for working within the green energy sector and industries including Aerospace, Automotive and Maritime energy complex.

World Pipelines **talks to two companies at the forefront of pipeline protection, and asks them some questions about surface preparation, cleanliness, coatings, and coatings application technologies.**

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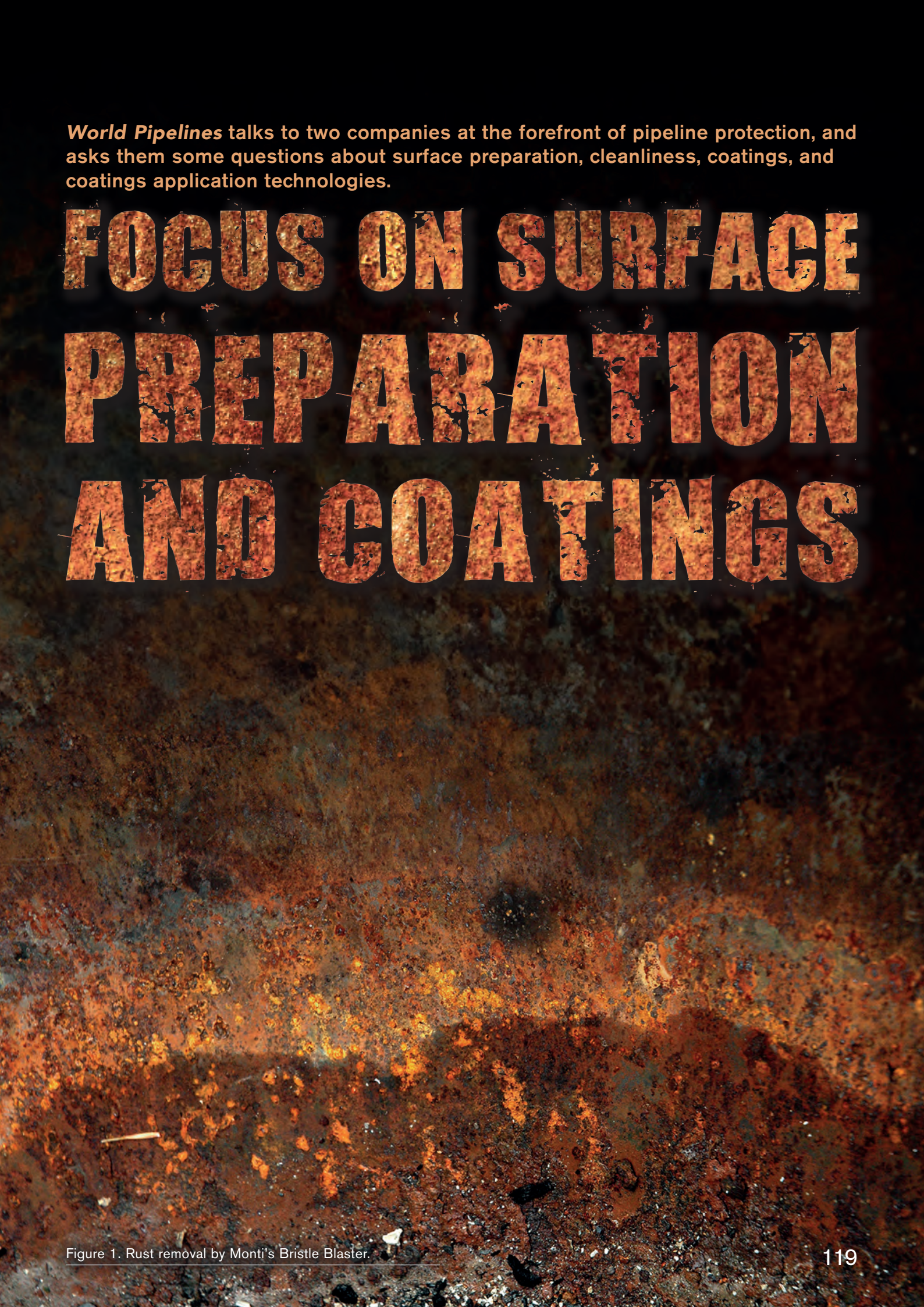

Figure 1. Rust removal by Monti's Bristle Blaster.

MontiPower

How does your company provide corrosion protection for oil/gas pipeline assets?

MontiPower (based in Germany, with five offices in the USA, one in Netherlands, one in Brazil and one in Australia) offers globally, through a vast network of distributors, surface preparation by the method of bristle blasting before reinforcements, coating and the applications of adhesives for the optimal long-term bond to steel and other substrates such as PE/PP. MontiPower produces specially designed and patented bristles driven by a powertool. This tool can be pneumatic, cordless, electric or waterdriven. Underwater, semi-automatic solutions for field joints, or robotic for weldseam prep, is also part of the system.

Figure 2. Monti Bristle Blaster.

Figure 3. Bristle blasting a field joint.

Explain a technology that you use to protect pipelines.

Blasting in the field without grit is possible. The bristle blasting technology makes use of spring steel wire. Per belt of 23 mm, 576 sharpened spring steel wires hit the substrate in such a way that it does not smear, or burnish the steel. Very gentle, these bristle tips can remove mill scale, layers of PE/PP, adhesives, FBE, epoxy coatings and create a reliable, uniform surface profile for adhesion at the same time. During operation, particles are generated which can easily vacuumed. It is a very easy way to reach the highest grit blasting cleanliness qualities according to the ISO 8501-1 cleanliness grades.

What part does environment play in the work you do to protect pipelines?

Each bristle can be resharpened for a longer working life. Re-sharpening can be done by reversing the bristle on the tool, and then rotating it for more than 15 secs on sand paper or a special grinding stone. The bristles can also be re-used for other purposes, like cleaning wood, stone, brick, etc. MontiPower offers contractors special recycling carton bins. In the Netherlands, we offer special programmes in cooperation with a recycling firm, as one bristle is still worth 3 eurocents and one alu adaptor is worth 30 eurocents per kilo. One bin can hold 180 belts. The rule of thumb is one belt, one hour, one person, 1 m^2 of surface preparation, for flash rust removal. According to various studies for outdoor blasting, conventional blasting equals 33.5 kg CO_2. Bristle Blasting is therefore an environmental alternative, saving emissions and chemical waste removal.

How important is surface preparation to the success of protective coatings and wraps?

For liquid curing coating, the rule of thumb is that 60% of coating success depends on proper surface preparation. The question is, what is proper for removal of all visible and not visible contamination, mill scale, corrosion, existing coatings and for profiling. Keep in mind, the cleaner is always better. This rule is valid for all underground field-applied coatings. In practice, always select a method that offers the best repetitive cleanliness results and uniform surface profiles, so that the selected coating can rely on it for a sustainable performance. There should be no disagreement over quality of prep and coatings. Montipower offers proven, and practical solutions for field application. For instance, the BB double is fast (3 m^2/hr/flashrust removal per person), but Montipower can also offer semi-automatic or robotic solutions including particle suction control.

Allter

Figure 4. Sander and Frits at the Allter HQ in Belgium.

How does your company provide corrosion protection for oil/gas pipeline assets?

The Allter Prevention Group from Belgium (with JV offices in the UAE and Mexico, and distributing partners in Korea, South Africa, Brazil, France, Switzerland, India, and China), offers various kind of corrosion prevention and sealing solutions for pipelines. These include CUI for plant piping, line pipe coating on-site, riser piping, offshore and onshore field joints and aboveground piping work, with a wide range of coatings. Today, all over the world more than 40 corrosion engineers are active on a daily basis to engineer solutions. Dutchwerk is a contractor brand of Allter that installs coating systems, including surface preparation. Strongpipe is another Allter company, carrying out pipeline reinforcement. The Dutchwerk team apply this composite technology to reinforce pipelines based on our patented vacuum controlled system.

Explain a technology that you use to protect pipelines.

For CUI and hot piping, Allter makes use of polysiloxanes for hot piping, but Allter also makes use of pure polyisobutylene, known as Oppanol, from Basf as the basis ingredient for Visco-Rite. Visco-Rite comes as a prefab roll which can be cut to size for underground (also for condensating pipe), aboveground and subsea applications. The rolls come in different thicknesses and with different backings. Aboveground the backing is non-woven, which can be coated with a special, stress-free, one component topcoat. 'Do it right, do it once, but with ease' is our credo.

What part does environment play in the work you do to protect pipelines?

Visco-Rite is a product and system to rely on. This coating type does not require loose abrasive blasting. Per square metre, a contractor can save circa 45 kilos of grit, plus the removal cost as chemical waste, if the contractor goes for the prefab coating in a roll form called Visco-Rite. In the case of new build pipelines, mill scale must be removed. Allter promotes the use of 43 mm MBX brushes for pipecleaning. Subsea, condensating pipe and offshore, <150 °C Allter Visco-Rite System are prefab, easy and fast to apply and meet the requirements of pipeline service life. Allter offers more than 60 years service life against corrosion.

Figure 5. Visco-Rite pipeline coating onsite.

How important is surface preparation to the success of protective coatings and wraps?

The Visco-Rite range of products, based on polyisobutylene, which come as a putty, filler or roll do not require loose abrasive blasting according to the ISO 8501-1. St 3 removal of any loose rust or coating particles is enough in case of maintenance and spot repair, as long as prep work withstands the quick 5 mins cleanliness check at ambient temperatures. We recommend the use of isopropanol as a degreaser and cleaner before a dry application. The cleanliness test is the most important. Just take one piece from the roll: the rule of thumb is that if the piece exhibits a cohesive failure to the cleaned substrate within 5 mins at ambient, then the cleanliness grade was sufficient and reliable for continuation of the protective coating job.

PIPELINE MACHINERY FOCUS

World Pipelines' quarterly pipeline machinery focus.

PETTIBONE USA

Pettibone offers the Cary-Lift 204i in its line of pipe and pole handlers. The machine is purpose-built to deliver numerous safety and performance benefits over other material handling alternatives.

The Cary-Lift 204i features a unique overhead lift arm design, giving the operator full front visibility when lifting or transporting loads – a sharp contrast to the lift arms on wheel loaders, which are located directly in front of the vehicle. Additionally, Cary-Lift forks are capable of tilting down 90° for specialised lifting tasks.

The 204i is powered by a 200 hp Cummins QSB6.7 Tier 4 diesel engine with DOC and SCR aftertreatment. The unit includes an engine-driven fan, cooling package and engine block heater as standard equipment. The machine provides a maximum load capacity of 20 000 lb and max lift height of 16 ft. Offering 4-wheel drive with 2-wheel, 4-wheel and crab hydraulic power steering modes – and with the wheelbase limited to just 12 ft – the 204i can achieve a turning radius of 21 ft, 6 in.

Unlike forward-reaching articulated loaders, the Cary-Lift's heavy-duty, solid steel frame design allows it to take full loads into sharp turns without sacrificing load capacity or stability. Hydraulic frame sway control and side shift capabilities further stabilise loads by levelling the lifting frame when driving on uneven ground. The sway cylinder moves 7° both right and left of centre.

The Cary-Lift 204i comes standard with X-Command®, a Pettibone telematics programme that offers real-time access to machine data, saving time and money for equipment owners and service technicians.

A sliding door offers quick access to the comfortable operator cab, which includes a tilt/telescopic steering column and a swivelling, adjustable suspension seat with seat belt, padded armrests and

Rather than having lift arms in front of the vehicle, the Cary-Lift's arms are mounted behind the cab. This overhead lift arm design provides a completely unobstructed forward view for the operator.

lumbar support. Dual joysticks provide intuitive controls to efficiently shift gears and control the hydraulics. Large tinted safety glass windows and a rear-view camera with 7 in. display are standard.

A quick attach system increases the machine's versatility, with fork frames, pipe and pole baler, log baler, and scrap baler all available as attachments.

Pettibone/Traverse Lift, LLC is part of the Industrial Technologies Group, an affiliate of The Heico Companies. Founded in 1881, Pettibone has been recognised as an industry leader in material handling equipment since the company launched the first forward-reaching, rough-terrain machines in the 1940s.

HERRENKNECHT

GERMANY

With increasing environmental awareness and a rising number of HDD projects for the installation of underground cables and landfalls, smaller installation diameters are required. This increases the potential for smaller rig sizes, reducing emissions and saving resources. For HDD operations, environmental aspects include fuel consumption and emissions, water and bentonite consumption, disposal of drilling fluids and excavated muck, jobsite footprint, and fluid release. In the future, contractors will have to provide environmental evidence, as part of an increasingly important part in contract awards.

Equipment manufacturers' environmental initiatives include the electrification of the complete jobsite. Running the jobsite only on electricity, including the HDD rig itself, enables the contractor to operate with considerably lower CO_2 emissions.

The HK300TE's control container perspective.

All-electric HDD rigs

The recently developed all-electric HDD rigs HK300TE and HK45CKE, are a significant step towards the energy transition, making green energies usable in the drilling industry. A directly electrically driven rig enables the use of green electricity and assures higher efficiency without the losses associated with the hydraulic system.

Improved efficiency

To improve efficiency, the hydraulics have been removed. The electric motors are directly installed on the carriage on the gearboxes, greatly increasing efficiency and reducing emissions. If a grid is possible as a power source for the electricity and the grid gets its power from a green source such as a wind turbine, hydropower or solar panels, CO_2 emissions are close to zero.

Even if a generator with a diesel engine as power source is used, these engines are made to run continuously in the best possible revolution range to have the best power output. Combined with the highly efficient direct electric drives, diesel consumption can be significantly reduced. With the new electric drives, noise has been reduced by about 10 dB. Noise reduction is a side effect of electrification, but most recognised and highly appreciated by the jobsite personnel.

To ensure high equipment reliability, the most sensitive electronic parts are taken off the rig and transferred in a separate power module. This module is

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disconnected from all vibrations and other disturbances from the drill rig. In a protected capsuled environment, the frequency converters and other components are not affected by any disorders which can cause failures.

All-electric rig in operation

Herrenknecht's first all-electric rig HK300TE has already completed several HDD crossings in various ground conditions up to date. In Belgium, Germany and the Netherlands, the HK300TE all-electric Trailer Rig was used to install water and sewage lines, cable protective pipes and gas pipeline sections, with up to more than 1300 m of single crossing length.

The HK300TE rig on jobsite in the Netherlands, 2023.

Expanding the all-electric rig fleet, in addition to the 300 t all-electric HK300TE rig, the next focus were the medium-sized rigs, such as the 45 t range and with the new all-electric HK45CKE. The driving force to reach into this size range, which is currently the smallest rig made by Herrenknecht, was the development of the power grid in central Europe. With the extraordinary amount of drill rigs required to fulfill the schedule for completion by the government, a lack of available rigs can surely be foreseen.

Small rigs mostly come in track style, so the crawler needs to be driven independently from external power sources. The HK45CKE comes with battery packs to run the tracks for a minimum of 30 min., which is considered as the time needed to unload the rig and driving it into the final drilling position. Fully electric, with 45 t push and pull force, 24 kNm of rotary torque, an onboard 1.000 l/min mud pump and an automatic loading magazine makes this one of the most versatile drilling rigs manufactured by Herrenknecht.

Outlook

Driven in part by greater environmental awareness and requirements, HDD is constantly evolving and an increasingly important method in construction projects for power grids and pipeline networks. Besides pipeline construction, which will not disappear, the emphasis is shifting from oil and gas to alternative green fuels e.g. hydrogen and new applications such as carbon capture storage, fibre optic cables and more.

McElroy USA

There are five aspects to producing a qualified fusion joint. McElroy's DataLogger® is an integral part of what is needed for a quality joint, along with qualified materials, procedures, equipment, and operators.

The DataLogger captures and records all pertinent data related to each fusion joint, including pressures, the fusion standard being used, the joint's GPS coordinates, and more. Whether you're performing butt, sidewall, mitered, or dual-containment fusion, the combination of the DataLogger software and ruggedised tablet is an invaluable tool for quality assurance and record-keeping in the field.

Streamline fusion and fusion training

In addition to providing datalogging capabilities to both hydraulic and manual fusion, the DataLogger 7 also offers Enhanced Guided Workflow for TracStar® iSeries machines and the Tritan™ 560. This easy-to-use Z operators through many parts of the fusion process, including machine setup and fitting pipe. Once the fusion begins, a FusionGuide™ live graph visualises the process recording times and pressures for opening, closing, and cooling joints during the fusion process. This provides an added layer of quality assurance by automatically highlighting areas that could have deviated from industry specifications.

"The enhanced guided workflow with the DataLogger 7 is impressive," said Fusion Technologies, Inc. (FTI) Founder Les Klaudt. "If you have somebody go into the field on an occasional basis, that guided workflow is fantastic as a reminder of how the process needs to work, and it has been a huge help for us in our training and for those of us who aren't as frequent (fusion operators) as we once were."

Fuse confidently – all day long

The DataLogger 7 is designed to function all day on a single charge, which means it's able to work as long as you do. In addition, the tablet is dustproof, waterproof, and shock-proof, allowing it to withstand even the toughest of jobsite conditions. Its 17 in. touch screen provides great readability, even in sunlight, and can be used with gloves and in wet conditions.

For jobs that don't stop, McElroy offers a DataLogger Extended Life Kit. The kit comes with an extra removable battery and charger, supplying endless power to the project. To streamline operations even further, the DataLogger 7 offers a hot swappable battery, which lets operators quickly and easily change the external battery without disrupting power to the tablet. During the 'hot swap', the DataLogger 7's internal battery keeps all applications running seamlessly.

Know the who, where, when and more

The DataLogger functions alongside the Vault™, McElroy's powerful cloud-based storage platform. When connected to the internet, the DataLogger allows users to upload their fusion data into the Vault, allowing for instant review and oversight, whether down the street or miles away.

Users can upload their fusion data from the DataLogger to the Vault for review. For engineers, managers, and inspectors, that means getting as granular as you want with the data that comes from each joint, with each machine, on each project.

Understanding and using the information provided by the DataLogger can significantly improve the bottom line. The DataLogger gives you the tools to improve decision-making and overall jobsite performance in the field. For example, a series of improperly fused joints, flagged for review by the DataLogger, could point to a need for improved training procedures for fusion technicians.

Added fuctionality

McElroy is continually updating the DataLogger 7 based on customer input and recommendations. One of McElroy's most recent additions to DataLogger functionality is remote diagnostic capability for machines that are integrated with the DataLogger, such as the TracStar iSeries or Tritan 560.

If an operator or contractor is encountering a problem with their TracStar iSeries, after obtaining permission to access the machine, McElroy technicians can login to the machine remotely and access the machine's full CAN traffic. By essentially 'seeing what the fusion machine sees', tech support can then provide help more quickly.

The DataLogger and Vault also offer exception reporting, customised Vault notifications and the ability to record manual fusions. The latest feature coming soon is to provide instructional videos that answer common questions, provide an overview of the fusion process, and demonstrate how to take advantage of the DataLogger's functionality.

Five things are needed to produce a qualified fusion joint.

The DataLogger® 7 captures and records the pertinent data related to fusion joints, boosting quality assurance and record-keeping in the field.

Setting the standard

McElroy leads the world in equipment, accessories, and technology to service the pipe fusion industry. As plastic piping systems continue to grow in scope and popularity, making sure those fusion joints are consistently inspected and documented for quality is critical to the industry's overall success.

The DataLogger is one of the tools that sets McElroy apart, by providing users with marked advantages for success. Know without uncertainty that fusions performed using the DataLogger are done properly each time, long before your pipeline goes into service.

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