October 2013

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Pipeline Technology Journal

ROSEN INSPECTION SOLUTIONS

Industry & Practice

- Reports about new technological developments
- Personnel and administrative developments

Research / Development / Technology

- ILI for Nord Stream
- UT-Inline Inspection
- Leak detection technologies
- High Performance Polyurea Pipe Coatings
- Biogas in the natural Gas Grid

Conferences / Seminars / Exhibitions

- Upcoming International events 2014
- 1st International Pipeline Seminar Pipeline Week IPSW
- Pipeline Technology Conference ptc 2014 in Berlin

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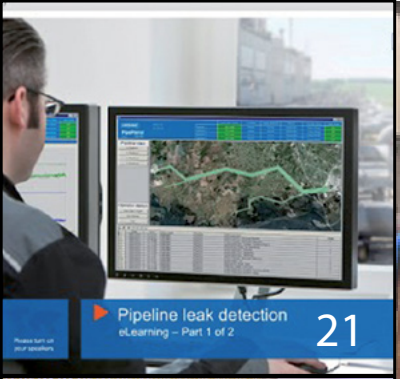

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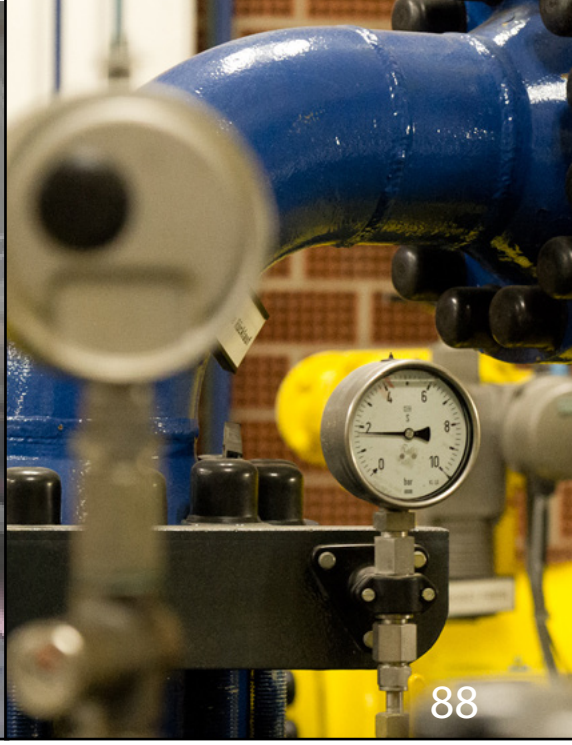
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Dear readers,

Dear readers thank you for responding to our appeal in sending us your results about development and reports about successful case studies which helps succeeding the exchange through the Pipeline Technology Journal ptj. Also your feedback and suggestions for improving after publishing the first issue are highly appreciated.

Equally as the pipelines which more and more cross state borders with different technical and cultural background, our Journal's aim is to more and more enable international exchange crossing the world likewise. As in our first issue underlined, it has never been more important to ensure the safety and reliability of pipelines (please see the keynotes article in this issue for detailed information). In the most economies, any risk to pipeline infrastructure can have a significant effect, whether it is a technical failure or simply mistaken damage caused by everyday activity as the non-fulfillment of delivery and transmission contracts. Hence reliability, security and longevity are the main requirements for pipelines today.

Using up-to-date techniques and innovations can help to meet the requirements. As in our international Pipeline Technology Conference ptc, we hereby continue discussing latest developments in pipeline monitoring and security technology in order to meet the challenges of today's challenging environment and economy. International exchange and new detecting solutions provide greater visibility into the pipeline network to reduce potential damage or losses.

Please inform us further about your results, developments as well as case studies.

Yours sincerely,

Dr. Klaus Ritter
President
Euro Institute for
Information and Technology
Transfer, EITEP

CHAIRMEN

Dr. Klaus Ritter, President, EITEP - Euro Institute for Information and Technology Transfer

Uwe Ringel, Managing Director, ONTRAS-VNG Gastransport

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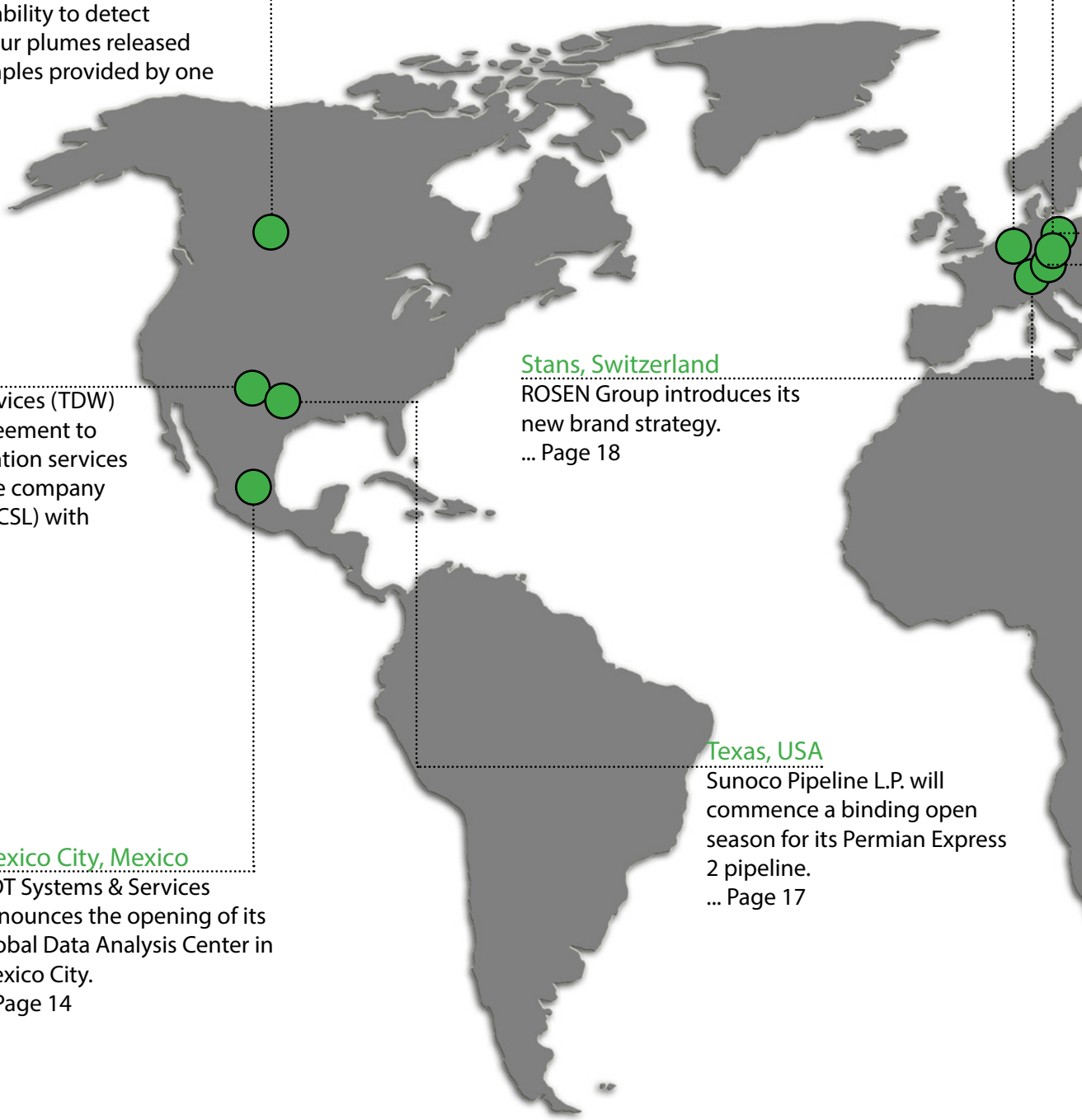

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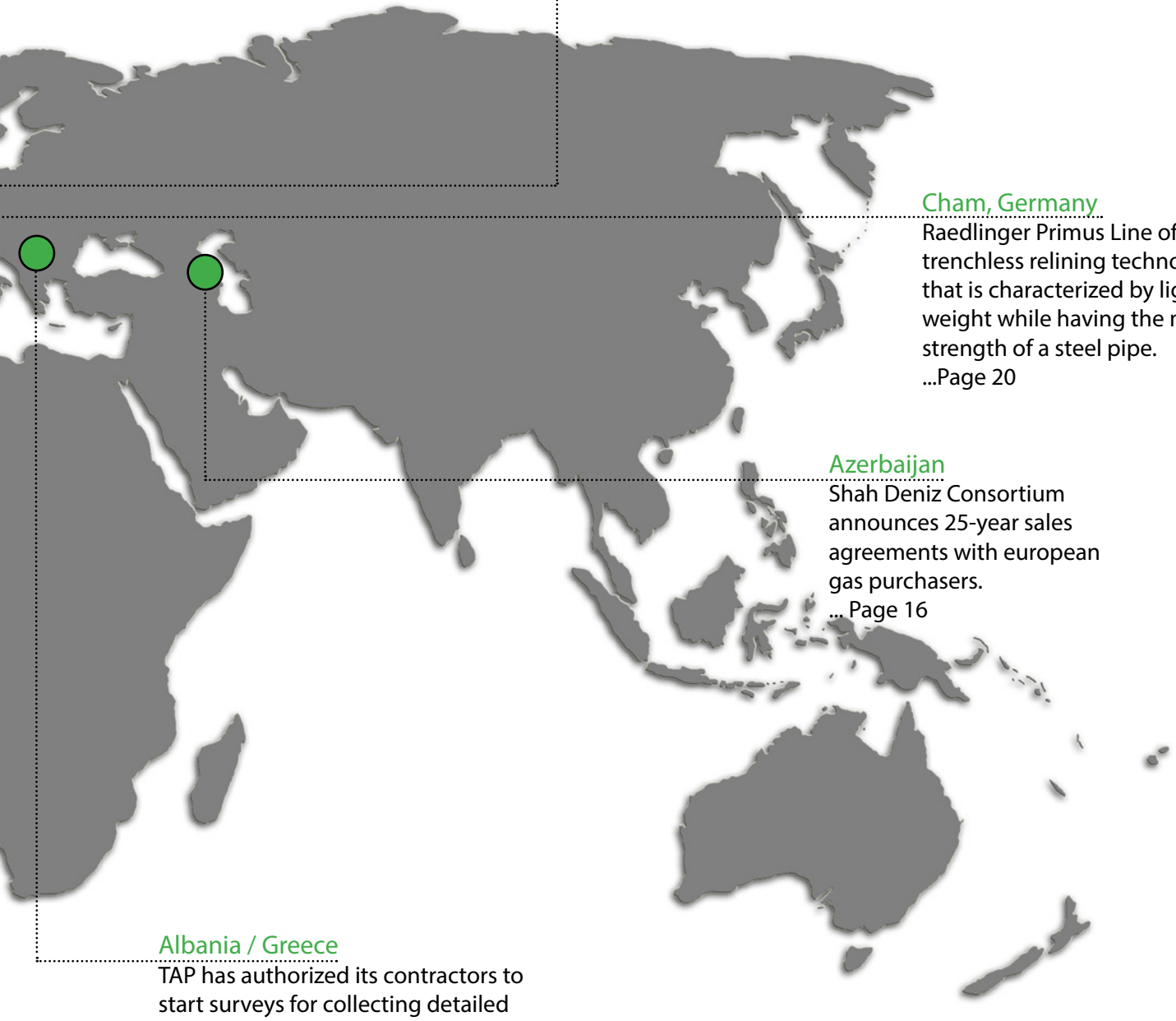

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Work management solution to provide auditing acceptability

Damages in the pipeline- and nuclear industry in the near past have shown that gaps in asset documentation and in operational processes record had not been transparent enough to avoid subsequent catastrophes. A more integrated approach is needed to allow reliable and continuous communication and data access.

More and more operational issues of maintenance and monitoring activities for complex facilities and pipelines are outsourced to external providers or plant/work managers working remotely. In all cases, a delayed process creates contradictory information about the actual status and asset condition in operational duties, commercial accounting and up-to-date planning activities. In most cases, the accounting problem becomes obvious close to year's end, starting budgeting processes on more or less reliable numbers.

Companies have implemented different information and billing systems to control daily work, but normally none of these systems are open for direct access for external staff to update information needed by the functionalities and processes listed to the right:

- Direct access to technical information for field operations
- Integrated use of spatial and technical asset information for risk- and condition assessment
- Analysis and display of measurement values from in-line inspection runs (georeferenced features lists) and CP data,
- Budgeting numbers based on planned, done and accounted-for issues, as well as commissioning and technical approval at projects' end,
- Activity list and work planning,
- Burden of proof in case of damages or reportable events.

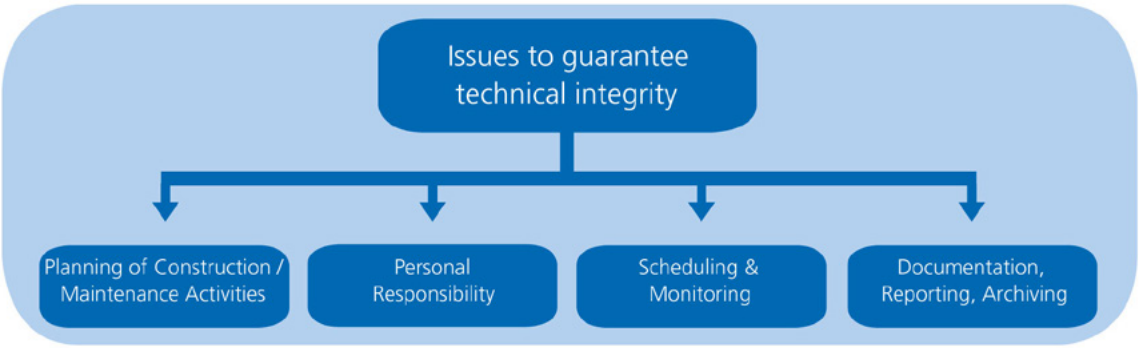


Figure 1: Business reasons for comprehensive documentation

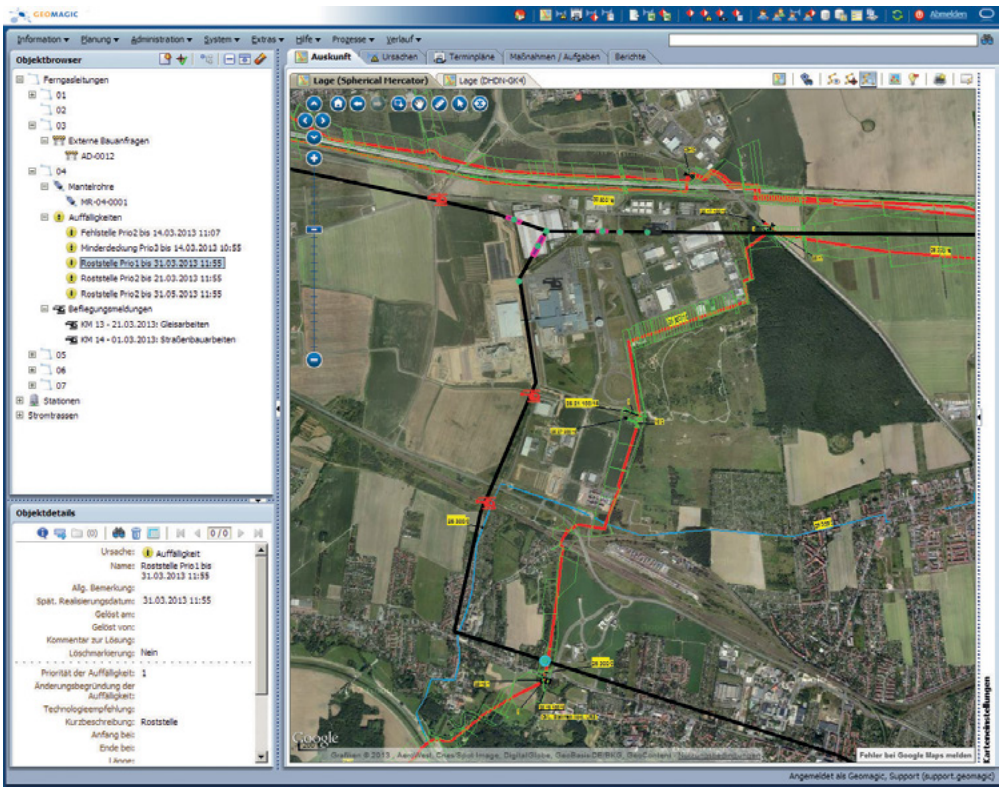


Figure 2: Google Maps integration in GIS

In combination with an existing Geographical Information System following PODS recommendations and the extension by a Pipeline Integrity Management System (PIMS), GEOMAGIC extends IT-infrastructure with with the new release of the Work Management Solution GeoNAM, which allows the planning, initiation and documentation of activities from the Integrity Management Plan (IMP). The three-part product family Smallworld GIS as the basis, trascue.PIMS and GeoNAM allows covering all data related demands from ASME recommendations for the Integrity Management Process.

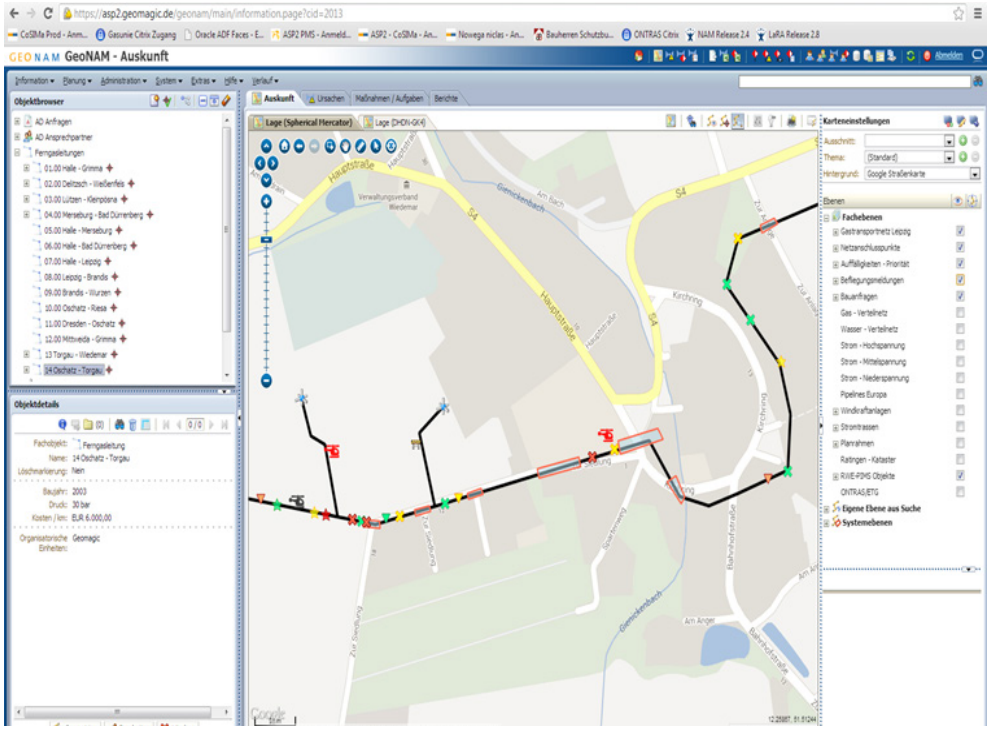


Figure 3: Thematic mapping

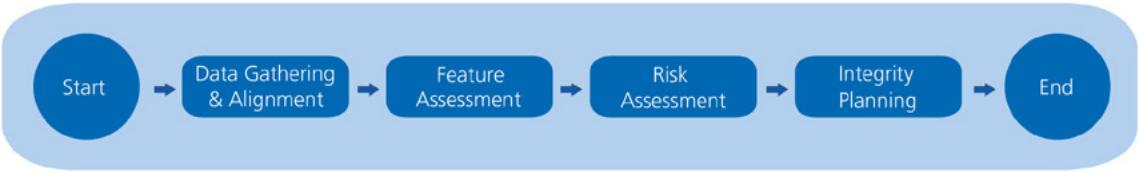


Figure 4: Process to organise the integrity management process

The existing implementations illustrate an integrated approach, where the need is understood to be up-to-date about one's own data/asset-status and to be informed about operation activities in daily work, about damages and legal examination. In the past few years, several pipeline operators in Germany and Switzerland have adopted. this product approach and have achieved a consistent asset data base from which input is created for condition and risk assessment Based on assessment results and best practices and obligations from rules and standards, the integrity management plan activities will become part of the WorkManagementSolution. Also, the other way round, the web-based infrastructure allows field crews to access all information and update activities and work times via internet access. All catastrophes in the near past have shown that complete and integrated asset information and its access for operational processes might have been avoided subsequent catastrophes.

Contact

Jens Focke
GEOMAGIC GmbH
Leipzig, Germany
+49 341 7111 700
jens.focke@geomagic.de

TAP begins its land easement and acquisition (LEA) activities for the 870 km long pipeline

TAP has authorized its contractors to start surveys for collecting detailed information on the landowners living along the pipeline corridor to complement the existing cadastral data. The goal is to identify rightful landowners, establish property boundaries and evaluate the affected properties. TAP's LEA process is based on acquiring access rights to land, in order to establish access for the pipeline. TAP will require temporary access to land for the construction strip where the pipeline will be buried and permanent access to land for installations such as compressor stations, block valve stations, etc. Following construction, TAP will also require land easements for the pipeline corridor and safety zones.TAP is carrying out its activities in accordance with the international standards of the European Bank for Reconstruction and Development (EBRD) to ensure that all affected people living along the pipeline corridor are compensated fairly and transparently.TAP has hired Royal HaskoningDHV (RHDHV) as its contractor for LEA activities. RHDHV is an international engineering and project management service provider and consultancy, based in the Netherlands. In 2014 TAP plans to enter into agreements with landowners regulating how the access to land can be granted. Royal HaskoningDHV will be contacting all affected landowners in the next months; it will mobilise a team of 200 staff members to carry out LEA activities in Greece, Albania and Italy. Albert Haak, TAP's Land Easement and Acquisition Manager, said: "TAP's LEA activities will be conducted in a very transparent manner and in accordance to the highest international standards. TAP is committed to an open dialogue and building trustful and lasting relationships with the communities living along the future pipeline route."Sjacco de Vos, Senior Project Manager for Royal HaskoningDHV, said: "Our goal is to ensure that access to land is secured and TAP can begin the pipeline construction on schedule, and also to ensure that people affected by the project are properly compensated according to the EBRD standards."TAP has also established an impartial "Grievance Mechanism" - an efficient and quick process to receive complaints/expressions of concern from people living near the proposed pipeline, and TAP commits to responding to these and providing relevant solutions.

Contact

Trans Adriatic Pipeline AG
Athens, Greece
+ 30 210 7454613

Synodon completes realSens(tm) crude oil detection demonstration

Synodon Inc. ("Synodon") announces that its realSensTM technology successfully demonstrated its ability to detect hydrocarbon vapour plumes released from crude oil samples provided by one of its customers. These results build on the previously announced pentane, condensate and gasoline detection tests performed and announced over the last year and represent the final phase in demonstrating the ability of realSensTM at detecting leaks from virtually all types of liquid hydrocarbons. Full reports for these tests are available upon request and will also be presented at upcoming industry technical conferences. For the demonstration, a Western Canadian light sweet synthetic crude (OSA) sample was used which contains one of the lowest percentages (about 5%) of volatiles when compared to other World crudes. The typical analysis, available on www.crudemonitor.ca, lists butanes (C4) at 1.33%, pentanes (C5) at 2.11% and hexanes (C6, a smaller contributor to vapours) at 2.33%. Vapour plumes were released from a custom evaporator containing 20 liters of OSA at 2 different flow rates while realSens™ passed over the leak area. The vapour flow rates were chosen to be below and above the previously derived detection threshold (0.035 litres per minute). The subsequent data analysis showed that the plumes were detected with 95% reliability for vapour rates between 0.04 to 0.06 litres per minute. In a practical open pool evaporation setting, this vapour rate would correspond to a crude oil leak of between 5 to 10 barrels per day, or <0.005% of the flow in a medium sized 200,000 bpd pipeline. This is a significantly smaller (over 100 times) release rate than the typical 1% that can be achieved by current pipeline monitoring technologies. The detectable leak size will be even smaller for products with a higher concentration of light hydrocarbons. "This demonstration validates the ability of the realSensTM technology at detecting very small leaks from low volatility crude oil products while airborne" stated Adrian Banica, CEO of Synodon Inc. "We have now proven the effectiveness of this technology at detecting a wide variety of liquid hydrocarbon products from pure pentane to gasoline, condensates and finally crude oil. Since most of the products transported through the World's liquid pipelines are crudes, this enables Synodon to now market its services to this entire infrastructure."

Contact

Adrian Banica
Synodon Inc.
Edmonton, Candada
E-mail: investors@synodon.com

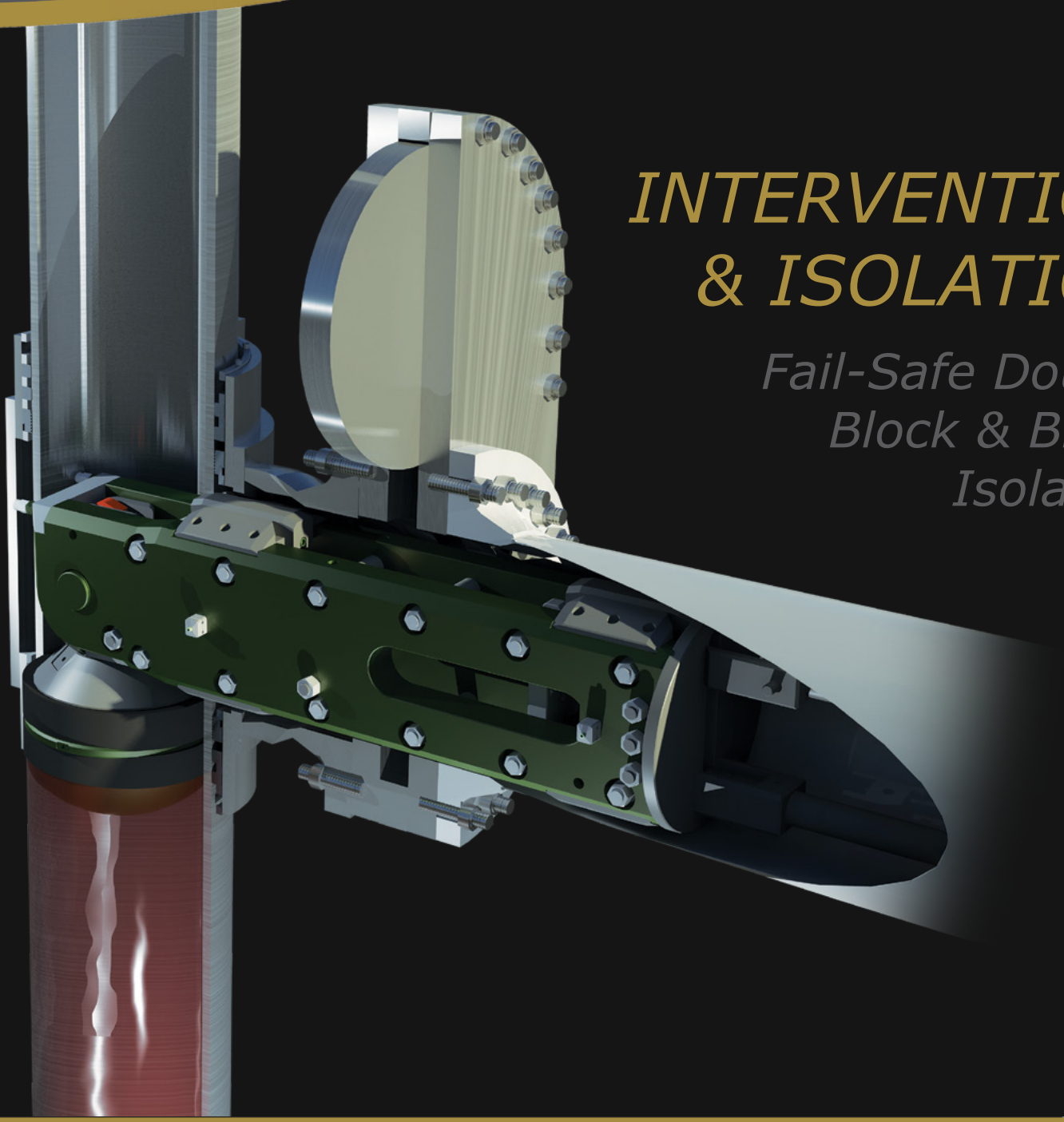
NDT Systems & Services opens Pipeline Inspection Data Analysis Center in Mexico City

NDT Systems & Services, a leading supplier of ultrasonic pipeline inspection and integrity services, announces the opening of its Global Data Analysis Center in Mexico City, Mexico. The new operational unit will serve as the company's global hub for analysis of pipeline data gathered by pipeline inspections worldwide. A team consisting of more than 50 analysts will analyze inspection data that are predominantly captured with ultrasonic technology, which is used to detect corrosion or cracks in liquid pipelines. Quality control and report production will be maintained at NDT sites in the US, Germany, Malaysia and Dubai. "Best inspection data quality and fast report delivery are NDT's top benchmarks", says NDT Systems & Services President Wolfgang Krieg. "The Global Data Analysis Center enables us to efficiently respond to our customer's onshore and offshore pipeline integrity requirements by significantly reducing delivery times." NDT's investments in technical resources and skilled workforce reflect the growing demand for enhanced inline inspection data accuracy and integrity services by regional and local pipeline operators and owners.

Contact

Peter Smorscek
NDT Systems & Services GmbH & Co. KG
Stutensee, Germany
+49 (0)7244 7415-851
peter.smorscek@ndt-global.com

STATS GROUP



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Shah Deniz Consortium announces 25-year sales agreements with european gas purchasers

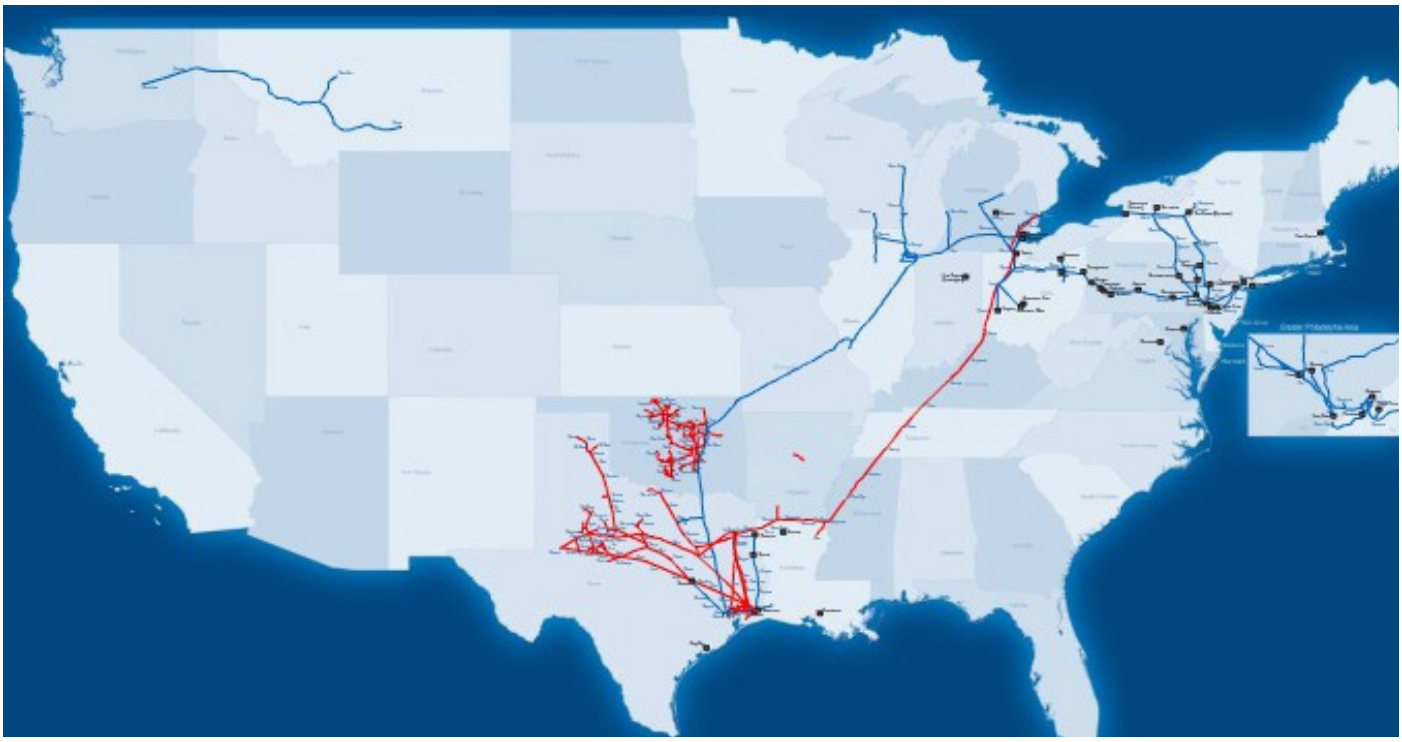
The Shah Deniz consortium announced yesterday that 25-year sales agreements have been concluded for just over 10 billion cubic metres a year (BCMA) of gas to be produced from the Shah Deniz field in Azerbaijan as a result of the development of Stage 2 of the Shah Deniz project. multiple European companies have come to a successful conclusion. These agreements mark the biggest gas sales in the history of Azerbaijan. They also mark the beginning of direct links between Azerbaijan's huge gas resources and the European markets Azerbaijan is committed in the history of the oil and gas industry.On behalf of the Shah Deniz consortium, I would like to thank all the companies involved in these negotiations. The deep cooperation that has led to the signing of these gas sales agreements sets the foundation for many years of partnership.

is set to bring gas directly from Azerbaijan to Europe for the first time, opening up the Southern Gas Corridor. In total 16 BCMA of Shah Deniz Stage 2 gas will be delivered through more than 3500 kilometres of pipelines through Azerbaijan, Georgia, Turkey, Greece, Bulgaria, Albania and under the Adriatic Sea to Italy. Today's agreements for European gas sales follow the signing of agreements with BOTAS in 2011 to sell 6 BCMA of gas in Turkey. "We are delighted that the years of negotiations led by SOCAR with to long-term cooperation with the Shah Deniz gas purchasers. I am sure that this cooperation will bring benefits to consumers across Europe and will play an important role in strengthening European energy security," said Rovnag Abdullayev, President of SOCAR Commenting on the agreements, Gordon Birrell, Regional President for BP in Azerbaijan, Georgia and Turkey, and President of the Operator of the Shah Deniz PSA, said: "The Shah Deniz consortium is proud to be involved in the conclusion of one of the biggest gas deals The strong demand for Shah Deniz gas gives us confidence in the long-term development of Azerbaijan's gas resources. Today's signings represent another important milestone bringing us closer to a final investment decision on the Shah Deniz 2 project".

Contact

Nizameddin Guliyev
SOCAR Press Office
Baku, Aserbaidschan
+994 12 521 01 29

Sunoco launches open season for Permian Express 2 Pipeline in Texas



Sunoco Logistics Partners L.P. announced that Sunoco Pipeline L.P. will commence a binding Open Season for its Permian Express 2 pipeline. The pipeline will provide additional crude oil takeaway capacity for the growing production in the Permian Basin. The pipeline will originate at multiple locations in West Texas: Midland, Garden City and Colorado City. Permian Express 2 will have access to multiple SXL and third-party pipelines to provide producers the ability to reach various markets and refineries on the Gulf. Coast and in the MidContinent "We are pleased to launch the Open Season for Permian Express 2," said Michael J. Hennigan, president and chief executive officer. "We remain bullish on the Permian Basin's growth. Crude oil production in this basin is projected to increase annually by approximately 200,000 barrels per day according to latest industry and consultant estimates.We are proceeding with the Open Season to determine market interest to develop this project to provide critical takeaway capacity to help producers and refiners deliver Permian crude oil to key markets. With the ability to reach multiple destinations, including our Nederland terminal, PermianExpress 2 is a very attractive, flexible option for shippers." The Partnership will construct approximately 300 to 400 miles of new pipeline pending customer interest for various locations. The Permian Express 2 pipeline is anticipated to have an initial capacity of approximately 200,000 barrels per day and is expected to be operational in the second quarter of 2015. The Open Season will commence on September 18, 2013.

Contact

Christopher Martin
Sunoco Logistics
Houston, U.S.A
cdmartin@sunocologistics.com

A new brand new strategy for ROSEN

ROSEN
empowered by technology

What began as an engineering company for inspection in the oil and gas industry is today a worldwide provider of cutting-edge solutions in all areas of the integrity process chain. The tremendous growth and diversification of the last 30 years required a few changes, not only for ROSEN as a company but also for the way it looks. A new corporate design and an even stronger customer-centric approach provide an optimum platform to meet this challenge. An evolution that finds its expression in the new brand appearance.

ROSEN's new corporate design now reflects ROSEN as a global provider of a vast collection of superior technologies in all areas of the integrity process chain suiting a wide range of industries: Oil & Gas, Energy, Manufacturing, Process, Mining, Telecommunications, Transportation and Agriculture for a wide range of assets, including pipeline, tanks and vessels as well as wind turbines, trains, telecommunication towers and many more.

Nothing is impossible

The history of ROSEN is characterized by a tremendous thirst for adventure – in technological terms, of course. Empowered by technology was – and still is – at the core of what is now a global company. From the outset, it was clear that the leader in this industry would be the company that could recognize customer needs before the customers even knew those needs existed. No problem is too difficult and no challenge is too big: the perfect solution can always be found

The key to this highly innovation driven approach is a sympathetic ear for the customer. Listening carefully to the specific needs and challenges that every customer brings along is the spark for every new product or service. Empowered by Technology – a promise that ROSEN systematically delivers by enhancing the operations of their customers and making them more safe, efficient and cost-effective and. Ultimately, this approach can enable customers to do things that were previously thought impossible.

Ready for the future

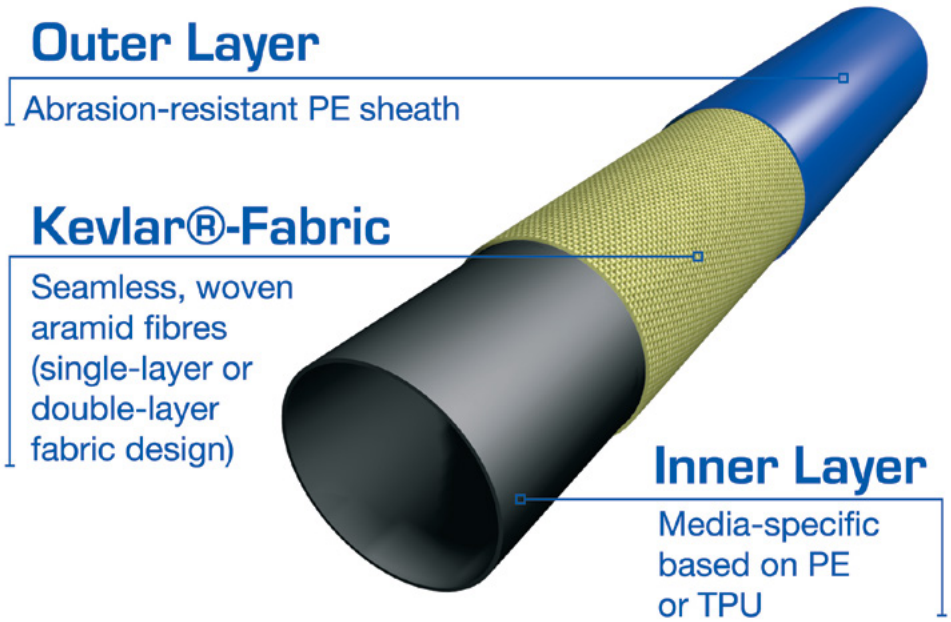
The ROSEN areas of expertise

- Inspection of critical industrial assets to ensure reliable operations of the highest standards and effectiveness
- Customized engineering consultancy providing efficient asset integrity management
- Production and supply of customized novel systems and products
- Market-driven, topical, state-of-the-art research and development providing "added value" products and services

Contact

Thomas Beuker
Corporate Marketing Pipelines
ROSEN Technology & Research Center GmbH
Lingen, Germany
49-591-9136-409
tbeuker@roseninspection.net

Rehabilitation of pipelines with flexible relining technology



With the increasingly aging pipeline infrastructure, Raedlinger Primus Line offers an economical and innovative trenchless relining technology that is characterized by flexibility, portability, light weight and low wall thickness while having the material strength of a steel pipe. It can transport different fluids such as drinking water, natural gas, crude oil, salt water, kerosene and even fluids containing abrasive components. The relining hose is produced in nominal diameters from 150 mm to 500 mm and can withstand pressures of up to 62 bars.

Composition & Installation

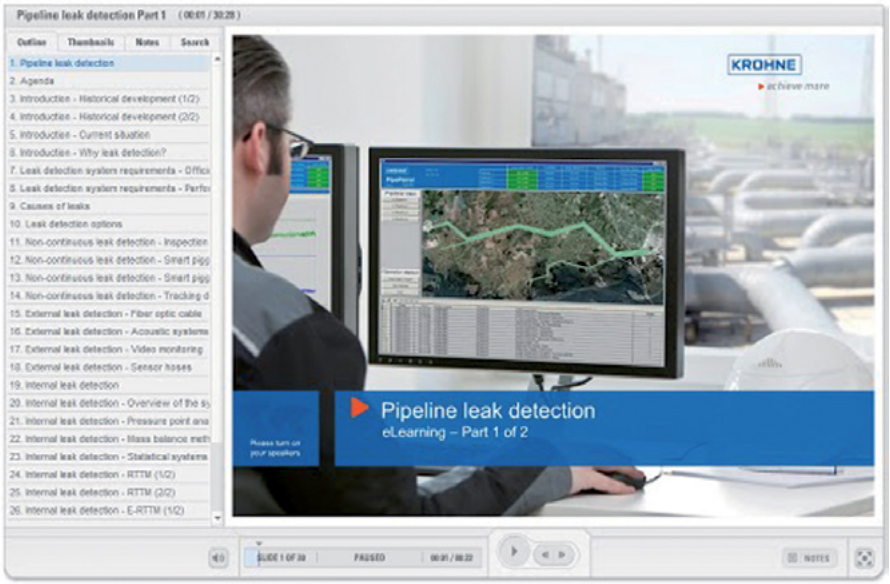
The hose consists of 3 different layers. The inner layer of the hose can be tailored to the specific can be tailored to the specific fluid being transported. The middle layer consists of a seamless aramid fabric which functions as a static load-bearing layer. The outer layer is made of wear-resistant polyethylene regardless of the transported fluid and protects the middle layer during the installation process. Specially developed termination fittings on each end connect the hose to the host pipe with flanges or welded ends. Thus, a durable and pull-proof connection is achieved. The hose is flexible and bends of up to 45 degrees can be negotiated and installation lengths of up to 2.000 m in one single step can be realized. Thus, fewer construction pits are needed and additional cost and time savings can be achieved. ends. Thus, a durable and pull-proof connection is achieved. The hose is flexible and bends of up to 45 degrees can be negotiated and installation lengths of up to 2.000 m in one single step can be realized. Thus, fewer construction pits are needed and additional cost and time savings can be achieved. ends. Thus, a durable and pull-proof connection is achieved. The hose is flexible and bends of up to 45 degrees can be negotiated and installation lengths of up to 2.000 m in one single step can be realized. Thus, fewer construction pits are needed and additional cost and time savings can be achieved. Furthermore, mobility costs can be reduced since little machinery is needed on-site and a single transport drum can hold up to 4.500 m of the Raedlinger Primus Line hose. The system has a minimum life span of 50 years

Contact

Andreas Gross M. Sc. (Univ.)
Rädlinger PRIMUS LINE GmbH
Cham, Germany
+49 9971 4003 240
andreas.gross@raedlinger.com

New eLearning on pipeline leak detection for engineers

KROHNE Academy online extends with free eLearning course dedicated to pipeline monitoring Two learning modules cover a broad range of topics from historical development to current fields of application. Pipeline transport of fluids is a growing market all around the world. As the volume of substances transported increases, so does the importance of leak monitoring. The free eLearning course keen to help engineers understand how leak monitoring systems work. Participants will find a broad range of topics related to pipeline leak detection in two course modules. The first module covers historical development, leak detection system requirements, causes of leaks, leak detection options, non-continuous leak detection, continuous external leak detection and continuous internal leak detection. The second module features leak localisation, Human Machine Interfaces, additional functions in leak detection and typical applications of leak detection systems. The course is part of the KROHNE Academy online which is a free online training tool covering topics in the field of industrial process measurement. It is suitable for staff in practical roles, who come into contact with a wide variety of measuring tasks daily, as well as students or anyone else with an interest in the subject, wanting to ensure they are up to date with measuring technology and applications in technical facilities As with the seminars, the content of the KROHNE Academy online is vendor-independent. The audio/video courses stand out for their clear structure, starting with the basics and moving on to interpretations, advantages and limitations, then applications and industries where the technology is applied. After a short evaluation, the participant can request a certificate to state successful participation. No previous knowledge is required for the web-based training, however. a certain level of technical understanding is helpful.



KROHNE Academy online extends with a free eLearning course dedicated to pipeline monitoring

Contact

Jörg Holtmann
KROHNE Messtechnik GmbH
Duisburg, Germany
+49 203 301 4511
j.holtmann@krohne.com

TDW and Centrica Storage sign pipeline services agreement

TDW Offshore Services (TDW) has signed an agreement to offer pipeline isolation services to UK's gas storage company Centrica Storage (CSL) with SmartPlug tool, which integrates a pressure test module. According to the US-based pipeline equipment and services provider TDW, using the tool, pressure can be isolated in an active pipeline and production can be maintained, besides carrying out maintenance. TDW Offshore Services SmartPlug operations director Larry Ryan said the five-year agreement extends the agreement between the companies. Using SmartPlug tools, new or repaired valve can be service pressure-tested and seat leakage tested in-situ from both sides with the help of nitrogen prior to releasing the isolation and admitting gas. CSL isolated the main sea-line that connects the offshore 47/3B platform recently with its Easington Gas Terminal using a TDW SmartPlug system, which is installed in the riser at the platform end. This allowed change-out of the platform Emergency Shutdown Valve without the requirement to vent down the 30km long pipeline, reducing the greenhouse gas emissions associated with natural gas venting.

Contact

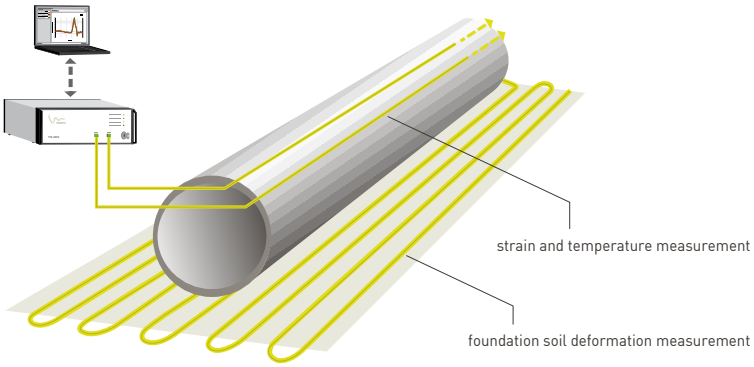
Larry Ryan
TDW Offshore Services
Stavanger, Norway
+47 51 44 32 40
lawrence.ryan@tdwilliamson.com

Pipeline integrity and leakage detection using the fTB 2505 monitoring system

fibrisTerre's fTB 2505 distributed fiber optic sensing system provides comprehensive leakage and structural integrity monitoring solutions for long distance pipelines.

Pipeline integrity and leakage monitoring

The strain sensing capability of the fTB 2505 system can pick up any section of the pipe experiencing excess amount of strain, which can be good indicators of potential structure damage. Further, as the temperature of the product transported in a pipeline is usually different than the environment surrounding the pipeline, a leakage can cause a sudden and localized temperature change. This temperature change can be quickly identified by the fTB 2505 monitoring system.



Pipeline foundation settlement monitoring

The rough terrains through which some pipelines are constructed bring about challenging foundation issues. Through integrating special fiber cables or fiber embedded geotextiles into the pipeline foundation, excess soil deformation can be timely detected before significant structural damage occurs.

Contact

Dr.-Ing. Nils Nöther
fibrisTerre GmbH
Berlin, Germany
+49 30 6290 1320
nils.noether@fibristerre.de

Keynote
The pipeline market from a European view.

1. WORLD ENERGY OUTLOOK

The actual development of world´s primary energy consumption and production data are not deviating dramatically to the prognosis of different sources like BP statistical review, Shell energy scenarios or other NGO´s data analysis and outlook over the past years. The trend is stable at 1,8% growth in global primary energy consumption. The real change has to be seen in the US shale gas revolution and therefore strong shifting of industrial development and economic benchmarks. Already in early 2013 US has taken over the pole positions in oil and gas output with an equivalent of 22 million barrels per day from former number one Russia.

Whilst many governments in Europe are still struggling to accept fracking methods and define safe codes and standards for harvesting shale gas, the US industry is reshaping and growing fast with lowest energy prices in the history (gas price Henry Hub 2,76 $ per million BTU). This economic awakening will put enormous pressure on Europe's markets, economics and industry (average German gas import price 11 $ per million BTU). Despite this pressure the highly populated areas within Europe, especially Germany, put the shale gas exploration under special evaluation and additional risks to be evaluated (amount of shale gas to be exploited, interference with potable water resources etc.) On the one hand Germany and its own energy revolution (Energiewende) is facing dramatic drawbacks. The price for electric power is exploding due to the taxes supporting renewable energy such as wind and photovoltaic (EEG). Nowadays the coal is cheap and obsolete in the US and is transported to Europe. Consequently the CO2 emissions are on the rise too. Old fashioned and even new coal fired plants are the winner in the merit order for the production of power. On the other hand low emission gas fired plants even with highest efficiencies (60%) are shut down or mothballed. They were thought being ideal partner of the renewable energy as they are able to control and minimize any variation in the load conditions during net transport. Fast response between minimum and full load only can be reached with gas turbines and their lowest carbon footprint within the fossil fuel family.

Whilst Asia´s coal and power industry is producing the biggest share in the world´s green gas emissions, the world's total primary energy production based on renewable is only at 4,3%. Germany is either not meeting its CO2 targets or not reaching the energy reducing limits established within the self-made energy revolution. Additionally it influences Europe's power transport systems with more than 20% of renewable power input and relevant fluctuations in load and frequency. So Europe is looking on Germany's new government how they will develop a countrywide energy master plan fulfilling targets for low energy prices and meeting climate limits.Moreover the EU has prepared already a plan to promote international energy transports and to limit permitting procedures to a maximum of three years. This powerful package will be rolled out with a nearby 6 billion € investment plan with the aim to stabilize the industry and economic wealth within Europe.

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2. OIL & GAS PIPELINE CONSTRUCTION REPORT

Still there is a high pipeline construction mileage reported especially for US, Canada and Asia with a cumulated length of some 25.000 km per year. As an example long distance export pipelines supplying US Midwest directly from Canada's oil sands are planned and will boost crude oil export figures. Dependence on far or mid-East oil imports will be minimized in the future and the new energy policy for US and Canada based on oil from oil sands and shale gas will shape the future of this continent.

Crude oil demand in Germany is stable, a slight decrease is foreseen. Further no pipelines have to be constructed but old transit routes will be kept alive or upgraded by new pumps or implementation of drag reducing fluids for increase in transport capacity (TAL Transalpine Pipeline). For gas the European Network of Transmission System Operators for Gas (ENTSOG) establishes the Ten Year Development Plan (TYDP) or Network Development Plans (NDP) for the German gas transport. Comparing the major hub function of Germany in the past this function will be taken over by Netherlands, Poland and France new gas infrastructure in the near future. According to German NDP2012 Scenario II the pipeline length which has to be constructed until 2022, sums up to 730 km with total costs of 2,2 billion € (incl. all other measures). The newly founded gas transport companies association (FNB) is nowadays working on the relevant update of the NDP2014 including new scenarios and taking care of the lower L-gas production in Germany and Netherlands.

As the EU´s target to create a European internal gas market to be fully established in 2014 will definitively not be met, German gas infrastructure is concentrating on German demand mainly. The golden age for gas, as clearly being implemented in the rest of the world, will not touch our German infrastructure leading to negative effects of increased carbon foot print. So summarizing the world trends on future energy consumption and production the shale gas revolution will not take place in main countries within Europe leaving Ukraine and Poland as test candidates.

3. PIPELINE SAFETY

Still pipelines are the safest, reliable, most efficient and economical way to transport any kind of gaseous or liquid energy over long distances. International statistics and reports such as EGIG (European Gas Pipeline Incident Data Group), CONCAWE (Conservation of clean air and water in Europe) in Europe, DVGW (Deutscher Verein des Gas- und Wasserfaches) for Germany and many reports for US and Canada witness this clear message. But beneath all this statistics and extremely low incidents rates compared to other transport systems like rail and truck, interesting trends have to be mentioned after more than 40 years of incident reporting:

- Third party impacts, created by excavators , soil rockets or product theft , remain the main cause of product release
- Mechanical failures have slightly increased in the past years
- Incidents due to ground movement or landslides are increasing

For oil & gas transport the 5 years moving average failure rate frequency equals to ca. 0,15 per year per 1000km. Although this figure has reduced consistently over the years, it has a tendency to stabilize. Even though pipelines are engineered and constructed with comparable standards worldwide and therefore incident rates do not deviate so much.

Moreover, it has to be mentioned that according to the DVGW incident statistic fatalities for the population have never ever happened in Germany. The deterministic approach within the German rules and regulations as well as control functions by the competent authority may be the key for this outstanding record. "Even most of the oil pipeline systems were built in the 60s and 70s there is no evidence that the aging of pipeline systems implies a greater risk of spillage. The use and further development of internal inspection tools hold out the prospect that pipelines can continue reliable operation for the foreseeable future (CONCAWE)".

Summarizing the mileage of oil & gas pipelines reported by EGIG, CONCAWE and DVGW more than 200.000km high pressure pipelines are covered within these databases in Europe.

4. DEVELOPMENT OF INNOVATIVE TOOLS

In order to keep these energy arteries reliable and safe and to avoid a dramatic increase in maintenance cost due to aging effects in the future the industry together with pipeline operators has to develop new and innovative tools and procedures. Taking the German high pressure gas industry as an example the following recent developments have to be highlighted:

- On few and specific pipeline sections mechanical failures like cracks and corrosion induced anomalies were detected and reported to the competent authority. First time a gas pipeline in hilly sections was filled with water and a crack detection pig based on ultrasonic waves was successfully inserted to find the failures. This procedure is very cost intensive and has a strong impact on pipeline operation. Therefore new pigs have to be developed to run in dry environment without a coupling medium. EMAT (Electromagnetic Acoustic Transducer) technology is the key but still more experience and successful runs at lower cost have to be demonstrated to minimize the impact of mechanical and material failures in gas pipelines.

- Climate change within the past years may be responsible for more flooding and landslide influence on pipeline infrastructure. To witness the original position of the line as constructed new and highly sensitive IMU (Inertial measurement Unit) tools have been developed. This data collected by these pigs can give indications where landslides or ground movements harm the integrity of the pipeline due to local bending and therefore stress impact.

5. INTERNATIONAL EXPERIENCE IS REQUIRED

These examples highlight how the pipeline operators together with specialized pigging industry influence the future pipeline incidents statistics. Competent authorities specifically the regulator has to support the operator and accept relevant costs for engineering, development, testing and operation of these leading edge technologies. As these kind of failures are not restricted to gas pipelines only the worldwide community of Oil & Gas operating companies have to share their experience more closely and open-minded. The PTC Pipeline Technology Conference may be used for the necessary exchange. To support this interaction the rules and codes of the German gas industry have to be published in English. Also the European and International incident reports have to be aligned with their nomenclature and therefore made fully comparable and transparent. These measures will increase the transparency of the energy transport via pipelines and

support by that authorities and politicians in the relevant permitting processes and acceptance of the communities and population effected.

Current focus on planning the construction and operation will be in the following fields:

- Steel Line Pipes
- Inline Inspection
- Integrity management
- Operational Improvements
- Corrosion Protection
- Planning and construction
- Monitoring

The conference is complemented by in-depth seminars in which operators and technology developers discuss about new and existing developments. With this electronic Pipeline Technology Journal ptj the editor has created a new instrument whereby relevant developments will be presented worldwide twice per year.

Author

Heinz Watzka

Former managing Director of Open Grid Europe and former member of the Board of DVGW, former member of the OPMG Team at CONCAWE.

watzka@eitep.de

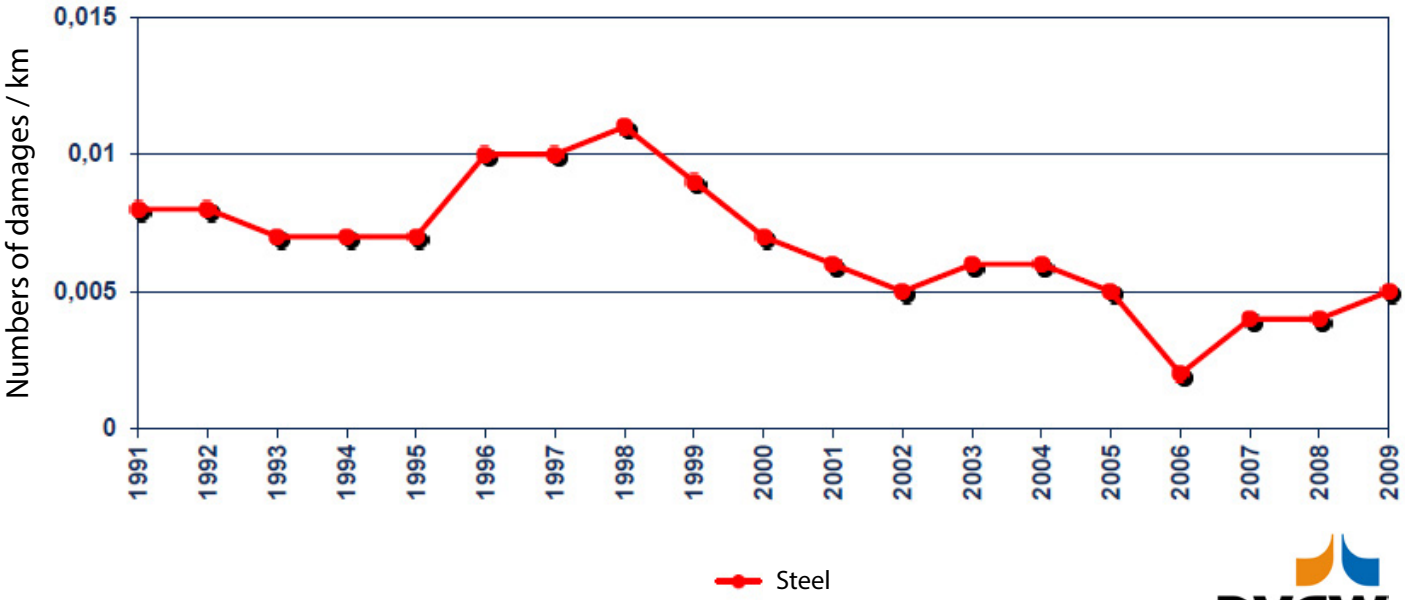


Figure 1: Damages on gas-pipes: high-pressure-pipes above 16 bar

Inline Inspection for the Nord Stream Pipeline

Jean-François Plaziat - Nord Stream AG, Switzerland

INSPECTION AS PART OF THE INTEGRITY MANAGEMENT STRATEGY

As an operator, Nord Stream offers gas transportation capacities via its 1,224-kilometre twin pipelines, which run from Vyborg, Russia to Lubmin, Germany. Line 1 began gas deliveries in November 2011. The second string of Nord Stream became operational as part of the fully-integrated twin pipeline system on October 8, 2012. Each pipeline is made up of about 100,000 concrete weight-coated pipe segments, each with an average length of about 12.2 metres and a constant inner diameter of 1,153 millimetres. The pipes are made of high-tensile steel, up to 41 mm in thickness that has an internal anti-friction coating and an external anti-corrosion coating. The internal coating consists of a two-component epoxy resin flow coat, which increases flow capacity by reducing friction.

To preserve the pipeline as a valuable asset for the security of European gas supply over the coming decades, a number of integrity management measures were designed, which cover the automation systems, landfall installations as well as the 1,224 kilometre offshore section of the twin-pipeline itself. Part of this maintenance is an external visual and instrumental inspection of the pipelines, conducted via remotely operated vehicles (ROVs) followed by support vessels. The external inspection confirmed that the pipelines themselves have not moved on the seabed due to changes in the seabed beneath them. It also helps to detect any foreign objects such as trawl nets or debris that may accumulate near the pipeline. Additionally, the inspection data is used to confirm the integrity of the rock berm structures used for stabilizing the pipelines on the seabed. The first external inspection (baseline inspection) for Line 1 was performed in 2012 following the completion of construction and the first period of operation to determine that the pipeline had settled under load. This year, the baseline inspection of Line 2 has been performed as well as the annual inspection of Line 1. The material integrity of pipeline is confirmed by performing an internal inspection of both lines. To that end, inline inspection tools, also referred to as PIGs (Pipeline Inspection Gauges) are sent through the pipeline, propelled by the gas flow. The high-resolution equipment can detect and identify even minor changes in the condition of the pipeline and serves to confirm the absence of corrosion or mechanical defects, in addition to measuring geographical coordinates indicating any pipeline movement compared with as-laid and design conditions.

INTERNAL INSPECTION PROCESS

The internal inspection process for both pipelines was performed for the first time in summer 2013. This baseline inspection has confirmed the quality of pipeline building process and has provided the very first data set with which all future inspection results will be compared to detect any changes or movements. During this baseline inspection, Nord Stream conducted consecutive internal runs of both lines with pipeline inspection tools. The different inspection tools are inserted into the pipeline via the PIG launchers at the Landfall Facilities Russia (LFFR). Gas is redirected into the launcher and once the pressure behind the tool exceeds the pressure in front of it, it is pushed through the pipeline. Each line is "pigged" individually. The first tool, the gauge PIG took three-four days to reach Germany. Once it is received and analysed, a cleaning tool is sent through the pipeline. If deemed necessary based on the amount of debris and

dust it collects a second cleaning tool could then have been sent down the pipeline. After the gauge and cleaning tools, the inspection tool is sent through the pipe. This took ten days. Once received in Germany, the tools are cleaned, maintained and in the case of the inspection tool, the recorded data is recovered and sent to post processing and a three stage analysis. The complex inspection tool sent through each pipeline was designed specifically for the Nord Stream Pipeline by ROSEN Group. The tools underwent extensive testing, such as a pull-through test in a test line with artificial features in the metal pipe wall, a pull-through test in a line with artificial features in the concrete coating and a pneumatic pump test, in order to confirm functionality and specification. The in-line inspection tool was also tested on a similar but shorter 48"-pipeline in Malaysia prior to its use for Nord Stream.

THREE TYPES OF INLINE TOOLS USED

During the inspection campaign, three different tools are used: one gauge tool, one cleaning tool and the in-line inspection tool, which maps potential corrosion and metal loss as well as the exact curvature of the lines via an inertial navigation system.

The gauge tool

The gauge tool is used to detect any substantial anomalies in the internal diameter along the pipeline which could potentially obstruct the inline inspection tool during its run. Any protruding object would chip away at the gauge plate – the damage of which would later be analyzed to determine the extent of the potential obstruction. The process was previously performed as part of the pre-commissioning phase of the pipelines, when each section of the lines was flooded, cleaned and gauged. To remove the water, dewatering tools, were pushed through the pipeline with pressurized air on that occasion. The gauge tool is inserted in the pipeline in the PIG launcher in Portovaya and takes about three-four days to travel with the gas flow downstream to Germany. It weighs roughly 1.5 tonnes and measures 2.2 metres in length.

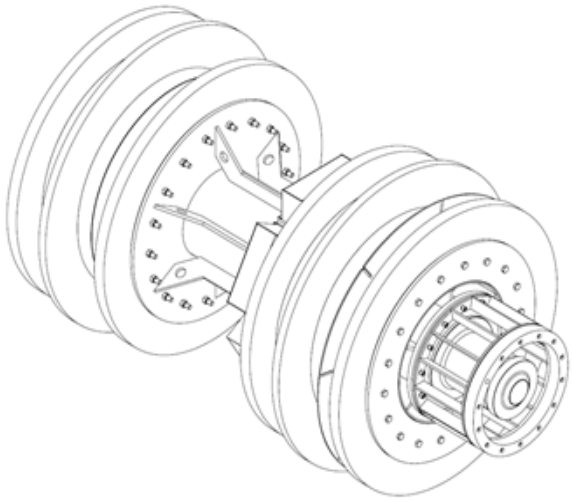


Figure 1: 48 Inch Longrun PIG with Gauge Plates (Gauge Tool)

The cleaning tool

The cleaning tool is sent through the pipe to remove small particles of dust that may have accumulated in the pipeline during operations and tiny particles of coating material that may have become loose from the inside of the pipeline. The cleaning tool is equipped with brushes to pick up dust particles. In addition, the dust is also pushed ahead in front of the tool by the sealing discs that are sized larger than the pipeline's interior diameter. A bypass lets parts of gas pushing the tool pass and so limits the speed and creates a flushing effect in the downstream area as well as transporting any particles collected en route. The tool measures 2.6 metres and weighs 1.8 tonnes. When received in Germany after about three-four days in the pipe, the tool is cleaned and the material it collected along its run is analysed.

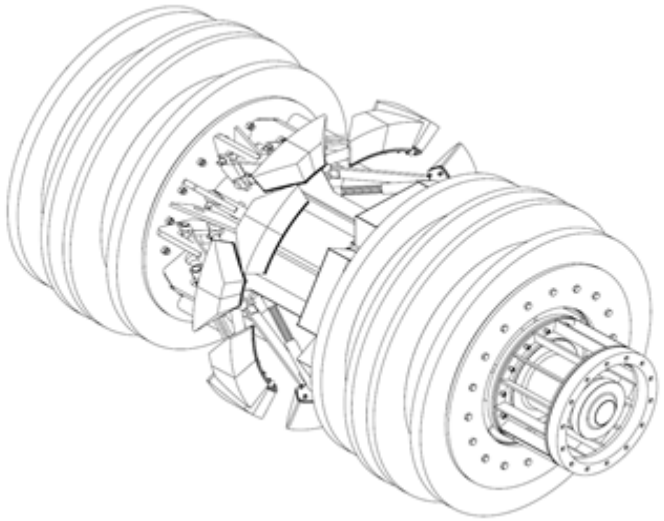


Figure 2: 48 Inch Brush PIG with Magnets (Cleaning Tool)

The inline inspection tool

The main inspection tasks are performed by what is commonly referred to as an intelligent combo tool since it combines arrays of sensors to perform different integrity inspection tasks. The tool constantly measures its distance travelled via wheels rolling along the inner pipe walls – which helps map measurement along the length of the pipeline. Since the tool works best at a speed of 1.5 metres per second, an active speed control system measures the speed of the tool and controls a bypass valve to slow the tool to the required speed. The tool weighs over 7.3 tonnes – and measures 6.6 metres in length. The tool is equipped with batteries to power the sensors during the inspection and a high-density memory device to record the data for analysis.

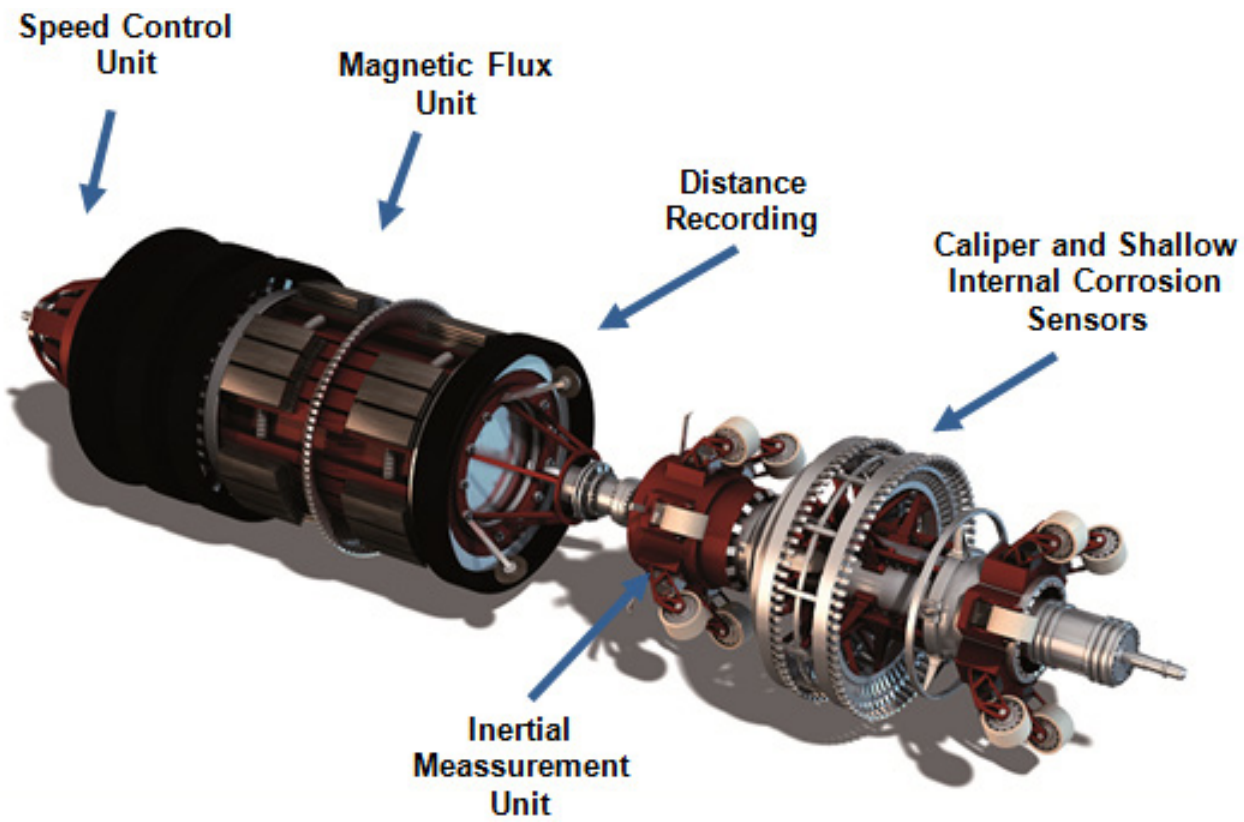
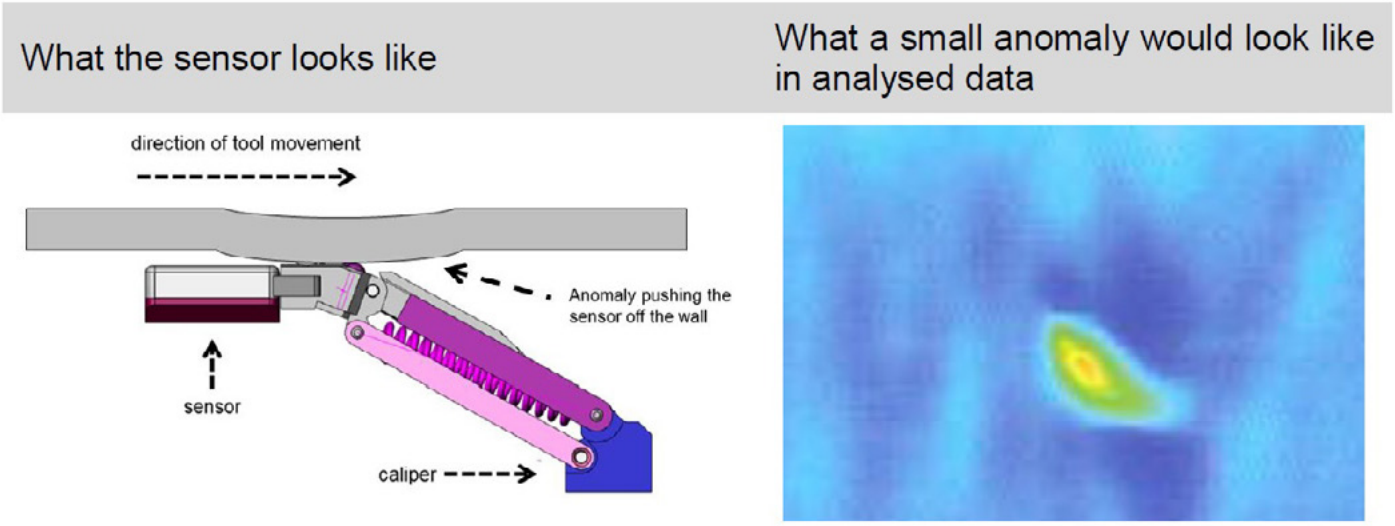


Figure 3: 48 Inch HiRes Metal Loss Mapping Tool (Inspection Tool) and functionality

An **internal diameter (ID) mapping caliper** detects and characterizes any deviations from the original pipe shape, some even smaller than one millimetre. Internal diameter changes, ovalities and dents can be detected, precisely located and identified. The tool is also able to detect and map any misaligned welding joints. The sensors function by measuring incremental changes in how far any of the spring-loaded caliper arms that guide the sensors along the pipe wall are bent when the sensors run through even very small dents or ovalities.



Corrosion is not expected during the operation of the Nord Stream Pipeline. The pipeline gas is constantly measured at the inlet to exclude the contamination of the gas with water, a necessary condition for corrosion. Also, the internal walls of the pipe are coated with flow coating, which seals the steel from external influences as well.

The shallow internal corrosion sensor is a proximity sensor attached to the caliper arm which can map surface metal loss defects. Small defects on the surface of the inner pipe wall lead to a change of the sensor's proximity to the pipe wall, which the sensor is measuring.

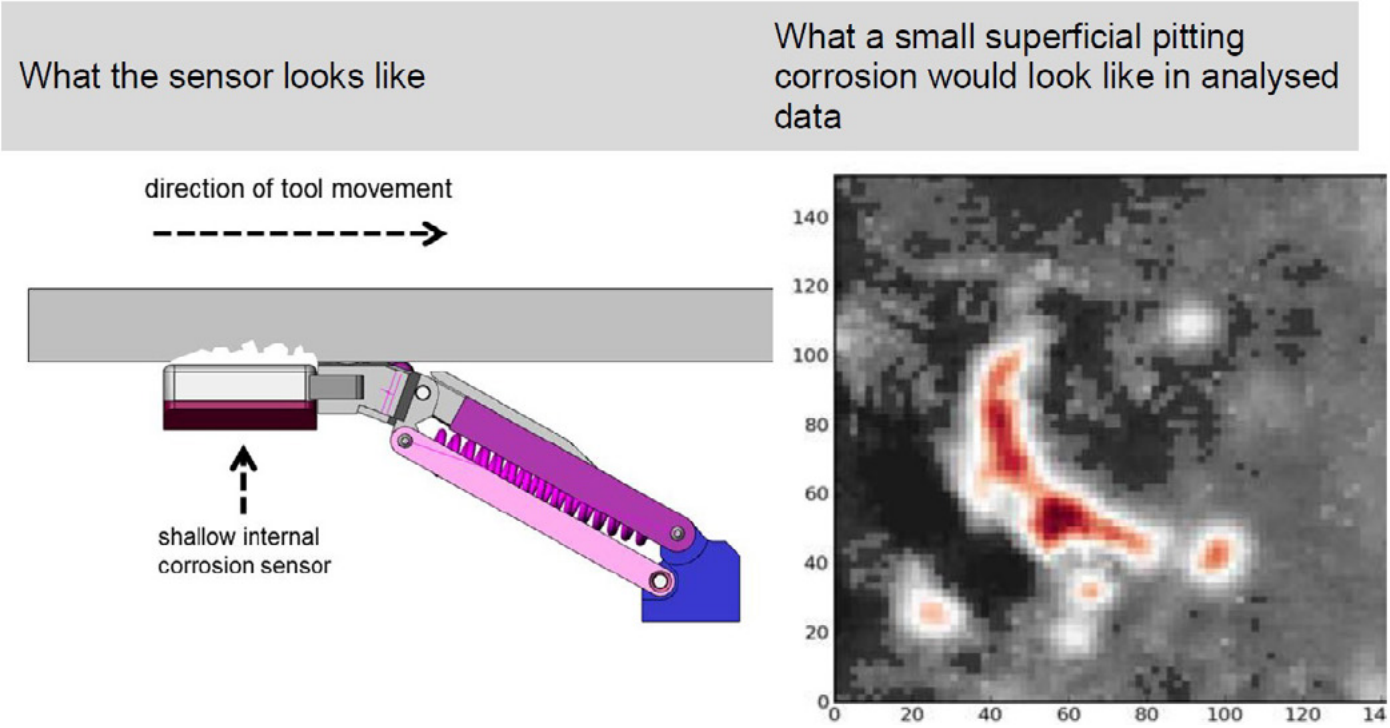


Figure 5: Shallow internal corrosion sen

Material loss or corrosion that may be enclosed in the steel or occur between the steel and the outside concrete coating would be detectable by a magnetic flux leakage sensor. A strong magnetic field magnetizes the pipe wall and an electromagnetic sensor records any changes in magnetic feedback from the pipe steel. It can detect changes in wall thickness stemming from material loss from corrosion or coating materials coming off.

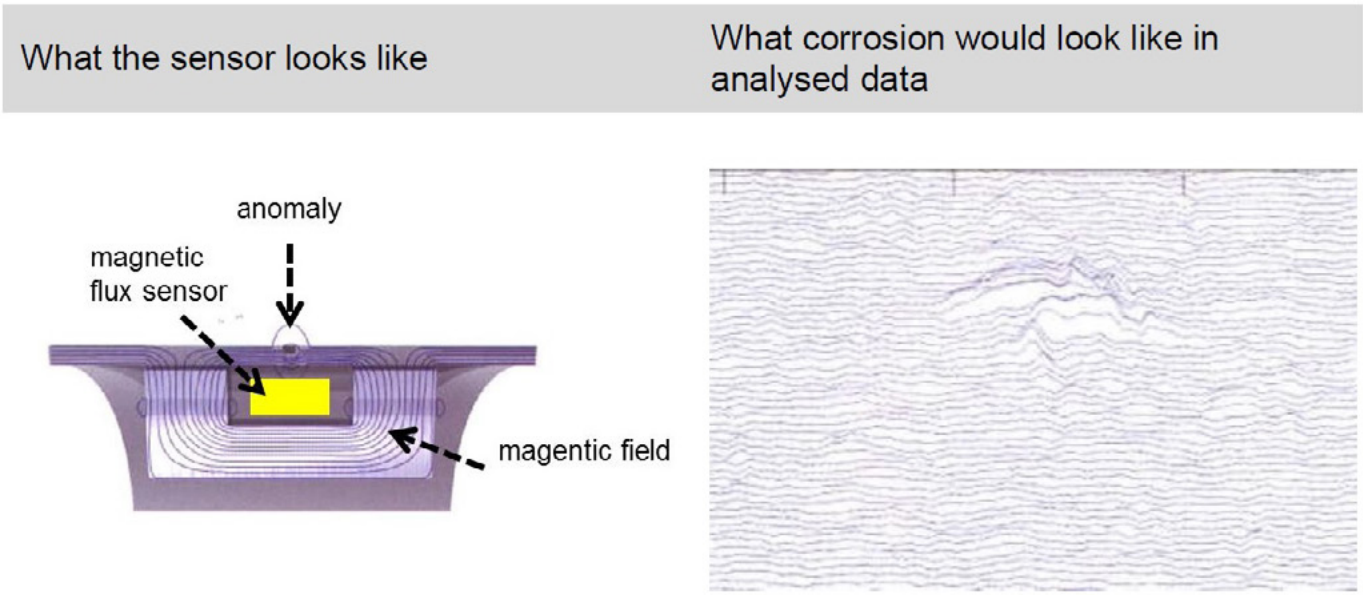


Figure 6: Magnetic flux leakage sensor

An inertial navigation system or XYZ-unit is installed on the inspection tool to accurately map the pipeline's geometry. The baseline data on all curves and bends in three dimensions is later compared with data gathered during subsequent inspections. The aim of the geometry measurement is to detect any incremental movement of the pipeline that could result in bending strains. The tool works by measuring the strain placed on the inertial gyroscope sensor when it traverses a curve in the pipeline. There are of course curves in the pipeline and any changes would register in the comparison. In that case, stabilizing countermeasures such as rock placements could be considered to keep the pipeline from shifting.

Author

Jean-François Plaziat
Deputy Technical Director
Operational Maintenance/
Engineering.
Nord Stream AG
Zug, Switzerland

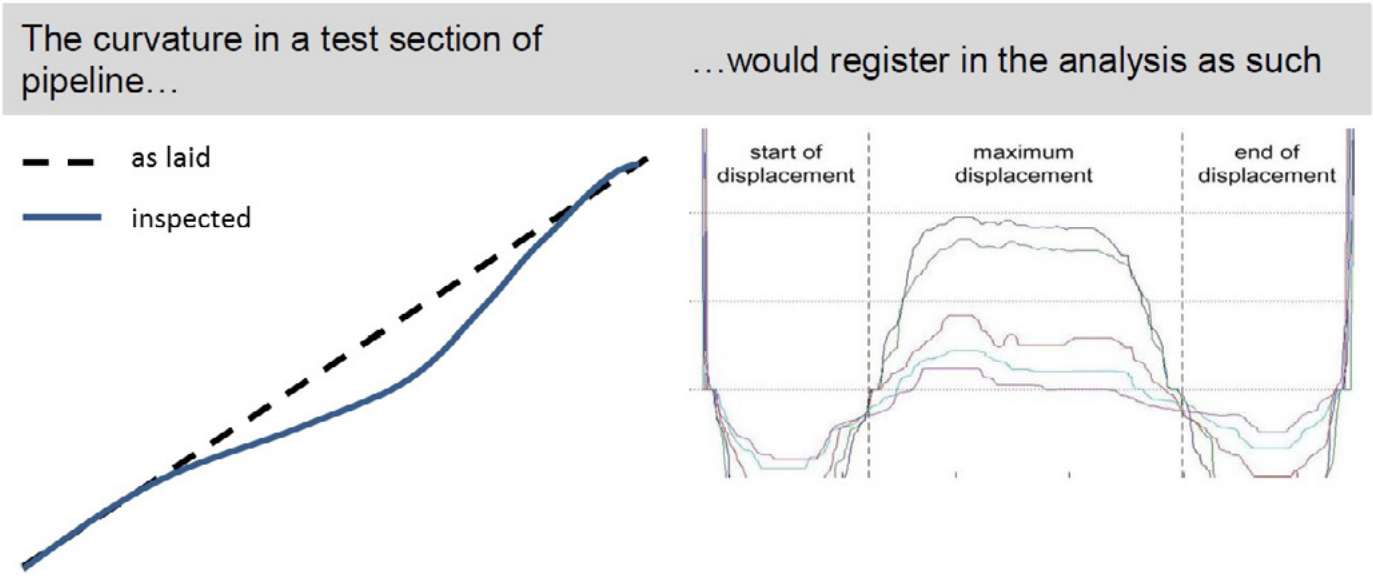


Figure 7: Inertial navigation system

UT-ILI and Fitness-for-Purpose analysis for severely internally corroded crude oil pipeline

Abdul Wahab Al-Mithin and Shabbir Safri - Kuwait Oil Company, Kuwait
Andreas Pfanger - NDT Systems and Services AG, Germany

KOC constructed a 36" dia. crude oil pipeline in 2005 to transport its share of crude oil from oil field located at Wafra, south Kuwait. The pipeline receives crude oil from a 20" pipeline. The crude oil velocity is very low due to restricted oil production. Severe internal corrosion was detected during ultrasonic thickness measurement in 2008. Subsequently ultrasonic ILI by NDT Systems and Services detected severe internal corrosion almost through the pipeline length. Initial analysis of anomalies as per ASME B31G code showed that almost half of the pipeline requires repairs.

This being uneconomical, KOC decided to carry out Fitness for Purpose assessment and entrusted this work to NDT Systems and Services. The analysis reduced required repair to only 3 km. from 12 km. Simultaneous action to control internal corrosion enabled KOC to operate the pipeline safely.

1. INTRODUCTION

In the year 2008, a small section of 36" dia. crude oil pipeline was excavated for installing corrosion monitoring fittings and internal corrosion was detected on the bottom of the pipeline. Based on this inspection finding, KOC requested NDT Systems & Services to carry out ultrasonic In-Line Inspection. The pigging activity was carried out in the year 2009. The ILI revealed the presence of dents, laminations, and severe internal corrosion almost through the entire pipeline length. Initial analysis of the data was carried out as per ASME B31G code[1]. Based on the initial assessment of the corrosion anomalies according to the ASME B31G code, a total of 12 km, nearly the half of the pipeline length, would require repair. This is obviously not an economical repair strategy. Hence, NDT Systems and Services was again contacted to carry out a Fitness-For-Purpose analysis based on advanced assessment methods, such as the RSTRENG effective area method for corrosion anomalies and the API 579 Standard[2] for lamination anomalies and blister anomalies.

The FFP analysis reduced the total length of pipeline to be repaired from 12 km to 3 km. and also provided a timeline for repairs to be carried out. For KOC, this was an enormous saving in maintenance cost and resources. It also provided a favorable time to take pipeline shutdown, arrange for pipe material and carry out repairs. The paper discusses the complete process of detection of corrosion, inspection, FFP analysis and repair strategy in detail.

NOMENCLATURE

FFP :- Fitness for Purpose
HDPE :- High Density Polyethylene
ICDA :- Internal Corrosion Direct Assessment
ILI :- In-Line Inspection
SRB :- Sulfate Reducing Bacteria

1.1 Kuwait Oil Company

Kuwait Oil Company (KOC) is in the business of exploration, production, treatment and export of crude oil in the state of Kuwait. It operates a network of pipelines for transportation of crude, gas and condensate. No other mode of transport is utilized for transportation of products and hence, fully depends on its pipeline network for operational needs. It is a complex network consisting of different feeds, inter-connections and inter-dependencies. Pipeline diameter ranges from 3" to 56" with maximum single length being 170 km. Total number of pipelines are 442 and total pipeline length being 5000 km. All pipelines are buried and travel through different terrains and soil environment. Maintaining this important asset in healthy condition is a challenge.

In the South of the country, oil reservoirs on the border of Kingdom of Saudi Arabia are shared. The operation of the reservoir is jointly managed by Kuwait and Saudi Arabia and the production is shared. The geographical area is called Wafra. Kuwait share of crude oil produced at Wafra fields is managed by KOC and transported through pipelines to KOC tank farms.

Figure 1: 36" dia. pipeline route

1.2 The crude oil pipeline

A 36" dia., 25 km long pipeline (CR088) was built and put into operation in 2004 to transport R/B crude oil. R/B crude oil is named after the reservoir located in joint operation (with Saudi Arabia) area. Another 20" pipeline (CR058) originating from Wafra feeds crude oil into this CR088 crude oil pipeline at a manifold MF/TB-1.

The pipeline is piggable with launcher at a manifold MF/TB-1 (a crude oil manifold) and receiver at North Tank Farm (NTF). Though the pipeline is meant for transporting crude oil coming from Wafra, piping connections are provided to flow crude oil from other Gathering center through MF/TB-1 header. Offtake and intake connections have also been provided at Centre Mixing manifold (CMM) at a distance of approx. 20 km, as shown in Figure 1.

The pipeline has been in operation for only 82,000 to 90,000 bpd of crude oil though it was designed for higher flow to cater for higher crude oil production. This has resulted in a very low liquid velocity in the pipeline, leading to internal corrosion. In mid 2008, KOC decided to install corrosion monitoring devices on the pipeline. The pipeline was excavated at two locations and thickness survey was carried out prior to hot tapping work. Internal corrosion was detected at both these locations. Further, as a part of manifold inspection program, thickness measurements were carried out on the pipeline at all isolation valves and branch connections locations, which have been provided with concrete pits for access. Here again internal corrosion was detected.

Detection of internal corrosion in a short span of 4 years was alarming, since such high corrosion rate has never been detected in KOC pipelines. It was then decided to carry out In-Line Inspection survey as soon as possible.

2. UT INLINE INSPECTION SURVEY

KOC decided to utilize ultrasonic intelligent pigging for obtaining accurate information on internal pitting and bottom channel corrosion anomalies. NDT Systems and Services was entrusted with carrying out cleaning pigging and In-Line Inspection. The high sensitivity of the ultrasonic principle applied leads to low detection thresholds and reliable detection of all features with a potential influence on the integrity of the line. The inspection revealed the presence of internal channeling corrosion, dents and laminations. Blistering, a typical feature found in the presence of a sour medium, was detected in a few pipe joints as well.

3. INTERNAL CORROSION FINDINGS

Internal corrosion in oil or gas pipelines is termed "sweet" or "sour" depending on the hydrogen sulphide content. The condition "sour" is defined by the National Association of Corrosion Engineers (NACE) as partial pressure of more than 0.0003 MPa hydrogen sulphide. Below this pressure the condition is called "sweet". Sweet corrosion can occur when there is carbon dioxide and water in the pipeline. The carbon dioxide dissolves in the water to form carbonic acid which reacts with the pipeline steel causing corrosion damage. Metal loss corrosion due to the presence of hydrogen sulphide is a mechanism similar to carbon dioxide corrosion as hydrogen sulphide dissolves in the water associated with oil production, forming a weak acid[3].

Sweet and sour corrosion can occur as general corrosion and pitting corrosion. In sour conditions, additional corrosion mechanisms such as hydrogen-induced cracking (HIC), stress-oriented hydrogen-induced cracking (SOHIC) and sulphide stress corrosion cracking (SSCC) can pose significant threats to the integrity of the pipeline. The ultrasonic inspection performed by NDT in 2009 identified about 60 external and 1600 internal metal loss anomalies in this sour crude pipeline. The majority of the internal anomalies is characteristic of internal corrosion in the bottom area of the pipeline which is designated as channeling corrosion. Their distribution over the distance and the circumference is shown in Figure 2.

Many of the corroded pipe joints are affected by extensive internal channeling corrosion over the entire joint length. Approximately 12 km of the 25 km long pipeline is affected by internal corrosion with depths up to around 60 % of the reference wall thickness. The width of the channeling corrosion varies between 110 and 1200 mm. The internal corrosion anomalies in the bottom area of the pipeline are distributed between 0 and 20 km. In the last five kilometers of the pipeline there is no considerable internal corrosion.

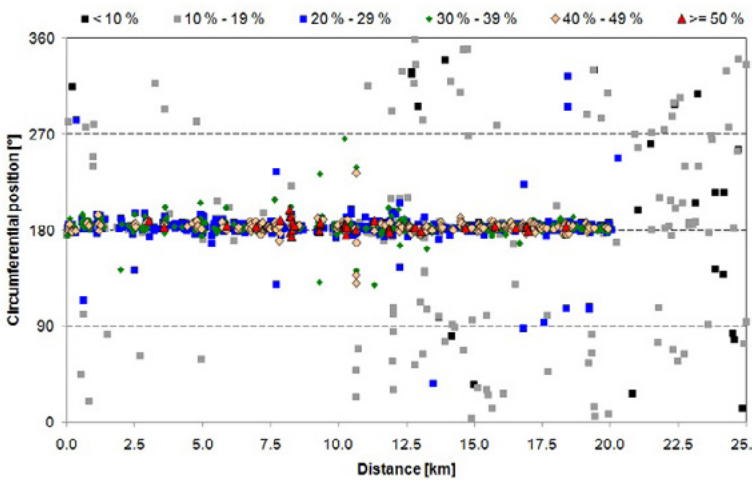


Figure 2: Distribution of internal anomalies

4. FITNESS-FOR-PURPOSE ANALYSIS

4.1 Corrosion Assessment in Terms of Immediate Integrity

A typical example of the channeling corrosion with an uneven depth profile is given in Figure 3. Among the published defect assessment methods, the most appropriate method for assessing the significance of corrosion reported in this pipeline is the RSTRENG[4,5], effective area method which takes into account the river-bottom profile of each metal loss anomaly. The river-bottom profile is a two-dimensional representation of the corrosion along the pipe joint based on the high-resolution ultrasonic wall thickness measurements with an axial sampling distance of 0.75 mm. An iterative effective area analysis is performed to determine the most critical subsection of the anomaly profile that yields the lowest safe operating pressure. This procedure accounts for the local reinforcing effects due to the varying local wall thickness along the defect profile. Therefore, this RSTRENG method results in more precise and less conservative predictions for the safe operating pressure compared to standard methods such as the B31G criterion which considers only the maximum depth and the total length of a defect. The RSTRENG safe operating pressure of each corrosion anomaly was compared to two different assessment pressures (MAOP of 630 psi and reduced MAOP of 450 psi). The safe operating pressures of around 60 anomalies (all of them are characteristic of internal channeling corrosion) are below the MAOP of 630 psi. In terms of pipeline integrity these features are therefore not acceptable at 630 psi and would require immediate repair. Using the simple B31G criterion, four times more anomalies would be unacceptable at 630 psi. Considering the reduced MAOP of 450 psi, no immediate repairs are required, as the safe operating pressures of all anomalies are above 450 psi. An overview of the anomaly acceptance is given in the assessment chart of Figure 4. The dashed green line represents the acceptance curve at the MAOP of 630 psi and the red line the curve at the reduced MAOP. Anomalies located above a certain curve are not acceptable at the corresponding assessment pressure, e.g. the anomalies requiring repair at the MAOP are located above the dashed green line.

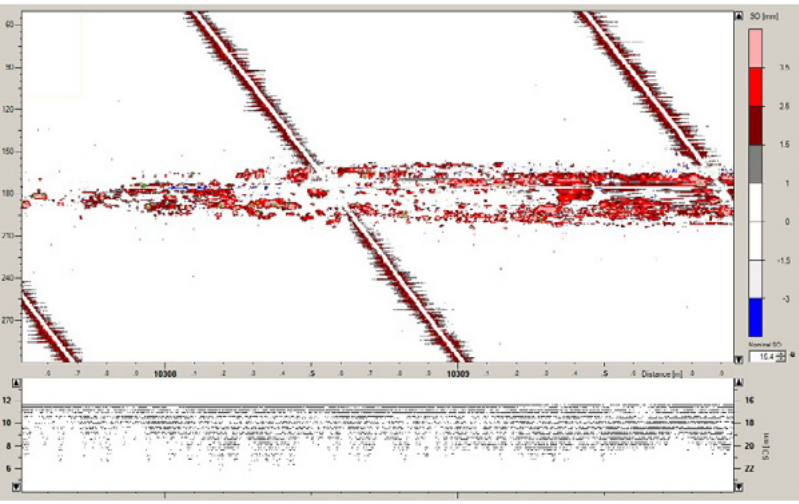


Figure 3: UT ILI data representation of bottom channeling

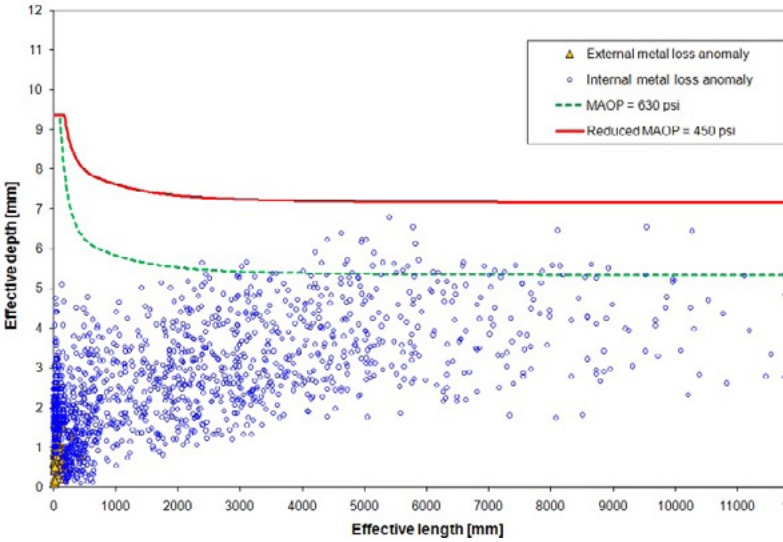


Figure 4: MAOP curve

4.2 Integritiy of the pipeline in the future

The target is to investigate the potential effect of external and internal corrosion growth on the future pipeline integrity. Analyzing corrosion growth and conducting an integrity assessment enables the operator to prioritize repairs and to develop a rehabilitation program. Corrosion growth rates can be determined based on the comparison of consecutive inspection runs. As the 2009 ILI is the only inspection conducted so far, the growth rates need to be determined in a different way. A common approach for estimating corrosion growth rates is to assume that the corrosion anomalies have been active for a given proportion of the pipeline life. For example, it can be assumed that corrosion growth initiated right after the date of commissioning in 2005 or at the half life of the pipeline anytime in 2007. The half-life approach (corrosion is active between 2007 and the date of the inspection in October 2009) leads to higher growth rates than the full-life approach (corrosion is active between 2005 and October 2009) and is therefore more conservative. Corrosion initiation and corrosion behavior is influenced by many factors. Internal corrosion depends for example on the product composition (water content), the flow rate or the use of inhibitors. The pipeline has been transporting sour crude oil since the date of commissioning in 2005. The product or product composition has not been changed during life time. Due to the low flow and velocity of the sour crude, it is very likely that the internal corrosion process started quite soon after commissioning the pipeline. Therefore, the full-life approach was applied for the estimation of internal growth rates. The resulting distribution of the internal growth rates is illustrated in Figure 5.

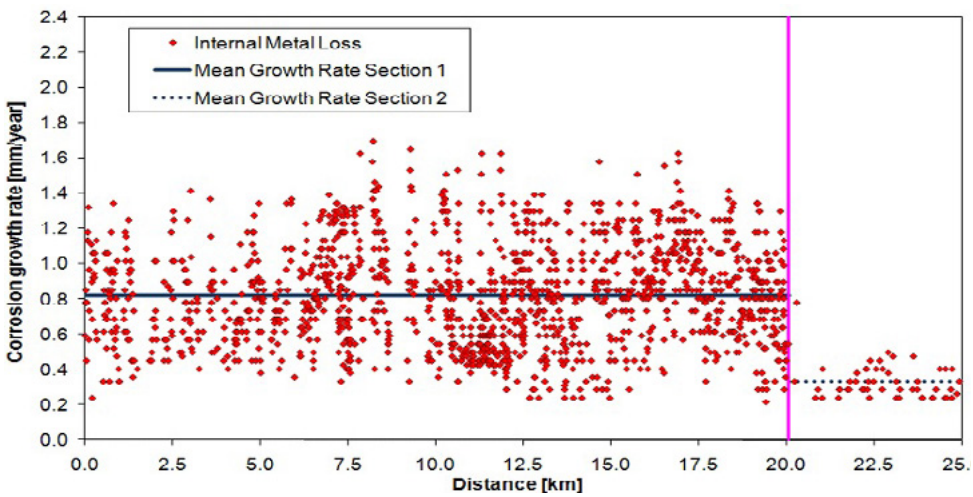


Figure 5: Distribution of corrosion growth rate

4.3 Calculation of repair dates

In order to determine future repair dates of each corrosion anomaly, the anomaly depths as reported by the 2009 inspection are extrapolated and the anomalies are assessed using the RSTRENG approach. Different options for the application of growth rates are feasible:

1. local growth rate of each anomaly
2. maximum growth rate of each section used for all anomalies within that section
3. mean growth rate of each section used for all anomalies within that section

Option 1 is not the most appropriate one as anomalies that have grown at lower rates so far may show higher rates in the future. Using the maximum rate to all anomalies (option 2) is over-conservative and using the mean rate (option 3) not conservative enough. In order to be not too conservative on the one hand but to minimize the risk of failure on the other hand, a combination of option 1 and 3 was applied. The maximum of the local corrosion growth rate or the calculated mean value of the respective section was used for the depth extrapolation of each anomaly. The estimated future repair date of. a corrosion anomaly was obtained by calculating the time when its dimensions exceed the values not tolerable at the two assessment pressures or its maximum depth exceeds 80 % of the wall thickness. The earlier of the two calculated repair dates of each metal loss anomaly has been taken as result for the future repair plan The annual numbers of anomalies recommended for repair until 2020 are illustrated in Figure 6.

At the time of the inspection at the end of October 2009, around 60 metal loss anomalies were unacceptable at the MAOP of 630 psi according to the immediate integrity assessment. In addition to those anomalies, approximately 100 more anomalies require immediate repair although they were acceptable at the time of the UM inspection. However, applying the estimated corrosion growth rates, the anomalies have been growing since October 2009 and they were unacceptable at the time of the report delivery in June 2010. Looking at the reduced MAOP of 450 psi, all metal loss anomalies were acceptable at the time of the UM inspection. Applying the estimated corrosion growth rates, the anomalies have been growing since October 2009 and, at the time of the report delivery (in June 2010) slightly over 10 anomalies were unacceptable. For the reduced MAOP of 450 psi, the annual number of repairs until 2013 is much lower than for 630 psi.

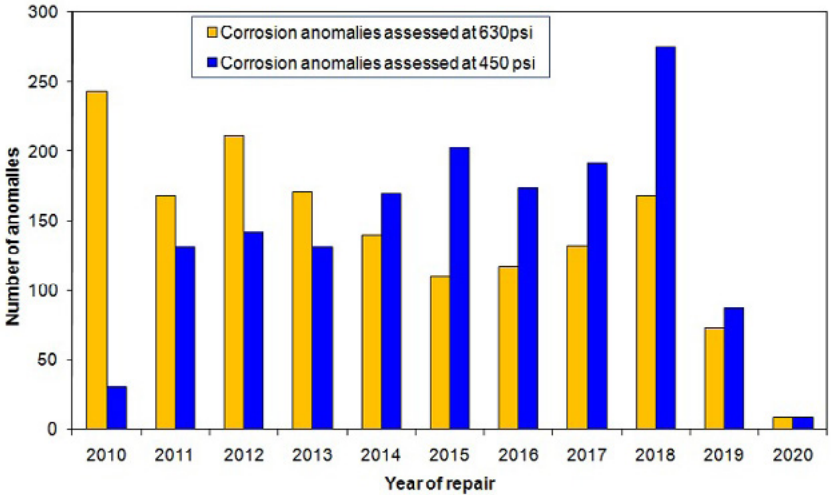


Figure 6: Anomalies requiring repair in each year

5. REPAIR PLAN

In order to outline a repair plan appropriate for this pipeline and to reduce the upcoming repair costs, it is recommended to define so-called repair areas. A repair area consists of an anomaly requiring repair at an appointed date and anomalies requiring repair at a later date but located in a pipe spool next to the previous one. Repairing several anomalies in one mobilization is more cost-efficient than to repair them separately, e.g. an anomaly is repaired now and the one in the adjacent pipe spool with a recommended repair date of July 2012 will be repaired two years later. Since the number of repairs required at the MAOP is much higher than at the reduced MAOP, all anomalies due for repair until the end of 2011 at the reduced MAOP are selected as basis for the suggested repair plan. If pipe spools with channeling corrosion due for repair until the end of 2012 are located next to those, repair areas are developed. As a result, approximately 300 anomalies can be combined to around 40 repair areas consisting of 2 to 20 pipe spools each.

6. OTHER INSPECTION AND STUDIES

6.1 In-Ditch inspection

Since 2008 there have been several opportunities to carry out thickness measurement and ultrasonic scanning at different locations along the pipeline length.The discovery of internal corrosion was from thickness measurement at 14.3 km as discussed in the introduction. Thereafter, during manifold inspection program in 2008, all accessible locations like isolation valves, branch connections etc. which are provided with concrete pits were inspected and ultrasonic thickness measurement/scanning was carried out on the pipeline sections in the pits. For verifying the ultrasonic ILI findings of 2009 the pipeline was excavated at 10.3 and 14.0 km.External ultrasonic wall thickness measurements confirmed the internal corrosion sites as reported by the ILI. Further to this, 10 locations were excavated and inspected in 2011 in order to investigate the growth of the internal corrosion. Again internal corrosion was found at all locations as reported by the ultrasonic ILI results. However, the corrosion growth rate was found to be negligible and not as calculated in the FFP report.

6.2 Internal corrosion direct assessment

In order to find out the root cause of the severe internal corrosion and to determine the best possible solution for eliminating further corrosion, KOC decided to carry out an Internal Corrosion Direct Assessment as per NACE SP208 . The assessment was carried out by Allied Engineers, India and Broadsword Corrosion Engineering ltd., Canada. Though it was known that internal corrosion has occurred due to very low product velocity, the study threw further lights on how water wetting and solid accumulation is affecting pitting corrosion. The study served as a corrosion investigation for the entire pipeline. A technical paper is presented on this study at NACE 2012, Utah, USA.

6.3 Corrosion monitoring

Two corrosion monitoring stations were constructed on the pipeline. One at distance 7.5 km and another one at 14.3 km based on the profile of the pipeline available at that time. Flush disk coupons were installed on the bottom and top of the pipeline at both locations. The first monitoring service took place in Dec'09. The corrosion coupons at the top of line positions at both. locations showed low to moderate corrosion rates but the corrosion rates at the bottom of the line positions showed very severe general and pitting corrosion rates (30 mpy general corrosion rate and 38 mpy pitting corrosion rate).On the fluid samples collected from the corrosion monitoring fittings a bacteria analysis was carried out in May 2010. SRB counts were found to be on higher side indicating likelihood of bacterial corrosion.

6.4 Cleaning Pigging sample analysis

A cleaning pigging program was initiated in 2009 after the detection of internal corrosion. Debris/liquids brought out during cleaning pigging were collected and analysed for iron based compounds, organic matters and salts. Initially, the cleaning pigging started with 3 months frequency. The analysis showed a decreasing trend of internal corrosion. Since August 2011 no corrosion product has been detected. This confirms the effectiveness of the applied cleaning program. It also gave KOC confidence that the corrosion growth rate has been contained and will not reach critical dimensions as predicted in the FFP analysis.

7. RECOMMENDATIONS

7.1 Repairs

Based on the ultrasonic ILI results, the FFP study and the in-ditch inspection findings, a detailed repair program was recommended.The infrastructure available with KOC, operational needs, repair contractors capability and limitations were also considered. Following is the summary of the recommendations.

- The pipeline MAOP was reduced to 289 psig with immediate effect.
- Since the number of repairs for a MAOP of 630 psig was considerably higher than for a MAOP of 450 psig and a higher MAOP was not required for the intended operational crude oil throughput, it was decided to do all required repairs for restoring the pipeline MAOP to 450psig.
- It was also decided to repair anomalies due for repair at the end of 2011. Thereafter a re-inspection is planned to revise corrosion growth rate, as it is seen (during in-ditch inspection in 2011) that the corrosion has been contained with the help of cleaning pigging and increased oil flow.
- Several anomalies were predicted (by FFP study) to reach 80 % wall metal loss by Dec. 2010 and hence, it was recommended to carry out all required repairs (for 450 psig MAOP) by Dec. 2010.
- Accordingly, 52 locations, totaling 3 km length were recommended to be cut out and replaced before Dec. 2010.

This repair is still considered a significant work for maintenance contractors particularly the procurement of pipe material needed for repairs before Dec. 2010. At the same time, it was not possible to drain the pipeline and keep it shut down for a long period of time till pipe material is procured and repairs are carried out. It was then decided to inspect anomalies which were expected to reach 80 % wall thickness loss by Dec. 2010. At the same time, the pipeline was taken out of service at the end of Dec. 2010 as a precautionary measure. These anomalies (10 nos.) were excavated and inspected in early2011 and found to be dormant. Also, result of analysis of product samples collected during cleaning pigging and data from internal corrosion monitoring devices (installed at two locations) gave us confidence that the internal corrosion growth has reduced considerably. Based on this analysis, the rigorous cleaning pigging and the increased flow in the pipeline, it was concluded that the pipeline can continue to operate at 289 psig beyond Dec 2010 without the required repairs being carried out. The pipeline was put back to operation and continued till Dec 2011. By the time, the pipeline material was procured and repairs are carried out.

7.2 Control of internal corrosion

Based on the findings of UT ILI and ICDA study, two major steps were taken to control internal corrosion which has threatened the integrity of the pipeline in a short life span. The first one was carrying out rigorous cleaning pigging backed up by analysis of debris. The frequency of pigging was optimised based on analysis of debris. The second step was to increase

crude oil flow and hence velocity. To achieve this, crude oil from other gathering centers were diverted to the subject pipeline at MF/TB-1. It was not possible to achieve recommended minimum flow of 496,00 bpd (as per ICDA report), which would have resulted in low flow in other pipelines. Nevertheless, crude oil flow was increased to the extent possible which was substantially higher than transporting only Wafra crude oil.

8. CONCLUSIONS

The pipeline was designed for a much higher flow rate but later developments in oil production resulted in much lower flow and hence low velocity in the pipeline. Early detection of internal corrosion enabled KOC to implement comprehensive inspection and mitigation measures. Further analysis using Fitness-for-Purpose methodology ensured that the required repairs are kept to a minimum which can be carried out in time. Cleaning pigging program and internal corrosion monitoring ensured that the pipeline continued to remain in operation while new pipe material is procured and repair work is planned. Ultrasonic intelligent pigging and Fitness-for-Purpose analysis carried out by NDT Systems and Services helped KOC to sustain crude oil production and avoid costly repairs while ensuring safe operation without leak incident.

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Authors



From left to right:

Abdul Wahab Al-Mithin
Kuwait Oil Company
Kuwait, Kuwait

Andreas Pfanger
NDT Systems
and Services AG
Stutensee, Germany

Sabbir Safri
Kuwait Oil Company
Kuwait, Kuwait

Pipeline leak detection technologies and emergency shutdown protocols

Gerhard Geiger, Prof. Dr.-Ing., Westphalian University Gelsenkirchen, Germany

Pipelines are the least expensive and most efficient way to move liquids and gases over land, but there is a high potential risk of danger in case of leak. This paper therefore describes pipeline leak detection technologies and emergency shut-down protocols ensuring reliable and safe pipeline operations. It starts by listing requirements and performance criteria and highlighting regulation issues concerning leak detection. Relevant regulations related to leak detection from U.S.A. and Germany are listed.

The next part is a short summary of external-based leak detection systems according to the definition found in [API RP 1130]. These systems provide very good performance but investment and operational costs are usually very high, and in many cases it is impossible to retrofit existing pipelines with this type of leak detection system (LDS). Therefore, external systems will only be used in critical applications, for example when pipelines cross nature reserves or high consequence areas. Consequently, the main focus of this paper is on internal leak detection systems. These systems usually run continuously. Sensitivity is somewhat lower than for external systems, but so are investment and operational costs. For this reason, internal systems are very common and are required by law for some countries.

Internal LDS are classified into two categories: Balancing methods using the principle of mass conservation, and non-balancing methods evaluating pressure and/or flow sig-nals according to assumptions about signal characteristics. Applying model-based techniques for balancing methods leads to RTTM-based methods (RTTM = real time transient model) resulting in a significant shorter leak detection time. After a LDS leak alarm declaration, appropriate actions are required to limit the con-sequences of a leak, to protect people and environment, to take appropriate emer-gency actions etc. The last part of the paper therefore is devoted to emergency shutdown protocols initiated manually and/or automatically after a leak alarm.

1. INTRODUCTION

Pipelines are the least expensive and most efficient way to move liquids and gases over land, but there is a high potential risk of danger in case of leak. This paper therefore describes pipeline leak detection technologies and emergency shutdown protocols ensuring reliable and safe pipeline operation. It is divided in different parts: The first part (Chapter 2 and 3) introduces in the subject by listing requirements and performance criteria and highlighting regulation issues concerning leak detection. Relevant regulations from U.S.A. and Germany are listed.

The second part (Chapter 4) is a short summary of external-based leak detection systems according to the definition found in [API RP 1130]. These systems provide very good performance but investment and operational costs are usually very high, and in many cases it is impossible to retrofit existing pipelines with this type of leak detec-tion system (LDS). Therefore, external systems will only be used in critical applica-tions, for example when pipelines cross nature reserves or high consequence areas.

For that reason, main focus of this paper is on internal leak detection systems which are subject of the third part consisting of Chapter 5 (overview) and 6 to 8 (methods). Internal systems usually run continuously. Sensitivity is somewhat lower than for external systems, but so are investment and operational costs. For this reason, internal systems are very common and are required by law for some countries, see Chapter 3. The focus of this paper therefore is on internal systems being classified into two categories: Balancing methods (Chapter 6) using the principle of mass conservation, and non-balancing methods evaluating pressure and/or flow signals according to assumptions about the signal, see Chapter 8. Applying model-based techniques for balancing methods leads to RTTM-based methods (RTTM = real time transient model) resulting in a significant shorter leak detection time. After an LDS leak alarm declaration, appropriate actions are required to limit the con-sequences of a leak, to protect people and environment, to take appropriate emer-gency actions etc. Chapter 10 therefore is devoted to emergency shutdown protocols initiated manually and/or automatically after a leak alarm. Last Chapter 11 finally summarizes the paper.

2. REQUIREMENTS AND PERFORMANCE CRITERIA

Leak detection systems (LDSs) have to fulfill different requirements.

2.1 Kind of fluid

LDSs should be capable to monitor pipelines transporting specific type of fluids like liquids, gases and fluid compositions. Examples for transported liquids are [CSA Z662]:

- Liquid hydrocarbons including crude oil, multiphase fluids, condensate, liquid petroleum products, natural gas liquids, and liquefied petroleum gas
- Oilfield water and steam
- Carbon dioxide used in oilfield enhanced recovery schemes
- Water and waste water

Sophisticated model-based technologies like RTTM-based (Chapter 7.1) und E-RTTM-based leak detection (Chapter 7.2) permit leak detection (and localization) also for gas applications (carbon monoxide and dioxide, ethylene, oxygen etc.).

2.2 Kind of operation

Some pipelines may be operated nearly 365 days per year and 24 hours per day without interruption in single-batch operation. Other product pipelines used for transporting refined liquid petroleum products will be operated on a scheduled base in multi-batch operation.Sometimes the operational procedures result in slack-line flow where the liquid pipeline locally is not entirely filled, sometimes as a result of va-porization of the transported product. Columns separation may also happen. LDSs have to cope with the operational characteristics of a specific application.

2.3 Leak characteristics

Depending on the causes and circumstances, leaks may have a sudden or gradual characteristic. Sudden leaks develop quickly for example by external damage to the pipeline. Gradual leaks may occur by corrosion. Sudden leaks usually show significant effects on physical variables like flow, pressure, temperature and so on and therefore may successfully be detected by internally-based LDs. Gradual leaks usually are very low in magnitude,

and their effects on these physical variables are often very small. It therefore may be required to use dedicated measurement equipment being part of externally-based LDSs in order to detect these kinds of leaks.

2.4 Operational phase

There are two main pipeline conditions: Pumping conditions, where the product will be transported by means of fluid flow, and paused flow conditions, where fluid flow is (near) zero. In some applications valves will be used to block the fluid flow in the monitored segment. This special paused flow condition will be called shut-in or blocked-line condition. The focus of this paper is on leak detection during pumping conditions.

2.5 Steady State and transient operation

Steady state conditions exist when all relevant physical variables such as flow, pressure, temperature and density are sufficiently constant over time to ensure that no wave effects can be observed. Transient conditions exist when the physical variables change significantly with time, so wave effects propagating with speed of sound are present. Reasons for these transient effects are product compressibility and pipe elasticity, together with special operational conditions such as:

- Starting and stopping pumps or compressors during start-up and shutdown
- Valve operation anywhere before, along or beyond the monitored pipeline seg-ment
- Flow or pressure control actions
- Changes of target throughput
- Special cases such as column

separationLiquid pipelines are often sufficiently close to steady state operation, but on close examination transient effects can also frequently be observed. Experience shows

2.6 Performance criteria

[API RP 1130] defines the following important performance criteria for an LDS:

 Sensitivity: The sensitivity is a composite measure of the size of a leak that a sys-tem is capable of detecting, and the time required for the system to issue an alarm in the event that a leak of that size should occur. Volume or mass lost be-tween the occurrence of a leak and its detection is a more objective measure of performance than the smallest detectable leak flow.

 Reliability: Reliability is a measure of the ability of a leak detection system to ren-der accurate decisions about the possible existence of a leak on the pipeline, while operating within an envelope established by the leak detection system de-sign. It follows that reliability is directly related to the probability of detecting a leak, given that a leak does in fact exist, and the probability of incorrectly declar-ing a leak, given that no leak has occurred.

 Accuracy: Accuracy covers estimation of leak parameters such as leak flow rate, total volume lost, type of fluid lost, and leak location within the pipeline network. These leak parameter estimates should be as accurate as possible.

 Robustness: Robustness is a measure of the leak detection system's ability to continue to function and provide useful information even under changing condi-tions of pipeline operation, or in conditions where data is lost or suspect. A sys-tem is considered to be robust if it continues to function under such non-ideal conditions.

An ideal LDS should be able to detect arbitrary small leaks immediately (sensitivity) without any missing alarm and false alarm (reliability) and under all circum-stances (robustness). If leak flow and/or leak location are calculated, there values should be perfect (accuracy). A real LDS has to come as close as possible to this ideal case.

3. REGULATORY FRAMEWORK

Safe pipeline transport of liquids and gases is very important, in particular because of the high potential risk of danger in case of leak. Industrialized countries regulate design, construction, operation, and maintenance of pipelines. Parts of these regulations address leak detection systems (LDSs) and its worth to take a closer look to these parts.

3.1 API RP 1130 (U.S.A.)

The first edition of API (American Petroleum Institute) Recommended Practice (RP) 1130 "Computational Pipeline Monitoring for Liquid Pipelines" was published 2007 [API RP 1130]. API RP 1130 does not directly impose legal requirements but:

- Gives a technical overview of leak detection technology
- Describes infrastructure support for LDS
- Discusses LDS operation, maintenance and testing

It provides the necessary technical information for conscientious operators and pipe-line controllers to manage their pipelines safely. [API RP 1130] covers liquid pipelines only. LDSs are divided into two groups:

 External systems using dedicated measurement equipment such as a sensor ca-bles. Such systems are listed in Chapter 4.
 Internal systems using existing measurement sensors for flow, pressure etc. Cor-responding systems are listed in Chapter 5 (overview) and 6 to 8 (methods).

[API RP 1130] also defines criteria (or metrics) for comparing LDSs from different man-ufacturers. For details refer to Chapter 2.6. [API RP 1130] is worldwide well known. Within the U.S.A, the Code of Federal Regulations Title 49 … Part 195 [49CFR195] references to [API RP 1130] by stating that "each computational pipeline monitoring (CPM) leak detection system installed on a hazardous liquid pipeline transporting liquid in a single phase (without gas in the liquid) must comply with API 1130 in operating, maintaining, testing, record keeping, and dispatcher training of the system". That means that LDSs are not mandatory. There are no special recommendations, requirements or regulations concerning steady state or transient pipeline operation. Issues like redundancy, paused flow monitoring, detection of gradual leaks or leak localization are not covered. Please note: other relevant regulations might exist.

3.2 TRFL (Germany)

German TRFL stands for „Technische Regeln für Rohrfernleitungsanlagen" (Technical Rules for Pipeline Systems) applying to most German pipelines transporting liquids or gases. It demands:

a) Two autonomous, continuously operating LDSs that can detect leaks in steady state conditions.

b) One of these systems, or a third one, must be able to detect leaks in transient conditions.

c) One system to detect leaks in paused flow conditions.

d) One system or procedure to detect gradual leaks.

e) One system or procedure to detect the leak position.

In contrast to [API RP 1130], LDSs that are able to detect leaks during steady state and transient state are mandatory for liquid and gas pipelines (with some exceptions). Redundancy has to be provided as well as leak detection in paused flow conditions and for gradual leaks. Leak localization is also required.

3.2.1 Installations according to TRFL a) and b)

[TRFL] requires two autonomous, continuously operating LDSs that can detect leaks in the steady state. Either of these systems, or both, or a third one, must be able to detect leaks in transient conditions. Special attention should be paid to the difference between the steady state and the transient state; for details refer to Chapter 2.5.

3.2.2 Installations according to TRFL c)

[TRFL] requires that each pipeline has one system to detect leaks in paused flow con-ditions. In this context, paused flow just means "flow equal or close to zero"; nothing is said about how this will be achieved. If the flow is blocked by valves locking pres-sure with the pipeline segment, it is said to be in the shut-in condition.

3.2.3 Installations according to TRFL d)

Gradual leaks (for example caused by corrosion) have two important characteristics: leak flow usually is (very) small, and it develops slowly. Installations according to TRFL a) are not well-suited to detecting this type of leak, so [TRFL] requires a dedi-cated LDS for this purpose. An external LDS can be used (Chapter 4), but usually this is very expensive. Some sophisticated internal LDS techniques and leak detec-tion procedures intended for pipelines during shut-in operation (e.g. pressure test) may also be used to detect gradual leaks.

3.2.4 Installations according to TRFL e)

The [TRFL] additionally requires a system (or other procedure) to locate leaks rapidly, enabling targeted actions for repair and re-establishing safety. This function may be part of an externally or internally-based LDS.

4. EXTERNAL LEAK DETECTION SYSTEMS

Externally-based systems according to [API RP 1130] use dedicated measurement equipment, such as probes and sensor cables. This equipment is often called leak detector. These systems provide very good performance but investment and opera-tional costs are usually very high because they need dedicated measurement equipment such as sensor cables that must be laid along the pipeline. Furthermore, in many cases it is impossible to retrofit existing pipelines with this type of leak detection system (LDS). Therefore, external systems will usually only be used in critical applications, for example when pipelines cross nature reserves or high consequence areas. Consequently, main focus of this paper is on internal leak detection systems, see Chapter 5 (overview) and 6 to 8 (methods), and only a short overview about externally-based systems is presented here [ADEC]. Manual inspection methods (e.g. using trained dogs) are omitted as well as air-based and satellite-based methods.

4.1 Fiber optic hydrocarbon sensing probes or calbes

With this technology, fiber optic sensing probes are driven close to the pipeline, or cables are laid throughout the pipeline. When fluid escapes, the local changes in temperature, pressure or concentration causes a change in the transmission charac-ter of the optical fiber. This change in the transmission characteristics is monitored using lasers and optical detectors. Sensing probes are used for point-type monitoring areas, while sensing cables are used for longer line-shaped monitoring areas like pipelines.

Fiber optic hydrocarbon sensing cables basing on local temperature change of the cable additionally permits leak localization and can be used for liquid and gas pipe-lines, but the temperature change due to fluid escape must be sufficiently large in any case. They operate continuously, and the required time for leak detection usually is short. Cable replacement may be necessary after a leak occurrence.

4.2 Liquid sensing probes or cables

As fiber optic systems, liquid sensing probes or cables are driven close (probes) or are laid throughout (cables) the pipeline. Again, probes are particularly suitable for point-type monitoring areas, while cables are preferable for longer line-shaped monitoring areas like pipelines. When a leak occurs, the cable is saturated with liquid changing the electrical properties (electrical resistance, and impedance, dielectric constant etc.) of the cable locally. These changes can be detected using a dedicated evaluation unit connected to the cable. Liquid sensing cables additionally permits leak localization but can only be used for liquid pipelines. They operate continuously, and the required time for leak detection usually is short. Cable replacement may be necessary after a leak occurrence.

4.3 Hydrocarbon sensor cables

With this technology, a secondary conduit is installed along the entire route of the pipeline. The conduit may be a small-diameter perforated tube attached to the pipe-line, or it may completely encompass the pipeline allowing the annular headspace to be tested. When a leak occurs, fluid diffuses into the conduit, will be transported to the evaluation unit using an appropriate (vacuum) pump, and finally will be analyzed by hydrocarbon sensors to determine the presence of a leak. Usually more than one monitoring segment is required to monitor longer pipelines. Hydrocarbon sensing cables additionally permits leak localization and can be used for liquid and gas pipelines. They operate continuously, but the time required for leak detection may be long for longer pipeline segments. Cable replacement may be necessary after a leak occurrence.

4.4 Acoustic emission detectors

Escaping fluid in pipelines creates a local acoustic signal when it passes through a perforation in the pipe. Acoustic sensors installed along the pipeline route are used to acquire these signals. Evaluation units connected to these sensors perform signal evaluation for leak alarm decision. The main problem here is to distinguish acoustic patterns created by the leak from normal acoustic components like flow noise etc. A large number of acoustic sensors are required to monitor longer pipelines. Acoustic emissions detectors additionally permits leak localization and can be used for liquid and gas pipelines, but the technology is unable to detect small leaks that do not produce acoustic emissions at levels substantially higher than the background noise. These sensors operate continuously, and the required time for leak detection usually is short. There is no need for component replacement after a leak occurrence.

4.5 Leak detection pipeline inspection gauges (PIGs)

As already mentioned in previous Chapter 4.4, escaping fluid in pipelines creates a local acoustic signal when it passes through a perforation in the pipe. This local acoustic signal will be acquired by acoustic sensors installed within a leak detection

pipeline inspection gauge (PIG). This device is inserted into the pipeline using a PIG launcher (or launching station). The launcher is then closed and the pressure driven flow of the fluid in the pipeline is used to push it along down the pipe until it reaches PIG catcher (or receiving station). As for acoustic emissions detectors, the main problem here is to distinguish acoustic pattern created by the leak from normal acoustic components like flow noise etc. Leak detection PIGs additionally permit leak localization but can only be used for liq-uid pipelines. The technology is unable to detect very small leaks that do not produce acoustic emissions at levels. substantially higher than the background noise. Leak detection PIGs are operated non-continuously either in regular time intervals (e.g. once a month) or on-demand in case of suspicious pipeline behavior

5. AN OVERVIEW OF INTERNAL LEAK DETECITON METHODS

Internal systems use existing measurement sensors for flow, pressure etc. and usu-ally run continuously. Sensitivity is somewhat lower than for external systems, but so are investment and operational costs.For this reason, internal systems are very common and are required by law for some countries, see Chapter 3. The focus of this paper therefore is on internal systems being classified into two categories:

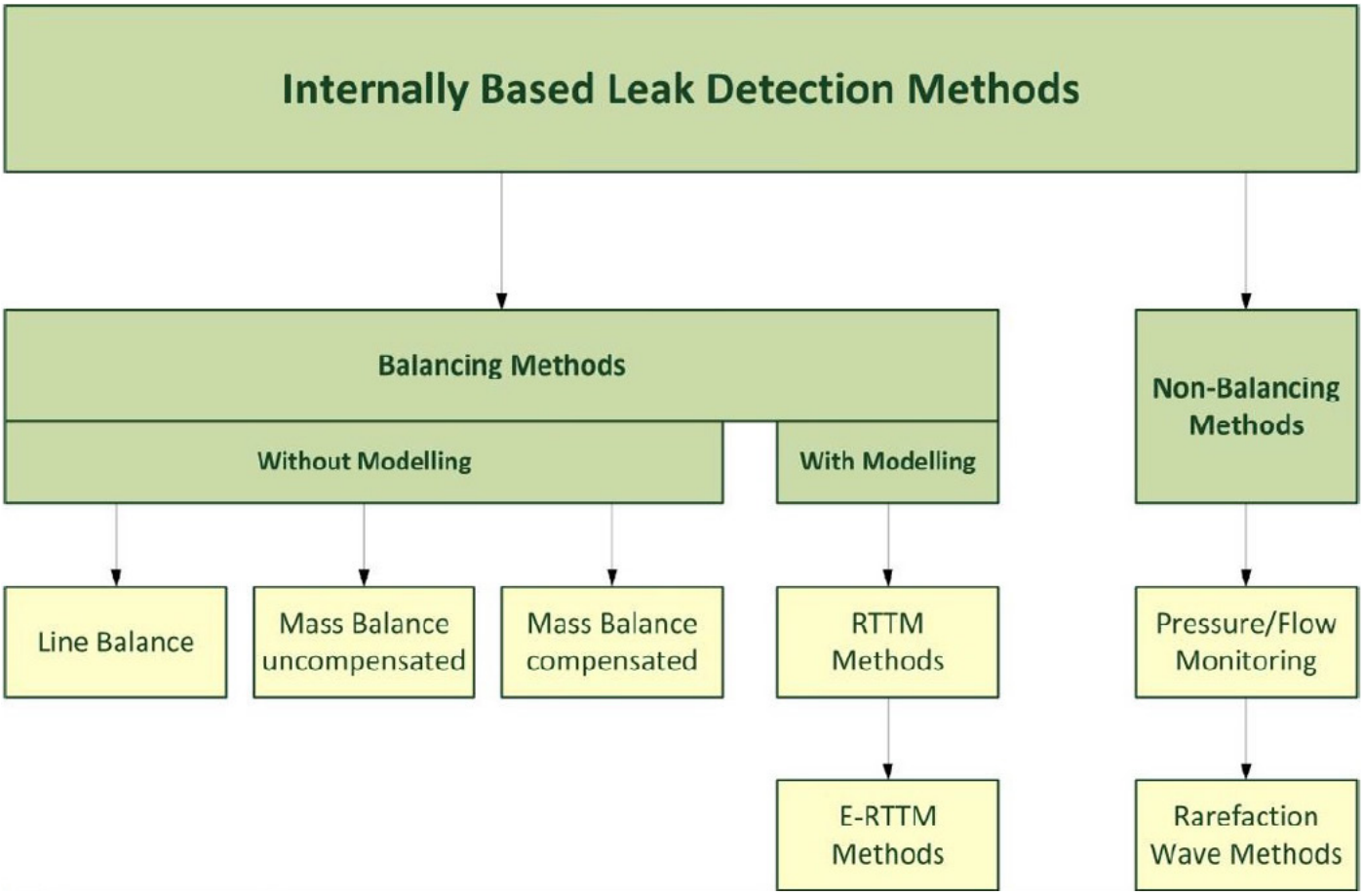

Figure 1: An overview of internally-based leak detection methods

6. BALANCING METHODS

Balancing methods use the principle of mass conservation: In absence of a leak, all mass (or material) entering a pipeline must leave it after some time. Without real-time modeling, these methods are limited to basic approaches like mass balancing where the difference between mass I ΔM entering the pipeline within some time interval Δt to corresponding mass O ΔM leaving the pipeline within Δt is analyzed, see Chapter 6. Applying model-based techniques permit compensation for change of mass inventory hence resulting in a significant shorter detection time. See Chapter 6 for non-model-based methods and Chapter 7 for model-based methods.

Non-balancing methods don't use the mass conservation principle. Instead, signals for pressure and/or flow are monitored and evaluated according to assumptions about signal characteristics, see Chapter 8.

These methods and principles are well-known since decades. Great improvements in the field of computer hardware and software make it possible to simulate sophisticated transient models of the pipeline in real-time. Chapter 7 therefore describes methods using Real-Time Transient Models (RTTMs) for leak monitoring.

All methods presented so far are used when the pipeline is in pumping condition where fluid is transported from inlet to outlet using pumps or compressors. If the pipeline will not be operated continuously there are pausing times where the pipeline is in paused flow conditions where in some applications valves will be used to block the fluid flow. This special paused flow condition will be called shut-in or blocked-line condition.

Balancing methods base on the principle of conservation of mass. In the steady state, summed over a sufficently long time persiod Δt , the mass ΔM_1 entering a leakfree pipeline at inlet will balance the mass ΔM_0 leaving it at outlet.

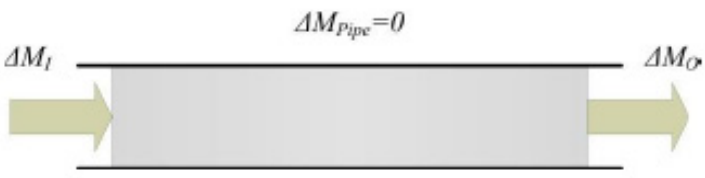

Figure 2: Mass balancing for a pipeline in steady state conditions

Steady state operation ensures that the change of mass inventory ΔM_{Pipe} is sufficiently small, so $\Delta M_{Pipe} = 0$ for sufficiently long Δt and hence we can say

$$\Delta M_1 = \Delta M_0 \iff \Delta M_1 - \Delta M_0 = 0 \quad (1)$$

there is no leak. Any additional mass imbalance indicates a leak. This can be quantified by adding a term for leak mass yielding

$$\Delta M_{Leak} = \Delta M_1 - \Delta M_0 \quad (2)$$

where ΔM_{Leak} denotes the mass lost by the leak during Δt. These equations are valid for liquid and gas pipelines in single- or multi-phase flow in any consistent mass units.

Many balancing methods basically require steady state operation because $\Delta M_{Pipe} = 0$ is assumed. Given this pre-condition, the smallest detectable leak rate is only limited by the accuracy of the flow measurement system, [API 1149]. In practical applications the use of such methods is limited because there are significant time periods and events where non-steady or transient pipeline operation is present, see Chapter 2.5:

- Starting and stopping pumps or compressors during start-up and shutdown
- Valve operation anywhere before, along or beyond the monitored pipeline segment
- Flow or pressure control actions
- Changes of target throughput Special cases such as column separation

For gas pipelines, the larger fluid compressibility compared with liquid pipelines is a further problem leading to the conclusion that gas pipelines are rarely in steady state. As a result, balancing systems without compensation for change of inventory need long times to detect a leak during these states and events, or even must be switched off to avoid false alarms. This can only be avoided by considering the change of mass inventory yielding

$$\Delta M_{Leak} = \Delta M_1 - \Delta M_0 - \Delta M_{Pipe} \quad (3)$$

The principal differences among the various balance methods are outlines below.

Basic volume balance uses fluid volume ΔV_1 and ΔV_0 instead of ΔM_1 and ΔM_0, and hence can be used with volumetric flow meters like turbine meters, ultrasonic meters etc. It does not compensate for changes of mass inventory ΔM_{Pipe}, and application is limited to cases where densities p_1 and p_0 and (and hence temperatures t_1 and t_0) at inlet and outlet are sufficiently close. Volume balancing therefore is only suitable for liquid pipelines at steady state where inlet and outlet fluid temperature varies only slightly; such flow conditions are called isothermal flow. **Uncompensated mass balance** uses Eq. (2) and therefore requires mass flow meters (e.g. of Coriolis type) or alternatively volumetric flow meters together with flow computers and additional temperature and pressure measurements. It does not compensate for changes of mass inventory ΔM_{Pipe} , but in contrast to line balancing temperature at inlet and outlet may differ, and it may be used for liquids as well as for gases. Application is limited to steady state, or a very long detection has to be accepted.

Compensated mass balance methods use additional temperature and pressure sensors at each end of a pipeline segment in order to calculate ΔM_{Pipe} in Eq. (3) by means of a fluid bulk modulus and a simple steady state flow model. This type of calculation for ΔM_{Pipe} yields only an approximation of the real value. Real-time transient models have to be used in order to calculate the change of pipeline inventory correctly. These methods are presented in detail in Chapter 7.1 and 7.2.

Line Balance is a generic term covering all balancing methods (mass balance or volume balance). Balancing methods are very common so many references address this topic. Examples of definitions found in the literature include:

- Mass balance
- Material balance
- Line balance
- Volume balance
- Modified or compensated volume balance

Unfortunately, some of the listed definitions are misleading. Volume balance, for example, might sometimes be confused with mass balance. But there is no principle of conservation of volume, so

$$\Delta V_1 - \Delta V_0 \neq 0 \quad (4)$$

for leak-free pipelines even for $\Delta t \rightarrow \infty$ and ideal steady state conditions. Definitions used with this paper consider strictly the physical facts thereby insuring consistency.

6.1 Improving performance using statistical approaches

Statistical approaches can improve the performance of balancing methods introduced previously. An example is hypothesis testing using methods from decision theory [Barkat]. The hypothesis test for leak detection based on the uncompensated mass balance uses

$$\Delta M[i] = \Delta M_1[i] - \Delta M_0[i] \quad (5)$$

where ΔM[i] denotes sample of the instantaneous imbalance between inlet and outlet mass flow [Zhang]. These samples can be used to decide between two hypotheses, H_0 and H_1:

$$H_0 = \text{No leak} \;/\; H_1 = \text{leak}$$

Likelihood ratio tests including variations like generalized likelihood ration test [Kay] and sequential probability ratio test (SPRT, [Wald]) may be used as decision principles.

6.2 Requirements and fields of application

All balancing methods require at least two flow meters, one at the inlet and the other at the outlet. All mass balance methods require mass flow; either directly measured using mass flow meters or indirectly measured using volumetric flow meters together with flow computers using pressure and temperature sensors. Volume balancing only requires volumetric flow meters. Volume balancing is basically limited to steady state liquid pipelines because the change of pipeline mass inventory is not considered. Density at inlet must be sufficiently close to the density at outlet, so isothermal flow conditions are required. For transient operation, sensitivity (detection time and/or smallest detectable leak flow) ispoor. Density at inlet and outlet (and hence temperature at inlet and outlet) may differ for uncompensated mass balancing, but still the change of pipeline mass inventory is not considered. This method therefore is limited to steady state liquid pipelines; during transient operation sensitivity is poor. Compensated mass balance methods need additional temperature and pressure sensors at each end of a pipeline to estimate the change of pipeline mass inventory by means of a simple steady state pipeline model. The calculated inventory values are only approximations; RTTM are required to calculate the correct values, see Chapter 7. These methods can be used for liquid and gas pipelines during for steady state and moderate transient operation.

7. MODEL-BASED LEAK MONITORING

During the operation of a pipeline, physical variables like pressure, flow, temperature and density vary with time due to following reasons:

- Start and stop of pumps or compressors during start-up and shutdown
- Valve operation anywhere before, along or after the monitored pipeline segment
- Flow or pressure control action
- Changes of throughput
- Special effects such as column separation

These effects change the mass inventory M_{Pipe} of a pipeline transiently; therefore, liquid and gas pipeline often are in transient state meaning that sudden changes in these variables may occur and propagate with speed of sound c through the pipeline. Gas pipelines are almost always in a transient state, because gases are very compressible. Even in liquid pipelines transient effects cannot be disregarded most of the time. In these transient states, balancing methods presented so far (line balance, uncompensated and compensated mass balance according to

Chapter 6) must be switched off or need a very long detection time in order to avoid false alarms. Use of statistical procedures may alleviate but not solve the problem.

7.1 RTTM – Real time transient model

Using mathematical models, it is possible to compensate for the transient change of mass inventory M_{Pipe}, but two requirements have to be met:

- The corresponding solution algorithms have to be calculated in real time
- The mathematical model must be able to describe the transient flow behavior within the pipeline sufficiently accurate

That is the reason for calling these methods RTTM-based methods, RTTM = real time transient model [API RP 1130]. RTTMs may be used in different ways ([Colombo], [Whaley]). The method presented within this paper is the residual approach ([Billmann]).

The RTTM calculates mass flow estimates $\hat{M}_1$ and $\hat{M}_0$ at inlet and outlet using appropriate pressure (P_1, P_0) and temperature (T_1, T_0) readings at inlet an outlet as well as ground temperature T_G. For these calculations it is assumed that no leak exists. It is possible to check for the difference between measured and calculated flow. A difference between the two indicates a leak. Both of the flow-residuals can be used:

$$x = \dot{M}_1 - \hat{\dot{M}}_1$$

$$y = \dot{M}_0 - \hat{\dot{M}}_0$$

where $x \approx 0$, $y \approx 0$ if there is no leak, and $x > 0$, $y < 0$ in case of a leak. The residuals therefore can be used as leak indicators.

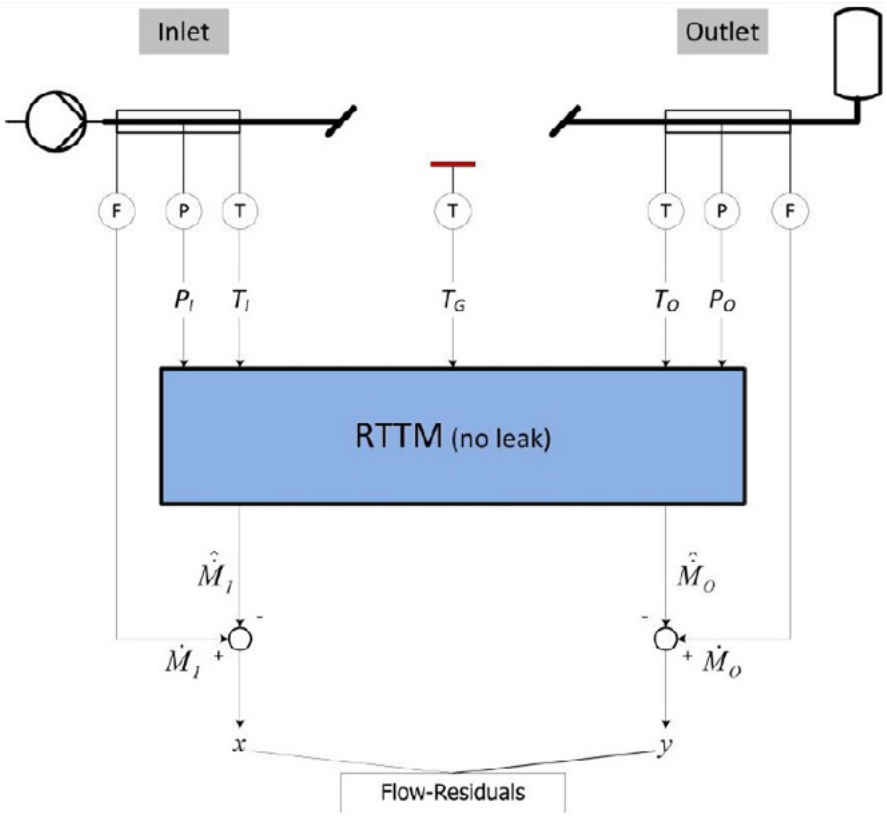

Figure 3: RTTM-based residual approach for leak detection

7.2 E-RTTM – Extended Real Time Transient Model

RTTM-based LDSs quickly detect small leaks during steady states as well as transient states. But there still is the problem of false alarms which have to be avoided. For that reason an extension of RTTM-based leak detection had been proposed [Geiger03]:

The task of the first RTTM component is to calculate the flow residuals as shown before. A second component analyzes the residuals for leak signatures:

- Sudden leak. This "classical leak" develops quickly for example by external damage to the pipeline. It causes a dynamic signature in residuals. When such a leak recognized, a leak alarm is declared.

- Sensor drift or gradual leak. These may occur by contamination of the flow meters or by small leaks caused by corrosion. They result in indistinguishable, slow signatures. When drift is recognized, a sensor alarm is declared.

This boosts the reliability and the robustness of the system without compromising sensitivity and accuracy. False alarms are prevented, even with low alarm thresh-olds.

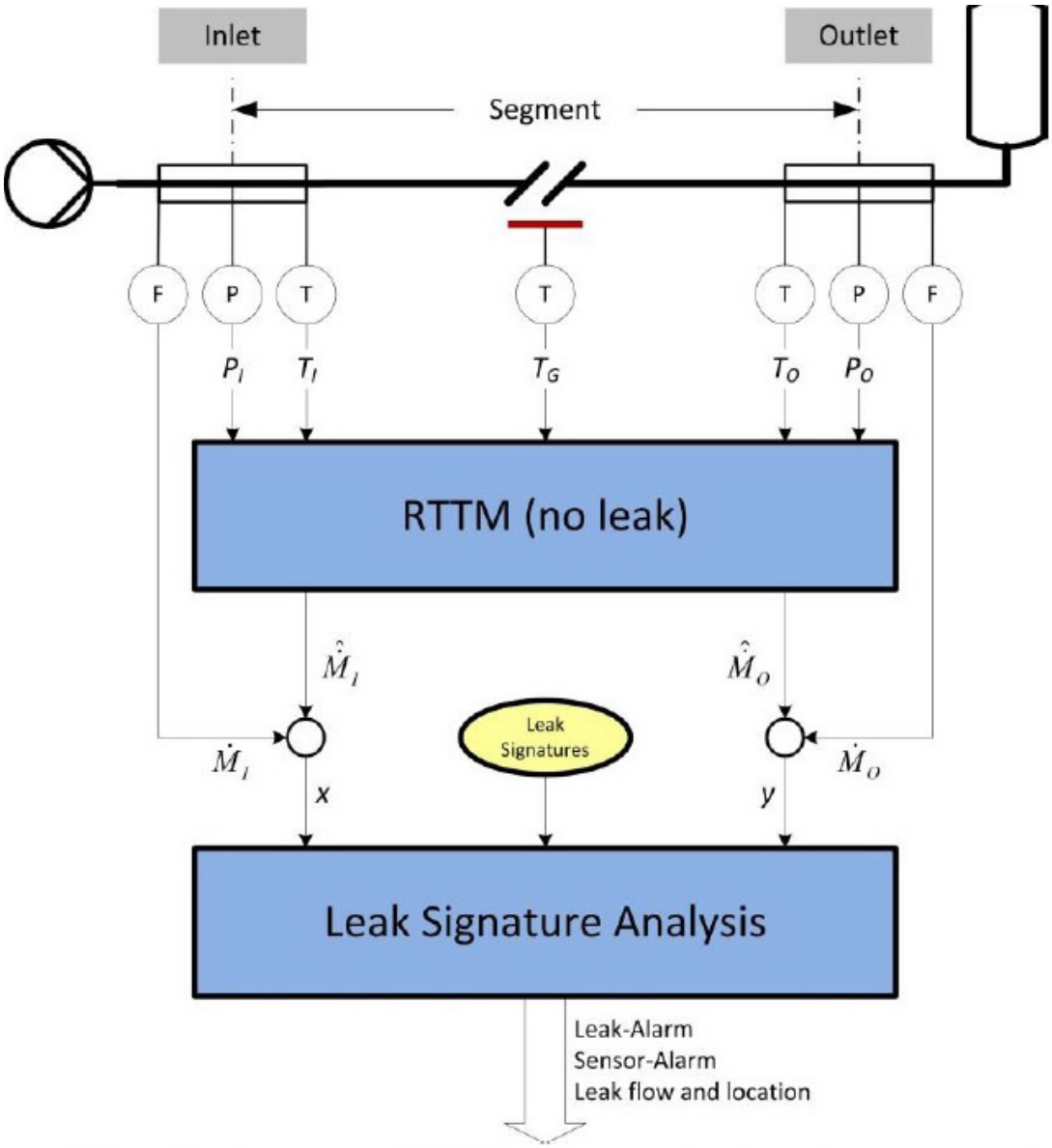

Figure 4: E-RTTM-based leak detection

7.3 Requirements and fields of application

Model-based leak detection methods usually require flow meters, pressure and fluid temperature sensors at inlet and outlet, respectively. Sophisticated approaches use a temperature model considering heat transfer into the ground; in that case, ground temperature sensors are also required.

RTTM-based leak detection is useful for liquid and gas pipelines in steady states and transient states as long as the operational transient effects are modeled sufficiently accurate. System configuration is more complex than for other methods presented because model parameters like length of the pipeline, diameter, height profile,

fluid parameters etc. are required. The accuracy of the model and of the model parameters is significant for sensitivity and reliability, so these methods are sensitive against configuration errors limiting the sensitivity (leak detection time and/or lowest detectable leak flow) in practical applications. E-RTTM-based leak detection is also useful for liquid and gas pipelines in steady states and transient states; again, system configuration is relatively complex. E-RTTM-based leak detection is much less sensitive to configuration parameter errors giving better sensitivity in practical applications.

8. NON-BALANCING LEAK DETECTION

A leak changes the hydraulics of the pipeline, and therefore changes pressure and flow readings after some time [Krass/Kittel/Uhde]. Local monitoring of pressure and/or flow at only one point can therefore provide leak detection.

8.1 Pressure/flow monitoring

If a leak occurs, the pressure in the pipeline will fall by an amount . As pressure sensors are almost always installed, it is natural to use them for leak detection. The pressure in the pipeline is simply compared against a lower limit after reaching the steady state condition. When the pressure falls below this lower limit, a leak alarm is raised. This approach basically requires no data communication, for example to compare flow rate at inlet an outlet, as local monitoring of pressure or flow rate is sufficient.The same method can also be used with flow where flow readings are tested against limit values, but it is more convenient to use flow for balancing leak detection meth-ods Chapter 6 and 7.

8.2 Rarefaction wave methods

A sudden leak caused, for example, by careless use of an excavator, leads to a neg-ative pressure wave propagating at the speed of sound up- and downstream through the pipeline. Such a wave, called a rarefaction wave, can be recognized using installed pressure transmitters, giving a leak alarm. In contrast to pressure/flow monitoring, these methods analyzes the signature of the acquired pressure signals. A positive pressure wave e.g. as result of a closing valve, would not lead to an alarm, for example. [Farmer] proposed and patented a statistical procedure called pressure point analysis (PPA) evaluating the manner in which each individual pressure reading changes. Pattern recognition algorithms determine whether these specific changes show a significant movement away from recent, normal operation. The algorithms are de-signed to filter out background hydraulic noise thereby making the expansion wave associated with a leak visible.

8.3 Requirements and fields of application

Pressure/flow monitoring is very simple and easily implemented but only useful in steady state conditions; in that case it is usable for liquid and gas pipelines. Positioning of the sensors has to consider operational conditions. Pressure sensors cannot be placed at positions where pressure control is in operation, for example. Sensitivity and/or reliability are poor because transients created during normal operation can easily cause false alarms. Rarefaction wave methods including PPA analyze the pressure signal signature thereby theoretically enhancing the sensitivity. Appropriate LDSs only require pres-sure sensors with local signal evaluation. Note that there is only one chance for the sensors to detect the leak. If the rarefaction wave passes the sensor and it doesn't alarm, the ability of that sensor to detect the leak is lost. Positioning of the sensors has to consider operational conditions. Pressure sensors cannot be placed at positions where pressure control is in operation, for example. A long pipeline segment has to be divided in short segments as the rarefaction wave will be attenuated while

propagating through the pipeline thereby losing leak signature. Practical applications prove that operational transients often show signatures close to the signatures of leaks leading to a significant number of false alarms. During highly transient states like start-up and shut-down, corresponding LDSs have to be switched off. In gas pipelines, wavefronts of rarefaction waves normally are very smooth; rarefaction wave methods therefore very often are not useful for that kind of fluid.

9. COMPARISON OF ALL METHODS

This chapter is dedicated to the comparison of all presented leak detection technologies presented so far. External leak detection systems (according to [API RP 1130]) like

- fiber optic hydrocarbon sensing probes or cables (Chapter 4.1),
- liquid sensing probes or cables (4.2),
- hydrocarbon sensor cables (4.3), and
- acoustic emissions detectors (4.4)

use dedicated measurement equipment, such as probes and sensor cables thus giving these systems a very good sensitivity. But on the other hand, additional equipment like cables or detectors must be installed along a usually buried pipeline requiring extensive construction works and installations when retrofitting existing pipelines. Overall system costs therefore usually are very high. As a consequence, external systems will usually only be used in critical applications, for example when pipelines cross nature reserves or high consequence areas.

Method	Application	Instrumentation	Limitations
Balancing Methods not model-based			
Volume Balance	• Mainly liquids • Only steady-state • Only isothermal	2 x Q	• Poor sensitivity for transients
Mass Balance uncompensated	• Mainly liquids • Only steady-state	2 x Q	• Poor sensitivity for transients
Mass Balance compensated	• Liquids + gases • Steady state + moderate transients	2 x (Q,P,T)	• Poor sensitivity for strong transients
Model-based Methods			
Mass Balance RTTM	• Liquids + gases • Steady state + transients	2 x (Q,P,T); T_G	• Configuration not trivial • Sensitive against configuration errors
Mass Balance E-RTTM	• Liquids + gases • Steady state + transients	2 x (Q,P,T); T_G	• Configuration not trivial
Non-balancing Methods			
Pressure/flow Monitoring	• Liquids + gases • Only steady state	1 x P/Q	• Very poor sensitivity for transients • Only for large leaks
Rarefaction Wave	• Mainly liquids • Only steady-state	1 x P/Q	• Poor sensitivity for transients • Only one chance for leak detection

Table 1: Comparison of presented internal methods

For leak detection pipeline inspection gauges (PIGs, Chapter 4.5), no cables or detectors have to be installed, but the pipeline must be "piggable", and PIG launcher and catcher (receiver) must be present. Overall system costs may be lower as for the other systems mentioned above. Leak detection PIGs are operated non-continuously either in regular time intervals (e.g. once a month) or on-demand in case of suspicious pipeline behavior, so they cannot be used if the LDS must run continuously.

Internal systems (according to [API RP 1130]) use existing measurement sensors for flow, pressure etc. and usually run continuously. Sensitivity is somewhat lower than for external systems, but so are investment and operational costs. ***Pressure/flow monitoring*** (Chapter 8.1) can still be found in industry using pressure sensors (indicated by P) checking pressure for limit violation against a lower threshold. These LDSs are extremely sensitive against transients and hence are restricted to the detection of large leaks. Not model-based balancing methods (Chapter 6) like volume balance and uncompensated mass balance as well as rarefaction wave methods (Chapter 8.2) are used mainly for liquid pipelines in steady state operation. Balancing LDSs need flow meters (indicated by Q) either for volume flow (volume balance) or mass flow (uncompensated mass balance). In practical applications transients are always present. The consequences depend on the used method:

- For volume balance and uncompensated mass balance, the imbalance $\Delta M_{Leak} = \Delta M_1 - \Delta M_0$ can be calculated over a sufficient long time period Δt so that transient effects can be neglected. This leads to long detection times depending on the magnitude of the transients.
- Rarefaction wave methods tend to misinterpret transients as leak signatures leading to an increased number of false alarms. Alternatively the leak alarm threshold may be raised accordingly.

Compensated mass balance methods according to Chapter 6 use a simple steady state model in order to estimate the change of pipeline mass inventory using flow Q, pressure P and temperature T at inlet and outlet. They are used for liquid and gas pipelines in steady state operation and for operation with moderate transients.

Model-based methods Mass Balance RTTM (Chapter 7.1) and ***Mass Balance E-RTTM*** (Chapter 7.2) are the first choice if leak detection for steady states and transient states is required. These LDSs are useful for liquid and gas-pipelines needing flow Q, pressure P and temperature T at inlet and outlet, sometimes together with the ground temperature T_G. System configuration is more complex than for the other methods presented. Mass Balance RTTM is sensitive against configuration errors while Mass Balance E-RTTM is much less sensitive giving better sensitivity in practical applications.

10. EMERGENCY SHUTDOWN PROTOCOLS

Pipelines usually are equipped with dedicated emergency equipment such a check valves in order to limit damage in case of a leak. Dedicated emergency equipment as well as an emergency response plan may be required by law [TRFL]. Leak alarm declaration of a leak detection system (LDS) poses the question of leak alarm handling. The strict and most obvious answer is to automatically shut down pumps, activate emergency equipment like check valves and activating responsible personnel like fire department. The problem here is that even the most sophisticated system like E-RTTM-based LDS (see Chapter 7.2) may raise false alarms, e.g. if an important sensor fails. The following leak handling strategy therefore should be preferred.

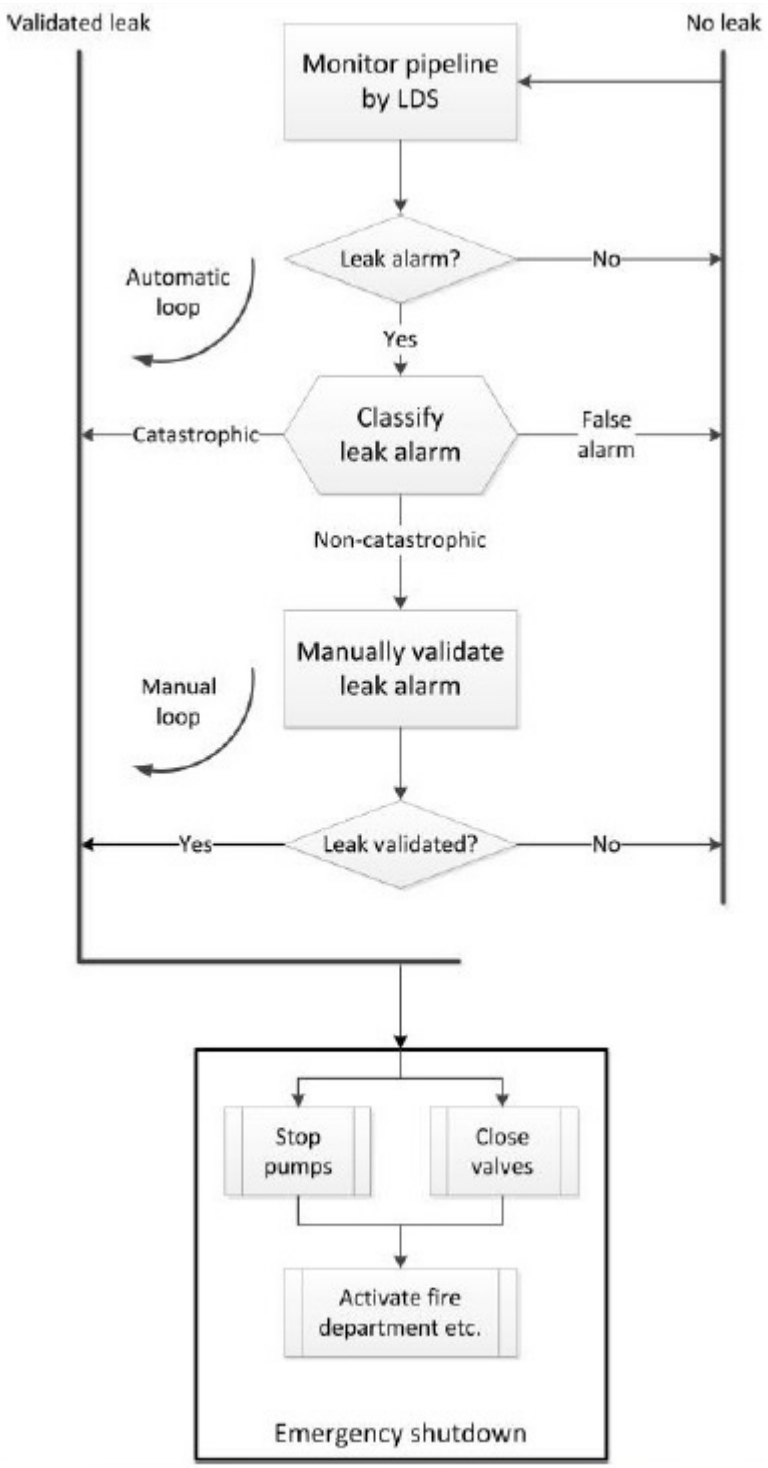

Figure 5: Flow diagram of leak alarm handling

Any leak alarm declaration will be assigned to one of following classes:

- If a leak is significant, no more validation is required, and immediate reactions (shut down of pumps, activating check valves, activating fire department etc.) are recommended or absolutely necessary. These actions should be initiated auto-matically without participation of pipeline controllers resulting in an automatic leak evaluation loop.

- Insignificant leaks usually are much smaller and therefore should be validated manually. To this end, pipeline controller interactively use the pipeline control sys-tem to check LDS connected devices like sensors, evaluate pipeline operation and check the leak declaration state of redundant LDSs, if existing. The emergen-cy shutdown procedure will be initiated manually if the leak will be validated resulting in a manual leak evaluation loop.

- Leak declarations being not validated are handled as false alarms and therefore don't initiate emergency shutdown actions.

  It should be noted that emergency shutdown protocols usually are part of emergency response plans, and hence generally more actions are required in case of a leak incident than listed in Figure 5.

11. SUMMARY

This paper presented pipeline leak detection technologies and emergency shutdown protocols. Relevant regulations for U.S.A and Germany were analyzed, and (after a short look on externally-based LDSs), the main part was dedicated to internally-based LDSs. Non-balancing methods like pressure/flow monitoring and rarefaction wave methods might be easily installed, but usage is strictly limited to steady state pipeline operation. Therefore, in practical applications, a significant number of false alarms must be accepted. Classical balancing methods like line balancing as well as uncompensated and com-pensated mass balancing (Chapter 6) are known since decades and have successfully been used. A major disadvantage is the long detection time in practical applica-tions where transient effects are unavoidable. Compensation of transient effects using real time transient models (RTTM, Chap-ter 7) reduces the detection time significantly, but LDS configuration is more com-plex, and LDS behavior depends on accuracy of model parameters like length of the pipeline, diameter, height profile, fluid parameters etc. E-RTTM-based leak detection Chapter 7.2 is much less sensitive to deviations in model parameters, so the accura-cy of model parameters is less significant for sensitivity and reliability.

Author

Prof. Dr.-Ing.
Gerhard Geiger
Westphalia University
Gelsenkirchen / Germany



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EITEP Euro Institute for Information and Technology Transfer
ROSEN
NDT Systems & Services
EUROPIPE
ILF Consulting Engineers
GLD Gottsberg Leak Detection
Herrenknecht Tunnelling Systems
STATS Group
TÜV SÜD
GSIST
DVGW
EPRG European Pipeline Research Group
PRCI Pipeline Research Council International
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Development and field experience with high performance polyurea pipe coatings

Michael Magerstaedt, Rosen Swiss AG, Switzerland
Gunther Blitz, ROPLAST GmbH, Germany
Frank Bublitz, ROPLAST GmbH, Germany
Holger Rosenbleck-Schmidt, ROSEN Technology and Research Center GmbH, Germany

Exterior pipe coatings are used on more or less all pipelines, no matter if the pipeline is buried or runs offshore on a sea bed. Main purpose is corrosion protection, but there are a number of applications in which protection from other external factors plays a role, e.g., abrasion protection in pipes that are laid by thrust boring (HDD), e.g., for road or river crossings. Historically, bituminous coatings, polyethylene tape wrap, as well as "modern" multilayer PE or epoxy coatings were used to protect buried pipelines from corrosion. Long-term coating stability of 40 years or more vs. the environment into which the pipe has been laid is required. Often, however, such life times are not reached by these coatings. Coating disbondment, corrosion under insulation, and mechanical damage to coatings are key words describing issues that occur with exterior pipe coatings over time. Today, a vast number of pipelines built during the economic boom of the decades between world war II and the 1990s have reached an age where major overhauls or replacement are required to keep operating these assets safely. If corrosion or other damage in areas where coating defects occurred has not yet reached a level that renders the steel pipe unusable, the pipe can be refurbished. Removal of the old coating, measures to stop corrosion, pipe surface preparation and recoating of the steel pipe can add decades to the lifetime of an aged pipeline. steel. Novel high performance polyureas fulfill these requirements to a very high degree. can add decades to the lifetime of an aged pipeline. An ideal external coating for refurbishment should possess a strong adhesion to steel, be resistant to the environment in which the pipe is embedded, and its application should require a minimum of time. Polyurea spray coatings are very fast curing elastomers that exhibit a high adhesion to steel. Novel high performance polyureas fulfill these requirements to a very high degree.

This paper will describe the development of spray coatings from these materials as well as first field experience in both highly corrosive salt marsh environments. A special material grade for thrust boring through hard rock was developed and field tested as well. The excellent results of high performance polyurea spray coatings in field trials as well as in predictive laboratory tests simulating long-term application in hostile environments. These materials open up a new method for refurbishment of aged pipelines, but they also provide a type of coating for new pipelines that holds promise to outlast other types of coatings by far.

1. HIGH PERFORMANCE ELASTOMERS

Long-term exterior corrosion protection of buried pipelines is and remains one of the most prominent issues for pipeline operators. Pipelines with a design life of 40 years or more normally are protected by more than one corrosion barrier. Cathodic Protection (CP) inhibits steel oxidation by turning the steel pipe into the cathode of an electrochemical cell. Polymeric coatings prevent direct contact of soil, water, or air with the steel pipe surface thereby reducing the probability of oxidizing attack. Coatings used in the past, from bituminous materials to polyethylene wraps or thermoset epoxy or FBE coatings, often did not yield the lifetime originally expected. More recently, a number of novel coating types were introduced. Besides viscoelastic polymers, which have no structural strength, but a very high adhesion to just about any surface, elastomers based on polyurethane (PUR) and polyurea (PuA) have made inroads into this application. Definition of Elastomer[1]: "A formation of a thermoplastic or thermoset that can stretch and then return to its original shape without permanent deformation". For external pipe coating, an elastomer needs to have the following set of properties:

- Thick-film-coating 1.5-5 mm (60-200 mils)
- Spray applied and solvent free
- Fast setting
- High degree of corrosion protection, i.e. barrier function vs. water, low or no swelling
- High degree of mechanical protection and flexibility
- Strongest possible adhesion to the steel wall
- intrinsic stability against hydrolysis

In the past, polyurethanes often did not exhibit strong enough bond to the steel wall. In addition, PUR curing times in the half hour / hour range often prohibited the use of these materials. Polyurea Coatings cure much faster than polyurethanes. Novel thermoset PUR and PuA materials (as well as combinations thereof) that exhibit extremely high adhesion to steel, fast curing, and a strong barrier function (corrosion protection), combined with high abrasion resistance have been developed and are summarized here under the term "High Performance Elastomers". Whilst PUR High Performance Elastomers lend themselves to spin casting and are therefore used as interior erosion and corrosion protection, e.g., in slurry pipelines and EOR piping, PuA High Performance Elastomers are ideal spray coatings with a property profile very much like that required for external pipe coatings.

Both polyurethane and polyurea are generated by a polycondensation reaction. Two base compounds and a number of other raw materials, amounting to a total of 5-10 components, are mixed at a defined temperature and mixing ratio to form the polymer. Due to the large number of available components and mixing ratios, there are a huge number of permutations possible. This translates into a "building kit" in which material properties can be tailored to the application requirements[2]. Figure 1 shows the building kit components and their influence on product properties using PUR as an example:

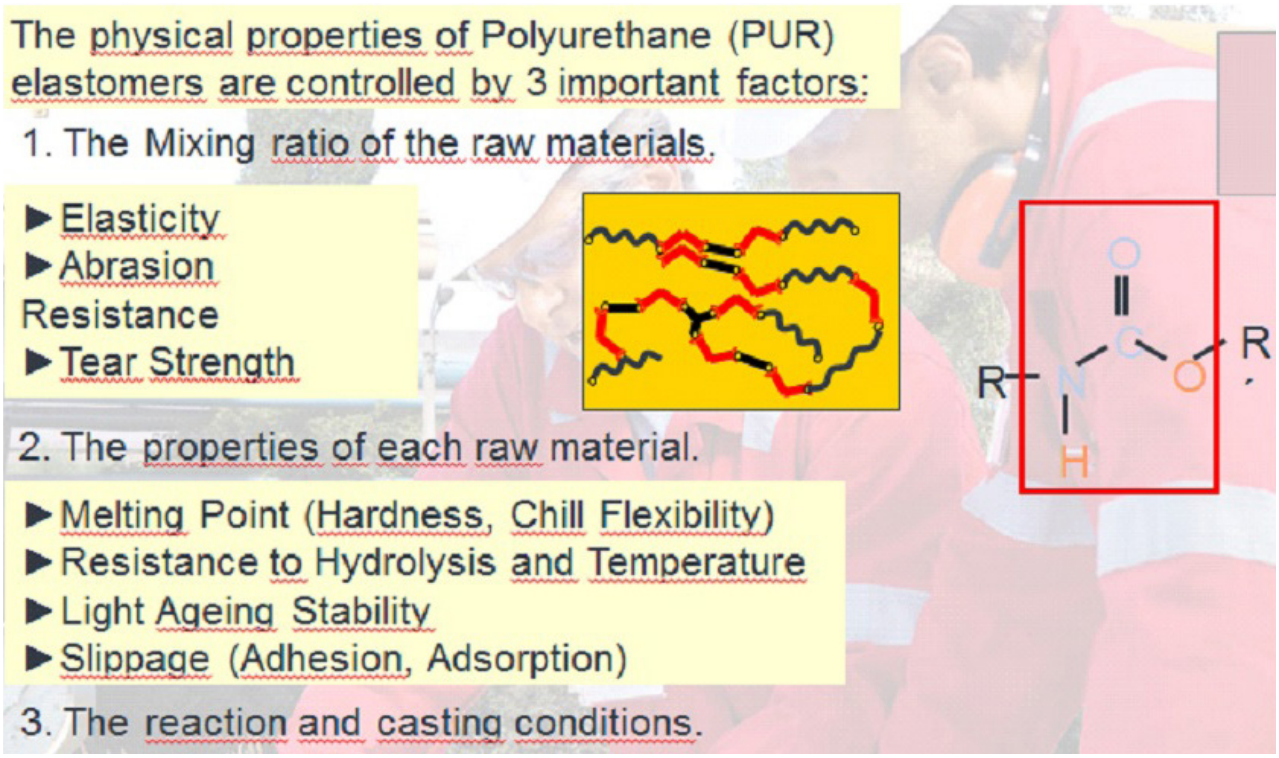


Figure 1: The polycondensation building kit; example: polyurethane

Most important physical properties of High Performance PUR and PuA Elastomers are listed in figure 2, together with a diagram comparing abrasion resistance and tear propagation resistance of High Performance Elastomers with standard PUR and with rubber:

- Very high tear propagation resistance
- Very high abrasion resistance
- Outstanding adhesion to metals and to other materials
- Excellent chemical resistance
- High hydrolytic resistance even at elevated temperature
- Antistatic, reinforced / filled, and food quality grades
- Extremly low- and high temperature resistant grades

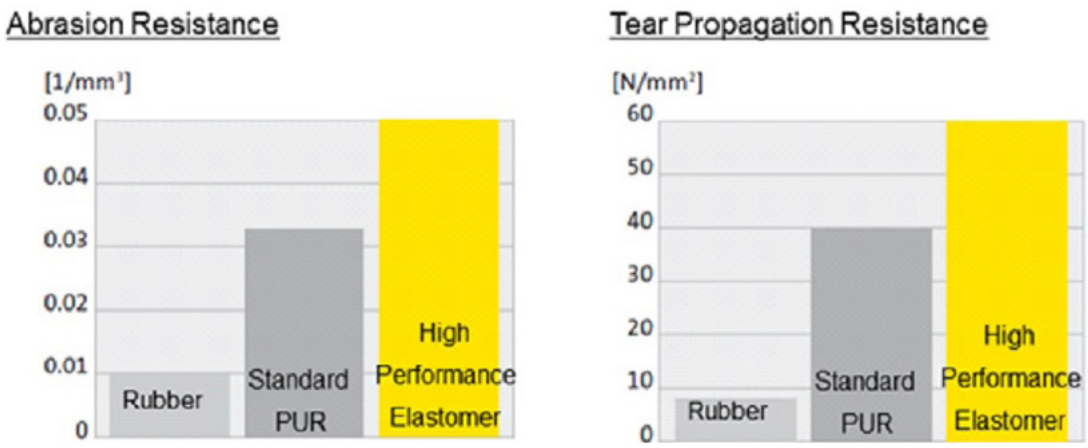


Figure 2: most important properties of High Performance Elastomers

2. POLYURETHANE / POLYUREA

Figure 3 shows a general schematic of the chemical composition of PUR and PuA as well as the polycondensation reactions used to synthesize these materials:

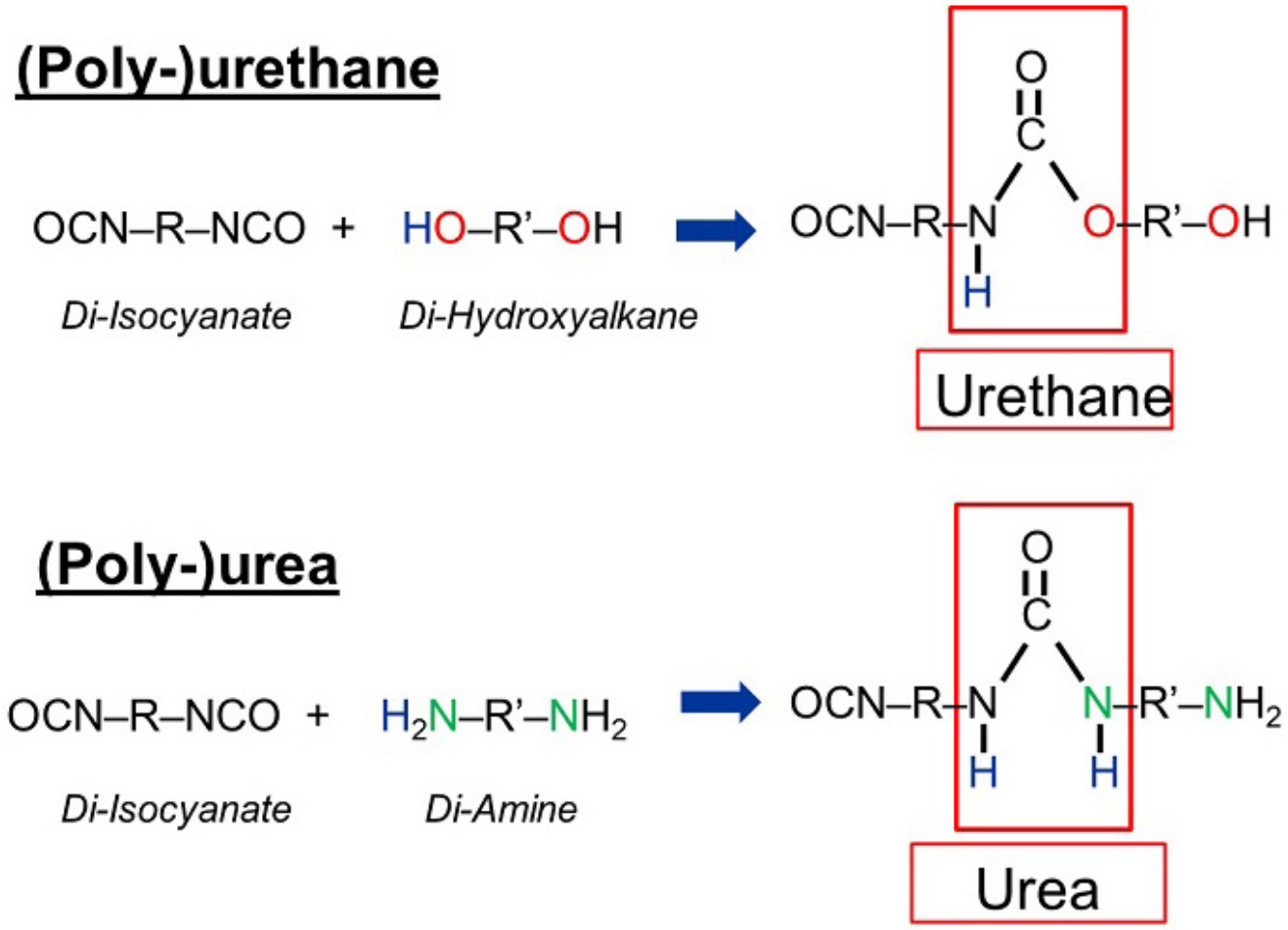


Figure 3: Basic formulae of Polyurethane and Polyurea; cross linkers and other property- influencing components omitted

	Polyurethane	Polyurea
Mechanical Properties	- Often hard / brittle - High abrasion resistance	- Soft / elastic up to hard - High abrasion resistance
Flexibility	Low at higher DFT	High at higher DFT
Chemical Resistance	Good	Very good
Thermal Resistance	Good	Very good
Tack-free / gel time	20 - 180 s	5 - 30 s
Adhesion to metal sub-strates	Strong adhesion	Strong adhesion
Water absorption properties	0.5 - 2 %	0.5 - 2 %
Processing	Spraying: 2K high pressure spray machine	Spraying: 2K high pressure spray machine (1:1)
VOC	0 % (no explosion zone needed)	0 % (no explosion zone needed)
UV-Resistance	yes / no (with topcoat, UV stabilizer)	yes / no (with topcoat, UV stabilizer)
Pricing	Lower	Higher

Figure 4: Comparison of properties PUR / PuA

Polyurea spray coatings become touch dry within minutes and fully cure in a very short period of time. Hence, they are particularly suited for in-field rehabilitation of external coatings, and for external coatings in general. Figure 5 shows the general structure of a polyurea spray coating. The multilayer structure is formed by a fast spray coating process which comprises of application of a very thin primer layer to the prepared pipe surface followed by a number of layers or fast-curing polyurea.

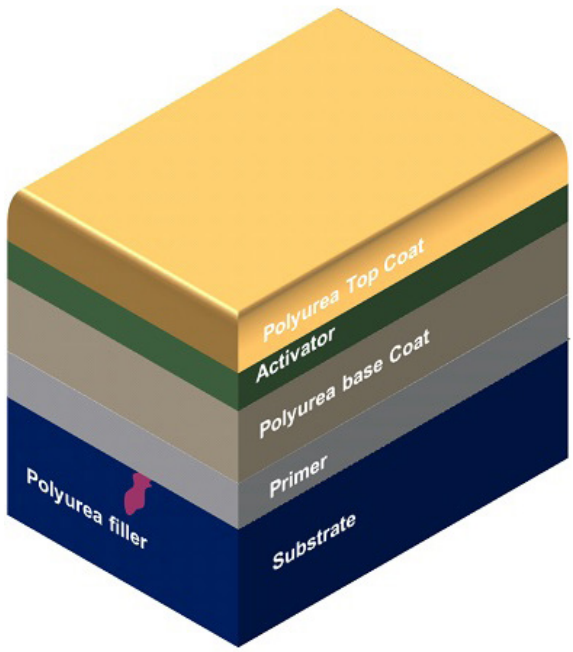


Figure 5: Schematic structure of a High Performance Polyurea spray coating

Figure 6 shows typical spray equipment and the manual spray process. For longer stretches of pipeline, in-factory as well as in the field, High Performance PuA Elastomers can be applied by fully automated equipment.

Figure 6: Polyurea Spray Coating Equipment and Process

New High Performance Polyurea spray coatings were developed and underwent extensive laboratory tests by independent, certified laboratories. Successful field trials in two applications will be described here.

3. THRUST BORING

For pipeline road or river crossing / underpasses as well as for tunneling through mountains, thrust boring (or horizontal directional drilling HDD) is widely used nowadays. In these cases, external pipeline coatings need not only provide long-term corrosion protection after the pipe has been inserted, the coating also needs to provide protection from the abrasive forces of the soil and rock through which the pipe is pushed or pulled.

Conventional bituminous coatings, PE wraps or epoxy coatings exhibit rather low resistance to such abrasion. High Performance Polyurea Elastomer spray coating ideally combines excellent long-term corrosion protection properties with a very high abrasion and tear resistance. The high elongation at break and strong tear propagation resistance of the elastomer prevents tears, e.g., by stone outcroppings which can cause coating disbondment.

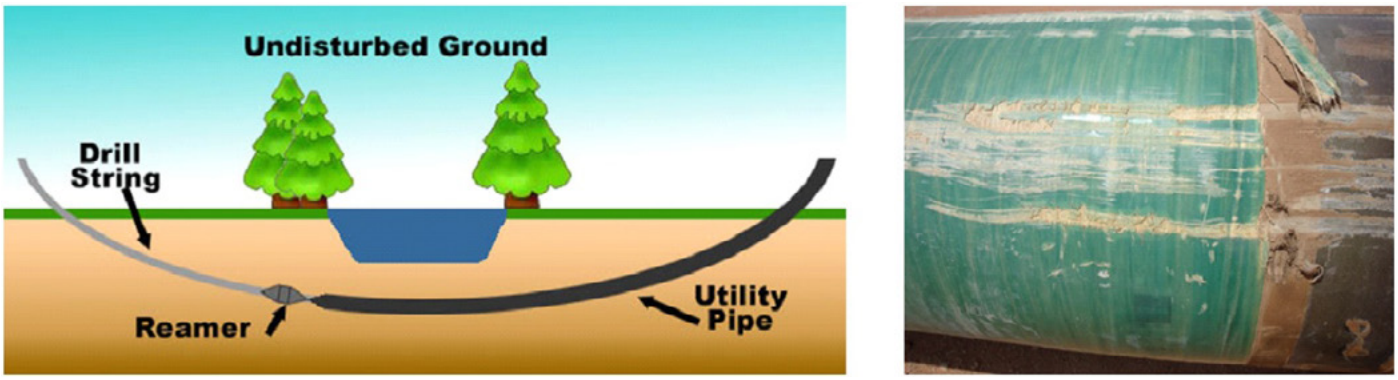


Figure 7: Schematic drawing of thrust boring process and damage of a fibre tape wrap coating by thrust boring

4. SALT MARSH ENVIRONMENT

Salty soil (known as "subkha" or "sabkha" throughout the MiddleEast) is a rather critical environment for steel pipelines. All over the world, such conditions exist near coastlines. Due to the importance of harbours for oil and gas transport, a large share of the world's buried pipelines are located close to an ocean cost. Hence, many pipelines are buried in salt or even salt-water containing soil. In some areas, tidal fluctuation of the water table actually leads to immersion of buried pipelines into salt water when there is high tide, at least at some peak tides during the year. For example, in Saudi Arabia, more or less all around the peninsula such subkha conditions exist. Along the gulf shore, there are the largest and most important refineries, transport hubs, and wells so that the number of pipelines in this particular region of subkha soil is very high. The salt water acts extremely corrosive on steel pipes. Although the pH is almost neutral, the salt content (mostly NaCl, but also other chlorides and carbonates as well as further ions) leads to ionic concentration gradients that can lead to an anodic reaction at the steel. Normally, cathodic protection used on these pipelines should prevent major corrosion once the coating fails, but after decades of service, often CP is not effective anymore; the reasons for this are described in the literature[3].

Figure 8: Typical tidal salt lake in subkha environment and damage to pipe caused by salt water containing soil.

5. LONG-TERM PREDICTIVE TESTS

For a design life of 40 years or more, a real-time test is obviously not feasible. Testing for the thrust boring process itself can be done under real-life and real-time conditions. Testing for the time the pipe rests in the ground afterwards as well as testing for salt marsh environment are different cases, however. To get a good estimation of long-term behavior, a number of standardized laboratory tests are performed that simulate strong and extreme environmental conditions. Adhesion, abrasion resistance, chemical stability, hydraulic stability and swelling resistance, as well as cathodic disbondment tests at various temperatures are typical tests performed in this context.

- Abrasion resistance: very important for thrust boring (see 3), but also in salt marsh or other environments, rock damage can occur. E.g., during pipe laying, backfilling, but also due to geological shifts or the mentioned tidal movements (see 4).

- Adhesion to the steel wall is the key feature of a coating. If adhesion is very strong, chances are very low that corrosion can occur. High Performance PuA Elastomer coatings exhibit an extremely strong adhesion to the steel wall.

- Chemical stability is a rather general term. Depending on the environment the pipe is laid in, resistance to a number of naturally occurring or man-made salt solutions, minerals, and even organic chemicals (e.g., in tar sands) may be required. The largest threat with regards to chemical stability is stability vs. hydrolysis (i.e., water and aqueous solutions) which is discussed below. Generally, Polyurea is rather stable against most chemicals that could occur in a pipeline environment.

- Hydrolytic stability and swelling resistance are two very important properties of external pipe coatings. If the coating can be hydrolyzed (i.e., the polymer chains can be broken down by water or aqueous solutions), it will not last in the long term. Swelling is a process in which water penetrates the polymer. If this happens, the water will eventually reach the pipe wall which means the start of corrosion at that point. Eventually, coating disbondment will occur. High Performance PuA Elastomer coatings exhibit low to no swelling so that even over a very long period of time, water will not reach the pipe wall.

- Cathodic disbondment is a test in which the resistance of the coating to an induced current is evaluated. Obviously, it must be avoided that the coating is removed by whatever current flows caused by CP or CP failure. In addition, it is important that the coating does not "shield", i.e., in case there ever is a disbondment, the coating should be hydrophilic enough to allow at least a part of the CP current to flow to the surrounding soil.

In combination with field tests that at least cover enough time to pass through annual cycles of e.g. water table (and to allow any chemical deterioration process to at least start), a good estimation of total life expectancy can be reached. Normally, this means at least 12 months of field testing which will be discussed under 6. For predictive testing, a number of international standards give guidance to the most important test regimens and conditions:

American Water Works Association

AWWA C222-99:
"Polyurethane Coatings for the Interior and Exterior of Steel Water Pipe and Fittings"

DIN EN ISO 10290:2002:
"Steel tubes and fittings for onshore and offshore pipelines - External liquid applied polyurethane and polyurethane-modified coatings"

ISO 21809:2007
Petroleum and natural gas industries – External coatings for buried or submerged pipelines used in pipeline transportation systems (Part 1: 3L-PE/PP, Part 2: FBE, Part 3: Field Joint Coating)

ISO 12944:1998:
„Paints and varnishes - Corrosion protection of steel structures by protective paint systems"

Figure 9: International Standards for testing of High Performance PuA Elastomer coatings

In the following table 1, standard tests performed on 2 different High Performance PuA Elastomer coatings, named RoCoat™ 221 (for thrust boring) and RoCoat 230 (for salt marsh environment), are shown.

Qualification program		criteria		
Dry film thickness EN 10290 - Annex A	12 measurements per sample	>1500 µm (60 mils) for class B	4450 µm (175 mils) average	3250 µm (130 mils) average
Hardness Shore D EN ISO 868	23±2°C (74°F)	Specified by the manufacturer	45-48 (43±5)	76-80 (75±5)
Appearance and continuity by visual examination	N/A	Uniform color, smooth appearance, free from defects	All samples show uniform color, smooth appearance and free from defects	All samples show uniform color, smooth appearance and free from defects
Holiday Detection EN 10290 – Annex B	20 kV	no pores	No holidays were detected	No holidays were detected
Impact Resistance EN 10290 – Annex C	4.25 J/mm, 23±2°C (74°F) 3 impacts	no holidays, pores	no holidays, pores	no holidays, pores
	4.25 J/mm, -5±3°C (41°F) 3 impacts	no holidays, pores	no holidays, pores	no holidays, pores
Test acc. to ROSEN Qualification program	**Test condition**	**Acceptance criteria**	**PUA 1**	**PUA 2**
Specific electrical insulation resistance EN 10290-Annex F	Immersed test surface ≥ 0.03m^2 Electrolyte: 0.1 mol/L NaCl in DI water Measurement voltage ≥ 50V 23±2°C/ (74°F) (100 days)	≥ $10^7 \Omega \cdot cm^2$ and Rs(100d)/Rs(70d) ≥ 0.8	After 3rd day: 3.17×10^8 After 100days: 2.11×10^7	After 3rd day: 3.17×10^8 After 100days: 3.17×10^8
	60±2°C (140°F) (30 Days)	≥ $10^4 \Omega \cdot cm^2$	After 3rd day: 7.70×10^5 After 30 days: 2.68×10^5	After 3rd day: 3.17×10^7 After 30 days: 9.59×10^6
Adhesion Test after immersion in Test Water EN 10290 – Annex G	Tap water, 23±2°C (74°F) (100 hours)	No pores (no holiday) and resistance to removal	No holiday Adhesion: Rating 1	No holiday Adhesion: Rating 1
Indentation EN 10290 – Annex H	Cylindrical punch OD: 1.8 mm (2.5 mm^2) Mass: 2.5 kg 23±2°C(74°F) (24 h)	≤ 0.2 mm	0.18 – 0.20 mm	0.00 – 0.03 mm
	Mass: 2.5 kg 60±2°C (140°F) (24 h)	≤ 30% of the initial coating thickness	10.3 – 16.7 %	2.8 – 5.1 %

Test acc. to ROSEN Qualification program	Test condition	Acceptance criteria	PUA 1	PUA 2
Flexibility – Bending Test CSA Z245.20-10, Clause 12.11	23±2°C (74°F), Mandrel diameter: 194 mm	No cracks, disbondment or pinholes, holiday detection at 20 kV	5.5°/PD No crack, no holiday	5.5°/PD No crack, no holiday
	0±2°C (32°F), Mandrel diameter: 294 mm	No cracks, disbondment or pinholes, holiday detection at 20 kV	2.6°/PD No crack, no holiday	2.6°/PD No crack, no holiday
Elongation ISO 537-3	Using tensile machine and dumb-bell specimen No. 5	Elongation ≥ 10%	> 500%	39.4%
Adhesion Test (Dolly test) ROPLAST and ASTM D4541	23±2°C (74°F)	Adhesion strength ≥ 4.125 MPa (≥ 600 psi)	12.6 MPa (1826 psi)	20.9 MPa (3036 psi)
	60±2°C (140°F)	Adhesion strength ≥ 4.125 MPa (≥ 600 psi)	16.7 MPa (2417 psi)	14.5 MPa (2096 psi)
	80±2°C (176°F)	Adhesion strength ≥ 4.125 MPa (≥ 600 psi)	16.4MPa (2370 psi)	14.0 MPa (2029 psi)
Cathodic Disbondment ASTM G42	80°C (176°F) (30days), 1.5 V, Electrolyte: 1% of each NaCl, Na_2SO_4, Na_2CO_3 in tap water	Maximum ≤ 15 mm from the centre of the artificial defect of two samples of three	5.7 mm (average)	0 mm (average)

Test acc. to ROSENQualification program	Test condition	Acceptance criteria	PUA 1	PUA 2
Chemical Resistance Water immersion Test ROPLAST and ASTM D 870	Immersion medium: Synthetic sea water 80±2°C (176°F) (120 days)	EIS ($\Omega \cdot cm^2$) measurements for information purposes only V= Vapor phase L = Liquid phase	Initial value: $V=2.69x10^{12}$ $L=2.44x10^{12}$	Initial value: $V=2.91x10^{11}$ $L=2.78x10^{11}$
			120 days: $V=1.30x10^{9}$ $L=5.59x10^{8}$	120 days: $V=3.66x10^{10}$ $L=1.14x10^{10}$
		Pull-off adhesion	Vapour Phase: 1297 psi (8.9 MPa) Water Phase: 1102 psi (7.6 MPa)	Vapour Phase: 2148 psi (14.8 MPa) Water Phase: 1110 psi (7.6 MPa)
	Immersion medium: Synthetic sea water 75±2°C (167°F) (120 days)	EIS ($\Omega \cdot cm^2$) measurements for information purposes only V= Vapor L = Liquid	Initial value: $V=2.20x10^{12}$ $L=2.53x10^{12}$	Initial value: $V=3.38x10^{11}$ $L=6.73x10^{11}$
			120 days: $V=5.09x10^{9}$ $L=1.38x10^{9}$	120 days: $V=2.50x10^{10}$ $L=2.98x10^{10}$
		Pull-off adhesion	Vapour Phase: 948 psi (6.5 MPa) (glue) Water Phase: 1643 psi (11.3 MPa)	Vapour Phase: 2376 psi (16.3 MPa) Water Phase: 1729 psi (11.9 MPa)

Test acc. to ROSEN Qualification program	Test condition	Acceptance criteria	PUA 1	PUA 2
Chemical Resistance Exposure to hot wet High Salinity Sand ROPLAST and ASTM D 879	Immersion medium: Hot cyclic wet-dry High Salinity sand 80±2°C(176°F) (180 days)	EIS ($\Omega \cdot cm^2$) measurements for information purposes only V= Vapor phase S = Sand phase	Initial value: V=1.78x10^{12} S=1.85x10^{12}	Initial value: V=1.06x10^{12} S=1.02x10^{12}
			180 days: V=2.77x10^{11} S=5.74x10^{8}	180 days: V=2.18x10^{11} S=1.02x10^{11}
		av. Pull-off adhesion after six month	Vapour Phase: 1029 psi (7.1 MPa) Sand Phase: 1065 psi (7.3 MPa)	Vapour Phase: 3045 psi (20.9 MPa) Sand Phase: 1749 psi (12.0 MPa)
	Immersion medium: Hot cyclic wet-dry High Salinity sand 75±2°C(167°F) (180 days)	EIS ($\Omega \cdot cm^2$) measurements for information purposes only V= Vapor phase S = Sand phase	Initial value: V=2.26x10^{12} S=2.16x10^{12}	Initial value: V=1.05x10^{12} S=2.08x10^{12}
			180 days: V=2.96x10^{10} S=7.76x10^{9}	180 days: V=2.28x10^{11} S=1.19x10^{11}
		av. Pull-off adhesion after six month	Vapour Phase: 850 psi (5.9 MPa) Sand Phase: 1305 psi (9.0 MPa)	Vapour Phase: 2912 psi (20.0 MPa) Sand Phase: 1468 psi (10.1 MPa)

Test acc. to ROSEN Qualification program	Test condition	Acceptance criteria	PUA 1	PUA 2
Fingerprint for Coating identification	N/A	N/A	See FT-IR Spectra	See FT-IR Spectra
Abrasion Resistance ASTM D 4060-07 (Taber)	1000 cycles at 1kg (2.2 lbs) using CS-17 wheel	≤ 100 mg weight loss	7.6 mg	123 mg
	1000 cycles at 1kg (2,2lbs) using CS-10 wheel	≤ 100 mg weight loss	N/A	93 mg
Gouge Test CSA Z245.20-10 Section 12.15	25 kg (55lbs) load 23±2°C and carbide burr (SL1 single cut)	No holiday	52.7% of the total DFT	16.0% of the total DFT
	50 kg (110lbs) load 23±2°C and carbide burr (SL1 single cut)		83.7% of the total DFT	64.7% of the total DFT

Table 1: Long-term predictive test results on 2 High Performance PuA Elastomer spray coatings

The following photos show test coupons of two of the most critical tests after testing:

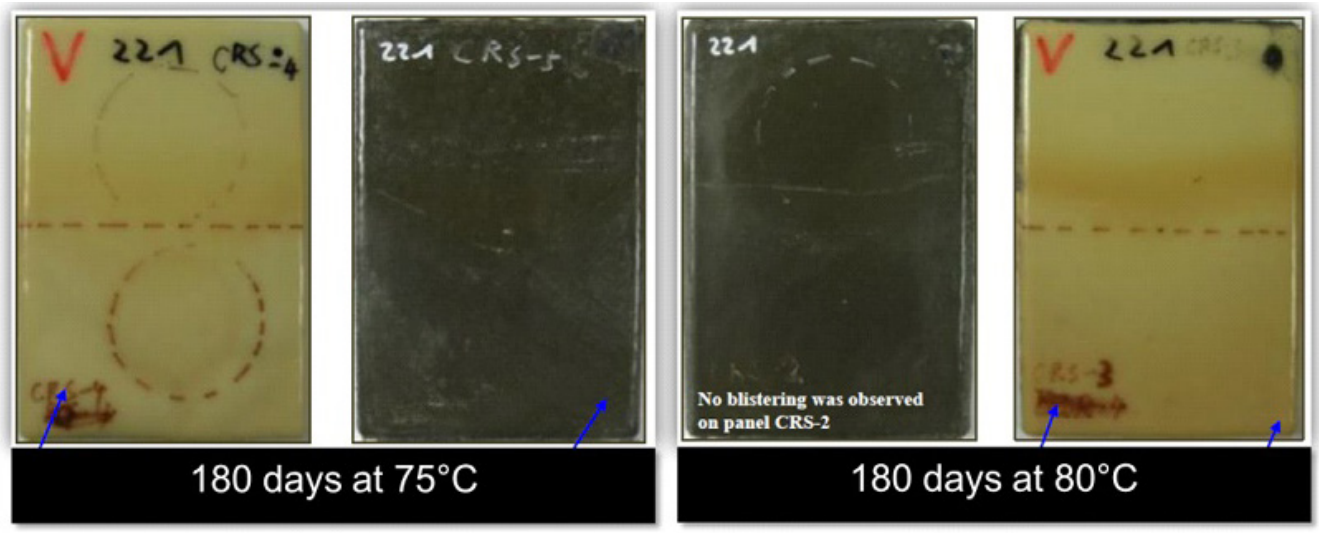


Figure 10: Adhesion test coupons after hot/wet cycling in high salinity sand

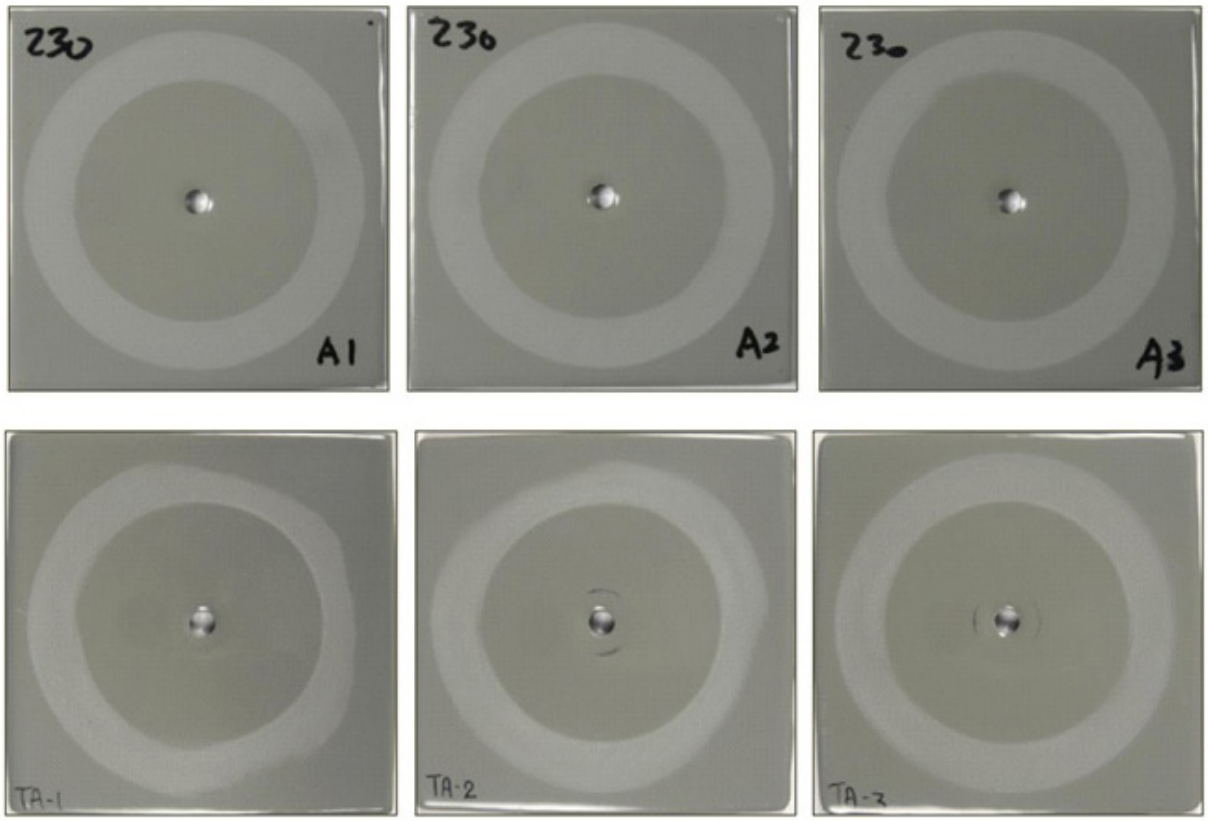


Figure 11: Taber abrasion tests acc. ASTM D 4060-0

In summary, the two High Performance PuA Elastomers tested passed all the standard tests with a good margin. No adhesion failure, low abrasion, good bendability and impact resistance, high hydrolytic stability and swelling resistance were proven. These test results, performed by certified independent laboratories, led a major operator to perform field trials with these two elastomers, a thrust boring test as well as a 13 months salt marsh environment test on an operating pipeline.

6. FIRST FIELD EXPERIENCE

6.1 Salt marsh environment

An operating pipe joint in salt marsh environment (desert, outside daytime temperature 30-46 °C) was excavated and the old, faulty coating removed. After grit blasting and application of a primer, PuA RoCoat™ 230 was applied and the pipe buried. After 8 months, the pipe was excavated again and was manually applied manually (after cleaning of the original PuA surface) to simulate an in-field repair. To enable identification of the "repair" later, this material contained a different dye from the original one so that two colors resulted. After altogether 13 months, the pipe was once again excavated. Neither blistering, disbondment, material loss, or any defects or faults were found on the coating nor on the "repair" patch. Figure 12 shows the stages of this experiment.

Figure 12:
First row: Pipe before rehabilitation (left) and after application of High Performance PuA Elastomer spray coating.
Second row: "repair" patch applied after 8 months in salt marsh environment (left) and entire pipe including repair patch after 13 months.

6.2 Thrust Boring

A number of 32" pipe sections with different exterior coatings on them were used in a thrust boring trial by a large operator. The pipes did not remain in the ground (as they would in a normal case), but pulled out again at the other end for evaluation. Pipe temperature was approx. 55 °C; the soil was rocky. Figure 14 shows the test setup; after the pulling head, sections bearing the various coatings were mounted and pulled through. Figure 15 shows a selection of tested coatings after the thrust boring trial.

Figure 14: Thrust boring setup

Figure 15: High Performance PuA Elastomer RoCoat™ 221 after thr

7. SUMMARY

High Performance PuA Elastomer spray coatings exhibit ideal properties to extend pipeline design life in corrosive environments as well as in mechanical demanding applications like thrust boring. Long-term predictive tests have shown that these materials are well suited to protect pipelines over decades.

Field trials in both thrust boring and salt marsh environment have demonstrated that High Performance PuA Elastomer spray coatings show significantly better results than other coatings. In thrust boring, even ceramic coatings showed more damage than these elastomers. This new generation of polyurea materials may prove to be a game changer in pipeline protection.

8. REFERENCES

1 = http://www.toolingu.com/definition-500115-41814-elastomer.html

2 = Konrad Uhlig, „Polyurethan Taschenbuch", Carl Hanser Verlag, München, Germany, 3rd edition, 2006

3 = http://www.npl.co.uk/upload/pdf/cathodic_protection.pdf

Author

Prof. Dr.-Ing.
Michael Magerstaedt
ROSEN Headquarters
Stans, Switzerland

Biogas in the natural gas grid as support for the change in energy policy, part 1

Uwe Ringel, Managing Director ONTRAS Gastransport GmbH, Leipzig

In Germany the role of renewable energies is subject to statutory regulation in many areas. In accordance with the energy concept of the German federal government regenerative energies will be responsible for generating at least 80 percent of the country's electricity by the year 2050. The aim is to cut energy consumption in half by the year 2008 and reduce emissions of environmentally harmful gases by up to 95 percent compared with the year 1990. In addition to wind and solar installations, gases produced from regenerative sources (e.g. biogas, hydrogen from power-to-gas) are to make a substantial contribution toward meeting these targets. Thus, for example, up to ten billion cubic meters of bio-natural gas are to be supplied to the existing gas grid by the year 2030.

Grid operators such as ONTRAS are obliged by law to connect biogas installations to the grid and give preference to the transport of bio-natural gas. To this end the raw biogas is processed to natural gas quality and then supplied to the gas grid by means of a corresponding feed-in facility. Allocation of the costs for the treatment and supply of the biogas as well as construction and operation of the corresponding plants are regulated by law. Thus far, however, there are no incentives for consumers to purchase bio-natural gas. Moreover, changing framework conditions and diminishing acceptance of biogas facilities on the part of the general population make new investments more difficult. This development has put the aim of achieving climate policy targets with the aid of biogas at risk.

LEGALLY REGULATED EMPLOYMENT OF REGENERATIVE ENERGIES IN GERMANY

The framework for energy policy in Germany is prescribed by EU regulations and directives. For the gas industry the Domestic Gas Market Directive, the Regulation on Conditions for Access to the Natural Gas Transmission Networks, the Regulations Concerning Measures to Safeguard the Security of Gas Supply as well as the Directive on Promotion of the Use of Energy from Renewable Sources are relevant in particular. The guiding principle for future development of the energy supply in Germany is defined in the federal government's energy concept from 2010 and in the concept on the change in energy policy from 2011. The German federal government has set ambitious goals for itself with regard to the change in energy policy. The role of fossil energy sources such as natural gas and renewable energies is concretely regulated in a set of laws and regulations. Particularly crucial in this regard are the German Law on the Fuel and Electricity Industries [EnWG], the Renewable Energy Sources Act [EEG], the Gas Grid Access Ordinance [GasNZV] and the Gas Grid Fee Ordinance [GasNEV].Thus the Renewable Energies Sources Act from 2012 provides that renewable energies constitute at least 35 percent of gross electricity consumption by the year 2020; by the year 2030 at least 50 percent, and by 2050 at least 80 percent of electricity is to come from renewable sources. By this time energy consumption compared with the year 2008 should also be cut in half. Emissions of environmentally harmful gases will then be 80 to 95 percent less than in the year 1990. Gas-fired power stations are to substitute as backups if wind and solar plants fail to supply electricity due to weather conditions. In many areas gas from regenerative sources is to increasingly replace natural gas from fossil sources.

GAS FROM REGENERATIVE SOURCES SUPPORTS CLIMATE PROTECTION AIMS

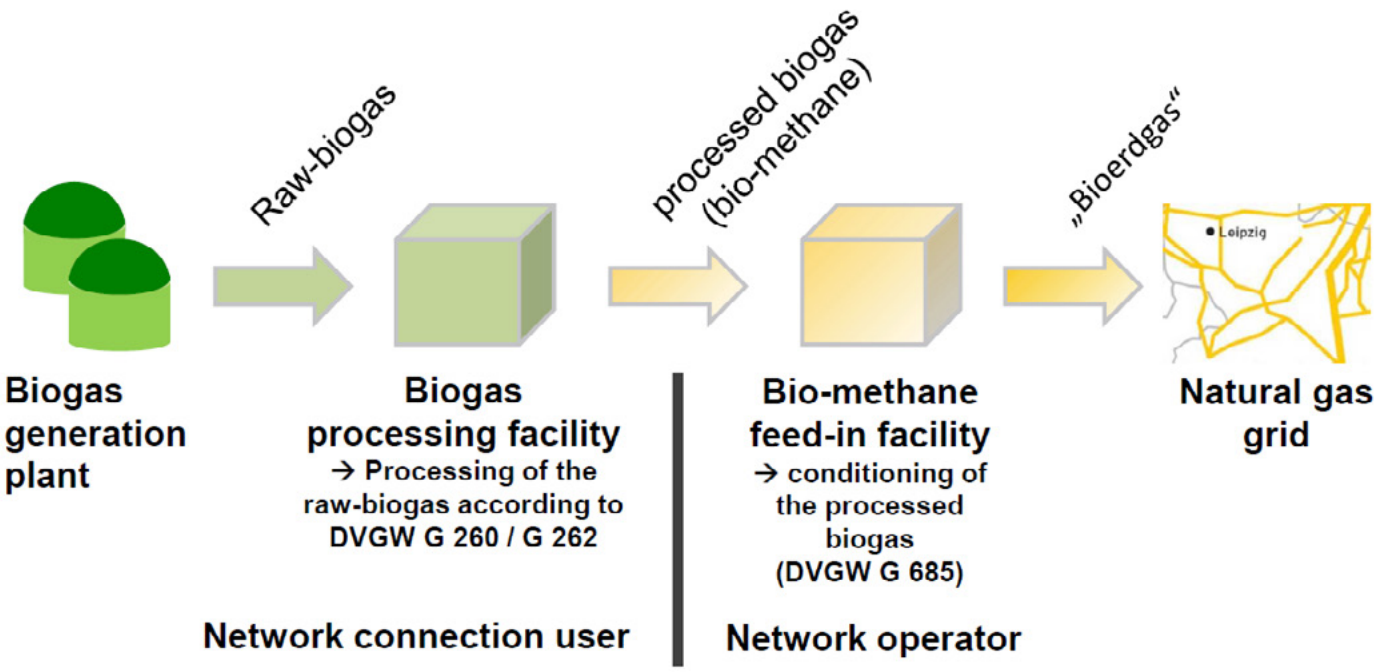
In the German Law on the Fuel and Electricity Industries regenerative gases such as bio-methane, gas from biomass, landfill gas, digester gas and methane as well as hydrogen produced by water electrolysis are put on an equal footing just as synthetically produced methane from this hydrogen if the carbon dioxide used for methanization stems primarily from renewable energy sources. Due to their many possible uses on the thermal energy and fuel markets through conversion into electricity in installations with combined electricity and heat production, these gases are able to assume an important role when it comes to the change in energy policy on the one hand. On the other hand substantial quantities can be supplied to the gas grid as so-called bio-natural gas – biogas processed to natural gas quality – instead of natural gas and thus improve the latter's already favorable carbon dioxide balance even further. In light of this the German federal government sees an annual biogas potential of up to ten billion cubic meters by the year 2030. With the help of specially designed statutory provisions this quantity is to have priority access to the gas grid. Thus since 2008 gas grid operators are obliged to give priority to the connection of biogas facilities to their grids and preferentially transport biogas that has been processed to natural gas quality. The same applies to hydrogen and synthetic methane from so-called power-to-gas installations. With surplus wind or solar electricity they generate electrolytically produced hydrogen and feed it directly into the gas grid. However, the feed-in quantity is limited because the natural gas quality in the grid changes with the increasing share of hydrogen. Alternatively synthetic methane is created with carbon dioxide from largely regenerative sources which, similarly to natural gas, can be used anywhere in the grid without restriction.

GAS CUSTOMER PAYS THE COSTS FOR BIOGAS IN THE GRID

Every connection of a biogas facility to the existing gas grid requires a substantial investment. Regardless of the maximum feed-in quantity, two to five million euros must be calculated for the planning and construction of a corresponding feed-in facility, depending on the connection parameters. Since amendment of the Regulation on Conditions for Access to the Natural Gas Transmission Networks in 2010 the power recipient and/or the operator of the biogas processing plant is only responsible for 25 percent of the connection costs; however, a maximum of EUR 250,000 for the biogas feed-in facility and the first kilometer of the connecting mains. The operator must completely assume the costs as of the tenth kilometer only for connecting mains longer than ten kilometers. Thus the grid operator initially bears the principal share of the connection costs. In addition, the operator is responsible for ongoing operating and maintenance costs and provides for operation of the feed-in facility. In this case 96% availability must be ensured. Feeding bio-natural gas into the grid takes place free of charge because the grid operator is not allowed to charge for this. However, according to the intentions of legislators the supply of biogas is ultimately not supposed to generate any additional costs for grid operators. That is why the statutory provision provides that these costs be allocated to the exit points to end consumers in Germany in accordance with defined rules. The annual biogas costs are calculated from the sum of the investment and operating costs for feeding in biogas in the preceding year as well as the corresponding costs forecast for the subsequent year reported by all of the grid operators. Up to now the resulting so-called biogas redistribution levy was allocated to all of the exit points of a market area with the exception of the

exit points to storage systems, border region and market area transition points. In the final analysis the political intention is that the community of gas consumers in the two German gas market areas of NetConnectGermany (NCG) and GASPOOL are responsible for the costs incurred for feeding in biogas. redistributed within a market area. The significantly higher connection density of biogas feed-in facilities in the market area of GASPOOL thus result in a one-sided increase in the gas transport costs and thus to competitive distortion vis-à-vis customers in the NCG market area. This effect is amplified by the fact

The way from biogas to bio-natural gas (schematic)



COMPETITIVE DISTORTION BY BIOGAS ELIMINATED

As a result of its geographical and agricultural structure more biogas feed-in facilities have been planned and realized in the northern and easternederal states in Germany – thus in the market area of GASPOOL – than in the remaining federal states (NCG market area). With the plants in Güstrow (max. 5,750 m^3/h under normal conditions, ONTRAS) and fSchwedt (max. 7,000 m^3/h under normal conditions, EWE) these include the currently most productive plants on the grid. Up to now the costs borne by grid operators for biogas feed-in facilities have only been that this higher amount is allocated to fewer exit points in relation to the NCG market area. For end consumers and downstream grid operators this means that they have to pay EUR 0.26/kWh/h/a in the NCG market area, in the GASPOOL market area on the other hand EUR 0.75/kWh/h/a in addition to the regular grid fees for biogas feed-in. In this case ONTRAS took over responsibility for determining the redistribution amount for the transmission system operators in the GASPOOL market area. As the transmission system operator with the largest number of biogas feed-in facilities in

operation and/or under construction or in the planning, ONTRAS warned about this competitive distortion caused by biogas on several occasions and at the political level pushed for a uniform regulation that would be valid throughout the entire country. After several efforts, in particular on the part of the federal states in the eastern part of the country, corresponding amendment of the gas grid fee ordinance has come into force. Thereafter there will be a nationwide uniform redistribution amount as of the year 2014.

GRID OPERATOR RESPONSIBILITY: CONNECTION OF BIOGAS INSTALLATIONS TO THE GAS GRID

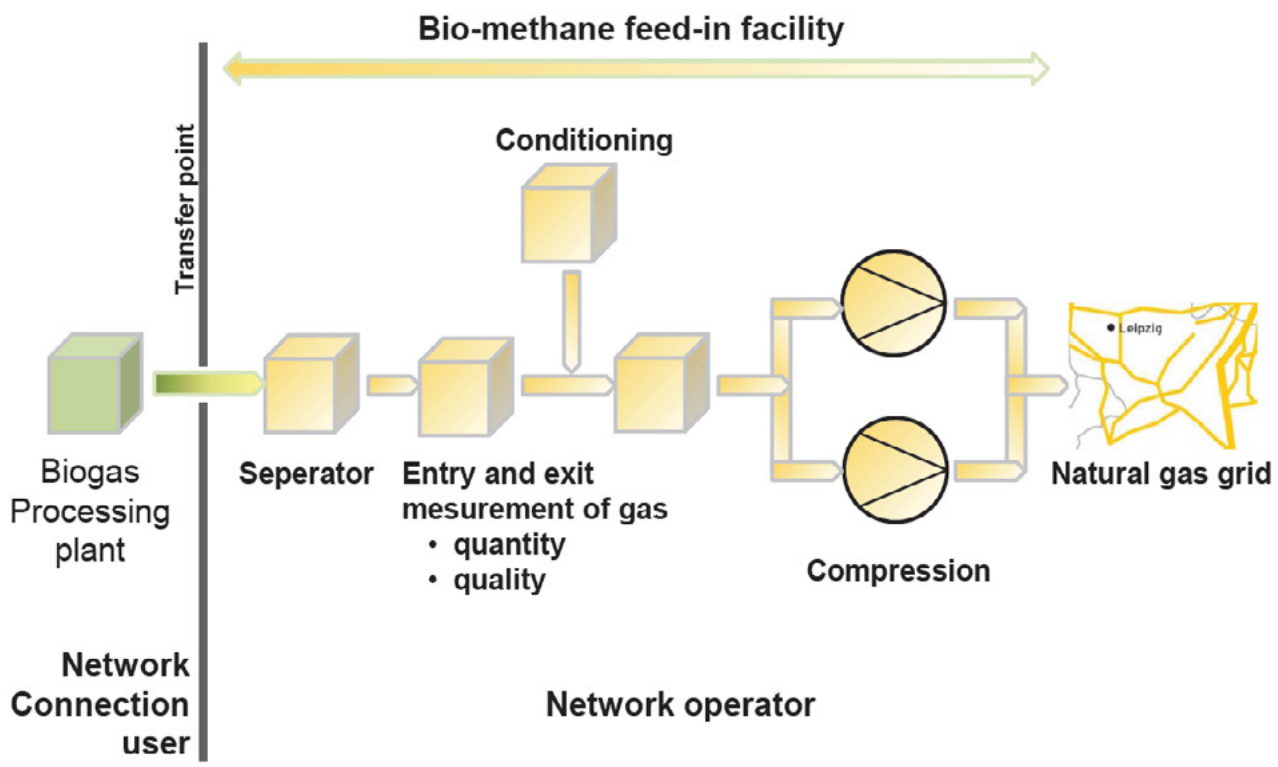
All applications for installation of grid connections acres processed in accordance with Section 33 of the German Regulations for Gas Grid Access (Gasnetzzugangsverordnung [GasNZV]). Provided the network connection request has been positively answered, ONTRAS concludes a Network Connection and Use Contract with the biogas which not only defines the technical and operational terms, but also includes a time schedule (realization schedule) for planning and construction of the grid connection as well as the subsequent operation and maintenance. This legally prescribed realization schedule is firmly coordinated between the operators of the biogas processing and the feed-in facility into the gas grid. In the event that a grid operator fails to adhere to the dates of this timetable, then loss of the entire power recipient share in the amount of EUR 250,000 threatens – unless the grid operator is able to prove that circumstances prevail for which the grid operator may not be held responsible (e.g. the absence of official permits). The only task that remains for the operator of the biogas processing plant is to provide a constant gas flow in accordance with the contract with a minimum gas quality as defined in DVGW Worksheets Gas G 260 and G 262. The reason is that compared with conventional natural gas, raw biogas still contains, among other things, components such as sulfur, carbon dioxide and nitrogen. Apart from the drying, cleaning and desulfurization of the biogas an essential step in the processing – for which a number of different processing methods have been established on the market – consists in the separation of carbon dioxide from the raw biogas (methane enrichment). The share of carbon dioxide in the raw biogas varies between 30 and 50 percent depending on the biomass used and the installation type. The operator of the biogas processing plant examines whether the gas quality corresponds to the prescribed minimum standard and as a rule also measures the gas quantity which is to be delivered before the processed biogas is delivered to the feed-in facility of the grid operator. However, what is important for billing is the energy quantity that is determined by means of a process chromatograph, myon-veto detector and volume flow measurement at the ingress point of the biogas feed-in facility

GRID OPERATOR RESPONSIBILITY: OPERATION OF THE FEED-IN FACILITY

ONTRAS set up standardized project management in the grid service division for the planning and construction of biogas feed-in systems. Planning, construction and scheduling take place in close cooperation with the power recipient on the basis of the jointly specified realization schedule. A number of parameters are variable depending on the design of the biogas processing plant when it comes to the feed-in quantity, pressure, composition of the processed biogas, etc. as well as the requirements of the respective feed-in grid, e.g. location of the processing plant in relation to the gas grid, pressure level and nominal width. Every connection of a biogas processing plant to the gas grid thus represents an individual project despite extensive standardization.

With each individual project the efficiency of the plant as well as its availability over the entire service life of the plant stand at the center of attention for the grid operator. The grid operator's responsibility for the biogas begins at the output flange of the biogas processing facility. From there the biogas is introduced into the biogas feed-in plant. This essentially consists of a measuring and control line with an upstream filter and separator combination, the conditioning plant, the compressor plant and peripheral components for the production of technological heat, for the production of control air and for closed-circuit cooling. In the measuring and control line gas quality and gas quantity are measured at different points of the plant and the energy quantity that is relevant for billing is thus determined. As a rule a conditioning plant then follows in order to adjust the calorific value of the bio-natural gas delivered in minimum quality to the prevailing calorific value in the gas grid using liquid gas (LPG) in accordance with the specifications of the DVGW Worksheet G 685 The latter regulates gas measurement as well as the calibration capability of gas measurements and thus sets quality standards that deviate from the minimum standard of the DVGW Worksheets G 260/G 262. After that the gas is compressed to the required grid pressure depending on the delivery pressure made available by the biogas processing. Up to three compressor stages are required depending on the final pressure that is to be achieved. Since biogas feed-in facilities are usually operated without personnel, extensive automatic control technology is installed for fully automatic plant operation. The minimum requirements for the planning, production, construction, inspection and commissioning of a biogas feed-in plant are specified in DVGW Worksheet VP 265-1. Moreover, through DVGW Worksheet G 265-2 there are minimum requirements to be met by the operation and maintenance of these plants.

Major components of a bio-methane feed-in facility



NATURAL GAS GRIDS "BIO-READY" ALREADY TODAY

As of July 2013 a total of 12 biogas facilities feed their gas into the ONTRAS grid. By the end of the year 2013 there will be presumably already be 16 plants. ONTRAS then annually transports up to 115 million m^3/a of bio-natural gas in the grid under normal conditions – a quantity with which more than 100,000 households can be supplied for over a year. And then there is the bio-natural gas of numerous biogas feed-in facilities on the downstream grids of ONTRAS. At the end of the year 2012 there were 107 biogas facilities connected to the gas grid altogether with an annual feed-in potential of 580 millions m^3 of bio-natural gas under normal conditions. According to estimates for the year 2013 from the German Energy Agency and the BDEW there will be approximately 170 plants with an annual feed-in potential of 900 million m^3 under normal conditions. That would correspond to approximately 15 percent of the quantity planned by the German federal government for 2020. In the future power-to-gas plants will also be connected to the gas grid that then feed hydrogen or synthetic methane into the gas grid. An initial plant with a feed-in potential of up to 350 m^3/h of hydrogen under normal conditions will be put into service already in August 2013 and feed into the ONTRAS grid. With such power-to-gas plants it will be possible in the future to use surplus wind and solar electricity, which up to now had to be throttled because of a lack of capacities in the transmission networks (electricity), for producing hydrogen or methane and to feed the regenerative gases into the gas grid. Transformed in this manner electricity will become capable of storage on a long-term basis. Power-to-gas will not replace expansion of the electricity grids, but used on a regional basis it could contribute to their system stability. However, the prerequisite is that policymakers coordinate cooperation among all of the parties involved, plant, electricity and gas grid operators as well as implementation of a reasonable economic model for the market.

BIOGAS CONTRIBUTION TO CLIMATE PROTECTION AT RISK

The future development of the biogas supply will be negatively affected by several factors. On the one hand the framework conditions for biogas facilities in Germany have changed several times, so that an investor today often does not have sufficient long-term planning security and therefore dispenses entirely with the construction of a plant or at least no longer considers a potentially possible feed-in of biogas into the gas grid. And the acceptance of biogas facilities is increasingly meeting with resistance among the population. Odor nuisances, unnecessary heavy transports and the competition of the energy plants for the cultivation of food and fodder are the most frequent topics of discussion. On the other hand policymakers have done a lot in order to get bio-natural gas into the gas grid; however, up to now there has been a lack of incentives for consumers to purchase bio-natural gas. While the users of green electricity enjoy financial advantages, the employment of bio-natural gas does not provide a benefit to gas customers. Here is where policymakers must improve, not least of all in order to meet the important climate protection targets. Each cubic meter of bio-natural gas instead of natural gas in the network improves the already good carbon dioxide balance: The burning of bio-natural gas produces only as much carbon dioxide as the plants consumed during growth. And it further reduces Germany's dependence on gas imports.

OUTLOOK

The network operators transport the bio-natural via the existing gas network to consumers throughout Germany. Like natural gas bio-natural gas can be used to generate electricity and heat as a fuel or chemical feedstock. Therefore ONTRAS actively supports this goal both as a transmission system operator and out of conviction – not only because we are obliged to in accordance with German law. We care about connecting biogas to the gas grid – from initial inquiry, to a formal grid connection request all the way through to design, construction and operation of the incoming feeder. The sooner we learn about such a biogas project, the better we can progress together with the connection owner in order to realize the grid connection. ONTRAS also promotes the development of biogas potentials by providing services within the scope of grid connection requests as well as the planning and construction of power lines. Part 2 of the contribution (next PTJ issue) sheds light on the practice of biogas feed-in into the gas grid and elaborate on the special challenges when planning, building and operating such plants using individual biogas feed-in facilities as an example and share the first experiences in the field.

Author

Uwe Ringel
Managing Director
ONTRAS Gastransport GmbH
Leipzig / Germany

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International infrastructure and pipeline events 2014

April 2014

3rd Issue Pipeline Technology Journal (ptj)

14.04. Pipeline Technology Journal covers reports about research, industry and practice, presentation of innovative concepts and technologies, latest information about pipeline conferences and other related event information.

May 2014

9th Pipeline Technology Conference (ptc)
12. - 14.05. Berlin, Germany
Europe's Leading Conference and Exhibition on New Pipeline Technologies.

City Solution Expo and Conference (CSEC)
21.-22.05. Doha, Qatar
International Conference and Exhibition on Innovations and Technologies for Smart Infrastructure Solutions.

September 2014

4th Issue Pipeline Technology Journal (ptj)

15.09. Pipeline Technology Journal covers reports about research, industry and practice, presentation of innovative concepts and technologies, latest information about pipeline conferences and other related event information.

October 2014

2nd Infrastructure North Africa (INA)
13. - 14.10. Tunis, Tunisia
Infrastructure North Africa, International Conference and Exhibition for the Revitalization of the North African Infrastructure Market.

2nd international Pipeline Seminar Week (IPSW)
tba. Hamburg, Germany
Pipeline life-cycle extension strategies, new technologies in operation.

November 2014

ptc Middle East
10.-11.10 Kuwait, Kuwait
Conference and Exhibition on New Pipeline Technologies.

MORE FOREIGN TRANSPORT NETWORK OPERATORS THAN EVER AT 8TH PIPELINE TECHNOLOGY CONFERENCE, PTC

In March 2013 the international pipeline community met for the 8th Pipeline Technology Conference (ptc) in Hannover, Germany. More than 300 delegates and delegations from 33 different pipeline operators from all over the world attended this year's conference. The opening plenary sessions again covered a wide range of operational aspects presented by speakers from international players like Open Grid Europe, Botas, Petrobras, TransCanada, Saudi Aramco and GDF SUEZ. Followed by 9 technical sessions, 3 specialized workshops and an ILI seminar, the whole event for the first time stretched over 5 full days.

Dr. Andreas Helget, Pipeline Solutions Business Head, Siemens underlined the importance of ptc as Europe's leading conference for new pipeline technologies: "Siemens sponsors the Pipeline Technology Conference for two years now because it brings together the mechanical integrity part of the business with the system integration part, the automation, the electrical sides of the business. That makes this eventvery interesting for us."

The city of Hannover is not just lying in the center of Germany and Europe but also in close distance to the one of the first boreholes in the world for the extraction of oil in Wietze. A unique place where the conference delegates could see during a dinner invitation at the "Germany Oil Museum" that in Germany oil was also extracted from underground mines from 1920 to 1963. ROSEN Group handed over a new exhibit for the museum during the dinner.

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). The next ptc will take place from 12-14 May 2014. The first sponsors have already confirmed their support for next year. Besides the whole range of pipeline technologies, the 9th ptc will focus on onshore and offshore pipeline construction and pipeline safety.

FIRST PTC SEMINAR ON ILI ATTENDED BY 16 INTERNATIONAL PARTICIPANTS

The 2-day seminar on "In-line inspection of transmission pipelines" started directly after the 8th Pipeline Technology Conference on 21 March 2013. Some of the international ptc delegates from Saudi Arabia, Libya, Switzerland and Germany made use of the opportunity to stay for two more days in Hannover in order to go further into details and to meet some potential future business partners. The two lecturers Dr. Michael Beller and Dr. Konrad Reber gave a comprehensive overview on the technical backgrounds, latest ILI technologies in the market, reporting and defect assessment. One of the participant summed up the seminar as "an excellent basic course in ILI-inspections. I recommend this to everybody working in the pipeline integrity business." Each participant received a certificate at the end of the seminar. Upcoming Pipeline Technology Conferences will feature more seminars that will cover all aspects for an extended life-cycle of pipelines.

THE ORGANIZER OF PIPELINE TECHNOLOGY CONFERENCE PTC OFFERS A DEEPER KNOWLEDGE OF THE NEWEST DEVELOPMENTS IN SEMINARS

The annual Pipeline Technology Conference ptc is known for its permanent dealing with the latest technological developments in the pipeline industry. Participants have increasingly requested to treat some developments with regard to a deeper application in their companies. Therefore in the past 1-2 years special seminars have been appended to the conference. Given the scope of the topic "Pipeline life-cycle extension strategies - new technologies in operation" a new seminar was extended to one week separated in time from the conference.

This first International Pipeline Seminar Week has taken place from the 21st till the 25th of October 2013 in Hamburg, Germany. Participants from different pipeline operators around the world joined this new idea. Within the five days of the seminar detailed information about well-approved strategies for a failure-free and economic operation and maintenance of high-pressure oil and gas pipeline systems were transferred. Three of Germany's largest pipeline operators (Open Grid Europe, Thyssengas, Ontras) gave an insight into their experiences together with lecturers from universities and technology and service providers. Within this system experienced lecturers and participants had the opportunity to discuss problems about Leak detection, Pipeline safety, In-line inspection, Pipeline integrity management systems as well as Repair works in depth.

Theoretical lectures and practical demonstrations combined with factory visits and sightseeing made the seminar to a very efficient event. Mr. Abdeljalil Chaieb, Chef de Département Audit Technique, sergaz (Société de service du Gazoduc Transtunisien), Tunisia stated that: "My colleagues and I got a very good insight into latest technologies in operation in the European pipeline market. I could really recommend the International Pipeline Seminar Week for any international pipeline operator".

The next seminar is planned for October 2014.
For more information please visit:
www.pipeline-seminar.com.

STRATEGIC PARTNER FROM THE MIDDLE EAST STRENGTHEN PIPELINE TECHNOLOGY CONFERENCE (PTC) 2014 IN BERLIN

Annually pipeline operators as well as technology and service providers come together to progress the main focus of the Pipeline Technology Conference (ptc) on latest technologies and new developments in the international pipeline industry. The event brings together speakers and participants from the developed and developing world in a dialogue which focuses on sharing the benefits of development and the burdens of the Pipeline world. The conference tackles themes including operation & maintenance, rehabilitation, in-line inspection and integrity management field studies and technologies. With moving next year to Berlin, the Pipeline Technology Conference (ptc) aims to more expand its international horizon and strengthens itself by a partner from the Middle East, JGB International Co, WLL. JGB International Co, WLL an ISO certified company is specialized in providing solutions and services for Oil & Gas Industry, Water Treatment, HVAC and other industrial segments. Headquartered in the Kingdom of Bahrain JGB International Co, WLL has branch offices and activities at other GCC countries Saudi Arabia, Qatar, UAE, Oman, Iraq and Kuwait, USA and India.

With a Memorandum of Understanding both parties define their efforts to enhance the participation from the Middle East, Asia as well as India at the Pipeline Technology Conference ptc 2014. The partnership will advance ptc's international expansion and broaden opportunities with more global prospective operators and technology providers. Please visit the Pipeline Technology Conference (ptc) website for more information: www.pipeline-conference.com/


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Editors 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

Editorial Management & Advertising
Rana Alnasir-Boulos
E-Mail: alnasir-boulos@eitep.de
Tel: +49 (0)511 90992-20

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