May 2015

e Journal

ptj Pipeline Technology Journal

EVENT EDITION

10th anniversary of
Pipeline Technology Conference
8-10 June 2015, Berlin, Germany

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10TH PIPELINE TECHNOLOGY CONFERENCE

Europe's Leading Conference and Exhibition on
New Pipeline Technologies

8-10 June 2015, Estrel Berlin, Berlin, Germany www.pipeline-conference.com

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Welcome
Message from the editor

Dr. Klaus Ritter

The Pipeline Technology Journal (ptj) is published for the fifth time. Its design as well as its internal structure clearly sharpened in comparison with the first issues. What remain are the close ties to the Pipeline Technology Conference (ptc) in Berlin and the occupation with research and development at an early stadium. It thus offers the possibility to support discussions among the pipeline community on new developments considering experiences worldwide.

Unlike the Poster-show that establishes a selective professional public during the annual ptc conference, the journal ptj will be thus published four times a year to intensively report about research and development helping to optimize the construction, operation and life support of pipelines.

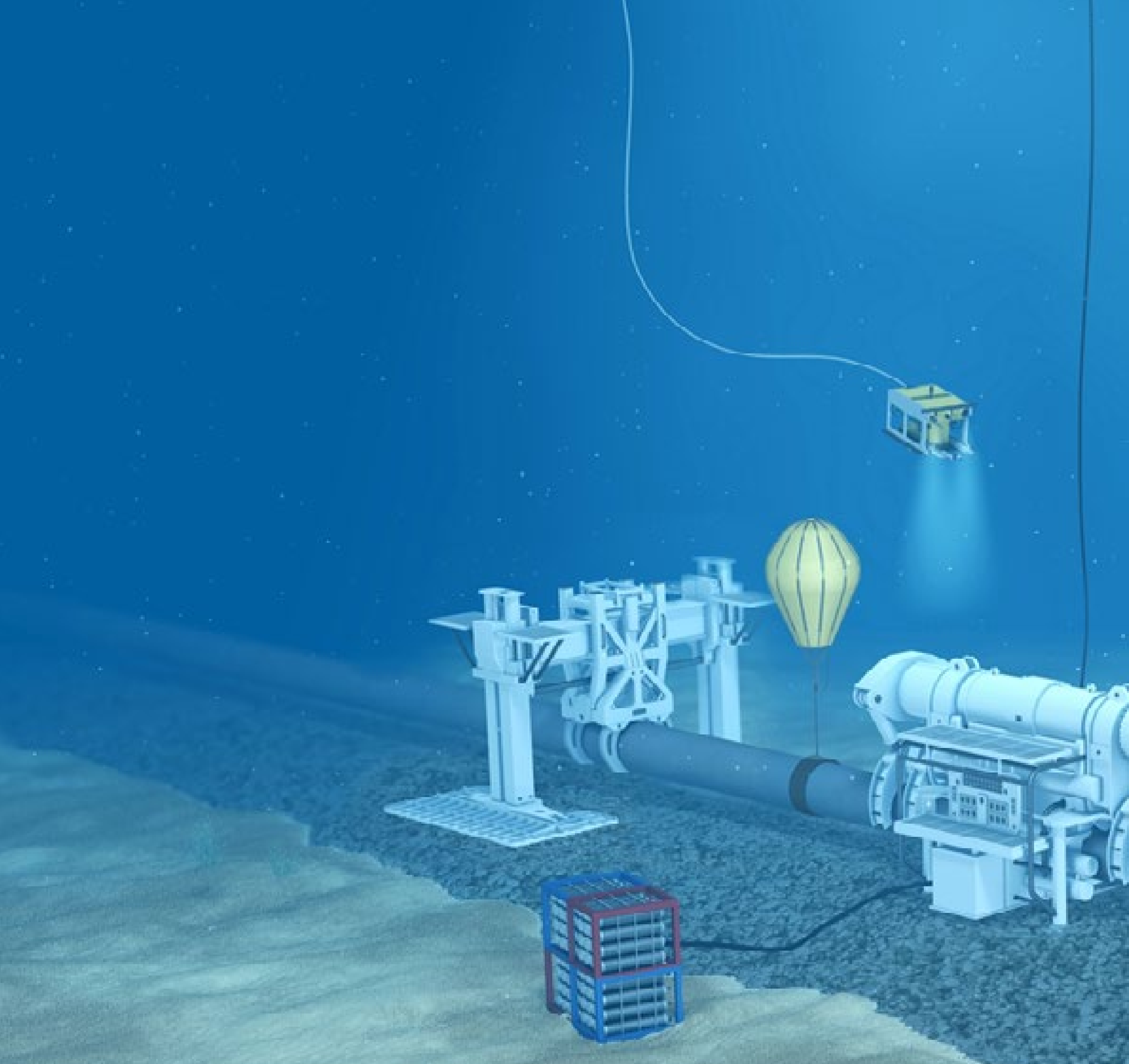
The triggers for this promotion were the requirements of many operators who are participants of the Pipeline Technology Conference (ptc) to speed in dealing with issues of pipeline safety and longevity.

Help us to meet these demands and provide us Your new solutions.

Our ptc Editorial and ptc Advisory Board are available to further encourage the development of Pipeline technologies from the point of view of safety and durability.

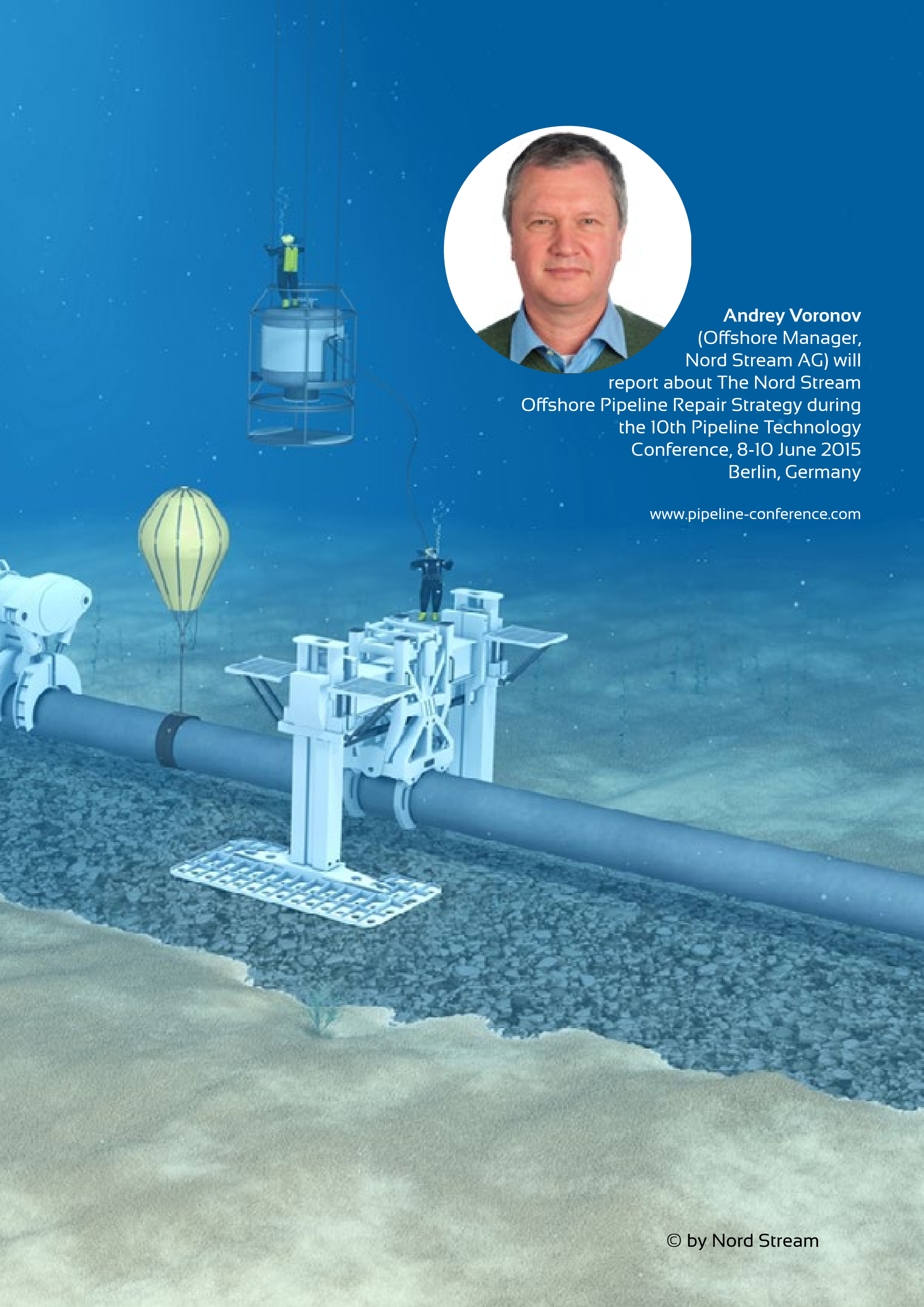
Yours sincerely

> Dr. Klaus RItter, Editor in Chief



NORD STREAM UNDERWATER TIE-IN BACKGROUND

Each of the two Nord Stream Pipelines is built in three sections. Once completed, the sections must be welded together to form the 1,224 kilometre pipelines. This "tie-in" process takes place on the seabed in an underwater welding habitat. Welding operations are remotely controlled from a support vessel, and divers assist and monitor the subsea construction work.



© by Nord Stream

HIGHLIGHTS

MAY 2015
EDITION 05

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INDUSTRY AND PRACTICE

Special Feature

PIPELINE TECHNOLOGY JOURNAL

PIPELINE TECHNOLOGY CONFERENCE (ptc)

PIPELINE TECHNOLOGY JOURNAL

RESEARCH / DEVELOPMENT / TECHNOLOGY

PIPELINE TECHNOLOGY JOURNAL

CONFERENCES / SEMINARS / EXHIBITIONS

INDUSTRY AND PRACTICE

SEATTLE / U.S.A

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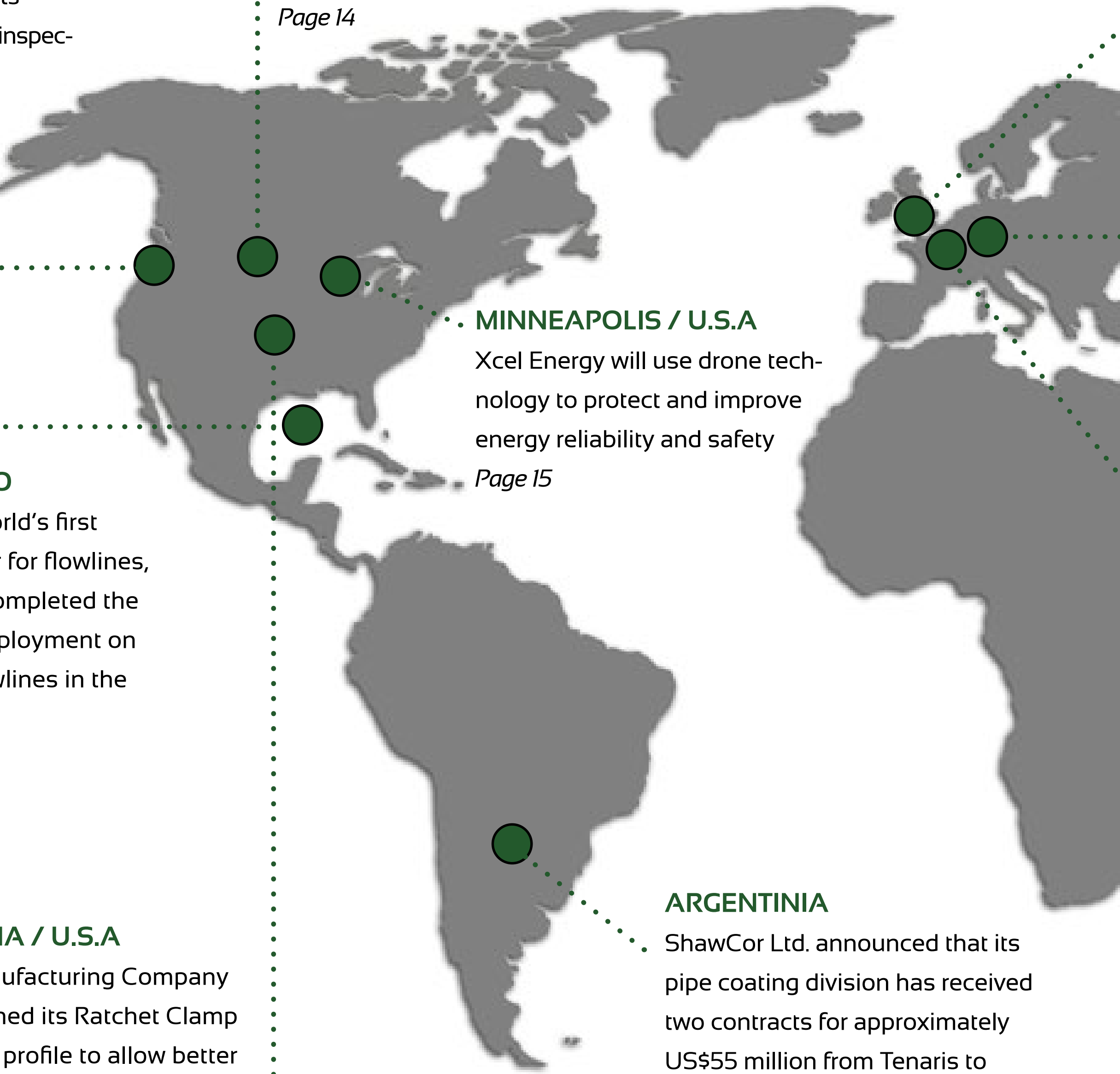

MINNEAPOLIS / U.S.A

Xcel Energy will use drone technology to protect and improve energy reliability and safety

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GULF OF MEXICO

Discovery™, the world's first subsea CT scanner for flowlines, has successfully completed the first deep-water deployment on Shell-operated flowlines in the Gulf of Mexico.

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OKLAHOMA / U.S.A

Sawyer Manufacturing Company has redesigned its Ratchet Clamp with a lower profile to allow better access to the butt join, helping welders effectively and quickly align and weld pipe.

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ARGENTINIA

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Atmos International (Atmos) will celebrate 20 years in the pipeline industry by exhibiting new theft detection solutions at Pipeline Technology Conference 2015 (stand 52).

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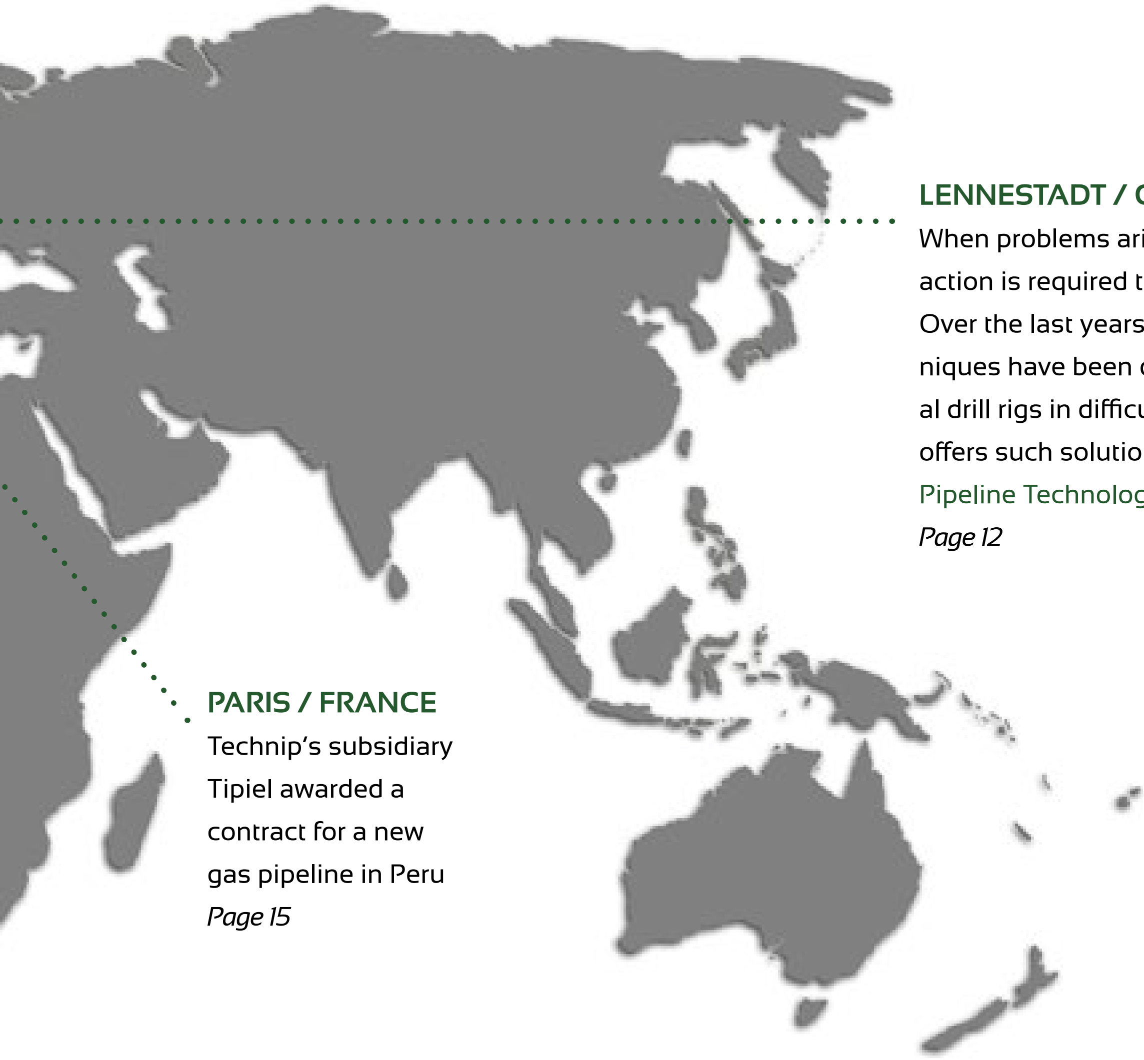

LENNESTADT / GERMANY

When problems arise on an HDD project, quick action is required to avoid a costly situation. Over the last years, several pipe ramming techniques have been developed to assist directional drill rigs in difficult situations. Tracto Technik offers such solutions for HDD projects during Pipeline Technology Conference (ptc) 2015

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PARIS / FRANCE

Technip's subsidiary Tipiel awarded a contract for a new gas pipeline in Peru

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WORLD NEWS

IN-LINE INSPECTION OF CHALLENGING PIPELINES VALIDATED WITH FLOW LOOP SIMULATIONS

Quest Integrity Group announces flow loop simulation capabilities, including client-specific pipeline configurations, to validate its InVista™ ultrasonic in-line inspection (ILI) technology in demanding environments. Visit Quest Integrity Group at ptc 2015 stand 41.

Quest Integrity conducts flow test loop demonstrations in various locations worldwide and can custom build flow loops for clients to include their real-world ILI challenges such as heavy wall piping, dual-diameters, reduced port valves, 1D bends, risers, unbarred tees and wyes. By simulating multiple ILI obstacles in a test environment, the company effectively demonstrates the navigational proficiency of the InVista tool, and pipeline operators gain first-hand knowledge of the tool's capabilities for their pipelines.

The company recently constructed a 6-inch custom flow loop for a large, international oil and gas client in Houston, Texas. The client needs integrity management data for a high-profile, heavy wall sour gas pipeline asset in the United States, but wanted to avoid failed run or stuck tool situations. Quest Integrity's flow loop simulations included running the tool at varying speeds and bi-directionally to validate data collection and operational capabilities. InVista successfully overcame the operational trials presented and collected accurate data for both known and unknown defects in the line.

"As an added value to our clients, we build flow test loops to their specifications to simulate an in-service challenging ILI run in a test environment," said Stefan Papenfuss, Vice President - Pipeline Resources, at Quest Integrity. "This provides our clients with procedural information and project confidence while demonstrating the many benefits of the InVista technology for their critical pipeline assets – without the potential risks associated with testing an in-service pipeline."

For further information:
http://www.questintegrity.com/services/inspection-services/pipeline-in-line-inspection

SAWYER MFG. CO. IMPROVES THE RATCHET CLAMP-MODEL 255

Sawyer Manufacturing Company has redesigned its Ratchet Clamp with a lower profile to allow better access to the butt join, helping welders effectively and quickly align and weld pipe.

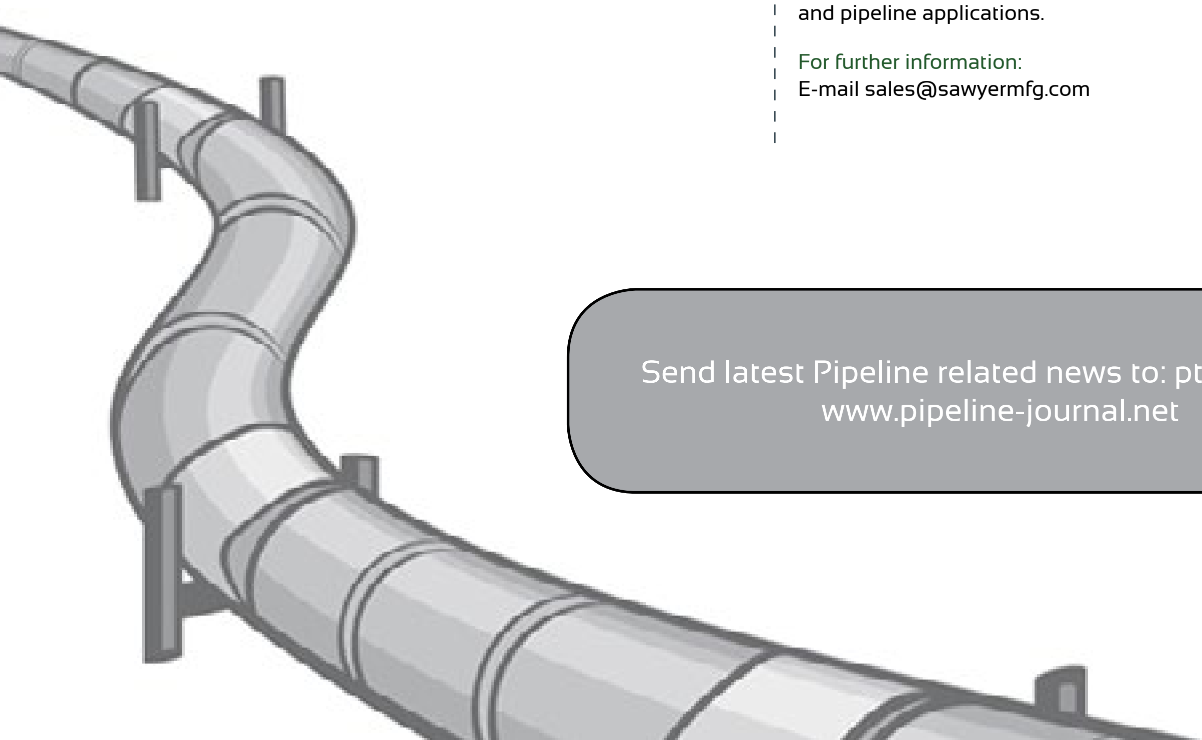
The ratchet mechanism was also improved with a built-in handle and enclosed threads to protect against dirt and weld splatter, all while retaining the true double ratchet feature that allows for quicker closure on the pipe to increase speed and performance. This mechanism permits the clamp to align pipe quicker than any other ratchet clamp on the market.

The Ratchet Clamp is built with a focus on speed and accuracy. This 10-ton ratchet will deliver precision and rugged durability with ease. The clamp is designed with an open bridgework to allow full 360-degree welding, ensuring a quality weld, and the machined headrings are precision bored for consistent and accurate fit up. Also, the Ratchet Clamp's new yellow color provides high visibility and improved safety.

Improvements in the manufacturing process have allowed Sawyer Mfg. Co. to offer a price that is even more competitive. "There are a lot of clamps out there," said Dave Hembree, Sawyer Manufacturing Vice President. "I believe our customers will be pleasantly surprised by the small but important changes we made with this clamp."

Sawyer equipment is used worldwide in the construction and maintenance of pipeline, waste water and sewer lines, marine and offshore applications, gathering and distribution systems, and other welding and pipeline applications.

For further information:
E-mail sales@sawyermfg.com



ATMOS INTERNATIONAL'S NEW THEFT SOLUTIONS AT PTC

Atmos International (Atmos) will celebrate 20 years in the pipeline industry by exhibiting new theft detection solutions at Pipeline Technology Conference (stand 52).

Atmos already offers Atmos Wave, which detects theft valve movement; and Atmos Wave Flow which, with sensitivity to 0.1% of the flow rate, can potentially detect theft within two minutes. However, Jun Zhang, Managing Director, Atmos, explained, 'We're seeing meticulously planned, near-invisible taps by well-organized gangs that significantly impact a pipeline user's profits. Rapid detection is essential for minimizing financial, environmental, and reputational damage.'

'Our powerful new detection solutions enable clients to react instantly and catch criminals red-handed.'

ATMOS THEFT NET

As illicit connections have become smaller, more intermittent and harder to detect, so detection systems must become more sensitive. This increases the rate of false alarms, which can be costly but also dangerous if they result in genuine alarms being ignored. Atmos experts are trained in the latest techniques for spotting theft in action – and offer this unique analysis service to save clients time and loss, and help them prosecute. To collect data, Atmos has developed:

ATMOS PORTABLE DATA LOGGER FOR LEAK AND THEFT DETECTION

This case-based autonomous data logging solution can be rapidly deployed – either by your staff or Atmos - to collect the pressure and flow data where taps are suspected. Data can be collected on site or remotely.

ATMOS HYDROSTATIC TESTER

This portable kit takes hydrostatic testing to unprecedented levels. It uses both pressure and acoustic sensors to identify even tiny leaks or intermittent tapping, with location accuracy to 2 meters. It is ideal for where pipeline integrity testing is mandatory, and negates the need for costly yet limited options with dyed or odorized water.

ODIN

This revolutionary battery-based theft detection solution has been designed for pipelines previously in a detection 'black hole' – for example, in areas without power or communications, or where standard detection units are undesirable for aesthetic reasons (as in National Parks.) Small and unobtrusive, it can be hidden near suspected tapping points, yet has the sensitivity of permanent detection systems.

For further information:
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Atmos Portable Data Logger for Leak and Theft Detection

Battery-based theft detection solution ODIN has been designed for pipelines previously in a detection 'black hole'.

TRACTO TECHNIK OFFERS SOLUTIONS FOR HDD PROJECTS DURING PIPELINE TECHNOLOGY CONFERENCE (STAND 47)

When problems arise on an HDD project, quick action is required to avoid a costly situation. Over the last years, several pipe ramming techniques have been developed to assist directional drill rigs in difficult situations. Having a ramming hammer on site during HDD projects ensures a trouble free installation as the combination of the HDD technique's static pulling force with the ramming technique's dynamic impact offers proven solutions for tough drilling problems.

CONDUCTOR BARREL: INSTALLATION OF CASING PIPES FOR HDD CROSSINGS

The concept behind the Conductor Barrel is creating a clear pathway through poor soil conditions so that drilling can begin in more favourable soil conditions. The success of a drilling operation can often be determined right from the outset. Loose, unsupported soils are prime candidates for this method. During the Conductor Barrel process, casings are rammed into the ground, at a predetermined angle, until desirable soil conditions are encountered. The spoil is removed from the casing prior to the drilling operation. Drilling starts within the casing in the favourable soil conditions. The conductor barrel can also serve as a friction-free section during the pullback operation or prevent situations in unstable soils acting in a similar fashion to containment cells.

PULLBACK ASSIST

The pullback assist technique incorporates the use of both a pipe rammer and an HDD rig working in tandem to get a problematic product pipe installed. When drilling underwater or in loose flowing soil conditions, hydrolock can occur. This happens when the external pressure being put on the product pipe from ground water pressure, drilling fluid pressure and/or soil conditions exceeds the drill rig's pullback capacity, or the product pipe's tensile strength. The percussive action of a pipe rammer in this situation is used to help free the jammed pipe.

DRILL ROD RECOVERY: LOOSENING OF JAMMED HDD DRILL ROD

The principal is the same during drill rod recovery, as it is during bore salvage, however, there are two possible tooling configurations. Depending on the situation, contractors can remove the drill rod from the ground or, if the rod is still attached to the drill rig, push on the rod while the drill rig pulls back.

BORE SALVAGE: RESCUING / REMOVING JAMMED PRODUCT PIPES

This simple yet highly effective technique is used to remove jammed product pipes. During the bore salvage operation the Grundoram pipe rammer is attached to the end of the partially installed product pipe. The pipe rammer is attached to the product pipe so that it pulls the pipe from the ground. This can be accomplished through a fabricated sleeve. A winch or some form of pulling device is used to assist the rammer during operation. In many cases, the percussive power of the pipe rammer is enough to free the jammed product pipe and allow it to be removed from the ground.

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NEW RESEARCH INTO AERIAL VEHICLE TECHNOLOGIES TO ENHANCE PIPELINE MONITORING

The pipeline infrastructure in Canada and the United States is showing growing signs of wear and tear. In the past few months a series of leaks and explosions from Mississippi to Calgary have led to a number of deaths, damaged property and polluted the local environment. Against this background Enbridge Pipelines, TransCanada Corporation and Kinder Morgan Canada have signed a Joint Industry Partnership agreement to conduct research into aerial-based leak detection technologies with the aim of enhancing pipeline safety throughout North America.The partnership suggests an interest in cutting-edge aerial vehicle technology to bolster pipeline safety and reliability. It is also an attempt to answer a chorus of public demands for responsible pipeline development and maintenance.

"We are committed to identify, develop and test new technologies to further progress key areas of pipeline safety, such as leak detection. Through collaboration with committed industry partners, we continue to make important advancements with leak detection technology," says Kirk Byrtus, Enbridge's Vice President of Pipeline Control. "This extension to the Joint Industry Partnership is another great example of the pipeline industry connecting to make important advancements with leak detection technology, and we look forward to closely working with our partners, TransCanada and Kinder Morgan."

Enbridge, TransCanada, Kinder Morgan working together to evaluate aerial-based pipeline safety technologies (© 2015, Enbridge Inc.)

DISCOVERY™ COMPLETES SUCCESSFUL DEPLOYMENT ON SHELL ASSETS IN THE GULF OF MEXICO

Discovery™, the world's first subsea CT scanner for flowlines, has successfully completed the first deep-water deployment on Shell-operated flowlines in the Gulf of Mexico.

Discovery™ was developed by Tracerco, part of the FTSE100 Johnson Matthey Plc, in response to an industry need for a non-invasive method of scanning subsea flowlines. The technology is used to establish the integrity of subsea pipeline assets.

In total, Discovery™ scanned ten flowlines including jumpers, steel catenary risers, and pipe in pipe flowlines all of varying diameters. Over 250 CT scan images over a pipeline length of 50,000 feet, at depths down to 4,200 feet, were generated. In the Gulf of Mexico, based on such data, Shell was able to build a complete profile of their pipeline, which helped to confirm the condition of the asset.

Shell undertook a comprehensive technology review to select an inspection solution to support safe, efficient, and competitive operations. Discovery™ offers three key advantages over alternative inspection technologies:

- The device attaches to the outside of the flowline, allowing the inspection campaign to be conducted while production continues;

- There is no need to remove the insulation coating on the flowline, minimising the risk of flowline damage or of the build-up of hydrates;

- Scan image data is available in real time, allowing engineers to rapidly evaluate and respond to any integrity and flow assurance problems.

Jim Bramlett, Business Development Manager for Tracerco's Subsea Technologies division, said: "Using Discovery™ we were able to quickly deliver data, drip feeding the scans through to Shell engineers then providing an in-depth analysis once we had all the information. We understand that for each day a pipeline is out of action, or not performing at peak, there are significant financial implications"

The planning, preparation and execution of the inspection campaign was a joint effort which provided access to the Discovery™ CT scan images, and Tracerco's expert interpretation, within the same day. Discovery™ scans pipelines from the outside to gain an accurate picture of the condition of the pipe and the flow, with no need to remove the protective coating and no interruption to production. It is a highly accurate, rapid and low risk solution to gaining information on flowlines including pipe-in-pipe and bundle systems. Discovery™ provides a 360 degree, high resolution scan of pipeline contents and pipe walls in real time, with defect resolution of 1mm.

Tracerco Shell deployment in Gulf of Mexico

TECHNIP'S SUBSIDIARY TIPIEL AWARDED A CONTRACT FOR A NEW GAS PIPELINE IN PERU

Tipiel(1) S.A., Technip's subsidiary in Colombia, was awarded by the Consorcio Constructor Ductos del Sur(2), a front-end engineering design and detailed engineering design contract, on a lumpsum basis. This covers the development of a new gas pipeline to transport gas from the Camisea field to Southern Peru.

Launched by the Peruvian government, the project consists of more than 1,700 kilometers of 32" gas pipeline. It aims to improve the existing Peruvian Energy Network, contributing to the development of an Energy Node and Petrochemical Hub in Southern Peru.

The overall work will be performed by Tipiel's offices in Bogota, Colombia. Marco Villa, Technip's Region B(3) President, commented: "This award reflects the importance to accompany the client since the very early stage of an initiative to help design an optimized project execution scheme."

Riccardo Nicoletti, Tipiel General Manager, stated: "This contract, which is related to one of the most important projects for the development of energy infrastructure in Peru, serves our objective to make Tipiel a leading engineering company outside Colombia as well".

SHAWCOR ANNOUNCES CONTRACT TO PROVIDE PIPE COATING SERVICES FOR THE GNEA PROJECT IN ARGENTINA

ShawCor Ltd. (TSX:SCL) today announced that its pipe coating division has received two contracts for approximately US$55 million from Tenaris to provide three layer polyethylene anti-corrosion pipeline coatings for the first and second phase of the Argentina Northeast Gas Pipeline (GNEA) project.

This project is owned by ENARSA, an Argentine state-run energy company, and it includes the construction of a gas pipeline that will transport up to 11,200,000 m³/day of natural gas to locations in northeast Argentina.

The execution of these contracts has commenced in ShawCor's coating facilities in Argentina and is expected to be completed by Q1 2016.

For further information:
ShawCor Ltd.Gary Love
Vice President, Finance and CFO
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E-mail: glove@shawcor.com
Website: www.shawcor.com

XCEL ENERGY WILL USE DRONE TECHNOLOGY TO PROTECT AND IMPROVE ENERGY RELIABILITY AND SAFETY

FAA approves company's request to use unmanned aircraft for energy infrastructure inspections

Xcel Energy inspects more than 320,000 miles of electricity and natural gas infrastructure to ensure the safety and reliability of its energy system. Now with approval of the Federal Aviation Administration, Xcel Energy will be able to more efficiently, effectively and safely monitor its systems using drone technology.

The FAA on May 11 approved Xcel Energy's request to operate small unmanned aircraft systems or drones commercially. Xcel Energy sought the approval so it can inspect its critical energy infrastructure.

Xcel Energy will use drones to visually inspect electricity transmission and distribution lines, power plants, renewable energy facilities, substations and natural gas transmission and distribution pipelines.

"We are pleased with the FAA decision as we study how this new technology can best be used to enhance employee and public safety at our operations," said Kent Larson, Xcel Energy's executive vice president and group president of operations.

The use of small unmanned aircraft systems will allow Xcel Energy employees to safely inspect hard to reach areas, keeping the workers out of danger. Employees will also use drones to observe environmentally sensitive areas without the use of trucks, helicopters or other utility equipment, minimizing the environmental impact.

"We believe these measures will increase electricity and gas system reliability, reduce customer costs and improve our emergency response times," said Larson. He added that the company's current plan is to use drones only over utility property or utility rights of way and away from populated areas and airports. The drones will be flown at low altitudes and in the operator's line of sight.

The XCEL Drone

PIPELINE TECHNOLOGY CONFERENCE

500+ DELEGATES

50+ EXHIBITORS

55+ DIFFERENT NATIONS

The Pipeline Technology Conference (ptc),

europe's leading pipeline conference and exhibition, the Pipeline Technology Conference (ptc), will take place for the 10th time offering again opportunities for operators as well as technology and service providers to exchange latest technologies and new developments supporting the energy strategies world-wide.

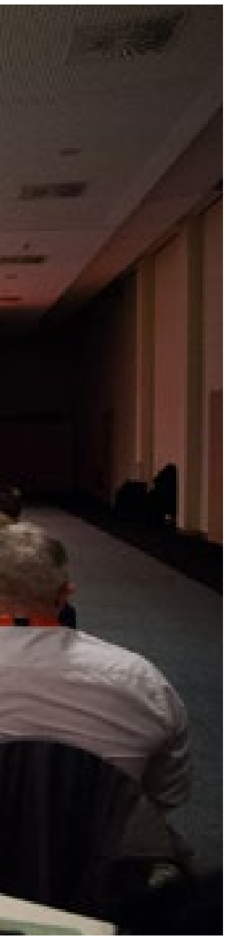
The conference will provide panel discussions and special focus sessions on "Pipeline Safety", "German Energy Turnaround", "Challenging Pipelines" and "Offshore Technologies". For the first time the conference will also feature an "Scientific Advances Poster Session" with latest updates on present and upcoming research activities.

ptc will feature lectures and presentations on all aspects surrounding oil, gas, water and product pipeline systems. The exhibition with more than 50 exhibitors will show latest pipeline technologies and products.

For more information kindly visit: www.pipeline-conference.com

"63% of the PTC Delegates are coming from abroad (Europe, Middle East, North America, South America, Asia, etc.)"

PIPELINE TECHNOLOGY CONFERENCE



EUROPE'S BIGGEST PIPELINE EVENT

THE ANNUAL GATHERING OF THE INTERNATIONAL PIPELINE COMMUNITY IN THE HEART OF EUROPE

After starting as a small side event of the huge HANNOVER MESSE trade show in 2006 in Hannover, the Pipeline Technology Conference developed into Europe's largest pipeline conference and exhibition. Since 2012 the EITEP Institute organizes the ptc on its own and moved the event to Berlin in 2014. The 10th anniversary will again be a record breaking event.

35+ SUPPORTERS

13 Technical Sessions at ptc 2015

- Integrity Management
- Geohazards
- Construction
- Materials
- Challenging Pipelines
- Inline Inspection
- Repair / Rehabilitation
- Management
- Pump & Compressor Stations
- Leak Detection
- Monitoring
- Coating
- Offshore Technologies

PIPELINE TECHNOLOGY CONFERENCE

ptc

Play Video

One of the world's major pipeline conferences will be held from June 8-10, 2015 in Berlin. With 500 to 600 participants from about 50 countries, the international Pipeline Technology Conference (ptc) is already among the largest and most important conferences of its kind in the world just 10 years after being initiated.

This "German" international conference is organized by EITEP (Euro Institute for Information and Technology Transfer in Environmental Protection), based in Hanover. It is especially supported by the major gas network operators (as to content) and by producers and service providers from Europe (exhibitors).

Content-related matters are managed by the internationally staffed 32-member Advisory Committee, AdCo. The AdCo is particularly active when it comes to putting together the conference program. AdCo members submit the received presentation proposals to a quality check, in which both the content (abstracts) and the potential speakers (CVs) are evaluated according to such criteria as relevance and topicality.

Over 150 proposals for 50 "free" presentations for the PTC 2015 were received by the EITEP following a "Call for Papers". The "Call for Papers" was sent out to about 22,000 verified addresses from the international pipeline community in July 2014. The returns were then examined together with the AdCo in the manner described.

This process ensures that participants are offered a high-quality program that addresses and presents for discussion all current and ongoing developments throughout the world.

Pipeline construction is booming worldwide – except in Europe. Instead, Europe can offer a lot of experience and technology for operations and maintenance as well as on issues of safety and long service life. That is ostensibly what participants from Asia, Africa, Australia and North and South America are looking for in Europe at the ptc.

For the ptc 2015, the presentation selection procedure for the 50 free presentations, which is supplemented by about 10 invited speakers, has resulted in one plenary session and 13 technical sessions with 3 to 5 individual presentations. They cover all important, complex current issues related to the technology of onshore and offshore pipelines. Due to high demand, the topics of "Inline Inspection", "Geohazards" and "Microbiologically Influenced Corrosion" will be offered as two-day seminars for additional information following the conference.

15 research institutes from academia and industry are taking advantage of the opportunity to present their latest research results in a structured poster show.

Two particularly topical issues will be addressed in discussion forums. This year, the topics will be: 1. "Pipeline safety" and 2. "The German Energy Transition". Both topics will be moderated by the former CEO of Open Grid Europe, Heinz Watzka, who has invited experts from North America and Europe to participate in the discussion. DVGW Vice President Dr. Hüwener will be involved in discussion round 1 and DVGW Chairman Dr. Linke in discussion round 2. This will ensure that there will be plenty of input into various aspects of the German gas industry.

The papers from the past 9 years of ptc are made freely available in a central abstract/paper database for research purposes at:

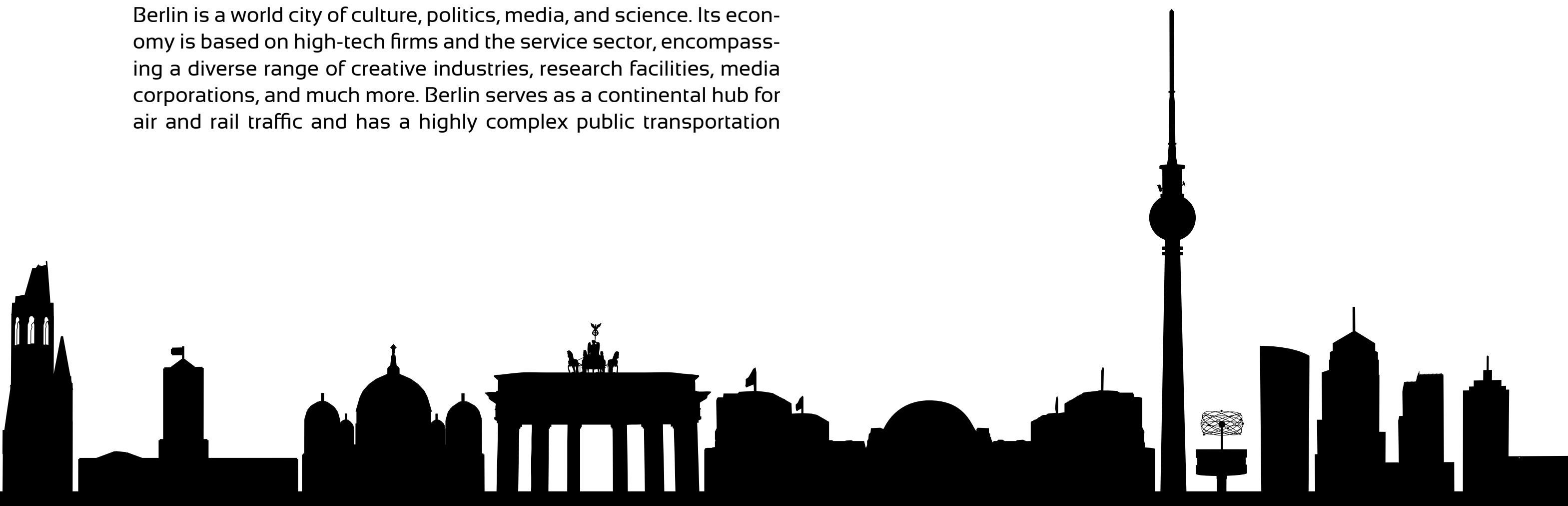
www.pipeline-conference.com.

Combine your **ptc** visit with **Berlin** sightseeing

THE INTERNATIONAL PTC COMMUNITY MEETS IN BERLIN

Berlin is more than 775 years old and over the decades, all generations have left their monuments and landmarks in town.The capital is a centre for international conventions and trade fairs and the number one among German cities for conventions. Berlin offers excellent infrastructure, the most up-to-date locations in Europe, a diverse range of services and a great shopping mile and night-life.

Berlin is a world city of culture, politics, media, and science. Its economy is based on high-tech firms and the service sector, encompassing a diverse range of creative industries, research facilities, media corporations, and much more. Berlin serves as a continental hub for air and rail traffic and has a highly complex public transportation network. The metropolis is a popular tourist destination. Significant industries also include IT, pharmaceuticals, biomedical engineering, clean tech, biotechnology, construction, and electronics. Berlin is one of the 16 states of Germany with a population of 3.5 million people. It is also the country's largest city.



PIPELINE TECHNOLOGY CONFERENCE

Impressions from

ptc 2014

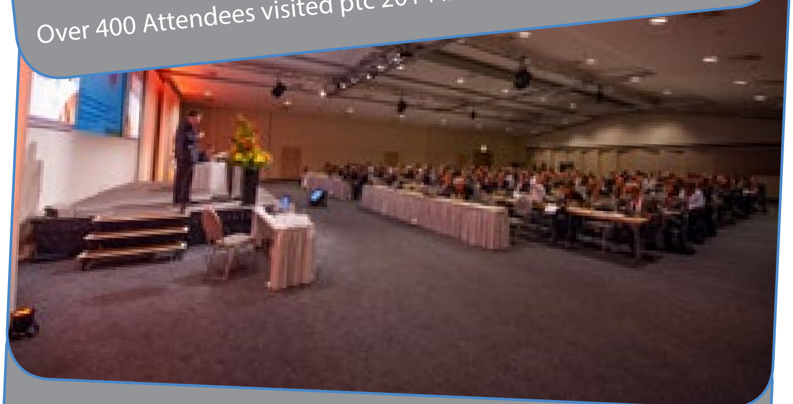
in Berlin

Attendees networking at the exhibition

Boat-Trip: "Dinner at Night"

Lively and interesting discussions

Over 400 Attendees visited ptc 2014 in Berlin

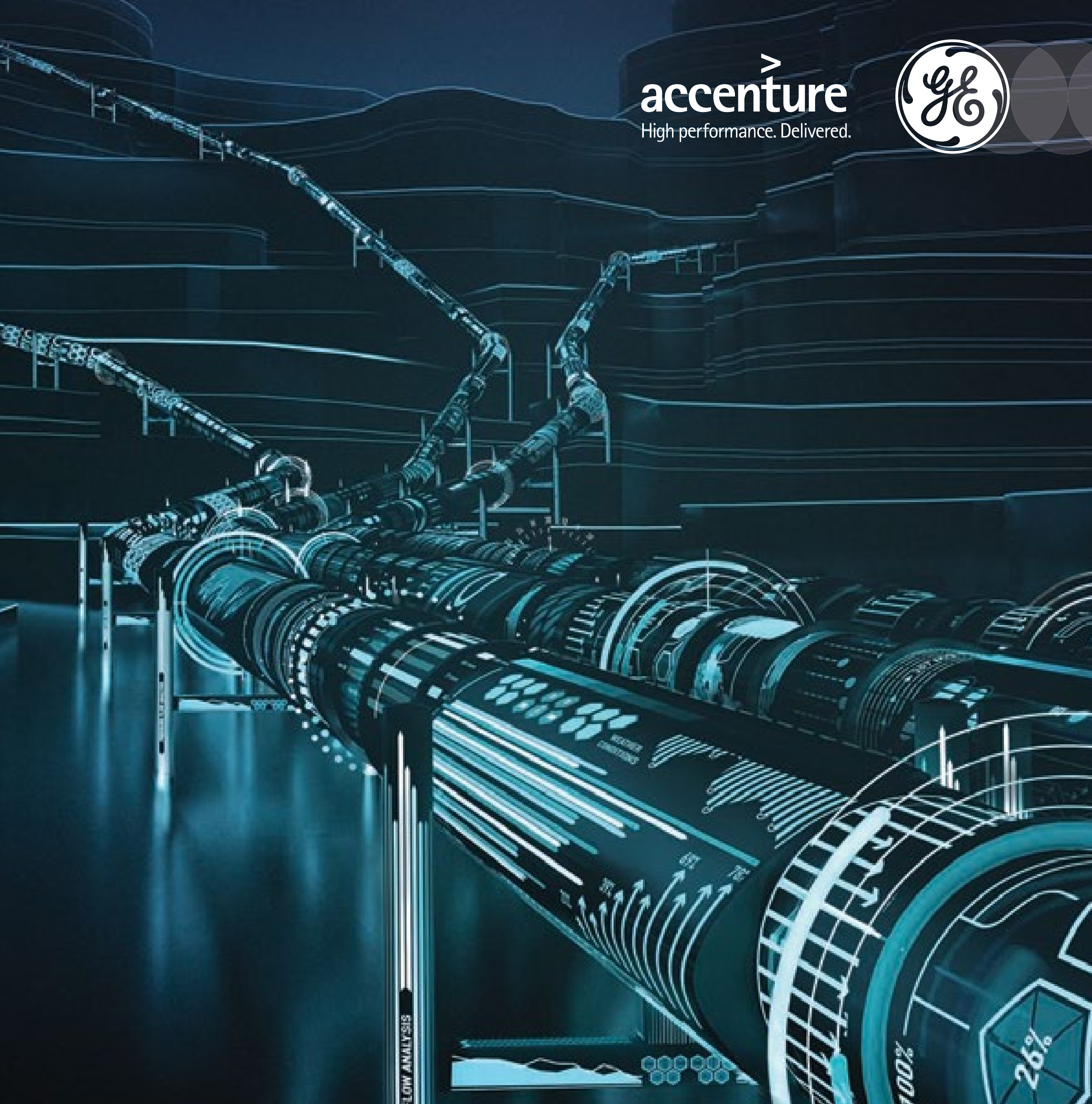


Plenary sessions during ptc

See you at

ptc 2015

www.pipeline-conference.com




HIGH
INDUCTIVE
interference on pipelines
due to nearby high voltage
overhead lines
PTC-POSTERSHOW
This paper will be presented during the
"Scientific Advances Poster Session" at
10th Pipeline Technology Conference

PIPELINE VOLTAGE

POSSIBLE REASONS WHY CALCULATIONS OF INDUCTIVE INTERFERENCE PIPELINE VOLTAGES ARE HIGHER THAN CONDUCTED MEASUREMENTS

> by: Christian Wahl
> and: Ernst Schmautzer
> Graz University of Technology
Institute of Electrical Power Systems

Abstract

Due to bundled energy routes, high voltage energy systems (HVESs), e.g. overhead lines or AC traction power supply systems, are often located near buried isolated metallic pipelines. Thus, a possible high inductive interference from energy systems may produce hazardous AC pipeline interference voltages (PIVs). High induced voltage levels can cause dangerous high touch voltages (personal injuries) and damages to pipeline system components (overvoltage, AC material corrosion). Therefore, for minimizing the risk of personal injuries and material corrosion, European standards and guidelines (EN 50443 [1], EN 15280 [2]) exist which limit the maximum voltage for long term and short term interference If the PIV is within given limits, the risk for personnel and material is acceptable and no further measures, e.g. AC earthing systems, special working methods or additional isolating joints along the pipeline are required and no further mitigation costs are generated.

For this reason it is necessary to calculate the induced PIVs already in the planning stage or in the case of significant changes in the pipeline or HVESs to specify necessary protection measures, particularly in areas where the PIV is already near the given limit.

Unfortunately, the results of these – standardized – calculations are often up to 7 times higher than conducted measurements on pipelines, despite using state of the art calculation parameters. Research on this discrepancy is needed to bring calculations and measurement data closer together to avoid excessive measures.

INDUCTIVE INTERFERENCE ON PIPELINES

Inductive coupling appears when a magnetic field between an interfered buried isolated metallic pipeline system and an interfering HVES exists. The inductive coupling impedances □z_gkL are affected by all of the below-described parameters and can be calculated with e.g. the formula of Dubanton [3].

These HVES parameters are load current or phase conductor arrangement as well as pipeline parameters such as the pipeline diameter, material or coating. Another parameter is the ambience soil resistivity which varies within a large spectrum. The final important parameter is the influence of several known and unknown grounded conductors, located near influenced or influencing systems. These conductors produce a voltage reduction on the induced pipeline and can be e.g. the PEN conductor of low voltage power lines, metal rails and compensation conductors of AC traction power supplies, conducting pipelines, foundation earth electrodes and global earthing systems.

The induced voltage $\underline{U}_i$ can be calculated by formula (1).

$$\underline{U}_i = \sum_{k=1}^{n} \underline{I}_k \cdot \underline{Z}_{gkL} \cdot \ell$$

If all currents and inductive coupling impedances z_{gkL} for one segment l are known, the induced voltage $\underline{U}_i$ can be calculated for a segment. Segmenting is needed because the geographical closeness and other parameters are not constant over the whole interfering distance and therefore the value of z_{gkL} is always changing see Figure 1. Also, other segments are not influenced as shown in Figure 1. When all induced voltages $\underline{U}_i$ have been determined, the induced PIV over the whole interfering distance is calculated with the lattice network model. As a requirement for using this model, all parameters must be (approximately) homogenous within one segment.

The parameters in this network model represent the longitudinal impedance (RL, LL), which stands for the pipeline material characteristics and the shunt admittance (CQ, RQ), which is a combination of the pipeline coating value, ambience soil resistivity, reduction conductors and reducing earthing systems. The PIV alongside the pipeline can be calculated with the node admittance matrix [4].

DIFFERENT POSSIBLE IMPACT FACTORS ON PIPELINE VOLTAGES

The following factors are suspected of having different degrees of impact on the induced voltages and the discrepancy between calculated and measured PIVs and has to be considered individually and in combination with each other:

- Load current instead of using the maximum operational currents
- Reduction effect of global earthing systems
- Reduction effect of practically achievable pipeline earthing systems
- Reduction effect of pipelines, running in parallel
- Reduction effect of parallel high voltage power systems with grounding conductors
- Reduction effect of local earthing systems
- Incorrect or inadequate pipeline coating parameter
- The influence of the model-conform specific soil resistivity

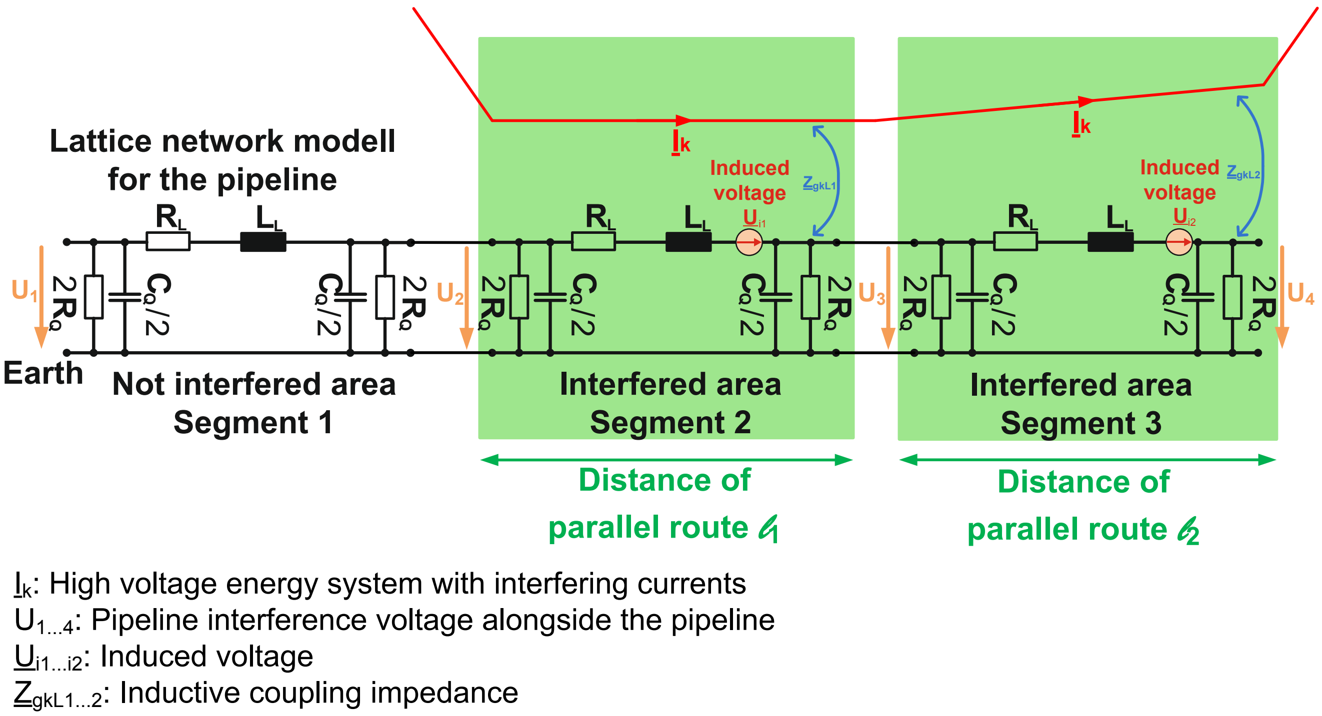


Figure 1: Pipeline subdivided into segments because of changing parameters

IMPACT OF THE LOAD CURRENT

As stated above, the value of the load current is a direct proportionality factor in the voltage calculation formula (1). Normally it is common practice to use the maximum operational currents in order to cover worst case scenarios for touch voltages or, depending on the type of the influencing system, 60 to 95 percent of this maximum load current for AC corrosion.

In reality, these operational currents rarely occur. For the comparison of a one week lasting measurement and its associated calculations on the same pipeline locations it is indispensable to use the correct actually used load currents to get comparable results. The difference between such currents and maximum operational currents is illustrated for an overhead line and a railroad system in Figure 2 [5].

POSSIBLE VOLTAGE REDUCTION EFFECT OF GESS, HVESS AND PIPELINES - GLOBAL EARTHING SYSTEMS (GESS)

In short, GESs consist of connected foundation electrodes and other conductive material buried in the soil within a (sub-) urban area. This connection can be realised intentionally or unintentionally either directly via conductive materials or in the common sense via the electric flow field. If an HVES is located near a pipeline and a GES, a configuration arises as depicted in Figure 3.

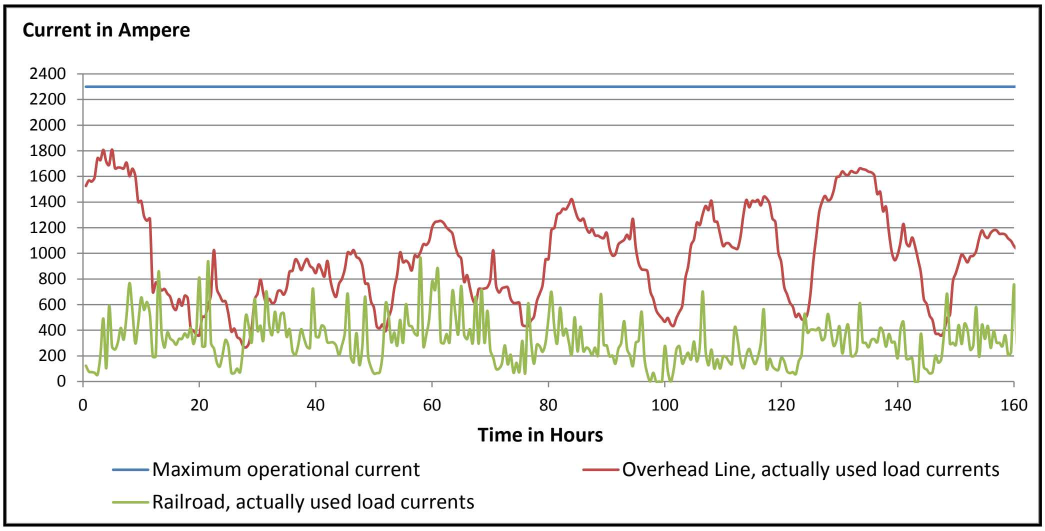


Figure 2: Difference between maximum operational currents and load currents for overhead lines

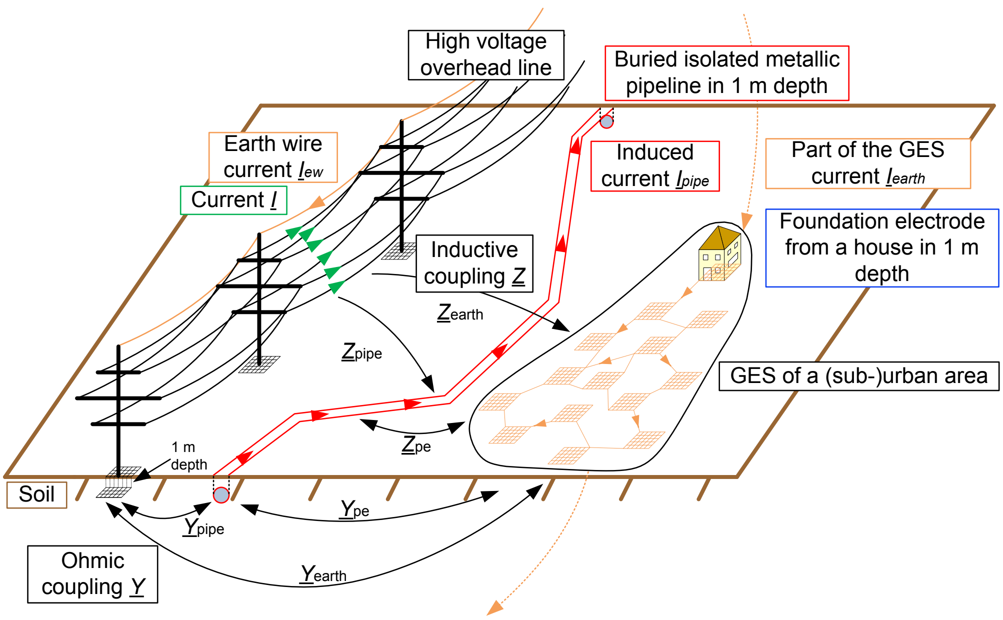


Figure 3: The complex interference and reduction situation between high voltage power line, GES and pipeline system

In these cases, pipeline and GES are more or less parallel metallic conductors due to their similar conductive material. The inductive coupling impedances $\underline{z}_{gkl.}$ from the energy system turn into a parallel connection of the pipeline coupling $\underline{z}_{pipe.}$ and the GES coupling $\underline{z}_{earth.}$ Consequently, the coupling impedance to the pipeline is reduced with the effect of a lower PIV. Thus, GESs have a reduction effect. How great it is depends on the expansion, grid structure as well as the material- and soil-conductivity. As a result of the inductive coupling, the pipeline voltage $\underline{U}_i$ is induced with consideration of this reduction effect. This leads to the currents $\underline{I}_{pipe}$ and $\underline{I}_{earth}$. These currents result in an additional inductive coupling $\underline{z}_{pe.}$, additionally increasing or reducing the current $\underline{I}_{pipe}$ and thus the PIV [5].

The following calculation example shows the impact of such interference between an HVES, a pipeline and three differently sized GESs. GES 1 and 2 represents a village with a low and GES 3 a small city with a medium density of conducting grounded material. The size and the amount of buried conducted metal leads to an accordingly high voltage reduction effect. Also, the general geographical alignment, e.g. distance between the systems or position along the pipeline, is important.

As depicted in Figure 4 the PIV calculation shows different reduction effects from the differently sized GESs. Since GES 1 (red line) and 3 (purple line) have a similar reduction effect, it can be seen that the geographical alignment is important. GES 1 is in the middle of the pipeline and the reduction effect evenly distributed over the entire PIV. Because GES 3 lies on the end of the pipeline, it has a notable PIV reduction effect especially in this area. Due to of the bigger size of the GES 2 (green line), a remarkable voltage reduction effect can be seen which shows that GESs has to be considered in calculations.

OTHER PIPELINES

Because of bundled energy routes, transport pipelines are built near other pipelines. Therefore two or more pipelines can run parallel over a long distance. If an HVES is located near a configuration with two pipelines, a setup appears as can be seen in Figure 5 and two interference effects have to be noted.

The first effect is due to the inductive coupling between the HV power line and the pipeline causing currents in both pipelines. Depending on the current flow direction, the current $\underline{I}_{pipe2}$ can increase or reduce the current $\underline{I}_{pipe1}$ and vice versa. Figure 5 shows an example, where both currents flow in the same direction.

The second effect is based on the fact that the second pipeline (blue) works as a reduction conductor (see Chapter 2.2.1) on the regarding pipeline (red). This means that both factors have to be considered to be able to state whether the pipeline current and interference voltage is increased or reduced.

Figure 6 illustrate how this reduction or increasing factor from a parallel pipeline works. It shows three different calculations which depict the influence of the current directions on the regarding PIV. The blue line shows the calculation of the PIV of the regarding pipeline without any other parallel pipeline; the other two lines already include the parallel pipeline reduction effect. This shows that when both pipeline currents flow in the same direction, the regarding pipeline current and therefore, the PIV, are increased (green line). Furthermore, it is clearly shown that a reduction effect is present when the currents flow in opposite directions (red line).

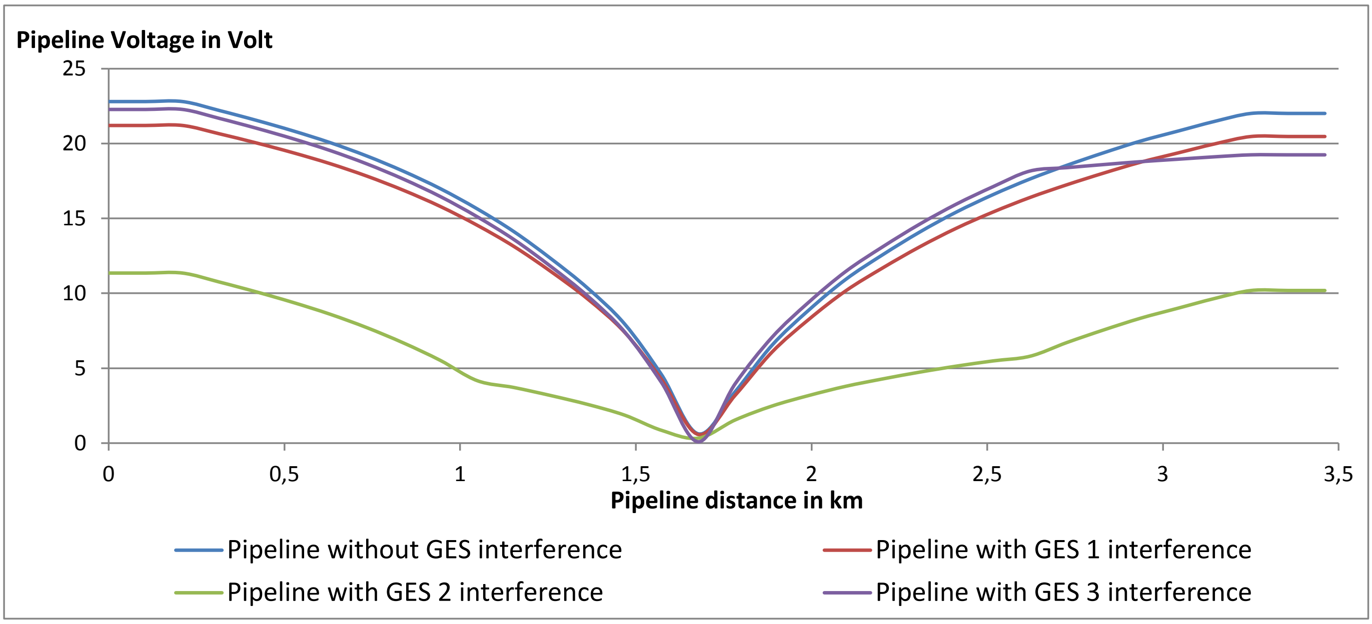


Figure 4: PIV reduction effect from differently sized GESs

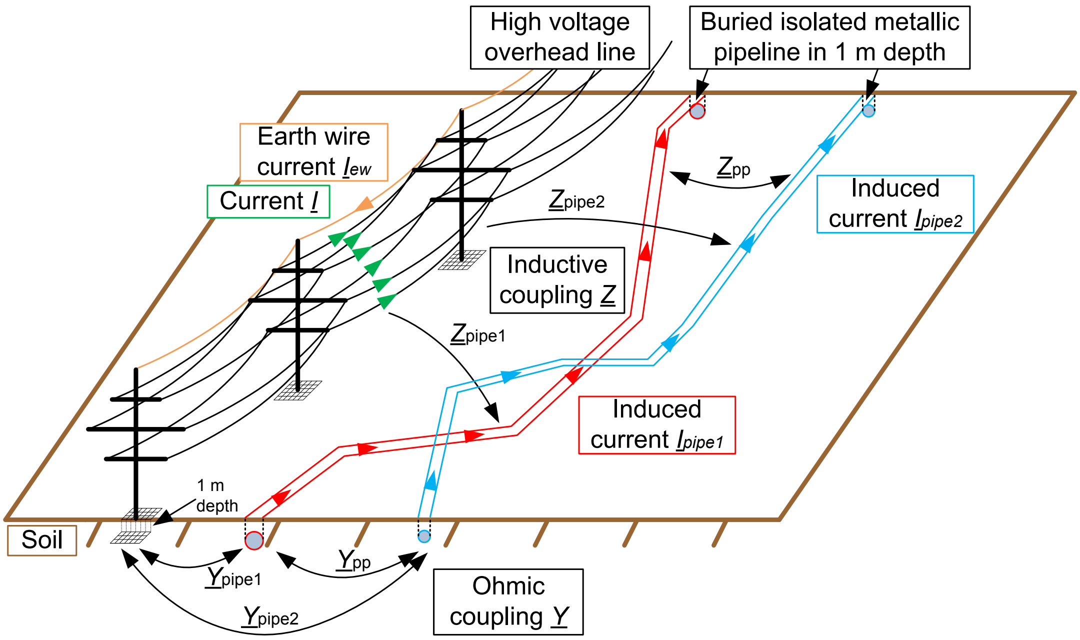


Figure 5: The complex interference and reduction situation between high voltage power line and two pipeline systems

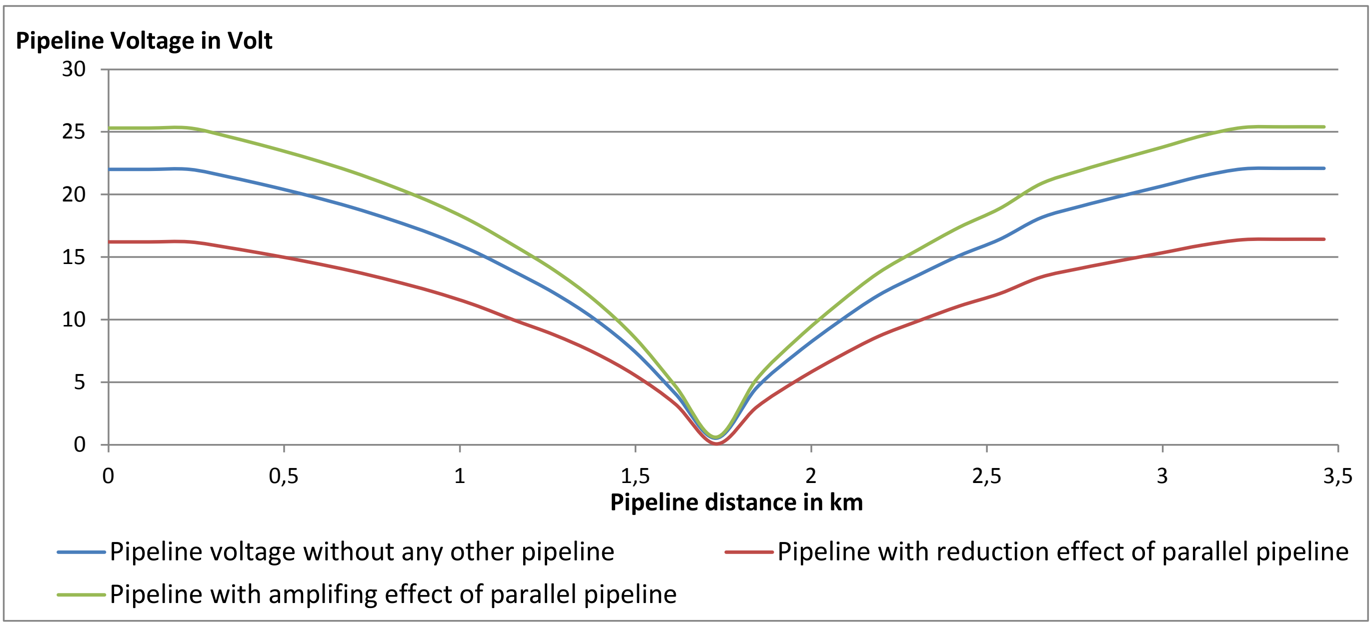


Figure 6: PIV with a second parallel pipeline

PARALLEL HIGH VOLTAGE ENERGY SYSTEMS

Especially, high voltage power lines but also railway systems are bundled on energy routes and therefore often have a long parallel routing. This leads to potentially high inductive interference. Besides the geographical alignment and HVES parameters, the load flow current situation is crucial. In case of the same load flow current in parallel HVESs, the pipeline inductive interference voltage rises dramatically. If the load currents flow in different directions, the PIV is massively lower. The overall load flow situation should always be reviewed when comparing measurement data with calculation results.

LOCAL EARTHING SYSTEMS

Local earthing systems are conducted materials, e.g. connecting water pipelines or earthed cable shields, buried in the soil. They are difficult to detect and usually not considered in calculations but can still act as reduction systems in the vicinity of HVESs and pipelines. This can lead to unexplainable reduced PIVs since the physical effects and the calculations are very similar to the above-mentioned cases.

OHMIC-INDUCTIVE COUPLING

An ohmic coupling $\underline{Y}$ exists between all interfered and interfering systems due to their earthing systems. In normal and fault operation conditions of HVESs, earth currents can flow through their earthing systems (e.g. pylons or transformer stations) into their ambience soil and, in the vicinity of a GES, pipeline or other conductive material, they can catch these currents and spread them to other regions. This results in a higher $\underline{I}_{earth}$ component with the effect of a higher influence on the current $\underline{I}_{pipe}$ and the resulting PIV.

INCORRECT OR INADEQUATE PIPELINE COATING PARAMETER

It is generally known that the pipeline coating is crucial to avoid material corrosion. It is problematic that the value of the coating resistance can vary within a wide range. On the one hand, the material has been changed from bitumen with a low value (1 MΩm) to polyethylene with a high value (100 MΩm). One the other hand, with time, the resistance value can fall to 10 kΩm (bitumen) or 50 kΩm (polyethylene) due to coating holidays. To summarise, with a lower coating resistance value, a lower PIV can be expected which one should bear in mind when comparing measurements and calculations [6].

VARYING THE SPECIFIC SOIL RESISTIVITY

The soil resistivity has a very strong influence on the PIV (as is shown in the paper of 2014 [6]). In areas with lower values, lower PIVs can be expected. However, weather and time of the year also influence the soil resistivity, changing the soil moisture and the soil temperature. The soil resistivity is lower when the soil moisture is high (e.g. due to high precipitation) and/or the soil temperature is high (e.g. during the summer). Therefore it is difficult to find the correct value of the soil resistivity along a pipeline.

Generally, the specific soil resistivity ranges between 25 Ωm and 10000 Ωm. Based on this wide range of values and the fragmenting of the different types of soil, the value for the representative respective ambient soil resistivity along the pipeline can be very diverse. Considering this variation is essential, both for calculations and measurements. Especially where measurements are conducted a detailed soil analysis is indispensable.

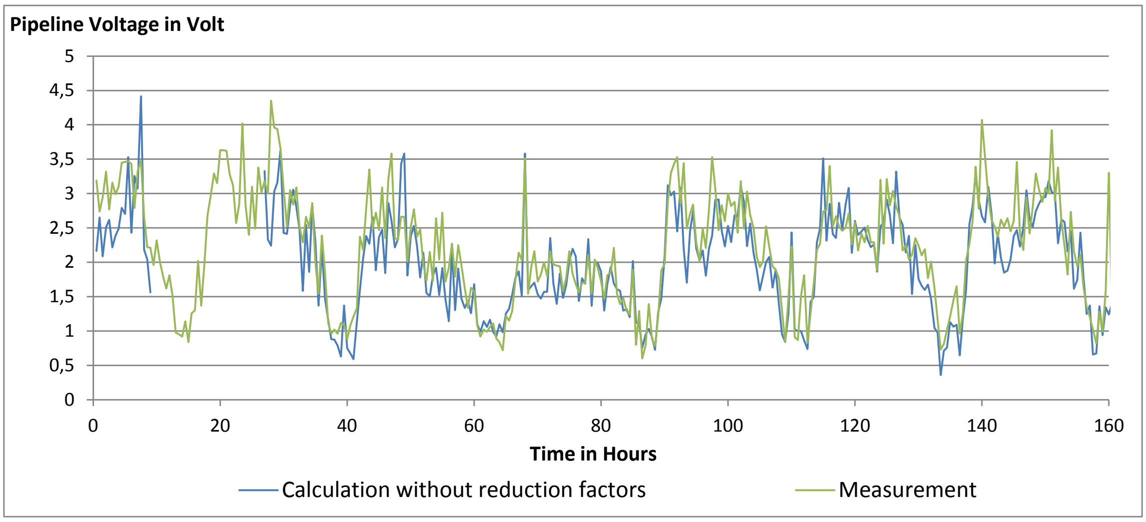


Figure 7: PIV calculation versus measurement, location 1, perfect example

PRACTICAL RESULTS

The following figures show different examples of calculations using the actually used load currents and comparing them to measurements during a measurement period of 140 to 160 hours at different pipeline locations. Figure 7 shows a nearly identical voltage characteristic between measurement and calculation since the model parameters reflect the real conditions very well.

The calculations in Figures 8 and 9 (which represent two different locations) without reduction effects show results higher by a factor of up to 7, compared to calculations considering conductive material nearby. These two figures show an intense voltage reduction, based on the geographical closeness of two different things: in location 2, another pipeline in combination with the reduction factor of two parallel high voltage overhead lines and in location 3, a rural area with a well-developed and extended GES.

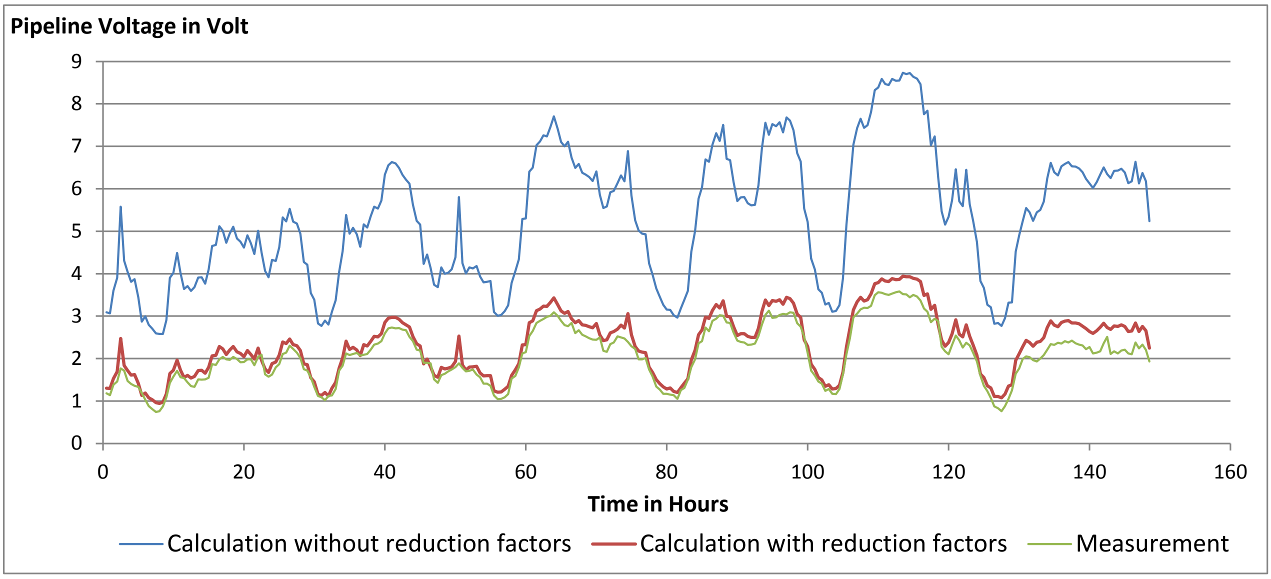


Figure 8: PIV calculation versus measurement, location 2, HVES

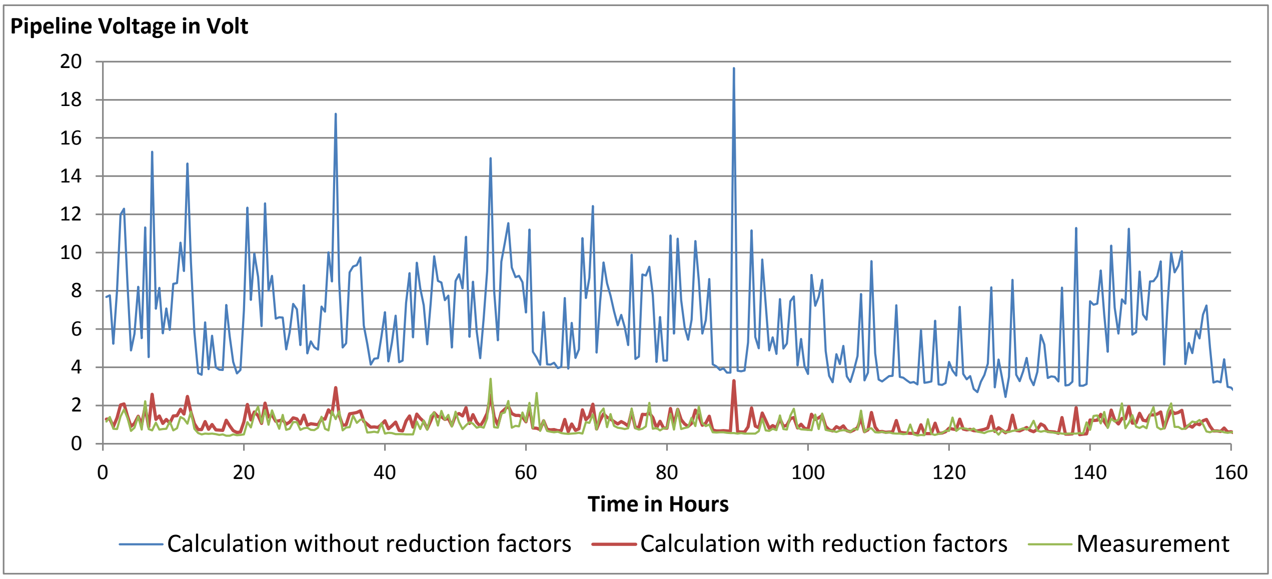


Figure 9: PIV calculation versus measurement, location 3, railway

Figures 10 and 11 show a combination of two reduction effects: the voltage reduction effect due to a parallel pipeline and also a voltage shift due to inadequate soil resistivity. Apart from the reduction effect, in location 4 the specific soil resistivity was essentially lower than expected while in location 5, the value was higher. Figure 10 because the calculation result is massively lower than before while in Figure 11, the average value is still remaining on the same level with consideration of the parallel pipeline reduction effect.

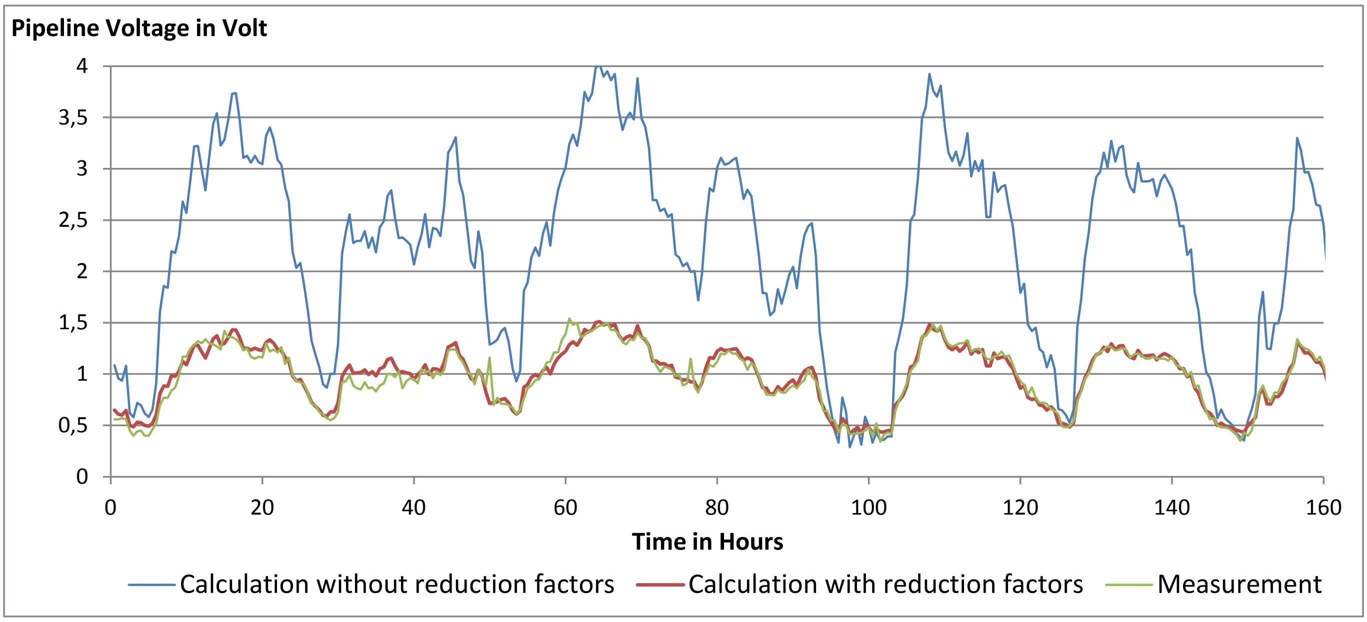


Figure 10: PIV calculation versus measurement, location 4, parallel pipeline with low soil resistivity

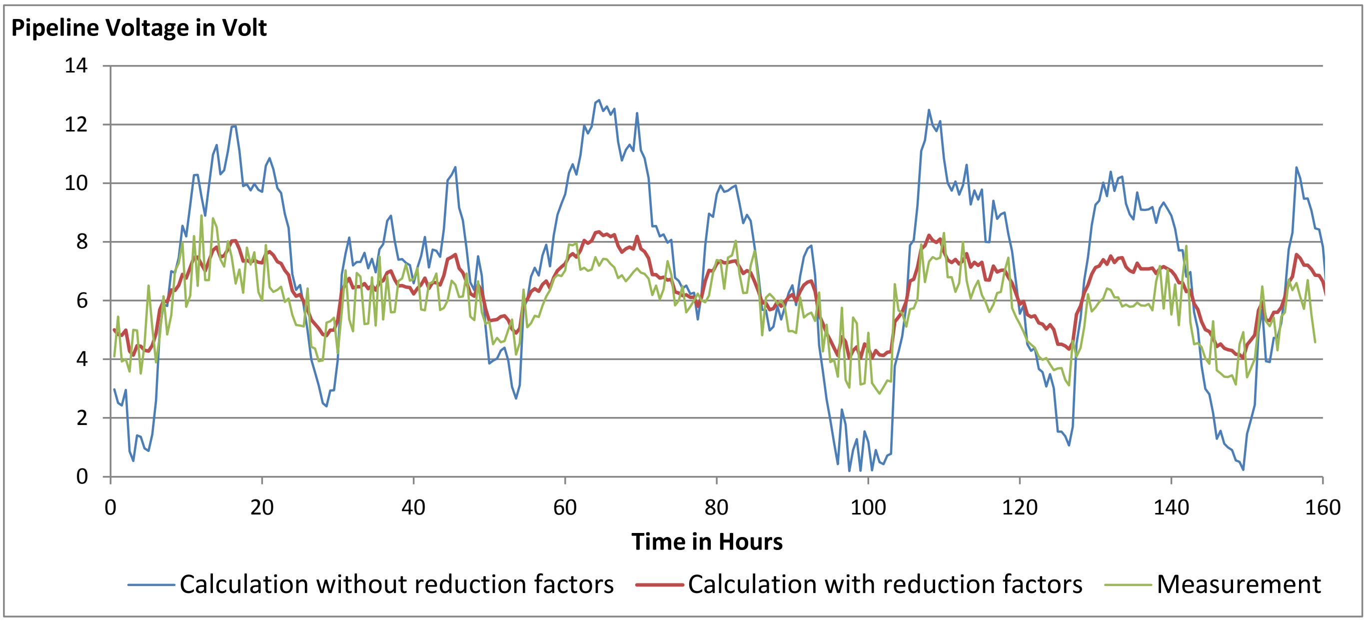


Figure 11: PIV calculation versus measurement, location 5, parallel pipeline with high soil resistivity

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SUMMARY

Even if calculations are done very carefully with established and generally agreed calculation methods, conducted measurements show mostly lower voltage levels than the calculated ones for the same pipelines and pipeline locations. With the consideration of the reduction – or even increasing – effects presented in this paper, most of the discrepancies between measurement and calculation can be explained when all important parameters are known.

Knowledge of the correct specific soil resistivity and pipeline coating resistance is a precondition since both parameters can influence the PIV in the measuring position. The value of the load currents during the measurement period must be known, as it is essential to correctly interpret the measurement data. Much more complicated are conducted materials within the interference area because they can act as a reduction factor, decreasing PIVs. They can also produce influencing voltages and in an unfavourable case, may even increase PIVs too.

The examples show that with consideration of all presented effects, most of the conducted measurements can be explained and even better, they can help to calibrate the calculation. With this research it is possible to reduce or avoid unnecessary measures while necessary actions, e.g. AC earthing systems or special safety working methods along the pipeline, can be used more effectively and efficiently.

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BURIED STEEL

SEISMIC ANALYSIS OF BURIED STEEL PIPELINE SUBJECTED TO GROUND DEFORMATION WITH EMPHASIS ON THE NUMERICAL MODELLING OPTIMIZATION

> by: Gersena Banushi, Technische Universität Braunschweig, Germany and Università di Firenze, Italy

Abstract

Steel pipeline systems traverse large geographical areas characterized by a wide variety of soil conditions and environmental hazards such as earthquakes which can threaten the pipeline integrity undergoing large deformations associated with widespread yielding, leading to fracture with consequent material leakage.

Buried pipelines installed in seismic regions are susceptible to the effects of transient ground deformation (TGD) due to seismic wave propagation and permanent ground deformation (PGD) resulting from earthquake induced soil liquefaction, surface faulting and landslides [1].

Post-earthquake investigations have shown that almost all seismic damages to buried pipelines were due to permanent ground deformation and there were very few reported cases of pipelines damaged only by wave propagation [2].

In fact, buried pipelines are primarily affected by large permanent ground deformations (PGD) which may produce pipe wall rupture due to excessive tension as well as buckling by either excessive imposed bending or uniaxial compression loading.

Therefore it is necessary to perform accurate finite element analysis taking into account the nonlinear soil and pipe interaction as well as the constitutive behavior of the pipe material subjected to extreme seismic loading.

At the state of art, detailed finite element analysis of the soil-pipeline system subjected to large ground deformations are computationally expensive resulting in extremely large numerical models that may require days to run using the normally available computational resources [3]. Within the present work, in order to reduce the needed memory and computation time of the calculator, the part of the soil-pipe system away from the fault is suitably modeled as a single equivalent axial spring, connected to the pipe shell elements through appropriate constraints. Furthermore, the seismic performance of the buried pipeline has been investigated through a series of parametric studies that permit to assess the structural response of the pipe components in function of various configurations of the soil-pipeline system. The obtained numerical analysis results allow to evaluate accurately the limit ground displacement inducing global failure on the pipeline components due to loss of strength capacity following large scale seismic loading, with the advantage of being computationally efficient.

"POST-EARTHQUAKE INVESTIGATIONS HAVE SHOWN THAT ALMOST ALL SEISMIC DAMAGES TO BURIED PIPELINES WERE DUE TO PERMANENT GROUND DEFORMATION"

> Gersena Banushi

PTC-POSTERSHOW

This paper will be presented during the "Scientific Advances Poster Session" at 10th Pipeline Technology Conference

NUMERICAL MODELING

Within the present study the seismic performance of a straight 36" x 9.53 mm X65 steel grade pipeline subjected to strike-slip faulting has been assessed through accurate finite element analysis taking into account the nonlinearities of the pipe-soil system, with emphasis on identifying the pipeline structural failure.

The buried steel pipeline is modeled a cylindrical shell using four-node reduced integration shell elements (S4R) available in ABAQUS (2014) [4] which account for finite membrane strains and arbitrarily large rotations, resulting suitable for large strain analysis. The soil surrounding the pipeline is discretized through eight-node linear brick continuum elements with reduced integration (C3D8R). The steel pipe material model is defined within the von Mises plasticity theory with nonlinear hardening. Instead, the soil material is described within the Mohr–Coulomb constitutive model, characterized by different parameters, like the cohesion, the friction and dilatation angle, the elastic modulus E, and Poisson's ratio v, as indicated in the table 1. The soil-pipeline interaction is assumed as frictional allowing for sliding and separation at the soil-pipe interface.

As schematically illustrated in the figure 1, the vertical plane containing the fault trace divides the soil in two equal antisymmetric parts. The fault movement is applied as a horizontal displacement of the lateral external faces of the moving soil part whereas the lateral external faces of the fixed part are restrained in the horizontal direction. Instead the faces of the bottom boundary of both soil parts are restrained to move in the vertical direction.

Moreover, it is noted that each of the ends of the shell pipeline is connected through appropriate constraints to an equivalent boundary spring, which represent the reaction of the part of the soil-pipeline system away from the fault to the pipeline displacement, as described in detail in the following paragraph.

The mesh of both the soil and pipeline components is refined in the central region, close to the fault trace, in order to better capture the large deformation behaviour of the system.

The numerical simulations for assessing the pipeline performance subjected to strike-slip fault movement are conducted in two steps. At first, a geostatic analysis is performed to establish the initial stress and strain state of the soil-pipeline system, which equilibrates the gravity loading and satisfies the boundary conditions. In the second step, a uniform horizontal displacement is applied at the lateral external faces of the moving soil part and the free end of the corresponding equivalent boundary spring, whereas the lateral external faces of the fixed soil part, as well as the free end of the corresponding equivalent boundary spring remain restrained in the horizontal direction.

	Clay Soil
Soil Cohesion	50 kPa
Friction angle ϕ	0
Young's Modulus E	25 mPa
Poissson's ratio *v*	0.48
Soil density *y*	20 kN/m^3

Table 1. Mechanical characteristics of the soil analysed.

CALIBRATION OF THE EQUIVALENT BOUNDARY SPRING.

Observing that the relative transverse displacement between the soil and the pipe segment away from the fault trace is negligible, this part is suitably modelled as a single equivalent axial spring connected to the pipe shell elements through appropriate constraints, assuring the deformation continuity of the system, as schematically illustrated in the figure 2. The force displacement relationship of the equivalent axial spring is obtained analytically taking into account the axial constitutive behaviour of the pipeline as well as of the axial soil-pipeline interaction. The latter is obtained by subjecting the pipeline statically to a uniform axial displacement, after establishing the initial geostatic stress-strain state in the system, as schematically illustrated in the figure 3.

The obtained axial spring constitutive behavior is subsequently implemented in ABAQUS [4] finite element software for the numerical analysis purposes. This modeling procedure permits to largely reduce the memory and computation time of the calculator, compared to the one where the entire length of the pipeline is modelled with nonlinear shell elements and the surrounding soil with solid elements.

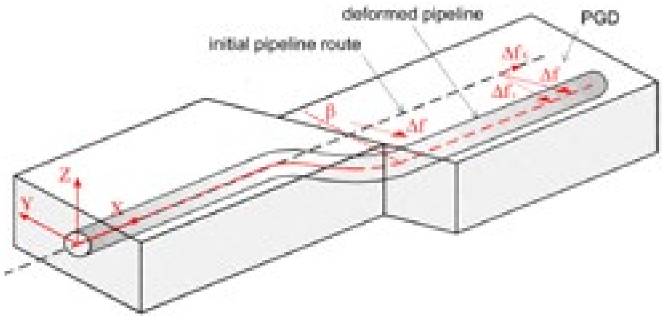

Figure 1. Schematic representation of the soil pipeline system subjected to strike-slip faulting.

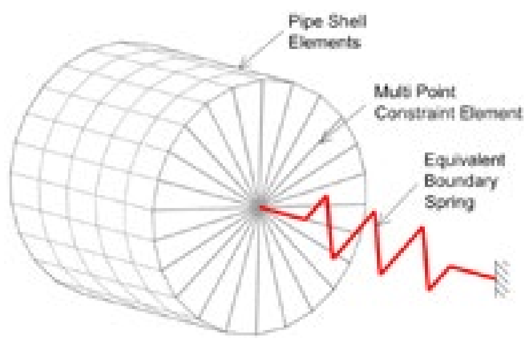

Figure 2. Schematic representation of the equivalent-boundary spring model

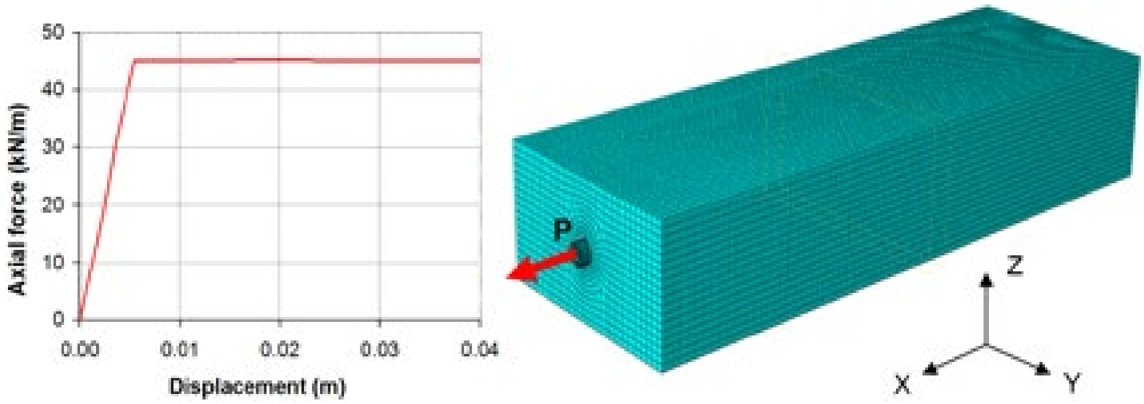

Figure 3. Schematic representation of the procedure for determining the soil reaction to the pipeline movement in the axial direction.

Considering the axial constitutive behaviour of the pipeline, as well as the axial soil-pipeline interaction, as schematically illustrated in the figure 4, the relationship between the equivalent spring axial force F and its elongation ΔL is expressed by the following formula:

$$\Delta L=\begin{cases}\dfrac{F}{\sqrt{kAE_1}} & , F\le F_o=\sqrt{AE_1 f_s u_0}\\[2ex] \dfrac{u_0}{2}+\dfrac{F^2}{2AE_1 f_s} & , F_o\le F\le F_1\\[2ex] \Delta L_{i-1}+\dfrac{1}{2AE_i f_s}\left[F^2+2(AE_i\varepsilon_{i-1}-F_{i-1})F+F_{i-1}^2-2AE_i\varepsilon_{i-1}F_{i-1}\right] & , F_1<F_{i-1}\le F\le F_i\end{cases}\qquad(1)$$

where ε_i, σ_i are the *i*-th strain and stress value respectively defining the steel pipeline material constitutive relationship, *A* is the cross section area of the pipe, $F_i=A\cdot\sigma_i$ is axial force in the pipe corresponding to an axial stress equal to σ_i, $E_i=(\sigma_i-\sigma_{i-1})/(\varepsilon_i-\varepsilon_{i-1})$ is the slope of the i-th segment defining the pipe multi-linear stress-strain relationship and ΔL_i is the pipeline elongation corresponding to the axial force F_i. In particular, E_1 and σ_1 are respectively the elastic stiffness of the steel pipeline and its yield stress.

Instead, f_s is the maximum soil friction force per unit length of the pipeline, u_0 the relative displacement between the soil and the pipeline when sliding occurs, $k=f_s/u_0$ is the rigidity of friction interaction at the soil pipeline interface and F_0 is the force in the buried pipeline when sliding occurs at the soil-pipe interface, as schematically illustrated in the figure 5.

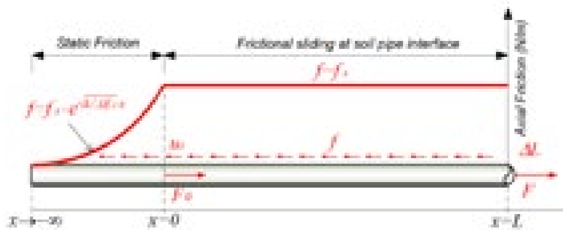

Figure 5. Schematic representation of the axial forces and elongations acting in the pipeline segment away from the fault.

Moreover, it is observed that in the case where the pipeline ends connected to the equivalent-boundary spring remain in the elastic range ($i=1$, $F<F_1$), the expression (1) is similar to the approximated formula proposed by Liu et al. [5].

In the figure 6 is illustrated the relationship between the elongation ΔL and the axial force F for the equivalent-axial spring corresponding to the clay soil conditions and pipeline characteristics considered in the present study, calculated using the expression (1).

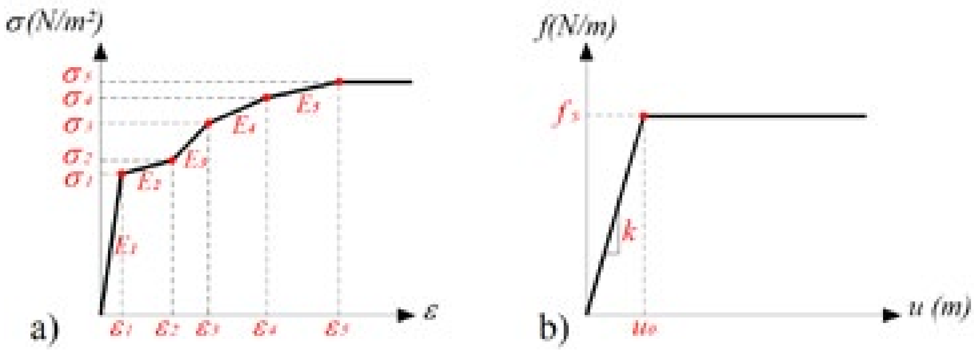

Figure 4. Schematic representation of the axial constitutive behaviour of the: a) Steel Pipeline; b) Pipe-Soil Interaction

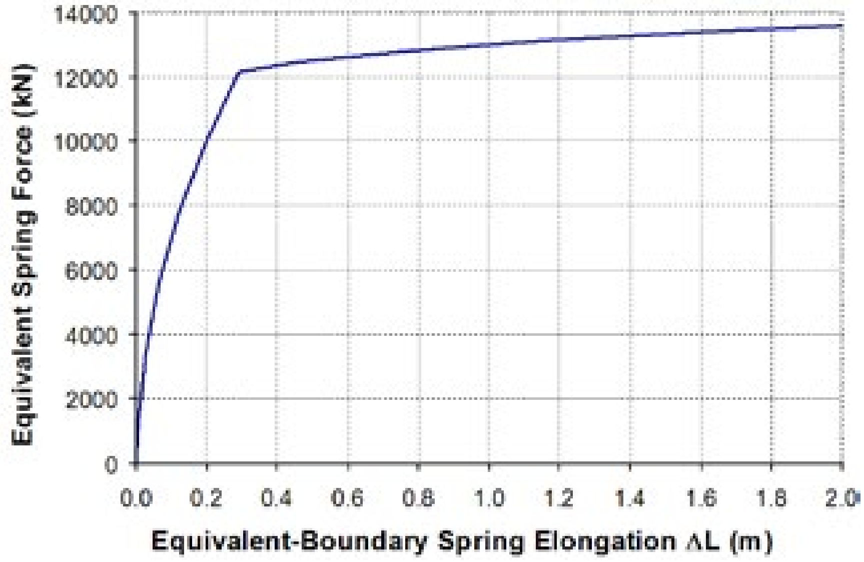

Figure 6. Relationship between F and ΔL for the equivalent-boundary springs corresponding to the soil condition considered, calculated using the formula (1).

ANALYSIS RESULTS

Similarly to the procedure followed within recent European Research Projects [6, 7] three principal modes of structural failure are considered for evaluating the pipeline seismic performance:

1. Tensile strain limit of 3%, as indicated in the Eurocode 8 - Part 4 [8] which can lead to consequent rupture of the pipe wall due to loss of strength capacity in the pipe material.

2. Local buckling of the pipeline caused by an abrupt increase of compressive strains at the compressive side of the pipe cross section.

3. Excessive ovalization of the pipeline cross section. Following the indications contained in Gresnigt, 1986 [9], the critical ovalization parameter, intended as the ratio of the minimum pipe diameter to its initial diameter, is assumed equal to 15%.

The variation of the plastic axial strain at the most stressed generator of the pipe wall, in the case of pipeline oriented perpendicularly to the fault trace (ß=0°), for different values of fault displacement Δf is indicated in the figure 7. It can be observed that the onset of local buckling occurs for a fault displacement equal to 41 cm, at a distance of about 4.3 m away from the fault trace, where the maximum compressive plastic strain in the pipeline reaches 0.45%. Beyond this plastic deformation region, the pipeline remains essentially elastic. In the figure 8 are illustrated the displacement contours for the pipeline and the fixed part of the soil close to the fault trace where the onset of local buckling occurs, whereas in the figure 9 is illustrated the evolution of the deformed shape of the pipeline and axial strain contour at the region of local buckling for different values of the fault displacement Δf.

In the case of the fault trace forming a negative angle ß=-10° with the normal to the pipeline axis, the onset of local buckling is observed earlier, for a fault displacement value equal to 23 cm, at a distance of about 3.75 m away from the fault, as illustrated in the figure 10.

Instead for positive values of the angle ß formed by the fault trace with the normal to the pipeline axis, the predominant limit state is the elevated section deformation. It is observed that the 15% performance limit of section ovalization is reached in the pipeline for values of the fault displacement varying from 85 cm to 1.09 cm, in function of the inclination angle ß. As schematically illustrated in the figure 11, the excessive section ovalization region in the pipeline is localized close to the fault trace which is also the area where maximum pipe axial forces occur.

CONCLUSIONS.

In order to evaluate the seismic performance of a buried pipeline subjected to strike-slip faulting, a detailed numerical procedure has been adopted that considers the pipe-soil system as a three dimensional continuum model, accounting for contact and friction interaction at the soil-pipe interface.

Being the continuum modelling computationally expensive, the region of the pipe soil system away from the fault is modelled as a single equivalent axial spring connected to the pipe shell elements through appropriate constraints. The force displacement relationship of the equivalent axial spring is obtained analytically taking into account the axial constitutive behaviour of the pipeline as well as the axial soil-pipeline interaction. The obtained axial spring constitutive behavior is subsequently implemented in ABAQUS finite element software [4] for the numerical analysis purposes. This modeling procedure permits to largely reduce the needed memory and computation time of the calculator, compared to the one where the entire length of the pipeline is modelled with nonlinear shell elements, and the surrounding soil with solid elements.

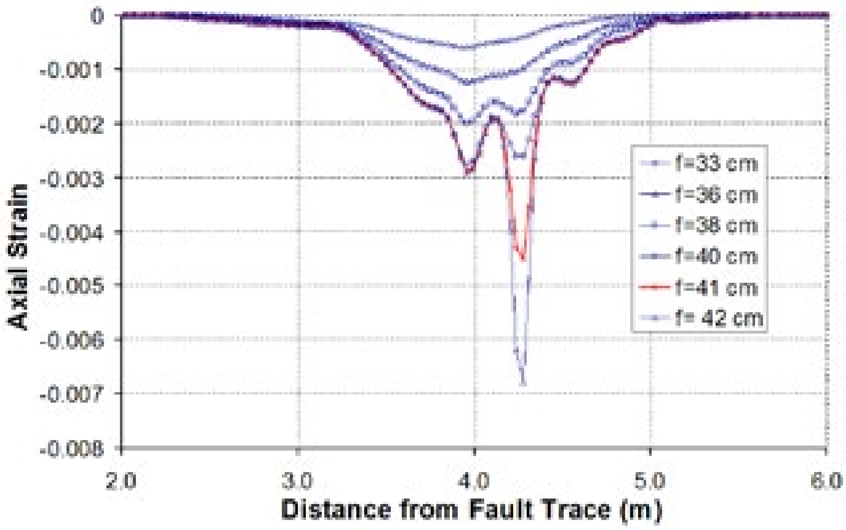

Figure 7. Variation of the plastic axial strain at the most stressed generator of the pipeline wall for different values of fault displacement, in case of ß=0°

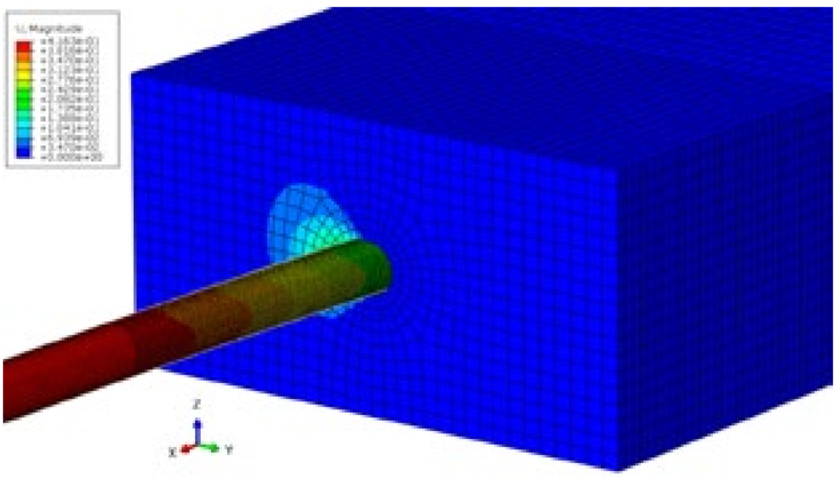

Figure 8. Displacement contours for the fixed soil part (ß=0°) close to the fault trace where the onset of local buckling occurs.

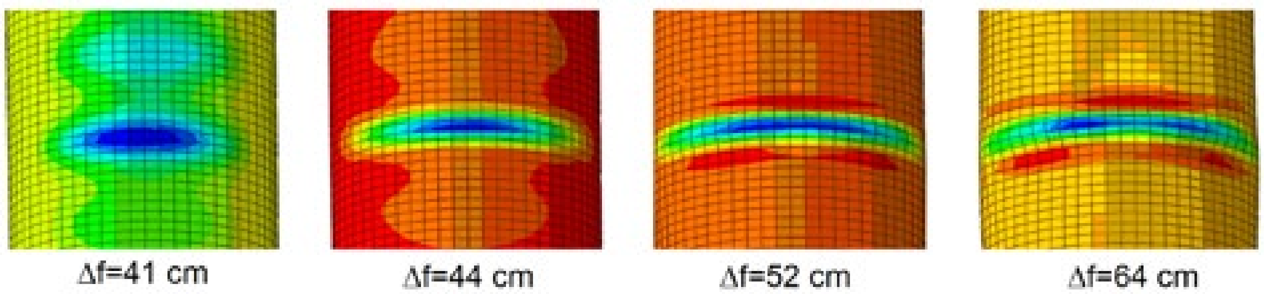

Figure 9. Evolution of the plastic axial strain contour and deformed shape of pipeline at the region of local buckling for different values of the fault displacement Δf, in the case of ß=0°.

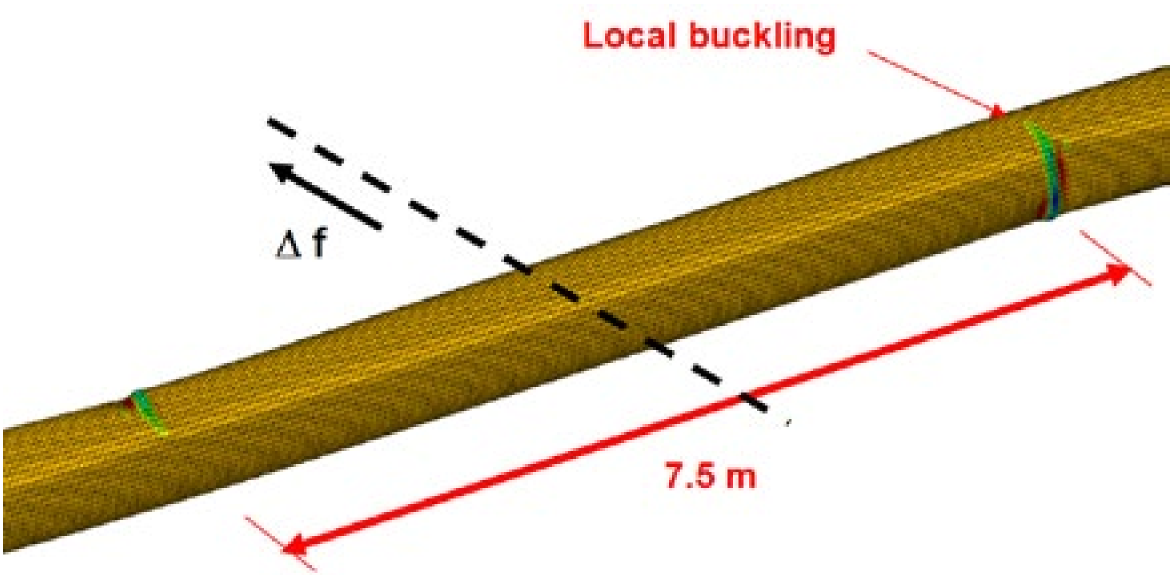

Figure 10.
Deformed shaped and localization of local buckling for the case of fault trace inclined at an angle ß= -10° with respect to the pipeline normal, and a fault displacement value Δf=23cm.

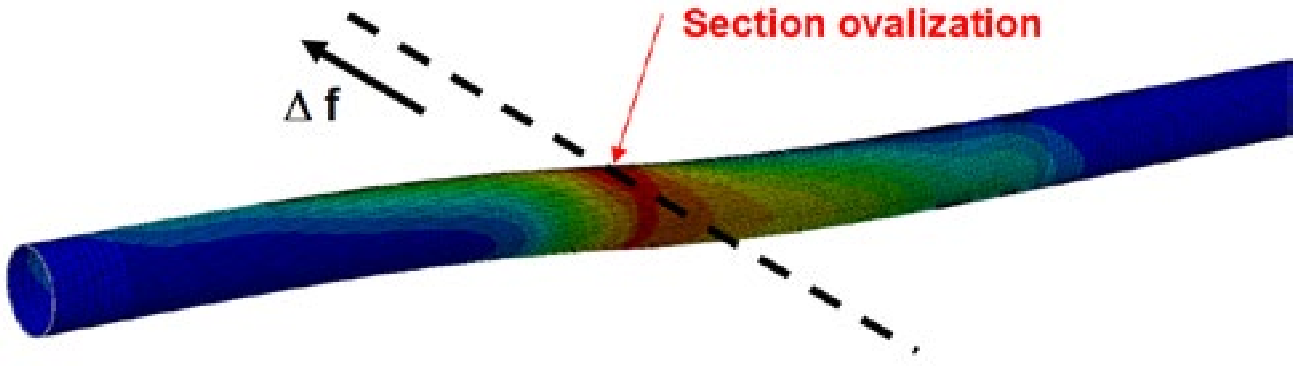

Figure 11. Deformed shape with indicated the localization of excessive section localisation close to the fault trace, in the case of ß = 40°

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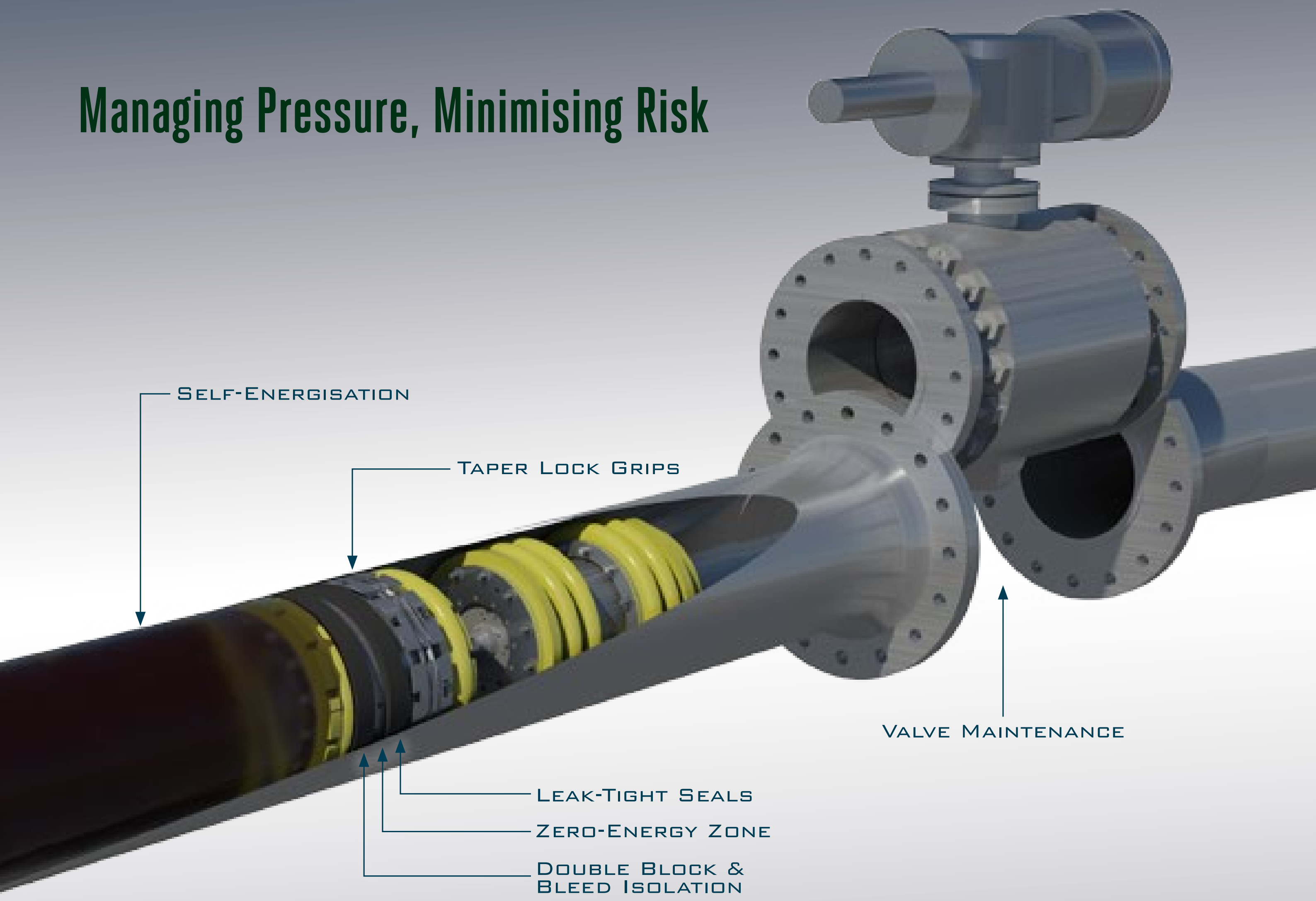

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GRAND THEFT PIPELINE

Finite element simulation of guided waves to detect product theft from pipelines

> by: Salisu El-Hussein, University of Aberdeen, UK / Dr. John Harrigan, Amec Foster Wheeler, UK / Dr. Andrew Starkey, University of Aberdeen, UK

PTC-POSTERSHOW

This paper will be presented during the "Scientific Advances Poster Session" at 10th Pipeline Technology Conference

Abstract

Product theft (hot tap) and intentional attack (vandalism) are among the major causes of reported pipeline failures. The existing pipeline inspection techniques are mainly reactive measures to detect damage/defect. Guided waves (GWs) have potential for the real time structural health monitoring (SHM) of pipelines and other structures. GW offers the advantages of long range examination of a structure and rapid detection of damage. As an example stress waves generated through physical attack on a pipeline propagate in the form of GWs. These signals can be detected to provide information about the source and location of the interference. Deliberately excited GWs can be used to detect the presence of additional features such as small branch introduced to initiate a product theft. Finite element (FE) analysis is conducted on a 12 in (305 mm) diameter steel pipe with 12 mm wall thickness to investigate the potential of longitudinal L(0,1) and torsional T(0,1) GW modes for long distance propagation. The results show that a low frequency tone burst excitation modified by a Hanning window produces a GW with low attenuation and dispersion. For example, at 2.5 kHz centre frequency, the attenuation coefficient is 0.00034 m-1. At this attenuation, the signal would theoretically retain more than 10 % of its original energy after a propagation distance of 8 km. The sensitivity of GW at this frequency was tested with detection of 2 in (50 mm) branch pipe attached along the 12 in pipeline.

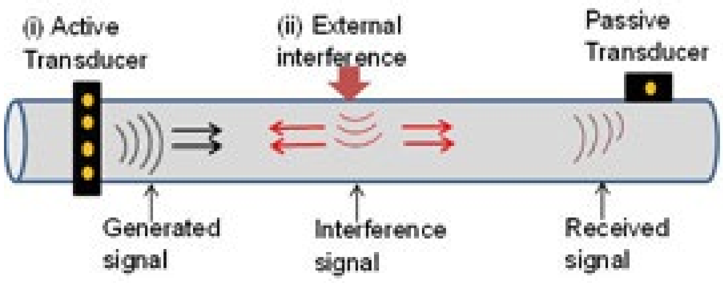

Figure 1 Illustration of guided waves generated by (i) an active transducer; (ii) external interference

"IN THE AREA OF THIRD PARTY RELATED DAMAGES, COST-EFFECTIVE PIPELINE MONITORING IS STILL REQUIRED"

> Salisu El-Hussein, Dr. John Harrigan; Dr. Andrew Starkey

INTRODUCTION AND BACKGROUND

Third party activities constitute about 60 per cent of the reported pipeline failures [1]. Intentional pipeline damage and oil theft are also sources of concern even in developed countries like United States [2], United Kingdom [3] and more especially developing countries like Nigeria [4]. In Nigeria for example, a total of 15,796 cases of pipeline vandalism was recorded between 2000 and 2010. These resulted in estimated 2,800 fatalities, $1.2bn cost of repairs and daily revenue loss to the government of $10.4 million [5]. The damages to the environment and ecosystem are unquantifiable in monetary value. There are many pipeline inspection and monitoring techniques in the literature. However, in the area of third party related damages, cost-effective pipeline monitoring is still required. At selected frequencies, GWs have the potential to meet this requirement. The stress waves generated during physical attack on a pipeline can provide a signal that is transmitted along the pipeline. Fig. 1 illustrates the stress waves generated either deliberately by a transducer or accidentally as a result of an attack on a pipeline. For an attack on the line, the signal generated can be detected to serve as an early warning for the occurrence of vandalism/theft. Alternatively, a GW can be generated deliberately for inspection of the line. The difficulties associated with interpreting signals recorded at a remote location are associated with: energy dissipation; dispersion; and formation of multiple GW modes.

EXISTING PIPELINE INSPECTION AND MONITORING TECHNIQUES

There are many pipeline inspection and monitoring techniques in the literature. They range from visual inspection, wireless sensor networks (WSN) to fibre optic, acoustic, electromagnetic, ultrasonic methods and magnetic flux leakage (MFL). The last two are the most common pipeline inspection and monitoring techniques [6]. Most of these techniques are reactive in nature or require point-to-point transducer movement. In addition, WSN and fibre optic methods are difficult to retrofit. Table 1 summarises the advantages and disadvantages of common pipeline monitoring techniques.

Methods	Advantages	Disadvantages
Visual Inspection	- Effective in a relativley small area	- Labour intensive - Accessability limitation
Electromagnetic method	- Cost-effective in surface and near surface defects	- Requires probe movement
Acoustic emission method	- can operate in passive and active modes	- High cost of sensors - Requires densely spaced sensors
Fibre optic method	- Sensitivity along the entire length - Dual function of communication and monitoring	- Susceptible to damage during installation - High installation cost
Wireless sensor network	- Little inteference with structure operation	- Large multi-hop network required
Ultrasonic methods	- Good sensitivity to the presence of defects	- Requires probe movement
Guides waves	- In-Service Monitoring - Long distance coverage - Cost effectiveness	- Multiple modes formation - Complicated signal processing

Table 1 Comparison of common pipeline inspection and monitoring techniques

BASIC GUIDED WAVE THEORY

GW forms as a result of superposition of longitudinal and shear waves reflecting between structural boundaries. The possible constructive interferences which result from these reflections represent the number of GW modes which will propagate along the length of the waveguide. Unlike longitudinal and shear bulk waves, their velocity is not only dependent on the material properties but also on the thickness of the material and the wave frequency. GWs experience energy leakage when in contact with a surrounding medium (e.g. soil) or internal fluid. Cylindrical waveguides (e.g. pipes) support 3 modes of GW vibrations: longitudinal, torsional and flexural. According to the convention by Silk and Bainton [7] they are labelled as L(0,m), T(0,m) and F(n,m) for longitudinal, torsional and flexural modes respectively. The letter 'n' represents the harmonic order of the circumferential variation within the wall thickness while 'm' describes the sequential number of modes of the same family. For example, L(0,1) is the first longitudinal wave mode to exist with zero cycles of particles' displacement variation around the circumference. GWs in cylindrical structures are governed by Navier's equation, which in vector form can be seen below [8]:

$$\rho\frac{\delta^2 u}{\delta .t^2}=(\lambda+2\mu)\nabla(\nabla .u)+\mu\nabla\times(\nabla\times u)$$

where *u* represents displacement, λ and μ are Lamés constants, ∇ is the 3-dimensional differential operator $\delta/\delta x+\delta/\delta y+\delta/\delta z$ and *p* is the material density. For detailed derivation of GW equations, the reader is referred to reference [8].

GUIDED WAVE STRUCTURAL HEALTH MONITORING

SHM is a technique employed for the maintenance of large structures such as rail-track and pipeline networks. SHM seeks to replace scheduled maintenance with condition based maintenance. In passive mode, SHM consists of measuring the operational parameters of a structure and indirectly assessing its state. Acoustic emission and thermal sensors are commonly used in passive SHM. Active SHM assessed the structure directly in order to detect the presence of defects. Permanent sensors and relevant monitoring techniques are used to provide information on the state of the structure. Resonant frequency measurements, WSN and GW sensors are commonly used for active SHM. T(0,1) and L(0,1) are the common GW modes used in NDT for defect detection. The T(0,1) mode has the advantage of being more sensitive to longitudinal defects while L(0,1) has more potential for long distance propagation. In most SHM techniques, there is a trade-off between resolution and spatial coverage. GWs combine long distance propagation with a good resolution for defect location and identification [9]. Due to these advantages, many studies have been carried out on the inspection of pipes and other structures using GWs.

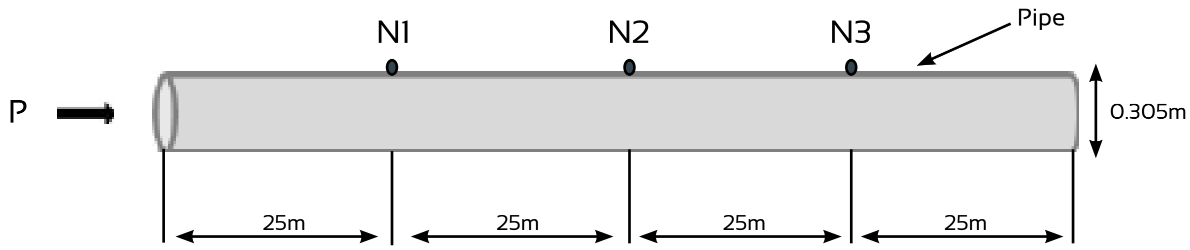

Figure 2: Configuration of model pipe showing nodal locations

FINITE ELEMENT SIMULATION OF GUIDED WAVES

The mathematical solution of GW has been obtained for simple geometries such as a circular cylinder [9]. For complicated geometries no mathematical solution is available. Numerical modelling such as boundary element and FE are used for the analysis of complicated geometries. FE analysis has been successfully employed as a tool for GW propagation analysis in plates and pipes [10]. The use of FE modelling can provide the required understanding of stress waves propagating along a pipeline for application against product theft and vandalism.

FE MODEL

The model was generated with ABAQUS/explicit version 6.12. The simulation was conducted on a 12 in (305 mm) outer diameter, 12 mm wall thickness and 100 m long pipe. Fig. 2 shows the configuration of the model pipe and three nodal locations (N1, N2 and N3) defined along the pipe. The pipe material was made from mild steel with a Young modulus $E = 209\ GPa$, Poisson's ratio $v = 0.3$ and density $p = 7850\ kgm^{-3}$. A 3-dimensional linear brick, 8 node solid elements with reduced integration (C3D8R) was chosen for this analysis. A sweep meshing technique was adopted with a 24 mm mesh size in the longitudinal direction. ABAQUS automatic time step (Δt) which stabilised at 0.676 μs was adopted and was sufficient to avoid numerical instability. The element length chosen met the requirement of 20 nodes per smallest wavelength in the model. The excitation signal was a 5-cycle tone burst modified by a Hanning window with a centre frequency of 2.5 kHz.

LONGITUDINAL EXCITATION

L(0,1) mode was excited by applying a uniform pressure pulse load at one end of the pipe as shown in Fig. 3. Stresses and displacements were monitored at the three nodal locations shown in Fig. 2. Time domain displacement signals recorded at these locations and their corresponding frequency spectra are shown in Fig. 4. From Fig. 4 (a) there is no appreciable change in signal shape as the wave propagates from N1 to N3 (low dispersion). Fig. 4 (b) also shows little decrease in magnitude of the frequency content (low attenuation). Using the signals at N1 and N2, the attenuation coefficient of the L(0,1) mode at this centre frequency was calculated as 0.00034 m-1. From this attenuation, the signal can theoretically propagate 8 km and retain more than 10 per cent of its original energy.

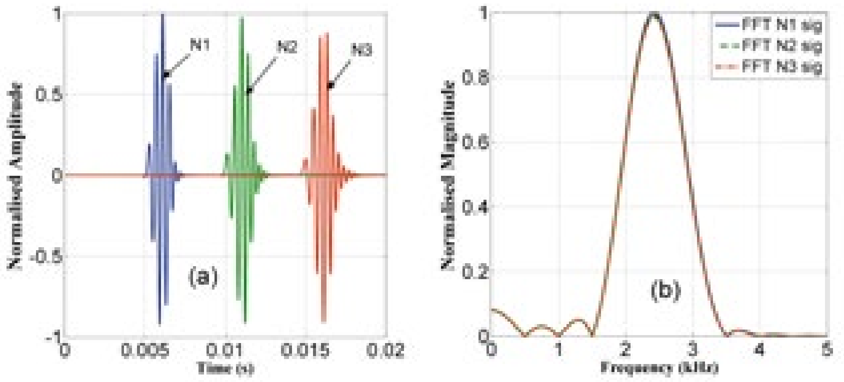

Figure 4 Longitudinal displacement signals recorded at 3 nodal positions: (a) Time domain and (b) frequency spectrum

TORSIONAL EXCITATION

T(0,1) modes were generated by assigning a displacement rotation to the edge nodes. The edge nodes were coupled to a master node as shown in Fig. 5. All other parameters remain the same as for the longitudinal wave simulations. Fig. 6 shows the rotational displacements at the three nodal locations and their corresponding frequency spectra. Compared to the L(0,1) modes, the change in shape as the signal propagates from N1 to N3 is more noticeable (higher dispersion) and the decrease in magnitude of the frequency spectrum is higher (higher attenuation) as shown in Fig. 6 (a, b). At a centre frequency of 2.5 kHz, the attenuation coefficient of the T(0,1) mode was calculated as 0.0083 m-1. From this attenuation, the potential propagation distance at this frequency is less than 1.5 km. This shows that the L(0,1) mode has more potential for long distance propagation than T(0,1) mode.

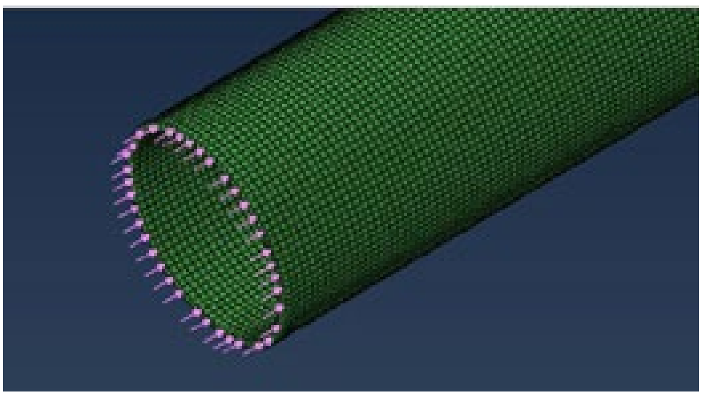

Figure 3 Longitudinal guided wave excitation

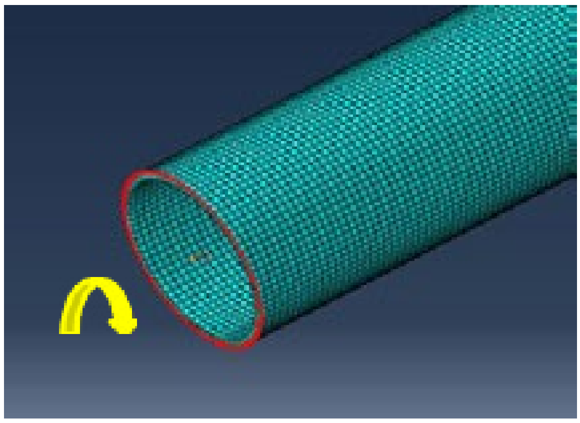

Figure 5 Torsional guided wave excitation

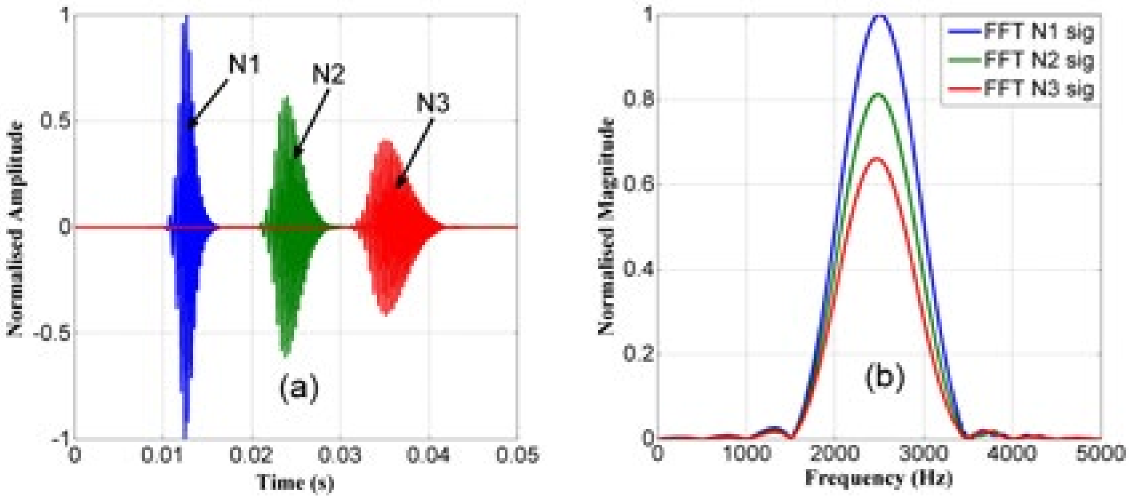

Figure 6 Torsional displacement signals recorded at 3 nodal positions: (a) Time domain and (b) frequency spectrum

INTERACTION OF LOW FREQUENCY GUIDED WAVE WITH A BRANCH PIPE

Oil theft is often carried out by attaching a branch pipe to siphon petroleum products. The model pipe was simulated with a 2 in. branch pipe attached at the N2 location and the stresses and displacements were recorded at N1 and N3. Fig. 7 shows a snapshot of the stresses as the wave propagates along the pipe and up the branch. Fig. 8 (a) shows the displacement history at node N1. The first pulse recorded is the incident signal, I, that travels from left to right in Fig. 2. Sometime later there is a similar pulse but of much lower amplitude. This is the reflection from the branch, termed RB in Fig. 8. The last pulse, termed RE, is similar in magnitude to the incident wave. This is the part of the wave that was transmitted across the branch and reached the far end of the pipeline before being reflected back towards node N1. Fig. 8 (b-d) shows the frequency spectra for the pulses termed I, RB and RE. The reflection from the branch was quantified in terms of reflection coefficient (RB/I) in the frequency domain. Comparing Figs. 8 (b) and (c), there is similarity between the frequency spectra of the incident and branch reflected pulses. This allows the reflected signal to be detected by cross-correlation with the incident signal. A time-shift of approximately 5 ms was observed from the cross-correlated signal. From this time-shift and phase velocity of the wave at 2.5 kHz the distance of the branch from the sensor location (N1) was calculated as 25.5 m. This shows the potential of GW at this frequency to detect and locate a small branch attachment to a pipeline.

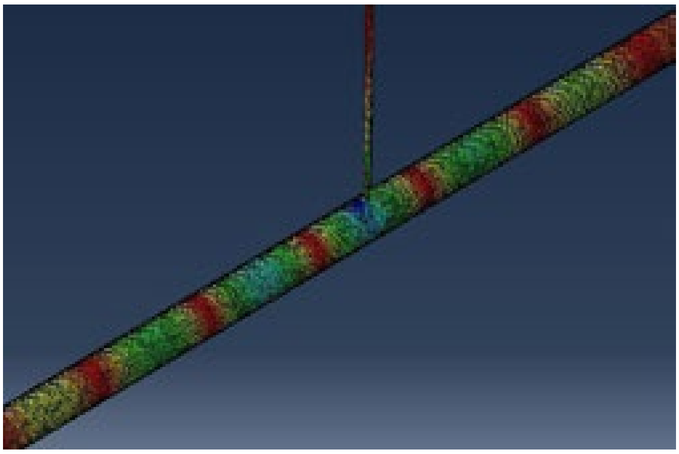

Figure 7 Snapshot of the stress contours along the model with a branch attachment

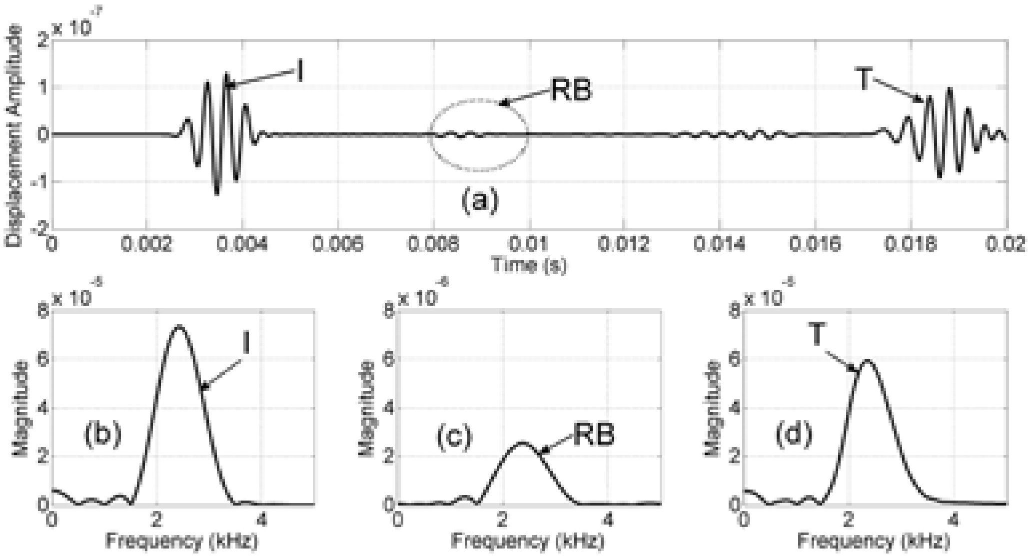

Figure 8 (a) Strain history at N1 showing Incident, branch reflection and end reflection pulses and (b-d) their corresponding frequency spectra

CONCLUSIONS

The results show that the longitudinal GW mode can propagate long distances without appreciable change in shape. In contrast, the torsional mode shows higher dispersion within the same propagation distance. It is shown that at low frequency (2.5 kHz) the L(0,1) mode can be used to detect a 2 inch branch in a 12 inch pipeline. The reflection coefficient for the case considered is approximately 4 % of the incident signal and the reflection will decay with distance. However, the reflected signal from the branch was observed to have the same frequency content as the incident signal. As the reflected signal therefore has a known frequency, it is more easily detected by e.g. cross-correlation. The reflected signal can be used to detect the presence and the location of a small branch on a pipeline.

ACKNOWLEDGEMENT

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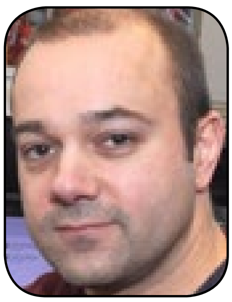

> Representative ILF Design, Major Water Pipeline, Middle East

> by: Tobias Walk , ILF Consulting Engineers

CSSP

COMMON SEAWATER SUPPLY PROJECT

Enabling one of the world's top oil producing regions

As the second largest oil producer of OPEC nations, Iraq's economy fully depends on the stability and growth of the national oil industry. It is therefore of paramount importance to keep the oil production at target level. To achieve this goal it is necessary to apply secondary oil recovery methods.

The method selected for the oil fields in Southern Iraq is to inject water into the reservoir in order to maintain the reservoir pressure and to increase the percentage of oil extraction

Water Source for Oil Field Pressure Maintenance

The amount of water required in Southern Iraqi oil fields for this purpose is in the range of 12.5 million barrels of water per day, which is equal to 24 m3/second.

Such quantities of water are not available in the project provinces of Al-Basrah and Missan, where temperatures regularly exceed 40 degrees Celsius and where the annual precipitation rate is less than 155 mm. Sourcing water from the famous Euphrates and Tigris rivers would only amount to 10% of the quantities required in the oil fields. Furthermore, use of these local water sources would significantly detract from the life sustaining water for the local population and community needs.

The only source available in sufficient quantity for the needs of the Project is seawater. In consequence it is logical to take this seawater from a single point, treat it and supply it via a common system to the various oil fields. The evolving Project is called the Common Seawater Supply Project CSSP.

ORGANISATIONAL SET UP OF THE OWNER

The South Oil Company (SOC) received a mandate from the Iraq Ministry of Oil and International Oil Companies (IOCs) to develop and operate the CSSP.

SOC's key stakeholders in development of the project include major global operators in the oil and gas industry such as BP, CNOOC, ENI, ExxonMobil, Lukoil, PetroChina, Petronas, and Shell.

In order to support SOC, the consultant CH2M Hill has been contracted as PMC (Project Management Consultant) to manage and coordinate the execution of this project.

ILF's CHALLENGING TASK

ILF identified this project as early as 2010 and presented preliminary technical concepts to ExxonMobil, who developed this project in the initial phase. Subsequently, as SOC took over the mandate for implementation of the project from ExxonMobil, ILF kept a strong focus on the developments. In 2013, ILF was pre-qualified as the only engineering company for both FEED packages (Front End Engineering Design) - i.e. for the STF (Seawater Treating Facilities) and the pipelines. Both proposals were submitted in January 2014. During the following five months, technical and commercial details were negotiated and at the end of June 2014, ILF received a Letter of Award to perform the FEED package for the CSSP pipelines. The contract between SOC and ILF was signed in Abu Dhabi on 20 August 2014.

ILF has since developed an execution plan to deliver the Tender Documents within one year, which is extremely challenging. It will require taking full advantage of ILF's broad know-how and experience in designing and managing the construction of large water transmission pipelines in the Middle East.

To provide the best value for SOC, ILF is leveraging the expertise of multiple offices. The project management team resides in Abu Dhabi, engineering is executed from the ILF Center of Excellence in Munich and the Basrah office handles all local project requirements.

FEED execution is split into two distinct phases: Optimization and Design Development, each within a 6 month schedule.

The project is currently in the optimization phase, which is a specialty of ILF. As a result of these studies a diameter of 56" has been selected for the multiple pipelines running from the Seawater Treatment Facility to the various delivery stations in the oilfields.

The route verification is nearly complete and has identified six major water course crossings including the Euphrates, the Tigris and the Shatt Al-Arab.

System design is well on its way including the simulation of transient flow conditions (another specialty of ILF) and the design of the pressure control and surge protection facilities at the delivery stations.

> Iraq Area Map showing CSSP location within Basrah province

> CSSP Pipeline Routing Overlay onto the Iraq Satellite Image

PROJECT SUMMARY

The Common Seawater Supply Project (CSSP) will supply seawater to the oil fields Zubair, Tuba, Rumaila, West Qurna, Majnoon, Gharraf, Halfaya and Missan in the south of Iraq.

The intake and the Seawater Treatment Facility (STF) will be approximately 40 km south of Basrah at the west bank of the Khor Al Zubair river.

Phase one of the project shall have a capacity of 7.5 million barrels of water per day allocated to the various oil fields in South Iraq. After completion, the full built out design capacity of the CSSP amounts to 12.5 million barrels of water per day which is equal to 24 m3/sec.

From the Shipping Pump Station (SPS), the water will be pumped via two pipeline corridors through multiple 56" steel pipelines to the oil fields over distances of up to 270 km.

The discharge pressure of the shipping pump station will be in the range of 45 bar.

At the delivery stations the water will flow into the tanks of the oilfield facilities, thereby providing hydraulic separation between these facilities and the CSSP.

The estimated cost of the project is in the order of magnitude of 12 billion U$ and it is envisioned that this megaproject will require 3 years for completion.

With an ultimate capacity of 12.5 million barrels of water per day, the CSSP will be one of the biggest plants of its kind in the world.

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DENT HUNTING

using high resolution in-line inspection technologies and finite element analysis

> by: Thomas Walther, ROSEN Group

Abstract

For pipeline integrity management detailed feature assessments based on finite element analysis (FEA) are getting more and more important. Considering dents as one of the major integrity threads of pipelines, the finite element analysis helps to differentiate between severe and benign dents.

Usually, the severity of dents is assessed by using standards and methods, which refer to depth, length and width as main criteria. In many cases, these methods turn out to be over-conservative and lead unnecessary pipe repairs or replacements, resulting in unnecessary costs for pipeline operators.

A more accurate differentiation between severe and un-severe dents can be provided on basis of strain and stress values. This type of information can be derived from high resolution geometry data, which captures a high accurate contour of the pipeline. This type of assessment is not only limited to plain dent conditions any longer. While high resolution geometry tools reliably identify dents associated with girth weld or long seams, dents associated with metal loss corrosion, mechanical damage or crack can be identified by additional ILI technologies, namely MFL, Dual Field MFL, UT and EMAT. An adequate categorization of dent conditions is key for the selection of the right measure.

For plain dent conditions the ROSEN Group developed an automated streamlined process, which allows to rapidly generate and provide stress concentration factors, using the established ABAQUS code. Based on this information, the remaining life can be concluded by taking additional information, coming from the SCADA System into account.

For dents, associated with metal loss or welds, an extended engineering assessment based on FEA allows an adequate assessment of these types of dents.

The article introduces ILI technologies and methods. It presents the results from large scale testing and case studies to underline the usage of finite element analysis as instrument to assess the pipeline integrity. The accuracy of the stress concentration factor, derived from high resolution geometry data, is validated in multiple test comparing the measurements with laser scans, taken with established optical devices.

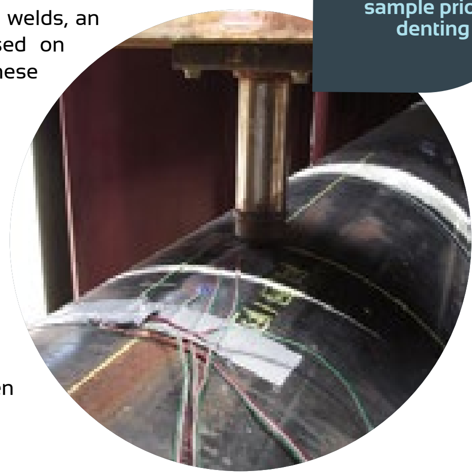
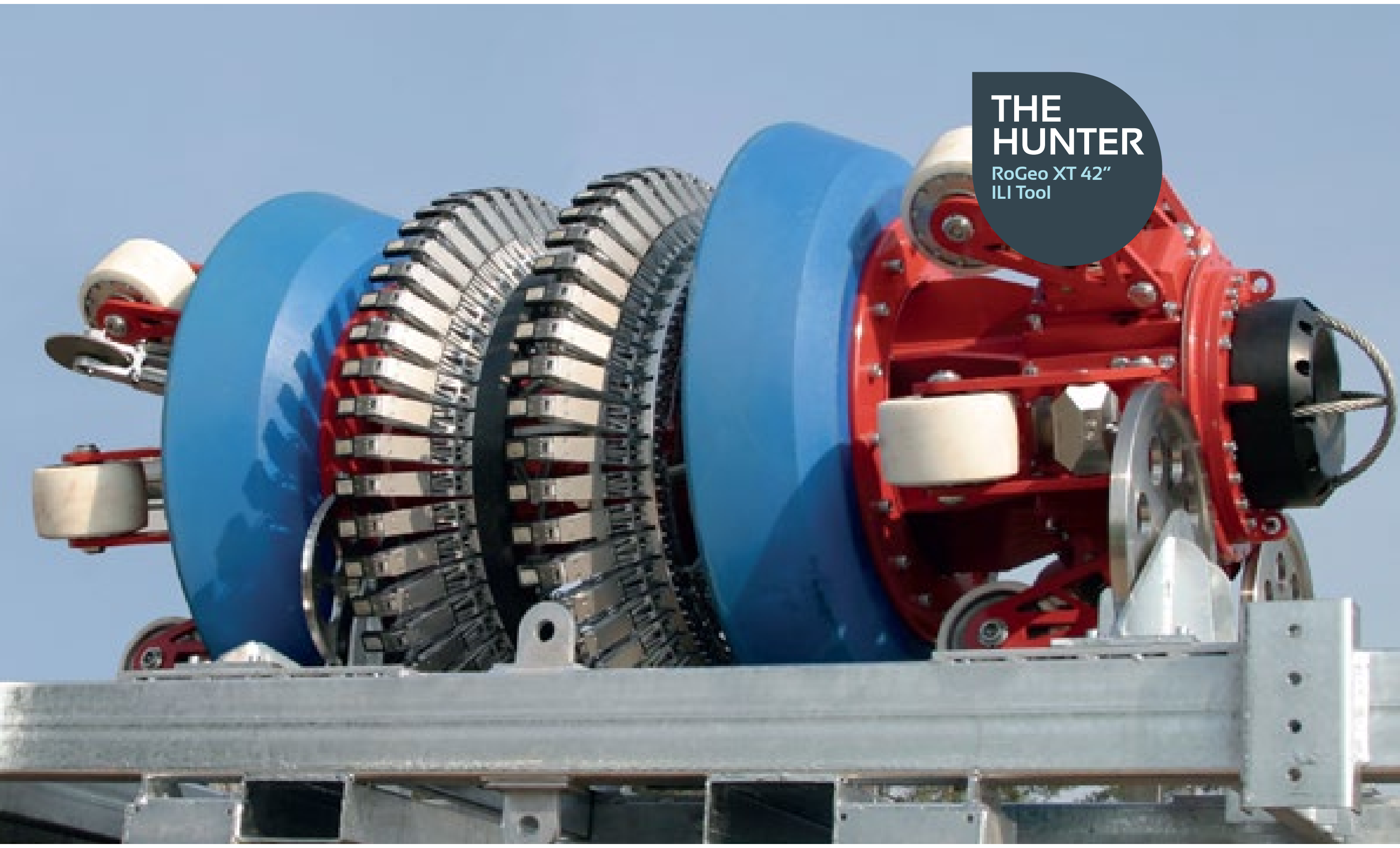


figure 1: 24-Inch test sample prior to denting

> "A SET OF DENT ANALYSES THAT MAY HAVE PREVIOUSLY TAKEN WEEKS CAN NOW BE REDUCED TO A FEW HOURS"
>
> > Thomas Walther, Rosen Group



INTRODUCTION

ID anomalies, especially dents, are a significant threat for pipeline integrity. They often fail due to fatigue, caused by varying pressure cycles within a pipeline over lifetime. But commonly dent severity is not assessed considering dynamic loads. Historically, regulations regarding the severity of dents have been governed by one of two metrics: dent depth or strain.

However, the technology and the inspection devices improved over the years, but still dents are assessed using the depth or the strain criteria. The dent depth criteria permits dents with a depth up to 6% of the nominal diameter in both, gas and liquid pipelines, although many operators already use stricter limits and targeting those above a depth of 2% for evaluation.

Using the strain-approach plain dents of any depth are considered acceptable, if the strain does not exceed 6%. The method becomes more common, as strain calculations have become readily available. Therefore, the strain in the hoop and axial planes of the dent is calculated based on the radii of curvature in each plane and the extensional strain based on the length of the dent. An approach is outlined in Appendix R of ASME B31.8. Both, the strain-based and dent depth approaches have similar shortcomings. First, neither approach is adequate for complex dents or in cases, where interacting dents may be present. In the case of depth, the shape of a dent is completely neglected. A long, deep dent is not distinguished from a shorter, steeper dent. While strain-based approaches improve on this shortcoming and can be useful for well-behaved dents, applying the methodology where varying curvatures may exist in a complex dent becomes significantly more difficult. To overcome these shortcomings Finite Element Analysis (FEA) can be used to analyze dents in a more adequate way. Complex dents and well-behaved dents are both suitable for FEA, and the results are not sensitive to small undulations in data. The severity is calculated directly based on the response of the dent to the applied loading, regardless of shape or size. In order to use FEA for detailed assessment of dents, a highly accurate recorded counter of those is required.

Confirmed effectiveness

The case study and additional investigations on more than 113 dents demonstrated that FE-DAT in combination with the RoGeo XT data provides reliable and repeatable stress concentration factors to assess the severity of dents.

Unique sensor array

The RoGeo XT has an unique combination of caliper and eddy current sensors, called the mechatronic measurement system, which can precisely measure the profile and contour of geometric features.

HIGH RESOLUTION GEOMETRY INSPECTION DEVICE (ROGEO XT)

In order to enable FEA of dents, an in-line inspection system needs to capture the shape of the dent with the utmost precision. Traditional caliper devices do not provide the required resolution to use the recorded data for FEA. Common caliper devices do not have full surface coverage. The majority of them is equipped with one senor plane, not covering the whole circumference of the pipeline. The resulting lower resolution compared to two sensor plane devices and the existing coverage gabs result into misinterpretations and less accurate measurements of the dent shape. But not only the amount of sensor planes guarantees a high accurate measurement of the counter. Even two sensor plane devices will be influenced under certain run conditions. Especially during high inspection velocities, caliper devices, independent of the coverage, will have an increased movement while passing ID reductions. This causes a loss of continuous contact with the internal surface, leading to inaccuracies and misrepresentations of the dent shape. But also at low speed abrupt changes along the pipe wall, like diameter changes may not be captured correctly.

The RoGeo XT has an unique combination of caliper and eddy current sensors, called the mechatronic measurement system, which can precisely measure the profile and contour of geometric features. With both information, coming from the eddy current and the caliper sensor, even movement on ID reduction and abrupt changes at the internal pipe surface can be compensated and will be precisely measured, even in the presence of wax or debris. The device is equipped with two sensor planes, resulting in an 100% circumferential coverage of the inner surface of the pipeline. This device fulfills the perquisite described above for highly accurate measurements to be used for FEA. The RoGeo XT tool fleet today covers pipeline sizes ranging from 6" to 48". Figure 1 shows a 42inch inspection device.

FINITE ELEMENT ANALYSIS, STRESS CONCENTRATION FACTORS AND REMAINING LIFE ANALYSIS

To characterize the severity of discontinuities in uniform load bearing objects, the stress concentration factor (SCF) is often taken into account. The SCF describes the ratio of the peak stress in a body to the calculated nominal stress. The local stresses within an object depend on the cross-sectional area of it. If the area contains a discontinuity, such as a hole, the local stresses around the discontinuity may be several times higher than the nominal stress. This relationship is characterized by the SCF. For simple shapes, such as holes, analytical SCFs are widely available. However, for more complex shapes the SCF is derived from finite element models. This approach is used in offshore structural analysis, where SCFs are combined with published S-N curves when determining fatigue lives for structural connections. In this case the SCFs is used to calculate the peak stresses, which is required for fatigue calculations.

It is straightforward to expand the SCF methodology to the assessment of dents in pipelines. The nominal stress state in a pipeline is easily classified as a function of the internal pressure according to Barlow's equation. The SCF can be derived from a precise model of the dent within a finite element program. The model can be directly constructed from the RoGeo XT data. Once the model is built, the SCF is calculated by the finite element program, considering an applied internal pressure and the maximum principle stresses.

Historically, finite element analyses have been cost intensive and time-consuming for operators, but advances in technology have removed both of these limitations. Improved inline inspection technology (ILI) as well as improved data processing power enable the effective usage of FEA for dents in pipelines and permitted the creation of a streamlined process, referred to as the Finite Element Dent Analysis Tool (FE-DAT). The FE-DAT is not limited to single dents only. It is developed to analyze a large number of dents precisely and accurate. It works by taking data directly from a high-resolution ILI tool, building a finite element model, and post-processing the results. A set of dent analyses that may have previously taken weeks can now be reduced to a few hours. The results from the analysis provide the SCF for each dent, which is directly proportional to the severity of each dent and indirectly proportional to the life. In addition, the stress profile in the region surrounding the dent is also provided in the form of stress contours.

Using the SCF a fatigue analysis can be done, if the operator provides pressure history data. Based on that a rain-flow analysis can be performed in order to calculate an equivalent number of cycles a particular dent experiences. This equivalent number of pressure cycles can be combined with the calculated SCF to determine the remaining life of a dent. Due to the fact that the relationship between stress and fatigue life is highly nonlinear, a fatigue analyses typically carry large factors of safety.

"THE SCF IS PROPORTIONAL TO THE SEVERITY OF THE DENT AND CAN BE USED TO CALCULATE THE REMAINING LIFE OF AN ANOMALY"

> Thomas Walther, Rosen Group

figure 2:
Pressure cycled to failure

CASE STUDY

In order to illustrate the effectiveness of the SCF method and provide a comparison between test data and analytical methods, a case study was performed. Therefore, a dent was generated in a 24-inch OD, 0.25-inch wall thickness, Grade X52 pipe sample. Figure 2 shows the test set-up, the indenter and the applied strain gages. The dent was generated by pressing a 2-inch diameter indenter into the pipe to a depth of 3.61-inches (15% OD) in an unpressurized configuration. Afterwards, the shape of the dent was recorded by an optical scanner and by the RoGeo XT inspection device.

Next, the pipe was subjected to target pressure cycles ranging from 100 – 780 psi (9% - 72% SMYS) until failure occurred. The strains were recorded at intermittent points during cycling. The sample failed after 39,800 cycles when a longitudinally oriented thru-wall crack developed in the shoulder of the dent as shown in Figure 3. The related SCF was calculated out of the recorded stresses from the strain gages and the nominal stress from the recorded pressure range of 690 psi. The SCF from the experimental data was 3.16.

In comparison to the experimental data, the analysis was performed using the FE-DAT and the finite element code ABAQUS. An internal pressure of 208.3 psi was applied to the model corresponding to a 10,000 psi hoop stress. The analysis completed by the FE-DAT showed a maximum principal stress of 32,784 psi on the OD of the pipe resulting in an SCF of 3.28. In addition the data from the optical scan was provided and analyzed using ABAQUS in order to maintain consistency with the FE-DAT. The same internal pressure of 208.3 psi was applied to the finite element model. The calculated maximum principal stress on the OD of the pipe was 38,014 psi yielding a SCF of 3.80.

In general, the calculated SCFs and depths compare well, particularly between the FE-DAT and the test data. The slightly higher SCF shown in the optical scan can be explained by the fact that the optical scan was recorded from the outside, while the RoGeo XT recorded the inner surface. Possible ovailities might not be recorded in the same way as the RoGeo XT does. However, the FE-DAT and the test data showed closer agreement for the dent depths and the resulting SCFs.

For the sample used for the case study, pressure history data was not available, but as it was ultimately destructively pressure cycled in the lab, comparisons can also be made between the predicted cycles to failure and the actual cycles to failure. Using the calculated SCF of 3.28 and a nominal stress of 33.1 ksi, the predicted number of cycles using the design S-N curve is 3674. The calculated number of cycles is significantly lower than the actual number of cycles (39,800). This was expected, as the usage of a standard S-N design curves provide more conservative results and laboratory testing has usually a higher scatter influencing the remaining life analysis. As previously mentioned, the relationship between stress and remaining live is highly nonlinear, so that even small variations in stress lead to high deviations in the predicted life.

CONCLUSION

The case study and additional investigations on more than 113 dents demonstrated that FE-DAT in combination with the RoGeo XT data provides reliable and repeatable stress concentration factors to assess the severity of dents. In comparison to the strain calculation the SCF correlates very well with depth. Furthermore there is also a slight correlation between the results using the strain approach and the SCF method. Therefore, the B31.8 strain assessment provide valid results for a momentarily situation, but not for a fatigue assessment.

The SCF is proportional to the severity of the dent and can be used to calculate the remaining life of an anomaly. The advances in computing and ILI caliper tools have allowed the process of analyzing dents to be streamlined to the point where hundreds of dents can be analyzed quickly and the data be made available as part of ILI reports. This approach has been validated through physical testing and represents an advanced metric that can be used to prioritize dents.

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REMOTE WELDING

THE HABITAT

RWS relies on the habitat, the systems foundation. It creates reference to the pipe and spool and provide a platform for the welding tool

> by: Jan Helge Johannessen, Technip-DeepOcean PRS JV

Remote Welding System (RWS)

New fully remote hyperbarbic welding system rated to 1000msw

Statoil have, after several years of testing and technical qualification work, developed a Remote Welding System that was qualified for contingency in the Pipeline Repair System pool services in December 2014. The system is rated for operation down to 1000msw and covers pipelines which are in depths exceeding the limit for diver assisted operations, which is currently 180msw.

The new fully remote hyperbaric welding system is mainly for subsea repair of pipelines and covers pipe dimensions from 30" up to 42". However, the equipment is a huge technical milestone for the subsea business and opens new opportunities in the industry when it comes to planned expansions of infrastructure, bypass of old installations and tie-ins.

Different from the diver habitat that operates with pipe ends, butt welding, the remote system involves installation of a pipe spool with pre-welded sleeves, threaded over both pipeline ends, before welding them together by a fillet weld.

CONCEPT DESCRIPTION – THREE MAIN MODULES

The Remote Welding System consists of three main modules; a habitat, a power & control module (POCO) and the welding tool. In short terms; the habitat is landed over the pipeline, before the pipe and spool are aligned. The habitat is then filled with welding gas (Argon) and dehumidified. The POCO carries the welding tool, and lands onto the habitat. A special designed sealing between the habitat and the POCO provides dry transfer of the welding tool into the habitat. When the welding tool is in position, the pipe and sleeve is preheated before welding operation starts.

The habitat main functions are to act as a foundation of the system, creating reference to the pipe and spool and provide a platform for the POCO and the welding tool. It is equipped with 4 individually operated legs, and longitudinal movement for accurately positioning of the habitat in reference to the welding position. The habitat functions are also to provide a dry and Argon filled hyperbaric welding environment before the welding tool enters. The operation is remotely operated from a topside control container on the vessel deck. All three modules are equipped with a wide range of cameras, LVDTs, pressure, temperature and proximity sensors for feedback and monitoring.

The POCO's main function is to house the welding tool and to provide services for the tool during operations. The POCO enclosure consists of two separate compartments:

- Electronic compartment containing most of the electronics and power distribution components required for operating the POCO and the welding tool.

- Tool compartment, containing equipment and systems required to transport the tool in and out of the habitat

Both compartments are pressurized with Argon whenever submerged and will have a maximum operating differential pressure towards the outside of about 0.5bar. Power communication and gas is supplied through an umbilical from surface.

In addition, power sources for welding and preheating is located in 1 bar containers outside the POCO enclosure.

When the welding area is dry and acceptable welding conditions are reached inside the habitat, the POCO is launched. After landing on the habitat, the interface (between habitat door and POCO door) is blown down. The doors are opened and the welding tool can engage around the pipe. After doing a path capturing +/-180□ and inspection of the welding area by cameras, 2 pre-heat bands are engaged around the pipe. The welding can start when pipe and sleeve temperatures are above 50□C.

For support and feedback the welding tool is among others equipped with welding torch tip changer, welding camera, a grinder and various sensors.

Play Video

TECHNOLOGY QUALIFICATION PROGRAM (TQP)

After going through various system and subsystem testing throughout the project such as Factory Acceptance Testing, Site Integration Test, Welding Robustness Testing and a Shallow Water Test, the last part to fulfill the TQP was the Deep Water Test. This test was to validate the system and to show that the equipment could produce acceptable welds offshore.

The test was twofold with depths on 400msw in Nedstrandsfjorden and 1000msw in Sognefjorden. Two weld sections on a pre-installed pipe spool in the habitat were done on both depths and all the tests were successful.

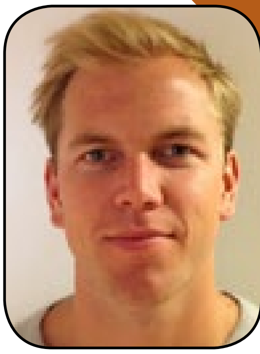
THE WAY FORWARD

The deep water test was the final milestone and completion of the project. Now the Remote Welding System is in contingency in the PRS pool, operated by PRS JV on behalf of Statoil. It is being evaluated to expand its limits with deeper depths, smaller pipes and welding of other pipe materials.

PRS Joint Venture

- Joint Venture between Technip Norge AS and DeepOcean ASA
- Contract awarded in December 2014, 5 years with 3 x 2 years option.
- Includes operation, maintenance, engineering and development of the Pipeline Repair System at Killingøy in Haugesund.

Author



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POCO MODUL
The Power and Control Moduls main function is to house the welding tool and to provide services for the tool during operations.

WELDING TOOL
The three moduls of RWS succeeded in all tests and are fully operational. The System can operate in areas down to 1000msw.

Intelligent Pigs for Internal Inspection & Repair Welding of Cross-Country Pipelines

Abstract

Oil and gas are an important transport method of the energy sources products worldwide nowadays and in the near future. However, the major reserves of the oil and gas are mostly located in remote areas. For this reason, pipelines have become the most efficient attractive method for oil and gas transportation. Pipelines are also the most economical method used nowadays for transporting any type of fluid. However, the capital cost for crude trunk pipelines is very high, depending on the pipeline steel grade, the design wall-thickness, and the length of the pipeline. These factors often force the product owners to construct most of the cross-country pipeline network in a single channel, making it difficult to shutdown for inspection, maintenance, or repair. In addition, the major part of the cross-country pipelines are buried and excavation is precluded. Likewise, offshore pipelines are extremely difficult to inspect, maintain, or repair due to deep-water factors and low-density environment. Inspection for integrity of pipelines is often conducted from the inside using an intelligent pigs with the capability of measuring any losses in the pipe wall thickness in the form of flaws, cracks, or corrosion damages while traveling inside the pipeline. Nowadays, new era of smart pigs for both; out-of-service and in-service pipelines have been developed/invented to perform an in-situ repair of these defects on the internal pipe surface before they reach a critical size and become hazardous to operation & safety. This paper will discuss the new era of the intelligent pigs and the benefits of carrying more developments in such tools.

Figure 1: Pig station
A pig launcher/receiver, for Natural Gas Pipeline in Switzerland

INTRODUCTION

Pigging of a pipeline refers to the use of a Pipeline Inspection Gauge or "PIG" to perform various maintenance operations on a transmission, onshore, and offshore pipeline. This usually is done without stopping the flow of production in the pipeline. These maintenance operations include but are not limited to either cleaning, or inspection, or both of a pipeline. This practice is achieved by inserting a pig into a "pig launcher" or a launching station. It is a funnel shaped Y in both end-sections of the pipeline. The launcher is then closed and the pressure-driven flow of the product in the pipeline is then used to push it along down the pipeline length until it reaches the "receiving trap" or a receiving station as shown in Figure 1 [1,2,3].

One of the most crucial aspects of pipeline operation is ensuring the pipeline integrity. For this reason, in-line inspection (ILI) pigs have become important. The Intelligent Pigs "smart pigs" are important tools for assessing the integrity conditions of a pipeline, and is set to become more integral part of the pipeline maintenance. Nowadays, more developments are made towards solving the integrity issues of Unpiggable pipelines [2,3].

PIPELINE PIGGING SYSTEMS

A Pipeline Inspection Gauge or "PIG" in the industry is a tool that sent through a pipeline and propelled by the internal pressure of the product in the pipeline itself. Therefore, pigging operations are mostly performed for in-service pipelines. There are four main uses for pigs: 1) Physical separation, 2) Internal cleaning, 3) Inspection of the internal condition, also known as an Inline Inspection (ILI) operations, and 4) Capturing and recording geometric information related to the pipelines (i.e. size, position, thickness loss, corrosion, etc.).

Depending on the type of pig, it can perform one or a number of specific tasks including [3,4]: 1) Cleaning debris from the pipeline, 2) Removing the residual products that accumulate with time, 3) Gauging the internal wall of a pipe to locate defects, 4) Assessing the condition and location. However, pipeline pigs can also be used for other purposes. These include but not limited to: 1) Hydrostatic testing, 2) Air/nitrogen removal from the pipeline, 3) Batch separation in case of using the same cross-country pipeline to batch multi-products, 4) Pre-inspection and certification of newly constructed pipeline, 5) Integrity assessment of an in-service pipeline, 6) Decommissioning unsafe pipeline for environment purposes. Nonetheless, the pigs can only be one of two main types: 1) Utility pigs, or 2) Intelligent pigs, also called smart pigs as mapped in Figure 2 [1,3]. However, since the utility pigging technology is relatively old and simple to deal with, this paper will focus more on the intelligent pigs.

THE ORIGINS OF INTELLIGENT PIGS INDUSTRY

In 1959 five decades ago, T.D. Williamson introduced the first "caliper tool" for detecting dents in pipelines. Pan-American Petroleum was developing a "Cooley tool" around the same time, which used the Magnetic Flux Leakage (MFL) technique. In 1961, Shell Oil Research developed a technique for detecting pitting corrosion in down-hole casings based on a "MacLean tool", which worked with a Remote Field Eddy Current (RFEC) [1,2,3].

In 1962, Tuboscope obtained a licence from Shell Oil Research for the MacLean tool and started developing a smart pig to carry an array of remote field eddy current sensors through a pipeline. Early test runs with the MacLean tool were unsuccessful, as they could not detect known pits in the test spools. Tuboscope then approached Pan-American Petroleum and purchased the Cooley tool patent. The MacLean tool was discarded and the smart pigging developments switched to Cooley tool or as known today as MFL technique. The new tool was branded LINALOG® [1,2,3].

In 1964 Tuboscope ran the first commercial instrument for the new LINALOG 90° tool. It used MFL technology to inspect the bottom portion of the pipeline. The system used a black box to record the information, a highly customized analog tape recorder. This first commercial job was for Shell company [1,2,3].

> "INTELLIGENT PIGS INDUSTRY CONTINUED TO GROW"
>
> *> Hamad Almostaneer*

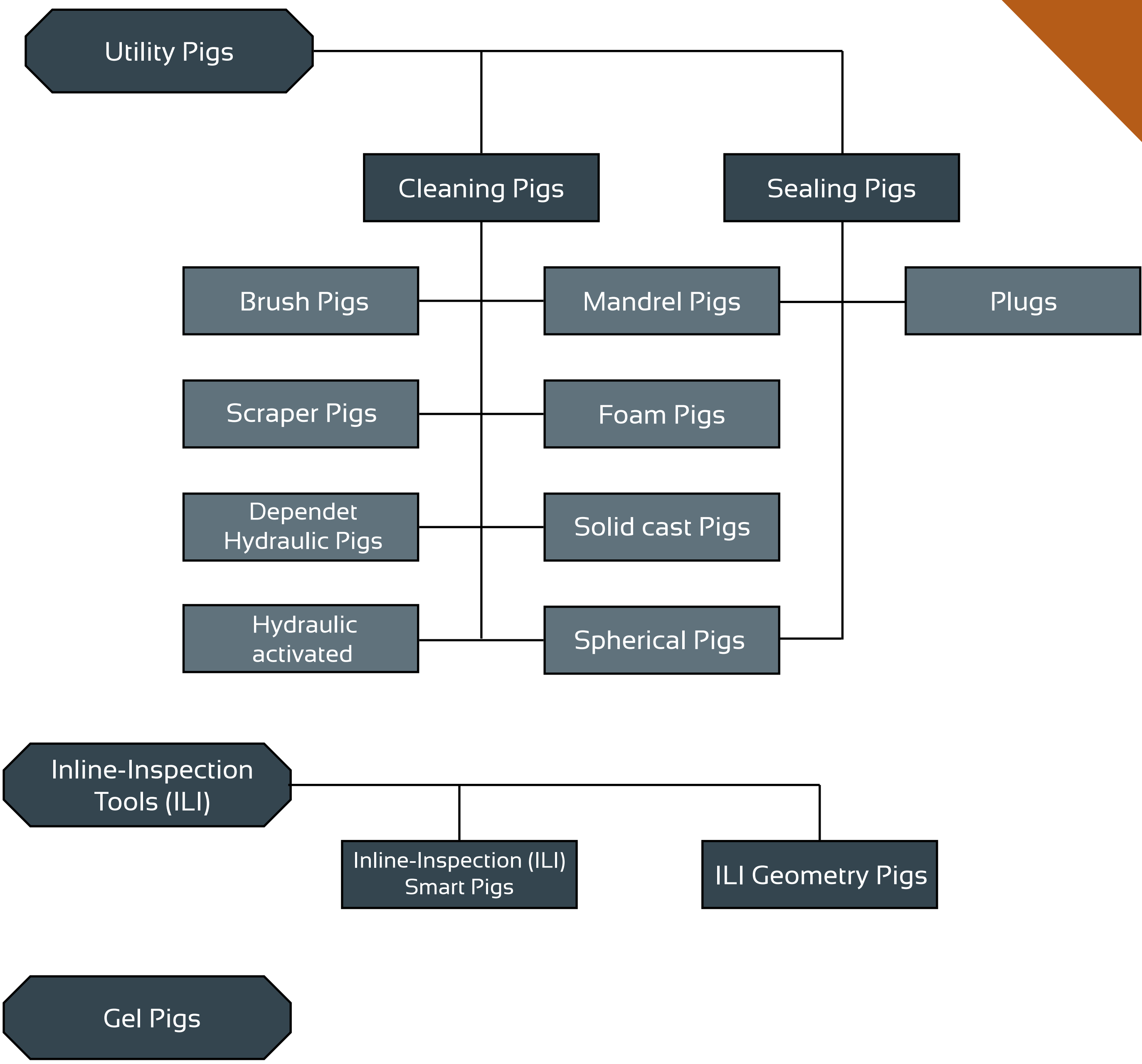


Figure 2: An overview map of the available tools for both 1) Utility pigs, and 2) Intelligent pigs.

THEORIES OF INTELLIGENT PIG TOOLS

Intelligent pigs are highly specialized tools for in-line inspection (ILI) which can detect, locate, and size flows in pipelines. There is no tool that can be used for all inspection purposes as each tool uses different physics and principles. However, each inspection tool must be selected accordingly and the ability of the used tool must correspond to the inspection requirements [4,5,6].

However, the difference between different tools can be identified due to the measurement accuracies and the detection threshold. The following tools will focus on in-line inspection (ILI) tools and techniques that are used within intelligent pigs to detect, size, and locate flaws that are reached subcritical sizes [7,8,9].

MAGNETIC-FLUX LEAKAGE TOOL

The magnetic-flux leakage (MFL) method can be used to measure and locate cracks and metal-loss in both circumferential and axial directions. It is a popular method for inspecting pipelines for both stress sensitivity or levels and corrosion defects and characterization. The magnetic-flux leakage (MFL) work principle is shown in Figure 3 [10,11,12].

AXIAL MAGNETIC-FLUX LEAKAGE TOOL

This type of tool usually consists of a central body of mild steel around which is mounted an annular arrangement of magnets. These magnets spread from center outwards in a radial arrangement to give opposing poles on either end of the body (north or south) as shown in Figure 4. There are steel bristles which create contact with the pipeline wall, to complete the magnetic circuit and allow the inspected pipe section to be uniformly magnetized in the axial direction as the tool passes down the line. If the pipe is not corroded, the magnetic flux will be locked-up within the steel pipe wall. However, corrosion or any other feature such as flaw will cause flux to leak out of the pipe wall which then can be detected by the circular array of the magnetic sensors [13]. This type of tools is directly related to the crack detection where axial MFL tool can detect crack geometries at right angles to the induced magnetic field such as cracks in girth welds [14,15].

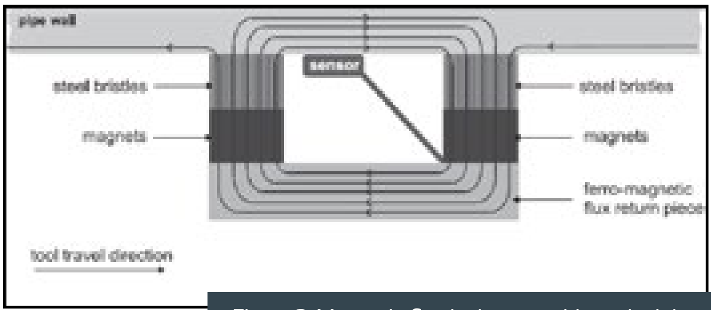


Figure 3: Magnetic-flux leakage working principle: a pipeline with a perfect wall.

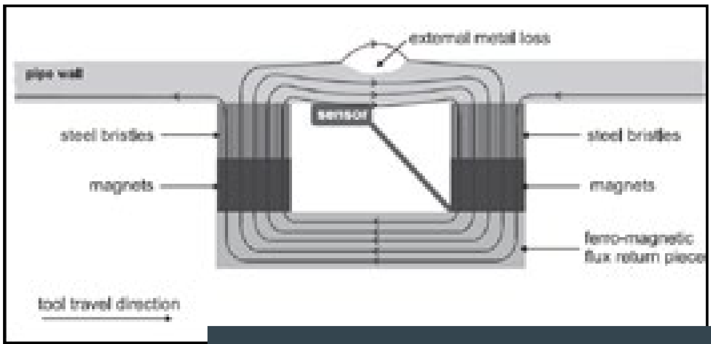


Figure 4: Axial magnetic-flux leakage system.

TRANSVERSE-FIELD MFL TOOL

MFL tools are good to detect flaws which are located at the angles to the induced magnetic field. Axially-oriented narrow flaws are hard be detected by the axial MFL. However, these narrow, long defects are serious threat to the transfer pipelines integrity especially metal-loss flaws and cracks in longitudinal seam welds of a pipeline. They can cause failures during operation to in-service pipelines. The occurrence of the long axial defects led to the development of MFL system incorporating transverse magnetic field. The schematic of such system is shown in Figure 5A. In theory, applying magnetic field in a transverse direction around a pipeline makes it easier to differentiate and characterize defects orthogonal to the field (long axial defect) [14,15,16,17].

ULTRASONIC TOOL

The major advantage of ultrasonic technique is the ability to provide quantitative measurements of a wall of a pipeline. The high accuracy levels make it an ideal ILI tool. UT inspection tools are fitted with sufficient number of ultrasonic transducers to ensure full circumferential coverage of a pipeline. The transducers operate in an impulse-echo mode. This means that they switch from being emitters of an acoustic signal in the ultrasonic sound range to being receivers [17,18,19].

It is often done by determining the pulse repetition frequency. The sensor emits an ultrasonic signal that is partly reflected at the internal wall surface and partly at the external wall surface of a pipeline. The first reflection provides a measurement of the stand-off distance and the second value for the wall thickness as shown in Figure 6. As the tool travel through pipeline, the sensor takes measurements at regular intervals, set by the traveling speed of the tool which later analyzes the whole pipeline length [17,20].

ANGLE-BEAM ULTRASONIC TOOL

An ultrasonic crack-detection tool utilizes angled-beam probes. The tool is designed to detect and size axial crack in a pipeline wall and long-seam weld joints. It also detects stress-corrosion cracking (SCC). The ultrasonic sensors are fixed at an angle to the wall at under a 45° angle which is optimum for crack detection. Depending on the tool size, this tool can have up to above one thousand ultrasonic transducers. Minimum detection threshold for this tool is 30 mm crack length and 1 mm crack depth. Circumferential cracks can also be detected but it would require modified sensor carrier which have to be turned by 90° angle. However, this tool as shown in Figure 7 successfully detected stress-corrosion cracks (SCC) [17].

The lower part of the picture shows the actual flaws and the upper-part are the displayed data by the UT tool. Nonetheless, detection accuracies, high confidence levels of detection, sizing, and repeatability are the main characteristics of ultrasonic ILI tools [17].

WALL-THICKNESS-MEASUREMENT ULTRASONIC TOOL

This type of ultrasonic tools is used for metal-loss measurements. It can be identified by the alignment of the ultrasonic sensors that are mounted at 90° angle to the wall. Figure 8 shows the physical principle for this tool. Ultrasonic transducers emit a signal directed to the internal surface of a pipeline wall and part of the signal is reflected and received by transducers. The other part of the signal that travels through the pipe wall is reflected back by the external surface of the wall. The signals of this part are also received back by the transducers and provide wall-thickness measurement. This ultrasonic tool besides the function of wall-thickness measurements is ideal for flaws that are present inside the pipeline wall such as hydrogen-induced cracks and inclusions [17].

EDDY-CURRENT TOOL

Eddy current inspection tool is another ILI-NDT tool that uses the principle of electromagnetism as the basis for conducting measurements. Eddy currents are created through a process called electromagnetic induction by applying an alternating to a conductor, such as a copper wire, a magnetic field will develop in and around the conductor. This magnetic field expands as the alternating current rises to maximum and collapses as the current is reduced to zero [21].

Figure 9 shows the principle of the Eddy Current sensor inducing a primary field, according to Lenz Law, 90° angle to the original field lines of the coil. Due to further induction of the Eddy Current in the primary field of the electric conductive material, a secondary field is induced which will effect the coil impedance. In case of a defect in the tube wall, the secondary field is changed in comparison to its origin. The change of the Eddy Current field lines causes a change of the impedance of the Eddy Current probe coil, which is related to the defects [22]. A remote field eddy current (RFEC) that uses a low frequency AC and relatively large exciter coils has become an excellent NDT technique to detect cracks of internal wall of pipes and tubes as shown in Figure 10 [23].

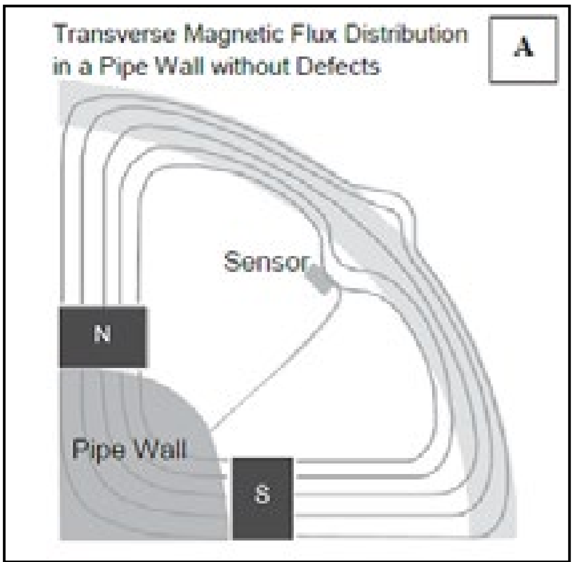
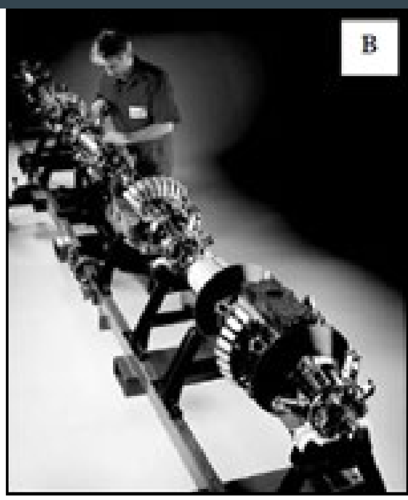


Figure 5: Transverse MFL tool: A) Schematic of the magnetization arrangement for transverse-field, and B) Transverse field tool capable of detecting cracks (Courtesy for TranScan).



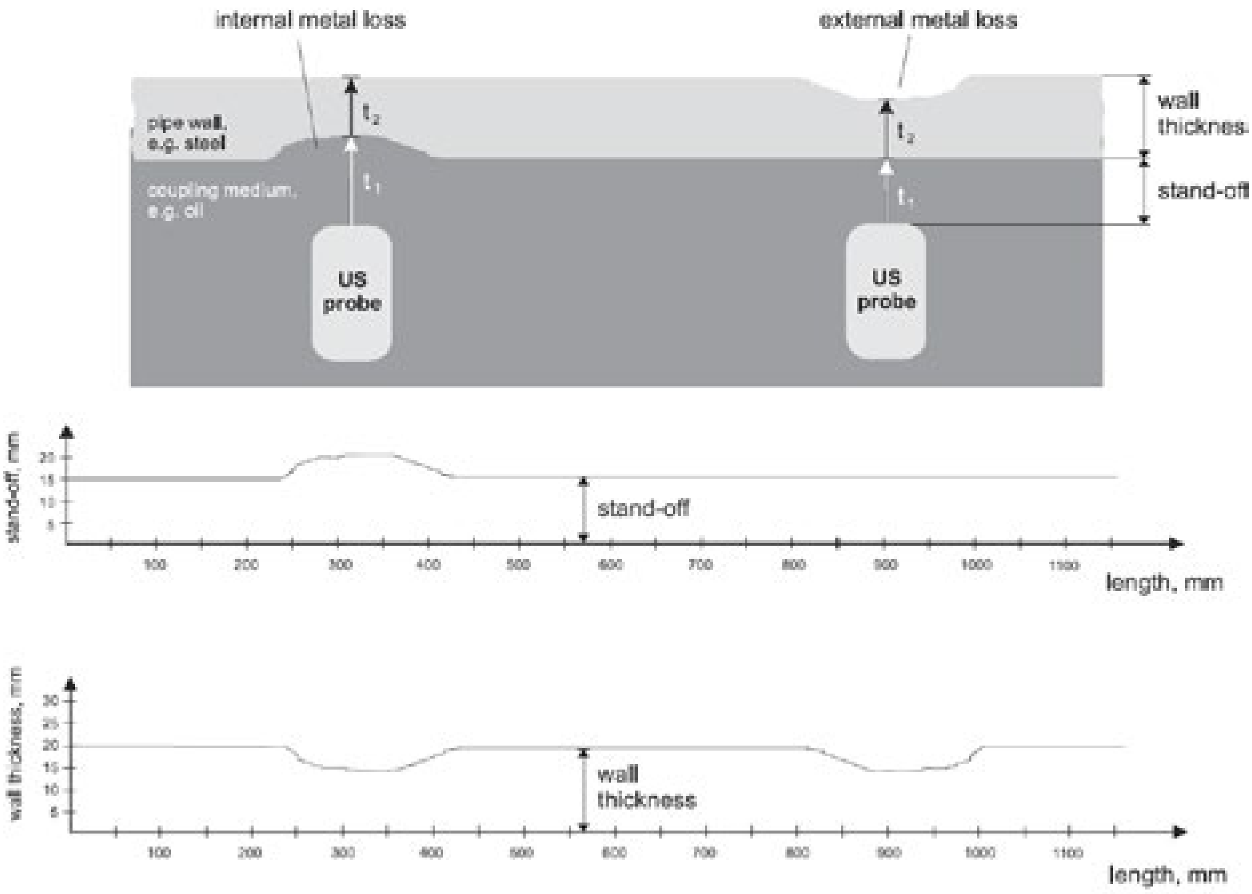


Figure 6: The principle of ultrasonic technique measurements.

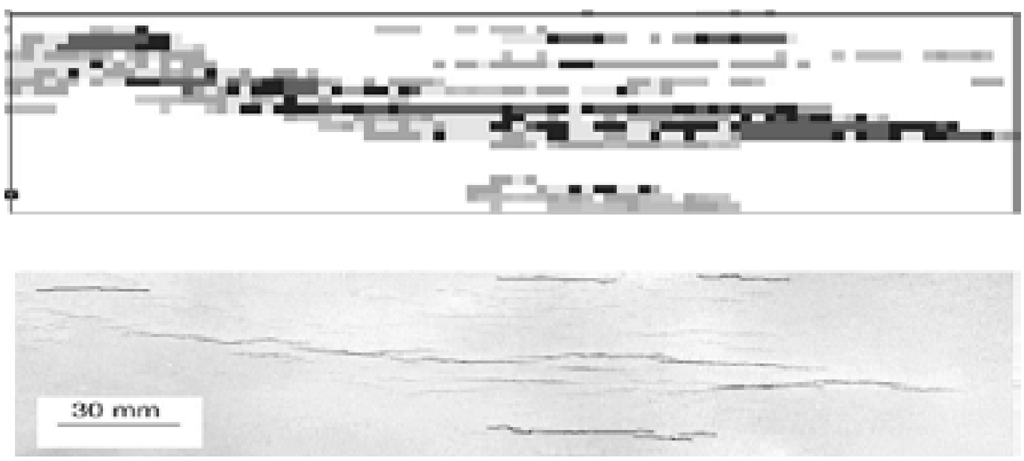


Figure 7: Stress-corrosion cracks (SCC) detected by angled-beam ultrasonic tool.

NEW ERA OF ADVANCED ILI INTELLIGENT PIGS

Intelligent pigs industry continued to grow due to the demands of increasing safety and reduce costs in maintaining transmission, onshore, and offshore pipelines. Osaka Gas studied various types of robots capable of inspecting and repair welding pipelines from inside, and have succeeded in developing automatic welding robots to reinforce welds from the inside of a steel pipeline. The configuration of one of Osaka Gas systems is shown schematically in Figure 11 [24].

The principle of the welding monitor, however, is all welding work is remote-controlled above ground. The torch is controlled with four axes, whose movement is programmed in a specified sequence. The welding conditions can be monitored via two TV cameras. If excessive spatter is deposited on the torch nozzle, the nozzle then can be automatically cleaned with a spatter remover as shown in Figure 12. However, application of this repair method to the inside of an in-service pipeline would require that welding be performed in a hyperbaric environment or to take the pipeline from service/operation [24].

Colorado School of Mines (CSM) invented a method that can be developed within an intelligent pig system to perform in-situ crack detection and repair welding internally, using the MAW-UO process on the internal pipe surface of in-service pipeline. Likewise, the system configuration module of the welding unit that carries the torch of MAW-UO process, NDE tool, grinding, and finishing tools connected to other controlling units on board to travel inside a defective pipeline that has flaws, cracks, or corrosion damage to be repaired is shown schematically in Figure 13 [25].

The concept of the MAWUO welding unit is to have an integrated robot to remotely locate of some widely dispersed perforations in the pipeline using remote laser profillometry (precision laser surface mapping followed by analytical form fitting). Then, eddy-current characterization of the defected areas and a remote positioning and repair welding of a patch, followed by inspection. The weld metal buildup or overlay and finally the inspection all should be remotely controlled with full vision and laser positioning as shown in Figure 14 [25].

There are no technical limitations to these repair methods to the inside of either an out-of- or in-service pipeline. It is direct, inexpensive to apply, and requires no additional materials beyond welding consumables. Typical system can be as schematically shown in Figure 15 [24].

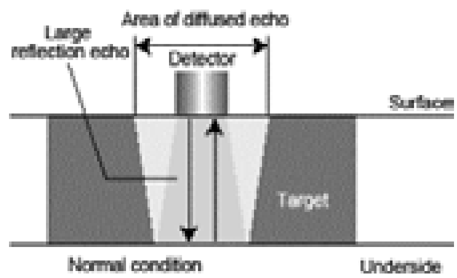


Figure 8:
Wall-thickness-measurement ultrasonic tool working principle.

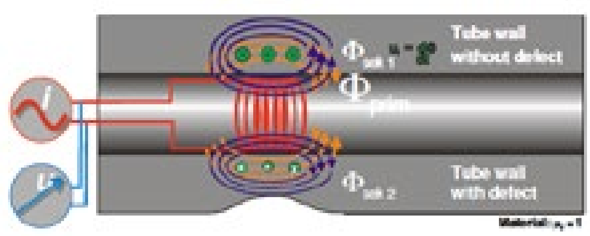


Figure 9: Principle of Eddy Current.

SUMMARY

The in-line inspection intelligent pigging of pipelines have grown tremendously in the last five decades and progressed from utility pigs that are used for cleaning, to smart pigs that are used for inspection purposes, and today to in-situ repair smart pigs.

The inspection/repair of pipelines using intelligent pigs is now well established, and interests are growing in the use of this versatile technique. Intelligent pigging tools offers a viable alternative to traditional, manual inspection techniques with several significant advantages.

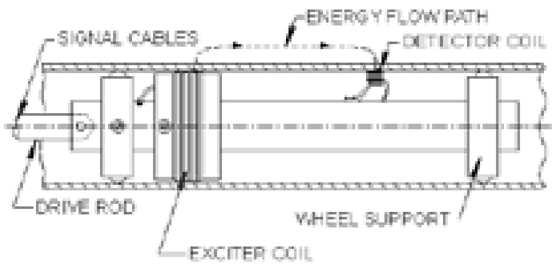


Figure 10:
Remote Field Eddy Current (RFEC) inspection technique.

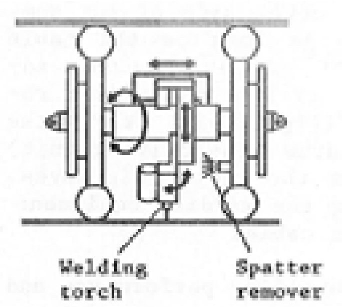


Figure 12:
Schematic of the welding unit.

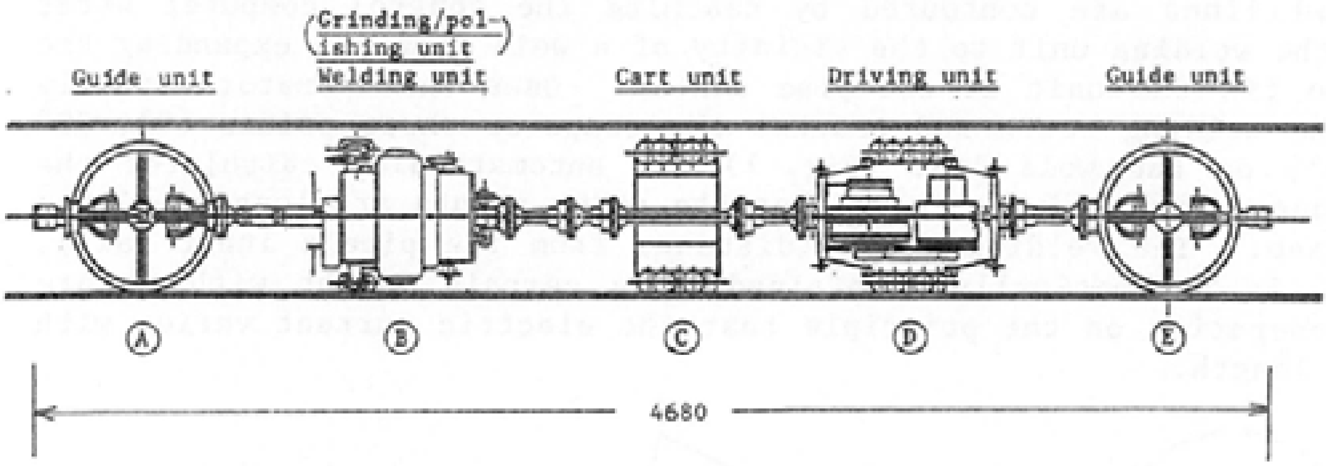


Figure 11: Osaka Gas Co./Sumitomo Metal Model; Internal Welding Robot system.

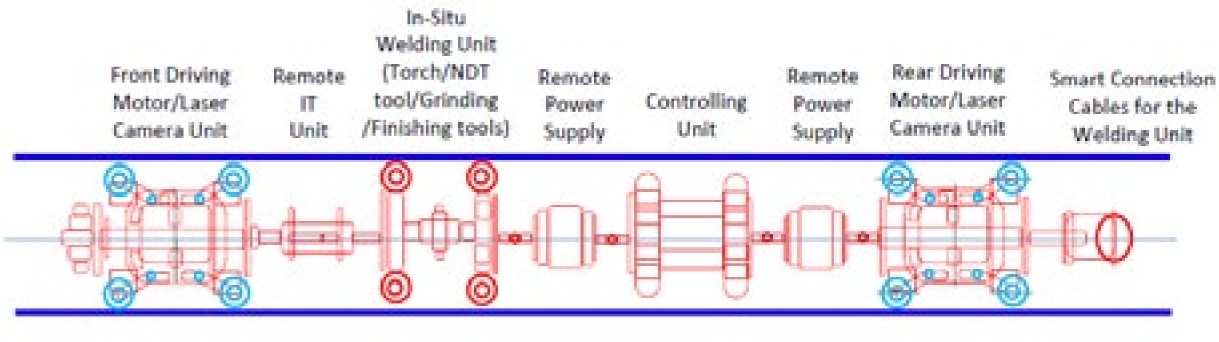


Figure 13: Colorado School of Mines Module; In-Situ Repair Welding Robot.

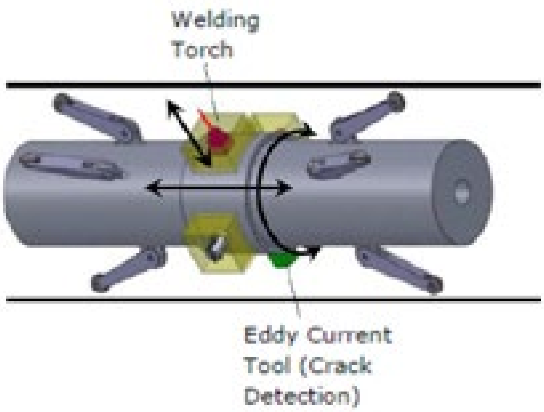


Figure 14: 3D view of MAWUO process welding unit.

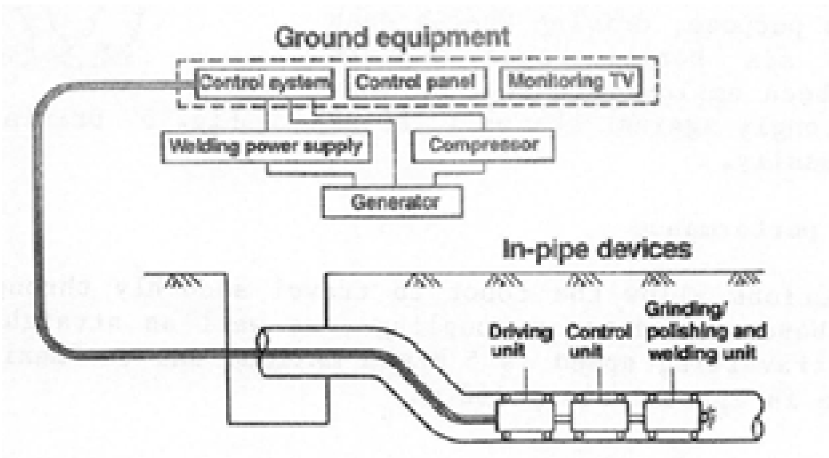


Figure 15: System configuration of intelligent pig for repair welding.

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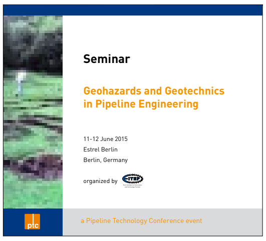
In-Line Inspection of Onshore and Offshore Pipelines

The course will provide an in-depth introduction into the subject and importance of pipeline inspection and integrity management. Delegates will learn about the need for pipeline inspection and the use of inspection for the analysis of the pipelines integrity and fitness-for-purpose.

The course will introduce the flaws and anomalies observed in pipelines. Suitable external and internal inspection technologies will be introduced including the strength and weaknesses of the non-destructive testing principles applied.

The material cover details on a pipeline inspection operation, including pipeline preparation, cleaning, gauging.

Final Reports, Reporting Formats are discussed. The course also includes a short introduction into integrity assessment.



Geohazards and Geotechnics in Pipeline Engineering

The course will provide an in-depth introduction into the subject and importance of Geohazards and Geotechnics during the stages of evaluation, design, construction and operation of a pipeline.

Delegates will learn about the need for Geohazard Assessment and Geotechnical Engineering in relation to the route selection and the pipeline integrity. Additionally, potential protection measures and/or monitoring techniques will be presented.

The main disciplines that will be presented during the course are Engineering Geology, Soil Mechanics, and Rock Mechanics, while special emphasis will be given on Slope Instabilities and Stabilization Methods.

Since many countries worldwide are characterized by moderate or high seismicity, the course will also introduce the topics of Geotechnical Earthquake Engineering and Pipeline Seismic Design.

Microbiologically influenced Corrosion (MIC) and its impact on pipeline corrosion management

Engineering importance is a function of cost and risk. Cost of corrosion is about 5% of the GDP of a country and microbial corrosion (MIC) accounts for about 1/5 of the corrosion cost. In addition to cost, what makes it even worse is that a great number of MIC cases are mistakenly attributed to corrosion phenomena other than microbial corrosion. In engineering terms, "Risk" is defined as the product of "likelihood" and "consequences": no matter how low the likelihood, as the consequences could always be critical, the risk of MIC is classified as "extremely high". Almost all engineering materials are susceptible to microbial corrosion. Corrosion- related bacteria can tolerate a wide range of pH and temperatures. A combination of the above factors makes MIC a very dangerous factor that must be dealt with meticulously. MIC can be observed in a wide range of industries from mining, oil & gas, power generation to marine industry, chemical industry and even in ships and in systems such as hydrants and pipelines.