January 2016

ptj

e Journal

Pipeline Technology Journal

ISSN 2196-4300

CORROSION PREVENTION

We preserve values

DENSO

DENSOLEN®
PE/Butyl-Tapes & -Systems

- For high temperatures up to +100 °C (+212 °F).
- Easy and versatile application.
- Several millions sqm applied worldwide – since 1973.
- Worldwide leading technology

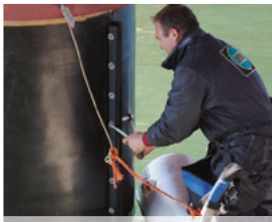
DENSO®
Petrolatum-Tapes & Mastics

DEKOTEC®
Heat Shrinkable Sleeves

DENSOLID®
Polyurethane Coatings

DENSIT®
Insulation and Sealing Tapes

VivaxCoat®
Coating System for Moist Surfaces



MarineProtect®
Jetty Pile Protection

made in Germany since 1922

www.denso.de

Pipelines - The Worlds Energy Vein

Dr. Klaus Ritter

We make sure that the international pipeline community gets access to all available experiences.

Dear reader,

Pipelines are the most important energy carriers worldwide, for both, industry and public sector. Pipeline construction is still booming, especially in the field of gas pipelines. Estimates suggest that every year between 25,000 and 30,000 kilometers of pipelines are build worldwide. However, there are regional differences.

While in North America and Europe the construction of new pipelines proceeds slowly, there are many pipeline construction projects ongoing in Asia, Africa as well as South and Central America. Therefore, main focus in North America and Europa is on:

- Safe operation
- Repair and Maintenance
- Rehabilitation

In general, pipeline life cycles can be extended significantly, if the operator is building on the experience that has already been gained by other companies from all over the world. Pipelines can be in service for up to 100 years, provided that those experience is accessible to all responsible persons involved during all stages of a pipeline's lifetime (planning / construction / operation).

It was our intention to enable this exchange of experience and best practice, that led us to the first Pipeline Technology Conference (ptc) 11 years ago. Today, the 11th Pipeline Technology Conference is just fortcoming and we continue to further develop this unique international platform for the global pipeline community.

We have done a great deal of work to maintain and expand the industries exchange during the past years:

- Buildup of an international Advisory Committee, currently consisting of 37 pipeline professionals
- Implementation and expansion of the autonomos Pipeline Technology Journal (ptj)
- Buildup of a database with 28,000 verified e-mail addresses from pipeline professionals worldwide
- Establishment of the ptj newsletter, which reports every two weeks about international pipeline news
- Pipeline seminars, which are executed worldwide
- Creation of a paper database, with all ptc-presentations accessible to the professional public.
- Etc.

And our efforts are constantly paying off: we are expecting more than 600 participants from 55 different nations to attend the next Pipeline Technology Conference in May 2016.

One reason for this development is the great acceptance the global pipeline community has placed in our Pipeline Technolgy Journal, ptj. Therefore, I would like to inform you about ptj's new frequency of publication: From 2016, the Pipeline Technology Journal will be published six times a year, providing you with crucial information about pipeline research, development and technologies more promtly.

Get involved! Participate in the communities exchange during the Pipeline Technology Conference in Berlin. Take the chance to talk about your experiences and challenges. Moreover, send us your technical articles for publication in the Pipeline Technology Journal and get the most out of the professional dialoge we offer.

Yours,

> Dr. Klaus Ritter, Chairman of the ptj Editorial Board / ptc Advisory Committee

FAR EAST-BASED LNG PROJECT SAKHALIN II

The first and still the only LNG plant in Russia is located at the Aniva Bay shore, in the southern part of the Sakhalin Island. The plant produced its first lot of LNG in 2009. Above 900 lots of LNG (one standard lot holds 65,000 tons) were shipped ever since to Japan, South Korea, China, Taiwan, Thailand, India and Kuwait. The plant's annual output exceeds 10 million tons of liquefied gas covering over 4 per cent of the global LNG supplies. And the figure is likely to grow – Gazprom and Shell signed the Memorandum on implementing the project for constructing the third train at the LNG plant within Sakhalin II in June 2015.

HIGHLIGHTS

JANUARY 2016
EDITION 07

THIS ISSUES COMPLETE CONTENT

PIPELINE TECHNOLOGY JOURNAL

INDUSTRY AND PRACTICE

PIPELINE TECHNOLOGY JOURNAL

RESEARCH / DEVELOPMENT / TECHNOLOGY

PIPELINE TECHNOLOGY JOURNAL

CONFERENCES / SEMINARS / EXHIBITIONS

WASHINGTON D.C. / USA

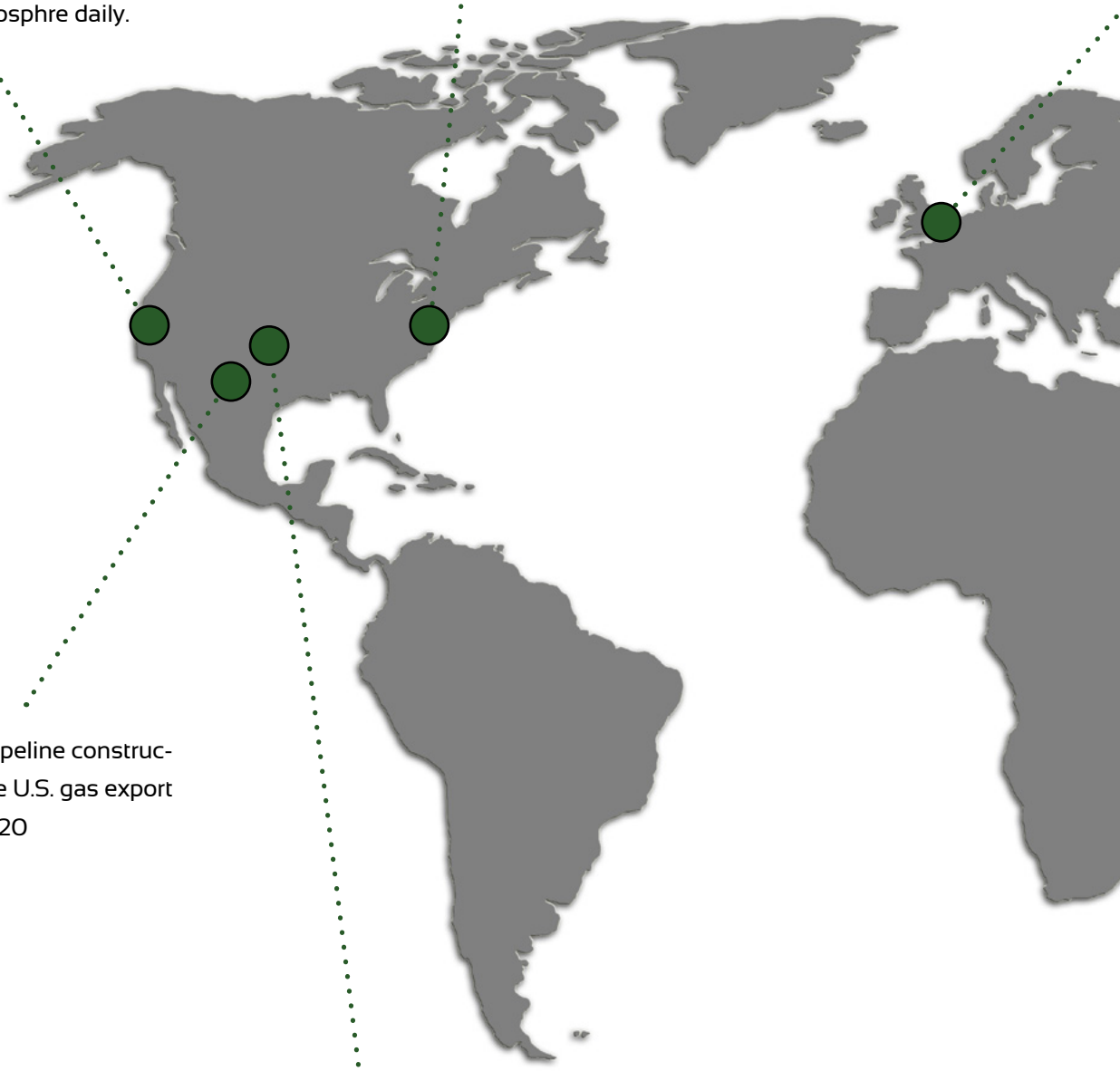
U.S. Senate passes new legislation to enhance the safety of the 2.5 million miles of pipelines in the U.S.

Page 12

LOS ANGELES / USA

A devastating gas leakage in californian underground is spewing 1200 tons of methane into the troposphre daily.

Page 14



MEXICO / USA

A flurry of gas pipeline construction will triple the U.S. gas export to Mexico by 2020

Page 10

SOUTHWESTERN UNITED STATES

Tailgrass Energy Partners (TEP) announced that it is acquiring an additional 31.3 percent interest in the 760 mile Tailgrass Pony Express crude oil pipeline

Page 14

UK / BELGIUM

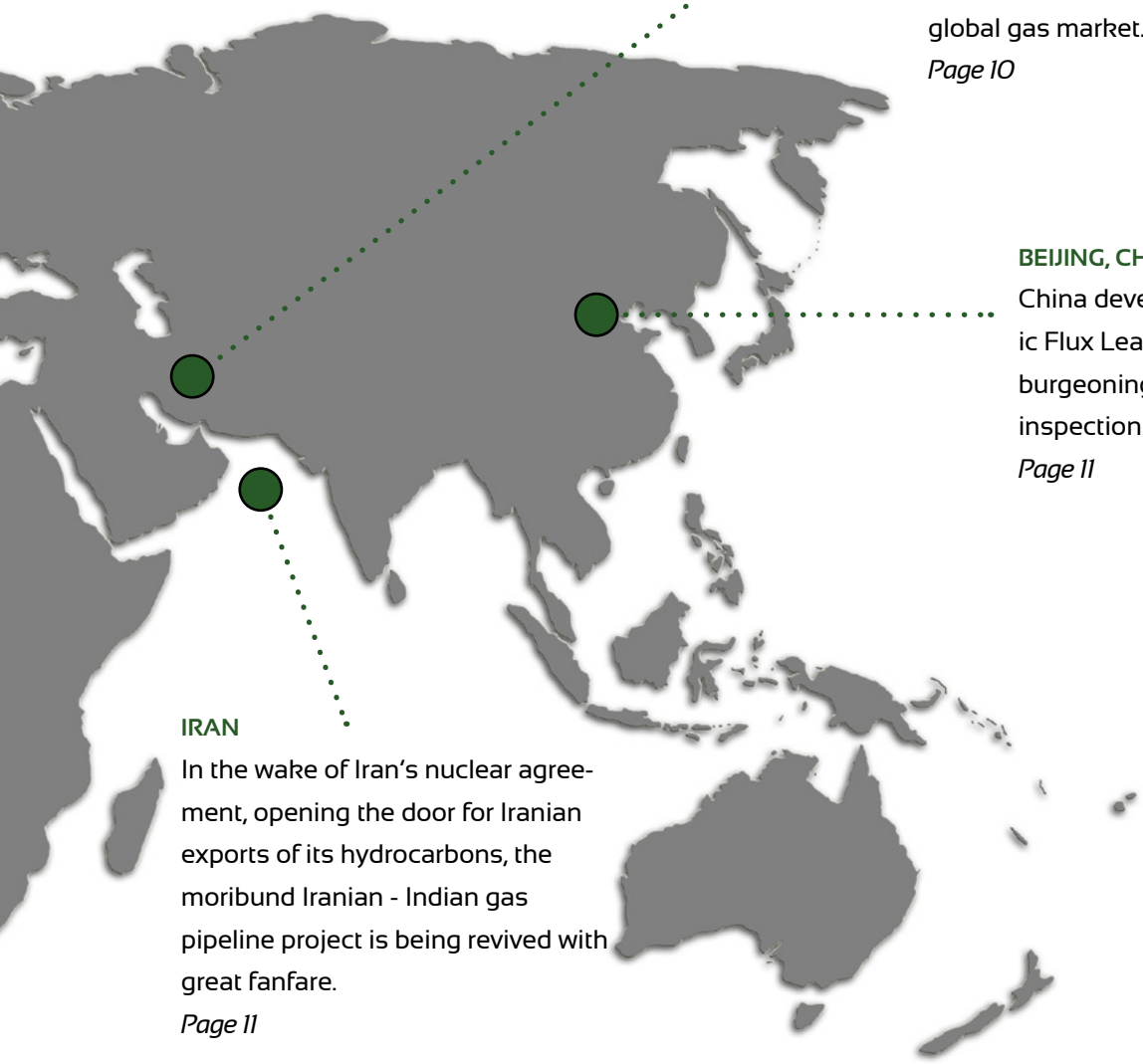
Fluxys expands its interest in Europe's gas infrastructure with UK Interconnector deal

Page 12

IRAN

Anticipating the complete lifting of sanctions on Iran's oil and gas sector, Iran's minister of petroleum says Iran will soon become a major player in the global gas market.

Page 10



BEIJING, CHINA

China develops own Magnetic Flux Leakage Detector for burgeoning offshore pipeline inspection

Page 11

IRAN

In the wake of Iran's nuclear agreement, opening the door for Iranian exports of its hydrocarbons, the moribund Iranian - Indian gas pipeline project is being revived with great fanfare.

Page 11

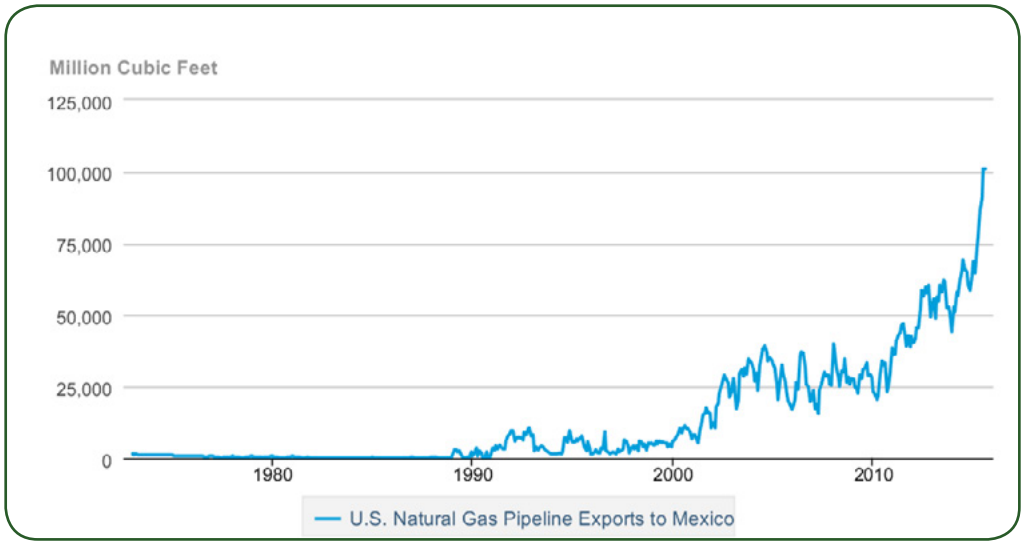
WORLD NEWS

A FLURRY OF GAS PIPELINE CONSTRUCTION WILL TRIPLE U.S. GAS EXPORT TO MEXICO BY 2020

In the wake on new border-crossing gas pipelines from the United States to Mexico, cheap U.S. shale gas is flowing into Mexico at an average of 3.26 billion cubic feet per day.

According to Citigroup and Genscape, during the next five years these pipeline flows are expected to more than double. That will help support U.S. gas prices, which have slid to a three-year low because of a domestic glut and sluggish consumption.

"That's the sleeper story," Richard Ennis, head of natural resources at ING Capital LLC, said in an Oct. 31 interview in New York. "In Mexico, if you look at how much natural gas they use, it's tiny. All these new pipelines are going to triple their daily use. It's pretty dramatic."



U.S. Natural Gas Pipeline Exports to Mexico (US Energy Information Administration)

IRAN ENVISIONS BECOMING MAJOR PLAYER IN GLOBAL GAS MARKET - RULES OUT SHIPPING ITS GAS TO EUROPE VIA PIPELINE

Anticipating the complete lifting of sanctions on Iran's oil and gas sector during the course of 2016, Iran's Minister of Petroleum Bijan Zanganeh says Iran will soon become a major player in the global gas market.

To this end Iran is in various stages of negotiation with its neighbors (Pakistan, India, Oman, Iraq) concerning the construction of gas pipelines. But more importantly, in Zaganeh's view, is the advanced development of Iran's first LNG terminal, providing Iran with more options for the export of its gas to Europe and to Asia in the near future: "LNG is the only option for the time being to export gas to Europe and Asia," he said.

Iran plans to build a capacity for exporting 40 million metric tons a year of LNG which is super-cooled to minus 162 degrees Celsius for shipment by special tankers.

The country is also in serious talks with several foreign oil refiners to buy their shares, Zangeneh said on Tuesday.

"If we manage to buy shares in foreign refineries, we can sell our oil at higher prices," he said.

Map of Iran's natural gas infrastructure (© 2015 EIA)

CHINA DEVELOPS OWN MAGNETIC FLUX LEAKAGE DETECTOR FOR BURGEONING OFFSHORE PIPELINE INSPECTION

With great fanfare the China Aerospace Science and Industry Corporation (CASIC) has launched the 'home-developed submarine pipeline Magnetic Flux Leakage (MFL) detector,' aiming to get a significant share of the lucrative pipeline inspection business in China and thus end foreign companies' monopoly on the submarine pipeline inspection in China.

After over 20 years' research and tests, CASIC successfully applied the high-precision magnetic flux leakage technology to detect the flaws and corrosion on the interior and exterior pipelines under the sea.

By using the self-developed MFL detector, state-run China National Offshore Oil Corporation (CNOOC) says it will reduce its submarine pipeline inspection cost by 30 to 50 percent and will save at least 80 million yuan (over $12 million) per year alone, a CNOOC official said. The concern over intelligence leakage, allegedly acquired through the deployment of German and American - made MFL rivals, will also be eased.

IRAN AND INDIA IN SERIOUS TALKS TO BUILD 1400 KM OFFSHORE NATURAL GAS PIPELINE

In the wake of Iran's nuclear agreement with the P5+1 (the United States, the United Kingdom, France, China, and Russia, plus Germany), opening the door for Iranian exports of its hydrocarbons, the moribund Iranian - Indian Gas Pipeline Project is being revived with great fanfare.

Known as the SAGE pipeline (for South Asia Gas Enterprises Ltd., the Indian company leading the project) or the Middle East to India Deepwater Pipeline (MEIDP), the trans-Arabian pipeline would be one of the longest and deepest oil or gas pipelines ever built, running for 1,400 kilometers (870 miles) at depths of more than two miles underwater from the Iranian port of Char Bahar to India's Gujarat. Projected to cost $4.5 billion, the new pipeline would bring 1.1 billion standard cubic feet of gas a day to India, roughly doubling the country's gas imports and bringing much-needed energy to the country.

Pakistan has often been mentioned in the past as a critical transit land, but continued geopolitical tension between Pakistan and India as well as advances in undersea pipe laying technologies has prompted India to look at offshore alternatives.

At the same time, the Iran-India pipeline would face unique technical challenges. For one thing, most undersea pipelines run relatively close to shore, easing the challenges of construction, repair, and resupply. The Iran-India route is hundreds of miles out to sea - and it runs across an underwater fault line associated with the Owen Fracture Zone, an active seismic area.

"Negotiations are under serious consideration and we welcome India's participation," said National Iranian Gas Export Company managing director Alireza Kameli at the ongoing World Energy Policy Summit in New Dehli.

Iran and India are planing to build a 1400 km offshore natural gas pipeline

SENATE PASSES NEW LEGISLATION TO ENHANCE THE SAFETY OF THE 2.5 MILLION MILES OF PIPELINES IN THE UNITED STATES

Last week the Senate Commerce Committee passed the Safe Pipes Act, a preliminary step to reauthorize the Pipeline and Hazardous Materials Safety Administration (PHMSA) before House and ultimately Executive Level approval.

The final passage of the bill will give PHMSA enhanced authority to regulate the 2.5 million miles of aging pipelines in the United States, including the appointment of more regulators to monitor pipelines as well as a special writ to prevent "inadvertent releases" otherwise known as leaks in industry parlance.

Key provisions of the bill include:

- Re-prioritizing and requiring PHMSA to complete outstanding mandates from the 2011 reauthorization bill.
- Requiring PHMSA to prioritize statutory requirements for rulemaking over new rulemaking.
- Requesting that PHMSA conduct an assessment of inspections process and Integrity Management programs for natural gas and liquid pipelines.
- Encouraging PHMSA to investigate and report on advanced mapping technologies for pipeline networks.
- Providing direct hire authority to the agency so PHMSA can address its staffing challenges.
- Calling for minimum standards to ensure the safety of natural gas storage facilities.
- Ensuring coordination and collaboration on research, development, and technology between PHMSA, industry, and public sector stakeholders .

FLUXYS EXPANDS ITS INTEREST IN EUROPE'S GAS INFRASTRUCTURE WITH UK INTERCONNECTOR DEAL

The Interconnector Pipeline (© 2015 Interconnector)

Fluxys has tied up an agreement with Gazprom to acquire the Russian gas giant's 10 percent stake in the UK Interconnector, owner and operator of the offshore pipeline between the UK and Belgium.

The Interconnector is a vital bidirectional transmission link connecting the UK to Continental European markets. The pipeline offers the UK market both security of supply and a unique tool for physical export to mainland Europe, contributing to the diversification of sources for Continental Europe.

With the acquisition Fluxys become majority shareholder in Interconnector, with a 35 % direct share as well as a joint share of 31.50% with its industry partner, Snam. Walter Peeraer, Managing Director and CEO of Fluxys, said: "Through the acquisition of Gazprom's stake Fluxys becomes majority shareholder in Interconnector and we are fully aligned with our co-shareholders to move the company forward."

The Senate side of the United States Capitol in Washington, D.C.

TRANSCANADA TAKES ON THE US GOVERNMENT OVER KEYSTONE XL PIPELINE REJECTION

TransCanada, the Canadian energy giant aspiring to be the leading energy infrastructure company in North American, has filed suit against the Obama administration for rejecting last November the proposed 2,639-mile cross-border oil pipeline to the U.S. Gulf Coast known as Keystone XL.

In a lawsuit filed Wednesday in the U.S. District Court for the Southern District of Texas in Houston, Calgary-based TransCanada Corp. alleged that President Obama exceeded his constitutional power by denying construction of Keystone XL. In addition to the lawsuit, TransCanada filed a notice of intent to initiate a claim Wednesday under Chapter 11 of the North American Free Trade Agreement seeking to recover more than $15 billion in costs and damages it alleges it suffered "from the United States's breach of its NAFTA obligations."

The pipeline, which TransCanada first proposed in 2008, would have helped deliver up to 900,000 barrels of crude oil daily from the tar sands of the Canadian province of Alberta through the U.S. Great Plains and to the Gulf Coast.

The law suit has given rise to a mixed reaction from interested Canadian parties: Green Party Leader Elizabeth May said she expects that TransCanada will lose its NAFTA claim if not the lawsuit too. "The larger economic power virtually always wins," said May, a lawyer by training and the only Green Member of Parliament in Canada's House of Commons. TransCanada "can huff and puff and complain, but the U.S. made the right decision" in rejecting Keystone XL, May said. Indeed, no Canadian company has so far succeeded in a Chapter 11 claim against the U.S. government. The oil industry, on the other hand, contends Obama's decision to reject Keystone exceeded his constitution authority, since the regulation of domestic commerce lies within the purview of the legislative branch, not the executive.

The case before the Court will likely take years to resolve.

The projected route of Keystone XL Pipeline (© 2015 TransCanada)

Pipeline Technology Journal

www.pipeline-journal.net
ptj@eitep.de

Publisher
Euro Institute for Information and Technology Transfer GmbH
Am Listholze 82
30177 Hannover, Germany
Tel: +49 (0)511 90992-10
Fax: +49 (0)511 90992-69
URL: www.eitep.de

President: Dr. Klaus Ritter
Register Court: Amtsgericht Hannover
Company Registration Number: HRB 56648
Value Added Tax Identification Number: DE 182833034

Editor in Chief
Dr. Klaus Ritter
E-Mail: ritter@eitep.de
Tel: +49 (0)511 90992-10

Editorial Board
Advisory Committee of the Pipeline Technology Conference (ptc)

Editorial Management & Advertising
Design & Layout
Admir Celovic
E-Mail: celovic@eitep.de
Tel: +49 (0)511 90992-20

Editorial Staff
Dennis Fandrich: fandrich@eitep.de
Mark Iden: iden@eitep.de

Terms of publication
Six times a year, next issue: March 2016
Paper deadline: February 15th 2016
Advert Deadline: February 26th 2016

DEVASTATING GAS LEAKAGE IN CALIFORNIAN UNDERGROUND STORAGE FACILITY SPEWING 1200 TONS OF METHANE INTO THE TROPOSPHERE DAILY

After months of ongoing but unsuccessful efforts by Southern California Gas Company to stem a massive natural gas leak spewing methane and other gases from a suspected 7 inch diameter, 61 year old underground natural gas pipeline into a Los Angeles neighborhood, California Governor Jerry Brown declared a state of emergency last week. As a result thousands of residents are being evacuated and schools are closing, turning the community of Porter Ranch into a virtual ghost town.

Up to 1,200 tons of climate-changing methane daily have been released since it was first reported in October. Unable to stop the flow with an injection of liquid into the well, SoCalGas called in experts at Boots & Coots Services, the Halliburton subsidiary considered the best in the world at killing leaks in underground pipeline systems and storage facilities. The pipe is surrounded by a cavity and then a cement casing. Engineers think the gas leaks from the pipe at 500 feet, fills the cavity and then escapes at a lower depth where the cement casing ends, at about 990 feet. The engineers surmise that the gas forces its way through the soil to the surface. Thus far all of their work has not yielded the desired result and Boots & Coots estimates another two months are needed to restore the integrity of the underground system.

The gas leak is "one of the most devastating environmental disasters in the history of California," Los Angeles Councilman Mitchell Englander said Wednesday. Englander is one of a growing number of local officials and community members who urged the governor to act. Southern California Gas President Dennis Arriola said in a statement Wednesday that the company was focusing on stopping the leak and minimizing the harm to residents. The utility would work with the state to offset the long-term environmental impact of the methane, Arriola said.

Aliso Canyon gas leak site (© 2015 Scott L from Los Angeles, United States of America (1_D4C1832) [CC BY-SA 2.0])

In the wake of the crisis Governor Brown has also directed a long-term look at the future of gas-storage sites in the state, including whether the fossil-fuel facilities fit Brown's ambitious plans to ramp up the use of solar, wind and other, cleaner energy sources.

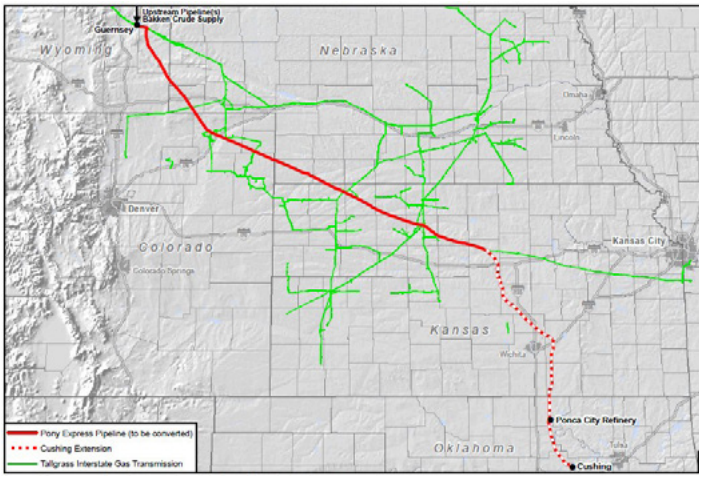
TALLGRASS ENERGY PARTNERS ACQUIRES BIG NEW STAKE IN THE PONY EXPRESS CRUDE OIL PIPELINE

Tallgrass Energy Partners (TEP) announced that it is acquiring an additional 31.3 percent interest in the 760 - mile Tallgrass Pony Express crude oil pipeline running from Guernsey, Wyoming to Cushing, Oklahoma.

The company will offer a cash consideration of $475 million and 6.518 million TEP common units issued to Tallgrass Development.

Based on TEP's December 31st closing price of $41.21, the total consideration of approximately $743.6 million represents a multiple of approximately 9.0x incremental cash flow to TEP as a result of the acquisition. The acquisition increases TEP's membership interest in Pony Express to 98 percent.

"This acquisition demonstrates our continued commitment to execute on our strategic plan to grow TEP and increase the cash distributions to our unitholders, even in challenging capital market conditions," said Tallgrass President and CEO, David G. Dehaemers, Jr. "The attractive acquisition multiple, the inclusion of equity consideration and other favorable terms of the purchase agreement showcase the supportive nature of TEP's relationship with Tallgrass Development."



Pony Express Pipeline PXP (© 2015 Tallgrass)

INSPECTION
INTELLIGENCE

NDT GLOBAL

EVO SERIES 1.0

THE FUTURE OF ULTRASONIC ILI TECHNOLOGY

HIGHEST PERFORMANCE AT MAXIMIZED FLEXIBILITY

- **No reduction of flow rate**
  Up to four times faster inspection speed
- **High performance crack and metal loss profiling**
  Up to four times higher axial resolution
- **Enhanced tool operation**
  Shorter tool lengths
- **Customization to your needs**
  Maximized ILI tool flexibility

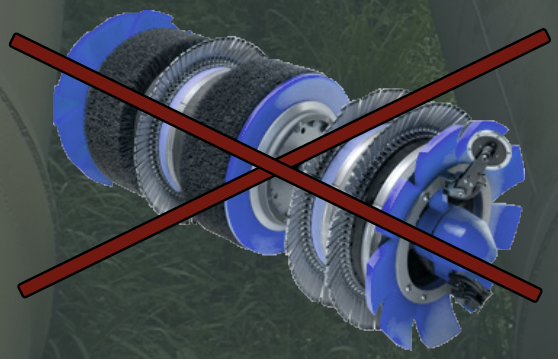
EVO SERIES 1.0
by NDT Global

www.ndt-global.com
Canada | Germany | Ireland | Malaysia | Mexico | Russia | Spain | UAE | USA

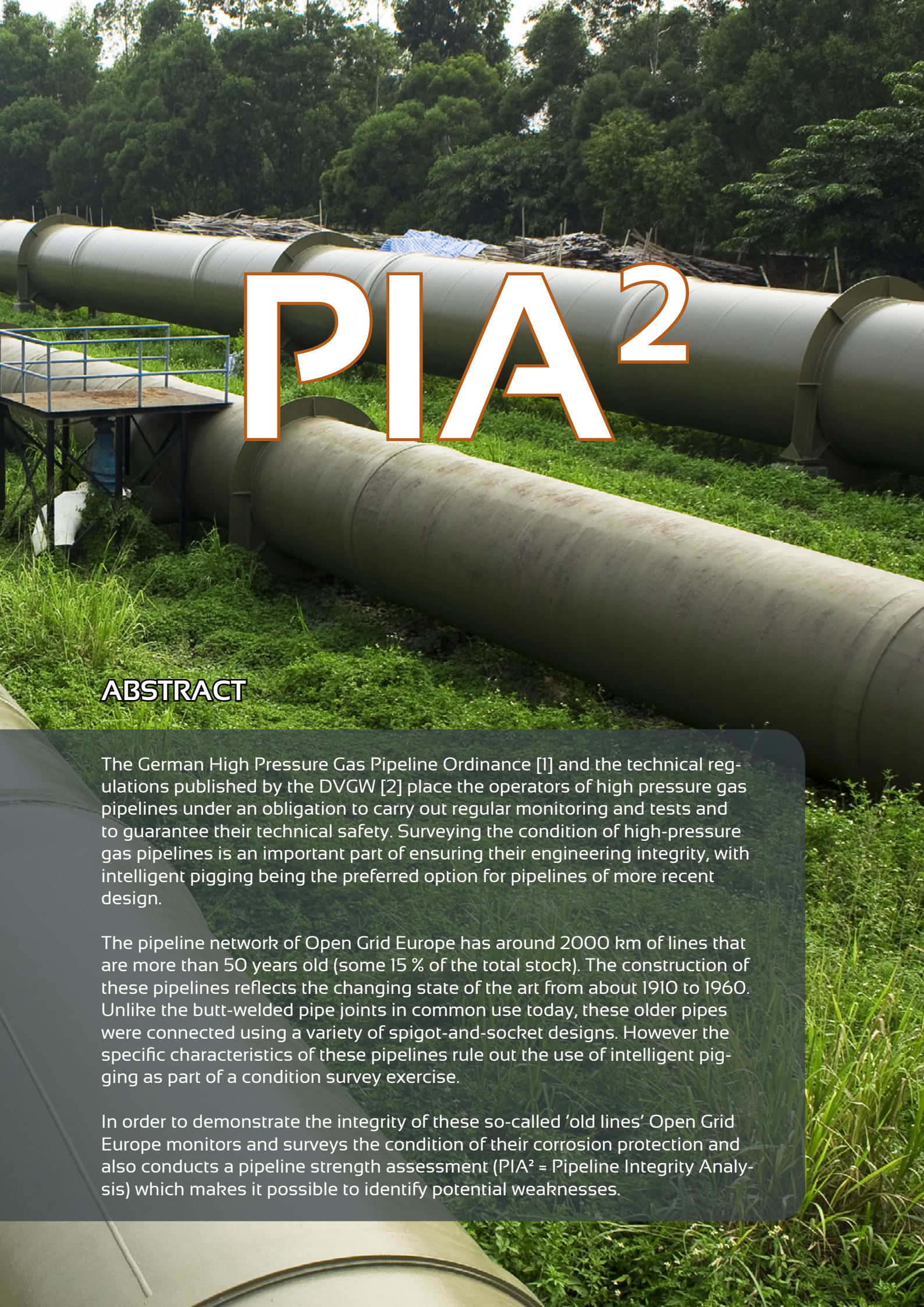
PIPELINE INTEGRITY ANALYSIS

Open Grid Europe GmbH
Dr. Carmen Acht, Dr. Ulrich Marewski, Dr. Michael Steiner

TÜV NORD Systems GmbH & Co. KG
Christian Engel



Non-Piggable Pipelines are a significant challenge for both, the pipeline operators and the inspection professionals. Frequently, the design of old pipes does not allow the use of comfortable state-of-the-art pigging solutions, increasing the need for alternative approaches.



PIA²

ABSTRACT

The German High Pressure Gas Pipeline Ordinance [1] and the technical regulations published by the DVGW [2] place the operators of high pressure gas pipelines under an obligation to carry out regular monitoring and tests and to guarantee their technical safety. Surveying the condition of high-pressure gas pipelines is an important part of ensuring their engineering integrity, with intelligent pigging being the preferred option for pipelines of more recent design.

The pipeline network of Open Grid Europe has around 2000 km of lines that are more than 50 years old (some 15 % of the total stock). The construction of these pipelines reflects the changing state of the art from about 1910 to 1960. Unlike the butt-welded pipe joints in common use today, these older pipes were connected using a variety of spigot-and-socket designs. However the specific characteristics of these pipelines rule out the use of intelligent pigging as part of a condition survey exercise.

In order to demonstrate the integrity of these so-called 'old lines' Open Grid Europe monitors and surveys the condition of their corrosion protection and also conducts a pipeline strength assessment (PIA² = Pipeline Integrity Analysis) which makes it possible to identify potential weaknesses.

HISTORY AND BACKGROUND

Pipelines with spigot-and-socket connections constructed between 1912 and 1958 were largely autogenously welded (up to around 1953) and in some cases electro welded (from around 1953). Initially these pipelines were operated without any cathodic protection (CP); CP was subsequently retrofitted to all pipelines by the early nineteen sixties. The pipelines were constructed with diameters of up to DN 800 using materials St34 and St35 with wall thicknesses of between 6 mm and 12 mm. The pipelines are generally operated at pressures below 16 bar.

The pipelines of the early years (spigot-and-socket lines) were built in the Ruhr district as part of plans to use the gas generated in coke ovens for long-distance transmission over a wide area and transport it to different consumers. Consequently much of this older pipeline stock is to be found in the Ruhr conurbation where initial defects in spigot-and-socket connections were identified as early as during the nineteen thirties [3]. The discovery of these defects prompted a number of refurbishment schemes in which many of these spigot-and-socket connections were either made safe or replaced. Even in recent years however, isolated defects in spigot-and-socket connections have been detected in the course of inspection operations.

The very location of these spigot-and-socket lines - many of them are in densely populated urban areas - rules out general renovation for a number of reasons. It was therefore necessary to develop an assessment method which facilitates selection and targeted upgrading. This method has been developed at Open Grid Europe over a number of years and today is used to evaluate pipelines with spigotand-socket connections which are unsuitable for pigging.

PIA² SURVEY SYSTEM

PIA² is a module of the overall Pipeline Integrity Management System (Figure 1) which addresses the specific safety and integrity aspects of spigot-and-socket connections [4]. Surveys of spigot-and-socket connections with PIA2 are planned and controlled by the Pipeline Integrity Management System and documented together with all resulting measures.

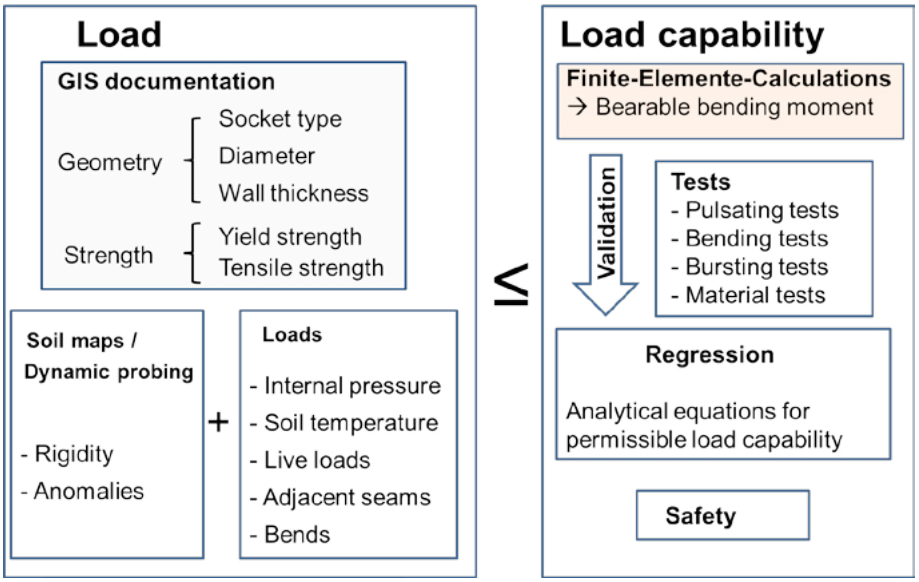


Figure 2: Schematic presentation of the PIA² survey system

The loadbearing capacity of the spigot-and-socket joint is compared with a potentially existing load (Figure 2). Finally, the survey applies certain factors of safety to make recommendations for where and to what extent further action is needed. This action is reviewed to take account of local conditions and may take the form of a simple check measurement, the upgrade of individual spigot-and-socket connections or the replacement of an entire section of pipeline.

DETERMING THE LOADBEARING CAPACITY OF SPIGOT-AND-SOCKET CONNECTIONS

Spigot-and-socket connections exist in different configurations. Figure 3 shows thesocket geometries which exist in the old pipeline network of Open Grid Europe for the 6°/10° cupped socket, the flanged socket, the twin flanged socket and the insertion socket.

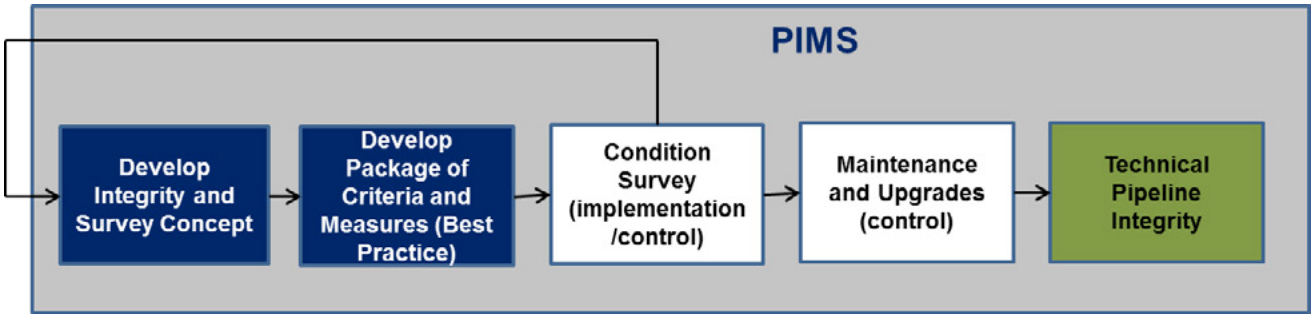


Figure 1: Pipeline Integrity Management System (PIMS) - Main processes

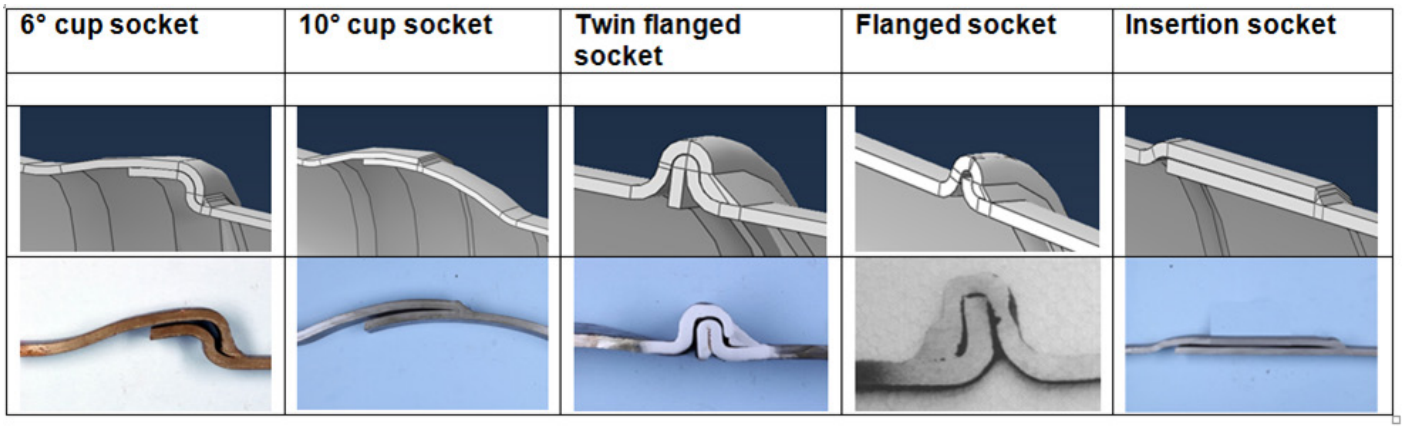


Figure 3: Types of pipe jointing sockets (Open Grid Europe)

The investigation revealed that the coating was a usually used bitumen insulating primer. The primer must had penetrated into the crack at a hot temperature during a coating process. It clearly showed that this longitudinal crack created already in the process of production and has existed in the pipeline for more than 40 years. During the whole period it remained hidden to all available internal inspection methods used in the last 13 years.

The load capability of the spigot-and-socket connections was determined by using elastic/plastic finite element simulations to numerically identify their strength. As part of the simulation the spigot-and-socket connections were subjected to stress using different combinations of bending and internal pressure up to calculated failure. The applied bending moment and the corresponding internal pressure at the time of failure represent the boundary loadbearing capacity of the particular socket. For example, Figure 4 shows the meshed model of a 6° cupped socket for the numerical simulation. Figure 5 shows the model loaded by internal pressure and bending and the resulting stress intensities.

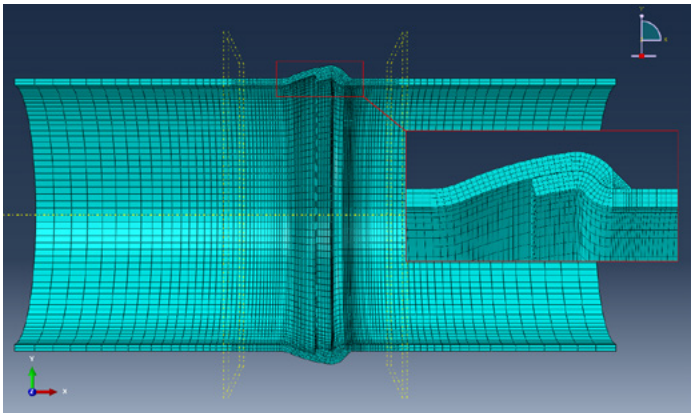


Figure 4: CAE network of the 6° cupped socket

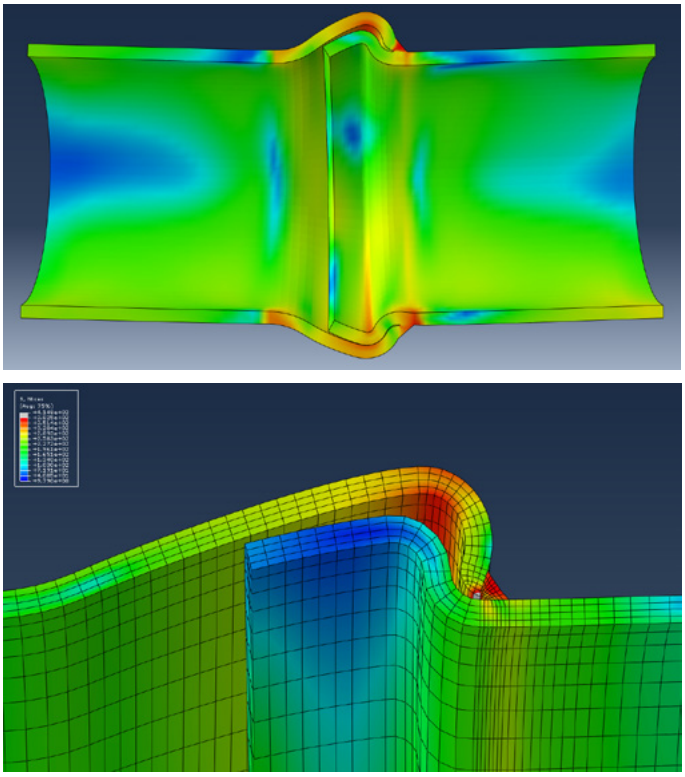


Figure 5: Simulating the load capability of the 6° cupped socket

The greatest loads are usually reached around the weld seams of the pipe joints. Depending on the combination of internal pressure and bending moment the instability of the system can occur on both the tension and compression side (due to buckling) of the bending line (Figure 6).

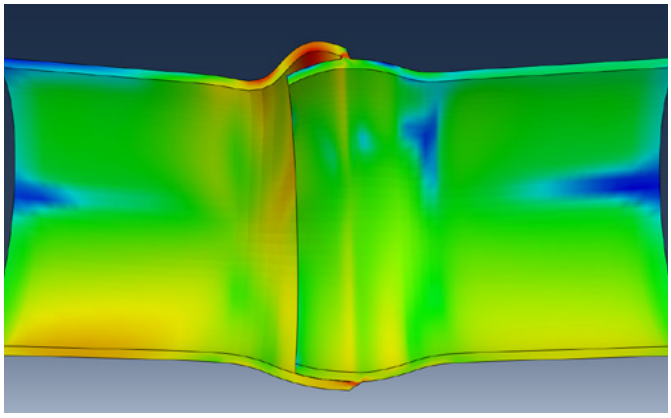


Figure 6: Instability due to buckling on the pressure side of the bend on the 10°

Different combinations of internal pressures and bending moments had to be simulated to determine the boundary loadbearing capacity of a socket. Sockets can also have different combinations of diameter and wall thickness so a very large number of numerical simulations were needed to generate complete limiting curves for the spigot-and-socket connections. Over 500 simulations were carried out in all.

When these simulations were complete, a regression analysis was used to convert the numerically calculated results to easy-to-handle analytical equations to describe the limiting curves. The chart in Figure 7 plots the loadbearing capacity of 10° cup sockets as a function of the outer diameter and the pipe's wall thickness. The limiting curves also indicate the influence of the mechanical and technological characteristics of the materials used.

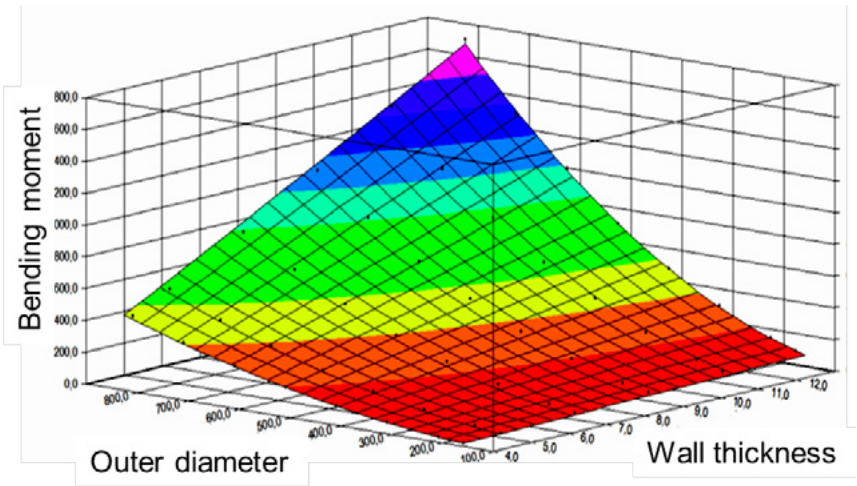


Figure 7: Load capability of the 10° cupped socket as a function of diameter and wall thickness

For the practical application of the limiting curves a graphic user interface was developed with which the corresponding limiting curves can be generated for every socket and for every possible combination of diameter, wall thickness and material characteristics (Figure 8). The calculated limiting curves are given a factor of safety of 2.5 against bending and 2 against internal pressure to consider potential uncertainties in respect of the welding seam as well as the variance in material properties and in component geometry. Under bending stress the 10° cupped socket and the insertion socket generally exhibit a more favourable behaviour than the 6° cupped socket and the twin flanged socket (see also [5]).

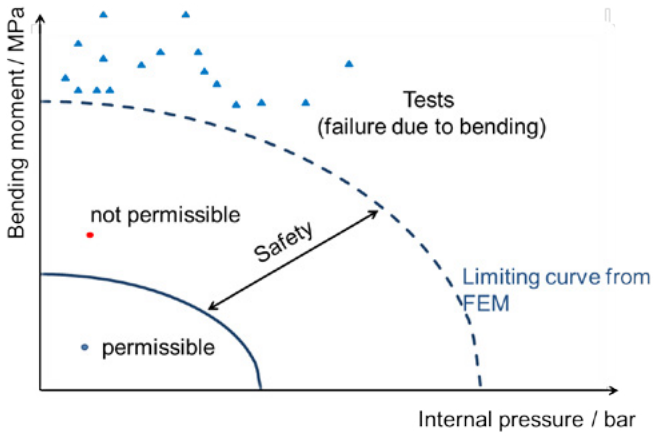


Figure 8: Boundary and admissible loadbearing capacities of a 6° cupped socket

As part of the PIA[2] survey the limiting curves as determined from the finite element calculations, and then reduced by the chosen factors of safety, are compared with a potentially existing load. If the resulting stress is outside the permissible limiting curve then a safety measure is implemented, e.g. spherical caps are welded on.

EXPERIMENTAL VALIDATION OF THE RESULTS

The boundary loadbearing capacities determined from the finite element simulations were validated by a large number of component experiments. Pipes incorporating spigot-and-socket connections were removed from sections of Open Grid Europe pipeline and subjected to a series of tests:

- Material tests (tensile tests, notched bar impact tests, hardness tests, metallographic investigations)
- Pulsating internal pressure tests to simulate cyclic fatigue
- Combined bending/bursting tests on a 4-point test stand

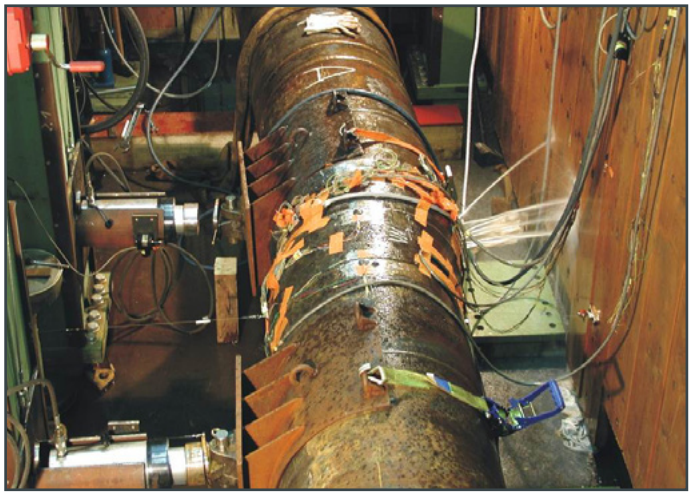


Figure 9: Combined internal pressure/bending test of a socket joint (test rig: Open Grid Europe)

Figure 9 shows a section of pipe with socket on the Open Grid Europe test stand undergoing a combined internal pressure/bending test at the moment of socket failure (leakage from the weld).

In all, more than 40 tests were performed on pipes with different spigot-and-socket connections and with a wide variety of diameter/wall thickness combinations. As well as the internal pressure and bending moment, stresses were measured at numerous points on the joints and the pipe using strain gauges to allow a comparison with the finite element calculations to be carried out. Taking into account the tests carried out on the components, the free boundary conditions of the finite element simulations were adjusted so that both the observed failure mechanism and the boundary loadbearing capacities achieved by the spigotand-socket connections were reproduced with sufficient accuracy or at least conservatively.

IDENTIFICATION OF LOADS

The true load to which a spigot-and-socket connection is subjected in reality is a function of many parameters and is often poorly understood in individual instances. When undertaking a survey therefore it is advisable to apply design loads that are as conservative as possible.

When identifying the load acting on a component, as well as internal pressure particular attention should be given to axial and bending forces which may also be present. The following loads are therefore taken into consideration:

- Internal pressure
- The longitudinal stress from possible soil settlement as a result of imposed loads (e.g. HGVs), allowing for local soil conditions and depth of coverage
- Longitudinal stresses due to seasonal temperature differences
- Longitudinal stresses as a result of welding operations (securing by means of spherical caps) carried out close to the sockets
- Increased longitudinal and bending stresses at elbows and bends
- Particular environment conditions (e.g. risk of settlement / subsidence, culverts, areas prone to flooding)

Determining additional stresses as a result of imposed loads is generally based on the requirements described in EN 1594 [6] Section 7.3/7.4 and Annexes A/F.

The size of the imposed load is selected according to DIN 1072 [7]. This defines a number of live loads (12 t, 30 t and 60 t) which can affect a pipeline if driven over. The bearing pressures on the soil resulting from the live loads were calculated with a finite element programme and match the particulars in [8] both qualitatively and quantitatively. This calculation also obtains the load on the pipeline or on the spigotand-socket connection; the rigidity of the soil and the depth of coverage must be seen as the main influencing factors here.

The possible longitudinal stresses due to differences in temperature between the ground and the pipe are calculated from the coefficient of thermal expansion of the pipe materials and an assumed temperature difference between the pipeline and the ground.

Practical experience shows that high longitudinal loads can occur in particular around spigot-and-socket connections that have already been upgraded with spherical caps as a result of inherent weld stresses. Open Grid Europe has undertaken extensive expansion measurements within the area of influence of welded-on spherical caps to quantify these additional stresses. The results of these investigations are taken into account in calculations, as is the additional load in the vicinity of elbows and bends.

Finally, all stresses arising from the individual load components are added together to form a total load. To assess the pipeline integrity, this total load is compared with the maximum permissible loadbearing capacity for each individual socket.

IMPLEMENTING THE PIA^2 SURVEY

Implementing the survey concept according to PIA^2, specific data which can be taken from the as-built drawings, the pipe logs, the geo information system (GIS) and associated soil maps are called for. Figure 10 shows a typical geographical location of a surveyed socket line. The soil conditions that are used in the calculation are derived initially from soil maps but if necessary they can also be determined with considerably more local resolution and precision by dynamic probing. Consequently the load variables can vary significantly depending on the location of the spigot-andsocket connection.

Figure 10: Typical GIS representation of a surveyed pipeline, showing the location of the spigot-and-socket connections to be upgraded

In terms of the magnitude of the assumed imposed loads, a distinction is made depending on whether the spigot-and-socket connections are close to buildings/roads (60 t) or are within undeveloped areas (12 t – 30 t). As well as data from the geo information system, experience gathered by the OGE field stations concerned is taken into account when specifying the particular load levels. To assess a section of pipeline, a load factor is determined from all the necessary input data for each individual spigot-and-socket connection; this load factor represents the ratio of calculated loading to the permissible load capability. If the utilisation factor is >1, further action such as safeguarding measures will be required.

SUMMARY

The pipeline network operated by Open Grid Europe has around 2000 km of lines that are more than 50 years old and which were constructed with spigot-and-socket connections. These gas transport pipelines were built and tested according to the state of the art known at the time. It is not possible to survey the condition of these lines using pipe pigs for example because the basic conditions necessary to carry out pig runs such as the required pressures, compliance with minimum pipe bending radii etc. are not met.

The PIA^2 survey system was therefore developed as a submodule of the Pipeline Integrity Management System (PIMS) to make it possible to compare a conservative, potentially existing load with the individual load capability of the pipeline joints. Although a survey using PIA^2 cannot altogether rule out future incidents affecting pipe integrity, the concept is nevertheless suitable for the selective identifying of sockets that require remediation and for performing a range of preventive safety measures. An expert opinion given by TÜV NORD [9] has asserted the conformity of the PIA^2 survey method described here with the current state of the art.

Authors

Dr. Carmen Acht
Open Grid Europe GmbH
Essen, Germany
carmen.acht@
open-grid-europe.com

Dr. Ulrich Marewski
Open Grid Europe GmbH
Essen, Germany
ulrich.marewski@
open-grid-europe.com

Dr. Michael Steiner
Open Grid Europe GmbH
Essen, Germany
michael.steiner@
open-grid-europe.com

Christian Engel
TÜV NORD Systems GmbH & Co. KG
Essen, Germany
cengel@tuev-nord.de

References

[1] Ordinance on High Pressure Gas Pipelines (High Pressure Gas Pipeline Ordinance – GasHDrLtgV), 18 May 2011, last amended 31.05.2013
[2] DVGW Code of Practice G 466-1, Gas pipelines made from steel pipes for operating pressure over 5 bar – Maintenance, November 2012
[3] Weckwerth, F.: Die Festigkeit und Beschaffenheit bisheriger und neuer Muffenverbindungen. Archiv für das Eisenhüttenwesen (1929) Vol. 3, p. 185 - 198
[4] Brecht, M.; Schülken, H.: Stand der europäischen und internationalen Normung zu Sicherheits- und Integritätsmanagementsystemen. Energie Wasser – Praxis (2012) Nr. 3, S. 42 – 49
[5] Wellinger, K.; Gaßmann, H.; Geilenkeuser, H.: Festigkeitsverhalten von geschweißten Rohrverbindungen. Heft 4, Technisch-wissenschaftliche Berichte der Staatlichen Materialprüfun sanstalt an der Technischen Hochschule Stuttgart, 1961
[6] DIN EN 1594 Gas Supply Systems – Pipelines for maximum operating pressure over 16 bar – Functional Requirements (2013)
[7] DIN 1072 Road Bridges – Design Loads (December 1985)
[8] VdTÜV Merkblatt Rohrfernleitungen 1063, Technische Richtlinie zur statischen Berechnung eingeerdeter Stahlrohre, May 1978
[9] C. Engel, Gutachterliche Äußerung zur Bewertungsmethode PIA^2 der Open Grid Europe GmbH für Muffen-und Siekenverbindungen in Gasleitungen, Neubewertung nach Erweiterung, TÜV NORD, 12.12.2014

11TH PIPELINE TECHNOLOGY CONFERENCE

23-25 MAY 2016, ESTREL CONVENTION CENTER, BERLIN, GERMANY

ptc

Platinum Sponsor

ROSEN
empowered by technology

Golden Sponsors

NDT GLOBAL

ILF CONSULTING ENGINEERS

Silver Sponsors

HERRENKNECHT Tunnelling Systems

GLD GOTTSBERG LEAK DETECTION

DNV·GL

an EITEP event

www.pipeline-conference.com

ptc ADVISORY COMMITTEE / ptj EDITORIAL BOARD

CHAIRMAN

Dr. Klaus Ritter, President, EITEP Institute

Uwe Ringel, Managing Director, ONTRAS Gastransport

MEMBERS

Muhammad Sultan Al-Qahtani, General Manager, Pipelines, Saudi Aramco

Arthur Braga, Director, RB&B Consulting

Mohamed Daoud, Manager (Projects QM), Abu Dhabi Company for Onshore Oil Operations (ADCO)

Andreas Haskamp, Pipeline Joint Venture Management, BP Europa SE

Maximilian Hofmann, Managing Director, MAX STREICHER

Dirk Jedziny, Vice President - Head of Cluster Ruhr North, Evonik Industries

Wolfgang Krieg, President, NDT Global

Ralf Middelhauve, Head of Central Dept. Process Industrie / Plant Engineering / Operation, TÜV NORD Systems

Hermann Rosen, President, ROSEN Group

Waleed Al-Shuaib, Manager Support Services Group (S&EK), Kuwait Oil Company (KOC)

Uwe Breig, Member of the Executive Board / BU Utility Tunnelling , Herrenknecht

Ricardo Dias de Souza, Oil Engineer - Senior Advisor, Petrobras / Transpetro

Dr. Hans-Georg Hillenbrand, Director Technical Service, Europipe

Dr. Thomas Hüwener, Managing Director Technical Services, Open Grid Europe

Cliff Johnson, President, PRCI - Pipeline Research Council International

Reinhold Krumnack, Div. Head, DVGW - German Technical and Scientific Association for Gas & Water

Prof. Dr. Joachim Müller-Kirchenbauer, Energie- und Ressourcenmanagement, TU Berlin

Dr. Prodromos Psarropoulos, Structural & Geotechnical Engineer, National Technical University of Athens

Juan Arzuaga, Executive Secretary, IPLOCA

Filippo Cinelli, Senior Marketing Manager, GE Oil & Gas

Jens Focke, CEO, BIL

Jörg Himmerich, Managing Director / Technical Expert, Dr.-Ing. Veenker Ing.-ges.

Mark David Iden, Director, Charterford House

Dr. Gerhard Knauf, Head of Div. Mech. Eng., Salzgitter Mannesmann Forschung / Secretary General, EPRG

Mike Liepe, Head Business Solution Line O&G Pipelines, Siemens

Frank Rathlev, Manager of Network Operations, Thyssengas

Ulrich Schneider, Business Development Manager Continental Europe, KTN

Markus Rieder, Head of Department Pipelines, TÜV SÜD Industrie Service

Prof. Dr. Jürgen Schmidt, Professor, Karlsruher Institut für Technologie (KIT)

Steffen Paeper, Offshore Engineering, South Stream

Tobias Walk, Director of Projects – Pipeline Systems, ILF Consulting Engineers

Carlo Maria Spinelli, Technology Planner, eni gas & power

Asle Venas, Global Director Pipelines, DNV GL

Heinz Watzka, Senior Advisor, EITEP Institute

Conference Management
Dennis Fandrich, Director Conferences, EITEP Institute

GAS LEAK DETECTION

Laser Methane Assessment

> by: Boris A. Horn > Business Development Manager > Pergam Technical Services, Inc.

Needless to say, safety is of the utmost importance within the gas transport industry. However, maintaining an effective emission monitoring and leak detection program in economical tough times is a challenge for operators. The approaches – or the utilized technologies - for the non-continuous leak detection have surprisingly changed little over the years. The tougher business environment in the gas industry and constantly stricter requirements from regulatory bodies give fresh impetus to alternative concepts such as the laser methane assessment.

Going back, there are three basic reasons why leak detection plays such an important part in the integrity management of a pipeline. There is the safety aspect which is beyond dispute. An incident quickly costs millions and severely harms the reputation of the company. With the 'go-green-movement' and all the different greenhouse gas emissions programs from several national and international environmental protection organizations, the general public has a close eye on the gas industry and its eco-credentials.

By the same token, the financial losses through leaks are substantial. Even through a medium sized leak, an amount of gas escapes that would have brought considerable income over time. By saying this, it becomes obvious that time – or rather the frequency – plays an important role in the leak detection program and its financial impact. "Find the leaks and find them fast" was recently the statement by an integrity manager after a presentation about leak detection programs. This statement defines the theme in a nutshell.

TRADITIONAL INSTRUMENTS VS. LASER METHANE ASSESSMENT

As diverse as the international gas industry is, the approaches to leak detection are diverse. Traditionally, a crew equipped with some kind of gas detection device such as a flame ionization detector (FID), a combustible gas indicator (CGI) or a gas sniffing dog walks or drives over the pipeline corridor and looks for gas indications. Excluding the dog, all technologies measure the gas concentration fairly accurate and the size of the leak can be pinpointed.

"An effective emission monitoring and leak detection program in economical tough times is a challenge for operators."

> Boris. A. Horn

Bell 206 JetRanger

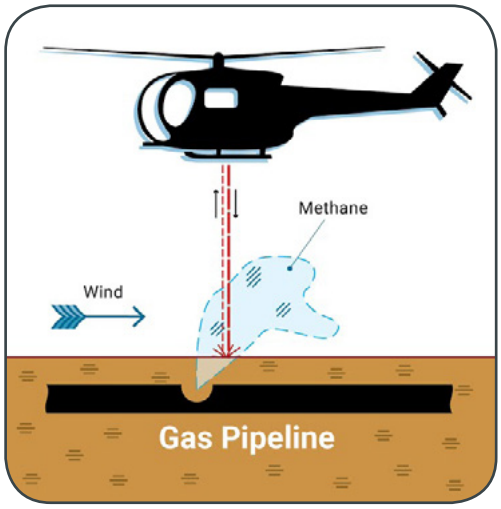
The multi-purpose helicopter can be quipped with Pergam's laser system within only one hour.

Used mainly for transmission lines, operators often trust a visual inspection from an aircraft. An observer on board looks out for starved vegetation over the pipeline; an indication for a leak. The vegetation situation as well as construction activities (especially earth movement) within the right-of-way are another required check during the patrols. Interestingly enough, even operators of pipelines with an installed continuous leak monitoring system often still complete an aerial or ground based leak detection.

There are basically two characteristics that distinguish a laser from a FID or CGI instrument: the laser can detect emissions remotely with up to 10 pulses per second. Within the application, this means that the crew doesn't have to be positioned over the pipeline and the potential gas cloud. Later, I will address the point why detection over a distance as well as speed can be very handy besides the increased safety for the crew. Furthermore, the laser can even measure through some materials like glass – an excellent characteristic of the technology to assess an emergency situation.

The sensitivity of a laser based detector is excellent, even the smallest emissions can be detected. If it comes to the accuracy of the measurement result, the FID or CGI wins the race. Nevertheless, the accuracy of a laser is more than sufficient for pipeline leak detection programs and finding the leak is commonly the priority and high accuracy quantification is optional. Comparing the deliverable from a pure visual patrol with a technology supported patrol; the value is based in the complete documentation and the early detection of minute leak indications.

Nowadays, leak detection lasers, including the related optics and electronics, are available in all sizes and designs. From handheld devices, over vehicle / aircraft mounted systems up to fixed installed platforms for single- or multipoint monitoring are commercially available and field-tested. A fairly new application of laser methane assessment systems for mainly LNG terminals are fixed installed monitoring solutions. Using highly effective retroreflectors, there are measurements along a line with a distance up to 2.5 miles (4 km) possible.



Laser Methane Assessment

The figure 1 above illustrates the basic principle of aerial laser methane assessment. The laser light is partially absorbed if methane is present somewhere along the path.

The base of laser methane assessment is a tunable diode laser that emits in the spectral range of 1.65 nm. At 1.65 nm, methane has very high absorption characteristics that makes this concept so effective. The laser is targeted through mirrors or prisms to the pipeline. The beam is reflected on the surface (either on the pipeline itself or in underground networks on the surface over the pipeline). The backscattered light is collected in the optical unit of the system and through spectroscopic signal demodulation and a complex algorithm, the gas concentration can be calculated if methane is present somewhere along the laser path [1]. This method can be used for many different gases, as long as the gas has a high absorption in a certain spectral range. Unfortunately, major changes in the laser, filter and algorithm are necessary to adapt a system to another gas.

If talking about aerial applications, low altitude and low speed are safety concerns. It is easy to imagine that the sensitivity is dependent on conditions like wind, distance and background. Modern aerial laser methane assessment systems can be flown at 500 ft. (150 meters) over the pipeline up to 90 mph (145 km/h) and deliver excellent results, even in windy environments up to 25 kt. This flight configuration gives the pilot enough time to start an autorotation landing in case of a turbine failure. The highest sensitivity is obtained at 250 ft. (75 meters) with maximum 15 kt. winds. Other aerial technologies have the benefit of visualizing the leak and can also detect different gases. Quantification is almost impossible and very specific weather conditions need to be present during the inspection to have enough radiation for the technology to work. These limitations restrict the commercial operation of these technologies in the field.

"This method can be used for many different gases, as long as the gas has a high absorption in a certain spectral range"

> Boris. A. Horn

Almost all systems today that are based on the laser methane assessment concept have a built-in reference cell. This reference cell is primarily used to get a stable signal of the reference channel but secondary also for an automatic system test and calibration check. Users of traditional instruments know the elaborate procedure of the daily check to ensure that the equipment works. In some countries, the check is even mandatory in regards to regulations. Besides this daily check, a yearly recalibration is required for most of the instruments. The built-in reference cell lasts up to six years and waives the yearly recalibration. Furthermore, it runs the system check automatically at each start-up. The process is usually done in three steps. In step one, the concentration of the reference cell is confirmed. Step two self-checks the instrument and step three is the calibration-check. Only if all three steps have successfully passed can the system be operated. These capabilities help to keep the costs of ownership low through saving time for the system check and especially the waived yearly calibration. Depending where the next service center is located, a calibration can typically take several weeks and can cost up to 12 % of the equipment price.

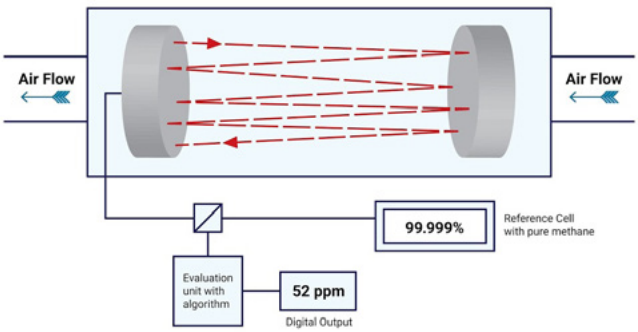
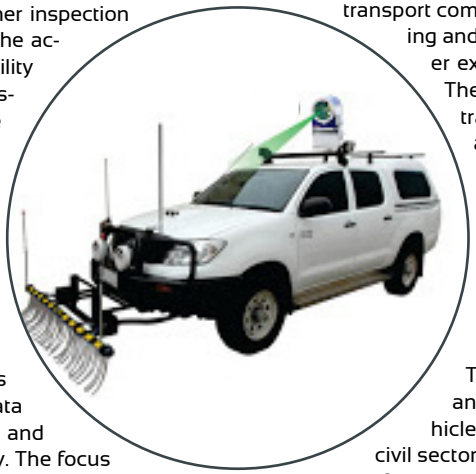


Figure 2: Multi Pass Cell

MULTI PASS CELL FOR VEHICLE BASED PATROLS

The gas concentration on the surface in city applications through low pressure pipelines is often extremely small. A special design of the laser methane assessment platform utilizes a multi pass cell in order to achieve sensitivities better than 0.1 ppm. The employed multi pass cell in the SELMA MPB systems reflects the laser 108 times (see graphic). A pump constantly sucks in air samples through nozzles close to the road surface and blows the sample through an optical channel. The alignment of the laser requires the highest precision in the optical channel, the use of only materials that are temperature stable and an installation with highly effective shock absorbers. The manufacturing effort with this extraordinary precision results in relatively high system costs. However, the high sensitivity and the stable readings can be utilized to gain inspection speed. Together with high capacity pumps, an inspection speed up to 30 mph (50 km/h) can be archived. The higher inspection speed might not sound crucial but considering the accidents that are caused through slow driving utility inspection vehicles, the speed remarkably increases the safety for the surveying team. Besides the economic advantages of having the job done faster, the higher investment is consequently justifiable.



VOICE FROM THE MARKET

Within the scope of its innovation process, Pergam has conducted a user study with 46 gas transport companies from 18 different countries regarding leak detection. The objective was to learn the work flow from planning through data archiving, the value in the leak detection chain and specific issues with today's available technology. The focus group were transmission pipeline companies without an internal continuous leak monitoring system. The result of the study shows that the three main concerns are data management, operator qualification / operator supervision as well as having proof of inspection that meets the requirements of the regulatory bodies, sometimes even the company internal compliance standards.

PROOF OF INSPECTION

When speaking about documentation, surprisingly many companies still use paper maps to plan, conduct and analyze the leak survey. The 'boots on the ground team' marks the areas that they have inspected and leaks are indicated with a marker or simply with sticky notes. This might sound very basic but there are a large number of utilities even in the developed countries that still follow this procedure. The operating platform of all laser methane assessment systems is fully digital which simplifies reporting capabilities. A GPS module or a connection to a mobile phone tracks the inspected route and matches the gas indications with the location. Furthermore, the data can be analyzed for quality assurance purposes of the patrol. The hired crews do not always follow the inspection procedure. A common problem is that leak surveyors use some kind of vehicle instead of walking to save time. In this case, the variance in speed shows the 'simplification measures'. Overlaying the shape files of the grid with the inspected route gives a clear overview about the inspection process. The logged data contain the track, time and date stamp, notes from the operators and basic instrument information together with the measured gas concentration. This information can be processed for compliance reports and saved in all formats. Optional available geo-referenced still frame or video cameras provide additional information for easy location of the found leak.

DATA MANAGEMENT

With the mass of data available in today's world, everyone seems to know the problem of data management. During the conducted survey in 2014 about the further use of the leak data, from which departments the data are used, who and how data can be reviewed and updated, it turned out that the bottleneck are often the highly paid internal GIS and IT experts. These departments are often required to enter the data in a management software or the field inspection software. A major gas transport company in Canada stated that the costs for preparing and post-processing the inspection data are a higher expenditure than conducting the field inspection. The inspection work itself is conducted by a contractor who gets the shape files and delivers back a report about the assets with a leak. This issue was addressed in the latest software and data can be imported and exported in a variety of industry standard data formats directly to and from the laser methane assessment platform.

THE LATEST AND GREATEST - UAV LEAK DETECTION

There are not many markets that are so dynamic and full of innovations as the unmanned aerial vehicle (UAV) industry. Within only a couple of years, the civil sector grew to a multi-million industry. The Unmanned Aircraft Systems report by the Congressional Research Service from September 2015 estimates 300,000 sold nonmilitary UAVs with projected revenues of $200-$400 million in 2015 [2]. A UAV methane sensor dedicated to the gas industry has been launched in the middle of 2015 and immediately received enormous interest from UAV manufacturer and UAV service providers but also from gas utilities. UAV providers consider the platform often as panacea for inspection tasks. The gas industry itself is more hesitant and sees it more as an additional tool.

Application studies showed that a UAV equipped with a camera and the laser methane sensor is excellent for inspections of spans e.g. pipes underneath bridges or the inspection of gas storage tanks; applications where traditionally scaffolding or a lifting platform were required. Another confirmed practicable application is the pipeline inspection in rural areas with pipelines through agriculture fields. A ground based inspection is possible but if grain is tramped down, the utility often has to compensate the damage. Inspectors in residential areas know the hassle if the last part of the line and the meter is behind a closed fence. Contacting the owner to agree a new appointment for the inspection is time consuming and expensive. The UAV based sensor enables them to continue the rest of the inspection without any mayor delay. The same applies to assets in back yards that have to be inspected. Applications beyond the pipeline industry are emission monitoring on landfills, the check of wellheads or measurements for first exploration indications.

The solution based on a variety of UAVs is commercially available and successfully tested. However, it is at this point in time only partially used in the industry. An obstacle in many markets is the unclear situation of the regulations. The national aviation authorities of most countries work on a framework for regulations but very little is adopted. The Federal Aviation Authority of the United States (FAA) requires, in addition to other requirements, visual contact with the UAV [3]. A typical distance for line of sight is 1.5 miles (2.4 km) – a distance that makes the inspection of even a small grid already difficult. Other countries have similar rules. Japan and Australia have probably one of the most developed UAV regulations. In these countries, UAVs are already established in other applications such as agricultural spraying. Another obstacle is the battery capacity today – not many platforms are able to stay longer than 40 minutes in the air before the batteries need to be swapped. Despite all the restrictions, a UAV equipped with a gas sensor and cameras is a very valuable additional tool for the right applications. For the classical long distance patrol, the main aerial platform will probably remain the helicopter and fixed wing planes for the next few years.

FUTURE

According to the Global Industry Analysts gas detection equipment report from September 2015, the global market for gas detection equipment is projected to reach US$ 3.2 billion by 2020, driven by the growing number of safety and environmental regulations worldwide [4]. For example, in October PHMSA (Pipeline and Hazardous Materials Safety Administration of the United States) proposed regulations for a more complete system for detecting leaks as well as inspections of affected pipeline following extreme weather events or natural disasters [5]. Currently, this proposal has only been reviewed but this and many other international rulemaking proposals will certainly lead to more stringent rules about pipeline leak detection around the world. New technologies such as the laser methane assessment and more automated data management systems with direct integration of the leak detection data into the work flow will be adapted from the industry and economize the leak surveying.

LMmini
A portable laser methane assessment instrument, initially.

References

[1] Hodgkinson J., van Well, B., Padgett, M., Pride, R,D., Modelling and interpretation of gas detection using remote laser pointers, Spectrochimica Acta Part A 63 (2006) 929-939, 2005
[2] Canis, B., Unmanned Aircraft Systems (UAS): Commercial Outlook for a New Industry, Congressional Research Service 7-5700 - R44192, 2015
[3] Federal Aviation Administration Press Release dated Feb. 15, 2015, Summary of Major Provisions of Proposed Part 107, 2015
[4] Global Industry Analysts, Inc., Gas Detection Equipment September 2015, Global Strategic Business Report 2014-2018 ID 347950, 2015
[5] Pipeline and Hazardous Materials Safety Administration (PHMSA), Department of Transportation (DOT), Notice of proposed rulemaking, Docket No. PHMSA-2010-0229, BC 4910-60-W, 2015

Author

Boris A. Horn
Pergam Technical Services, Inc.
Business Development Manager
Seattle, USA
bhorn@pergamusa.com

PIPELINE CORROSION

Due to Interference from High Voltage Transmission Line

> by: Yadav, B.D. > Executive Director (Operations) > Indian Oil Corporation Limited (Pipeline Division)

CASE STUDY

Abstract

In early years, when pipeline industry and HT transmission system were not so developed in India, AC interference for underground pipelines did not receive adequate attention. In recent years, due to paucity of land and lack of clear policy on utility corridors have led a situation, wherein cross country Oil & Gas pipelines are running parallel to HT transmission lines. AC interference on pipelines is a real and serious problem which can place both operator safety and pipeline integrity at risk.

When a long-term induced AC voltage exists on a pipeline, it can be dangerous and potentially Life-threatening for operations personnel to touch the pipeline or appurtenances as well as it can lead to pipe corrosion resulting from discharge of current.

Indian Oil Corporation Limited is India's largest company by sales with a turnover of over $76,250 million for year 2013-14. Indian Oil is also the highest ranked Indian company in Fortune 'Global 500' listing, ranked at 96th position. Indian Oil is an integrated energy company, with significant presence in refining, transportation, marketing and petrochemicals business. It also operates about 12000 km of petroleum pipelines, crude oil pipeline, multi product pipelines, dedicated LPG pipelines, Naphtha pipelines, Gas pipelines etc.

The paper presents a case study of about 100% metal loss in a 24" dia crude oil pipeline, having 6.4 mm wall thickness, apparent due to interference from HT AC transmission line is presented in the context of pipeline industry in India and also brought out the constraints pipeline industry face while mitigating different type of interference.

INTRODUCTION

Till 1990s, there were very few cross country pipelines were in India and, even if there were AC transmission lines were there, they used to cross the pipeline at 75 to 90 degree. After 1991, both power industry and pipeline industry saw rapid developments. However, both the industry faced same sort of challenges wherein land owners refused or resisted laying pipelines or transmission lines in their land. Though Government policies facilitated acquiring right-of-way for pipelines through consulting process, it was easier for both pipeline operator or transmission line operator to acquire right of lay pipeline or transmission line, if a transmission line or pipeline is passing through the land or corridor earlier and thereby, making the land unusable for residential or commercial developments.

Thus, tin last 10 years or so, it is quite a common sight to see pipeline corridors running parallel to transmission line networks. Unlike transmission lines, underground pipelines are not visible to outside world, but, pipeline operators in India are aware of the problem. Though most of the pipeline operators are sensitive to the increased tendency to lay transmission lines in utility right-of-way (ROW) of pipelines or vice versa, problems like AC corrosion in pipelines have still not received adequate attention of pipeline operators.

When steel pipelines traverse close to overhead electric transmission lines, interference can occur between the electric lines fields and the pipeline, as seen in Figure 1.1. Electric power is transmitted in three phase systems and on one or double circuit structure; each carried on a separate line held aloft by pylons or towers along the right of way.

The voltage sequence of the power is sinusoidal AC power phase and is 120° out of phase with the other two. If each phase is equal, the sum of the alternating currents in the three phases and the sum of the magnetic fields resulting from the alternating current in each phase should add up to zero in balanced three phase system. However, different distances between the pipeline and each phase in the transmission line, along with phase imbalance, lead to induced AC interference on the pipeline. Coatings on pipelines are provided so as to make impressed current cathodic protection system effective. However, paradox is that good coating system creates hurdle in AC mitigation problem as better coating leaves fewer defects in the coating for AC current to go to ground. Earlier, less well coated pipelines had sufficient grounding and thus, induced voltages were not a practical problem.

In India, there is another major problem which makes interference issues more intense in certain pipeline corridors. Due to high population density and limited availability of land, certain pipeline corridors have 5-6 pipelines of different diameter, different coating and pipelines laid at different timelines. As these 5-6 lines are laid at a lateral distance of 4-5 meters and all of them are cathodically protected, which further interference issue much more complicated.

"AC Interference on pipelines is a real and serious problem which can place both, operator safety and pipeline integrity, at risk."

> Yadav, B. D.

In India, many cross country pipelines are running parallel to HT transmission lines.

TYPE OF AC INTERFERENCE

AC interference between transmission systems and buried pipelines can be of three kinds:

Electrostatic or Capacitive Interference

In case of capacitive interference, a pipeline laid in the vicinity of transmission line picks up a voltage relative to the soil, which is proportional to the voltage in the transmission line.

Resistive or Ohmic Interference

Occur when lightning strikes a transmission structure, or when there is a phase-ground fault. When this occurs, a large voltage cone is created around the pylon grounding system. If a pipeline is located within this area, voltage can get onto the pipeline in the area within the voltage cone through coating defects. Anyone touching the pipeline outside the voltage cone could receive a shock from the potential between the pipeline and the surrounding soil.

Electromagnetic or Inductive Interference

This type of interference occurs when high voltage transmission pipeline runs close and parallel routing with underground metallic pipelines. The pipeline picks voltage due to any phase imbalance in the lines. The likelihood of interference increases with rising operating currents in the overhead lines, with increasing quality of the coating on the pipeline, and with the length of line parallel to and close to the high voltage AC (HVAC) transmission lines. Voltages are induced in the pipeline by magnetic coupling with the high-voltage lines, and results in currents flowing in the pipeline. These currents result in a voltage difference between the pipeline and the surrounding soil.

CASE STUDY

Indian Oil Corporation Limited is India's largest company by sales with a turnover of over $76,250 million for year 2013-14. Indian Oil is also the highest ranked Indian company in Fortune "Global 500" listing, ranked at 96th position. Indian Oil is an integrated energy company, with significant presence in refining, transportation, marketing and petrochemicals business. IOCL, with more than 11000 km of liquid hydrocarbon pipelines, has over 50 years experience in operation and maintenance of liquid hydrocarbon pipelines in different terrain of India.

This example is from its 1870 km long largest crude oil pipeline of IOCL. Salaya-Mathura pipeline, till 1997, was km long pipeline feeding crude oil from Salaya port to two of its refineries at Vadodara and Mathura. In 1997, one 347 km branch was added to link its upcoming Panipat refinery from Chaksu. Simultaneously, capacity of its 602 km 24" diameter Viramgam-Chasku segment was augment from 7.5 MMTPA to 13.5 MMTPA by adding 2 intermediate pumping stations and adding 110 km of looplines in 4 different segments.

One of the such loopline was 16.07 km long Sidhpur-Sherpura loopline was in Mehsana district of Gujarat State of India. Unlike old SMPL, which have comparatively poor coating conditions due to over the ditch coaltar enamel coating prevailing in 70s/80s, this loopline was made of plant coated 3 layer polyethylene coating. Thus, this loopline was having excellent coatings as compared to mainline.

IOCL provides best available coating, as primary protection against corrosion, to its pipelines supplemented by Cathodic Protection system. IOCL also carried out intelligent pigging of its pipelines at fixed periodicity to identify repair & maintenance requirement.

Both old mainline and new laid loopline were cathodically protected. Due to good coating, loopline was having only one transformer-rectifier unit for meeting impressed current requirement of loopline as against more than 2 units for identical length of mainline. A comparison of current requirement of old mainline and new loopline for identical length is as under.

	DC Output Current (A)			
	2010	2011	2012	2013
Sidhpur (M/L)	11.3	7.8	0.6	0.5
Chapi (L/L)	9.2	8.7	3.5	2.0
Chapi (L/L)	0.4	0.5	0.7	1.1
Palanpur (M/L)	9.8	4.5	3.9	3.0

DC Output Table

The entire loop line was cathodically protected consistently though current requirement for maintaining comparable pipe-to-soil potential (PSP) level was also increasing consistently. Refer PSP profile at Figure 1.

FINDINGS OF INTELLIGENT PIGGING

Though Sidhpur-Sherpura pipeline was commissioned in 1997, it was 2014, when IPS of Sidhpur-Sherpura loopline was carried out. Incidentally, Closed Interval Potential Survey of this pipeline section was also carried out about 2 months prior to IPS survey.

During intelligent pigging of Sidhpur-Sherpura, a signification metal loss (78%) feature was reported at Chainage5.7 km; though quarterly pipe-to-soil potential survey as well as CIPS survey report did not indicated at localized problem at given location as indicated in Exhibit 1 and 2. As the reported metal loss location was just 5.7 km away from the pumping station and was in high pressure zone, this location was immediately excavated for verification of reported anomaly.

It was also seen that the reported location was just adjacent (1m away) to a 66 KV power transmission line, running parallel to underground pipeline (Figure 4).

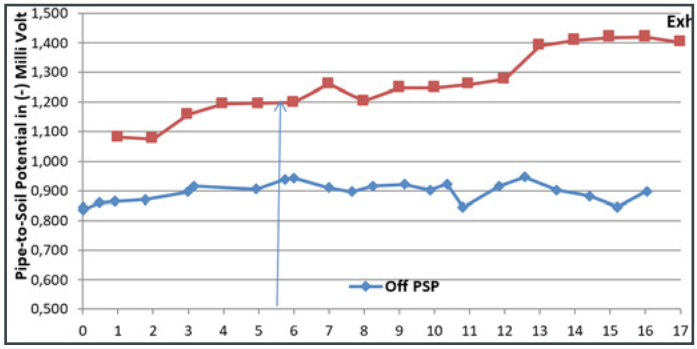


Figure 1: PSP Profile of Sidhpur-Sherpura Loopline

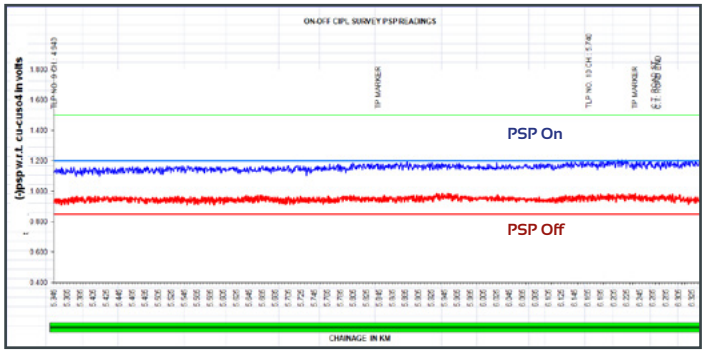


Figure 2: Close Interval Potential Survey in and around fault location, prior to identification of fault in Intelligent Pigging Survey

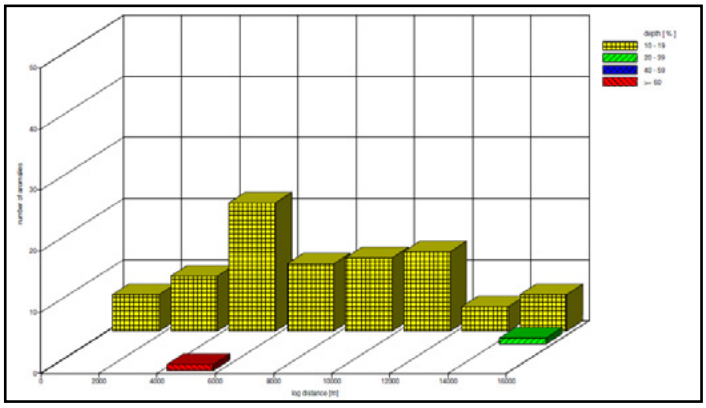


Figure 3: Distribution of Metal Loss Features in Intelligent Pigging in Sidhpur-Sherpura Loop line after 17 years of Operation

Getting Close

Indian pipe and a transmission line

On excavation, coating of the pipeline was observed to be relatively good conditions except for pinhole type damage on exterior of coating (Figure 5).

On removal of the coating an unusual pitting at unusual location (on spiral weld itself) was observed (Figure 6), implying flow of heavy current though that location. Incidentally, coating conditions and pipeline conditions, adjacent to this anomaly, were found to be in excellent condition.

It is also noteworthy to note here that IPS conducted 4 year back on the mainline, which was having much poor coating, did not indicate any major anomaly at the subject location.

ACKNOWLEDGEMENT

The authors would like to express their gratitude to all the support received during the course of this research from Indian Oil Corporation Limited, which allowed use of their own survey results to facilitate more research of the subject for the benefit of pipeline industry.

CONCLUSION

1. Pipe to Soil Potential surveys or even Close Interval Potential surveys may not be adequate to indicate A.C. interference issues.
2. As pipelines with good coating are more susceptible to A.C. interference, in case pipeline corridor is selected parallel to AC transmission line, suitable mitigation measures should be provided since construction of the pipeline itself.
3. AC interference is one issue, which can lead to significant damage to pipelines in short span of time. Considering huge consequential losses in case of pipe failures in case of Oil & Gas pipelines, policy makers should consider segregating pipeline corridors from power line corridors.
4. Existing protection mechanisms are costly as well as pone to damages and vandalism. Even if pipeline operators provide these mechanisms, they do not last long. There is need to make these mechanisms more robust and vandal proof.
5. Interference survey should also be carried out at periodic interval to confirm adequacy as well as healthiness of interference protection mechanisms.

References

[1] Peabody, A. W., and A. L. Verhiel, "The Effects of High Voltage Alternating Current (HVAC) Transmission Lines on Buried Pipe Lines," Paper No. PCI-70-32, Presented at the Petroleum and Chemical Industry Conference, Tulsa, Oklahoma, Sept. 15, 1970]
[2] M. H. Shwehdi and U. M. Johar "Transmission Line EMF Interference with Buried Pipeline: Essential & Cautions," Proceedings of the International Conference on Non-Ionizing Radiation at UNITEN (ICNIR 2003) Electromagnetic Fields and Our Health, 20th–22nd October 2003 Pipe line and Gas Journal, October, 1997
[3] A.C. induced current directive of State of Israel Ministry of Energy and Water Natural Gas Authority [http://energy.gov.il/Subjects/NG/Documents/Directive/34537-ACInducedCorrosionDirectiveRev.pdf; assessed on February 4, 2015]

Author

Yadav, B.D.

Indian Oil Corporation Limited

Executive Director (Operations)

Noida, India

yadavbd1@indianoil.in

Organised by:

Media partner:

ME PIPETECH

21st - 22nd March 2016
Rosewood Hotel Abu Dhabi, UAE

"Best practices to prolong the safe life of Pipeline at reasonable cost within the acceptable operating window."

COMMITTEE

Amer Al Shaikh Ali – **CEO, Abu Al Bukhoosh, Total UAE (Conference Chairman)**
Khalid Al Marzouqi – **COO, Dolphin Energy**
Mohammed Abu Four - **NDT Specialist, Saudi Aramco**
Auday Al Monam – **Asst. VP - Coating, Pipeline, NPCC**
Saif Ahmed Al-Shehhi – **Subsea Integrity Team Leader, ADMA**
Mohamed Ali Jaber – **Application Manager (Pipes), Borouge**
Abdullah Nami - **Sr. Project Engineer, Saudi Aramco**
Yahya G. Asiri - **Operations Manager, Tasnee**
Marwan Al Shamsi - **I&C Manager, ADCO**
Orlando Matos - **Head of Inspection, GASCO**
Sambar Mandal - **Inspection Section Head, Takreer**
Fidel Sanchez - **Pipeline and Inspection Team Leader, Shell UAE**

KEY SESSION TOPICS:

- Design & Planning
- Fabrication & Construction
- Operations & Integrity
- Rehabilitation Techniques & Life Extension

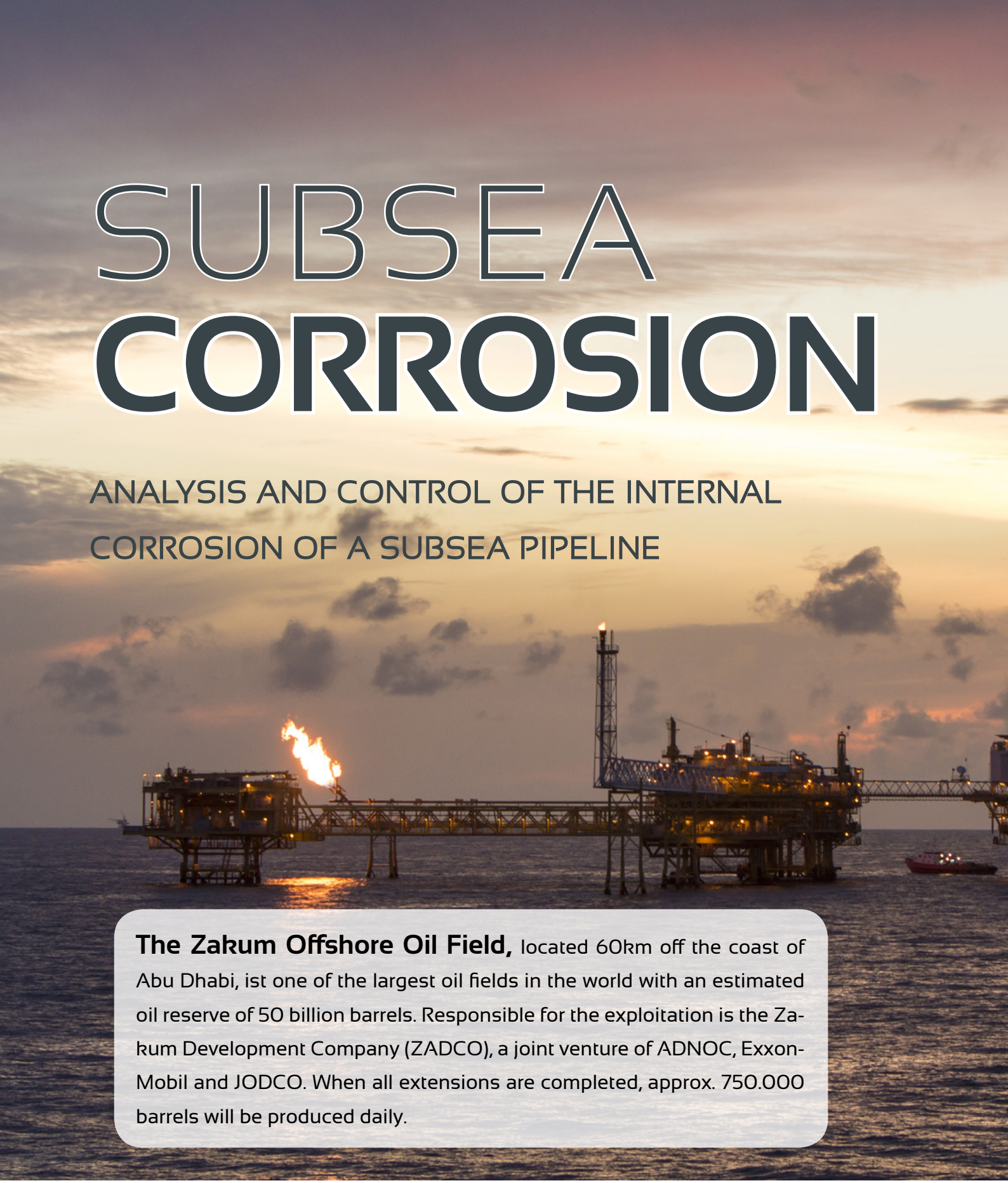
FOR MORE DETAILS CONTACT
Mr. Karan Kukreja - Tel : +971 566 421065 / +971 4 430 9983, E-mail : karan@eandp.ae

A CONFERENCE DRIVEN BY CASE STUDIES PRESENTATIONS.

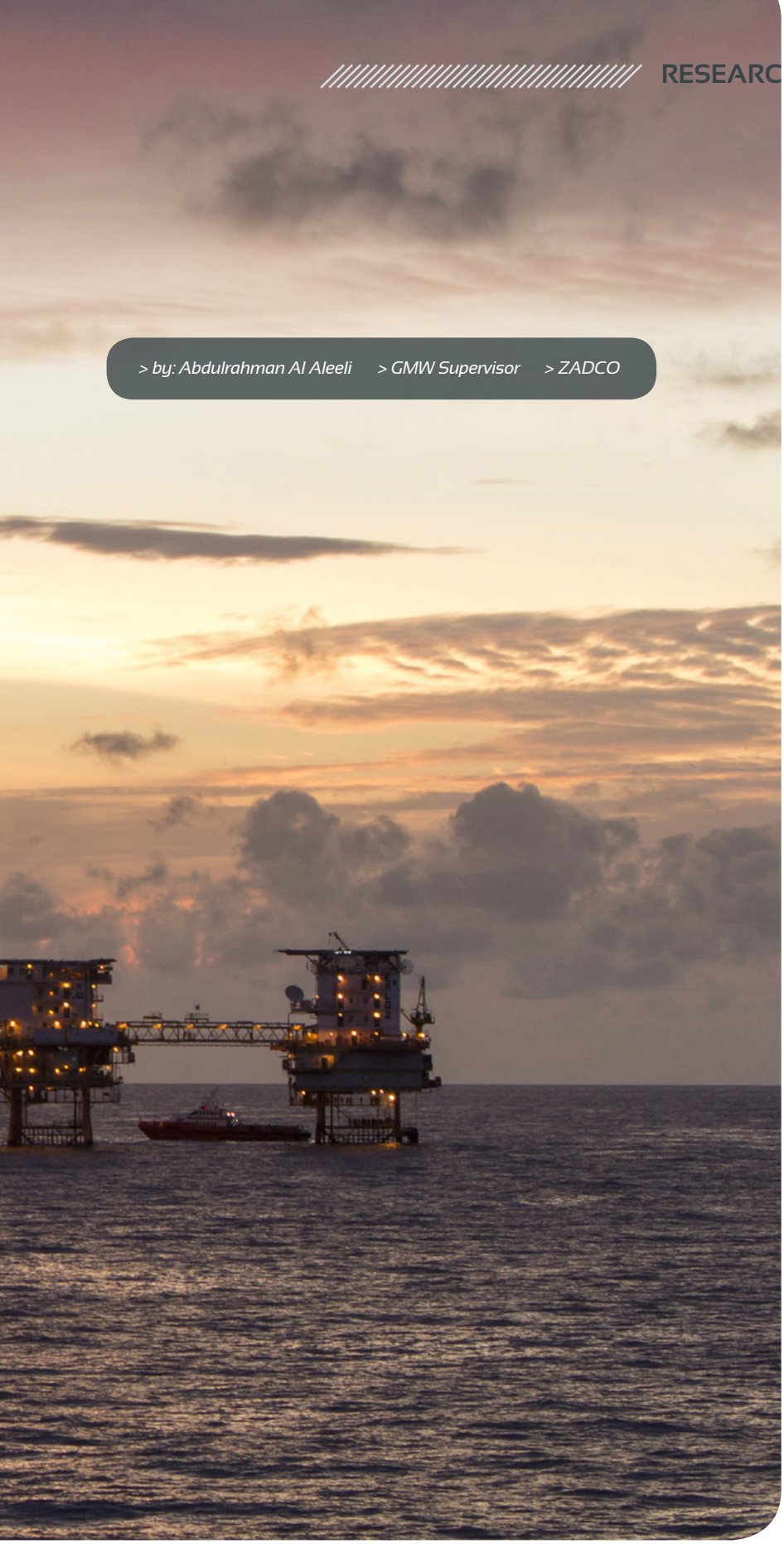
www.eandp.ae

SUBSEA CORROSION

ANALYSIS AND CONTROL OF THE INTERNAL CORROSION OF A SUBSEA PIPELINE



The Zakum Offshore Oil Field, located 60km off the coast of Abu Dhabi, ist one of the largest oil fields in the world with an estimated oil reserve of 50 billion barrels. Responsible for the exploitation is the Zakum Development Company (ZADCO), a joint venture of ADNOC, ExxonMobil and JODCO. When all extensions are completed, approx. 750.000 barrels will be produced daily.



> by: Abdulrahman Al Aleeli > GMW Supervisor > ZADCO

Abstract

A review of the intelligent pig report (IP) depicted an unexpectedly high concentration of localised corrosion in the CL-6 pipeline at the Zakum oil field. Additionally, it can be discerned from the report that the inhibitor performance was unsatisfactory in some pipeline parts. Even though the pipeline was monitored by the coupons system, readings from the system failed to reflect the problematic situation in the pipeline's low points. In order to analyse corrosion features, the ECE® program model and the coupon readings are used to compare the metal loss with the intelligent pig findings. However, results from this analysis showed that 90% of the corrosion features were formed by normal sweet corrosion and were predictable. The corrosion's features made up most of their metal loss during the uninhibited operation period and also resulted because of the periodic loss of the inhibitor treatment. The rest of the corrosion features existed at a low point that formed different conditions which may affect inhibitor performance. Furthermore, low points worked as a water trap and changed the oil-water ratio locally. This altered the inhibitor partitioning behaviour to become oil soluble. Moreover, sand and basic sediments accumulated in the low points which increased the open potential circuit in the present of the inhibitor while the area under deposit acted as an anode. The erosion factor cannot be indicated as the reason behind the expediting corrosion rate in the low points is because the slope is very low.

INTRODUCTION

The 18 inch pipeline was laid on the seabed in 1981 failed inspection due to a high concentration of localised corrosion in the six o'clock position. The pipeline is fabricated from API 5L X65 to send west satellite crud to the central complex, see figure [10].

However, the pipeline was uninhibited until 1992/3. Despite this, even after 1992/3, the localised corrosion continuously grew on the bottom half of the pipeline. Laboratory tests showed that the main corrosion products were siderite-FeCO3 with a black colour, siderite and calcium carbonate with a reddish brown deposit and iron sulphate, which was only observed in traces [3].

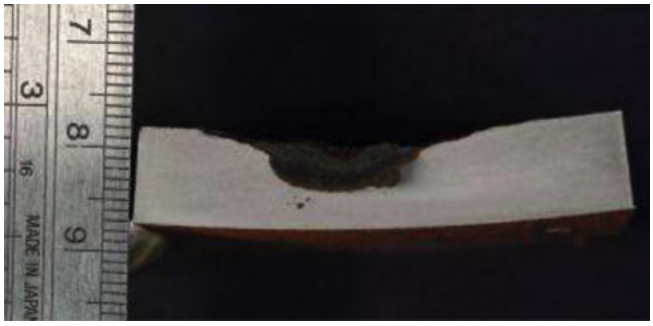


Figure 1: Black deposit (FeCO3) [3]

According to the technical report, a visual examination conducted at the time observed pits that were present throughout the pipe and corrosion features severity was high in the pipeline low points.

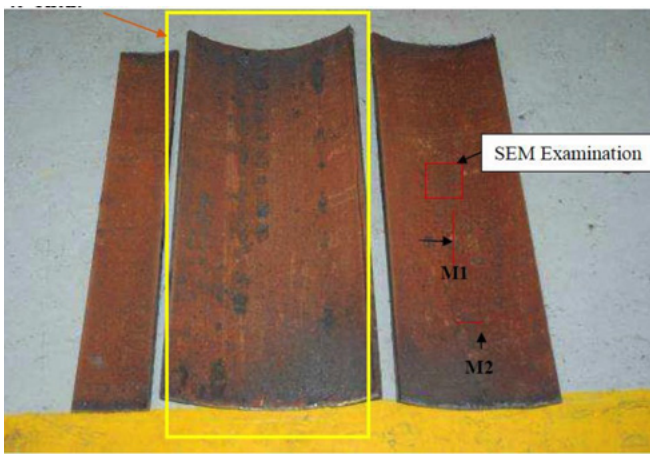


Figure 2: Corrosion features

Ninety percent of the corrosion features had metal loss of less than 20% WT while the deepest features made up 78% WT at 2303.32m. The majority of the features had a recorded length between 10mm to 150mm and the features width range was recorded between 5mm to 150mm, see figure 2. The in-line inspection data also showed that the number of internal corrosion features increased at pipeline concavities.

The company's database showed that the pipe was installed in the seabed and exposed to seawater without any chemical treatment from 1981 to 1986, which was before it began operation. Between 1986 and 1992 the pipe was operated without any inhibitor injection. The integrity measures were applied from 1992 onward.

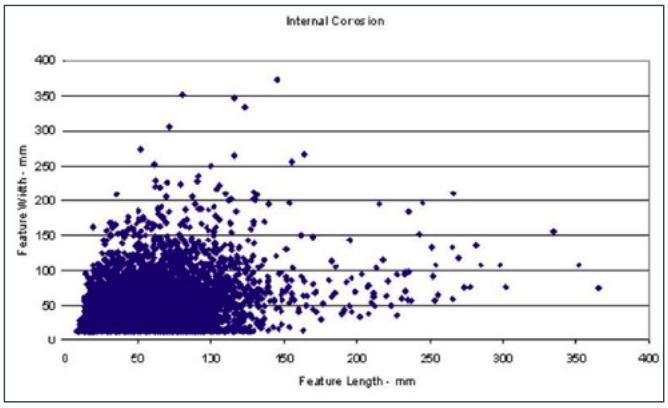


Figure 3: The size of the reported corrosion features [3]

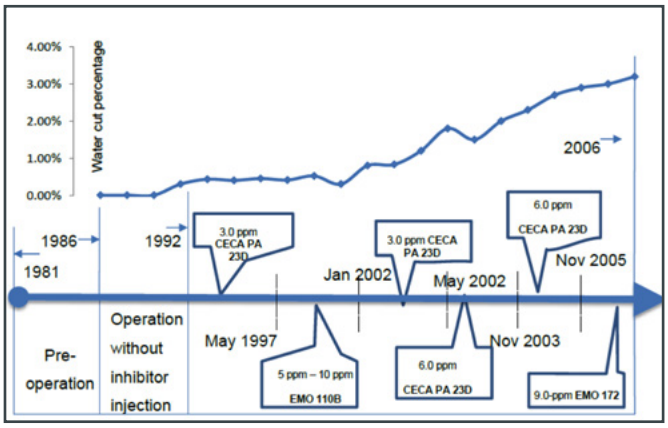


Figure 4: Timeline showing inhibitors programs and water cut percentage for CL-6

However, before introducing the integrity measures, the water cut percentage increased from zero in the first three years to 0.45% at the end of the period. The inhibitor and biocide injection were introduced to the pipe in 1992 as continuous injections and batch 24 hours post pig to the end of the pipe's life. Meanwhile, the water cut percentage increased from 0.45% to 3.2% in 2006. The CECA PA 23D was used as a continuous injection as well as batch dosing with an increasing concentration from 3ppm to 6 ppm and 15 ppm to 50ppm respectively for the whole lifetime except for the periods from May 1997 to Dec 2001, and from Nov 05 to the end of its life where EMO 110B with 5ppm – 10 ppm and EMO 172 with 9.0 – ppm, see figure 4.

METHODOLOGY

A. ECE® Model

The Electronic Corrosion Engineer (ECE®) model is used to analyse the corrosion during the period between 1989 and 1992 where corrosion may have existed in the system but there was no means of monitoring it directly. The corrosion rate is calculated based on the operational data.

B. Coupons reading

Since 1992, the monthly readings of the coupon metal loss for three months were taken for the pipeline and recorded in the ZADCO system. These readings are used in this study to analyse the corrosion features and evaluate the corrosion inhibitor's performance throughout the period

RESULTS

A. ECE® Model

It can be seen that from the conditions existing inside the pipe that the maximum corrosion rate scored 0.77 mm/y at the bottom line while the top line corrosion was negligible.

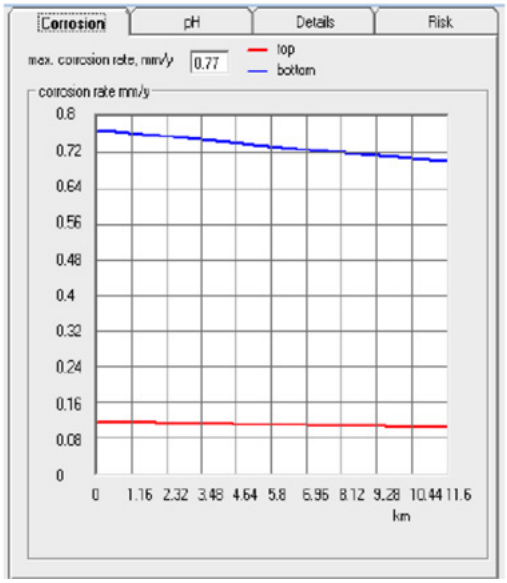


Figure 5: ECE® Outcome – Corrosion rate

Sheikh Zayed Road

3RD ANNUAL INTERNATIONAL PIPELINE COATING CONFERENCE 2016

LATEST INNOVATIONS AND TRENDS IN PIPELINES AND COATING TECHNOLOGY

20-21 APRIL, CROWNE PLAZA, SHEIKH ZAYED ROAD, DUBAI, UAE

Dubai Marina

First pipeline across Palestine, July 1933

KEY BENEFITS OF ATTENDING

- Network with key players in pipeline protection from the GCC and Internationally at the only event of its kind in the region
- Discover the latest technologies and solutions for the pipeline industry
- Hear key experts discuss the trends and opportunities in pipeline coating for the region
- Explore and debate on the latest application techniques
- Gain knowledge on important project updates in the Middle East

Diamond Sponsor:

AkzoNobel

RESICOAT® Experts in Functional Powder Coatings

Gold Sponsor:

JOTUN

Jotun Protects Property

Silver Sponsor:

JOTUN

Jotun Paints

Refreshment Break Sponsor:

valspar®

Conference Bag Sponsor:

AkzoNobel

International

Conference Gift Sponsor:

AUSTRALIAN GMA GARNET

IRAQ-TODAY AGENCIES Ltd.

Associate Sponsors:

BS coatings

CRC-EVANS

EUROBLAST

3M

METALLURGICA ABRUZZESE

SHAWCOR

HEMPEL

SME Speed Middle East

Media Partners:

DMS GLOBAL The DNA for Success

Inspectioneering

LATINCORR

Register today: E: info@mazeejevents.com | T: +00971 50 3949775 | W: www.mazeejevents.com/ipcc2016

B. Coupons reading

The coupons reading shows the corrosion rates were less than 0.025 mm/y for most of the period which is matched with the company standards and specifications. In the years between 2002 and 2005, the corrosion rates dramatically rose above the acceptable limits, as shown in figure [6]. However, the accumulated metal loss was less than 0.05 mm until the middle of 2002. After that, it increased dramatically to a level just under 0.23mm in 2006, figure [7]

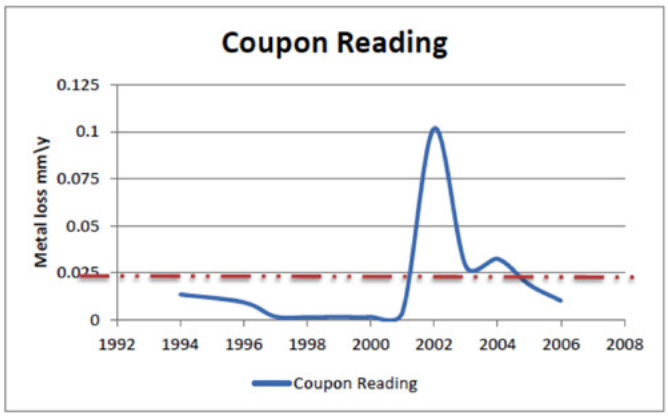


Figure 6: Corrosion rate according to the coupons reading

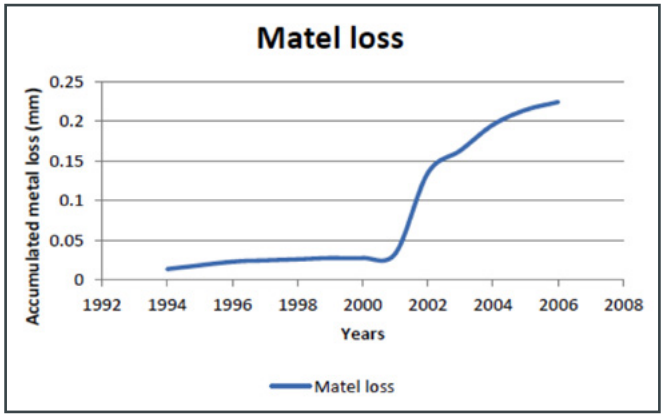


Figure 7: Accumulated metal loss according to the coupons reading

DISCUSSION

A. Analysis corrosion features with less than 20% WT

The ECE® model shows that the pits are initiated in the first operation period, prior to the inhibitor injection system's introduction. According to the model outcome, the corrosion rate in the pipeline before the inhibitor injection was 0.77 mm/y. Considering the fact that the watercut was absent in the first four years, the corrosion began within at least two years of the same period with an accumulated metal loss of 1.54mm, see following calculation. Cr = 0.77mm/year.

However, the coupon readings show that the accumulated metal loss for the period when the pipeline was inhibited was 0.222 mm. By adding to it the metal loss value during the period when the inhibitor injection was absent, the result will be 1.76 mm, %18.48 which matched with intelligent pig finding, see figure [8]

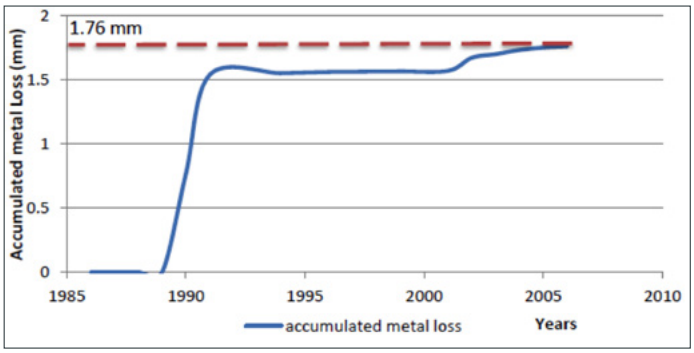


Figure 8: Accumulated metal loss

absent, the result will be 1.76 mm, %18.48 which matched with intelligent pig finding, see figure [8].

$$\&WT = 1 - \frac{9.52 - 1.76}{9.52} + 100 = \%18.48$$

It can be seen from the result, at the first period, when the pipeline was operated without an inhibitor injection system, that the pit initiated and produced the most metal loss. Moreover, the periodic loss during the inhibitor treatment led to a fluctuation in the inhibitor's performance, which accounts for the remainder of the metal loss.

This failure could have been avoided by adopting a comprehensive pipeline integrity plan, starting before the operation phase to avoid pit initiation. The inhibitor injections could be more efficient by linking its concentration directly with the watercut percentage, which changed over time.

B. Analysis of corrosion feature with high metal loss

The intelligent pig detected that 10% of the pits had major metal loss. These pits were located in the low points and just at the up-slope positions throughout the pipeline. According to the ECE® and coupons reading, these features were neither predicted by normal sweet corrosion models nor detected by the monitoring techniques. As all of these features have identical conditions, the corrosion feature at 2303.32m distant will be used as an example, see figure 9.

There are some phenomena that may arise in relation to the pipeline's low points, which may be the reasons behind the high corrosion rates in these locations of the pipeline. The validity of the reasons is checked in the study case as follows:

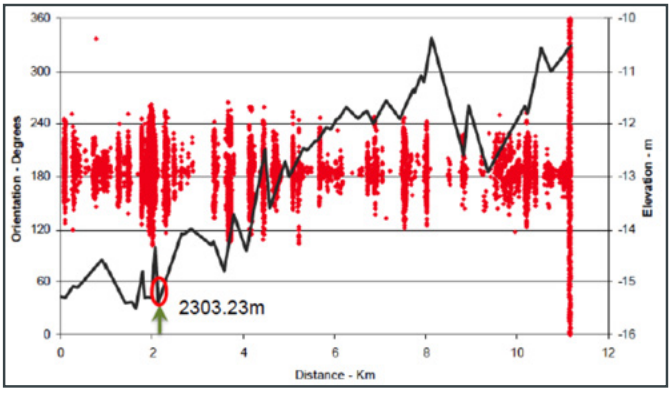


Figure 9: Increments in the corrosion features due to high water exposure

1) Erosion factor

At a relatively high slope, up-slope positions are associated with turbulence formations which apply mechanical force on the passivation layer, leading to pit initiation. Moreover, the erosion factor prevents scale healing. Therefore, the corrosion current is increased and thus increases the corrosion rate, which accelerates the pits' propagation [6].

The slope should be relatively high; otherwise, the effect will be negligent. At 2303m, where severe metal loss features exist, the slope is very low. The difference between the high point and low point is 1.5 m and the distance between them is 500m.

$$\text{Slope} = \frac{X}{Y} \quad ; \text{slope} = \frac{1.5}{500} = 3 * 10^{-3}$$

It can be seen that the slope is not high enough and, more probably, that the turbulence did not exist in the pipeline's low point.

2) Changing inhibitor partitioning behaviour with varying oil-water ratio

At the low point, the percentage of the formation water increased and changed the oil-water ratio locally. This can be seen in figure [9], which shows increments in the corrosion features in the circumferential orientation due to high water exposure.

Inhibitor concentration is mitigated pipeline low points due to the inhibitor partitioning phenomena and loses its efficiency [4]. This phenomenon happens due to the change in the inhibitor's nature with the change in water percentage in the presence of the hydrocarbon. The inhibitor changed from partitioning the water phase to partitioning the oil phase so that the inhibitor became oil-soluble instead of water-soluble in these conditions [4]. The lack of inhibitor concentration locally in the water phase at low points led to an increase in the corrosion rate and caused the non-predictable localised corrosion.

In order to control unpredicted corrosion at the low points, the inhibitor partitioning in the water should be checked for present oil with different oil-water ratios to determine the critical ratio where inhibitor behaviour is changed to partitioning the oil phase. The pigging activity could help by adopting the pigging frequency to remove the stagnant water once the oil–water ratio reaches the critical value to avoid any drop in the inhibitor efficiency.

Ninety percent of the corrosion features had metal loss of less than 20% WT while the deepest features made up 78% WT at 2303.32m. The majority of the features had a recorded length between 10mm to 150mm and the features width range was recorded between 5mm to 150mm, see figure 2. The in-line inspection data also showed that the number of internal corrosion features increased at pipeline concavities.

3) Effect of accumulated basic sediment

The basic sediments are accumulated in the CL-6 pipeline's low points. The presence of these deposits affects the corrosion rate of the corrosion features under these deposits in different ways.

Due to the competitive absorption of the basic sediment deposits, the inhibitor concentration is reduced in the water phase at the low point, which reflects on the inhibitor's performance efficiency. The deposit also forms a mass barrier and interrupts the inhibitor molecules from reaching the under deposit pits [5].

Moreover, inhibitors with a high imidazoline concentration can display backfire results as they increase the potential difference while the spots under deposit work as an anode [5][1].

CONCLUSION

In conclusion, 90% of the corrosion features were found to be the result of normal sweet corrosion. They can be predicted by a normal CO2 model and monitored by the coupons. On the other hand, the remainder of the features experienced unpredicted metal loss due to a drop in the inhibitor efficiency at the low points. The inhibitor performance declines at the low point due to the appearance of accumulated water and sand which create a different environment. All pits in this case study were most likely initiated during the period when the corrosion inhibitor was absent and made up the majority of metal loss. Apart from the short periodic loss, the inhibitor injection succeeded in decreasing the corrosion rate to the stipulated limits in the codes and standards of 90% of corrosion features. On the other hand, the inhibitor performance was unacceptable in failing to prevent pit propagation in 10% of the corrosion features which were located at the low points. The coupon reading was not relevant to the situation in this instance as they were under different conditions compared to the rest of the pipeline. This failure happened as a result of phenomena associated with the low point position such as changing inhibitor partitioning behaviour and effect of accumulated basic sediment, while the erosion factor had a negligent effect.

ACKNOWLEDGEMENT

This article was prepared in accordance with an MSc dissertation conducted by the author in Cranfield University and supported by ZADCO. Therefore, I would like to use this opportunity to thank Dr. Michael Robinson, who acted as adviser for the dissertation. Dr. Robinson's recommendations and guidance were highly appreciated.

References

1. Evaluation of corrosion inhibition at sand-deposited carbon steel in CO2-saturated brine. Vedapriya Pandarinathan, Kater ˇina Lepková , Stuart I.Bailey and Rolf Gubner. 2013, Corrosion Science, p. 3.
2. c.clausard. FFP Assessment report. Abu Dhabi : Rosen Inspection, 2006.
3. LLC, Exova. Technical Report. Abu Dhabi : A. Jawwad, 2010.
4. PARTITIONING OF CORROSION INHIBITOR IN RELATIONSHIP TO OIL FIELD APPLICATIONS. Michael W. Joosten, Juri Kolts, and Phillip G. Humble,Mark A. Gough and Irene M. Hannah. Huston : Conoco Inc, Nalco/Exxon Energy Chemicals Ltd, Britannia Operator Ltd, 2000. Corrosion reference . p. 4.
5. Understanding factors affecting Corrosion Inhibitor performance in under-deposit testing with sand. Yingrui Zhang, Jeremy Moloney and Sebastian Mancuso. Houston : Nalco Energy Services, 2013. Corrosion Conference
6. Electrochemical Investigation of Localized CO2 Corrosion on Mild Steel. Jiabin Han, Yang Yang, Bruce Brown and Srdjan Nesic. Houston : Ohio University, 2007. Conferance Expo. p. 5. 33
7. ROLES OF PASSIVATION AND GALVANIC EFFECTS IN LOCALIZED CO2 CORROSION OF MILD STEEL. Jiabin Han, Yang Yang, Srdjan Nesic and Bruce N Brown. Houston : Ohio University, 2008. Corrosion conference . p. 3.
8. clausard, A. Wilde and c. Corrosion Growth Comparison. Abu Dhabi : Rosen Inspaction, 2006
9. Matthews, Steve. Plant Asset Management - Review of ZADCO Corrosion Management Programs. Abu Dhabi : Petrofac, 2010.
10. James F. Cruise, Mohsen M. Sherif, Vijay P. Singh. Elementary Hydraulics . London : Thomson Nelson, 2006.
11. Acid Corrosion in Wells (CO2 , H2S):Metallurgical Aspects. Jean-Louis Crolet, Soc. Natl. Elf Aquitaine. s.l. : Society of Petroleum Engineers of AIME, AUGUST 1983, JOURNAL OF PETROLEUM TECHNOLOGY, p. 1553.
12. Overview of CO2 Corrosion Models for Wells and Pipelines. Nyborg, Rolf. s.l. : NACE international, 2002, Corrosion 2002, p. 1.
13. Investigation of Carbon Dioxide Corrosion of Mild Steel in the Presence of Acetic Acid—Part 1: Basic Mechanisms. Nesic, K.S. George* and S. 2007, Corrosion, pp. 178-179.
14. BASICS REVISITED: KINETICS OF IRON CARBONATE SCALE PRECIPITATION IN CO2 CORROSION. Nesic, Wei Sun and Srdjan. 2006, CorrosionExpo , p. 1.
15. IMPROVEMENTS ON DE WAARD-MILLIAMS CORROSION PREDICTION AND APPLICATIONS TO CORROSION MANAGEMENT. Girgis, Magdy, et al., et al. s.l. : NACE international, 2002, Corrosion 2002, p. 2.
16. The Effect of Temperature in Sweet Corrosion of Horizontal Multiphase Carbon Steel Pipelines. Jepson, A.K. Vuppu and W.P. Melbourne,Auatratia : socaity of Petroleum Engineering , November1994. SPE Asia Pacific Oil & Gee Conference.
17. Effect of Pressure, Temperature and Oil Composition on Corrosion Rate in Horizontal Multiphase Slug Flow. Bhongale, w. P. Jepson and S. Multi-Phase Systems Center, Department of Chemical Engineering, Ohio University.
18. A PARAMETRIC STUDY AND MODELING ON LOCALIZED CO2 CORROSION IN HORIZONTAL WET GAS FLOW. Nesic, Yuhua Sun and Srdjan. Houston : Corrosion in Multiphase Systems Center, Institute for Corrosion and Multiphase Technology, Ohio University, 2006. Corrosion . p. 9.
19. Fosbøl, Philip Loldrup. Carbon Dioxide Corrosion - Modelling and Experimental Work Applied to Natural Gas Pipelines. Ph.D. Thesis. Kongens Lyngby, Denemark
20. Investigation of Pseudo-Passivation of Mild Steel in CO2 Corrosion, ROLES OF PASSIVATION AND GALVANIC EFFECTS IN. Wei Li, Bruce Brown, David Young and Srdjan Nesic. Houston : Corrosion in Multiphase Systems Center, 2013. Corrosion Conference and Expo, Institute for Corrosion and Multiphase Technology, Ohio University. p. 2.
21. MECHANISM OF PROTECTIVE FILM FORMATION DURING CO2 CORROSION OF CARBON STEEL. Dugstad, Arne. Huoston : Institute for Energy Technology, 1998. Corrosion conference . pp. 3-5 .
22. THE FORMATION OF PROTECTIVE FeCO3 CORROSION PRODUCT LAYERS. E.W.J. van Hunnik, B.F.M. Pots and E. L.J.A. Hendrikseu. Houston :Koninklijke/Shell-Laboratorium. Amsterdam, 96. Corrosion conference . p. 1.
23. Nafday, Omkar A. Film Formation and CO2 Corrosion in the Presence of Acetic Acid. M.Sc thesis. s.l. : Ohio University, 2004.
24. Han, Jiabin. Galvanic Mechanism of Localized Corrosion for Mild Steel in Carbon Dioxide Environments. PhD dissertation. s.l. : The Russ College of Engineering and Technology of Ohio University, 2009, pp. 45-57.
25. Baboian, Robert. Galvanic and pitting corrosion: field and laboratory studies. Philadelphia : ASTM, 1976.
26. Mondal, Dr.Kallol. youtube. Mod-01 Lec-27 Pitting corrosion, Intergranular corrosion. [Online] 10 3 2014. [Cited: 11 10 2014.] http://www.youtube.com/watch?v=c2i_3JKGdNc.
27. Conflicting Views: CO2 Corrosion Models, Corrosion Inhibitor Availability Philosophies,and the Effect on Subsea Systems and Pipeline Design. Teh, J. Marsh and T. and Caledonia, Ionik Consulting/JPKenny. Aberdeen : Society of Petroleum Engineers, 2007. Society of Petroleum Engineers.
28. Bardal, Einar. Corrosion and Protection. London : Springer, 2003.
29. Schweitzer, Philip A. Fundamentals of Corrosion Mechanisms, Causes,and Preventative Methods. London : CRC Press, 2010.
30. Uhlig, R. Winston Revie and Herbert H. CORROSION AND CORROSION CONTROL. New Jersey : A JOHN WILEY & SONS, INC., PUBLICATION, 2008.
31. Gammon, Darrell D. Ebbing and Steven D. General Chemistry. Boston : Houghton Mifflin Company, 2009.
32. Carbonic Acid (Sweet) Corrosion. M.J.Robinson, Dr. 2014, lecture note, pp. 5-7.

Author

Abdulrahman Al Aleeli
Zakum Development Company
GMW General Maintenance
Supervisor
uuaqq@hotmail.com

الهيئة الوطنية للنفط والغاز
NATIONAL OIL & GAS AUTHORITY

Held under the Patronage of His Excellency Dr. Abdul Hussain bin Ali Mirza,
Minister of Energy, Kingdom of Bahrain

PIPELINE OPERATIONS & MANAGEMENT 2016 MIDDLE EAST

11–14 APRIL 2016
GULF CONVENTION CENTRE
MANAMA, BAHRAIN

PLATINUM ELITE SPONSOR

أرامكو السعودية
saudi aramco

SILVER SPONSORS

بابكو
Bapco

Clock Spring®

ROSEN
empowered by technology

مجموعة القريان
Al Qaryan Group





CONFERENCE – 12-14 APRIL

Technical tracks presented by industry leaders covering a wide range of subjects will run over the three day event.

The Conference tracks include;

- Track A – Corrosion
- Track B – Repair
- Track C – Design
- Track D – ILI
- Track E – Operations'
- Track F – Management
- Track G – Cracks and SCC
- Track H – Integrity
- Track I – Offshore
- Track J – Materials
- Track K – Coatings
- Track L – Leak detection
- Track M – Maintenance

View the full Conference programme at www.pipelineconf.com

WORKSHOPS – 11 APRIL

Preceding the conference, six Topical Workshops will be held.

The topics include;

- Workshop 1: In-line inspection of traditional and challenging pipelines – an overview
- Workshop 2: Microbiological corrosion
- Workshop 3: Direct assessment
- Workshop 4: Best practices in offshore pipelines
- Workshop 5: Managing black powder
- Workshop 6: Pipeline integrity – management and programmes

EXHIBITION – 12-14 APRIL

A comprehensive exhibition will be part of the event, allowing companies from around the world to showcase their products and services. Visit our website to book your space.

For more information or to register visit www.pipelineconf.com

600+ 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 11th 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. This years ptc will be held in parallel to the 1st PASC (Pipe and Sewer Conference and Exhibition). Focusing on lower pressure pipes and sewers, the new PASC offers a great opportunitiy for relevant providers to exchange latest technologies and devlopments from this area. Also, PASC provides synergy effects for provider, wo are active in both sections.

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

"64% of the PTC Delegates are coming from abroad (Europe, Middle East, North America, South America, Asia, etc.)"

ptc

11TH 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.

35+ SUPPORTERS

17 Technical Sessions at ptc / pasc 2016

- Integrity Management
- Inline Inspection
- Leak Detection
- Repair / Rehabilitation
- Materials
- Coating / Corrosion
- Pump & Compressor Stations
- SCADA / Automation
- Remote Sensing
- Offshore Technologies
- Planning & Construction
- Trenchless Construction
- Trenchless Rehabilitation
- Legal Assessment
- Inspection
- Asset Management
- Waste Water Disposal

Details about the conference program can be found on the following websites:

www.pipeline-conference.com
www.pipeandsewer.com

IN PARALLEL TO

1ST PIPE AND SEWER CONFERENCE

EUROPE'S NEW PIPE AND SEWER EVENT

PROVIDING A PLATTFORM FOR THE INTERNATIONAL EXCHANGE ABOUT CHALLANGES IN THE PIPE AND SEWER INDUSTRY

While ptc is focusing on high-pressure oil, gas and water pipelines around the world, PASC will bundle all topics regarding supply pipes for gas and water, district heating / cooling and sewers. Synergy effects with ptc are especially relevant for provider of all pressure levels.

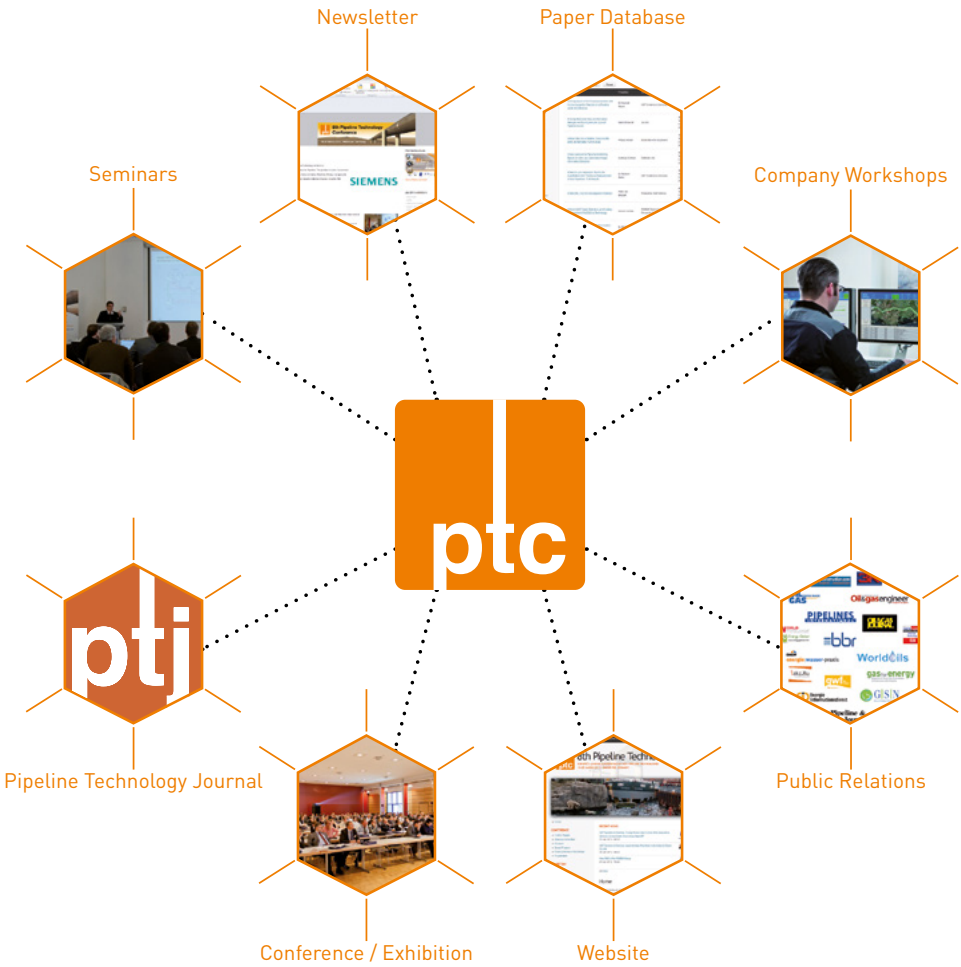
Benefit from our ptc-all-round service

A pre-show, at-show but also post-show marketing is the key to build your visibility.

Therefore our ptc-brand activities enhance greater success to your company also outside the confines of the conference and exhibition.

Increase the attention with a selective activity of the ptc:

Pipeline Technology Conference

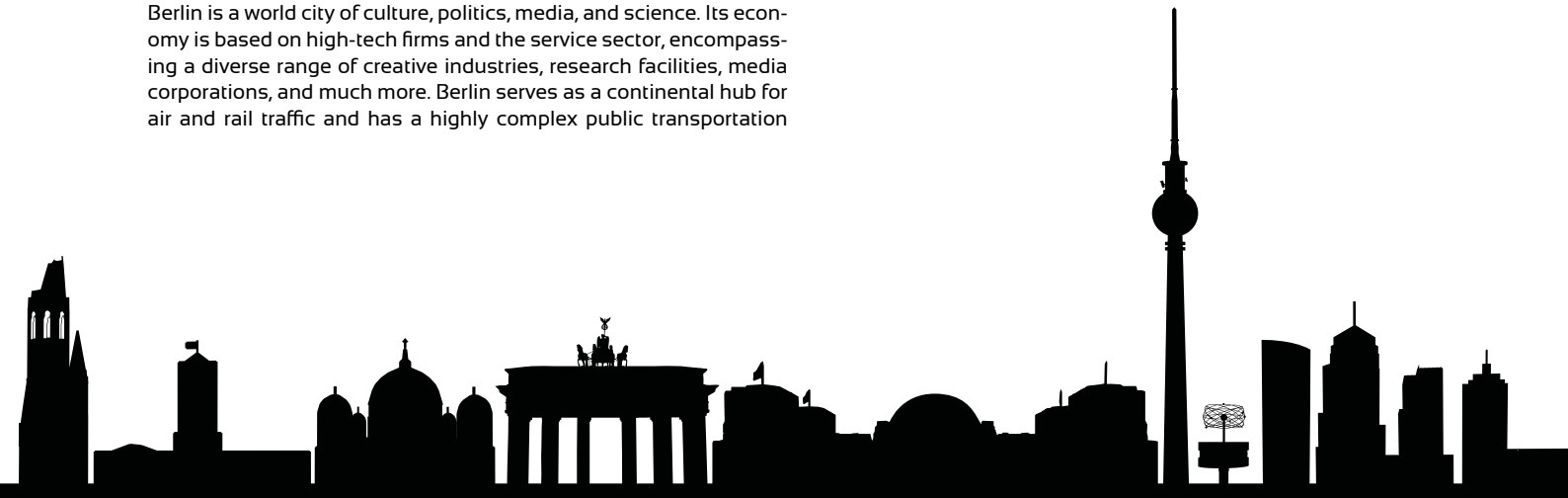


Combine your ptc visit with Berlin sightseeing

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.



Save The Date

11TH PIPELINE TECHNOLOGY CONFERENCE

23-25 MAY 2016, ESTREL CONVENTION CENTER, BERLIN, GERMANY

Europe's Leading Conference and Exhibition on New Pipeline Technologies

Almost 500 participants visited the 10th PTC in Berlin

New developments were introduced

Review of the 10th Pipeline Technology Conference 2015 in Berlin

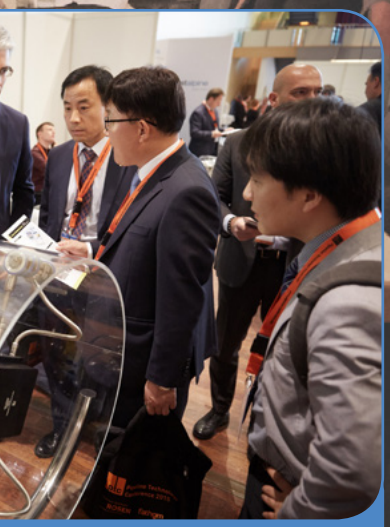
With delegates from 49 different nations with 493 participants including staff and management of 53 international pipeline operators, 47 exhibitors, 10 sponsors, 70 speakers and 12 poster sessions the 10th Pipeline Technology Conference (8-10 June, Berlin) is shaping up to be a pivotal event for the **global pipeline community**.

The purpose of the Pipeline Technology Conference (ptc) is to gather operators as well as technology and service providers on a global basis in order to enhance pipeline technology. Therefore the conference addressed in 13 technical sessions and its Opening Panel Discussion the major industry challenge faced by the pipeline community today. A wide range of recent and future "safety" aspects were presented by experts from international key players form the oil and gas pipeline industry. Their insight and expertise fed directly into discussions and involvement of the participants with live polling.

A technical exhibition accompanied the conference offering the opportunity to more than 30 media partners to be presented in the media lounge during the show. Followed by a poster show, post conference workshops and social programs the delegates took advantage of the sheer wealth of experience available from industry leaders and innovators gaining a comprehensive understanding of key industry issues and new solutions.

The unique Closing Panel Discussion on "German Energy Turnaround" focused on questions surrounding the future of pipelines in a renewable energy age in Germany, Europe and worldwide.

All abstracts and papers of the conference are published on the ptc website and are now publically available for international researchers and scientists from all over the world (www.pipeline-conference.com/abstracts).
For more information visit www.pipeline-conference.com.



to an international audience

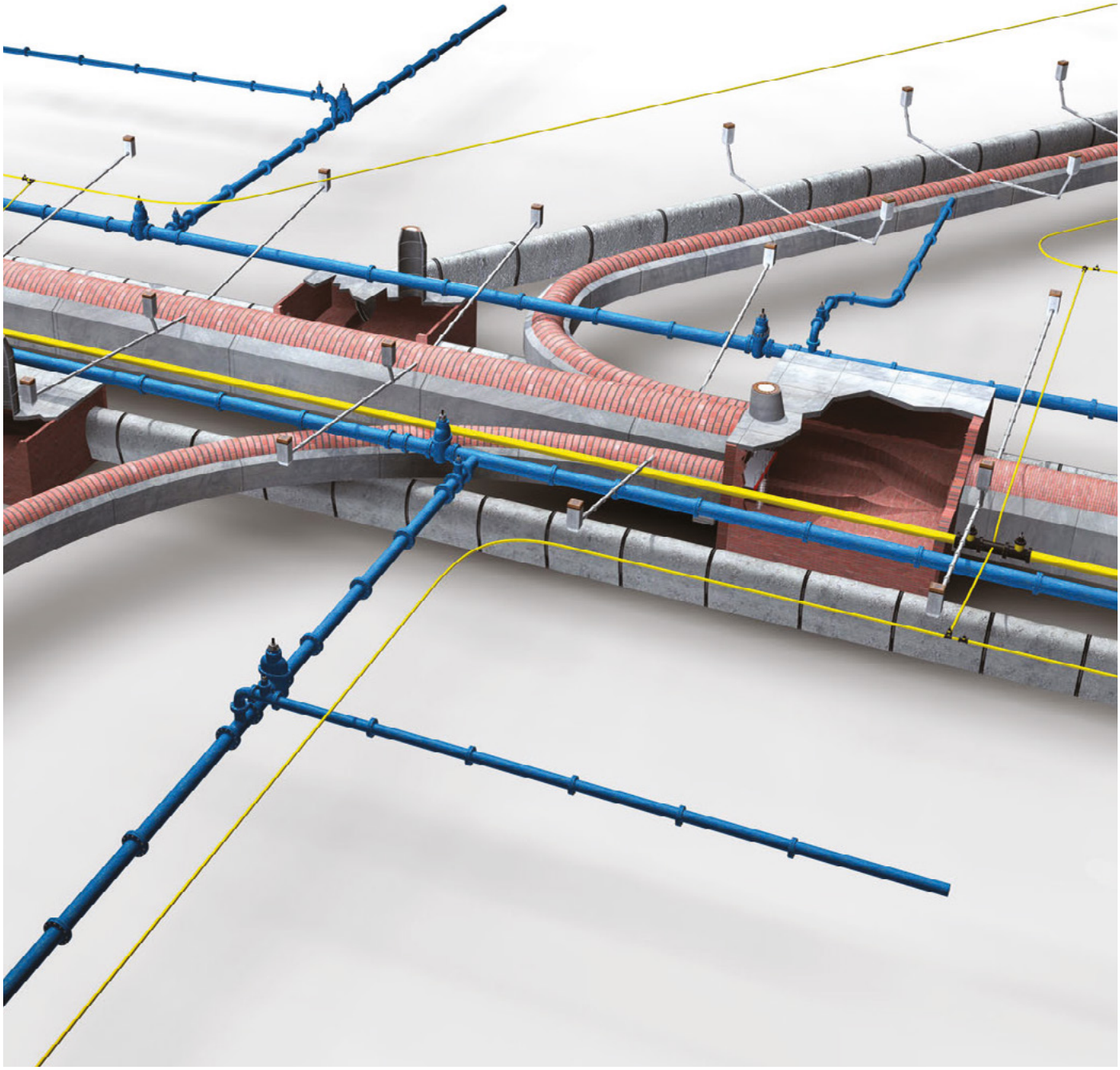
Attendees networking at the exhibition

IN PARALLEL TO EUROPE'S LARGEST PIPELINE CONFERENCE AND EXHIBITION

11TH PIPELINE TECHNOLOGY CONFERENCE

1ST PIPE AND SEWER CONFERENCE

23-25 MAY 2016, ESTREL CONVENTION CENTER, BERLIN, GERMANY



an EITEP event

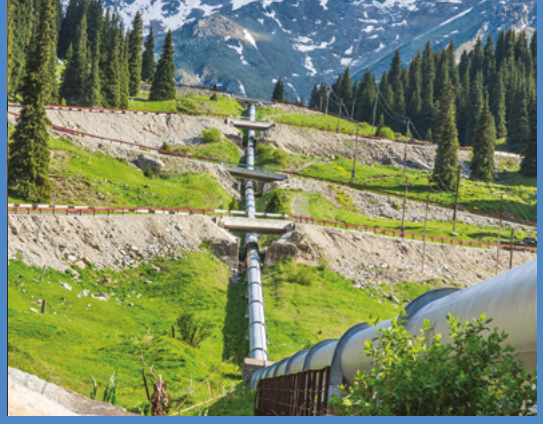
Euro Institute for Information and Technology Transfer

CONFERENCE TOPICS

(WATER, WASTE WATER, GAS, HEATING, COOLING)

- NETWORK PLANNING
- CONSTRUCTION
- TRENCHLESS INSTALLATION
- MATERIALS
- JOINING
- VALVES AND FITTINGS
- PUMPING AND COMPRESSOR STATIONS
- INSPECTION AND LEAK DETECTION
- CLEANING
- MAINTENANCE
- REHABILITATION
- MEASUREMENT AND CONTROL
- SMART GRIDS
- SMART METERING
- ASSET MANAGEMENT

BONUS DISTRIBUTION AT PTJ PARTNER EVENTS		
Pipeline Pigging and Integrity Management	8-12 February 2016	Houston, USA
ME Pipe Tech	21-22 March 2016	Abu Dhabi, UAE
Pipeline Operations and Maintenance	11-14 April 2016	Manama, Bahrain
3rd International Pipeline Coating Conference	20-21 April 2016	Dubai, UAE
11th Pipeline Technology Conference (ptc)	**23-25 May 2016**	**Berlin, Germany**
1st Pipe And Sewer Conference (PASC)	**23-25 May 2016**	**Berlin, Germany**


11TH PIPELINE TECHNOLOGY CONFERENCE

EUROPE'S BIGGEST PIPELINE CONFERENCE AND EXHIBITION

www.pipeline-conference.com

1ST PIPE AND SEWER CONFERENCE

INTERNATIONAL CONFERENCE AND EXHIBITION ON PIPE AND SEWER TECHNOLOGIES

www.pipeandsewer.com

23-25 MAY 2016
ESTREL CONVENTION CENTER
BERLIN, GERMANY

- 600+ DELEGATES
- 55+ DIFFERENT NATIONS
- 50+ EXHIBITORS
- DELEGATIONS FROM 50+ DIFFERENT PIPELINE OPERATORS



EITEP Euro Institute for Information and Technology Transfer | ROSEN empowered by technology | ILF CONSULTING ENGINEERS | NDT GLOBAL | HERRENKNECHT | GLD | DNV·GL

Europe's biggest onshore & offshore pipeline conference & exhibition:
www.pipeline-conference.com **www.pipeandsewer.com**