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Dear Reader...

Dr. Klaus Ritter
Editor in Chief

High pressure pipelines for oil, gas and water are often crossing several frontiers and geomorphological obstacles. Those pipelines have to be safe, reliable and durable to ensure a profitable and commonly accepted operation. Moreover, environmental sustainability becomes more important with each new pipeline project. To make sure that the best available technology is used to overcome all the potential challenges, it is of great importance to maintain and extend an international exchange of experiences and best-practices.

The Germany-based EITEP Institute (Euro Institute for Information and Technology Transfer) has created several services for the global pipeline industry to establish this critical international exchange on the highest level. These services are:

Annual Conferences

- Pipeline Technology Conference, Berlin - Germany
- Pipeline – Pipe – Sewer – Technology, Cairo - Egypt

Technical Seminars

- Accompanying the conferences
- Between the conferences

Electronic information

- Pipeline Technology Journal Newsletter
- Pipeline Technology Journal
- Abstract Database

An interesting development affects our Pipeline Technology Journal: we are going to transform ptj to a compendium for state-of-the-art pipeline technologies – a reference journal, including all current or upcoming high-end technologies available to the market. Pipeline professionals can get a condensed overview about solutions, products and services in all relevant pipeline related topics, provided by leading companies.

Every topic will be discussed particularly in a designated issue of Pipeline Technology Journal – updated every year – to make sure the latest technologies are visible to and callable for everyone interested. The refreshed ptj will be available from 2017 on.

In addition, the Pipeline Technology Journal Newsletter will maintain a two-week-rhythm and complement the focus compendia with further updates and current news making ptj and ptn to unique references for pipeline professionals worldwide.

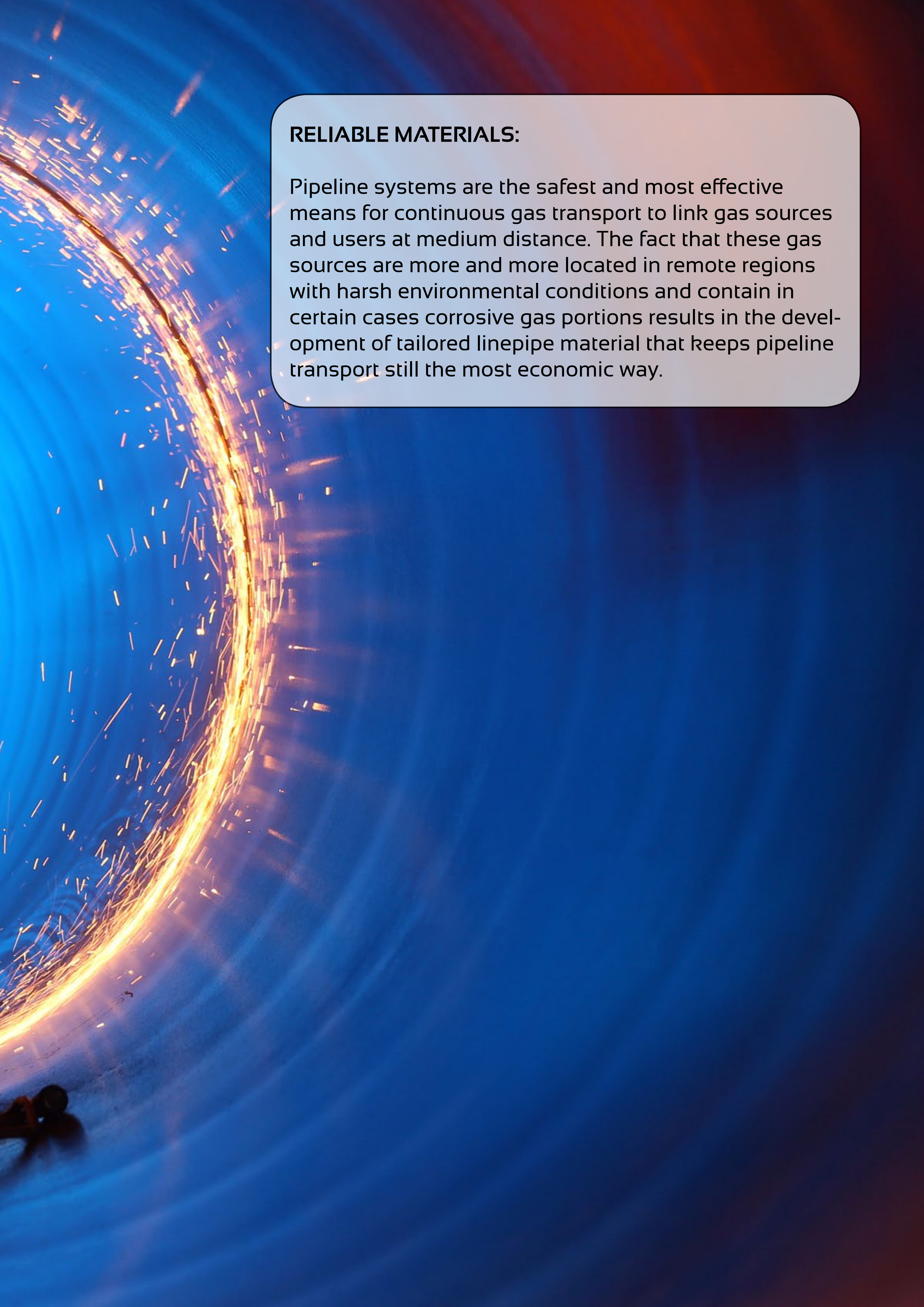
We have already implemented some changes to our global newsletter: away from plain news coverage - mainly from North America - toward a more diverse and multinational approach including Europe, Africa and Asia. Commentaries and political background reports for relevant pipeline-related events worldwide will be featured on a regular basis. To stay up-to-date, we have reinforced our editorial staff and we will continue to include ptc's considerable Advisory Committee and its resourceful and dedicated members in our efforts.

We are working constantly to uphold the continuous exchange within the international pipeline community. You are welcome to make use of the extensive opportunities we created. Kindly find additional information on our websites or contact us directly via mail:

eitep@eitep.de
www.pipeline-journal.net
www.pipeline-conference.com

Yours,

> Dr. Klaus Ritter, President EITEP Institut



RELIABLE MATERIALS:

Pipeline systems are the safest and most effective means for continuous gas transport to link gas sources and users at medium distance. The fact that these gas sources are more and more located in remote regions with harsh environmental conditions and contain in certain cases corrosive gas portions results in the development of tailored linepipe material that keeps pipeline transport still the most economic way.

TECHNICAL ARTICLES

SEPTEMBER 2016
EDITION 11

FOCUS:
MATERIALS

THIS ISSUES COMPLETE CONTENT

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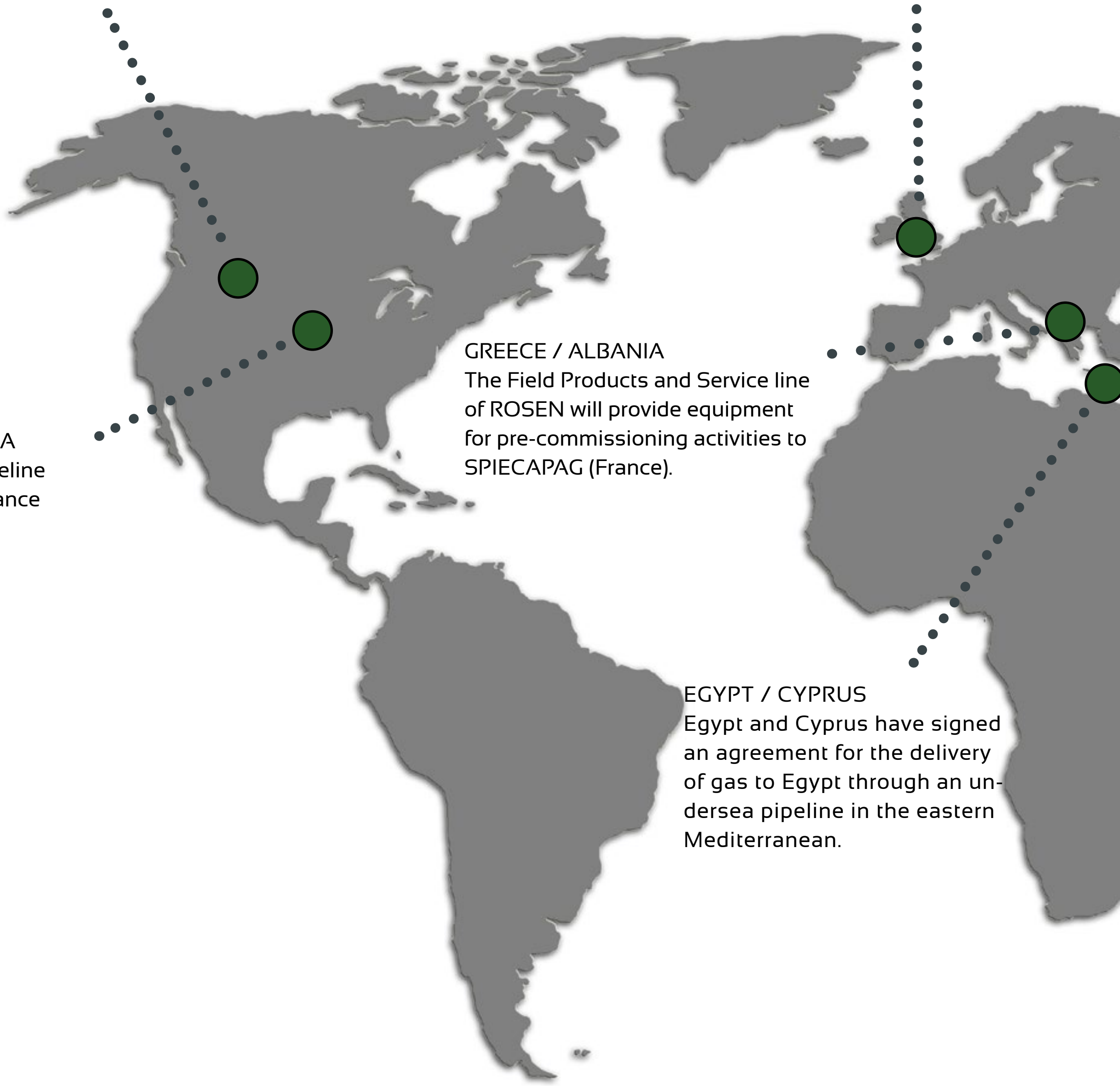
Enbridge and Spectra Energy have agreed to merge their respective companies in a stock-for-stock transaction to create the largest energy-infrastructure conglomerate in North America.

MANCHESTER / ENGLAND
Atmos International launches new Leak Detection System called Pipeline Guardian.



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The Field Products and Service line of ROSEN will provide equipment for pre-commissioning activities to SPIECAPAG (France).

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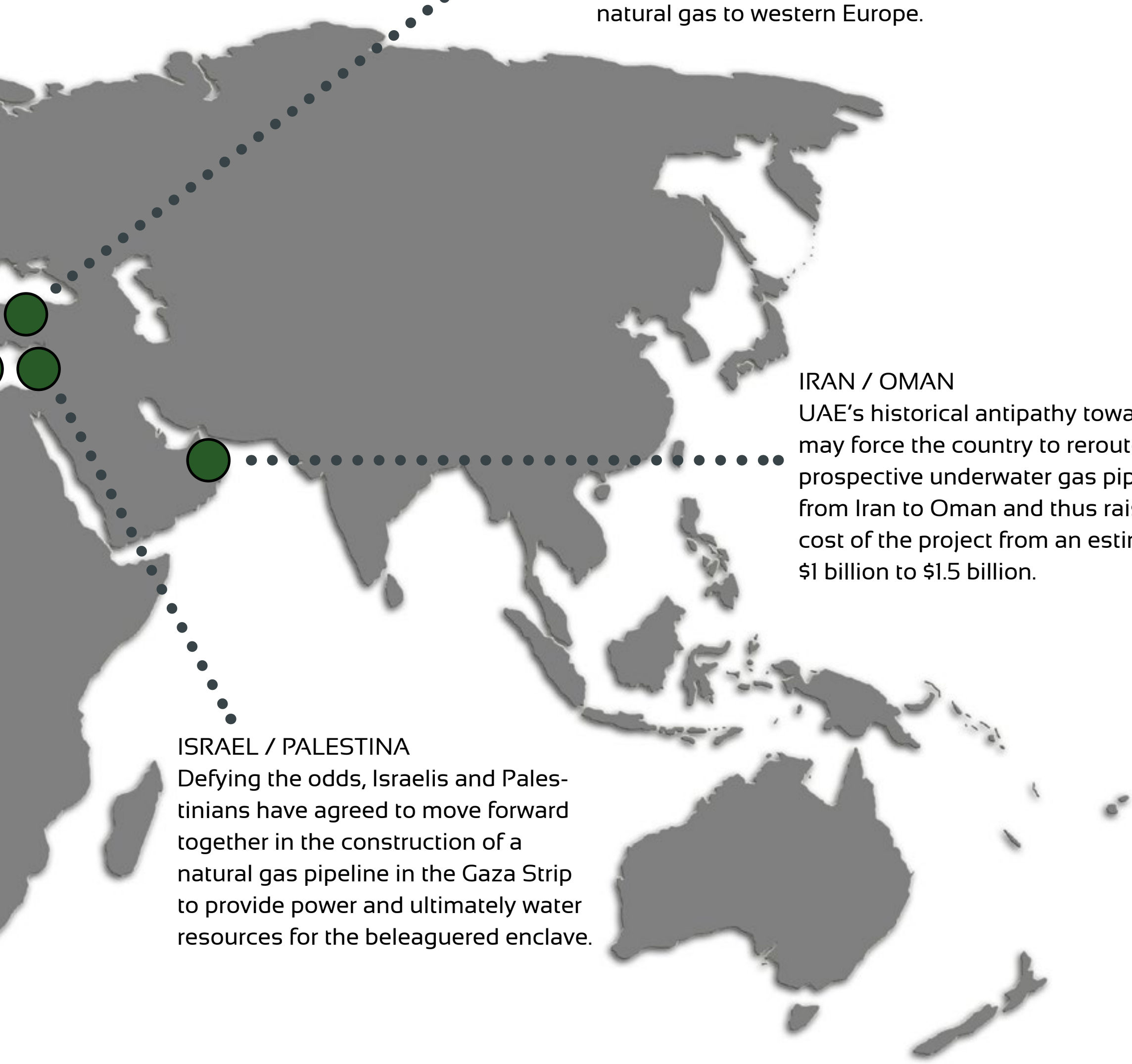


RUSSIA / TURKEY
Russian President Vladimir Putin and his Turkish counterpart Recep Tayyip Erdogan met recently to patch up their bilateral relationship and revive the on again off again Turkish Stream pipeline project, presenting Russia with another opening to export its natural gas to western Europe.

IRAN / OMAN
UAE's historical antipathy toward Iran may force the country to reroute the prospective underwater gas pipeline from Iran to Oman and thus raise the cost of the project from an estimated $1 billion to $1.5 billion.

ISRAEL / PALESTINA
Defying the odds, Israelis and Palestinians have agreed to move forward together in the construction of a natural gas pipeline in the Gaza Strip to provide power and ultimately water resources for the beleaguered enclave.

WORLD NEWS

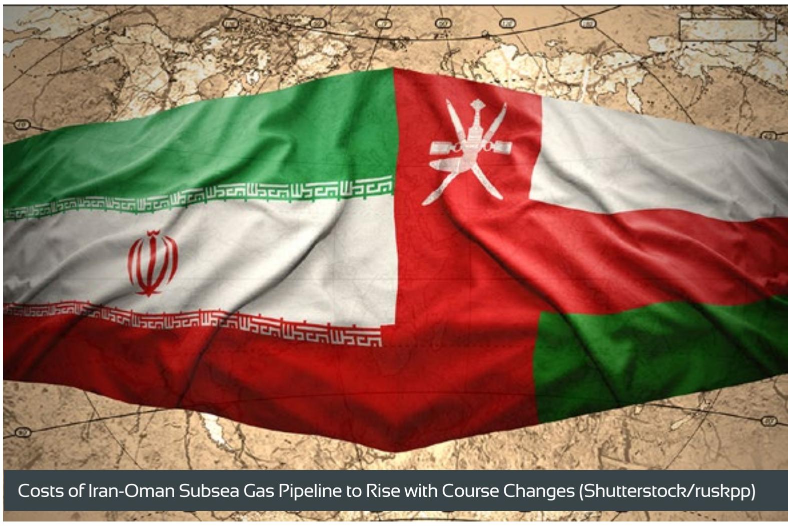
COSTS OF IRAN-OMAN SUBSEA GAS PIPELINE TO RISE WITH COURSE CHANGES

UAE's historical antipathy toward Iran may force the country to reroute the prospective underwater gas pipeline from Iran to Oman and thus raise the cost of the project from an estimated $1 billion to $1.5 billion.

The pipeline is projected to have shipment capacity of 1 billion cubic feet of gas per day, which may be increased to 2 billion cubic feet of gas daily to meet the growing gas demand in the region.

Oman, enjoying a good relationship with Iran, has long considered the country's prodigious gas reserves in the South Pars field as it hopes to feed energy-intensive industries and recently constructed liquefied natural gas (LNG) export plants.

Despite the lifting of international sanctions on Iran this past January, US pressure on Oman to find other suppliers have hampered progress on the project.



Costs of Iran-Oman Subsea Gas Pipeline to Rise with Course Changes (Shutterstock/ruskpp)

ISRAEL AND THE PALESTINIAN AUTHORITY PLAN NATURAL GAS PIPELINE IN GAZA

The Gaza Strip is a small self-governing Palestinian territory (iStock.com/chameleonseye)

Defying the odds, Israelis and Palestinians have agreed to move forward together in the construction of a natural gas pipeline in the Gaza Strip to provide power and ultimately water resources for the beleaguered enclave.

Gaza faces a severe energy crisis, with authorities using an 8-hour on, 8-hour off electricity rationing system. The sole power plant in Gaza routinely operates at half capacity.

Joined by the Mid East Quartet and chaired by a Dutch - supported task force, the undertaking will first consider a feasibility study on the route, costs and funding from donor states, most of which will come from the European Union. To this end a meeting of prospective donor countries will take place later this month in New York.

The organization said it launched and is chairing the Gas for Gaza (dubbed G4G by the Quartet) Task Force to "provide all relevant stakeholders with information coming out of the feasibility study as it progresses and to provide a platform for all stakeholders to coordinate and work together until the project is implemented."

BUMPY ROAD AHEAD FOR TURKISH STREAM

Russian President Vladimir Putin and his Turkish counterpart Recep Tayyip Erdogan met recently to patch up their bilateral relationship and revive the on again off again Turkish Stream pipeline project, presenting Russia with another opening to export its natural gas to western Europe.

Turkish Stream would theoretically transport Russian gas on the floor of the Black Sea to Kiyikoy, a city in northwestern Turkey before being shipped to Ipsala on the Turkish-Greek border for further distribution in Europe.

"Russia spent a lot of money on what was due to become South Stream, and is now looking for an alternative," Richard Mallinson, geopolitical analyst at Energy Aspects, said.

Yet with record low prices for natural gas in Europe it is hard to see Turkish Stream going forward in its current guise.

Indeed, while individual EU countries like Greece might been keen for a new source of energy supply that could reduce costs, there are still significant political and practical challenges ahead, with any European pipeline expansion subject to the same EU approval processes as South Stream.

"At the moment at least, the EU is saying it would prefer alternatives, more LNG (liquid natural gas) import terminals, and more pipeline supplies from Caspian (Sea) - not Russian - sources," Mallinson said.

COMMENT: DAKOTA ACCESS - THE POLITICS OF INTERSTATE PIPELINE CONSTRUCTION

As a general proposition, the longer the pipeline the more difficult it is to build it. This is related not just to technical issues surrounding construction. More than ever the success of a particular pipeline project depends on how well the pipeline operator can navigate the political thicket of interest groups along the proposed pipeline route.

Energy Transfer Partners, headquartered in Dallas, Texas has spearheaded the four-state,1886-km Dakota Access project, already constructing more than half the pipeline, which, when completed, would stretch from Stanley, North Dakota, near the Canadian border, to Patoka, in southern Illinois. The company has touted the creation of thousands of new jobs and compensation for landowners who grant access to their property for pipeline construction.

While the U.S. Army Corps of Engineers had approved most of the permits for pipeline construction, the native Sioux Indians declared the Corps hurried its decision, did not consult with the indigenous tribes and gave short shrift to environmental and cultural considerations. Of greatest concern is the routing of the pipeline under the Missouri River on a Sioux reservation which straddles North and South Dakota. The tribe argues the pipeline would affect drinking water for the thousands of residents on the reservation and the millions who rely on it downstream.

John Fleck, director of the University of New Mexico Water Resources Program and author of the new book Water is for Fighting Over, has said that this encounter adds to a long history of disregard for Native American water rights. "We've done a poor job of recognizing and respecting the rights and values of native communities to water. We can't keep doing that, both for legal reasons—Indian rights to water have a special legal status in U.S. law—but also for moral reasons.

Last week the Obama administration temporarily suspended further construction on the pipeline, in effect kicking the can down the road until after the next president enters the White House. It seems certain that a President Trump would approve construction of the pipeline on Indian land. It also seems certain that a President Clinton would exercise great caution before siding in the end with the Sioux.

On Friday, the U.S. Army, the Department of Justice, and the Department of the Interior announced the government would discuss with tribes how "to better ensure meaningful tribal input into infrastructure-related reviews and decisions and the protection of tribal lands, resources, and treaty rights." With re-routing the pipeline presently not an option it appears both sides will be digging in for months on end.

Bend In Missouri River in North Dakota (iStock.com/sakakawea7)

ENBRIDGE - SPECTRA ENERGY FUSION TO DOMINATE THE MARKET IN NORTH AMERICA

Enbridge and Spectra Energy have agreed to merge their respective companies in a stock-for-stock transaction to create the largest energy-infrastructure conglomerate in North America.

Enbridge shareholders will own about 57 percent of the combined company and Spectra's will own 43 percent, according to a statement released by the companies on Tuesday.

Al Monaco, president and chief executive of Enbridge, will continue in this capacity in the new company, while Gregory L. Ebel, president and ceo of Spectra Energy will serve as nonexecutive chairman. The headquarters will be in Calgary, where Enbridge is based.

The combined company's natural gas pipelines business would be based in Houston, and the liquids pipelines business would be based in Edmonton.

The companies are expecting to save about $415 million in costs, most of which will be achieved toward the end of 2018. Enbridge said it would divest $2 billion of noncore assets over the next 12 months to improve its balance sheet. The companies expect the deal to close in the first quarter of 2017, although it is subject to shareholder approvals from both companies as well as regulatory clearance.

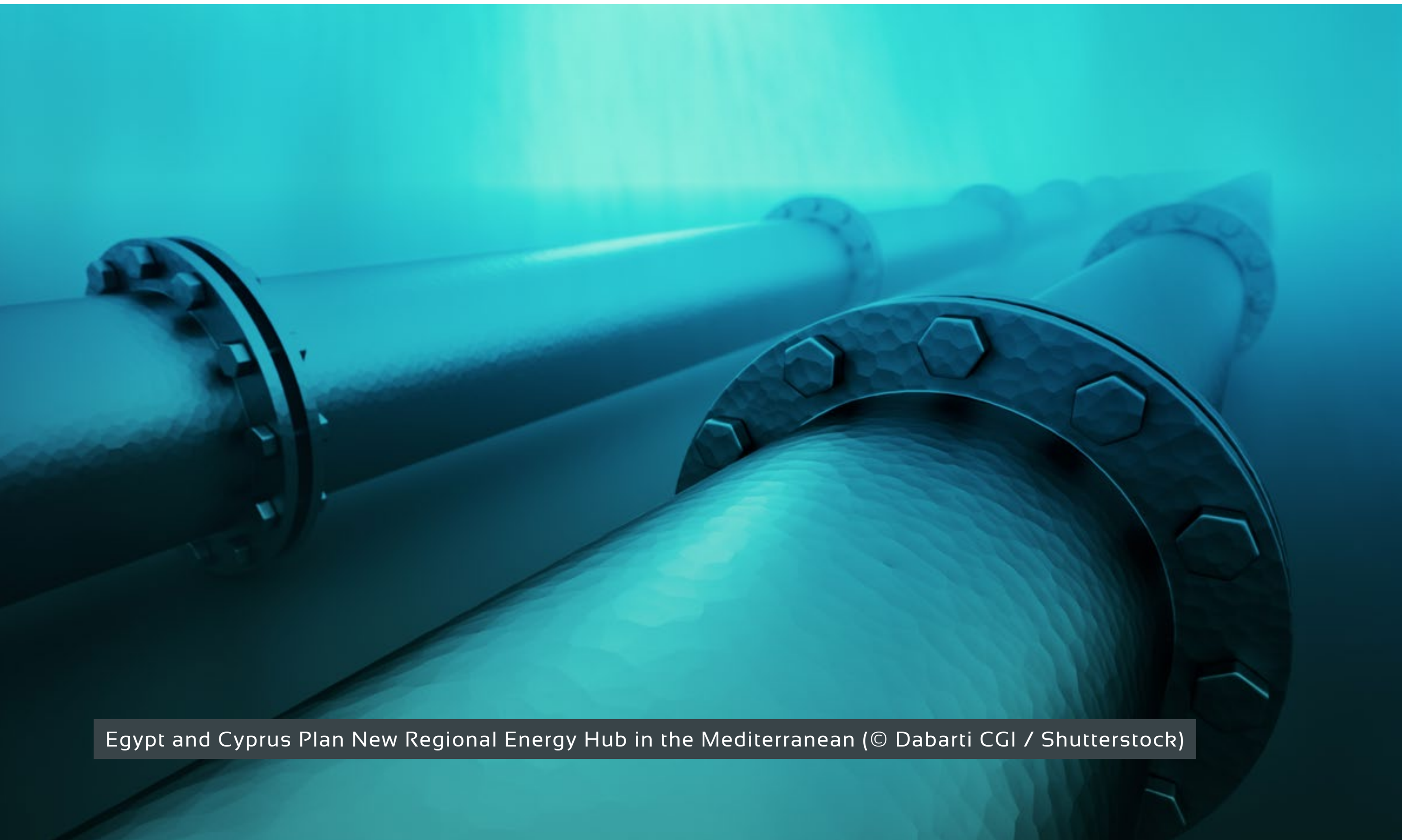
EGYPT AND CYPRUS PLAN NEW REGIONAL ENERGY HUB IN THE MEDITERRANEAN

Egypt and Cyprus have signed an agreement for the delivery of gas to Egypt through an undersea pipeline in the eastern Mediterranean. The deal is part of an effort to commercialize a gas reservoir discovered recently off of Cyprus's southern coast and holding an estimated 4 trillion cubic feet.

"This is part of the development of the east Mediterranean gas as a whole and I think our strategy optimally is to position ourselves as an energy hub in the region," said Tarek el-Molla, Egyptian Petroleum Minister.

Egypt is still considering whether to use the gas for growing domestic consumption or to liquify it in its LNG plant for export to international markets. The first gas through the new pipeline should reach Egypt sometime between 2020 and 2022, but officials will try to speed up the timetable.

El-Molla noted that, despite low prices on the international gas markets which have forced energy companies to slash costs and pull back on investments, international petroleum companies like Eni and BP have committed to developing the large new gas fields inside in the Mediterranean.



Egypt and Cyprus Plan New Regional Energy Hub in the Mediterranean (© Dabarti CGI / Shutterstock)

THE ROSEN GROUP SUPPLIES ALL 48" TOOLS AND EQUIPMENT TO SPIECAPAG FOR TAP

The Field Products and Service line of ROSEN will provide effective equipment for pre-commissioning activities to SPIE-CAPAG (France) by suppling 48" pre-commissioning tools, tracking equipment, as well as accessories to be used for the Trans Adriatic Pipeline (TAP). ROSEN's pre-commissioning tools have been recognized in the industry as a superior and competitive product, with excellent cleaning and dewatering performance. The equipment provided will be applied in the new pipeline in both Greece and Albania.

During the pipeline manufacturing process, oils, greases, protective coatings and mill scale can have an impact on pipe wall surfaces. Therefore it is important removing these materials before the pipeline is put into service. Equally important in the pre-commissioning process are dewatering activities. This process can optimize and potential reduce drying time ultimately saving costs, if done effectively.

Natural gas from the Shah Deniz II field in Azerbaijan will be transported by the 878km long Trans Adriatic Pipeline to Europe. Before coming ashore in Southern Italy, the Trans Anatolian Pipeline (TANAP) will be connected by TAP at the Turkish Greek border, cross Greece and Albania and the Adriatic Sea. SPIE-CAPAG was selected by TAP in March 2016 as the Engineering, Procurement and Construction (EPC) contractor for a 185km lot in Greece as well as two lots in Albania (215km in total).

The ROSEN Group supplies all 48" tools and equipment to SPIECAPAG for TAP

ATMOS INTERNATIONAL'S TURNKEY LEAK DETECTION SYSTEM A BOON FOR PIPELINE OPERATORS AND THE GLOBAL ENVIRONMENT

Atmos International Pipeline Guardian HCA River - © Atmos International 2016

The pipeline industry has long attempted to detect gas and oil pipeline leaks in a reliable and credible way. Frequently these attempts went awry, as many systems claimed to have identified a leak where none existed. Indeed, there were so many false leak alarms that the operator lost confidence in the systems. And pipeline operators, without this critical criterion, were slow to shut down the damaged pipeline and bring out the emergency response crews. Moreover operators did not regularly monitor pipeline systems and were ill-prepared to deal with technical problems once they arose.

Against this backdrop regulatory agencies worldwide have begun to apply a stricter set of rules governing the maintenance and operation of pipeline systems transporting hazardous materials and their potential leaking into the environment. Conventional technologies have been often not been up to this task.

In response to these needs Atmos International (Atmos) of Manchester, UK has launched what it calls the Pipeline Guardian, a line of software and hardware specifically designed to fill the gaps in leak detection, and detect pipeline leaks faster than conventional leak detection systems. The hardware options are ideal for pipelines where the absence of sufficient instrumentation, lack of power, or poor telecommunications have previously complicated the work of leak detection. The Pipeline Guardian hardware is ideal for adding sensitive, reliable, and accurate leak detection on high consequence areas such as river crossings and environmentally sensitive ecosystems.

In particular this intelligent system collects, analyzes, and transmits leak detection data. It contains an onboard data storage back up to prevent data loss during communication outages, and solar panels are available for sites that lack power. Data can be processed locally, or sent back to the pipeline control center for further handling. Communication options include TCP/IP, line-of-sight radio, GSM, and satellite.

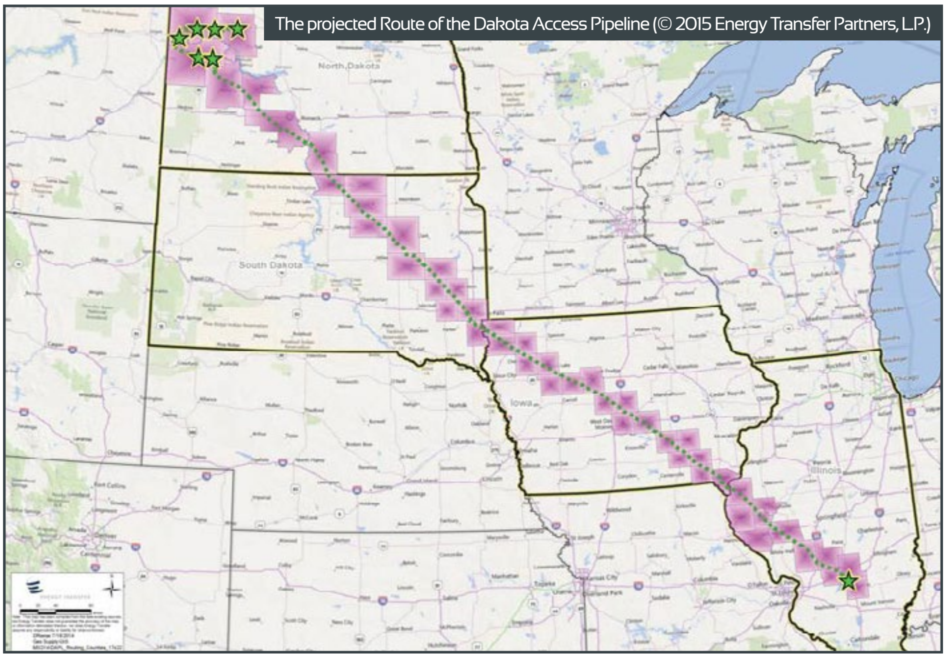
The addition of Pipeline Guardian hardware and software modules such as intelligent flow balance, negative pressure wave, dynamic pressure and flow rate modeling and acoustic noise correlation can improve leak detection sensitivity by as much as 50 percent on pipelines and reduce the all - important detection time to minutes.

DAKOTA ACCESS OIL PIPELINE MEETS GROWING RESISTANCE ALONG PIPELINE ROUTE

A 1,100-mile pipeline, dubbed Dakota Access and estimated to cost $3.7 billion, is nearly halfway complete. It would carry more than 400 000 barrels of crude oil per day to the Bakken region in western North Dakota across South Dakota and Iowa and ultimately connecting with an existing pipeline in Illinois.

Pipeline advocates laud the economic benefits the carrier would bring to the region. Its detractors, particularly the native American Sioux Indians, maintain the pipeline threatens to disrupt their ancestral homeland and pollute the water recources.

"Every time there's a project of this magnitude, so the nation can benefit, there's a cost," Dave Archambault, the chairman of the Standing Rock Sioux, who was among those arrested, said. "That cost is born by tribal nations."
The Sioux protest movement in North Dakota has blossomed, attracting not only other native Indian tribes but Hollywood celebrities as well, like Susan Sarandon and Leonardo DiCaprio. Moreover, the pipeline has met resistance elsewhere along its route, including from farmers in Iowa and property owners whose land is being taken by eminent domain.



The projected Route of the Dakota Access Pipeline (© 2015 Energy Transfer Partners, L.P.)

The Dakota Access is entering a critical phase, with a district court judge to rule no later than 9 September whether construction should be halted. Last week nearly three dozen environmental groups wrote to President Obama, saying the US Corps of Engineers approved the project using a fast-track process that was inadequate given its size and the many sensitive areas it would cross.

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INTELLIGENT PIPE SYSTEMS VIA THE SMART COMBINATION OF VARIOUS MATERIALS

Dr.-Ing. Thorsten Späth > egeplast international GmbH

Abstract

The properties of different materials are fundamentally different, and the available materials have always been combined with one another. Modern construction technology and looking outside of the box for other applications has introduced a range of smart ideas for combining various materials into the field of pipeline engineering. Composite constructions are taking over high-pressure applications, and sensitive pipes allow for continuous monitoring of both the protection of the environment as well as the medium. The usage of RFID chips has become self-evident in everyday digital applications. Documentation on piping network has now made some headway and components with recordable information storage devices have emerged.

Introduction

The properties of different materials are fundamentally different, and the available materials have always been combined with one another. Combinations of materials are now systematically used in many applications. The benefits of different materials can thereby be sensibly combined. These days, most automobiles and airplanes consist of more composite materials than metals, which has led to significant savings in both weight and fuel.

The usage of modern production procedures allows for PE pipes to be made in layers. Increasing demands as an engine of innovation for new solutions have thus allowed for a variety of "intelligent" piping structures to be made. Bright inner layers for better visibility during inspection with cameras, and inner layers with especially high chemical resistance against the media being transported through them, are now state-of-the-art. Plastic pipes with metal layers combine the advantages of plastic materials - such as the low weight, high chemical resistance, simple welding capability and sustainable production and laying processes - with the positive features of metal, such as the low permeability and good electrical conductivity. Pipelines have even begun being equipped with sensors.

Usage in high-pressure applications was once reserved exclusively for pipes made from metallic materials. The usage of high-strength reinforcement layers, however, also opens up new opportunities for using plastic pipes in these areas.

Alternative laying methods offer great potential for savings. Polyethylene pipes are very flexible and through welding axially force-locking connections are resulting and it is thus ideal for trenchless applications. Point-load resistent RC materials (resistance to crack) and "clever" multi-layer pipe structures facilitate the usage thereof without increasing the risk for the operator.

HOMOGENOUS MATERIAL LAYERS

Pipes must be systematically investigated with cameras for monitoring purposes. Polyethylene is commonly stabilised against UV radiation with carbon black. This stabilisation is necessary for transportation, storage and laying. A soot-blackened pipe is very difficult to illuminate from the inside. Nowadays, polyethylene pipes are thus equipped with a brightly coloured inner layer (Figure 1). Otherwise black pipes usually bear a blue or orange outer layer (Figure 2) to designate the medium being transported through it.

Figure 1: Pipe with bright inner layer

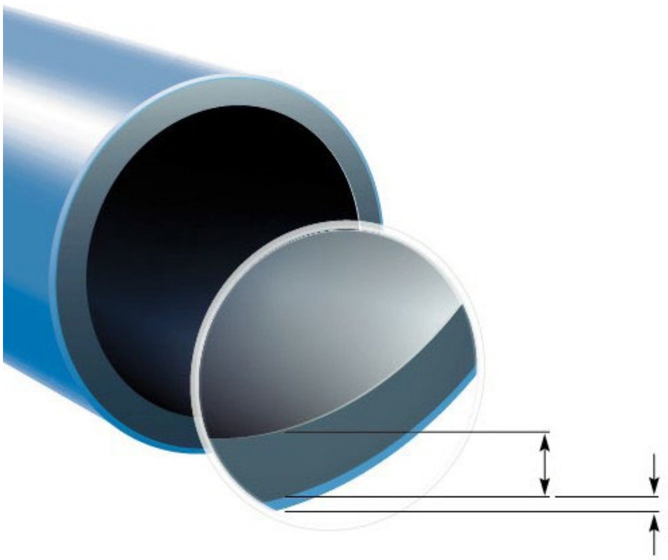

Figure 2: Drinking water pipe with blue signal layer

WEAR AND LAYING PROTECTION

These days, underground pipelines are usually no longer laid in open trenches, but directly integrated into the soil by means of various trenchless procedures. This places many more demands on the pipe. In particular, the exterior of the pipe must be protected from scratches and damage during the laying process. Now it is most common to lay pipes with a robust exterior wear-protection layer (Figure 3).

The newest generation of protective layer pipes is equipped with a protective layer of highly abrasion-resistant polyethyene. This single-material pipe structure simplifies handling and makes the pipes more flexible. The greatest advantage, however, is the possibility of direct butt welding of the protective layer pipes with no cutback of the layer, while adhering to the parameters stipulated in the DVS guidelines [1].

Figure 3: Protective layer pipes with outer protection layer

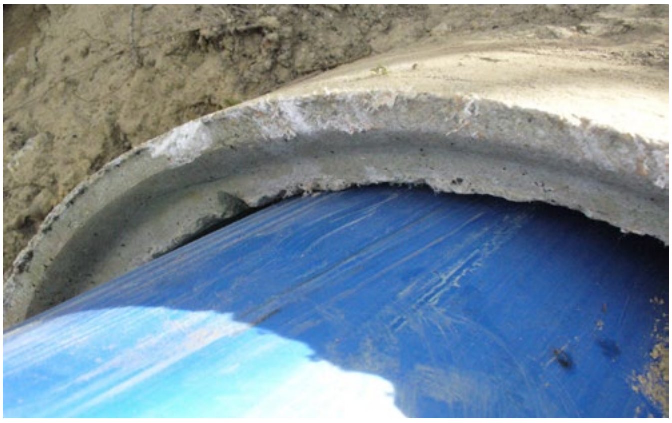

Figure 4: PE pipe during insertion

PE PIPE WITH REINFORCEMENT LAYERS

The strength of polyethylene is only minor when compared to that of steel. It is thus necessary to integrate stronger materials for reinforcement in the pipe wall. Fibre-reinforced polyethylene pipes, also known as RTP (reinforced thermoplastic pipes) pursue this goal and their pipe walls consist of integrated, high-durability fibres made from steel, glass or aramid, to name a few, so that high operational pressure levels even greater than 100 bar can be achieved [2, 3]. This type of high-pressure pipe is distinctive in that it concerns composite materials of various classes, and these are already state-of-the-art.

Self-reinforced high-pressure pipes are one design that consists entirely of known polyethylene materials, such as PE 100, or so-called monocomposites (Figure 5). The advantage of monocomposites is that both the tapes applied as a reinforcement layer as well as the core pipe and outer layer are made from the very same base material. This design strengthens the durability of the structure, and other positive features like weldability, corrosion-resistance, the low specific weight and flexibility remain almost completely unaffected. The basis for the almost doubled pressure resistance in comparison to equal-dimension PE 100 pipes is the usage of high-strength bands, so-called tapes, which can be used as reinforcement.The requirements of such tape-reinforced PE pipes will be disclosed by the DVGW (German Association of Gas and Water) in its handout GW 335 A5 [5].


Figure 5: PE pipe with integrated tape reinforcement


Figure 6: Welding a plastic high-pressure pipeline

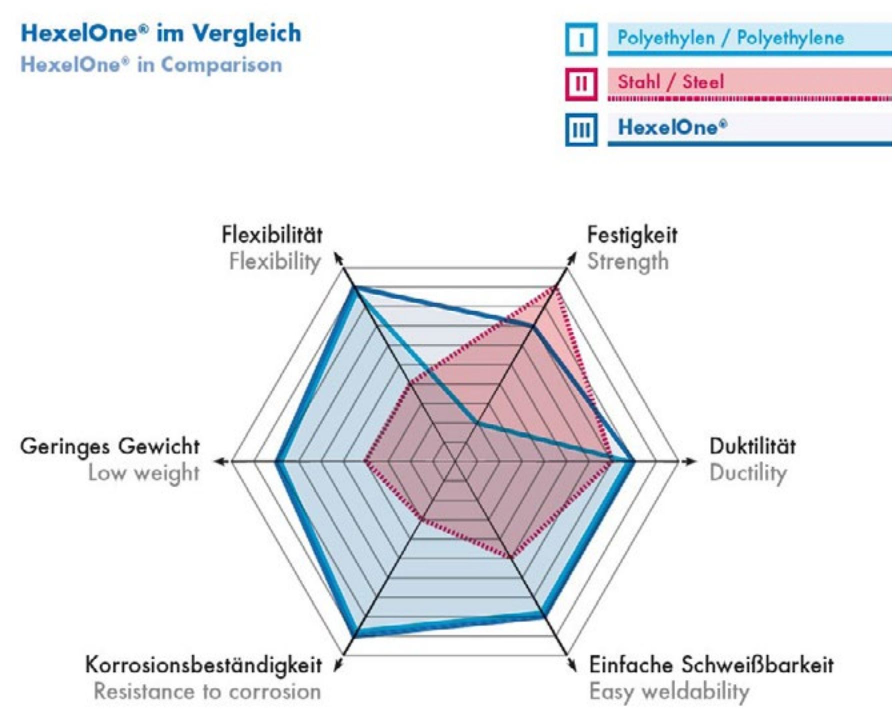

Figure 7: Features of polyethylene compared to those of steel

common measurement devices. The insertion of a new pipe through an unknown bore trench certainly entails the risk of damaging the new pipe. In order to monitor the integrity of the internal pressure pipe (groove depth = 0% of the wall thickness) during and after the insertion process, a simple continuity check suffices (Figure 8) provided the electrically conductive metal bands are inserted between the protective coat and the media pipe in a spiral formation.

Should notches form up to the bottom of the protective layer during insertion of the pipe, the electrical conductor coiled in a spiral formation beneath it has been severed. Following insertion, a simple continuity tester can be used to test electrical continuity, thereby verifying the integrity of the new pressure pipe (Figure 9).

PLASTIC PIPE WITH METALLIC LAYERS

The intelligent combination of flexible thermoplastic materials with the permeation resistance of metallic materials facilitates permanent protection of, to name one example, drinking water. Further-more, the electrical features of a metal layer embedded in a plastic pipe make it possible to localise the course of the composite pipe in the soil, or even to monitor operation. This especially in-creases security when transporting sensitive media.

INSERTION MONITORING VIA VERIFICATION OF INTEGRITY

An embedded metal layer facilitates both the localisation of a laid pipeline as well as the determination of the depth with

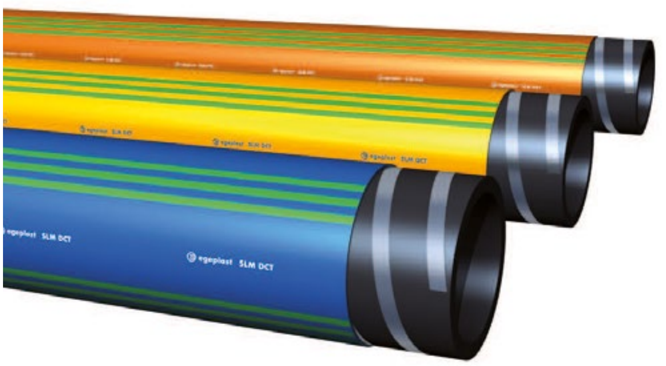
Figure 8: Pipe system with integrated conductive tapes

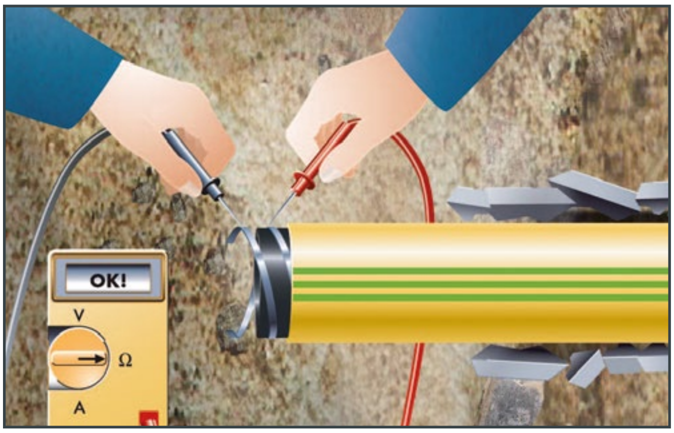

Figure 9: Continuity tester

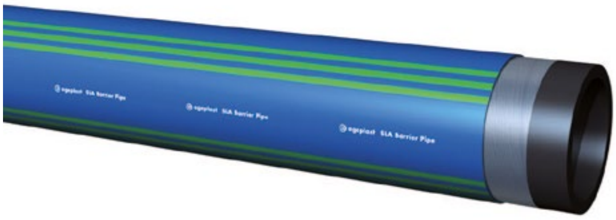
Figure 10: Pipe system with diffusion barrier


Figure 11: Laying a pipe with permeation barrier in milling procedure

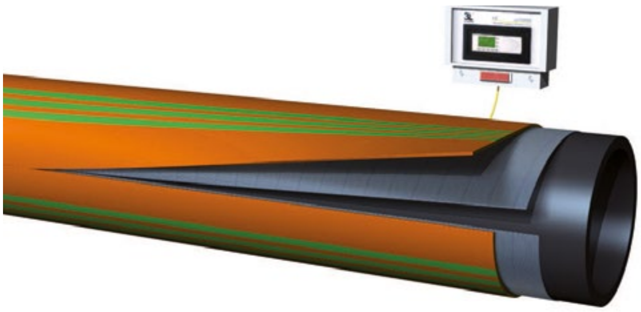
Figure 12: Monitored pipe system


Figure 13: Measurement of the resistance

DIFFUSION-RESISTANCE AND ELECTRICAL SCREENING

Permeation

Essentially all plastic pipes (PE, PA, PVC, etc.) exhibit greater gas permeability than metallic materials, although in practice this is negligible. The installation of a metallic layer in the pipe wall allows for various effects. Aluminium or galvanised steel is often used. The great tensile strength of a metal layer in comparison to plastic can be used to decrease both the wall thickness and the pliability of plastic pipes. Plastic pipes always return to their original position because of the so-called memory effect, which can be prevented with a metal layer. Such synthetic-metal composite pipes are used frequently in house installations.

Aluminium's far lower rate of diffusion when compared to plastics can be used to retain flexible, diffusion-resistant pipes. Diffusion from outside into the medium is often especially important. The figures to the right depicts a pipe system for drinking water supply in contaminated soil. An internal pressure-bearing, polyethylene layer is surrounded by multiple layers of fused aluminium as protection against diffusion. The aluminium layer itself is then surrounded by a wear-resistent protective layer in order to facilitate trenchless laying techniques with their special demands of the pipe for such a pipe system. Examples of the applications of such pipes include chemical areas, intensive agriculture, or former military grounds. A similar pipe structure can also be used to shield data lines.

MULTI-LAYER PIPE FOR CONTINUOUS LEAK MONITORING

Triple-coated pipes with an electrically conductive aluminium layer integrated between the polyethylene pressure pipe and a protective layer can also be continuously monitored for leaks (Figure 12). The aluminium layer is equipped with a charge and the resistance is measured to a contact point in the soil. If the plastic pipe is damaged, the change in electrical resistance is used to show the leak and to subsequently measure it to up to a half metre. Such secure pipelines are used for transporting environmentally toxic substances, for instance, but also for draining waste water from drinking water extraction areas. In the interest of pure condition monitoring, the possibility of continuously monitoring pipes for leaks, and localising the area of damage or the leak in such an event, is often in demand.

The aluminium layer integrated into the pipe-string to be monitored is connected by an adapter to a monitoring unit. It is now possible to either temporarily, in intervals, or permanently apply a metering voltage to the aluminium layer. Should the pipe be damaged, the aluminium layer comes into electrical contact with the surrounding soil. This triggers a pulse in the monitoring device. The damage alert may occur through acoustic or optical signals, or be sent directly to a smartphone.

PIPELINES WITH INTEGRATED SENSORS

Sensors integrated into a pipe wall for measuring moisture in order to monitor the insulating effects of buffering layers are now state-of-the-art. Should moisture begin to form, the conductvity between the electrically conductive layers increases and the corresponding measurement point can be located. This process is used in long-distance heating pipes or pipelines. The measurement device is not located in the wall of the pipe being monitored, but rather in the surrounding insulation.

Figure 14 Barcode allows for uninterrupted tracing

Figure 15: PE pipe with RFID chip

The usage of information media, e.g. barcodes or so-called RFID chips, for designating products is familiar to everybody. In the digital age, this technology is also increasingly becoming ubiquitous in pipeline construction products.The clear labelling of components, such as pipes with a barcode, allows for the implementation of clean grid documentation. The usage of RFID chips even facilitates the storage of individual grid information in the component after successful laying.

SUMMARY

The modern state of development of machine technology makes possible the precise combination of various materials in pipe construction. The beneficial features of different materials can thus be purposefully utilised, and the components can be customised to suit an application. Thinking outside the box for other applications has led to the implementation of good ideas in pipeline construction. Composite constructions are taking over high-pressure applications, and sensitive pipelines can be continuously monitored to both protect the environment and the medium. Modern documentation and information technology is also becoming ubiquitous in pipeline construction in the age of digitalisation. In the future, there will certainly be more applications for “intelligent” pipelines.

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NON-SHIELDING TESTING OF POLYMERIC BACKED MESH COATING

Luc Perrad > Manager ExParTech / Polyguard Representative

Polyguard Products is a manufacturer of pipeline coatings since 1953.
The Polymeric Mesh Backed Polyguard RD-6 coating has been used in the North American market since 1988 and occupies a very significant part of the American and Canadian girth weld and rehabilitation market share. It is differentiated from other multi-layer tape systems in materials, performances (adhesion, cathodic disbondment resistance, soil stress resistance, etc) and application. In addition, it is recognized to be a non-shielding coating system.

After successful introductions in South America 10 years ago; in Asia including Turkey recently and different countries in the Middle East, Polyguard RD-6 coating system had been introduced since 2014 in Western Europe and some key countries in Africa.

The topic of our paper consists of a general overview of different case studies, laboratories & field tests including non-shielding and application trials conducted in Europe and Africa for key pipeline operators. The presentation will also give a better understanding of the high performances of Polyguard RD-6 in comparison with the requirements from international standards (EN12068; ISO21809-3 and NACE SP0109:2009).

What we call "shielding coating" is a coating which shields Cathodic Protection (CP) current from the electrolyte to the steel. This happens when the "shielding coating" disbonds (lifts up) from the steel and insulates the CP current from the non-coated steel. Anodic and cathodic points develop under the disbonded shielding coating, resulting in pitting corrosion at the anodic points. The water under the disbonded shielding coating becomes acidic due to the corrosion reaction (low pH, typically 4 – 6). Pitting corrosion is probably the most critical corrosion phenomenon because it develops in very localized areas resulting in leaks by punching the steel. According to the US Pipeline and Hazardous Materials Safety Administration (PHMSA), some typically examples of shielding coatings are: Polyethylene tapes, shrink sleeves, coal tar mastics and asphalts. These coatings can prevent CP currents from reaching the pipe when they disbond from the pipe surface. See point 34: https://primis.phmsa.dot.gov/maop/faqs.htm

It is also important to note that field applied coatings have much more probability to disbond from steel due to the major following reasons:

- Ambient conditions during application are not 100% controlled (temperature, humidity, due point).
- Surface preparation on the field is not controlled as it can be in the plant (steel profile and salt contamination).
- Most of the coating applications are manual, not automated, resulting in some defects.

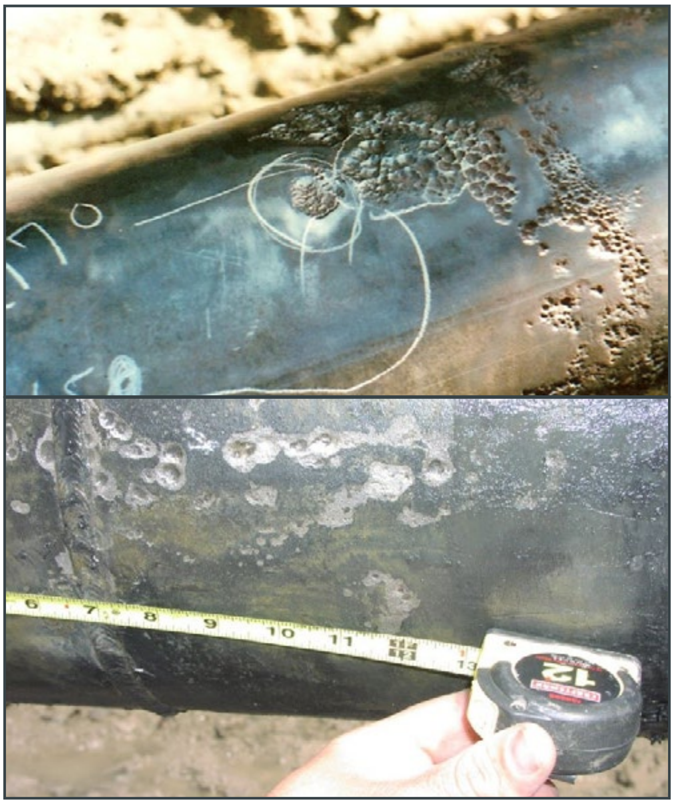

Figure 2: Above: Pitting corrosion occurs on field applied coating: The second Picture shows the distance from the weld bead

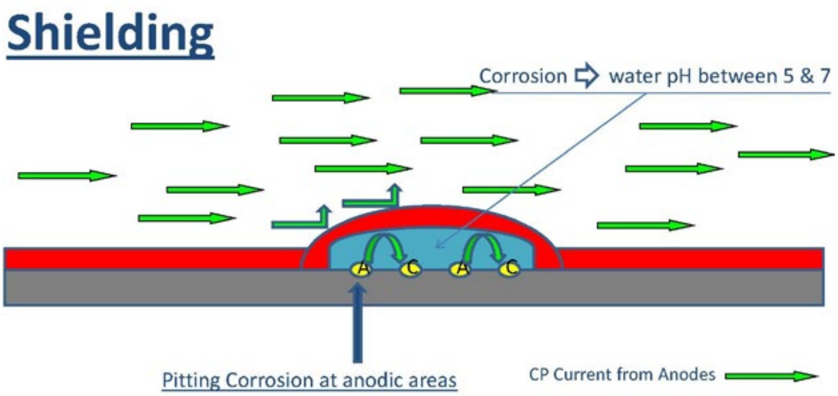

Figure 1: Cathodic Protection current (green arrows) can't penetrate the coating. Anodic & Cathodic points can develop under the disbonded coating: Pitting corrosion occurs with low water pH

Figure 3: pH color strip applied under disbonded Polyguard RD-6

Examples of pitting corrosion due to Shielding Coatings to the right:

Figure 4: pH color strip compared with pH color scale showing high pH of 9 to 10.

In North America, there is a grave concern about Cathodic Shielding Problems, standards like Nace SPO 169-2007 or US Code Federal of Regulation 49 CFR 192.461 & 195.551 and 49 CFR 192.112 prohibit to use shielding coatings. Example of incident: Two Florida Gas Transmission (FGT) incident reports identified failures (fracture of the gas pipeline) caused by pitting corrosion on polyethylene tape coated pipelines in Florida and Alabama. Many field tests had been conducted mainly in USA. The below pictures illustrate pH tests for Exon Mobile in the 90's: pH 9-10 had been observed under improperly applied Polyguard RD-6.

Even if the rest of the world seems to ignore the shielding problems, the majority of the pipeline operators I meet are complaining about pitting corrosion due to shielding coatings. Total for example published technical articles concerning this issue for pipelines in Syria, Argentina and Gabon. Maybe Total or the other pipeline operators can resolve the situation by use of Non-Shielding coatings like Polymeric backed mesh coating (ex: Polyguard RD-6). The Non-Shielding property of Polyguard RD-6 coating is illustrated in the drawing below. The woven geo-textile fabric (mesh) backing is conductive and allows CP current to enter under disbonded coating at overlap areas. This can happen only if disbondment occurs with water present past the overlap.

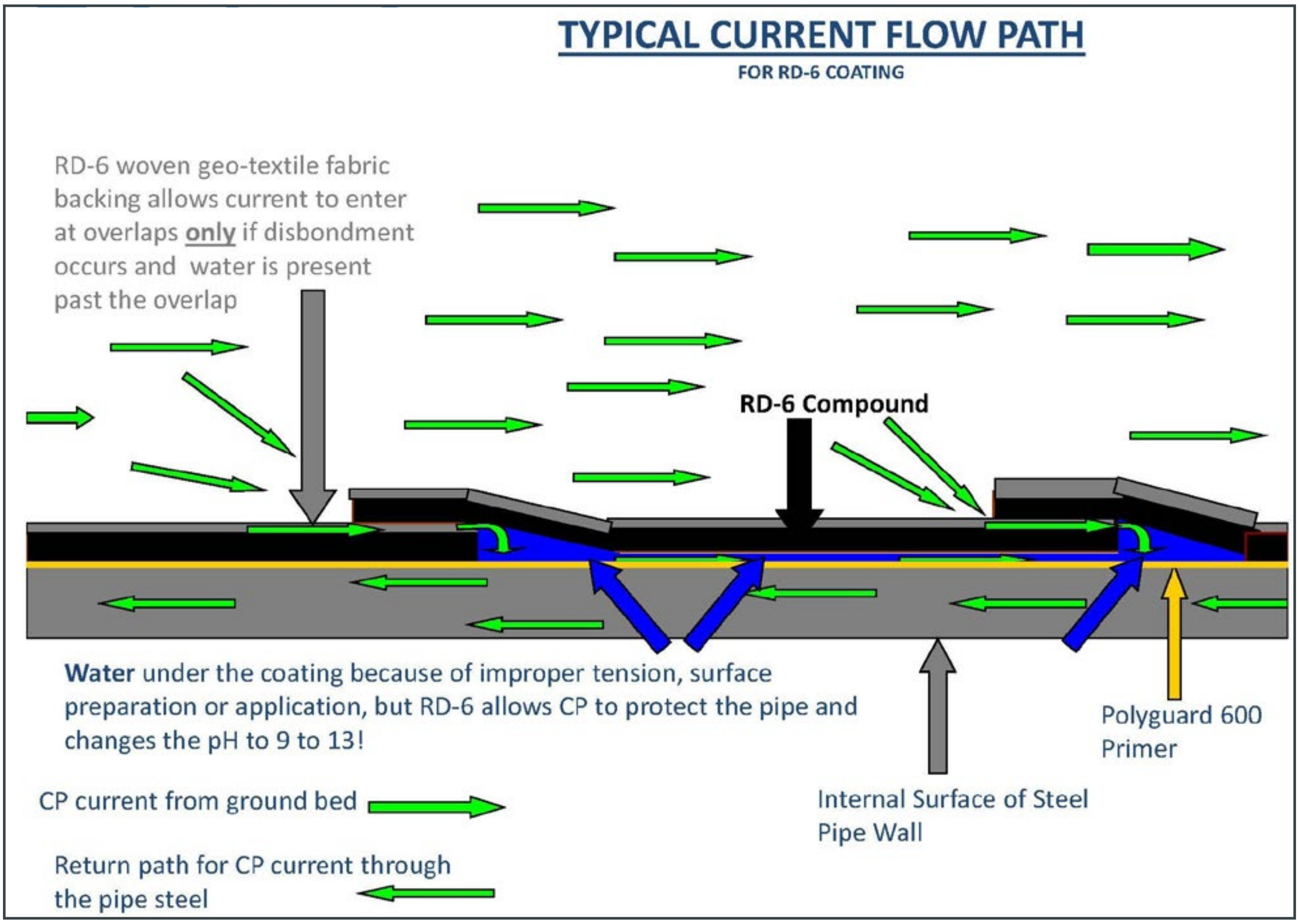

Figure 5: Cathodic Protection current (green arrows) can reach through the overlap the water under disbonded Polyguard RD-6.

To help pipelines operators to understand how Polyguard RD-6 coating doesn't shield CP current, we conducted laboratory tests by a French Pipeline CP expert (Ingeca). This article describes the test method (protocol) and results of the testing: October 19, 2015 three 30mm x 40mm steel coupons had been installed on a PVC pipe and coated by Polyguard RD-6 with overlap area just above each coupon:

- Coupons #1 and #2 had been coated with intentional Polyguard RD-6 disbondment, leaving a void filled with water between the coupon and the coating.
- Coupon #3 had been properly coated without void between the coupon and the coating.

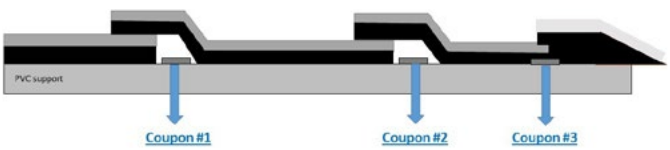

Figure 6: Coupon #1 and #2 are coated with overlap disbonded on purpose – Coupon #3 is properly coated (no disbondment).

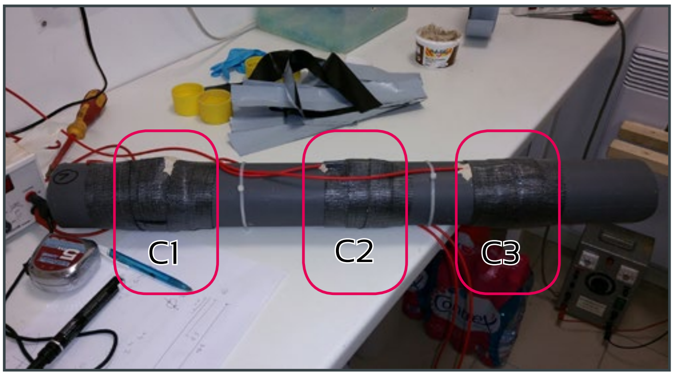

Figure 7: From left to right: Coupon #1, Coupon #2 and Coupon #3

Contrex commercial water had been injected under disbonded RD-6 coating. PVC pipe had been immersed in the same Contrex commercial water. Contrex commercial water with following salt composition: Ca: 468 mg/liter; Mg: 74.5 mg/liter; Na: 9.4 mg/liter; SO: 1121 mg/liter; HCO: 372 mg/liter. No additional salt had been added.

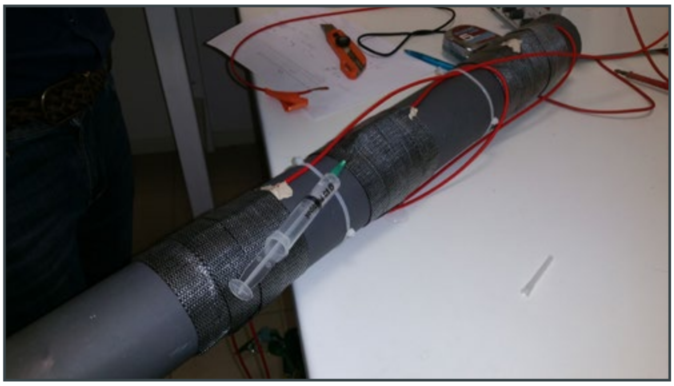

Figure 8: Injection of water in the void of Coupon #1 and #2.

<u>Two additional non coated steel makers had been used:</u>

- One marker in the same electrolyte and the same container as the three coated coupons (same CP protection) – Left below
- One marker in the same electrolyte and a different container from the three coated coupons (no CP protection) – Right below

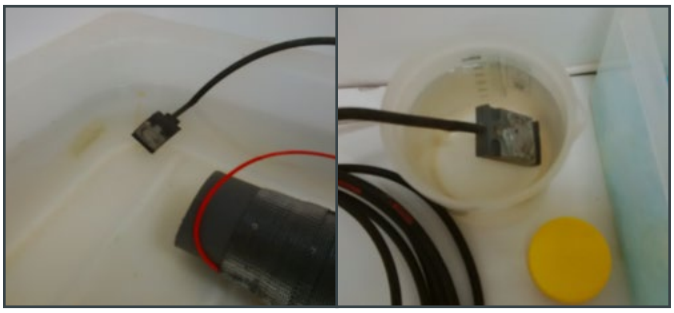

Figure 9: (Left) Marker in the same electrolyte as Coupons #1, #2 and #3 – (Right) Marker in a separate electrolyte (without Cathodic Protection)

Test had been conducted for 3 months: From 19 October 2015 to 25 January 2016.

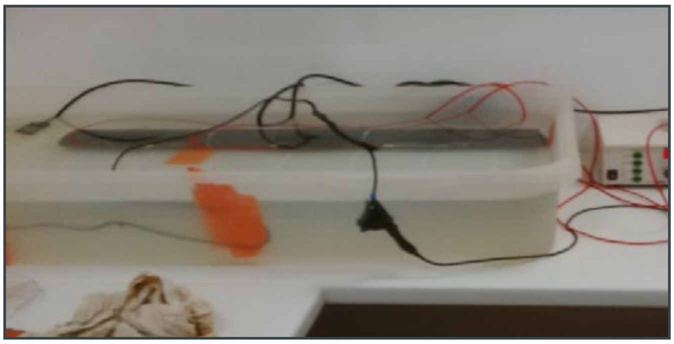

Figure 10: General overview of the testing in Ingeca's laboratory.

After 3 months ....
No corrosion had been observed on coupons 1, 2 and 3 after Polyguard RD-6 coating removal.

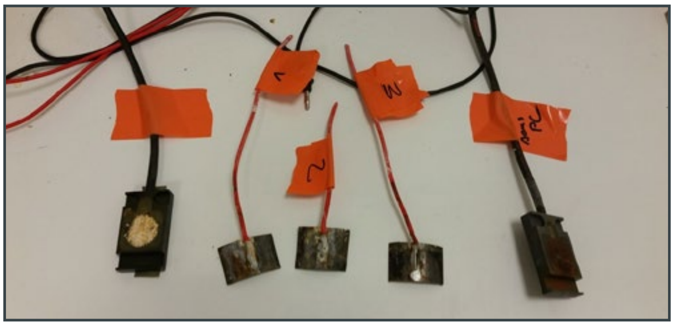

Figure 11: Visual inspection and comparison of Markers aspect (Left with CP: cover with sediment – Right without CP: corroded). No corrosion on the 3 coupons.

Uncoated marker with CP (left) was totally covered by calcareous sediment (chemical reaction due to CP current). pH tested on the surface of the sediment was 12. Uncoated marker without CP (right) was totally covered by rust. pH tested on the surface of the rust was between 6 and 7. pH 12 had been measured under disbonded Polyguard RD-6 coating on coupon's 1 & 2. As there was no water under coupon 3, no pH had been measured on this coupon. Original PH of the electrolyte (commercial water) was 7.

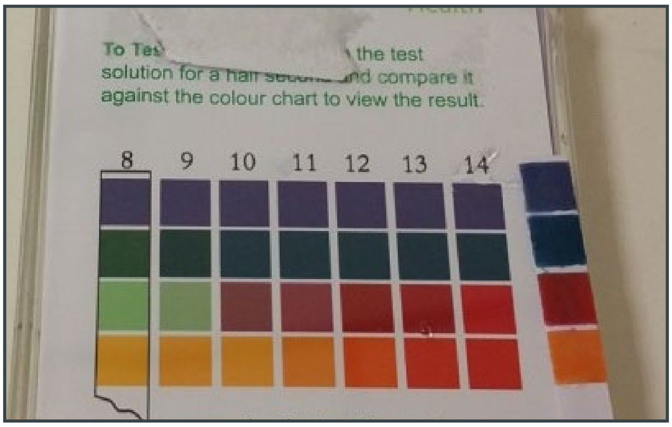

Figure 12: pH 12 measured on coupon 1 under disbonded Polyguard RD-6 coating.

Figure 13: Polyguard RD-6 coating removal on coupon 2 (no corrosion).

Non-Shielding Test results - INGECA – France Current measurements:

Samples	19-oct-15	20-oct-15	26-oct-15	03-nov-15	16-nov-15	14-dec-15	06-jan-16	25-jan-16
	uAmps	uAmps	uAmps	uAmps	uAmps	uAmps	uAmps	uAmps
1. With void	0,42	0,31	8	100	114	143	62	55
2. With void	2,87	6,5	38,2	120	360	297	219	230
3. Without void	0,26	0,2	7	120	98	146	105	81
5cm² uncoated Marker	170	10,5	290	280	292	370	120	121

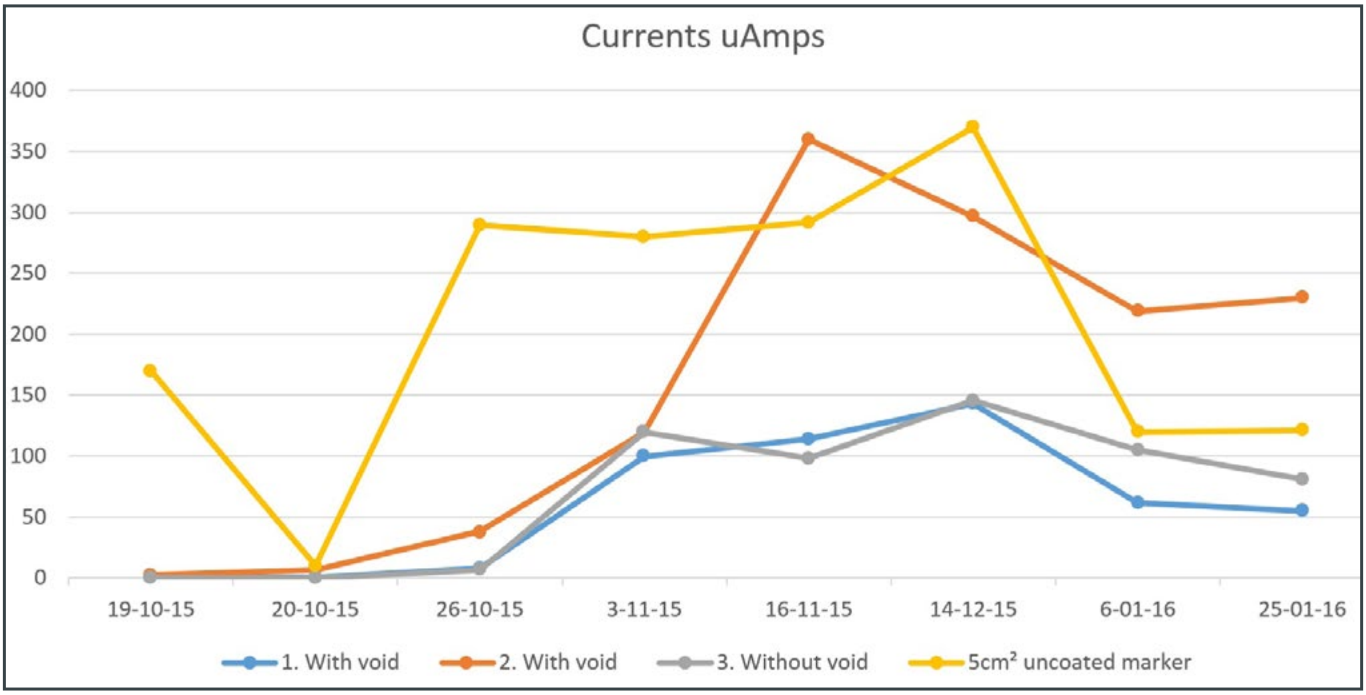

Figure 14: Above: current values graph in uAmps measured at different times between October 2015 and January 2016.

Conclusion: The tests had been totally convincing:

- Presence of current measured on each coupon.
- Visual inspection after 3 months: no corrosion under coupon's #1, #2 & #3
- pH 12 measured under disbonded RD-6 after 3 months

Polymeric mesh backed coating like Polyguard RD-6 does not shield CP current. Additional testing's will be conducted in 2016 for GRT Gaz France and Fluxys Belgium. 3 different electrolytes (resistivity) will be used with many more coupons.

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Integrity of longitudinal welds of induction bends for line pipe application – choice of relevant test methods

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ABSTRACT

Induction bends often serve as integral part of pipeline systems conveying oil or gas at high pressure. In this case, they are required to have comparable properties to straight pipes to maintain the integrity of the line. Bends are produced by heating the mother pipe by an induction coil to realize the free forming operation. Thereafter, the bend is treated with a full body tempering, or depending on dimensions and requirements, full body quenching and tempering (QT). The plate chemistry as well as the longitudinal weld metal has to be chosen to sustain meeting the requirements in the final product.

From time to time, occasional low Charpy impact toughness values are observed in the longitudinal weld and can lead to rejection of the product. This is a known phenomenon and has been intensively discussed for the weld of SAWL line pipes. Discussion quickly turns to the assessment of their relevance to structural integrity. It has been shown in the literature that commonly small scale tests lead to unnecessary impairment of the integrity. A way forward may be testing of the component that is known not to fully meet specified toughness requirements. Typically this is done by notching the relevant area of the longitudinal weld and pressuring either full pipe length or, if such equipment is available, a ring sampled from the pipe until failure. In such cases, besides notch location, the geometry of the notch is often challenged.

Within this investigation, a bend showing statistically distributed low Charpy impact toughness values in the weld metal was tested in ring expansion tests at temperatures below ambient that could be typical in certain design scenarios. The notch was inserted in weld centerline utilizing a machine tool. A finite element study was conducted to understand the impact of the notch geometry, especially width and tip radius. The results of the ring expansion tests suggest that the bend load bearing capacity of the product is not significantly impaired by Charpy impact toughness.

INTRODUCTION

Hot induction bends are an integral part of pipelines. Bends with large radii and small bending angles are fabricated on site by cold bending. When smaller radii and large bending angles are needed, hot forming is the favourable process. The choice of the mother pipe depends on the geometry needed, hot bending can be applied to virtually any pipe. In oil and gas pipelines, large diameter longitudinally submerged arc welded (SAW) pipes manufactured from thermo-mechanically control process (TMCP) plate are most often used. These can be hot-formed to produce bends provided that the chemical composition of the plate as well as the weld is suitable for the process related heat treatment. While the weld of SAW may occasionally, depending on the grade and wall thickness, exhibit areas of low toughness related to the formation of local brittle zones (LBZ) in the heat affected zone (HAZ), there is a small probability that a bend may also show such statistically distributed low values in the weld metal. According to the tests and related test frequency, these are often detected with Charpy impact (CVN) tests. Despite the overall improvement of both weld metal and HAZ in SAW welds, this cannot in all cases be completely avoided due to required over-matching behaviour combined with excellent toughness level down to low test temperatures and restrictions with respect to chemical composition and welding procedure (heat input, cooling time) within specific linepipe production. Although the formation of microstructural features that cause each of the phenomena is not identical, when it comes to structural assessment, the questions are comparable and are mainly related to a meaningful and effective testing procedure that is capable of being linked to the overall behaviour of the structure.

The focus of many research studies [1]-[8] has been on understanding the significance of occasional low toughness and on derivation of an appropriate testing method to determine toughness properties. These studies investigated the effects of geometry constraint in CTOD tests (size, crack depth, global geometry and mode of loading) and weld (yield strength mismatch, hardening mismatch) on toughness values. Little evidence is provided concerning the significance of Charpy impact values. Despite many useful findings and methods resulting from these studies, there is still no clear and satisfactory procedure included in standards on how to evaluate the effect of weld properties on the fracture performance of flawed pipes, let alone flawed bends.

The overall aim of this paper is to characterise the toughness properties of longitudinal welds of hot induction bends by means of Charpy impact tests as the typical production test as well as ring expansion tests that are close the stress and strain state of the actual pipe exposed to internal pressure. The effect of the actual notch geometry chosen for the ring expansion test is investigated within a dedicated finite element analyses (FEA).

BENDS

Material

The material investigated within this study was SAWL 450 according to DNV-OS-F101. The nominal mother pipe dimension for the fabrication of 140 bends with a radius of 5D and 20D originating from 5 material heats was 735 mm inner diameter and 42 mm wall thickness, to be connected to a line pipe with dimensions of 32” x 39 mm. Due to the heavy wall thickness and low design temperature the mother pipes were welded using SAW multi-layer technique. Especially for full body QT heat treatment of the bends, the multi-layer technique is beneficial to maintain adequate toughness level at lower test temperatures. But in case the notch position of a single Charpy-V sample is located predominantly in one single weld bead, the positive effect on toughness of multilayer welding is not tested any more. Consequently samples from this kind of “single weld bead-testing” are showing significantly lower results, not representing the properties and behaviour of the weld seam.

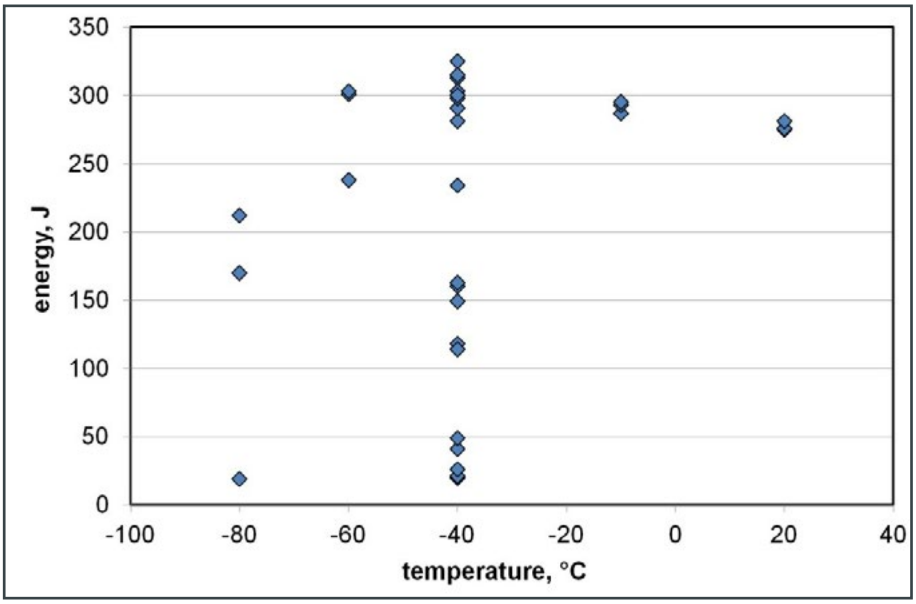

Figure 1: Results of Charpy impact tests from SAWL seam of full body QT 5D-bends

EXPERIMENTAL PROCEDURE AND RESULTS

Charpy impact tests

As part of production testing, CVN tests according to ISO 146-1 were conducted for the longitudinal weld of the tangent and the bent arc. Two different positions were included in these tests, mid-wall as well as inner wall position. Due to the structure of the multi-layer weld, the former specimens sampled several weld layers whereas the latter sampled predominantly one single layer. The requirements were at 38 J for single values and 45 J for the average value at test temperature of -40 °C for all production tests. Further tests at different temperatures were conducted to characterise the temperature-transition curve. The results are plotted in Figure 1. There are two apparent clusters of energy values. The higher values including all results of tests at differing temperature were achieved at mid-wall. The lower values at design temperature that include the ones not complying were identified at inner wall position. The latter display a relatively large scatterband typical for transitional behaviour.

Ring expansion tests

Ring expansion tests can be conducted to estimate the effect of areas of low toughness on the fracture performance of flawed linepipe exposed to internal pressure. The test rings have a width of 150 mm. In the case of bends, it is necessary to extract the specimens from the straight pipe. The rings are then notched targeting the relevant micro structure, in this case the weld metal at a defined location that was indentified within CVN tests (Figure 2). The notch is placed along the weld metal centre line in longitudinal pipe direction. Target notch depth is 8 mm with respect to the inner pipe surface. The nominal notch width is close to 1 mm. Three rings were tested to achieve a statistical relevance.

Figure 3 shows set-up of ring expansion tests. The rings are positioned between two steel plates and subjected to internal pressure. The resulting stress state on the pipe ring is without axial stresses. This is be ensured by utilising seals and supports slightly higher than the ring.

Tests are usually performed at relevant temperatures, often below ambient. Cooling is achieved locally at the notched section of the ring by attaching an external device consisting of two separate chambers located left and right of weld seam. The desired temperature is reached by circulating cooling liquid through the system. The testing is carried out at design temperature of -30 °C. Pressurisation is conducted according to the following scheme: firstly the design pressure of 300 bar is targeted. Thereafter, a pressure of 400 bar equal to net section yielding is applied followed by pressurising to the limits of the machine that are at 500 bar. All rings survived without any sign of leakage. Figure 4 shows an exemplary pressurisation cycle of one of the tests.

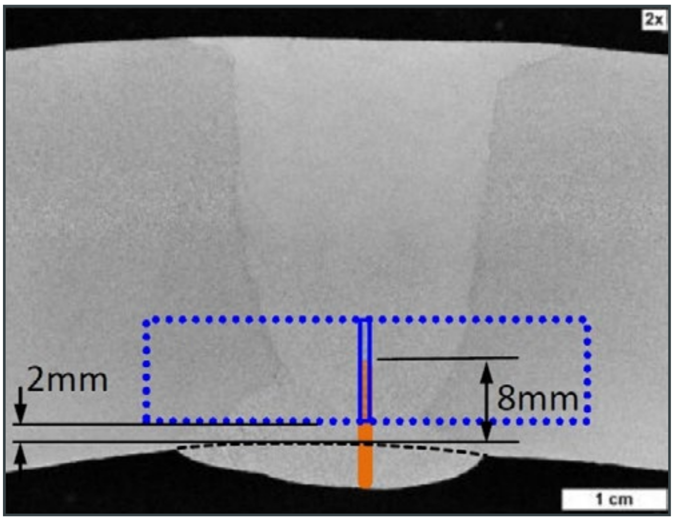

Figure 2: Notch location in WMCL (orange) and indicated CNV location (blue) on the cross section of the multi-layer SAW longitudinal seam after full body QT

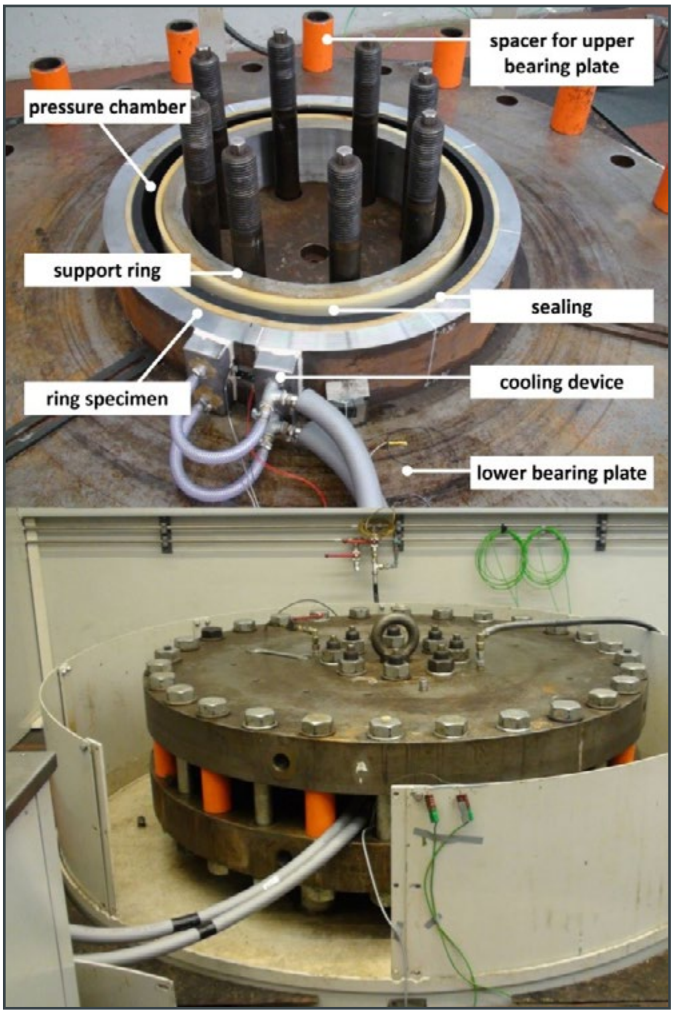

Figure 3: Ring expansion test set-up with removed upper bearing plate (above) and upper bearing plate in position (below)

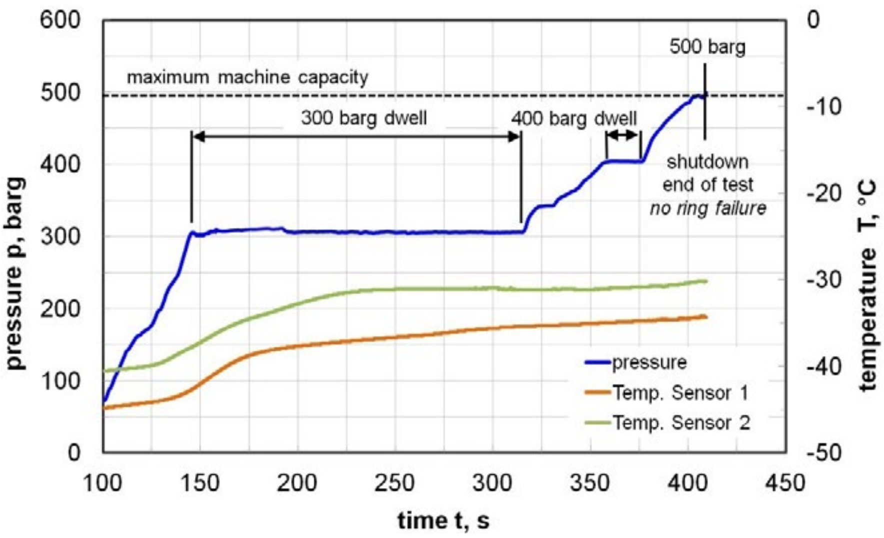

Figure 4: Pressurisation cycle of a ring expansion test

In place of the notch along the inner weld center line the embedding ring model was designed to be easily connectable to fine-meshed parts that inherited the specified notch geometry. Micrographs of the notched weld seam gross section in the tested ring specimens revealed a typical corner radius of R = 0.15 mm at a notch width of N = 1.2 mm, both generated by side and face milling process. In the parameter study, the corner radius of a 1.2 mm-notch was varied from the sharpest possible configuration at R = 0 mm up to an entirely rounded notch tip at R = 0.6 mm. Intermediate steps were made at values of 0.25 and 0.5 of normalized notch tip corner radius R_n, which is the radius R in reference to half notch width N. According to this definition, R =0 mm corresponds to a normalized radius of R_n = 0 and R = 0.6 mm to a normalized radius of R_n = 1. In comparison, the radius was varied in the same way for a narrow notch of N = 0.2 mm. All simulations were performed using implicit solver Abaqus Standard, with a quasi-statically applied pressure load on the inner ring surface up to ring failure. The overall element type was 3D hexahedral with reduced integration.

NUMERICAL STUDY OF NOTCH GEOMETRY INFLUENCE

In the ring expansion test set-up with ring specimens provided with a notched longitudinal weld seam, the notch geometry could be suspected of affecting the test result. To quantify the sensitivity of the tested load bearing capacity of the rings and, thus, the extent of the geometry influence on toughness, a parameter study was carried out with the aid of finite elements simulation technique. Measures of interest are the notch width, N, and the notch tip corner radius, R, as depicted in Figure 6. On the one hand it can be discussed which configuration is best-suited for the proposed test procedure. On the other hand these measures could reveal minor deviations from the targeted values due to exceeding specified tolerances during the machining process. In this numerical study, models with two different values of the notch width and varying notch tip corner radius were analysed.

Model geometry

The FE model captured the general specimen dimensions as featured in the previously conducted ring expansion tests. Using symmetry planes, it was sufficient to configure the ring as a quarter model. A region was provided to accommodate the weld seam in a simplified form, neglecting the weld camber, see the red-marked mesh in Figure 5.

Material model

The base material as well as the weld metal was provided with elastic-plastic behaviour. Required flow curves were

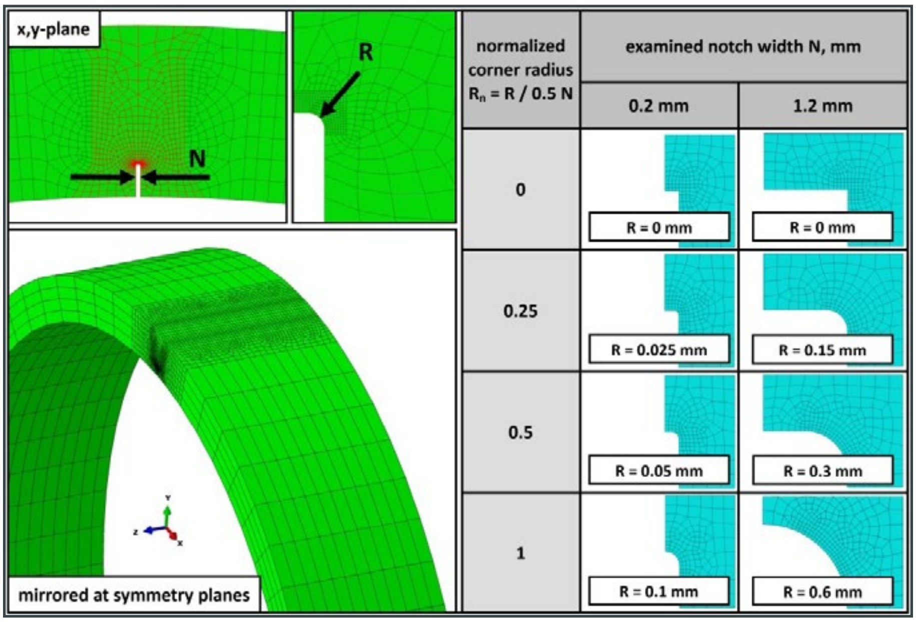

Figure 5: FE model of the ring specimen with variation of the notch width N and the notch tip corner radius R

derived from round bar tensile tests at room temperature. The specimens were machined from the base material, transverse to the rolling direction. Flow stress σ_f is determined to be 550 MPa. By curve fitting of the Hollomon approximation

$\sigma_w = k_H * \varphi^{n_H}$

the parameter k_Ha and the hardening exponent n_H, both describing the flow curve, were set to k_H = 798 MPa and n_H = 0.085. However, with this flow curve the plastic behaviour of only the base material is characterized. In previous studies regarding tensile properties of comparable material it had turned out that the shape of the weld metal flow curve equals that of the base material in good approximation if the true stress values are shifted to a higher level by an offset of 10 percent. In this numerical study, the plastic response of the weld metal was derived according to this approach.

Fracture model

Material damage was represented using the Gurson type porous metal plasticity model as implemented in Abaqus Standard. A set of suitable parameters was applied here, whereby the parameters were adopted from the base material to the weld metal with no special adaption. An element was considered to have lost its stiffness once the void volume fraction of f_F = 0.18 was encountered. To keep computational time short, just the element region directly adjacent to the notch tip was provided with damage behaviour. Since no further detail of a propagating crack is needed and only the instance of failure is of interest, this simplification is legitimate. The element size for those elements was kept at 0.025 mm both in the direction of the ligament and in the direction of the crack-opening stress component.

Results

The study's results can be gathered from Figure 6. Here, the calculated failure pressure is given in relation to the modelled normalized notch tip corner radius. Failure pressure was conceived as the applied pressure load at the instance of first element failure and is, thus, accounted for by the damage model's response to the stress state induced by notch tip geometry. Independently, net section yielding starts at p =540 barg, a pressure level below the computed failure pressures. For the notch width N = 1.2 mm, marked in blue, the lowest failure pressure was found to be p = 560 barg at the sharp cornered notch tip. With increasing corner radius, the failure pressure level is raised to higher values, reaching its maximum of p = 624 barg at the totally rounded notch tip. This is attributed to decreasing stress concentration zone with reducing notch sharpness. A similar effect can be found for the narrow notch of width N = 0.2 mm, marked in red. Here, the burst pressure level is reduced in general compared to that encountered at the wider notch geometry, beginning from p = 558 barg at R = 0 up to the maximum value of p = 588 barg at a normalized corner radius of 0.5. An explanation is, again, the stress concentration that is higher for a narrow overall notch width than for a wider notch. Unlike the observed tendency for the 1.2 mm notch, the pressure level slightly drops to p = 586 barg for the rounded notch tip configuration at normalized radius r = 1. This effect could not be covered in detail in this study. The principle observation is that, as expected, variations of the notch geometry do affect the values of failure pressure, but not significantly. All calculated failure pressure values remain within a range of 5.9 % maximum deviation from 590 barg that marks the arithmetic mean value. The simulations indicate that, at this pressure level, failure is promoted by net section yielding and, thus, plastic collapse. The typical distribution of the crack-opening maximum principal stress in the ligament at this pressure level is also shown in Figure 6.

A verification of the numerically derived failure pressures with test results, then regarded as burst pressures, could not be provided due to the fact that it was not possible to test the ring specimens up to failure pressure.

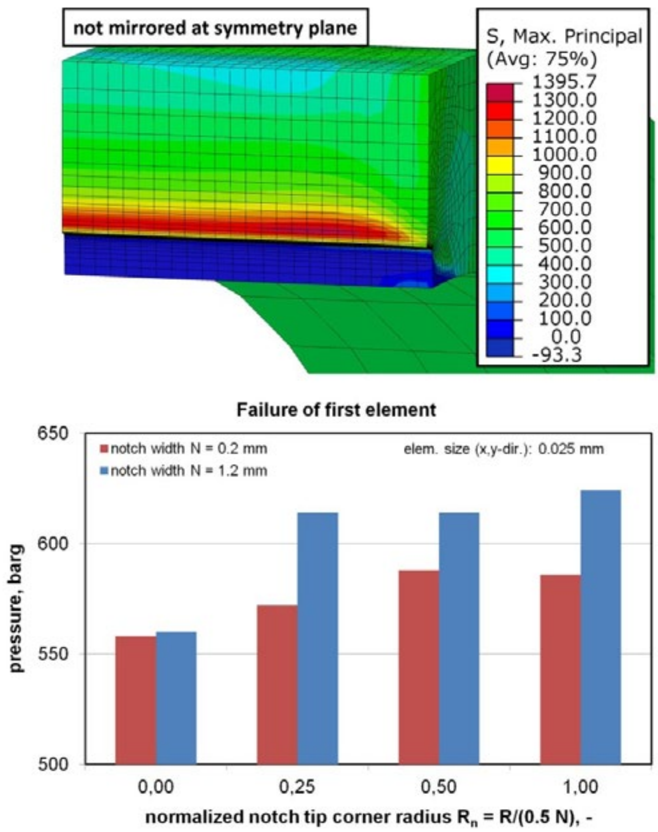

Figure 6: Distribution of maximum principal stress [MPa] in the ligament of the simulated ring with notch width N = 1.2 mm and corner radius R = 0.3 mm (above). Calculated failure pressures in dependence of the modelled notch configuration (below).

CONCLUSIONS

The rings tested within this investigation were taken from 5D bends (tangents) showing occasional low CVN values during production testing. Consequently, these bends fell below requirements and would have been rejected. In view of numerous publications addressing the impact of occasional low toughness values on structural performance and integrity, it was of interest to prove once again that the latter is not impaired. This can be assessed best with ring expansion tests in which the specific area of low toughness is targeted with a notch and providing the chance to perform a kind of full-scale test, instead of evaluation based on very limited cross section testing due to the small size of a standard CVN-sample. These tests can be conducted with rings containing different notch geometries and at different temperatures

Depending on the desired depth, the notching process can prove to be difficult if a small notch width is needed or if strict tolerances concerning notch radii are stipulated. Therefore, a dedicated FEA study was conducted to demonstrate the effect of differing notch geometry on failure pressure.

The investigation revealed that the structural integrity of SAW welds was not impaired by occasional low CVN values found at the inner wall position due to compensating constraint effects. Each test ring was pressurised to net section yielding without failing, one ring was exposed to an even higher pressure without any sign of leakage. The FEA analysis showed that, within the given boundaries, the failure pressure was not significantly influenced by notch geometry.

On basis of this investigation, it may be concluded that ring expansion tests being suitable to represent structural behaviour can be considered as a viable alternative when typical lab tests reveal occasional low CVN toughness values.

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A practical process for managing the threat of circumferential Stress Corrosion Cracking

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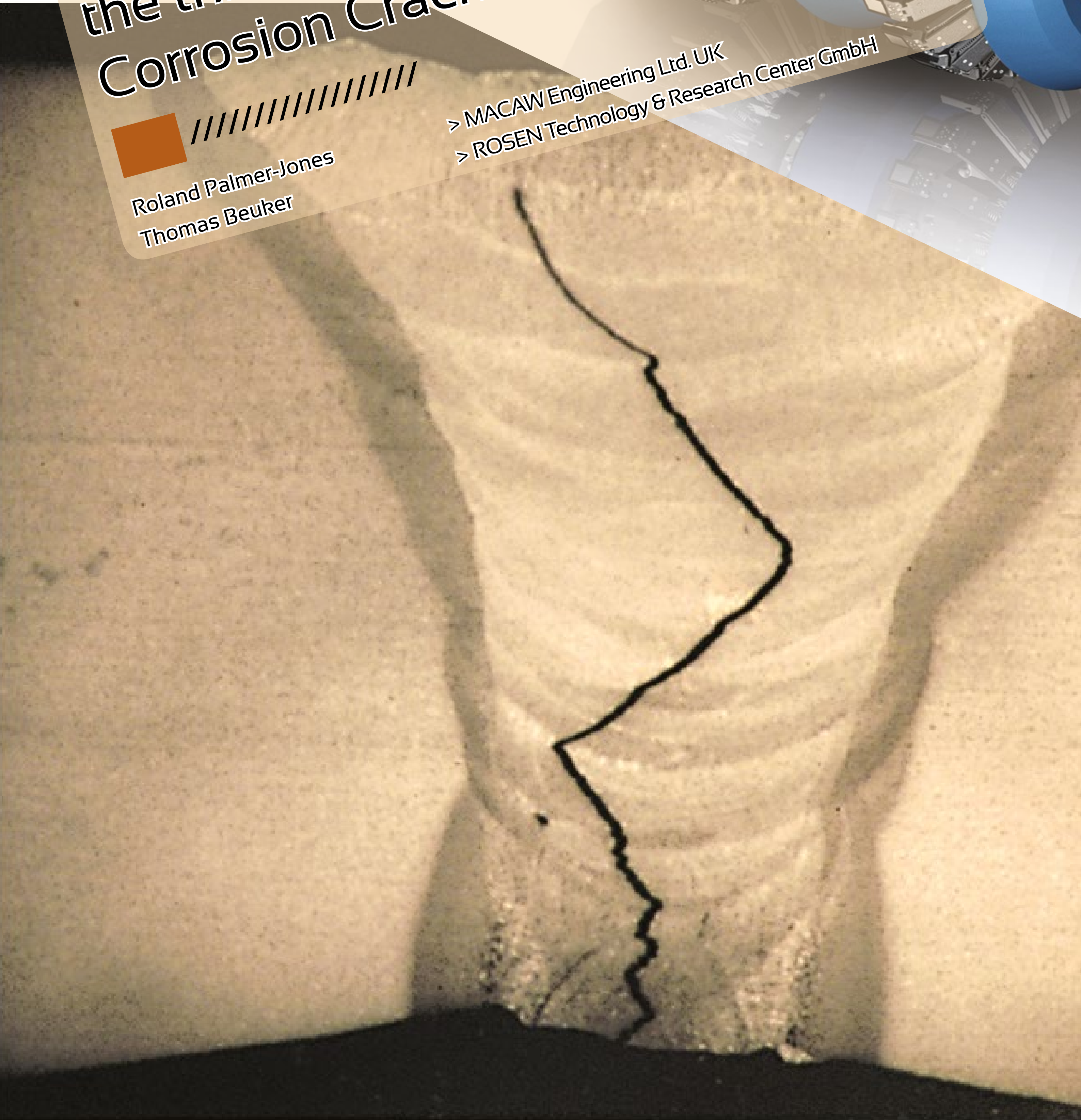

ABSTRACT

In recent years there have been a number of pipeline failures attributed to circumferential cracking. These failures remain rare but are often unexpected (a hazard not previously identified or included in any risk assessment) and can create a major hazard with significant disruption to pipeline operations.

Failure investigations of circumferential cracking have identified tensile axial strain and a corrosive environment as contributing to the development of stress corrosion cracking (SCC). Most cases of SCC result in axial cracking, often linked to stress raisers such as dents, areas of corrosion, and weld toes. The industry has developed tools capable of detecting these axial crack, but also in-line inspection tools for detecting circumferential cracks are now available in particular tools utilizing liquid coupled piezo electric ultrasonic sensors. Sensor technology for ILI of gas pipelines is being developed.

In this paper a process for identifying pipelines potentially susceptible to circumferential SCC, picking out specific high risk sites, and developing appropriate inspection and mitigation plans is proposed. The process is based on readily-available information on pipeline design, construction, and routeing, publically available spatial information including terrain models, soil data and rainfall records, combined with proven in-line inspection technologies for coating disbondment detection and bending strain estimation.

Following this system will provide a justifiable basis for decisions on managing the threat of circumferential SCC such as running specially configured circumferential crack detection tools, and completing site investigations.

INTRODUCTION

Failure investigations have identified tensile axial strain and a corrosive environment as contributing to the development of stress corrosion cracking (SCC). These failures remain rare but they are often unexpected (a hazard not previously identified or included in any risk assessment) and of course can create a major hazard and cause significant disruption to pipeline operations.

In recent years there have been a number of pipeline failures attributed to circumferential stress corrosion cracking [Pope et al., Chauhan et al.], or where the nature of the failure is not confirmed but is indicative of circumferential stress corrosion cracking (CSCC) [Carroll et al.]. The industry has taken steps to develop protocols for managing CSCC, for example a recent pipeline research council international (PRCI) report reviewed 55 cases of CSCC [Fessler and Batte].

Most cases of SCC result in axial cracking, sometimes linked to stress raisers such as dents, areas of corrosion, and weld toes [CEPA 2015]. Hence the industry has developed tools capable of detecting these axial cracks, but now in-line inspection tools for detecting circumferential cracks are available using liquid coupled piezo electric ultrasonic (UT) sensors. More recently, magnetic flux leakage (MFL), and electro-magnetic acoustic transmission (EMAT) sensor technology have been developed such that circumferentially-orientated cracking can be detected. These UT, MFL and EMAT based tools for the detection of circumferential cracking are not widely-available as the incidence of circumferential cracking is rare and hence the market demand is limited. This results in the requirement for the tools to be set up on a one-off basis, which is, of course, costly. Therefore it is unlikely that these tools will be available as a standard service similar to the tools used for metal loss detection. Accordingly, a rigorous methodology is needed for identifying where and when to run a tool to detect circumferential cracking.

In this paper a system for identifying pipelines potentially susceptible to circumferential SCC is proposed, and specific high risk sites are isolated. The framework uses readily-available information on pipeline design, construction, and routeing, publically-available spatial information (including terrain models, soil data and rainfall records), combined with proven in-line inspection technologies for coating disbondment detection and bending strain estimation. Using this framework will help operators whether or not to run a smart pig to detect and size circumferential cracking.

CIRCUMFERENTIAL CRACKING

Circumferential cracking is rare in pipelines, and is not a common cause of failures; however, failures have occurred [Hopkins 1993, Amend 2010] and any comprehensive integrity management program should consider the possibility of this type of cracking. The causes of circumferential cracking in pipelines are summarized below.

Girth Welding Flaws

Cracks may develop during or after the fabrication of girth welds in pipelines, if there were problems with the welding [Hopkins 1993]: an example is shown in Figure 1.

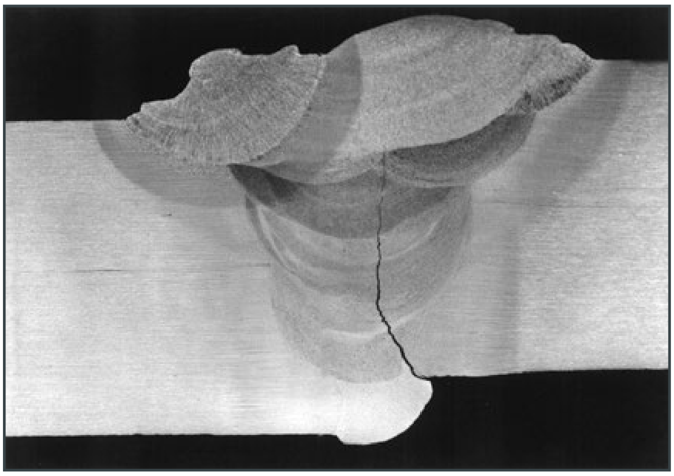

Figure 1: Example of Cracking Associated with a Weld (photograph from www.kkai.com (Kevin Kennedy and Associates)

These circumferential cracks are not allowed by girth welding standards, and may cause failures if the pipeline is subjected to high axial stress. Typically, these cracks will have survived a pre-commissioning hydrotest, and will only be a problem in service if there is a significant change in the support conditions; for example, an increase in axial stress due to differential settlement.

For most pipelines axial stresses are low, and do not change significantly; therefore, circumferential cracks that remain stable in size are not a primary concern. Inspection for girth weld cracks caused by fabrication would only be required if a potential source of load increase was identified. This load increase can now be achieved through repeat inertial measurement inspection and pipe movement analysis.

Vortex Induced Vibration

Loading from fluid flow where a pipeline is in free span either exposed in a river bed, or on the seabed in an area with high currents, can result in cyclic bending caused by vortex shedding induced vibration (VIV) [Dooley et. al.]. Industry experience indicates that when significant cyclic bending stresses occur due to cross flow VIV fatigue cracks can develop in the girth weld or the pipe body and grow to a critical size within a few hours.

VIV can be hard to predict, all the factors for VIV may be present but interaction with the river/sea bed, or debris collecting on the pipeline can cause damping that will reduce the vibration. Consequently, inspection systems for circumferential fatigue cracking caused by VIV are more likely to be needed to provide reassurance that there is no cracking after an event (for example river flooding and pipe exposure) has occurred rather than to identify actual cracks.

Stress Corrosion Cracking

There are two types of SCC known to cause external cracking in pipelines [NEB 1996]: high pH SCC; and near-neutral ('low pH') SCC. These refer to the pH of the corrosive environment at the crack tip. The combination of a susceptible steel microstructure, corrosive environment and sufficiently high tensile stress can result in stress corrosion cracking (SCC):

- pipeline steels generally have a susceptible microstructure to SCC;
- for most cases of SCC the corrosive environment is a result of coating disbondment, and ineffective, or shielded cathodic protection; and,
- the stress is generally caused by internal pressure, and hence the cracks are axially orientated, perpendicular the direction of stress.

Circumferential SCC can occur when there is a significant axial stress, usually attributed to some form of ground movement [Ward 2012]. Other sources of locally high axial stress can be dents caused by rocks in the trench, residual stresses from pipe bending, and thermal contraction [Fessler and Batte].

CSCC SUSCEPTIBILITY – INDUSTRY GUIDANCE

A number of publications have addressed the issue of CSCC [eg Leis and Eiber 2007].The Canadian Energy Pipeline Association (CEPA) has published detailed guidance on the management of stress corrosion cracking [CEPA 2015]. This includes a section on first level susceptibility assessment for CSCC, based primarily on the Fessler and Batte 2013 report to PRCI.

Factors identified in the CEPA 2015 guidance as relevant are:

- Coating type
- Proximity to previously discovered CSCC or axial SCC
- Year of pipeline construction
- Construction season
- Age of the pipe
- •errain
- Grade of pipe
- Pipe diameter
- Wall thickness

Further guidance is given in the CEPA 2015 guidance on how to investigate for CSCC, with the following additional factors:

- Coating condition
- Deformations
- Bends
- Angle of terrain
- Location on slope
- Soil type for tape-coated pipe
- Soil type for asphalt-coated
- Soil moisture for tape-coated pipe
- Soil moisture for asphalt-coated pipe
- Pitting corrosion in the pipe joint

Where CSCC is identified as credible the CEPA 2015 guidance references the use of circumferential crack detection ILI technology as an option.

This CEPA guidance provides a very useful starting point; however, for practical application some thought is needed on how to gather all the relevant data, and how to make use of other data sources not explicitly referred to that may be of benefit.

For example 'terrain' is given as a factor linked to the potential for pipe movement or unstable slopes, and by association high axial stresses that may wrinkle the coating allowing water in and create the tensile loads that are required for SCC. Terrain can in most places be relatively easily identified from topographical maps of a pipeline route. However, high localised bending can occur in relatively flat terrain where there are areas of differential ground settlement.

CSCC SUSCEPTIBILITY AND INVESTIGATION – PROPOSED PROCESS

It is clear from the very broad basic susceptibility criteria given in the CEPA guidance that many onshore pipelines will have some susceptibility to CSCC. Therefore, most operators will require a reasoned method for improving their understanding of the likelihood of CSCC. The following process is proposed based on the CEPA/PRCI guidance, and the authors' experience. Key parameters are selected and technologies available for collecting and aligning relevant data are proposed. An overview of the process is presented in Figure 2. Additional details are given in the following sections of the paper.

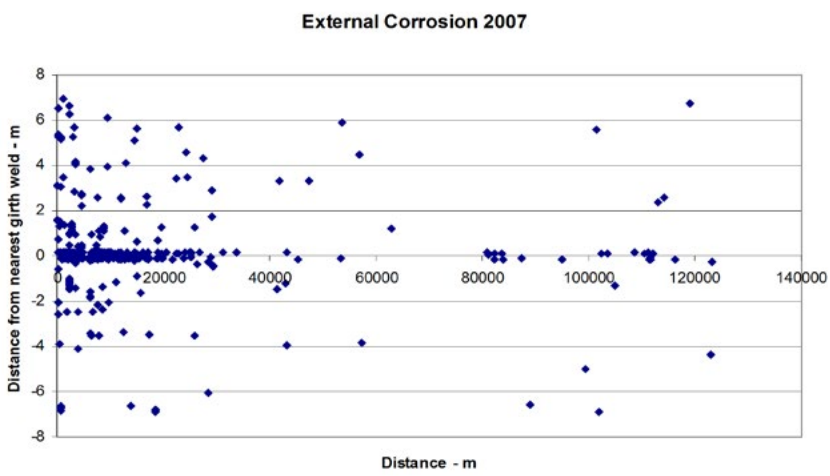

Figure 3: External Metal Loss Pattern Typical of Field Joint Coating Failure

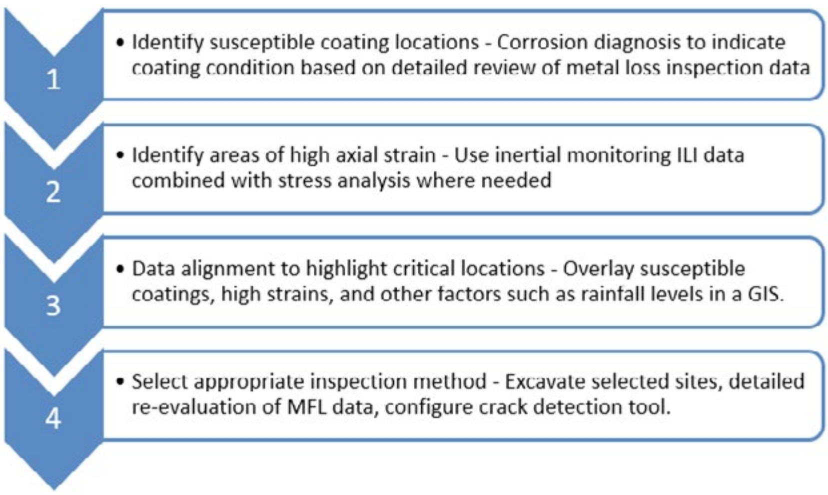

Figure 2: Proposed Process for Addressing CSCC

Coating type and condition

Coating types are generally known, but EMAT in-line inspection may give an indication of coating type, and for some coatings (e.g. bitumen) can identify areas of disbonding.
The condition of the coating can be qualitatively evaluated based on factors such as age and operating temperature. Information from past excavations can also give an indication of coating condition. The detailed review of metal loss internal inspection data, particularly where all metal loss features are reported can give a very good indication of both coating type and condition from representative patterns or distributions of features. For example the pattern of metal loss in Figure 1 where there are multiple features close to the girth weld is indicative of a systematic breakdown of the field joint coatings, perhaps due to poor initial application, or inappropriate specification and higher temperatures near the start of the line.

Other patterns of corrosion features may be associated with tape coatings, bitumen coatings subject to soil stress, rock damage to the coating, etc..

Axial Tensile Stress Levels

Terrain can be qualitatively evaluated from maps; however, the real interest is in axial stress levels, and higher stresses from bending or axial soil loading are typically found in areas with slopes than flat terrain. Ideally we would take direct measurements of the stress level in our pipelines using an internal inspection device. There has been some development in this area, but it is not yet well proven [Westwood et al.].

Most modern ILI tools have the option to include inertial measurement units (IMU). These allow every change in direction of the pipeline to be identified and hence curvature and bending strain to be calculated [Aue et. al.]. The bending strain will often give a good first indication of absolute strain level, particularly if account is taken of pressure and temperature effects. Absolute levels of strain can be estimated with reasonable accuracy using stress analysis techniques [Lockey and Young 2012, Young and Lockey 2013]. These strain levels can be compared with allowable or expected levels. Patterns in the curvature and bending strain can be identified and associated with features including field bends, forged bends, lateral landslides, rotational landslides, differential settlement, etc.. The typical shapes of common features are shown in Figure 3.

An example of real ILI data identifying an area of bending strain is shown in Figure 4.

Repeat IMU inspection can be used to identify locations of pipe movement and hence changing bending strain.

Local Deformation such as Dents or Pipe Wall Buckles

High resolution geometry tools, Figure 5, are now well-established and able to provide accurate measurements of deformation, including ovality, dents, and pipe wall buckles.

Soil Types, Location on Slope, Rainfall Levels

Factors such as soil types, location on slope and rainfall levels contribute to the potential for coating damage and soil movement induced stresses. This data is often available in the public domain in digital map form, or may be included in original pipeline design information. Modern geographic information systems allow these types of data to be overlaid with data from the pipeline design, construction and inspection, as illustrated in Figure 6.

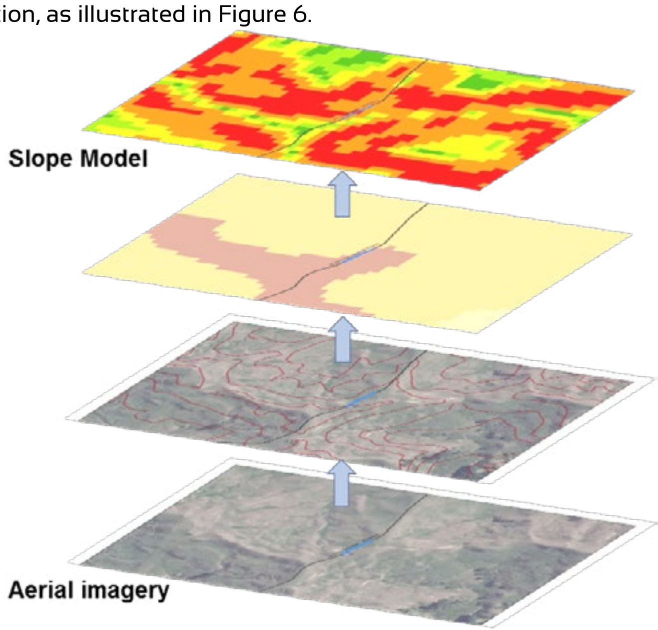

Figure 7: Illustration of Data Layers

This data overlay enables operators to build up and visualize a detailed picture of the changing conditions along the line.

CSCC INSPECTION AND IDENTIFICATION

Where CSCC is considered credible there are a number of options for inspections. Sometimes the number of locations where there are the full combination of factors is relatively

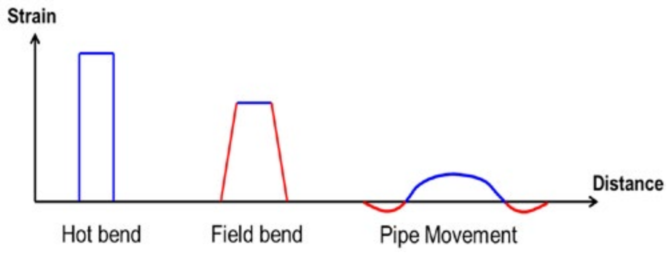

Figure 4: Typical Strain Profiles for Common Pipeline Features

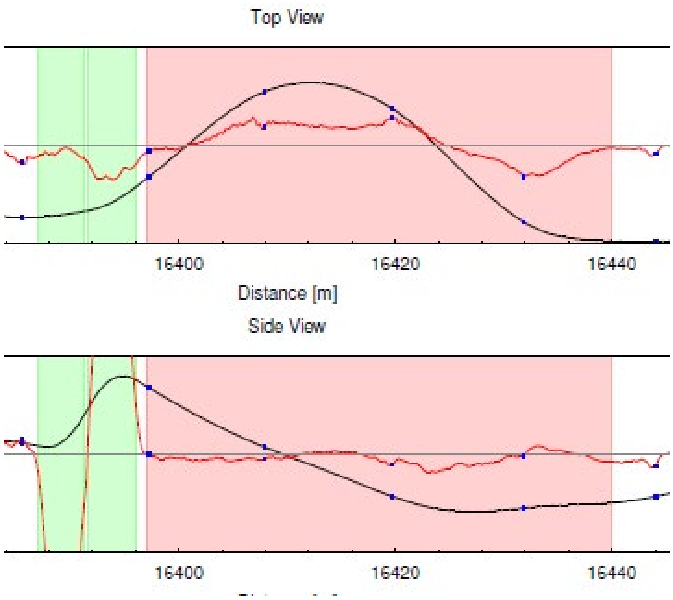

Figure 5: Example From IMU Report Showing Calculated Bending Strain and Hot Bends

Figure 6: Example of Geometry Tool (RoGeo Xt)

small and hence excavations may be cost-effective. However, for cases where there are several possible locations, in-line inspection may be preferable. In general, for cracks, the use of a sensor technology such as shear wave UT or EMAT is the preferred choice. These crack detection ILI tools can be reconfigured to inspect for circumferential cracking. The accuracy and reliability of these re-configured systems is not yet well understood due to the infrequent use. In theory the capabilities should be similar to the performance with axial cracks. Prototype testing has demonstrated the feasibility of using both tool types. Data obtained using an EMAT-A prototype is shown in Figure 8.

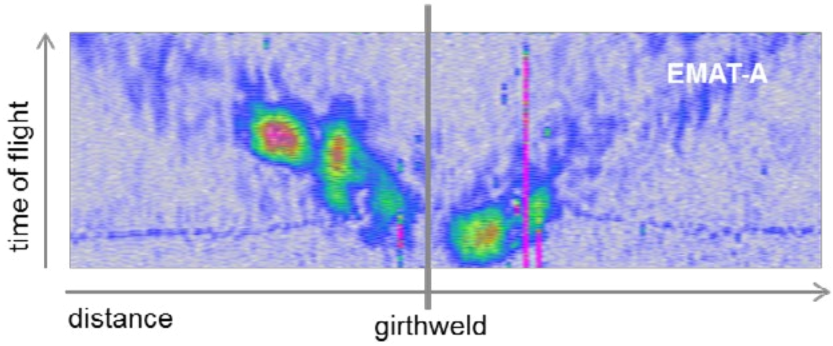

Figure 8: EMAT-A Data for a circumferential linear girthweld anomaly

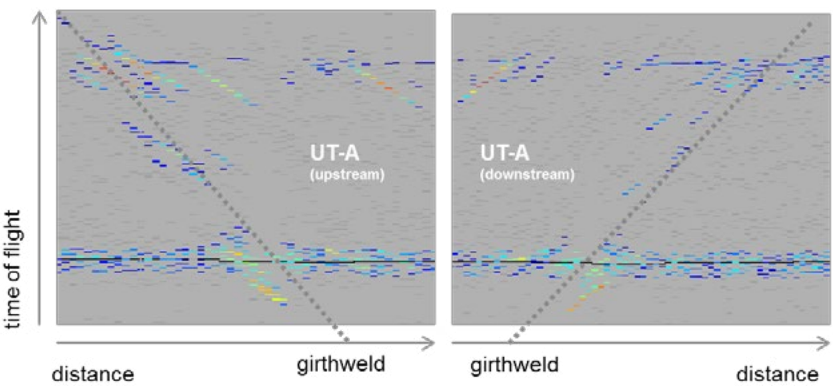

Figure 9: UT-A Data for a circumferential linear girth weld anomaly

A reflection is obtained from a circumferentially oriented linear girthweld anomaly. The data shown here were obtained with a single sensor. In a distant position (left) the reflection from the flaw requires a longer time of flight than at the position of the girthweld (center). After passing the girthweld the traveltime is increasing again, while the sensor is still catching reflections from the flaw although moving away from the girthweld.

Therefore information from the girthweld will be obtained as the tool approaches, passes across, and moves away.Data obtained with a commercial UT-A ILI tool is shown in Figure 9.

The two data sets are taken from two sensors scanning in opposite directions. Similar to the EMAT-A data an angled signal pattern can be observed. This is caused by the fact that the sensor is moving towards and away from the girth weld. The reflections with a short time of flight are related to the ID of the pipe, while reflections with a longer travel time are related to the OD of the pipe. The raw data displayed here reveal reflections from the girthweld at ID and OD position, but also three distinct circumferentially oriented crack like indications on the girthweld or in the close vicinity.

An example of the development of a UT tool for inspecting deep water steel catenary risers for potential circumferential girth weld cracking caused by VIV is presented by Baumeister et. al.. The performance of that tool in a test sample is illustrated in Figure 8.

Where the axial stresses are very high then circumferential cracks may open to such an extent that they become detectable by very careful review of typical MFL data collected to identify external metal loss.

CSCC is a form of corrosion, influenced by the stress state of the metal. Therefore it is time dependent, and if the potential for this threat can be identified the process presented here illustrates how the existing industry guidance can be used in a practical way incorporating the detailed evaluation of bending strain evaluation and pipeline load modelling to better understand the threat and justify either location specific excavations or the deployment of re-configured inspection vehicles.

Any CSCC identified should be repaired. Hydrotesting is suggested as an option by CEPA but it should be noted that hydrotesting does not generate high axial stresses, and it is known that circumferential cracks require high axial stresses to cause failure [Knauf and Hopkins].

CONCLUSIONS

Circumferential cracking and specifically circumferential SCC has caused a number of pipeline failures. It is not a common hazard and may be neglected in integrity management planning.

Good industry guidance, for example from CEPA, is available that gives advice on the management of CSCC. However the guidance on how to collect and integrate the information required is limited. In particular ways to identify areas with damaged coatings, and how to get good estimates of axial stress levels.

The process described here integrating inertial monitoring ILI data to calculate bending strain, with modelling to estimate total axial stress, corrosion diagnosis to understand coating condition, and GIS based data alignment to correlate other risk factors fills some key gaps and aids in identifying pipelines where there may be a real threat of CSCC and where there is a genuine benefit in running tools designed to detect circumferential cracking before the combination of cracking and loading reaches a critical level and there is a failure.

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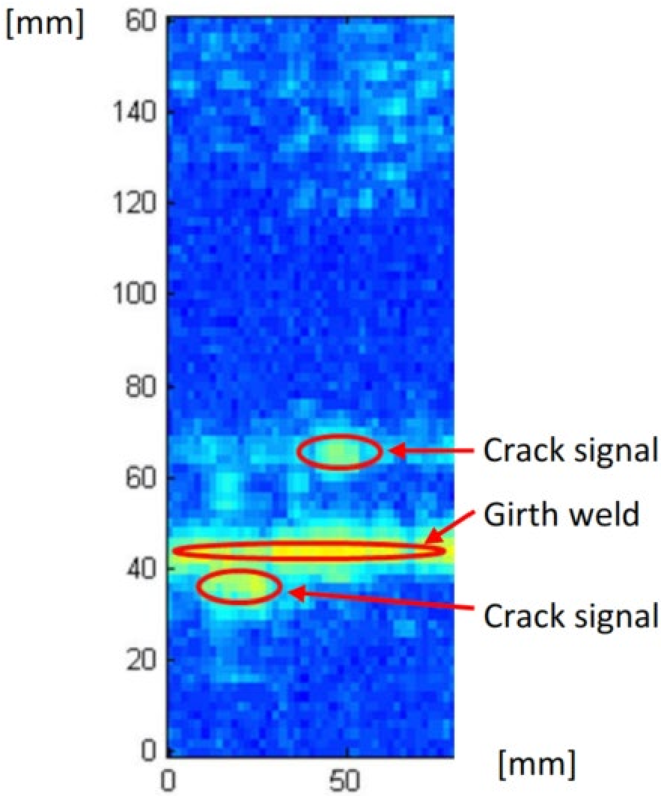

Figure 10: C Scan of two cracks close to a girth weld. Crack depths are 2.5 mm (upper crack signal, length 15 mm) and 4 mm (lower crack signal, length 14 mm).

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The civilized world has constructed some 3.5 million km of high pressure pipelines for oil, gas and water over the last 100 years - about 25,000 km of new pipelines are added every year. On the side of medium and low pressure pipe networks for gas and water distribution, district heating and cooling as well as sewers for waste water disposal we are talking about roughly 25 million km. The annual construction of new lines is estimated at 30,000 km. According to statistics the length of the supply and disposal network within different economies correlates very closely to their economic success. The largest networks could be found in the industrialized countries of North America and Europe. But poorly constructed and uneconomically operated, leaking pipeline, pipe and sewer networks are major cost drivers and can damage the environment.

In many places around the world water losses are extremely high and damaged sewers pollute the ground water. Losses in the district heating and cooling networks are also a waste of financial resources and gas leakages could even lead to serious and fatal accidents.

Organizations all around the world work on technical solutions for safety improvements, maximum reliability, economic efficiency and environmental protection of supply and disposal systems. The Pipeline - Pipe - Sewer - Technology Conference & Exhibition (PPST) intends to further appropriate solutions and the international exchange of experiences.

Please take a closer look at the following pages and get involved now - send in your presentation suggestion and reserve your place at the accompanying exhibition. I look forward to seeing you in Cairo.

Yours,

Dr. Klaus Ritter
Pipeline Technology Conference Chairman
Pipeline Technology Journal Editor in Chief
President of EITEP

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