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Challenging Pipelines:

Inspecting and Operating extraordinary pipeline systems

Dr. Klaus Ritter
Editor in Chief

Gas pipeline systems are not necessarily designed and constructed in such a way that modern inline inspection methods can be used successfully. This applies in particular to older lines constructed around the second half of the last century. The consequences of this are expensive problems for many pipeline operators because the mechanical configurations of many pipelines deem it impossible to use common inspection solutions. These pipelines are challenging because individual solutions have to be found to ensure the functionality of the lines.

Another factor that creates challenging pipelines is the idea of rationalization, which many operators see as imperative in their present and future actions. Merging different pipeline segments for cost-effectiveness, resulting in multi-diameter systems, leads to additional levels of difficulties in terms of inspecting the pipelines and ensuring their operational safety.
A third important source of influence for challenging pipelines are the conditions associated with a particular pipeline. Difficult soils, rock formations, low pressure levels or similar complications influence the inspection possibilities and require technology suppliers to deliver innovative solutions to complex challenges.

In this issue of Pipeline Technology Journal we present a multitude of interesting case studies regarding challenging pipelines and their safe and profitable operation. However, ptj is not the only platform that present solutions in this respect. The annually Pipeline Technology Conference (ptc) displays solutions for challenging pipelines too.

The inspection of challenging pipelines is only at the beginning of its development. Pipeline Technology Conference (ptc) and Pipeline Technology Journal (ptj) are international platforms where developments can be discussed.

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Yours,

> Dr. Klaus Ritter, President EITEP Institut

FEBRUARY 2018 / ISSUE 1

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REPORTS

CONFERENCES / SEMINARS / EXHIBITIONS

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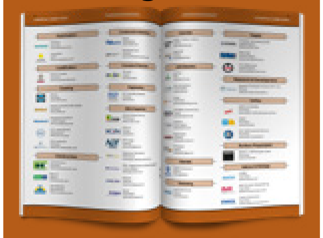

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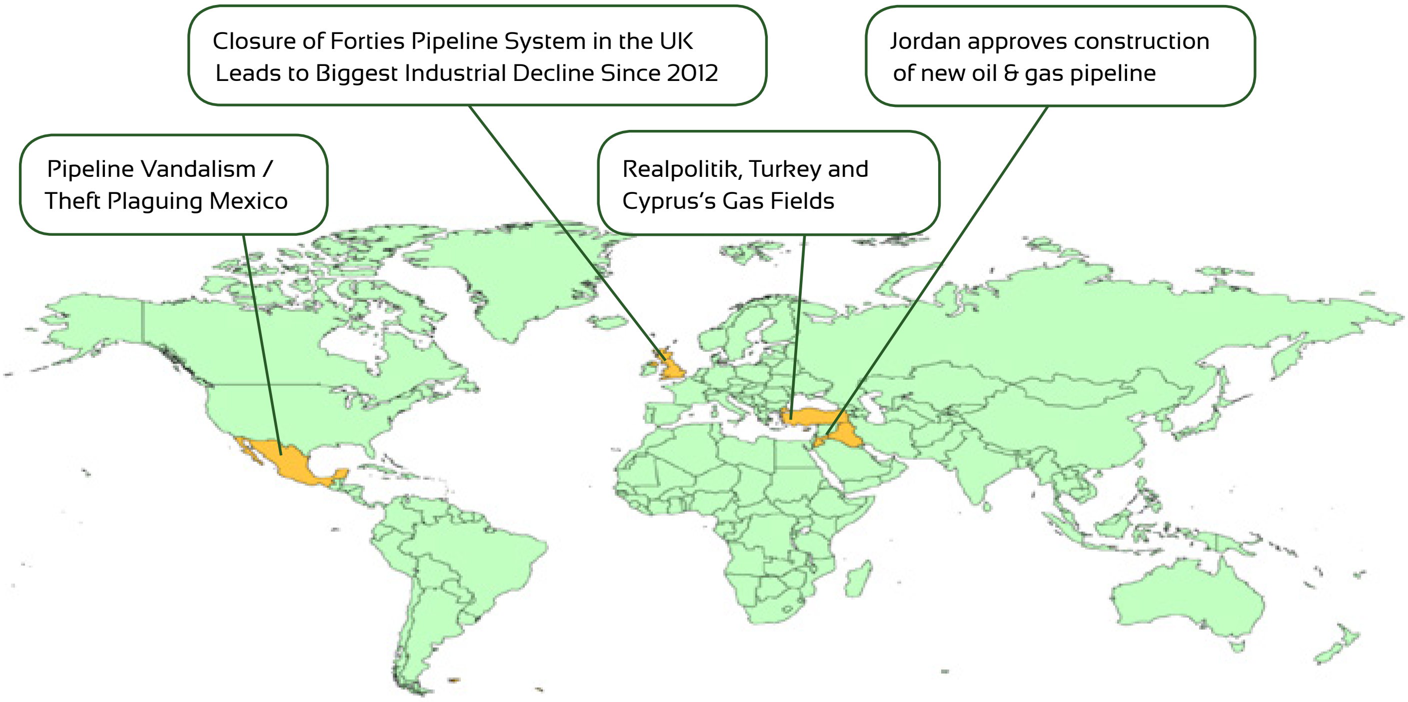

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INSPECTION OF MULTI-DIAMETER PIPELINES OPERATING AT LOW PRESSURE

Stefan Vages > ROSEN Group

ABSTRACT

Particularly in the 1940s and 1950s, gas pipeline systems were not necessarily designed and built with inline inspection in mind. As a result, mechanical configurations are encountered that cannot be inspected with currently available inspection equipment. Furthermore, operators are trying to reduce capital and operational expenses by merging different pipeline segments together, resulting in multi-diameter systems. In addition to the challenges presented by the mechanical configuration of these pipelines, the prevailing operating conditions often increase the difficulty of inspecting these pipeline systems.

ROSEN has been working on a variety of projects related to this problem in the past 24 months, and has developed solutions around the following parameters[1] :

- Diameter range: 10/12″, 12/16″, 16/20″, 20/26″, 24/30″
- Pipeline length: up to 65 km (40 miles)
- Min. bend radius: 1.5D 90° back-to-back in the smallest diameter
- Wall thickness range: 5.08 mm to 12.70 mm (0.200″ to 0.500″)
- Miter bends: 10 degree – single cut
- Pressure during ILI: 17.24 bar (250 psi)

While the design of an inline inspection system that complies with the mechanical requirements listed above is feasible, if challenging, the low operating pressures in the pipeline systems to be inspected presents an additional hurdle to be overcome. Especially for the utilization of MFL technology in gas pipelines, higher operating pressures are required to achieve constant velocity profiles. When inline inspection of a gas pipeline needs to be executed at low operating pressures, the risk for speed excursions that negatively impact the acquired data is increased. This is a result of the compressibility of the medium in the pipeline. Higher differential pressures are required to move the inline inspection systems through restrictions like bends, diameter transitions and, for smaller diameters, even wall thickness changes. Once the restriction is passed, the differential pressure to move the tools decreases again, allowing the gas to expand. This happens at a rapid velocity, creating a speed excursion.

To minimize the extent of speed excursions and therefore improve the data acquisition effort, special characteristics that were previously implemented for single diameter inspection tools are applied to optimize the run behavior of these tools. Furthermore, additional measures need to be taken to optimize the sealing elements in order to achieve the best possible compromise between sealing and the differential pressure required to propel the tool.

In the following paper, an overview will be provided on the general approach for these projects as well as the process related to deploying these new tools in the pipeline industry.

PIPELINE INFORMATION

As a first step in these projects, the available pipeline information is reviewed. Some of these projects, e.g. the 12/16″ project, consist of up to ten (10) different pipeline segments that require inspection. Therefore, all available information on the individual pipeline segments is reviewed and summarized. Once this step is completed, information gaps are identified and a gap closure process is initiated. This ensures that all required information is available to the project team. Depending on how detailed the available information is, it may be required that some assumptions, e.g. 10-degree miter bends, are taken into consideration to prepare for unforeseen events.

Once the information is reviewed and consolidated, an assessment of the critical information is carried out. First the mechanical information is reviewed. A primary concern in these projects is the requirement to pass 1.5D bends in the smallest diameter for the multi-diameter inspection systems. The passage of regular 1.5D 90° bends in single diameter pipelines already presents a challenge, as additional differential pressure is required to move the ILI tools through these restrictions. Other requirements typically include the passage of full-bore tees, special valves, bell-bell-chill-rings, wye pieces, and other pipeline fittings.

In this process, a discussion also takes place as to whether certain pipeline features are required to be removed to simplify the design process, or to make certain design objectives feasible. This discussion is very important to level the expectations around the feasibility of the overall project objectives.

When all the requirements are established, a requirement specification is created that is used by the design team as the framework for designing the new equipment.

DESIGN AND TESTING

Once the review and consolidation of the pipeline information is completed, a requirement specification is established. This is the input used by the mechanical engineers in designing the inspection systems. Typically, the measurement units for metal loss, an MFL system, and a caliper system for geometry are designed first. The minimum ID, maximum ID, and the narrowest bends to be negotiated are the main factors limiting the design choices.

A first concept of the MFL unit is established that is in line with the design requirements. This concept is then utilized to perform finite element modeling, to evaluate the anticipated magnetic properties.

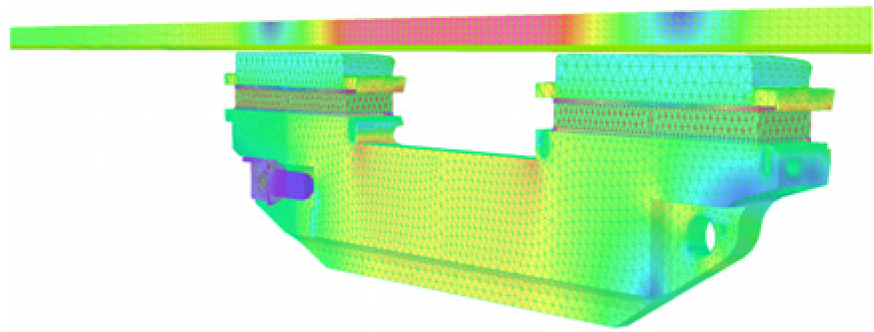

Figure 1: Example of an FEA model of a magnetizer

In the above illustration, a finite element analysis (FEA) model of a magnetizer is shown. The different colors indicate the flux density in the yoke of the magnetizer as well as in the pipe wall. Blue colors indicate low flux density values. Measurements are taken in the highest flux density area, which is indicated by the red color. For a good MFL measurement, the area with a high flux density in the pipe wall needs to be fairly wide. This ensures that the system is less sensitive to higher velocities during an inspection survey.

Another important aspect of designing measurement units for multi-diameter pipelines is circumferential sensor coverage. While single-diameter inspection systems only need to cover a relatively short throw, multi-diameter systems are required to cover a larger range. Multiple sensor planes may be necessary to achieve full coverage in the largest diameter and the desired resolution on the circumference. The following illustration shows the two geometry measurement units of the 12/16" RoGeo XT inspection system.

The sensors in each plane are offset to each other to cover the gaps in between the individual caliper arms. When looking at the sectional view of a 12/16" geometry measurement unit, it is clearly visible that full coverage in the largest diameter is achieved.

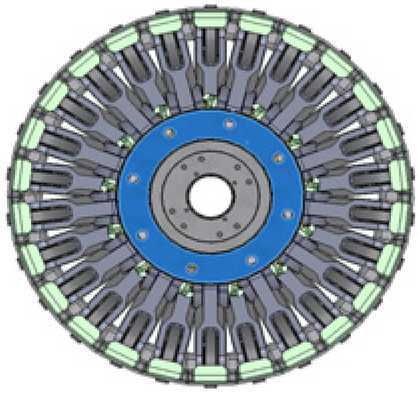

Figure 3: Sectional view of the 12/16" geometry measurement unit

A similar approach is utilized for the MFL measurement system. Especially on smaller diameter dual- and/or multi-diameter systems, it is necessary to have two MFL modules to achieve full coverage of the circumference while maintaining the required flexibility.

On larger diameter tools utilizing MFL technology, it is feasible to have a single magnetizer module, since there is more room for the individual magnet bars to collapse. It is also possible to design a magnetizer that provides sufficient field strength, since there is more room for yokes with more cross-sectional area — one of the major contributors to higher magnetic field strength. This means that even with increased separation between the yokes when the magnetizer is fully extended, sufficient field strength is established in the entire pipe wall, ensuring that the required measurement properties are met. Figure 4 shows such a magnetizer for a 24/30" RoCorr MFL-A tool.

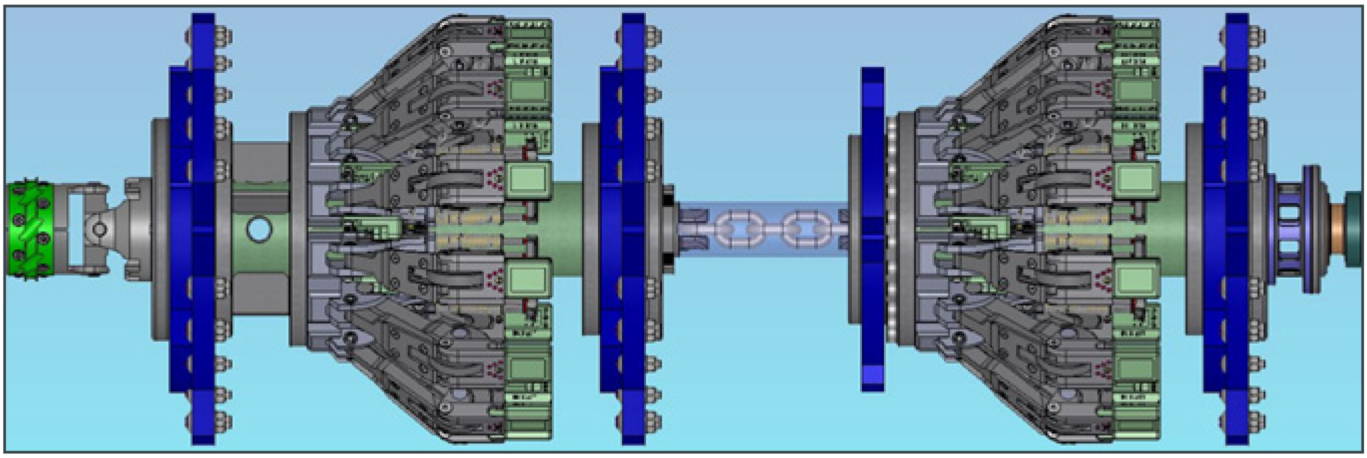

Figure 2: Geometry measurement units of the 12/16" RoGeo XT inspection system

Figure 4: Single magnetizer of a 24/30" RoCorr MFL-A inspection system

An advantage of the single-module magnetizer is that fewer components come into contact with the pipe wall. This decreases the overall friction created by the entire system, leading to more stable run behavior. What must be considered when utilizing a single magnetizer for an MFL inspection of multi-diameter pipelines is the distribution of sensor carriers over the circumference. Two sensor planes are necessary to provide full coverage in both the smallest and the largest diameter segments. In the example shown before, the sensor carriers are mounted on a separate suspension system that pushes the sensors against the pipe wall and ensures equal distance between adjacent sensor carriers. The system is designed to have overlap between the two sensor planes, so that adjacent sensors from one sensor plane can cover any gaps created by sensor loss in the other plane. The overlap is most predominant in the smallest diameter of the inspection system.

Overall it can be noted that the design of measurement units for multi-diameter applications is significantly more complex in comparison to regular inspection tools utilized in single-diameter pipelines. It is important to also consider the downside of this complexity. As there are usually more moving parts and, as a result, more cavities where debris can accumulate, it is very important to have a thorough cleaning program in place to ensure the inspection systems are functioning optimally when traversing the pipeline. Furthermore, it must be noted that the magnetizer is particularly subject to wear, specifically the wheels used to support the yokes. Depending on debris and inspection velocity, wear on the wheels can impact the inspection results. Distances that can be covered by these friction-optimized inspection systems typically range from 35 km (22 miles) to 60 km (37 miles). Shorter pipeline segments are not of concern from a wear point of view.

The sealing elements are next to be designed after the measurement units. Depending on the size range, it may be possible to include electronics and batteries in these elements to save space and keep the tool length to a minimum. For the newly designed 12/16" inline inspection systems, a new approach for the sealing elements was developed, which enhances the sealing capabilities while optimizing the friction of these elements. Whereas standard multi-diameter sealing elements usually have a central suspension system, the newly designed elements feature a separate suspension system for each arm of each sealing.

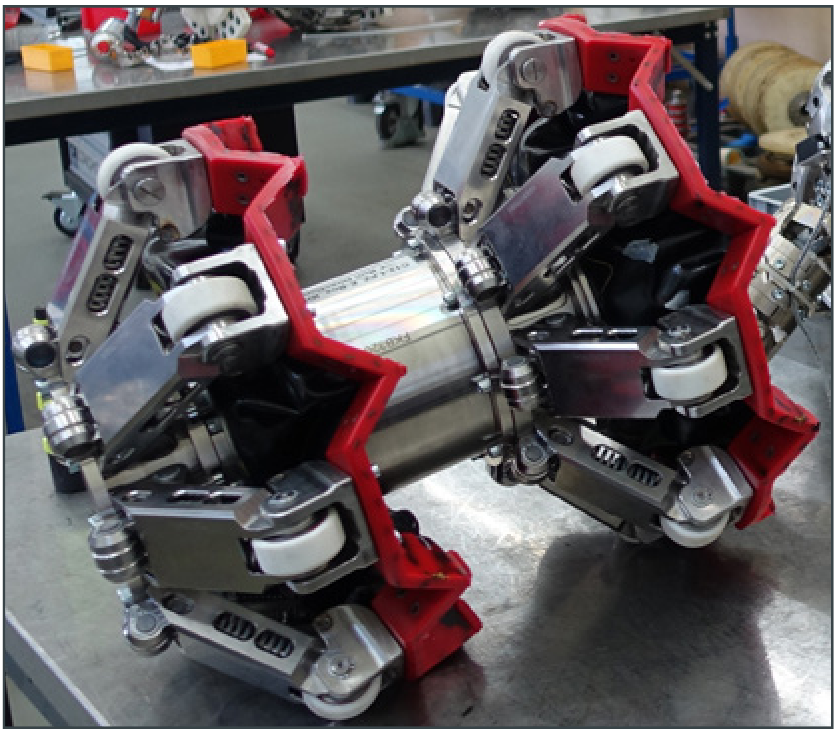

Figure 5: A sealing element of the 12/16" inspection system

This individual suspension approach enables each sealing plane to adjust to the geometry, independent of its position in the pipe. While sealing requirements in straight pipe are fairly simple, the geometry in bends for example is more complex and requires an approach that allows for the sealing of oval and other geometries that are not perfectly round. As the objective of these projects was to inspect pipelines at relatively low gas pressure, sealing is very important. The best sealing is established in straight pipe, where the differential pressure creates sufficient force to move the inspection system efficiently. This changes in complex mechanical configurations such as narrow bends. More force is required to move the inspection system through these complex pipeline features, partially because the sealing is not optimal, creating the need for increased differential pressure to pass these fittings. The new design approach takes these boundary conditions into consideration and addresses them effectively.

> *"Another improvement over sealing systems with central suspension system is that the space in the center of the modules can now be used for other things. Here, the electronics and batteries are housed on the inside of the sealing elements. Saving additional space and shortening the overall inspection time.*
>
> Stefan Vages

Another improvement opportunity over sealing systems with a central suspension system is that the space in the center of the modules can now be used for other things. In this particular case, the electronics and batteries are housed on the inside of the sealing elements. This saves additional space, shortens the overall inspection system, and reduces the number of elements that come into contact with the pipe wall, which in turn positively affects the friction of the entire system.

Once the design process is completed, parts are manufactured and the inspection system assembled. Upon completion of the assembly, another important step in the process of preparing the equipment for the actual inspections is carried out: the testing of the inspection systems. Pull testing is used for the calibration of the measurement systems. The pull test setup consists of multiple pipe spools of different wall thicknesses covering the typical ranges present in the diameters to be inspected. In case non-standard wall thicknesses are to be inspected, pipe spools with the required wall thicknesses are added to the test setup. All pipe spools have a standard population of artificial defects that were manually introduced into the pipe wall for the evaluation of the inspection system's performance.

In Figure 6, the 24/30" RoCorr MFL-A inspection system can be seen prior to pull testing. In addition to the standard pull tests done to establish the standard calibration of the inspection system, pull tests were performed at higher velocities to provide additional insight on the behavior of the measurement system under these circumstances. In this case, pull tests were performed at velocities up to 7 m/s (15.7 mph). A total of 17 pull tests were completed in order to collect a sufficient subset of data: three pull tests at 0.5 m/s (1.1 mph), and two each at 1.0

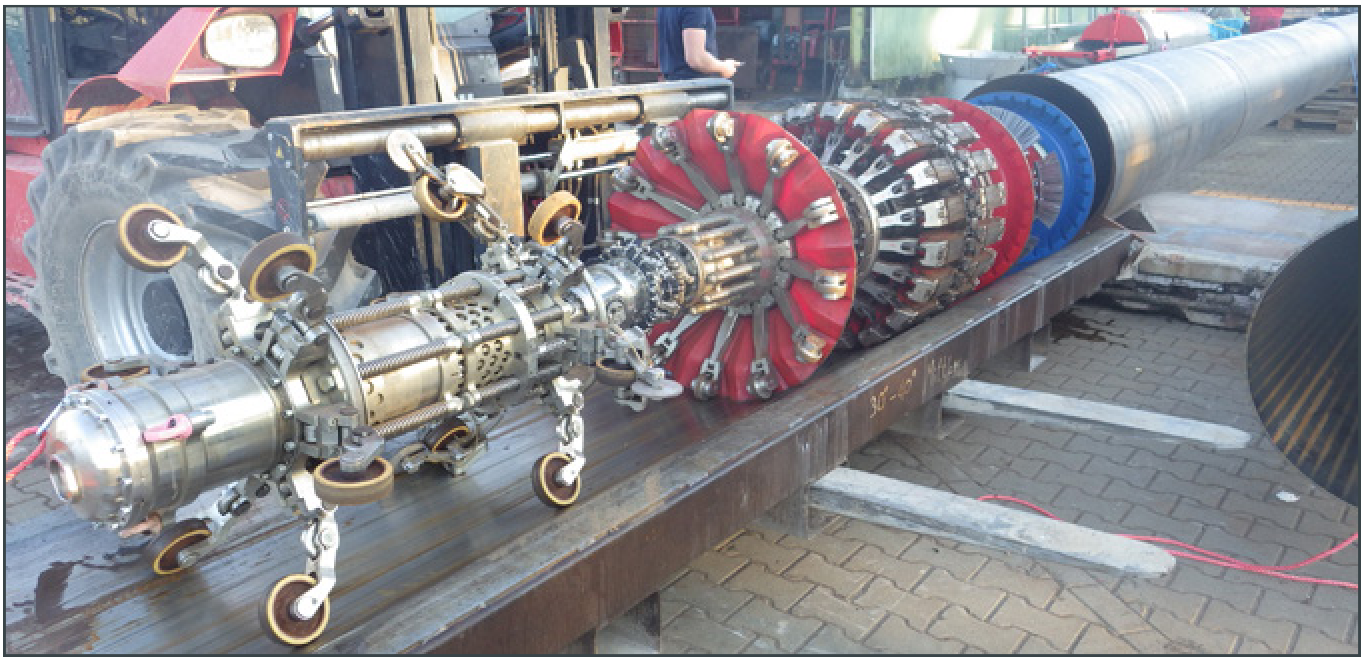

Figure 6: 24/30" RoCorr MFL-A prior to being pull tested in 30" pipe

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m/s (2.2 mph), 2.0 m/s (4.5 mph), 3.0 m/s (6.7 mph), 4.0 m/s (8.9 mph), 5.0 m/s (11.2 mph), 6.0 m/s (13.4 mph), and 7.0 m/s (15.7 mph). The data was then reviewed and an evaluation performed with regard to the possibility of detection (POD) and possibility of identification (POI), as well as sizing accuracy. This process allows the additional evaluation of data recorded outside the specified velocity range of the inspection system. In this case, the performance specification is valid for a velocity range of 0.5–5.0 m/s (1.1–11.2 mph).
The illustration below shows how data is affected when the same feature is recorded at different velocities.

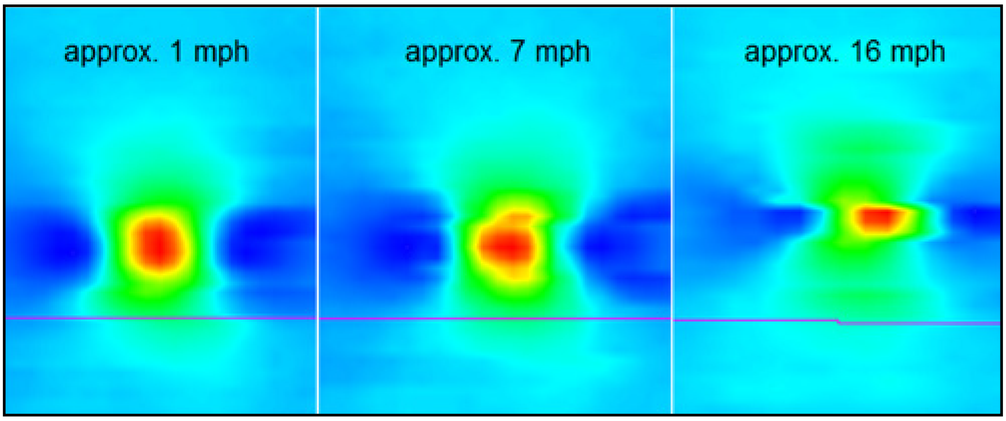

Figure 7: Screenshot of the same metal loss feature recorded at different velocities during pull testing

As can be seen in the illustration, the recorded data at 0.5 m/s (1.1 mph) and at 3.0 m/s (6.7 mph) is nearly identical and the shape of the defect can be reproduced accurately. The same defect recorded at a velocity of 7.0 m/s (15.7 mph) changes its signal pattern slightly. While the general shape can still be identified, the amplitude is significantly lower. This is a general observation in the assessment of the pull test data. The data evaluation process therefore takes the velocity of the inspection system into consideration when sizing defects. Statistical analysis shows that for 24″ and 30″ pipe spools with a wall thickness of 7.5 mm (0.295″), the POD remains unchanged up to maximum tested velocity. This means that the minimum defect size to have a POD of 90% does not change. Similarly, the POI of metal loss features is not affected. Only depth sizing accuracy is compromised at velocities outside the specified range. At a velocity of 6.0 m/s (13.4 mph), depth sizing accuracy is reduced by 30%, resulting in a depth sizing tolerance of ±13%. At the highest tested velocity, 7.0 m/s (15.7 mph), the reduction in depth sizing accuracy is 40%, resulting in a depth sizing tolerance of ±14%. These results are summarized in table 1.

	7.5 mm (0.295")	0.5 - 5.0 m/s (1.1 - 11.2 mph)	6.0 m/s (13.4 mph)	7.0 m/s (15.7 mph)
24"	Depth at POD = 90%	0.10t	0.10t	0.10t
	Depth sizing accuracy	±10%	±13%	±14%
	7.5 mm (0.295")	0.5 - 5.0 m/s (1.1 - 11.2 mph)	6.0 m/s (13.4 mph)	7.0 m/s (15.7 mph)
30"	Depth at POD = 90%	0.10t	0.10t	0.10t
	Depth sizing accuracy	±10%	±13%	±14%

Table 1: Summarized results of the statistical analysis for 24″ and 30″ pipe spools with a wall thickness of 7.5 mm

The same evaluation was made for a higher wall thickness, 12.7 mm (0.500″). In that scenario, the increased velocity affects a variety of parameters. For the 24″ segment, the minimum defect depth is increased to 30% metal loss at a velocity of 6.0 m/s (13.4 mph) for a POD of 90%. At 7.0 m/s (15.7 mph), the minimum metal loss for a POD of 90% is 40%. Similarly, depth sizing accuracy is reduced by 70% respectively 90%, resulting in depth sizing tolerances of ±17% and ±19% respectively.

While these are relatively significant reductions in the detectability of features and their sizing, the evaluation supports the assessment of situations where such velocities cannot be avoided. And although small metal loss features might not be detected, significant metal loss features are. The details are summarized in table 2 below.

	12.7 mm (0.500")	0.5 - 5.0 m/s (1.1 - 11.2 mph)	6.0 m/s (13.4 mph)	7.0 m/s (15.7 mph)
24"	Depth at POD = 90%	0.10t	0.30t	0.40t
	Depth sizing accuracy	±10%	±17%	±19%
	12.7 mm (0.500")	0.5 - 5.0 m/s (1.1 - 11.2 mph)	6.0 m/s (13.4 mph)	7.0 m/s (15.7 mph)
30"	Depth at POD = 90%	0.10t	0.40t	0.50t
	Depth sizing accuracy	±10%	±23%	±25%

Table 2: Summarized results of the statistical analysis for 24″ and 30″ pipe spools with a wall thickness of 12.7 mm

As a general rule of thumb, it can be noted that particularly with multi-diameter MFL inspection systems, the magnetization capabilities are best in the smallest diameter that can be inspected, as the magnetic field strength is higher and the field itself is more homogenous, especially with smaller wall thicknesses. This is favorable when considering low pressure multi-diameter pipeline inspections, since speed excursions are more likely to occur or to be more severe in the smallest diameter that will be inspected.

Another important part of the testing is pump testing, which serves to validate the mechanical capabilities of the inspection systems. In addition, baseline parameters for tool operation are established, such as the differential pressure required to pass certain fittings. Last but not least, these tests serve to validate the overall functionality of the inline inspection systems. For this purpose, a pump test rig is set up that includes the most difficult features the inspection systems will encounter in the actual pipeline inspections. For reasons of safety and convenience, pump tests are usually executed with water. In the case of the newly designed 12/16″ inspection systems, pump testing was also completed with a gaseous medium: compressed air. The differences between the two testing methods will be discussed following the description of the different test results.

Pipe spools of various wall thickness were positioned in the 16″ segments of the test setup. Items 3, 6, 7, 17 and 19 are straight pieces of 16″ pipe utilized for the testing. The wall thicknesses of these spools are either 6.3 mm (0.248″) or 12.5 mm (0.492″). For the 12″ segments — items 11, 13, 15, 24 and 26 — wall thicknesses of 5.0 mm (0.197″), 6.3 mm (0.248″) and 12.5 mm (0.492″) were chosen. These wall thicknesses were the closest to the specified wall thickness range for inspection (5.6 mm to 12.7 mm / 0.219″ to 0.500″). During the pump test, it was particularly critical to validate the sealing capability of the ILI tools traversing the largest internal diameter, which can be found in the 16″ section with the thinnest wall, and traversing the smallest diameter, which can be found in the 12″ section with the heaviest wall. Therefore, the following values need to be assumed for maximum and minimum internal diameter:

Maximum Internal Diameter

$$(\text{max.ID}) = 16.00'' - 2 \times 0.219'' = 15.562'' = 395.3 \text{ mm}$$

Minimum Internal Diameter

$$(\text{min.ID}) = 12.75'' - 2 \times 0.500'' = 11.750'' = 298.5 \text{ mm}$$

The maximum internal diameter present in the test section is 393.8 mm (15.504″) which is 0.37% smaller than the largest expected internal diameter. The minimum internal diameter present in the test section is 298.9 mm (11.766″) which is 0.13% larger than the smallest expected internal diameter.

The deviation to the expected values is small enough not to impact the results of the test.

In addition to validating the sealing capabilities in various diameters, the test also confirms the magnetization levels in different wall thicknesses. This is, however, not a primary objective for pump testing, as pull testing is conducted for this.

In addition to the straight pipe spools, two manufactured bends have been included in this test rig: a 12″ 1.5D 90° bend and a 16″ 1.5D 90° bend. Both bends have a wall

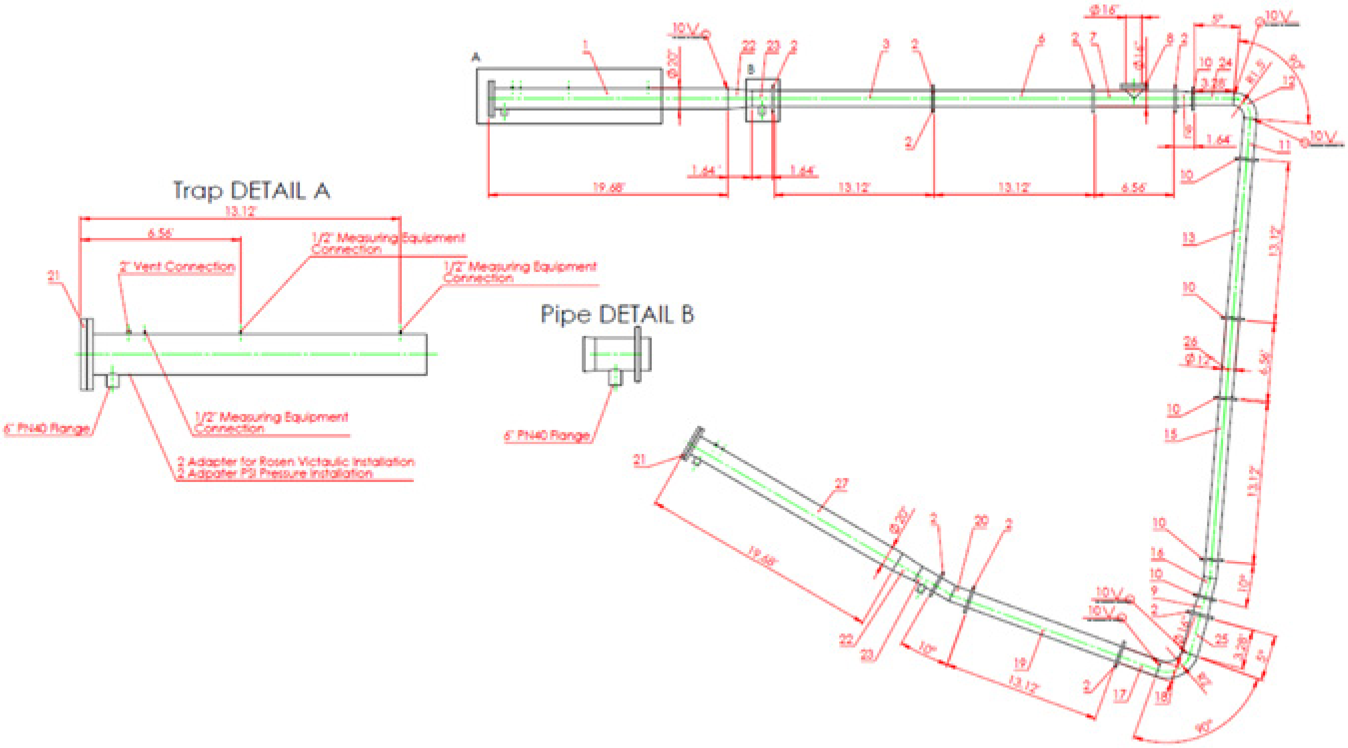

Figure 8: Overview of the test setup for the 12/16″ ILI tools

thickness of 12.5 mm (0.492"). For the 12" bend, this represents the narrowest feature in the test setup. The wall thickness of the 16" 1.5D 90° bend is not that relevant since it doesn't present a similar restriction to the ILI tools to be tested as its pendant in 12". To test the passage of miter bends, 10° single-cut miter bends were installed in both the 12" and 16" segments of the test set-up. The miter bends were prepared out of pipe with a wall thickness of 12.5 mm (0.492") for each diameter and were welded manually to ensure that they were comparable to those assembled in the field.

The above-described test setup is then connected to the pump spread. When performing the pump tests in water, the test setup is not pressurized during the pump test. It is only filled prior to launching the tools. This results in very minimal head pressure going in, since the only restrictive element is the return hose, which is of 6" diameter and allows the water to flow back into the water reservoir. In order to simulate the low-pressure environment, it was decided to pump the tools at relatively low flow rates when pumping with water. With low flow rates, momentum is not a significant factor, therefore sealing capabilities can be properly assessed, especially within complex mechanical features.

The velocities that the inspection systems were pumped at were 0.2 m/s (0.44 mph), 0.3 m/s (0.67 mph), and 0.5 m/s (1.12 mph).

The inspection systems passed all mechanical features without any issues, thus confirming mechanical compliance. The following observations were made during evaluation of the pressure data from each of the individual pump tests:

- The required differential pressures (dP) were comparable in all pump tests
- There was significant variance in the peak differential pressure

Pump test velocity	0.2 m/s (0.44 mph)	0.3 m/s (0.67 mph)	0.5 m/s (1.12 mph)
Launch dP	1.52 bar (22.0 psi)	1.46 bar (21.2 psi)	1.45 bar (21.1 psi)
Peak dP	4.29 bar (62.2 psi)	5.81 bar (84.3 psi)	5.02 bar (72.8 psi)
12" straight pipe dP	1.25 bar (18.2 psi)	1.38 bar (20.0 psi)	1.67 bar (24.3 psi)
16" straight pipe dP	0.46 bar (6.7 psi)	0.54 bar (7.8 psi)	0.57 bar (8.1 psi)
16" 1.5D bend dP	2.64 bar (38.2 psi)	2.70 bar (39.2 psi)	2.66 bar (38.6 psi)

Table 3: Differential values gathered for the 12/16" RoCorr MFL-A inspection system

The lowest peak values were recorded at the slowest flow rate, while the highest peak value was recorded at the medium flow velocity. As all other values were close to each other, it was concluded that further testing would be required to more accurately determine the maximum value for differential pressure during the pump test. Additional pump testing in compressed air was already planned, therefore the results of that test were used for further comparison.

To complete pump testing in air, the test setup was modified so that it could be pressurized prior to launching the inspection systems. A manifold was established to connect multiple air compressors, as well as a silencer to control the pressure at the receiving end. The setup can be seen in the photograph below.

Figure 9: Overview of the pump test setup for testing in compressed air

For the execution of the pump test in compressed air, the inspection systems were loaded into the launcher, after which the system was pressurized without moving the tool. The pressure chosen for the test was 17 bar (246.5 psi) to establish operating conditions similar to those in the pipelines to be inspected.

First the 12/16" RoGeo XT inspection system was pumped through the test setup. The recordings of that pump test can be seen in Figure 10. The absolute pressure measured at the launcher (blue line on the graph) and the receiver (green line on the graph) is displayed on the primary y-axis. The secondary y-axis displays the differential pressure (dP — red line on the graph). The x-axis displays the time of day (hh:mm:ss).

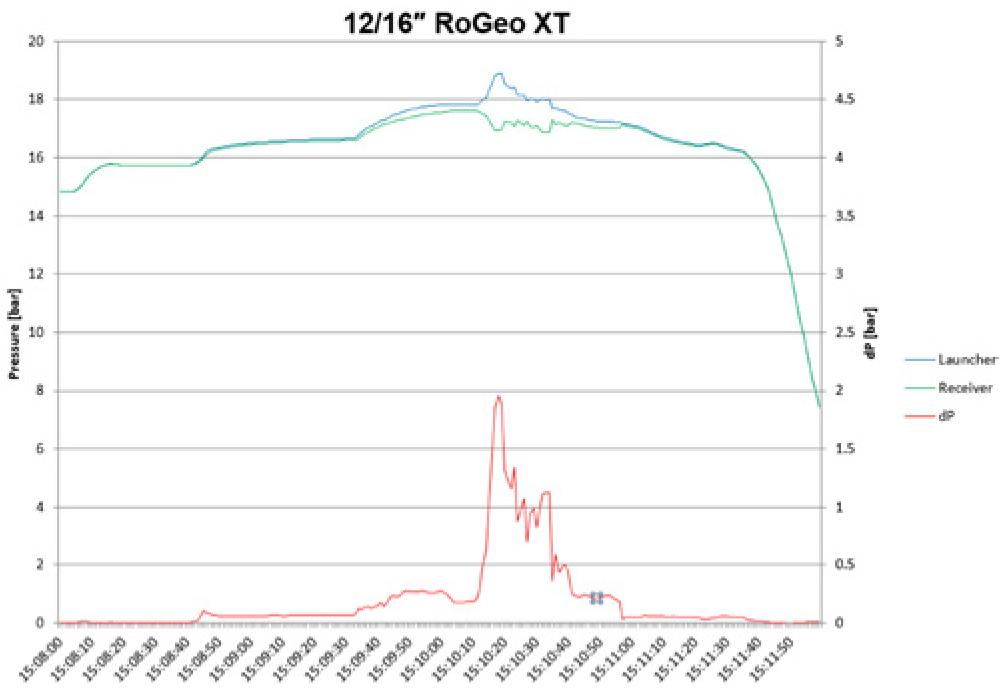

Figure 10: Pressure recordings of the 12/16″ RoGeo XT pump test

It can be observed that a differential pressure of approximately 0.106 bar (1.5 psi) was required to get the tool moving in the 16″ portion of the test section. An increase in pressure can be observed once the tool enters the reducer to 12″. A peak differential pressure of 1.950 bar (28.3 psi) is recorded while the tool is passing the 1.5D bend. The differential pressure required in 12″ straight pipe is approx. 0.230 bar (3.4 psi), while the differential pressure required in 16″ straight pipe is approx. 0.060 bar (0.8 psi). No differential pressure increase in the 16″ portion can be observed that would indicate passage of the 1.5D bend. Therefore, it is assumed that the passage of a 16″ 1.5D bend does not require additional differential pressure in comparison to straight pipe.

Next, the 12/16″ RoCorr MFL-A inspection system was tested. Results of that pump test are displayed in Figure 11. The axis description is identical to the previous graph.

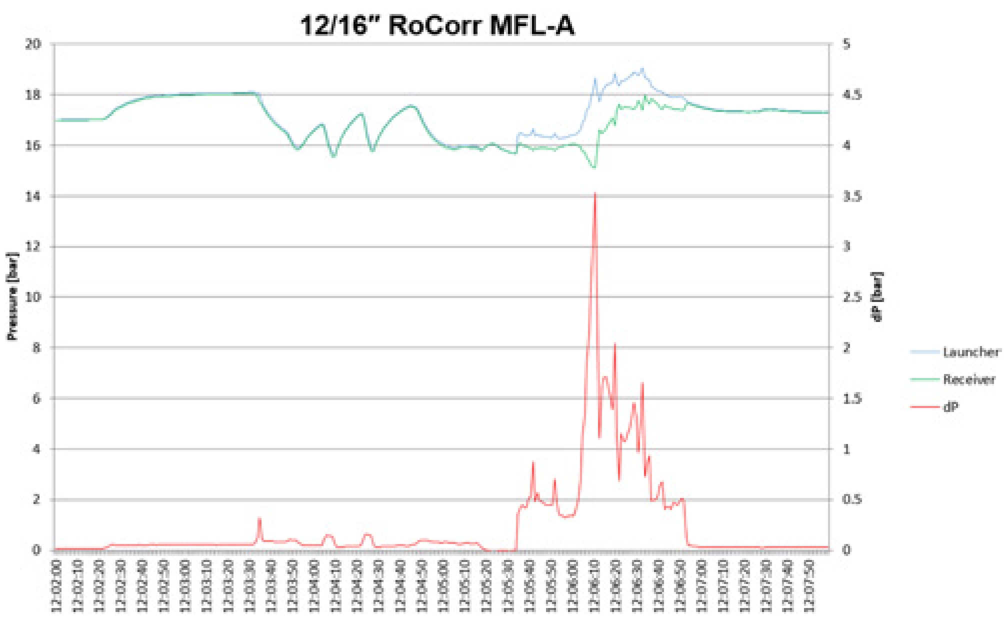

Figure 11: Pressure recordings of the 12/16″ RoCorr MFL-A pump test

A differential pressure of approximately 0.323 bar (4.7 psi) was recorded in the 16″ portion of the test section. As the system enters the reduction to 12″, the differential pressure increases. The maximum differential pressure recorded in this transition, including the 1.5D bend, is 3.530 bar (51.2 psi). The differential pressure required in 12″ straight pipe is approximately 0.380 bar (5.5 psi) on average, with a peak of 0.873 bar (12.7 psi), while the average differential pressure required in 16″ straight pipe is approximately 0.069 bar (1.0 psi) with a peak of 0.158 bar (2.3 psi). No differential pressure increase in the 16″ portion can be observed that would indicate passage of the 1.5D bend. Therefore, it is assumed that the passage of a 16″ 1.5D bend does not require additional differential pressure in comparison to straight pipe.

As the pump tests in water delivered higher values in comparison to the pump tests completed in compressed air, it was concluded that pump tests in water at low-flow velocities are suitable for a conservative testing approach. The results of the pump tests in water confirmed the capabilities of the equipment and established a baseline for anticipated operational parameters. The additional pump testing in gas provided improved values, increasing the confidence for successful deployment in a first pipeline.

After successful completion of the testing activities, the tools were prepared for their first inspection.

FIELD OPERATIONS

The newly designed 12/16″ ILI systems were deployed for the first time in August 2017. The pipeline to be inspected consists of both 12″ and 16″ pipe. After approximately 2.7 km (1.7 miles), the pipeline transitions from 16″ to 12″. Shortly after the 10 km (6.2 mile) mark, it transitions back to 16″. Geometry information was available from a previous inspection. The measurement of the internal diameter can be seen in the graph below. The internal diameter in millimeters is displayed on the x-axis. The y-axis shows the overall distance in meters.

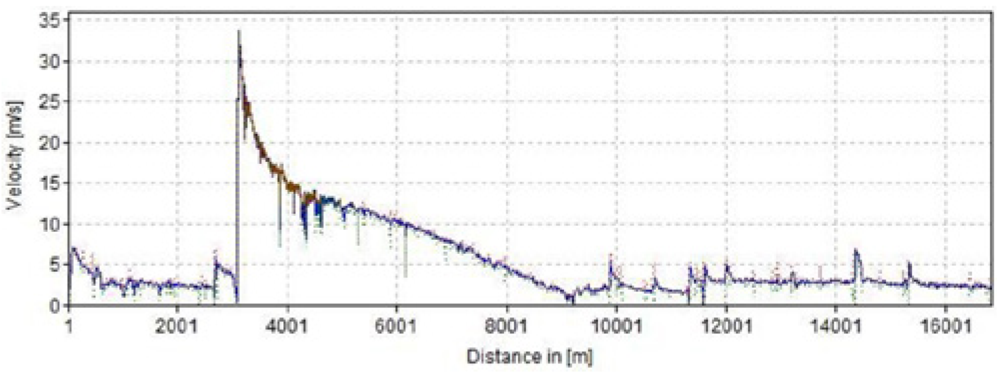

Figure 13: Velocity chart of inspection with conventional multi-diameter MFL inspection system

The previously described speed excursion can be clearly identified. To ensure comparability, the following graph of the re-inspection with the newly designed 12/16″ RoCorr MFL-A has the same scale on the y-axis.

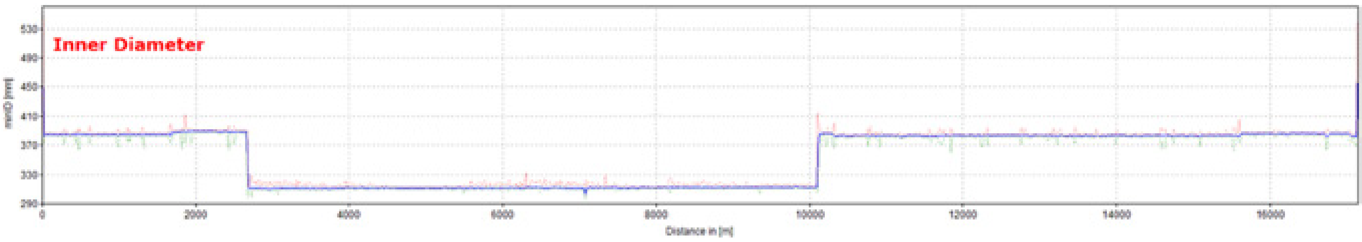

Figure 12: Graph showing the ID over distance for the first pipeline subject to inspection

While the geometry inspection with standard equipment was successful in 2016, the following metal loss inspection with a multi-diameter inspection system was not successful. During transition from 16″ to 12″, high differential pressure was required to move the tool through the restriction. That high differential pressure resulted in a significant speed excursion once the pressure was relieved, reaching a maximum velocity of >34.0 m/s (76 mph). It took more than 4.0 km (2.5 miles) for the velocity to return to below 5.0 m/s (11.2 mph). The data collected during that excursion was too compromised for proper evaluation. The re-inspection of that pipeline segment in August 2017 was performed at similar operating pressure and slightly reduced flow in the same period of the year.

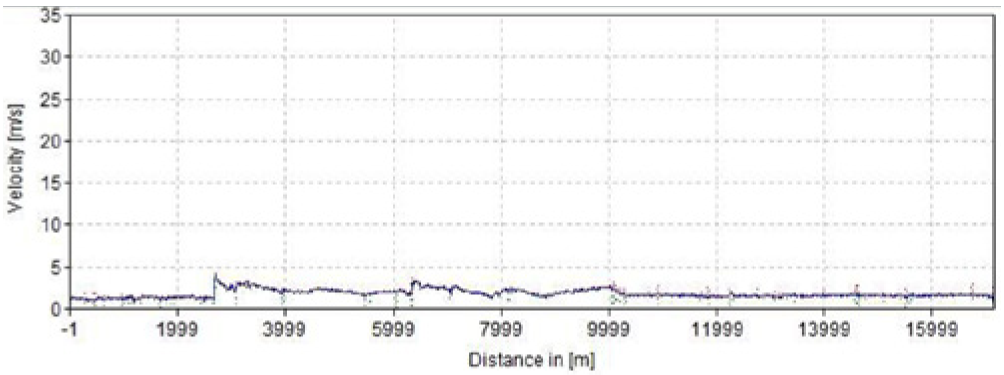

Figure 14: Velocity chart of inspection with newly designed 12/16″ RoCorr MFL-A

In the graph below, the velocity profile of the first inspection in 2016 with a conventional multi-diameter MFL inspection system can be seen. The velocity is displayed on the y-axis in m/s, and the distance on the x-axis in m.

When comparing the two graphs, it is clear that the speed excursion at the transition from 16″ to 12″ has a significantly lower maximum velocity of <5.0 m/s (11.2 mph). The differential pressure recorded at that location was 1.86 bar (26.9 psi), which is considerably lower than the comparable transition in the test setup. In addition, differential pressures of 0.55 bar (8.0 psi) were recorded in straight 16″ pipe, and 1.03 bar (15.0 psi) in 12″ pipe. These values are in line with the test results obtained during pump testing in compressed air.

Figure 15: Newly designed 12/16″ RoGeo XT

A full set of data was recorded with both inline inspection systems, the 12/16″ RoGeo XT and the 12/16″ RoCorr MFL-A. No sensor loss occurred during the inspections and the velocity was within the desired range throughout the entire duration of each survey. This means that the data can be evaluated with no restrictions and the standard performance specification applies.

> *With these new inline inspection systems a huge step forward has been made, enabling inspection of pipelines that are currently operating in a pressure regime below the requirements of conventional MFL-based inline inspection systems.*
> Stefan Vages

CONCLUSION

With the deployment of these new inline inspection systems for multi-diameter applications in pipelines operating at low pressure, a huge step forward has been made, enabling inspection of pipelines that are currently operating in a pressure regime below the requirements of conventional MFL-based inline inspection systems.

The information gleaned from these development projects can be transferred to future projects covering smaller diameter ranges like 8/10″ and 6/8″. While some details may not be applicable to all such projects, the general process and approach will be similar.

Additionally, the performance of the multi-diameter inspection systems for application in pipelines operating at low pressure in their largest diameter is excellent — better, in fact, than existing solutions for single-diameter pipelines. Therefore, these systems can also be utilized in situations where existing single-diameter solutions are no longer suitable.

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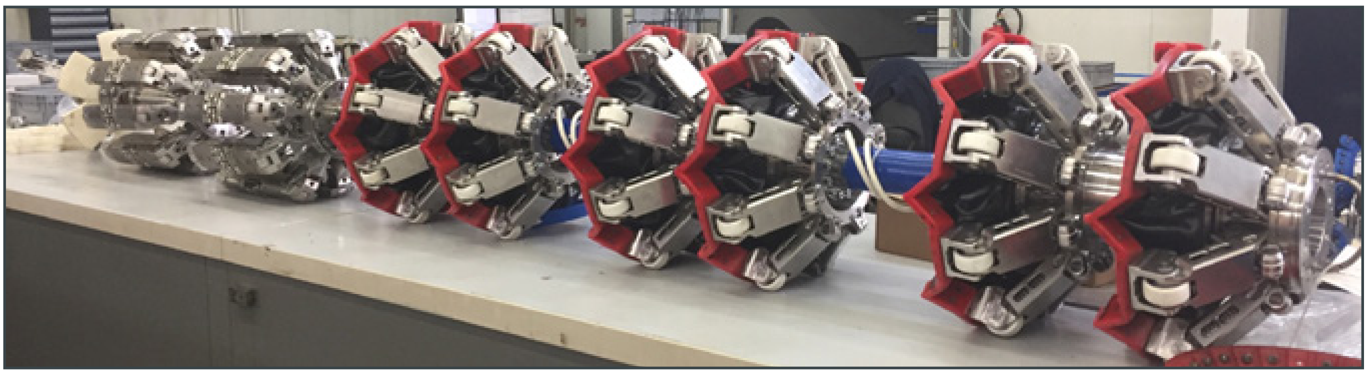

Figure 16: Newly designed 12/16″ RoGeo XT

INSPECTION OF CHALLENGING PIPELINES
LATEST DEVELOPMENTS + CASE STUDIES

Thor-Ståle Kristiansen > KTN AS; **Arild Solberg** > KTN AS; **Wilhelm Kelb** > Kontrolltechnik GmbH; **Ulrich Schneider** > KTN AS

Figure 1 (above): SLOFEC® tool / Figure 2 (below): pipeline mockup

ABSTRACT

Pipeline inspection using intelligent pigs is currently the safest and most reliable way to detect relevant defects, to plan repairs and maintenance and to calculate the pipeline lifetime.

However, there are still many pipeline systems on- and offshore which were never designed and built for conventional ILI tools and modifications would be extremely expensive.

For that reason, some vendors have developed tools which do not need 2 traps for launching and receiving, are more flexible in passing installations, tight bends and multi diameter and even provide their own propulsion unit.

KTN AS, Bergen, Norway, has developed during the last 15 years a flexible tool platform for tethered, bidi, self-driven inspection tool for challenging pipelines which can combine technologies for measurement of the pipeline geometry (dents, ovalities, roofing etc.), wall thickness / corrosion / laminations, crack detection and precise crack sizing. Technologies used are piezo UT pulse echo vertical beam and angular beam, phased array and TOFD, all for one phase liquid lines, high resolution camera for all clear media, grinding machine and SLOFEC®, an eddy current based technology for dry and multi -phase lines even with thick internal coating as for example cement lining.

The paper introduces shortly the different technologies with the corresponding specifications and then focus on 2 case studies:

1. A 42" oil loading line with a problem in their long seam welds (axial cracking) was successfully inspected for geometry, wall thickness / corrosion and cracking in one single run
2. A 10" gas line with corrosion problems (2a) and pipelines with thick internal coating (2b)≥ were inspected with the new SLOFEC® tool in a dry atmosphere.

In the paper the inspection concept and the setup of the new tool are described. Results from the qualification tests as well as from the inspection runs performed with the new tool will be presented.

INTRODUCTION

The ageing pipeline network worldwide needs to be maintained, the integrity must be assessed due to internal and external corrosion problems sometimes in connection with dents, manufacturing related defects which could grow under certain conditions and finally crack problems due to fatigue or other reasons.

Pipeline inspection using intelligent pigs is currently the safest and most reliable way to detect relevant defects, to plan repairs and maintenance and to calculate the pipeline lifetime.

Geometry-, wall thickness / corrosion inspection tools are available since about 50 years and crack-tools since more than 20 years which have inspected millions of KM pipelines, helped to assess and repair in time and to avoid catastrophes. These conventional tools need access points (launching + receiving traps) from both sides of the pipeline and typically run with the flow.

However, there are many pipelines which were not designed for pigging and have only access from one side or even no access points which could be good enough for launching a conventional ILI tool or they have no pumping facilities. These pipelines are for example loading lines, short terminal lines, river crossings, flow lines, riser lines and vertical lines into an underground storage. Sometimes it might be possible to install a temporary launcher and receiver, however, the costs for that could be extremely high especially for subsea launching / receiving, including supply boat and divers for the launching or receiving typically several times higher than the inspection costs itself.

KTN INSPECTION SOLUTIONS

Fortunately, during last years also other technologies were developed which can be used without access from both sides and without pumping. KTN AS, Bergen, Norway, has experience in inspection of these kind of pipelines which are called "Unpiggable" or "Challenging" or "Difficult to inspect Pipelines". With these bidirectional and self-propelled tethered operated inspection tools, only access from one side is required, an open pipe or flange is sufficient.

These intelligent tools can inspect per today pipelines ≥6" up to 12 km depending on amount and angle of bends. 1.5D 90° or sometimes even1D bends are possible. Up to 28 x 90° bends were inspected in one run with such a tool. They can measure/inspect on the way in and out. The data are available online (real time).

Different types of measuring technologies are offered and can be used in the same run: Geometrical and wall thickness measurement with Ultrasonic vertical beam (pulse-echo), ultrasonic measurement with angular beam for detection and grading of longitudinal and circumferential cracks (pulse-echo 45° shear wave), TOFD (time of flight diffraction) for the exact measurement of the crack depth / profile for longitudinal and circumferential cracks plus Phased Array (PA).

In addition, KTN can equip their tools also with eddy current- and SLOFEC® - technology – a development of Kontrolltechnik GmbH in Schwarmstedt, Northern Germany, for measurements in dry atmosphere or in multi-phase lines, with camera and even a grinding machine for example to grind down a penetrating girth weld or an internal crack.

In principle KTN can do multi technology inspections in one go, for example UM measurement (UT metal loss / wall thickness measurement) and UC (UT crack detection) on the way into the line and the same plus measurement of the longitudinal and/or circumferential welds with TOFD on the way out.

KTN use fixed sensors in all corrosion survey tools in pipe sizes from 10" and upwards. Compared to the rotating mirror principle this solution can go with higher speed, find smaller defects, does not loose data due to high stand-off in bigger diameters, has more and better data in bends.

er, at the KTN tools on a stiff ring of one pig body. The principle of the UT WT measurement was described in many papers; therefore, we will only highlight the special features at the KTN tool:

Due to the stiff sensor carrier the geometry of the pipeline can be measured (dents, ovalities, roofing) looking at all the stand-off signals at the same distance.

Typical circumferential resolution e.g. for 10" at the KTN UT wall thickness tools is 5 mm (calculated/measured from mid of sensor to the mid of the next neighboured sensor). In axial direction, the KTN tool triggers measurements with all sensors every 1.5mm or for shorter lines even every 0.75mm.

With such a tool defects with a diameter of 4mm can be detected and sized from 8mm diameter (confidence level (90%).

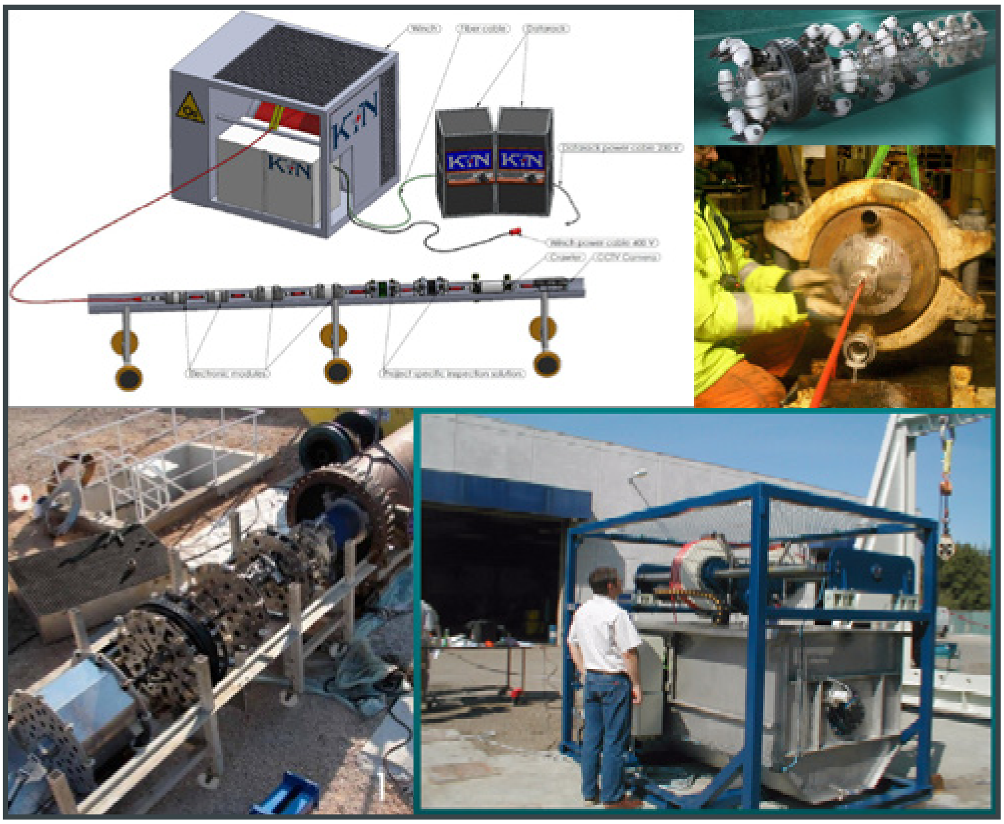

Figure 3: tethered bidi tool equipment (tool, cable, winch, control unit, stuffing box)

The theoretical resolution of this UT wall thickness tool is 0.06mm. In reality, wall thickness changes of 0.2mm can be detected and wall thickness measurements even in corroded areas are guaranteed with ±0.4mm.

Therefore, even starting corrosion is visible and corrosion growth easier and more precise measurable.

In addition, the deepest point of a defect contour is easier to see which improves the MAOP (maximum allowable operation pressure) calculation. Due to the high amplifying the tool is delivering high signal strength in the range of 65-75 dB (which makes the measurement even in some products with high dampening / attenuation possible). This is helpful not only for bad products bad also for rough wall thickness surface and bad cleaning to achieve good data quality.

Technologies used in KTN tethered tools

Ultrasonic technology for wall thickness measurement

Piezo-electric Ultrasonic pigs (UT pigs) require a suitable 1 phase liquid coupling medium. These pigs have vertically installed sensors typically within a flexible sensor carri-

Ultrasonic technology for crack detection

At the ultrasonic pig for crack detection, sensors are installed in a 17-21° angle to the vertical so that after reflection at the internal wall the signal is running on a

45° zig-zag path through the wall until it hits an internal or external crack and is reflected there. The position of the crack (internal or external and axial position) can be determined via the time of flight. The crack depth is estimated by the signal amplitude. Because the typical and most common cracks (SCC=stress corrosion cracking) are running in axial direction the sensors must be installed so that they send their beam vertical to that direction (in circumferential direction, clockwise and counter clockwise).

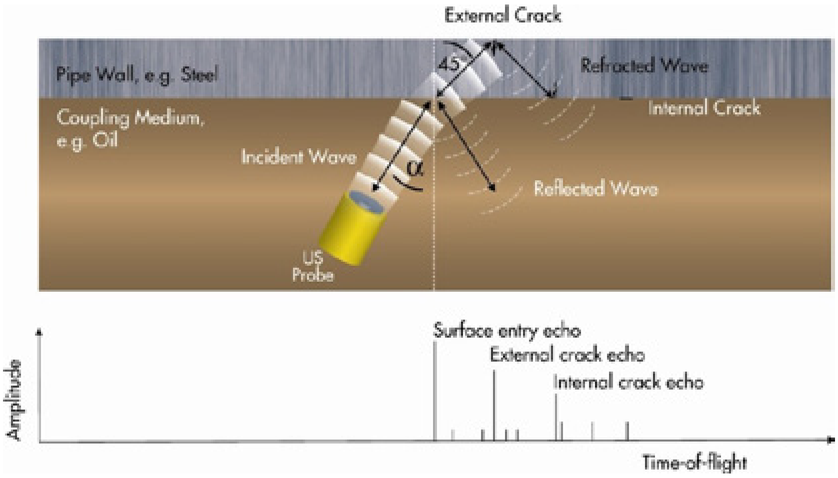

Figure 4: UT crack detection principle

If one is looking for circumferential cracks (e.g. girth weld cracks) the sensors must send their beams in axial direction (upstream and downstream).

If required, it would be possible to build a sensor carrier also for detecting cracks along the spiral weld.

Detection threshold in depth direction guaranteed from 1mm (visible even from 0.5mm) with 90% confidence level.

Detection level in axial and circumferential direction was guaranteed from 15mm crack length (reported was even down to 5mm) with 90% confidence level.

Depth classification typically:

- >1mm until 2mm,
- 2-4mm,
- >4mm (with 80% confidence level).

Cracks with depth >4mm cannot be easily determined in depth (statement: ≥4mm depth).

TOFD (Time of Flight Diffraction) for Crack Sizing

The quantitative TOFD method is the most reliable and accurate measurement for the crack depth / profile sizing.

An ultrasonic probe is positioned on either side of the weld, one acting as a transmitter and the other as receiver. The longitudinal sound beam can encounter obstacles on its path, which cause reflected and diffracted signals.

When the probes are moved in a parallel motion along the weld, the resultant waveforms are digitized, stored on hard disk and displayed on the video-screen as a grey scale image.

The image build -up is in effect a through sectional view of the weld examined and can be used for accurate sizing and monitoring of indications.

In KTN tools there are TOFD modules for axial and circumferential crack sizing available, for example for cracks along or in the longseam and the girth weld.

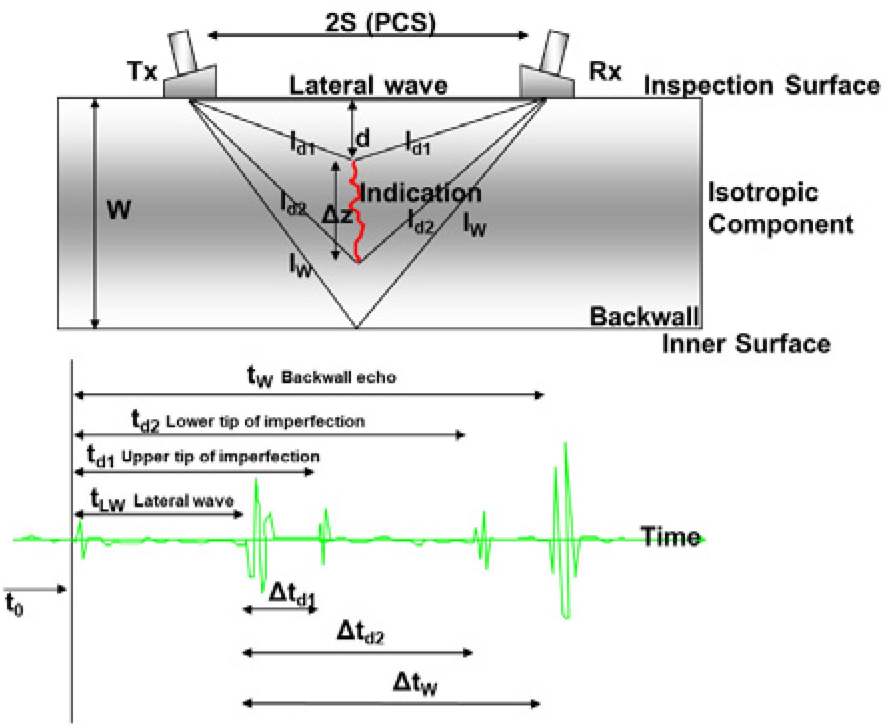

Figure 5: principle of UT TOFD

SLOFEC® technology for corrosion inspection of dry/empty pipelines through thick coating.

The SLOFEC® (saturated low frequency eddy current) inspection is based on the eddy current principle with superimposed DC field magnetization. A wall thickness reduction due to e.g. a corrosion pit will result in a change of the magnetic field density around the defect. The change of the magnetic field density results in a change of the relative permeability (μR) of the pipe material, which will be detected by the eddy current field generated by the eddy current probes.

The eddy current field is an active electromagnetic field and therefore able to penetrate through relative thick non-conductive coatings as well as through conductive, non-magnetic coatings. By this ability the SLOFEC® is a preferred technique for the inspection of internally coated pipes. The technique can also be deployed for inspection in pipelines with multiphase. This method works in carbon pipe, stainless steel and also cast -iron pipe.

For this application the inspection task is to detect defects at the inner and outer pipe wall as well as to determine the coating thickness respectively to detect local damages in the coating itself.

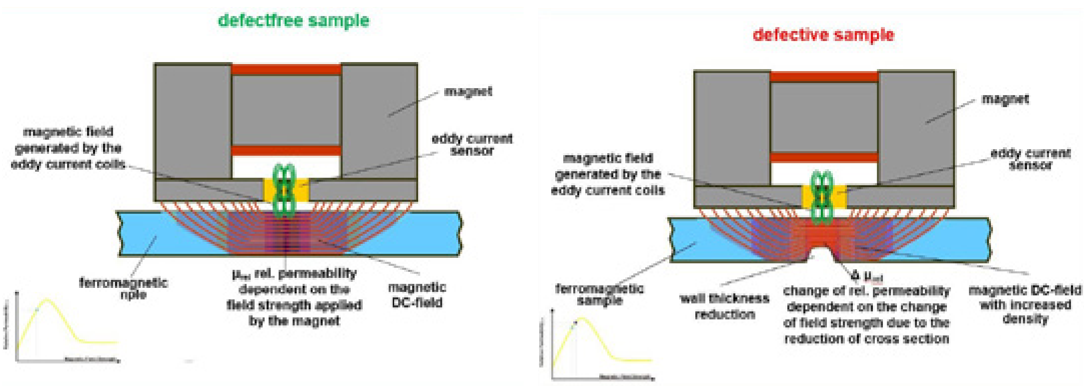

Figure 6: SLOFEC® principle

Detection of Defects through Thick-Coating by SLOFEC® Technique

The applicability of the SLOFEC® technique depends on the relation between pipe diameter to pipe wall thickness and coating thickness. In practice that means that the inner pipe diameter must be big enough to generate a sufficient DC field strength and the eddy current sensors must be large enough to generate an AC field with a spreading bigger than the coating thickness. As a rough estimate it can be stated that the ratio between pipe diameter and combined wall and coating thickness should be in the range of 20:1 or bigger, whereas due to weight limitations the maximum wall thickness is 20 mm and the coating thickness itself should not be much bigger than 10 mm.

Due to phase difference between signals of OD defects and ID defects inspectors can distinguish between OD and ID defects as well identify defect signals from none defect signals. The SLOFEC® signal amplitude of an OD or ID defect is a measure of wall thickness loss. Importantly, in performing the inspection no special coupling medium is necessary!

The defect detection capacity results are similar to a standard MFL tools.

Eddy current layer thickness measurement

Figure 7 shows the working principle of the eddy current method for the measurement of the thickness of the mortar liner.

When the coil comes closer with its alternating field to an electrical conductive material an alternating current will be created in it, the so-called eddy current. This current creates again an electromagnetic alternating field, however, in the opposite direction, and it weakened the original field. The effect to the coil is a change in its inductivity, a characteristic property of each coil.

For the inspection the eddy current sensors are installed in a sensor carrier and pressed against the internal pipe surface with springs

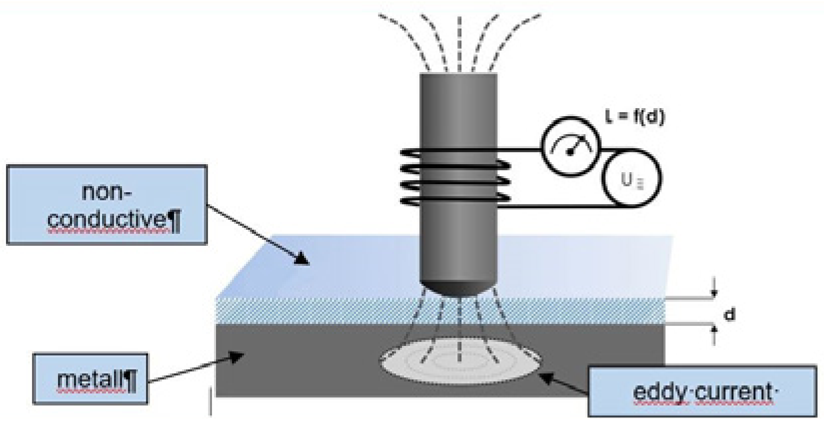

Figure 7: principle of eddy current layer measurement

(Figure 8). The eddy current field created by the sensors spread out through the mortar layer to the steel pipe. So, every sensor shows the thickness layer (Figure 9). The sensors are ball-shaped at the top to be able to follow the contour best. Local metal loss between the mortar layer and the internal pipe surface will be shown as increase of the mortar layer.

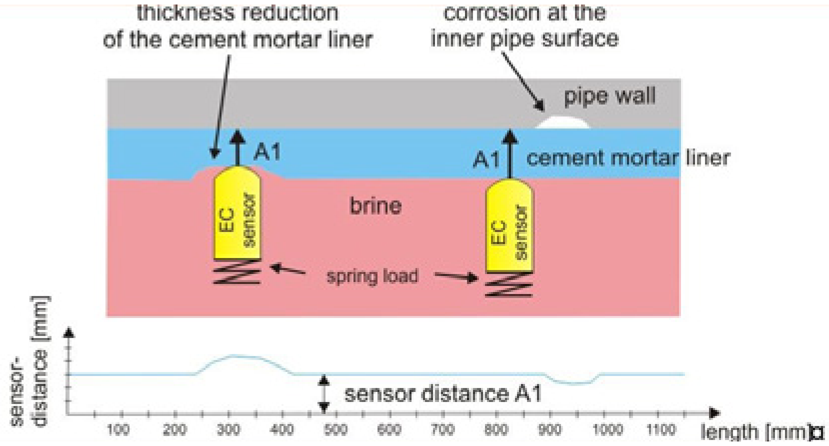

Figure 8: Guidance of eddy current sensors für the inspection of the mortar layer

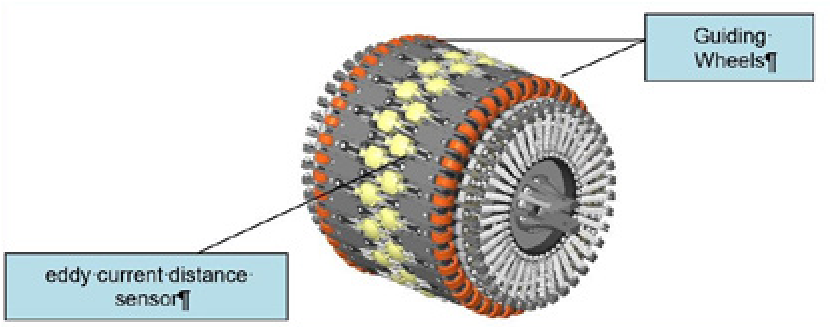

Figure 9: Eddy current sensor carrier for thickness measurement of a mortar layer

CASE STUDY 1

A loading line operator found out by accident that one of their 42" lines has a problem with their long seam welds (axial cracking). This line was not piggable with a conventional tool. Fortunately, a spool piece could be taken out to install a shorter tube for launching and receiving a bidi tool. Because this line had no pumps (pumps are on the boats for pumping to shore) the operator was looking for an inspection company which could offer a self-propelled bidi inspection tool for wall thickness and crack inspection in this crude oil pipeline. KTN could offer this service launching a bidi UT tool with a crawler in the front and modules for geometry- and wall thickness measurement and TOFD scanner. The tool was launched via this short launching tube, the winch could be placed sideward for space reason, the cable was guided with wheels from winch to launcher. Inspection was done within one day (day + night shift) with wall thickness + geometry measurement on the way in and out and additionally with TOFD scanner for the long seam weld inspection on the way out. The tool always stopped at the end of each girth weld, looked for the position of the next seam weld and started scanning it again. Already during the inspection run the worst locations could be assessed and in the final report a full integrity report was included with repair plan.

CASE STUDY 2A

A 10" gas / vent line in an offshore field, more than 40 years in operation, should be inspected – a governmental obligation - from the starting platform down the riser to sea bottom and further approx. 650m to the bend from horizontal to vertical at the end, no inspection was required on the vertical part of the end (vent stack installation). The section to be inspected was built with seamless carbon steel pipe, approx. 10mm wall thickness and contained 5 x 5D bends. This line was never inspected before, some corrosion was expected, especially in the splash zone from outside and also in the bottom area internally. The cleaning condition was unknown, however, not much debris was expected, only some liquid / condensate in some bottom areas which would be even beneficial for the inspection because the liquid would reduce the friction for the tool and the umbilical. Inspection should be done in dry atmosphere. The

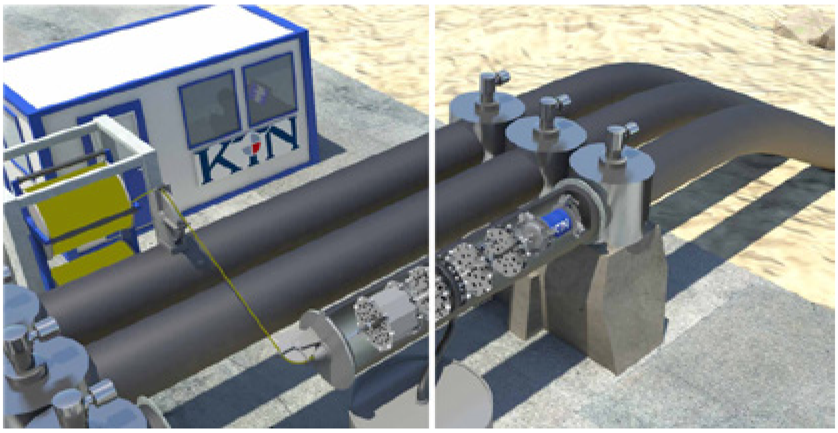

Figure 10: 42" launching situation

client selected the KTN/KT SLOFEC® tool due to several reasons: It is less sensitive to any debris on the internal surface than any other technology, the method works well in dry and liquid phase and because of the fail -safe effect – the magnet power can be switched off or is automatically switched off in case of power supply loss to make it easier to pull the tool back.

The propulsion should be done with KTN crawlers in tandem configuration to have more pulling force.

As first step a site visit was done to discuss all technical details and procedures with the client. Afterwards a report was prepared which included everything from preparation of the tools and testing in KTN's premises, Bergen (build-up of test pipe), shipping, supply of power generator, lifting from boat to the platform and locations for placement of all equipment incl. guiding wheels and how to launch. Then a full - scale test was done in Bergen in a specially prepared short pipeline which had the same bend configuration as the real one.

This test pipe contained several test spools with 80 test defects, all with different direction, length, width, depth and shape to verify the defect spec of the SLOFEC® tool in that pipe. In addition, the test should show the required pull forces of the entire tool in the pipe. The pull and pull back forces were measured in 8 test runs. The pull-back forces were less than 1/3 of the pulling forces. KTN/KT and the client were sure that the tool could be safely used in the life pipeline. The client did not perform a cleaning procedure on this section of pipeline prior to the inspection because it was not possible or required without major modifications.

The complete tool launched consisted amongst others of one CCTV camera module in the front (with pan + tilt function), 2 connected crawlers, a SLOFEC® sensor carrier with 32 electromagnetic sensors, and the rear camera. The total length of the tool was therefore 6.1m.

The actual inspection run was done with an average tool speed of 0.06m/s within one shift successfully.

Already during the run the worst defects were evaluated and reported directly after the run. The final data analysis and reporting was done after demob in the KTN/KT home base. Both data sets were of good quality and both were used for the final evaluation. The analysis also showed that the 2 data sets were very good reproduceable, the same features appeared in both runs with the same sizes. Fortunately for the client the report could show that there were no features deeper than 28% and the ERF (estimated repair factor) pressure ratio was <<1.0, which means no repairs had to be done at the moment.

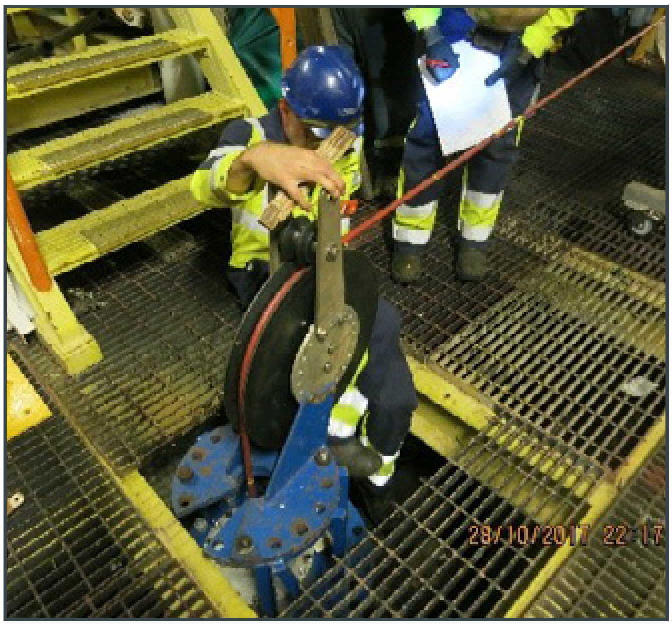

Figure 11: launching situation

Figure 12: launching situation

CASE STUDY 2B

During the last years KTN and Kontrolltechnik got many enquiries for the inspection of pipelines with thick internal coating. Most of them had a 10mm mortar liner. UT technology or MFL did not work, clients had already leaks in their lines, however, did not know whether the condition of their lines was equally bad or just in one or a few locations. An inspection technology should be found to determine whether repair would make sense or replacement of the lines were necessary which was difficult and extremely expensive.

KTN/Kontrolltechnik was sure that the combination of eddy current and SLOFEC® technology would give good results and did a study and some testing with 12" pipe with mortar liner during 2017 to confirm the detection capabilities and get more precise knowledge about the depth sizing capabilities of this combined technologies within these kinds of pipes.

A test pipeline at Kontrolltechnik premises in Northern Germany was built up with 12" diameter 26m long with 2x 90° 1.5D bends, 85 artificial defects and 8 natural defects. The range of the external defects in the pipe was from 10mm diameter in steps (30mm + 50mm) to 100mm diameter and with depths from 18% to 100%.

See Figure 1 and 2 on the paper introduction page for Images of the SLOFEC® tool and the pipeline mockup.

The SLOFEC® tool with the KTN crawler and winch was used to pull the inspection tool through the line and back. KTN/Kontrolltechnik could verify that the technology was working as promised, all defects which were installed in the test piece were detected and sized according to Figure 14.

The results are shown in graphical form. The diagram shows the defect depths evaluated by the SLOFEC® technique versus the mechanically measured defect depths. It can be clearly seen, that most of the defect depths were evaluated within an accuracy of ± 10% the worst was 20% of the nominal wall thickness.

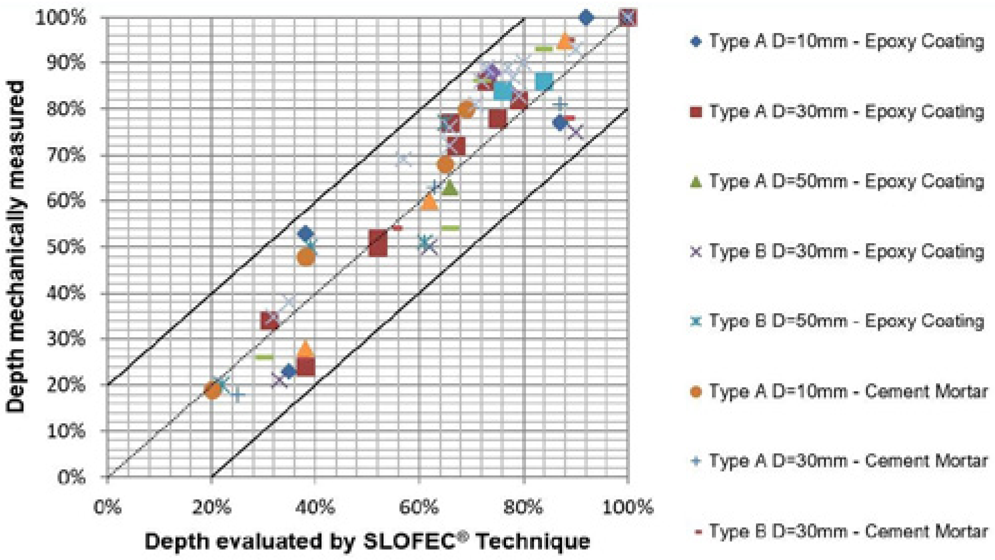

Figure 14: Defect depths of the artificial defects evaluated by the SLOFEC® technique versus the mechanically measured defect depths

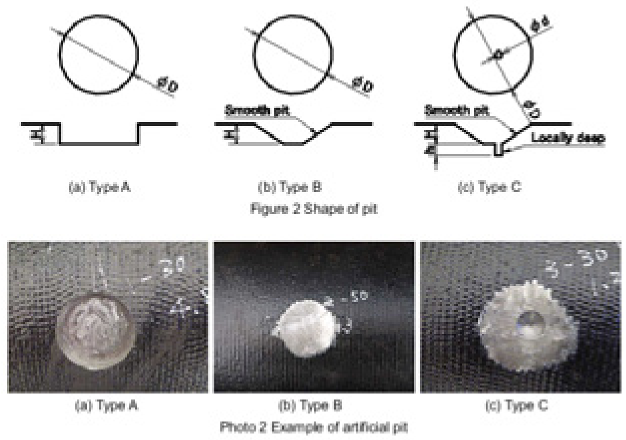

Figure 13: types of defects used for the examination

Examination of the natural defects

Beside the examination of artificial defects an examination on a pipe sample with natural defects was performed. Picture 15 on the following page shows pictures from examined sample.

Table 1 shows the examination result for the natural defects. In the table the mechanically measured defect depth versus the evaluated defect depth as well as the deviation from the mechanically measured defect depth for each pipe section is shown.

The maximal deviation is also 17% from the mechanically measured depth, in most cases the deviation is below 10%.

Figure 15: Natural defects in pipe section no.2

Defect No.	Mechanically measured defect depth	Defect depth evaluated by SLOFEC® technique	Deviation from mechanically measured depth
1	17 %	27 %	+ 10 %
2	31 %	34 %	+ 3 %
3	57 %	65 %	+ 8 %
4	19 %	25 %	+ 6 %
5	16 %	33 %	+ 17 %
6	32 %	34 %	+ 2 %
7	22 %	30 %	+ 8 %
8	23 %	30 %	+ 7 %

Table 1

With the available technology and carried out tests KTN / Kontrolltechnik can offer now services in the following range:

Diameter range : 8"– 18"
Max. wall thickness : 16 mm (depending on the pipe diameter, the coating thickness and the detection limit)
Max. coating thickness : 10 mm (depending on the pipe diameter, wall thickness and the detection limit)
Smallest passable radius: 1,5 x pipe diameter (for 8" – 2,5 x pipe diameter)
Max. inspection length : up to 1.000 m (longer under evaluation)
Max. inspection speed : 6 m/min
Drive systems : electrical crawler 8" – 18" (or pulling winch 8" – 18")

if not only the condition of the external pipeline should be inspected but also the internal mortar layer a combination of the eddy current and SLOFEC® technology was tested successfully. With this combo tool the following advantages can be achieved:

Advantages of the eddy current and SLOFEC® technology Advantage of the eddy current method for the detection of break-outs in the mortar liner

- the real thickness layer will be measured
- surface roughness has minor influence on the inspection results
- the influence of debris is very little
- metal loss under the mortar liner will be shown

Based on the described principle the main features of the SLOFEC® method can be highlighted as follows:

- The SLOFEC® method does not need a direct coupling with the surface to be inspected, can also be used in dry or partly with liquid filled pipelines
- The requirement for the cleanliness of the surface to be inspected is low because non -conductive and non-magnetic layers / debris do not influence the signal
- Because the eddy current sensors create an active magnetic field and this field will spread out over several millimetres around the sensor, the detection of defects through relatively thick and non-conductive, non- magnetic coating layers as Epoxy, mortar etc is possible. The inspectable wall thickness and coating thickness is, however, depending on the pipe diameter. In smaller pipe diameter smaller wall thickness and coating thickness is inspectable / measurable.
- By frequency adjustment of the eddy current field the depth of penetration of the eddy current field can be increased, therefore also the inspection through electrical conductive, however, non- magnetic cladding as stainless steel- or aluminium – cladding is possible.
    - The eddy current signals provide in addition to the amplitude information also a phase information. By evaluation of the phase information defects at the internal pipe surface can be differentiated from defects at the external pipe surface and other disturbing signals.

CONCLUSION

The KTN self-propelled tool can be used for distances up to 12km depending on the geometrical structure (e.g. type and number of bends) of the pipeline (solutions up to 24km under development).

Depending on the requirements different technologies as UT for wall thickness and cracks, TOFD for cracks, all in liquid lines are available.

Together with Kontrolltechnik eddy current and SLOFEC® for corrosion in dry and multi-phase lines is offered for shorter lines.

While UT is ideal in carbon steel and stainless-steel pipe, SLOFEC® is also usable in cast iron, stainless steel pipes and pipes with thick internal coating with nearly no surface preparation.

The results are visible in real time, action can be taken immediately if required.

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PIPELINE MANAGEMENT 4.0

– A NEW PARADIGM FOR PIPELINE SAFETY AND PROFITABILITY

Hartmut Leistner > HIMA Paul Hildebrandt

ABSTRACT

Pipelines are the most economic and secure transport systems for oil, gas, and other products. But they can rupture, leak, or be damaged or destroyed by improper operation, theft, cyberattacks, terrorism or sabotage. Every day, many millions of tons of liquids and gases are transported via overland pipelines or pipelines within facilities. As a means of conveying masses of material, pipelines must fulfill strict safety, cybersecurity availability, and environmental requirements.

One particular pipeline hazard is leakage. If a leak occurs, it needs to be detected and located as quickly as possible – especially if the pipeline is transporting fluids or gases that can contaminate water or are toxic or flammable. The quicker that countermeasures are initiated, the less severe the damages caused by the leak. Damage to a pipeline can have various causes. The consequences and cleanup of damages caused by pipeline leakages can cost the operator huge sums of money – not to mention the potential harm to people, the environment, and reputation. On the one hand, costs arise according to the value of the product that is leaking from the pipeline. The later a leak is discovered, the more money is lost in this way. But, in many cases, the costs arising from the subsequent cleanup and fines are many times higher than those caused by the loss of materials. Rapid leak detection can significantly reduce these costs.

To help companies run their pipelines safely and cybersecure, HIMA combined software and hardware to create a unique solution for pipelines. HIMA calls it a hybrid solution. It is the combination of an emergency shutdown system and a leak detection system. The new integrated hybrid solution for pipeline management offers pipeline operators considerable benefits. It complies with current and upcoming global safety standards according to SIL 3. It ensures maximum functional safety and extremely high reliability by automatically shutting down any affected areas during critical situations. And it offers maximum cybersecurity. As a result, it cuts the operating costs of pipelines, significantly reduces false alarms, and increases the profitability of installations. At the same time, the closed HIMA system with integrated cybersecurity provides a strong line of defense against cyberattacks.

INTRODUCTION

Pipelines offer the most dependable and cost-effective solution for transporting oil and gas, but they are not infallible. They can leak or rupture, they can be damaged accidentally or deliberately and they can be compromised to allow theft of the product they are transporting. Effective – and safe – management systems must provide pipeline operators with the tools they need to detect and localize these problems quickly and reliably, so that swift remedial action can be taken. And, in today's challenging world environment, management systems must not only be effective and safe, but also cybersecure. This paper introduces a new paradigm in pipeline management – Pipeline Management 4.0 – which integrates leak detection and safety systems to fully address these challenges.

PIPELINE MANAGEMENT

Every day, millions of tons of liquids and gases are transported safely and securely by pipelines. Pipelines are exceptionally reliable, but given the large numbers in use and the huge distances they cover, it is inevitable that, from time to time, problems will occur. When they do, the environmental and financial impact can be enormous. In recent times, the situation has been further complicated by the growth in terrorism and cybercrime, both of which can have a devastating effect on pipeline operation and integrity. For these reasons, pipeline operators in almost every country of the world are now legally required to implement management systems that make it possible for them to meet strict safety, cybersecurity, and environmental requirements.

LEAK DETECTION: AN ESSENTIAL ELEMENT

An essential element of every pipeline management system is leak detection. It is of the utmost importance that leaks are detected and dealt with promptly, especially if the fluid that's being transported by the pipeline is flammable, toxic, corrosive, or otherwise damaging to the environment. Delays will not only lead to greater loss of product, but will also greatly increase the potential for consequential damage. The costs associated with the damage are often much greater than the cost of the lost product.

Figures from the United States Department of Transportation Pipelines and Hazardous Materials Safety Association (PHMSA) confirm that leak detection is at least as important today as it ever was. Since 2002, the number of pipeline incidents per year in the USA has remained above 600 and, in several years, it has approached 700.

Some of the resulting spills are large, as was demonstrated by the incident that occurred in South Dakota in November 2017 and affected the Keystone pipeline operated by TransCanada. The total volume of this spill has been estimated at 5,000 barrels (about 210,000 gallons) of crude oil, and aerial photography released by the news media dramatically confirmed that a large swathe of land was affected.

In recognition of the ever-present need for leak detection, the American Petroleum Institute (API) has produced a suite of standards to guide and help pipeline operators to reduce the occurrence of leaks and to minimize the impact of those leaks that still occur. The standards are:

- API 1160 – Overall standard to cover pipeline integrity management
- API 1130 – Design and implementation of leak detection systems
- API 1149 – Theoretical calculation of leak detection system performance
- API 1175 – Selection, operation, maintenance, and continuous improvement of leak detection systems.

Similar standards apply in most countries of the world; in Germany, for example, leak detection must comply with the Technical Rules for Pipelines (TRFL). While various standards differ somewhat in their approach and detail, all guide operators must consider the following when specifying or implementing a leak detection system:

- Sensitivity – A combination of the size of detectable leak and the time needed to detect it
- Reliability – A measure of the system's ability to accurately assess whether or not a leak exists
- Accuracy – The ability of a system to estimate key leak parameters such as leak flow rate, total volume lost, and leak location
- Resilience – The ability of a system to continue to function under unusual hydraulic conditions or when data is compromised

In addition, pipeline operators are now being expected to meet increasingly onerous safety, security and cybersecurity requirements. And it should be noted that these requirements apply not only to long-distance pipelines, but also to the much shorter pipelines found in chemical and petrochemical facilities.

> *"An effective – and safe – management system must provide pipeline operators with the tools they need to detect and localize these problems quickly and reliably, so that swift remedial action can be taken.*
>
> *Hartmut Leistner*

Pipeline leakage is, of course, not a new problem and leak detection systems of various kinds have been in use for a very long time. It is instructive to examine the evolution of these systems to uncover the limitations of traditional approaches and to better understand how the latest advances help operators to meet today's increasingly stringent regulatory and commercial requirements. The first step is to look at the ways in which leaks can be detected.

EXTERNAL METHODS OF LEAK DETECTION

There are three principal external methods of leak detection: acoustic sensor, fiber-optic cable, and vapor sensor.

Acoustic sensors are installed along the pipeline to monitor internal noise levels. A leak produces low-frequency acoustic noise that the sensors detect. This method is sensitive to small leaks but it is liable to produce a large number of false alarms caused, for example, by vehicular traffic and the operation of pumps or valves. The efficiency and accuracy of this method depends on the skill of the operator. It is not well suited to long pipelines, as costs are too high.

Fiber-optic leak sensing uses a fiber-optic cable installed along the entire length of the pipeline. The cable looks continuously for the temperature changes produced by leaks. This method offers high leak location accuracy and is effective for identifying theft. However, installation cost is high, leak identification can be slow, stability over time is as yet unproven, and the entire pipeline must be excavated to install the cable. This method provides no information about the size of the leak.

Vapor sensing uses a sensing tube installed along the entire length of the pipeline. This carries air at a constant speed toward a sensor at the end of the pipeline. Scans are carried out periodically and, during a scan, a test peak of hydrogen is injected into the airflow. If vapor from a leak is detected, the system calculates the location of the leak based on the time difference between the arrival at the sensor of the vapor and hydrogen peak. This method gives good information about the size and location of the leak, but is costly to install. Also, scanning is usually carried out only once or twice a day, so leaks can become very large before they are detected.

INTERNAL METHODS OF LEAK DETECTION

There are five principal internal methods of leak detection: statistical analysis of pressure and flow, real-time transient modelling, volume balance, pressure drop, and negative pressure wave.

Statistical analysis relies on pipeline pressure and flow profiles reacting to a leak in a specific way. The profile reactions are calculated using the correlations between inlet and outlet flow, and between inlet and outlet pressure. Unfortunately, this correlation only exists in steady state conditions, which means that statistical analysis doesn't work under transient conditions. This method has the advantage of using existing instrumentation, but leak location accuracy tends to be low.

Real time transient modelling (RTTM) uses basic physical laws to create mathematical models of flow within the pipeline. When the measured flow deviates from the model, this indicates a leak. RTTM is very good in transient conditions and can potentially use existing instrumentation. However, to minimize false alarms it is necessary to continuously monitor the noise level and modify the model accordingly. RTTM is expensive and sometimes difficult to program. The training cost for operators is high.

Volume balance is based on the principle of conservation of mass: What goes in must come out – unless there's a leak! The compensated volume balance variant is best for leakage detection, as this takes into account changes in pressure and temperature. This method uses proven technology and algorithms, it uses existing instrumentation with minimal programming, and it remains effective in transient conditions. It can, however, only estimate the location of the leak.

Pressure drop is a simple approach that uses existing instrumentation. During shutdown conditions, a pressure drop indicates a leak. This method can detect very small leaks (seepage), but it can only estimate the location of the leak.

Negative pressure wave leak detection works on the principle that when a leak occurs, it produces a negative pressure wave of known velocity both upstream and downstream of the leak. The leak location can be calculated by comparing the arrival times of the negative pressure wave at each sensor. This method uses existing instrumentation to provide extreme leak sensitivity and excellent location accuracy, combined with a low level of false alarms.

Leak Detection 1.0

The simplest of leak detection systems – which can be considered as Leak Detection 1.0 – use just one of the methods described above. This means that, although the system may seem simple to implement and, depending on the method, easy to operate, it necessarily suffers from all of the limitations associated with the chosen method.

Leak Detection 2.0

The next evolutionary step – Leak Detection 2.0 – uses multiple detection methods in combination; the benefits of each of the methods combine, and the weaknesses effectively cancel out. A successful approach to Leak Detection 2.0 has proved to be a combination of three internal leak detection methods: enhanced pressure wave, compensated volume balance, and pressure drop. The simultaneous application of these three methods means that system availability is assured for all pipeline operational phases, with a minimal level of false alarms. This approach also reduces programming costs, and the system requires little if any tuning to compensate for changes in the physical properties of the pipeline.

Leak Detection 3.0 – standalone rupture detection

While the approach and technologies of Leak Detection 2.0 are very effective in what they set out to do – detect leaks – they are designed only to warn operators of the problem rather than to initiate actions that will reduce the impact of the leak. Leak Detection 3.0 systems combine the concept of detection with automatic action, albeit only in the special case of a pipeline rupture, which is defined as a leak that reaches or exceeds around 30 percent of the pipeline flow rate.

These systems are designed for standalone operation, working independently of the leak detection implementation. They provide invaluable extra protection because they offer the immediate reaction to a rupture, which is essential to minimize spills and environmental damage, and these systems are, therefore, particularly appropriate for use on pipelines that traverse environmentally sensitive areas.

A typical Leak Detection 3.0 rupture control system incorporates a proven rupture detection algorithm that directly controls pipeline valves. When a rupture is detected, the system reacts immediately to initiate an emergency shut down (ESD) that isolates the affected pipeline segment.

Figure 1: Pipelines are the most economic and secure transport systems for oil, gas, and other products. But they can rupture, leak, or be damaged or destroyed by improper operation, theft, cyberattacks, terrorism or sabotage.

Pipeline Management 4.0 – a hybrid solution

The most recent development is a logical progression that combines all of the key features of Leak Detection 2.0 with the ESD functionality of Leak Detection 3.0. The result is a hybrid solution that, because of its scope, exceeds the designation Leak Detection 4.0 and is more appropriately described as Pipeline Management 4.0.

Put simply, unlike traditional systems that detect leaks but take no action, Pipeline Management 4.0 is a complete automation system designed to help pipeline operators to improve safety and reliability. It can continuously monitor pipelines and shut them down automatically in hazardous situations, thereby significantly reducing or even eliminating direct and consequential damage.

A further important benefit is that sequences of automated actions to be carried out in response to specific events can be defined during the planning phase. This means that the behavior of the management system can be accurately matched to the needs of individual applications. In particular, shutting down the pipeline in response to a leak doesn't need to mean instantly closing all valves in the affected area.

> *"Management systems must not only be effective and safe, but also cybersecure.*
> *Hartmut Leistner*

Figure 2: One particular pipeline hazard is leakage. If a leak occurs, it needs to be detected and located as quickly as possible – especially if the pipeline is transporting fluids or gases that can contaminate water or are toxic or flammable.

In many cases, a smart multi-step shutdown sequence offers significant advantages. It might be useful to close one valve instantly, while delaying the closure of a second valve so that a section of the pipeline can be emptied to minimize the amount of leakage. Solutions of this type are particularly appropriate for inclined sections of pipeline.

Designing and implementing a system that can deliver on the promise of Pipeline Management 4.0 is not without its challenges.

As the system performs key safety functions, it should conform with existing and, as far as possible, upcoming global safety standards. Because of this, most operators will require the system to comply with the requirements for Safety Integrity Level 3 (SIL 3) as defined by the IEC 61508 standard.

PIPELINE MANAGEMENT 4.0 – A PRACTICAL IMPLEMENTATION

Devising and implementing practical, efficient, and effective Pipeline Management 4.0 solutions involves many challenges, but these have been successfully addressed and these solutions are now entering service and delivering important benefits for pipeline operators that have adopted them.

In an excellent example of such an implementation, flow rate monitoring is handled by SIL 3 capable safety hardware, with pressure and temperature data transmitted to the control center for visualization via a safety-compliant Ethernet protocol. The safety hardware at various locations along the pipeline is interconnected using the same protocol, so that each system knows the state of the overall pipeline. If a leak occurs, the controller implemented in the safety hardware automatically adjusts the flow, and shuts down the pipeline immediately in an emergency.

> *"Pipeline Management 4.0 integrates leak detection and safety systems to fully address these challenges.* Hartmut Leistner

This prevents or significantly reduces damage.

The software used for leak detection and localization also ensures that pipeline flow rates, pressures, and temperatures remain constantly visible to operators, and that anomalies are reliably recognized. As well as the main functions of leak detection and localization, the software supports batch and gauge tracking as well as data archiving and analysis. The system also accommodates pressure and temperature correction calculations.

In addition, the software can detect pipeline rupture and ensure that the damaged pipeline section is automatically and rapidly isolated, thereby minimizing the amount of product released.

Operators can adapt the detection algorithms to their specific needs. Unlimited changes, modifications, extensions, improvements and even prescribed verification tests during ongoing system operation, in line with the SIL 3 standard, are possible.

In addition, the system can be easily integrated with almost any existing automation environment through open interfaces.

Even though it offers wide-ranging functionality and exceptional versatility, the system described makes no sacrifices in terms of performance. The SIL 3 capable leak localization system conforms to API 1130, TRFL and other relevant standards.

To ensure continuous system availability, leaks are analyzed and localized using multiple methods. The enhanced pressure wave method, the volume balance, and the pressure drop method are used individually or in combination, depending on the nature of the leak and the operating state of the pipeline (static, transient, or shut down).

This approach ensures reliable detection of even the smallest leaks and minimizes false alarms.

For example, the extended pressure wave method increases the detection sensitivity of the system, allowing detection of leaks that produce as little as 0.35 percent pressure change. Leaks can be localized accurately, and this method works in semi-static operating states. Its high accuracy eliminates over 80 percent of false alarms.

CYBERSECURITY

The discussion of the Pipeline Management 4.0 system so far demonstrates that it addresses many of the key challenges associated with pipeline operation, but there is one vital area that has not yet been mentioned: cybersecurity.

Today's pipeline management solutions, as is the case with all modern automation and control systems, rely at their core on sophisticated software and networking. These are potentially vulnerable to cyberattacks by individuals and organizations intending to cause costly and potentially dangerous disruption.

Figure 3: To help companies run their pipelines safely and cybersecure, HIMA combined software and hardware to create a unique solution for pipelines. HIMA calls it a hybrid solution.

Unfortunately, cyberattacks are a fast-growing risk.

In the past, hacking was the domain of individuals and small groups with the primary aims of achieving notoriety or extorting money. Now however, there is increasing evidence that countries and states are involved, and their objective may well be to deliberately compromise key infrastructure – including oil pipelines – as a method of achieving political objectives. One of the most worrying aspects of this development is that countries and states have access to far greater resources than lone hackers or small groups of hackers, which means that they can be expected to mount much more sophisticated attacks.

In fact, an example of state-sponsored malware may have been seen already, in the form of the WannaCry ransomware cryptoworm, which is estimated to have affected around 300,000 computers in 150 countries.

For those affected, the impact was substantial. Many were without IT facilities for hours or even days, and data loss was widespread. Admittedly, this attack targeted IT rather than automation systems but the well-known Stuxnet worm, which was deployed to derail Iran's nuclear program, confirms that automation systems are by no means immune.

It is almost certainly true that complete protection against the most skillful cyberattacks is impossible. Nevertheless, much can be done to protect systems against less determined attacks and also to make them less attractive targets for attack.

One very effective measure for enhancing cybersecurity in automation systems is to avoid the use of mainstream operating systems such as Microsoft Windows. Because these operating systems are so widely used, their vulnerabilities are quickly uncovered and exploited by hackers.

A dedicated special-purpose operating system, as is used in state-of-the-art pipeline management solutions, is much less appealing to hackers as they will need to start almost from scratch to find ways in which it can be compromised, and there is no vast body of information they can draw on to help them achieve their nefarious ends.

The best pipeline management implementations are designed from the outset with cybersecurity very much in mind, using as guidance the IEC 62443 standard, which covers the security techniques necessary to prevent cyberattacks on facility networks and systems.

IEC 62443 requires the separation of key system elements and introduces the concepts of security zones and defined conduits to connect the zones. Crucially, it requires firewalls at every conduit that connects one security zone to another with different requirements.

This arrangement creates a tiered structure of defense mechanisms, a technique that is often described as 'defense in depth'.

But what precisely needs to be protected? According to the most recent version of IEC 61511, the standard that covers Safety Instrument Systems (SISs), the answer is that organizational demands and physical structures need to be given equal consideration.

The standard calls for these steps:

- Carry out a security risk assessment of the SIS
- Make the SIS sufficiently resilient against the identified security risks
- Safeguard the performance of the SIS, error detection and correction, protection against unwanted program alterations, protection of data for troubleshooting the safety instrumented function (SIF), and protection against bypassing restrictions to prevent the deactivation of alarms and manual shutdown
- Enable/disable read/write access via a sufficiently secure method

In terms of structural requirements, IEC 61511 instructs plant operators to conduct a further assessment of their SIS. The objectives are: to ensure independence between protection layers; establish diversity between protection layers; physically separate the protection layers; identify and avoid common-cause failures between protection layers.

There's no doubt that these requirements are complex and onerous, but this need not be a concern for pipeline operators that choose to adopt a modern pipeline solution. Leading suppliers of these solutions will have already taken steps to ensure that their products are cybersecure and compliant with the relevant standards. They will also be ready to offer advice about how their solutions should be deployed to maintain maximum protection against cyberattacks.

CONCLUSION

Pipeline operators are today offered a wider range of leak detection and pipeline management systems than ever before, which can make choosing the best system a challenging task. Before making a decision, however, operators should consider the benefits of the latest Pipeline Management 4.0 technology, which for the first time, integrates accurate and dependable leak detection with a SIL 3 compliant emergency shutdown system. The best systems have also been specifically engineered to provide robust protection against the growing threat of cyberattack.

This new hybrid pipeline management solution puts operators in full control of their pipelines whatever their operational status, and deals promptly and automatically with potentially hazardous occurrences such as major leaks and ruptures.

The result is a reduced risk of product loss and environmental damage, both of which translate directly into consistent cost savings. Secure pipeline operation without disruption also contributes positively to the reputation and standing of the pipeline operator. Considered together, these factors make Pipeline Management 4.0 an exceptionally sound investment that will reliably minimize the effects of both intentional and accidental events in future.

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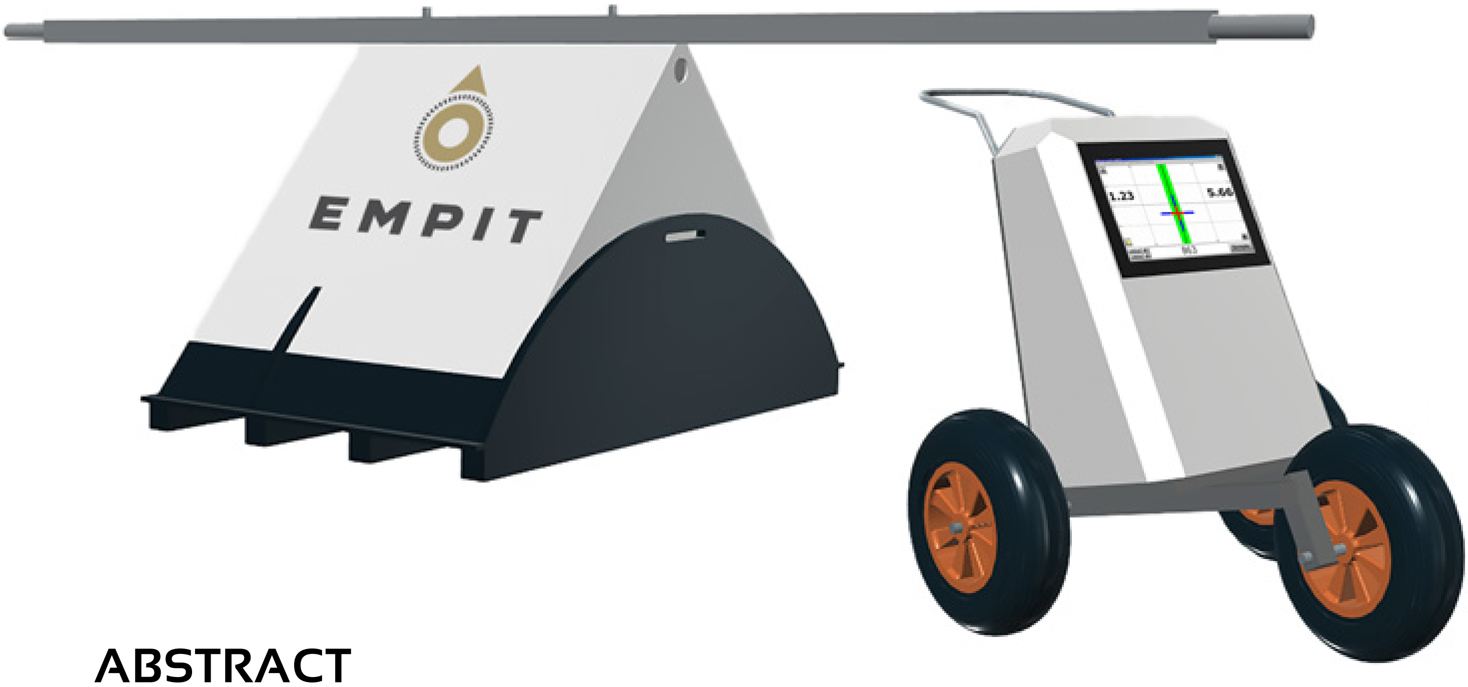
IMPROVEMENTS OF AN INSPECTION TECHNIQUE FOR UNPIGGABLE PIPELINE DIAGNOSTICS FROM ABOVE GROUND

Dr. Guennadi Krivoi > EMPIT GmbH); **Mark Glinka** > EMPIT GmbH



ABSTRACT

There are thousands of unpiggable and challenging pipelines running through Europe alone. The integrity management of these pipelines requires nondestructive evaluation techniques, which can be applied without introducing inspection tools into pipelines.

Pipeline diagnostics shall, therefore, be executed from above ground. Indirect approaches such as DC Voltage Gradient (DCVG) survey or External Corrosion Direct Assessment (ECDA) can be used for this purpose. However, such approaches are characterized by distinct limitations, i.e., properties of soil (DCVG), or necessity of reference excavations (ECDA). Consequently, the latterly mentioned techniques can only be used for external corrosion and coating damage detection and not for information about a metal loss in the pipe wall.

The presented Above Ground Inspection Technique (AGIT) has been developed to overcome limitations of DCVG, ECDA, and In-Line Inspection (ILI). Thus, AGIT is capable of localizing and categorizing external and internal metal losses in unpiggable pipelines. All crucial information of the pipeline will be given to the customer through only one inspection run. The Electromagnetic Pipeline Testing GmbH (EMPIT) holds all exclusive rights and assets of AGIT.

At first, the physical basics and technical principles of AGIT will be explained. Briefly spoken, the technique is based on above ground measurements of the magnetic field of a buried pipeline under test. Metal loss defects in the pipeline wall become detectable through AGIT as they result in measurable changes of the magnetic field at different frequencies. In addition to the magnetic field data, the pipeline's depth of cover, the test current in the pipeline, and the chainage along the pipeline will be stored and used for further evaluation. Moreover, information on coating holidays based on registered local leakages of the test current and the presence of metal objects in the close vicinity to the tested pipeline will be highlighted and presented to our customers. Secondly, a review of performed inspection runs, including a comparison of detected features and their validation through excavations, is presented. It has been proved that AGIT demonstrates a high level of reliability in detecting pipeline defects. Lastly, the goals, approaches, and test results of improvements, achieved by a new development of the AGIT, including the method itself, the field inspection unit, and the evaluation procedure, will be discussed.

INTRODUCTION

Oil, gas and, water pipelines are indispensable for product transportation in all countries of the world. The greatest proportion is made of steel and slow expansion of oil and gas infrastructure is adding pressure to existing, aging infrastructure. In industrialized countries, the majority of the pipeline network was built between the 1950s and 1970s. The risk of pipeline failure due to corrosion and other external effects is higher than it was ever before. Consequently, reliable solutions for mitigating this risk are needed.

Nowadays, most of the pipelines are operated under cathodic protection (CP) as an anti-corrosion measure, but nevertheless, a lot of undesired environmental factors are present, which lead, despite CP, to corrosion of pipelines. Their integrity is the most important factor for a safe environment, secure production, and transportation. To prevent the dangerous influence of corrosion on pipeline integrity, different inspection techniques have been introduced to the market. The mainly used ones are:

i. water pressure test,
ii. inline inspection (intelligent pigging) [1],
iii. DC voltage gradient survey (DCVG) [2],
iv. current mapping (CM) [3], and
v. External Corrosion Direct Assessment (ECDA) [4].

Inline inspection is the only method that provides direct information about the condition of the pipeline wall. However, not all pipelines can be inspected using intelligent pigs. The main limitations of inline inspection are

i. the inability to work with varying inner diameters of pipeline joints;
ii. the inability to pass through sharp bends and tees, and
iii. the inherent lack of pig launches/receivers in pipelines.

Also, mandatory cleaning of the pipeline prior the inline inspection takes additional time and raises inspection costs. Other techniques, either deliver only "passed" / "not passed" assessment (hydrostatic pressure test) or merely identify coating damages, which might lead to corrosion and therefore need costly excavations for physical verification with direct access to the pipe wall.

> *"Diagnostics of challenging pipeline is made possible with the Above Ground Inspection Technique (AGIT).* Dr. Guennadi Krivoi

As an alternative to indirect survey techniques for unpiggable and challenging pipelines, the herewith-presented Above Ground Inspection Technique (AGIT) shall be used. After only one inspection run the AGIT inspection delivers information about internal and external metal loss, girth weld locations, depth of coverage, and coating defects. The inspection is performed from above ground along the Right Of Way (ROW) of the pipeline without any influence on the transportation mode of the inspected line. Simultaneously, GPS coordinates of desirable points will be defined and stored. In this way, not only mapping of the pipeline is realized, but also precise localization of faults is possible and our costumers save money and time.

PHYSICAL PRINCIPLES OF THE INSPECTION TECHNIQUE

The inspection technique [7] is based on measurements from above ground of the AC magnetic field, which will be induced around the inspected pipeline by a specially generated test current. This test current will be conducted into the pipeline wall via two electrical contacts on the edges of the inspected range.

The current contains several harmonic components with frequencies ranging from a few to a few hundred Hertz. The chosen frequency range is caused by the electromagnetic properties of the pipeline steel. The magnetic field, induced by this current is surrounding the pipe. Due to the skin effect, the current density distribution in the pipeline wall along the pipe radius, is frequency-dependent. The higher the frequency is the higher is the current concentration under the outer surface of the pipe's wall. The harmonic components with lower frequencies are flowing through the whole wall cross-section, whereas the harmonic components with higher frequencies are flowing mainly through the thin layer under the outer surface of the pipe.

Due to the fact that the pipe is made of ferromagnetic steel, another physical effect plays a crucial role for metal loss recognition. This is the stray magnetic flux from the pipe wall. Similarly to the current, the magnetic field distribution in the pipe wall towards the radial direction is also frequency-dependent. Due to the relatively high magnetic permeability of steel, the magnetic field density in the pipe wall is much higher than outside the wall. In case of a metal loss in the pipe wall, the magnetic field appears (strays) from the wall over the defect. This leads to a corresponding deformation of the surrounding magnetic field. This effect is also frequency-dependent. The deformation of the magnetic field will be registered by the AGIT inspection system and later recognized when the data is evaluated.

When considering two different situations "with" and "without" metal loss in the pipe wall, a difference in the magnetic field curves shape becomes evident. In case of a pipe without any metal loss (cf. Fig. 2a), the surrounding magnetic field lines 1; 2 for some but the same field density is circular and independent to the frequency of the test current. However, a different situation takes place if a metal loss fault is present (cf. Fig. 2b). In this case, the surrounding magnetic field lines are egg-shaped and their shape is frequency-dependent. The lowest frequency 3 and the highest frequency 4, which have the same field density like the corresponding field lines in Fig. 2a, illustrate this.

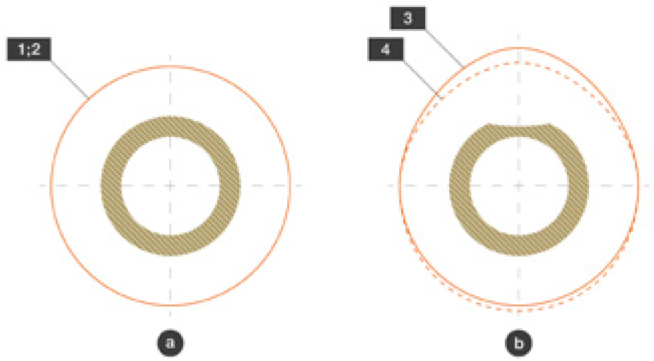


Figure 2: Magnetic field lines for the same field density at the lowest (cf. 1, 3) and the highest (cf. 2, 4) frequencies; (a) – pipe without metal loss; (b) – pipe with metal loss

The frequency-dependent deformation of the magnetic field lines exists not only in case of an outer metal loss, as shown in Fig. 2, but also in case of an inner metal loss. If a metal loss fault lies in another clock position, the magnetic field lines deformation is also present and thus allows AGIT to recognize the fault at all clock positions. When using both, the measurement and the comparison of the magnetic field outside the pipe at different frequencies, it is possible to clearly differentiate between the situations "with metal loss" and "without metal loss". This is the basic principle of the AGIT method.

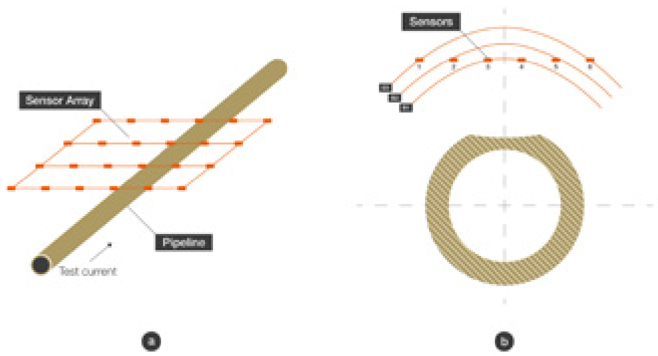


Figure 3: (a) Sensor Array in the measuring position over the pipeline; (b) sensor line in the measuring position (B1 > B2 > B3) over a metal loss defect

Instead of using just one sensor, the AGIT inspection system uses six sensors in one line, which is perpendicular to the pipe. This allows the determination of both, the depth of coverage, and the actual current flowing through the pipe. Additionally, a higher sensitivity of the system is achieved. For a higher productivity of the inspection, four sensor lines are used, which are placed next to one another in the inspection direction along the pipe. In this way, a 6 x 4 matrix of sensors is built – the so called Sensor Array (SA) (see Fig. 3a). The AGIT sensors measure the pipeline's surrounding magnetic field above ground (see Fig. 3b).

The output signals from the sensors are transferred to the Data Collector Module (DCM) where they are digitized, stored and used for the determination of the pipeline position related to SA and the actual test current in the pipeline. The DCM is equipped with a display, which is used to show graphically the actual pipeline position (depth of coverage and displacement). This supports correct orientation of the SA above the pipeline at every step of the inspection.

The complete field unit of the AGIT system contains the SA and the DCM (Fig. 1 on the Introduction Page).

Thereafter, the stored magnetic field data will be evaluated at EMPIT´s office. For the evaluation, an analysis algorithm is used, which is based on 2D comparison and digital filtering of magnetic field data for all used frequencies of the test current.

This algorithm also includes current-independent analysis because the test current can slightly change at every moment and at every location during diagnostics. For this purpose, specially developed evaluation software is used. The digital filtering in the software allows an essential reduction of different kind of interferences from outside, like distorting magnetic fields from power lines, moving vehicles etc. Finally, the output of this analysis will be data about metal loss, girth weld positions, depth of coverage, and current leakage through the coating. All the information will be summarized in a final report and presented to our customers.

FIELD EXPERIENCE WITH THE AGIT INSPECTION SYSTEM

The AGIT inspection system has been used for hundreds of kilometers of pipeline diagnostics. All buried steel pipelines are eligible for diagnostics. Neither the type of coating nor the transported product has an influence on the quality of measurements. AGIT has been used to inspect oil, gas, chemical, water, jet fuel, and brine pipelines and has detected internal and external corrosion metal loss faults, blisters, dents, gauges, mill defects, and pipe deformations in those. Over 90% of the defects diagnosed with the AGIT system have been verified by contact non-destructive testing of excavated pipelines on positions of found faults. Therewith the technique has proven its reliability to the market hundreds of times.

The system is certified for the inspection of pipelines ranging from 3" to 42". When inspecting such pipes, the response threshold for defects starts at 20% metal loss. The AGIT inspection system can be used on both, seamless and longitudinally welded pipelines. Spirally-welded pipelines can also be inspected by using an additional filtering algorithm.

An AGIT inspection begins with the deposition of the connection cable between the AGIT Current Source (CS) and the pipeline connection points. As connection points, different contact possibilities can be used: available CP (cathodic protection) posts, above-ground parts of the pipeline or built-in valves, as well as the pipeline itself, in case of excavation holes, which allow direct contact to the pipe. For one range only two contacts are necessary. The inspection will be performed between these two contacts (Fig. 4). After contacting and laying out the connection cable, a quick functional test is carried out. Then, the actual inspection begins.

The starting point is one of the two connection points. The monitor of the DCM shows a live-report of the depth of the pipeline, the exact position of the SA, the inspection current, and the positioning of the SA over the pipeline. The analysis of the magnetic field data and the calculation process take approx. 6 sec. During this time, the system is not moved. Afterwards, the SA and DCM will be moved 1 m further to the next inspection step. The storage of the data happens after every step. The assembly of the sensors in the SA allows a seamless capture and analysis of the magnetic field data and allows the inspection crew to archive an average productivity of 800 m per day (depend on the surface over the pipeline).

The AGIT inspection can be used for nearly all challenging buried pipelines, also piggable pipelines can be inspected with the technique. If a pipeline is piggable, AGIT can be used for regular monitoring in ranges where intelligent pigging has indicated small defects which have not been repaired yet. In this case, AGIT is an inexpensive alternative to verification excavations for monitoring. In ECDA, AGIT can also be used to estimate possible metal losses before a suspicious range of a pipeline will be dug out.

The terrain inspected has ranged from plane field and forest to cities. Also, parallel pipelines have been inspected and field experience has shown that a distance greater than 60 cm has no influence on the quality of measurements.

FURTHER DEVELOPMENTS AND IMPROVEMENTS OF THE AGIT INSPECTION SYSTEM

Since last year, EMPIT has started intense experimental research in the field of sensitive magnetic field measurements driven forward by a highly skilled and engaged team to further develop the inspection technique. This team is led by Dr. Guennadi Krivoi, who is EMPIT´s head of R&D. The long period of field experience with AGIT inspections has shown that it would be highly beneficial to pipeline operators if AGIT could recognize smaller metal loss faults. This is due to the fact that in some cases, depending on the operation pressure, wall thickness, and pipe diameter, critical dimensions of defects are below AGIT's reference defect. The reference defect has the dimensions of 50 mm x 50 mm x 50% of metal loss and can be detected with a probability of detection (POD) not smaller than 96%. Thus, further developments and im-

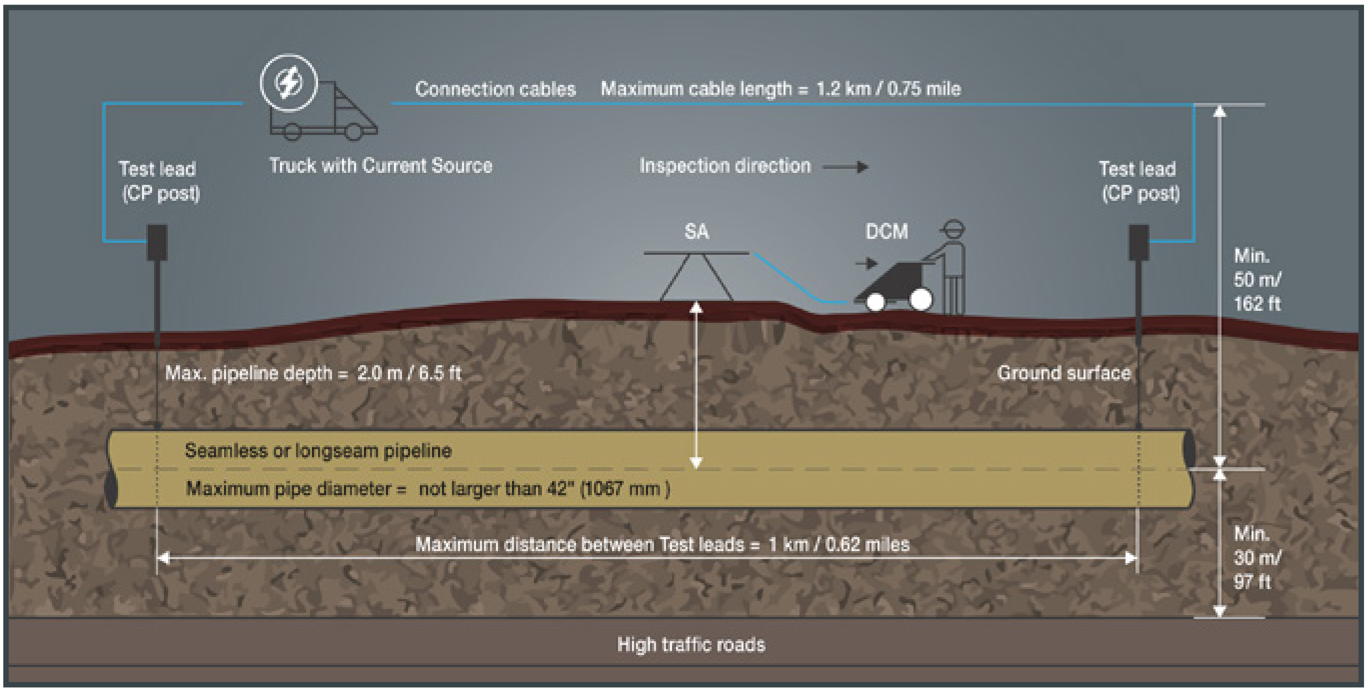


Figure 4: Schematic presentation of the AGIT inspection

provements of the AGIT inspection technique are based on the following goals: (i) better reduction of electromagnetic interference from outside in the "normal" industrial environment, (ii) better sensitivity for recognition of smaller defects, and (iii) better definition possibilities of dimensions of the faults. Therefore, a clustering matrix will be introduced where at least 3 or 4 clusters with defect dimensions will be defined. Additionally, the system will be operated by two instead of three people and better day productivity up to 1000 m shall be reached in the future. The first step of the goals has been archived and tested in the field and laboratory. Through the implementation of a newly developed analog to digital converter, the usage of an improved algorithm for data analysis after the diagnostics, improved sensor calibration, and the improved stability of the current source, not only the influence of electromagnetic interferences has been significantly reduced, but also smaller defects have been detected in the recent past. Below, an example of found defects on a gas pipeline is shown (Fig. 5). Detection of such defects is made possible through recent improvements.

In order to achieve the second step of the development, 3D modelling of the magnetic field around the pipe was extensively done.

After this step was successfully completed, the output parameters of the actual and future (next generation) configurations of the AGIT system were simulated. The configurations are based on the output magnetic field data from the 3D modeling. As a defect indicator, the so-called output parameter b will be used. It combines quotients of magnetic field values computed for positions of particular sensors. In this way, the output parameter is test-current-independent and responses only to deformation of the magnetic field lines caused by metal loss faults. The comparison of the simulated output parameters b of both variants of the AGIT system (bn for the "new" and bo for the "old" variant) is presented in Fig. 6. The simulated case was a 16" steel pipe with the outer defect dimensions of 50 mm x 50 mm x 50% metal loss.

The graphs in Fig. 6 show the output parameter b as a function of the frequency at two different values of the pipe depth (pipe depth is the distance between the axis of the pipe and the sensor line). Coordinate Z is along the pipe axis; Z = 0 means that the sensor line is positioned over the middle of the defect, the other Z values show the axial displacement in mm of the sensor line from this "zero" position.

It can be seen, that the maximum value of the output parameter b of the new configuration is 6 to 7 times bigger than old configuration. This fact guarantees a better resolution of the new configuration for small defects and consequently the possibility of defect clustering. The next step in the development is prototyping and experimental investigation of the AGIT system's new configuration on pipes with artificial and natural defects at the company facilities. Afterwards, field tests are planned to be executed and EMPIT is searching for eligible test lines at the moment. Lastly, the use of new measurement com-

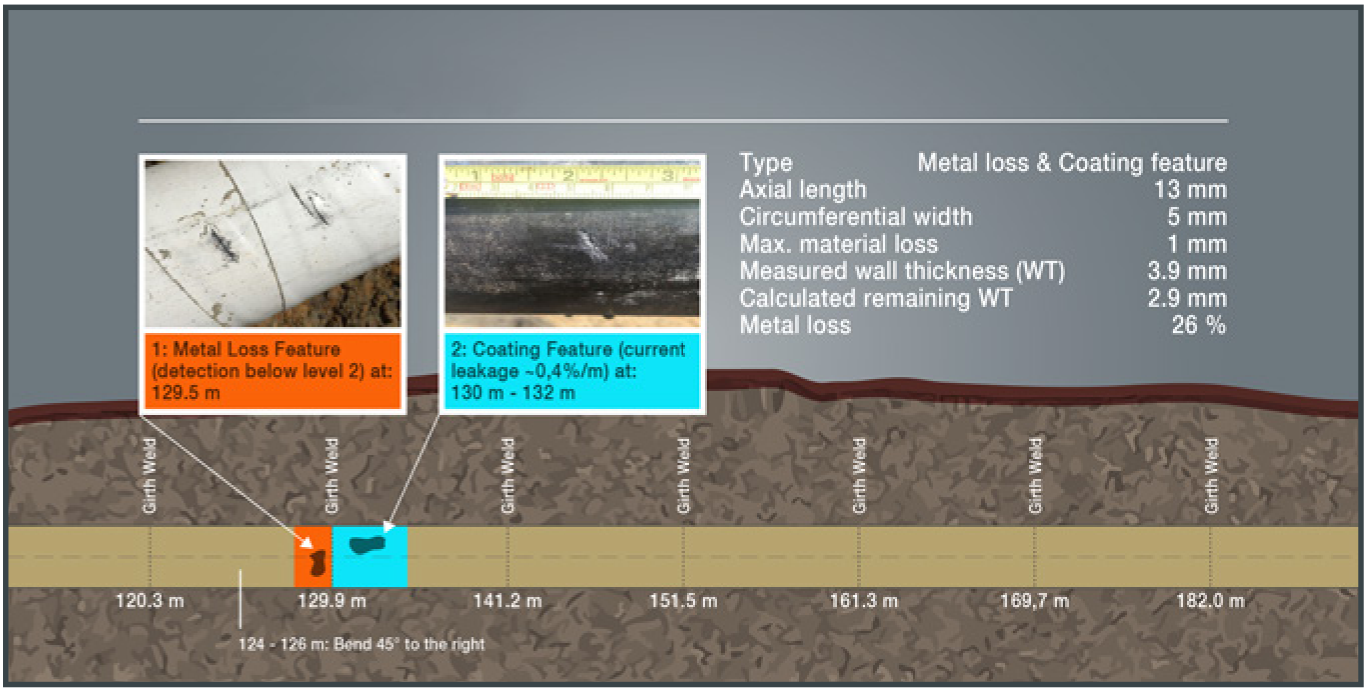


Figure 5: A sample of recently detected defects

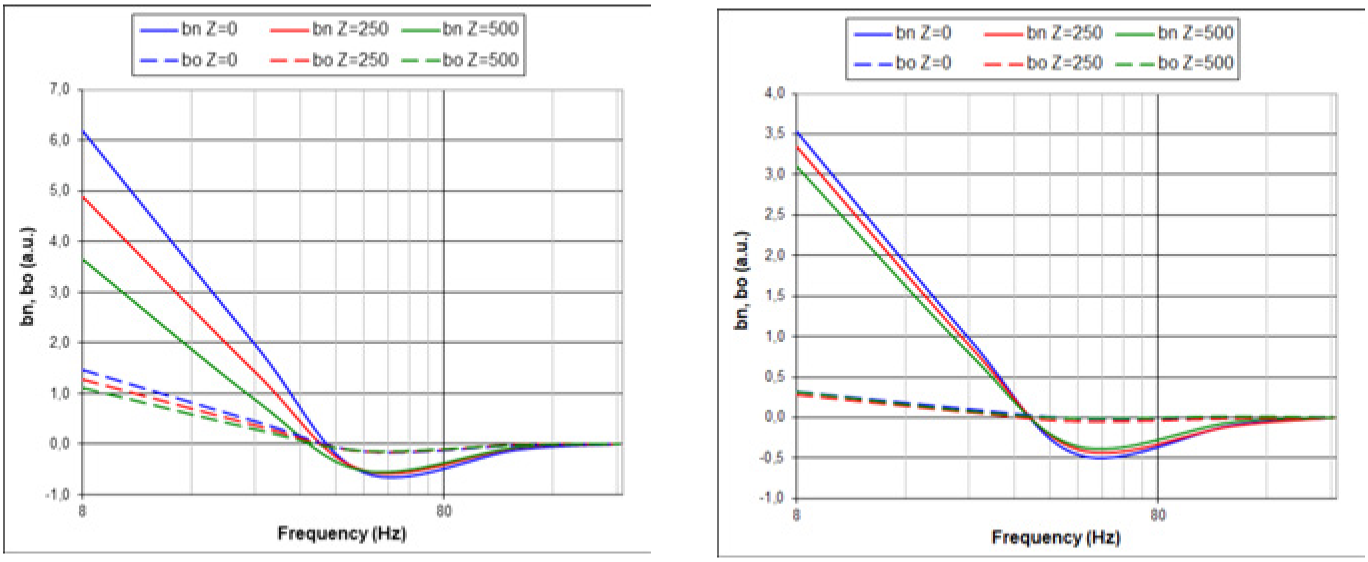


Figure 6: Output parameters b (bn for the "new" and bo for the "old" variants) of the AGIT system for different values of pipe depth: (a) 1m, and (b) 1.5 m

ponents promises a reduction of the needed measurement time per meter and leads to a better productivity of inspections.

CONCLUSION

AGIT is an above-ground inspection technique, which is currently used on gas, oil, fuel, and water pipelines. It is a technique built for challenging pipeline diagnostics whilst remaining truly non-destructive. The transportation of the product through the pipeline can continue normally during an inspection. The preparation for the AGIT inspection is simple and does not require cost-intensive launches and the prior cleaning of pipelines. The best sensitivity of the AGIT method can be achieved under field conditions for buried pipelines which depth is below 1.5 m. The detection of defects does not depend on their clock position.

Modelling of the magnetic field around the pipe, with defects and later simulation of the response of the currently used and further developed AGIT system, have shown that the new configuration of the inspection system will be more sensitive to smaller defects and allows to develop clustering of metal loss faults in terms of their dimensions.

The authors would like to thank their colleague Alexander Kroll for the great dedication and involvement in 3D modeling of the magnetic fields around the pipe.

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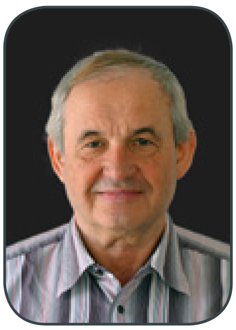

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SIMPLIFICATION IMPROVES BATCH-TRACKING ACCURACY IN PIPELINE WITH SLACK CONDITIONS

Michael Twomey > Atmos International; **Giancarlo Milano** > Atmos International

ABSTRACT

A "lean model" that minimizes uncertainties by simulating only the necessary characteristics for batch tracking proves to be more accurate than complex models that make a plethora of assumptions in attempting to model every single characteristic of pipelines with extreme elevation changes and slack.

Energy supply chains require energy companies to transport crude oil from oil fields to refineries and refined products to regional depots. A recent report by the National Academies of Sciences, Engineering and Medicine (NASEM) found pipelines and barges to have more comprehensive safety systems than train transportation systems. Pipelines are preferred over trains and trucks in the transportation of crude oil and batched products not only because they are safer but also because they are efficient, cost-effective and cause less pollution.

Despite the significant transportation advantages of pipelines, permitting, protests and politics make it hard to add to the pipeline infrastructure not only in North America but virtually everywhere around the world. This capacity shortage keeps our multi-products fully operational, pumping millions of barrels of fuel, the energy-blood of the world economy, to most corners of the earth. To meet the rising demand, pipeline operators must juggle the limited capacities of pipelines and tanks to optimize the quantities of products pumped and minimize the volume of each product wasted when injecting product into a pipeline and delivering products to different tanks along pipeline routes. Understanding the exact positions of transmix volumes (contaminated volumes between consecutive batches of disparate quality) helps reduce waste by cutting only transmix from a batch when delivering to a tank.

When transporting multiple products in a pipeline, it is essential to always know the location of the head and tail of each batch.

The operator, informed on where batch interfaces are in real-time, will be ready to swing the valve at the exact time a batch arrives at a station to deliver product to the right storage tank or an end-customer with minimal contamination. The commercial department can use the accurate visual display of batch locations to optimize sales revenues.

It is relatively easy to track multiple batches in a pipeline with no elevation changes, and a fixed internal diameter. However, it is far more complicated to track multiple batches in a pipeline with drastic elevation changes and many different sizes in diameter. Column separation of the liquid, also known as slack, occurs when the pipeline pressure drops below the vapor pressure calculated at the liquid temperature in a specific area of the pipeline. This effect reduces the amount of liquid volume contained within the pipeline segment, changing the physical position of the batch head and tail interfaces, and affecting the accuracy of the corresponding Estimated Times of Arrival at upcoming stations. Draining or filling a pipeline section by delivering product at a higher rate than injected, or vice-versa causes the same effect.

A scientific approach calculates the areas of slack and volume contained within a pipeline and provides sufficient information to track batches with a high degree of accuracy. However, it is neither simple nor straightforward to simulate this phenomenon offline, and it is much more challenging in an online, real-time environment.

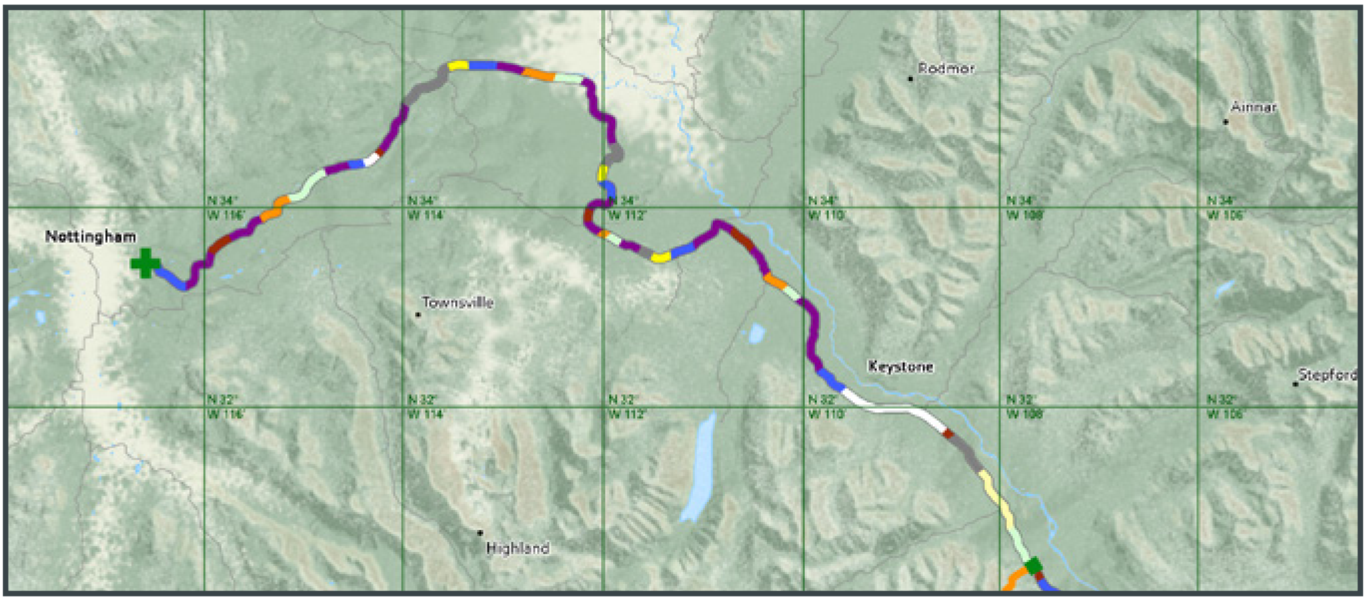

Image 1: Coordinated batch colors easily distinguish the products

In an online system, additional complexities can affect how batches and their interfaces are tracked, causing considerable discrepancies between Estimated and Actual Time of Arrivals.

Atmos International this year successfully implemented a batch tracking system using an empirical approach to calculate the volume contained within a pipeline segment by tracking the volume entering and leaving that segment.

Estimated and Actual Times of Arrival are within a 15-minute time window after a batch traveled over 1,000km (621 miles) in a pipeline with drastic elevation changes along its route.

This method has proven that batch tracking can be highly accurate and reliable with less of the theoretical assumptions used in a hydraulic simulation package, with no need to model every single characteristic of the pipeline in detail. This technique removed the uncertainties that attend those unnecessary assumptions and allowed this system to perform well on a pipeline with a severe slack flow region, and periodic draining/filling operations.

The "lean model" solution, already deployed on several pipelines around the world and has been operational for well over a year, supporting product shipments on one of the most complex pipelines in North America. This new solution has proven to be far more robust and accurate than other systems that depend on highly complex pipeline models.

SWINGING VALVES WITH CONFIDENCE

Atmos Batch assures operators of the location of the head and tail of every batch with a high degree of accuracy in a multiple product pipelines in real-time and gives them the confidence to execute valve swings at the exact time a batch arrives at its destination. Other features include;

- Real-time calculation of the batch 'Head' and 'Tail' positions reported in distance and volume units from main inlet
- Real-time Estimated Time of Arrival to all subsequent stations or points-of-interest along the route
- Real-time distance from main injection and real-time distance to all subsequent stations or points-of-interest
- Real-time volume from main injection and real-time volume to all subsequent stations or points-of-interest
- Works on bi-directional pipelines
- Unaffected by changes in pipeline conditions, such as stoppage, restart, or flow reversal
- Calculates and tracks product mixing interfaces between products of different properties and qualities
- Smart automatic batch-scheduled import tool via OPC
- Smart manual batch-scheduled import tool via CSV or user interface
- Controlled delivery of fungible products
- Real-time tracking of drain/fill volumes
- Real-time tracking of slack volume in regions with significant elevation changes
- Comprehensive, intelligent reports for arrival, custody, and inline content

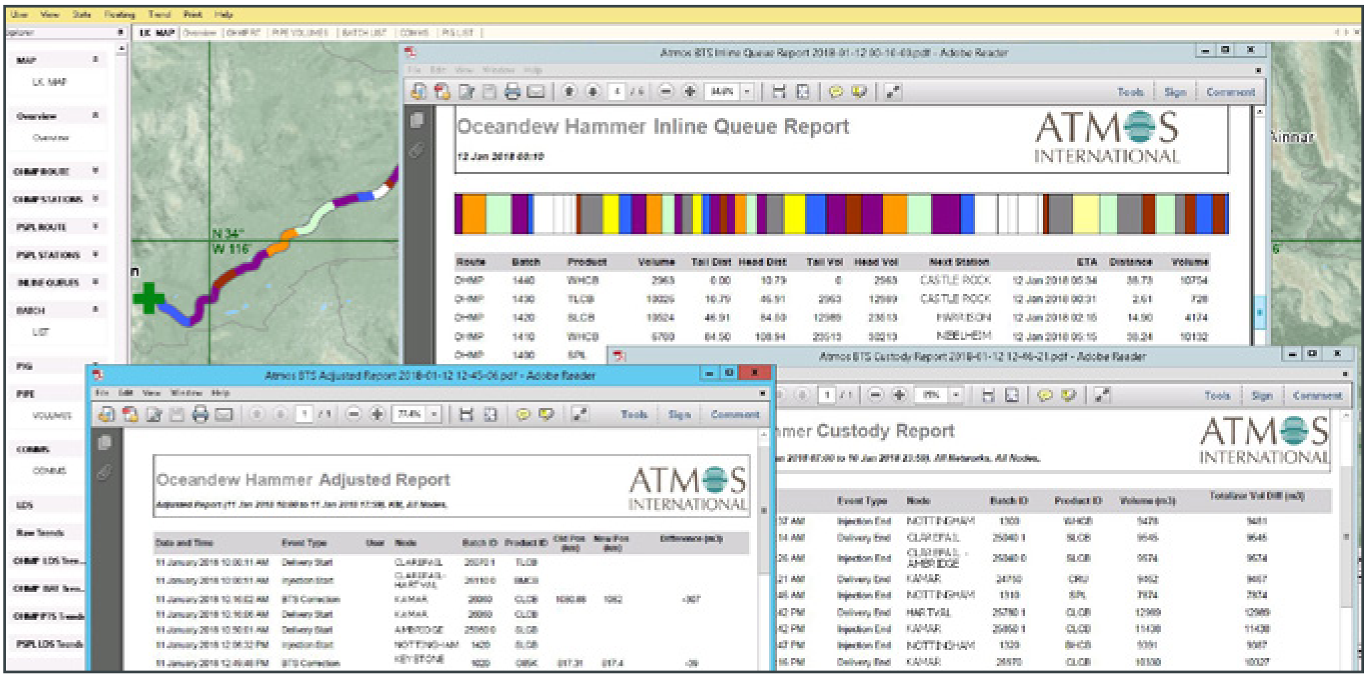

Image 2: Comprehensive reports make the operator's tasks easier

> *"A "lean model" that minimizes uncertainties by simulating only the necessary characteristics for batch tracking proves to be more accurate than complex models that make a plethora of assumptions in attempting to model every single characteristic of pipelines with extreme elevation changes and slack.*
> *Michael Twomey*

The lean-model technology uses flow measurements and flow totalizers to calculate the volume of fluid injected and delivered and can identify batch injections and deliveries from many indicators, such as an operator decision, valve movement, or other instrumentation changes. The system uses the physical volume of the pipeline and fluid velocity to estimate the time of arrival of each batch at subsequent stations.

With the planet currently experiencing extreme and drastic weather changes not seen before from season to season, users need to manually adjust the pipeline internal volume based on predetermined assumptions to correct for ambient temperature conditions. Atmos Batch Tracking System makes it easy for a user to make these manual temperature-volume corrections.

A change in density at a station can signal where batches begin and end. Interface detectors or colorimeters can also confirm batch changes, especially when dye is added to separate the interfaces.

The system uses information such as in the following examples to track the positions of batches accurately:

- Internal diameter and length
- Flow rate and totalizer readings for every injection and delivery along the pipeline route
- Recognition of start and end of batch injections and deliveries from operational conditions and SCADA/DCS signals such as, but not limited to:
    - o Valve movements and alignment
    - o Density readings from dedicated instrumentation
    - o Color dye recognition by dedicated interface detectors
    - o Manual inputs from the controller using the Atmos Batch-tracking user interface
- Scheduled volumes, flow rates, and estimated time of injections and deliveries (optional)
- Pipeline ambient temperature-volume correction reference table (optional)

The operations team can access every report needed to compare and review the progress of current and past batches via the intuitive reporting tool.

POWERFUL SIMULATION ENGINE

This batch tracking system takes advantage of a real-time transient model to optimize its accuracy as operating conditions change. The batch-tracking can be configured as a full model, or as lean, in-compressible model, depending on the industry, operation, and fluid type.

A unique Maximum Likelihood State Estimator (MLSE) uses available flow and pressure data to provide a highly-accurate calculation of the hydraulic and compositional properties of the products in a pipeline in real-time, while the Tuning Assistant keeps the model as close to reality as possible.

The model calculates hydraulic information related to the current process and inline content of the pipeline and displays the information together with the corresponding maximum and lowest allowable pressure and head pressure, calculated pressure, dynamic head pressure, and elevation concerning the pipeline distance profile.

The batch tracking system gets the data from the SCADA or DCS, or directly from the PLCs and RTUs

Sensors used

- Flow meters at inlets and outlets of the pipeline
- Flow totalizers at inlets and outlets of the pipeline
- Batch ID, and Product ID at injections and deliveries. Typically associated with flow instrumentation (optional)
- Pressure sensors (optional).
- Density meters, and optical interface detectors, colorimeters (optional)
- Valve and pump status (optional)
- Ambient temperature sensors (optional)

System outputs

- Batch and product identifiers
- Batch head and tail location color-coordinated per product type by distance and volume
- ETAs to subsequent stations and any intermediate point, including points without instrumentation
- Product volume between the launcher and the pig, the pig to the receiver, and the pig to any intermediate

point, including points without instrumentation
- Arrival distance alarm
- Arrival time alarm
- Arrival volume alarm
- Scheduled/upcoming batch injection/delivery time alarm
- Actual arrival alarm
- Interface tracking and volume growth
- Historical archiving and reporting of Actual Time of Arrival for every batch
- Arrival, custody, and inline reports in PDF, CSV, and excel format
- Automatic generation of inline report in CSV format for a specific time and location for accounting purposes

CONCLUSION – LESS IS MORE!

The success of this lean-model batch tracking system on the pipelines where it is installed and particularly on the 1,000-km (621 miles) long, multidiameter pipeline with slack line conditions proves that less is indeed more. An empirical approach that calculates the areas of slack and volume contained within a pipeline without introducing unnecessarily assumptions and their attendant uncertainties provides sufficient information to track batches with a high degree of accuracy. The reduced complexity minimizes the system maintenance costs. Estimated and Actual Times of Arrival are within a 15-minute time window after a batch traveled over 1,000-km (621 miles) in a pipeline with drastic elevation changes along its route.

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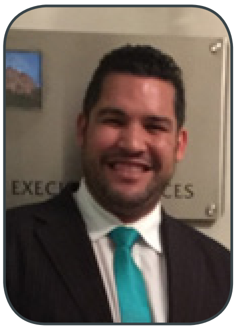

CHALLENGES WITH CO_2 EOR PRODUCTION PIPELINES

Ivana Kalicanin > INA - Industrija nafte

Figure 1: Inserted HDPE (High Density Polyethylene) pipe in production line

ABSTRACT

Enhanced Oil Recovery (EOR) technology with injection of carbon dioxide (CO^2) in production oil fields become common method of oil recovery increase. From the first commercial CO^2 EOR injection project on the Kelly-Snyder Field in West Texas past more than 45 years.

However, there can be significant corrosion management challenges resulting from planned CO_2 EOR projects in relation to new and specially existing oil and gas production infrastructure and specially production pipeline systems.

In this paper it would be given sort review of different approach to pipeline protection due to increasing carbon dioxide contribution in production. Company INA implemented EOR method of injection CO_2 in production area Ivanic and Žutica oil fields in northern Croatia for several years. Several method of corrosion protection was implemented during this period of production.

INTRODUCTION

Enhanced Oil Recovery (EOR) technology with injection of carbon dioxide (CO_2) in production oil fields become common method of oil recovery increase. From the first commercial CO_2 EOR injection project on the Kelly-Snyder Field in West Texas in 1972 past more than 45 years [1].

Today, they are nearly 50 CO_2 transportation pipelines with length of over 7.000 km just in USA. Also, recently completed two long distance CO_2 pipelines – the Green Pipeline in Louisiana and Texas and the Greencore Pipeline in Wyoming and Montana [2].

There can be significant corrosion management challenges resulting from planned CO_2 Enhanced Oil Recovery (EOR) projects in relation to new & existing oil and gas production infrastructure.

Dry CO_2 is not corrosive to metals and alloys. However, presence of water containing produced fluids severe corrosion of the infrastructure may results due to the formation of carbon acid.

Corrosion of materials in contact with CO_2 – containing fluid is dependent on various factors. These include:

- Concentration of CO_2
- Water chemistry
- Operating conditions
- Material type

Many mitigation methods have been implemented. However, as implementation of enhanced oil recovery method is started including increasing temperature, pressures and varied produced fluids compositions are explored, the corrosion performances of existing and new materials need to be assessed.

FUNDAMENTS OF CO^2 CORROSION

For the beginning, it should emphasize that term CO_2 corrosion and the effect of CO_2 is not related to one mechanism only. A large number of CO_2 dependent chemical, electrochemical and mass transport processes occur simultaneously on the close to the corroding steel surface.

Some fundaments of CO_2 corrosion is presented in next few sections. [3]

When CO_2 is dissolved in water it is partly hydrated and forms carbonic acid:

$$CO_2 + H_2O \leftrightarrow H_2CO_3$$

Carbonic acid is diprotic and dissociated in two steps:

$$H_2CO_3 \leftrightarrow H+ + HCO_3-$$

$$HCO_3- \leftrightarrow H+ + CO_3^{2-}$$

The resulting pH is a function of the CO_2 partial pressure.

When the steel corrodes, Fe^{2+} and an equivalent amount of alkalinity are released in the corrosion process.

$$Fe + 2H_2CO_3 \longrightarrow Fe^{2+} + 2HCO_3- + H_2$$

The pH in the solution increases and when the concentrations of Fe^{2+} and CO_3^{2-} ions exceed the solubility limit, precipitation of $FeCO_3$ can occur:

$$Fe^{2+} + CO_3^{2-} \longrightarrow FeCO_3$$

When solid $FeCO_3$ is formed at the same rate as the steel corrodes, the pH becomes constant in the corroding system.

The mechanism of carbon steel corrosion in a CO_2 containing environment has been studied and debated for many years. It is developed a number of prediction models to take account of the various parameters that determine the corrosion rate.

Research institutions and oil companies have developed a large number of prediction models for CO_2 corrosion of carbon steel. Models are often rely on companies field experience and conditions of each specific project so usually is not suitable for other projects.

On the other hand, several models are mainly based on empirical correlations with laboratory data and less to field conditions. Just to mentioned few of them: De Waard Model, Norsok M-506 Model, Hydrocor, Corplus and many others. [4]

A group of corrosion experts from different oil companies has prepared guidelines for use of CO_2 corrosion prediction tools. A methodology for defining the likelihood of corrosion and the impact of CO_2 prediction is developed in this brochure [5].

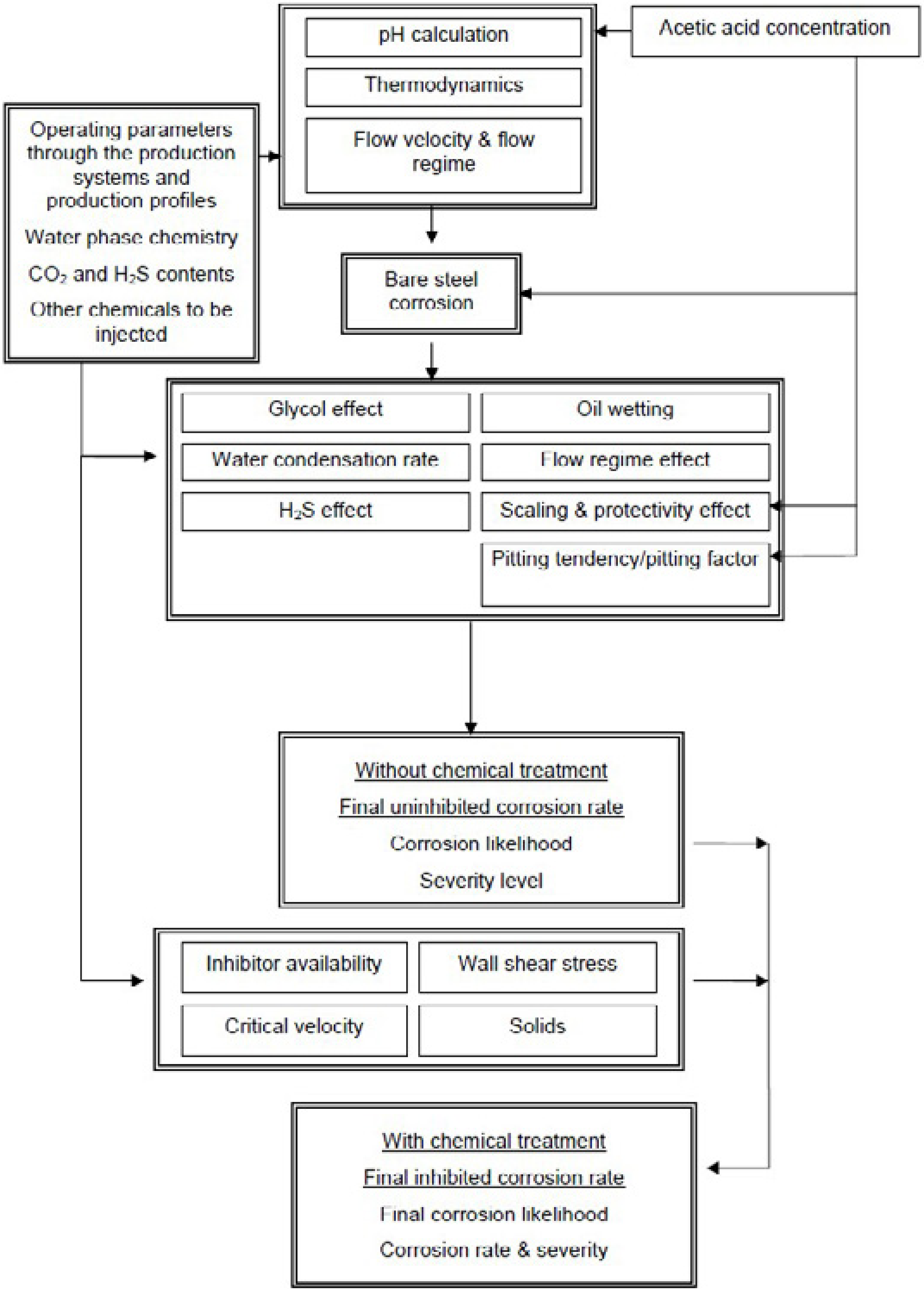

Figure 2: CO2 corrosion prediction diagram [5]

Corrosion prediction models help corrosion engineers to make decisions for the design of oil and gas production and treatment facilities.

The objective is to predict the order of magnitude of the CO_2 corrosion rate, including localised corrosion.

When we are talking about implementation of EOR projects, the main task is corrosion protection of downwhole equipment as most vulnerable location for corrosion appearance. On the other hand, production lines with surface process facilities should be also carefully monitored.

Prediction models may be categorised as either being mechanistic or empirical. Mechanistic models take chemical, electrochemical and transport processes into account. Empirical models lie down on simple empirical correlations.

For good results of prediction models it needs laboratory testing and field data for calibration.

CORROSION PROTECTION OF PRODUCTION PIPELINES

The enhanced oil recovery projects of oil fields are usually tertiary phase of long life of oil fields. There is no such project that could survive cost benefit analysis with calculations of new downwhole equipment and all surface facilities.

It should be done detailed screening of existing equipment with field's measurement to determine corrosion state before preparing final cost analysis. Although, corrosion protection on the oil field exist from beginning of production life. There are different kind of protections like cathodic protection and inhibition of corrosion protection chemicals. That is part of daily basis maintenance. However, during EOR projects corrosion caused by elevated carbon dioxide is increasing.

There are many studies that gives results of EOR monitoring data. The time of increasing CO_2 during the period of injection is generally 12 – 18 months from the initial injection of CO_2 , as shown in Figure 3. [6]

It is clear that once the injected CO_2 gas comes out from production wells, its concentration will sharply increase from few percentage to very high valued of even more than 70%. In that case, the corrosion rate can increase rapidly.

Complex projects, as implementation of EOR usually consist of various list of new facilities like new CO_2 lines, CO_2 compressor unit, membrane separation units and so on.

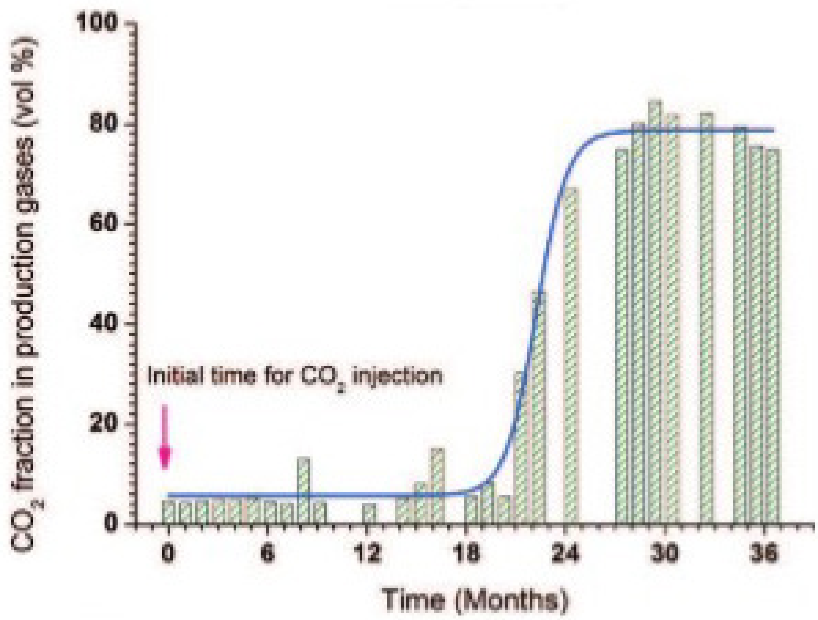

Figure 3: Long-term monitoring of CO2 fraction in production [6]

Figure 4: Fiberglass pipes

Figure 5: Different types of spoolable pipes

Common practice is to change part of existing pipeline system in area that was already detected corrosion problems, with or without fluid leakages. The main question is what kind of material should be used. Except changing existing steel pipes with new ones, there is also different kinds of pipelines rehabilitation. [7]

One of them is installation of composite pipes instead of steel ones. It is especially suitable for water injection systems on production fields.

Rehabilitation of production pipelines inserting pipes – High Density Polyethylene, spoolable re-enforced fiberglass or other inner liners is also common practice.

HDPE pipes with re-enforcement of fiberglass or steel lines from different producers is shown in Figure 5.

The only negative aspect of such rehabilitation is reduction of pipeline inner diameter. It should be very carefully when to choose which pipeline would be suitable for such work. The main goal of EOR projects are increasing of fluid production. The last thing we need is bottleneck situation in production pipeline system.

EOR PROJECT IN CROATIA

Enhanced oil recovery on production oil fields Ivanic and Zutica in northern Croatia was implemented after several years of research, laboratory testing, pilot – project and numerical simulations. Many different specialists were worked on preparing this complex project, especially it was first implementation in Croatia.

Also, during first stage of project it was constructed several new facilities like CO_2 dehydration unit, cooling tower, pumps station and others. It was installed pipelines network from 2 – 8" pipelines in length more than 40.000 meters including CO_2 8" collector pipeline. [8] On the same time it was reconstructed with different rehabilitation methods more than 25.000 meters of existing production lines one both oil fields. Rehabilitation was done with all methods that was described – HDPE rehabilitation of production lines and reconstruction of water injection lines with fiberglass pipes.

Few years ago two main production pipelines were rehabilitated with fiberglass re-enforced pipes.

CONCLUSION

Enhanced Oil Recovery (EOR) technology with injection of carbon dioxide (CO_2) in production oil fields become common method of oil recovery increase.

There are significant corrosion management challenges resulting from planned CO_2 EOR projects in relation to new and specially existing oil and gas production infrastructure and specially production pipeline systems.

Many different corrosion protection models can help corrosion engineers to achieve acceptable level of protection during increasing of CO_2 concentration in production lines.

Company INA successfully implemented different kind of corrosion protection methods including rehabilitation of production lines with non-steel materials.

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Figure 6: CO2 injection well – oil field Ivanic

OFF-LINE INTERNAL INSPECTION OF PIPELINES – AN IMPORTANT TOOL FOR INVESTMENT DECISIONS

Aleš Brynych > CEPS a.s.

Figure 1: Launching/receiving pig trap

ABSTRACT

A natural gas leakage was detected on the unpiggable high-pressure DN 600 pipeline Kasejovice – Mikulášov in Czech Republic after 50 years of operation. The pipeline was excavated and found to suffer from extensive corrosion; corrosion of a similar extent was also found when another section of the pipeline was excavated on the same location. The operator therefore decided to carry out inspection on a representative 15 km section in order to check the actual condition of the pipeline system and, based on its result, to determine further procedure for repair or renovation. Conventional in-line inspection during operation was not feasible on this pipeline section, and therefore the inspection was carried out "off-line". An ultrasonic inspection tool was propelled through the pipeline section with a controlled speed by water.

Figure 3: A composite-filled steel sleeve on a pipe

CEPS provides a comprehensive portfolio of pipeline services and pipeline integrity services needed during pre-commissioning, commissioning, decommissioning, shut-down, repair and rehabilitation as well as pipeline abandonment works.

In the field of internal inspections CEPS provides propelling of ULTRASONIC, MFL, TFI and any other inspection tool in the pipeline when the flow of transported medium is insufficient or medium is not available. Our company uses water or combination of water/air as the substitute propelling medium and assure constant inspection tool velocity so that the operator gets high quality inspection data. This method also enables ultrasonic inspection of gas pipelines. CEPS provides turn-key solutions of off-line inspections, design, and manufacturing of temporary launching /receiving traps.

The course of standard off-line inspection carried out by CEPS is described in the following.

Figure 2: DN 600 pipeline corrosion

CAUSE OF THE GAS LEAK – GENERAL CORROSION

The natural gas leakage was detected on the DN 600 high-pressure gas pipeline Kasejovice-Mikulášov in spring 2016 in South Bohemia near village Čížová. The pipeline segment was excavated and extensive corrosion damage was discovered (see Fig. 2). Subsequently, another preventive excavation found a similar corrosion damage of the pipeline nearby. Both corrosion defects were repaired using composite-filled steel sleeves (see Fig. 3).

The pipeline was constructed mainly from spiral welded tubes (630 x 7 mm, made of Czech steel similar to L 245 NB) bituminous coating reinforced with glass fibres. This type of pipeline hadn't shown any corrosion defects signs at the locations inspected in the past.

The longitudinal welded pipes (630 x 8 mm, made of Czech steel similar to L 245 NB) were used in locations with difficult accessibility and for production of cold bends only. Jute-bituminous coating was applied on site manually.

20 m long pipeline segment was excavated in the location where the gas leakage was detected and pipes of the both types were found.

As expected, the coating of spiral welded pipes was in good condition. On the contrary, the coating of bends was in a bad condition. Removal of the coating revealed several general corrosion spots. In addition to that, almost zero cathodic protection potential was detected in the location. Therefore, it was concluded that the cause of the corrosion and the resulting gas leak were poor quality coating of the bends together with very low cathodic protection potential.

A REPAIR OR EVEN A REPLACEMENT?

Based on the corrosion damage findings, the operator was seeking answers to the following questions:

- What is the actual extent of the corrosion at the DN 600 gas pipeline?
- Is the corrosion damage present only in this single location or are there more corroded spots?
- Are there also different types of defects present? How many and where?
- Are they worth repairing?
- Would it not be better to replace by new one?

The pipeline was not designed for ILI. That is why an alternative solution had to be found. A solution that answered the operator's questions turned out to be off-line ILI of a representative DN 600 pipeline section. As a suitable pipeline inspection tool a UT tool with metal loss sensors and a mapping module was selected.

DEFINITION OF A REPRESENTATIVE SECTION FOR ILI

The pipeline operator selected 15,4km section between Borečnice and Sedlice shut-off valves for the ILI. This segment contained the original leak spot near Čížová, see fig. 4. The route started near the Otava river and ran through uninhabited little developed countryside towards the village Sedlice. The DN 600 pipeline was designed as unpiggable. Therefore, it was not equipped with either launching or receiving pig traps.

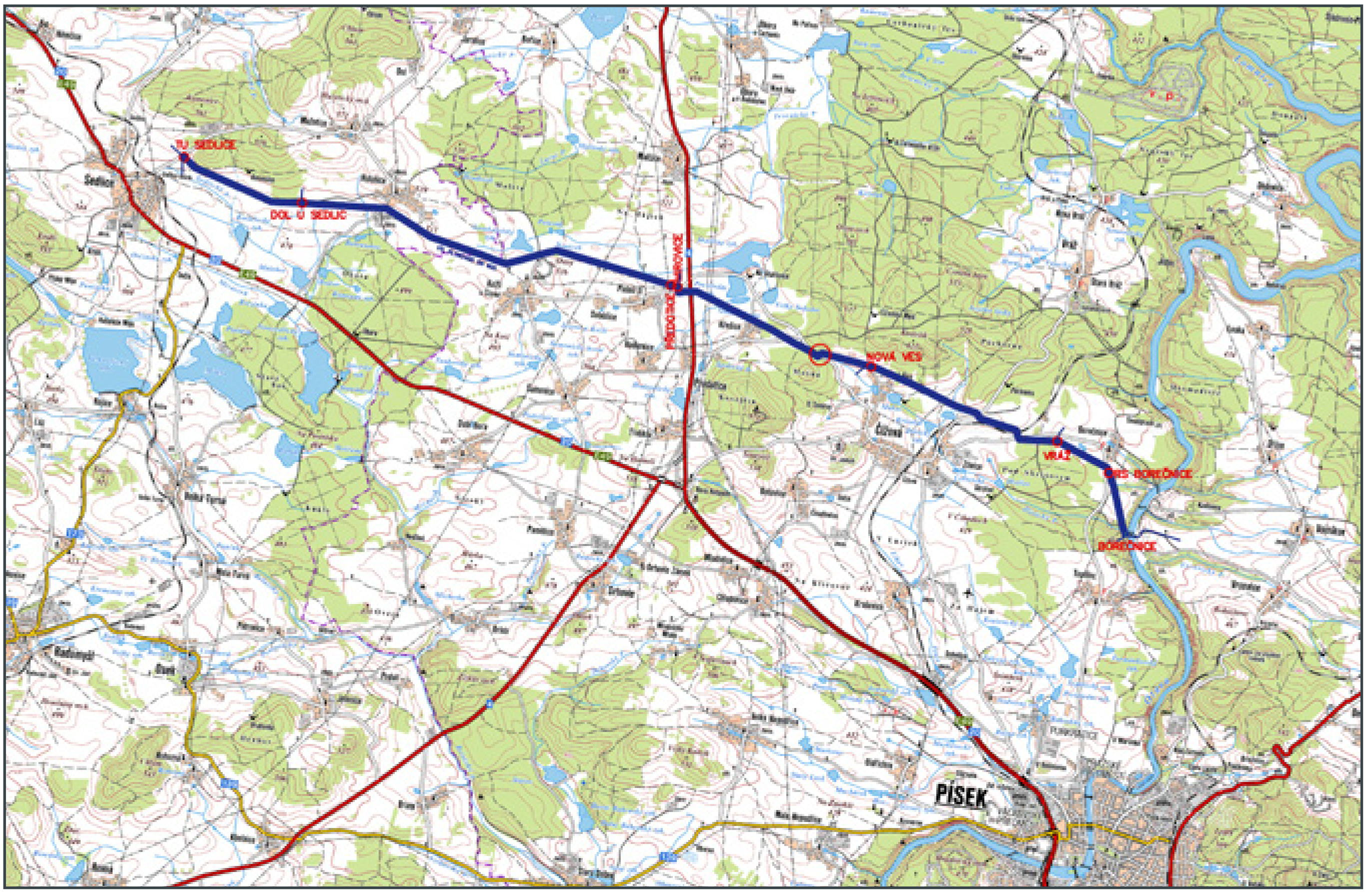


Figure 4: The pipeline route

SCHEDULE OF WORK

Prior to the ILI, the pipeline section had to be put out of operation – isolated from the network. These required earthworks in several locations, and construction of temporary access roads to the job sites after obtaining permits from the local authorities. The ILI tool was supplied by a subcontractor. Based on the dimensions of the ILI tool, temporary launching and receiving traps were designed and manufactured. The described preparatory work started two months before the inspection tool run.

Overall, the whole job comprised the following subsequent stages:

- Property access permits,
- Design and manufacturing of the temporary pig traps
- Cathodic corrosion survey by Pearson method
- Access roads construction
- Earthworks in the locations of planned DN600 pipeline disconnections and in the branching locations
- Provision of a temporary gas supply to the affected end-users by means of CNG trucks
- Disconnection and blinding of branch pipelines and isolating of inspected pipeline section
- Shutting-down the inspected pipeline section
- Mechanical cleaning and gauge pigging of the pipeline section
- Chemical cleaning of the pipeline section
- A controlled run of a calliper pig propelled by air through the pipeline segment
- A controlled run of the UT (+MAPPING) ILI tool propelled by water
- Drying of the pipeline section
- Interconnections of branches and putting the section in operation

Figure 5: A gauging pig

PRE-INSPECTION PIPELINE ASSESSMENT – EXAMINATION OF PIGGABILITY

The pipeline section was shut–down and isolated from the network. Afterwards, it was put out of service using nitrogen inerting mixture produced on site. Subsequently, the cutting works were done and the pig launching and receiving traps were welded to the ends of the pipeline section.

The pipeline was cleaned by a gauging pig equipped with a pig tracker. A diameter of an aluminium plate fitted to the pig had been defined by the ILI subcontractor. Approximately 2 dm3 of debris were removed. All the segments of the aluminium plate were deformed after the run, see fig. 5. Nonetheless, neither cuts nor scratches were present. After examination of the aluminium plate, the ILI subcontractor approved to proceed with a calliper pig run.

Figure 6: A calliper pig run

The calliper pig was propelled by compressed air see fig. 6. Based on the calliper pig data the ILI subcontractor confirmed that there were no unacceptable geometric defects in the pipeline. Hence, the UT ILI tool run was approved.

CHEMICAL CLEANING

One day before the UT pig run, chemical cleaning of the pipeline segment was performed. A CEPS proprietary cleaning agent PETROSOL was used for the job. Tasks of chemical cleaning were:

- To remove residues of hydrocarbon condensate from the historical transportation of city gas were removed
- To remove a major portion of residual natural gas odorant.

The chemical cleaning prevented contamination of the water used for the UT pig run with hydrocarbons and the odorant.

OFF-LINE UT ILI

CEPS purpose designed, manufactured and installed special pig traps for launching and receiving the ILI tool, see fig. 1 at the Introductionpage and fig. 7. Water from the Otava River was used to propel the pig. After the inspection the water was drained back into the river stream. To maintain the velocity of the ILI tool above 0.5 m/s, as recommended by the tool supplier, the water pumping flowrate had to be at least 540 m3/h. During the inspection the whole pipeline section (4560 m3) was filled with water.

Figure 7: Launching/receiving pig trap

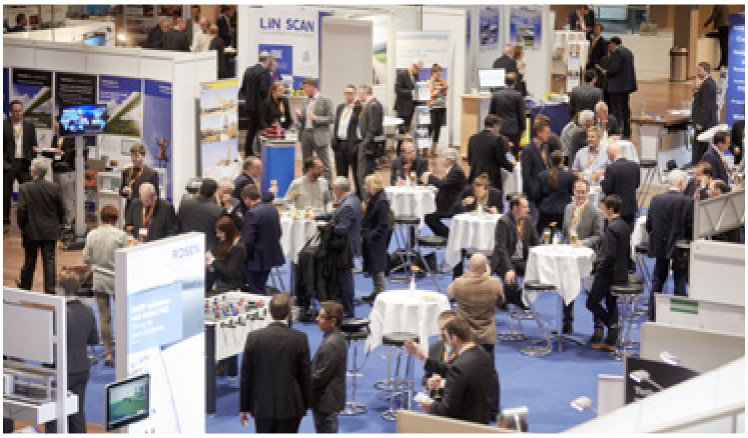
Water was pumped from the river into the pipeline indirectly. Low pressure pumps were feeding the water into two mobile container tanks. From the tanks water was pumped into the pipeline section by two parallel diesel-fuelled pumps FPMU 420/60 MARLY – max. flowrate 2x420 m3/h, max. discharge pressure 63 bar. The overall aerial picture of the job-site set-up is presented in fig. 8.

Figure 8: An aerial photo of the job-site

During the inspection run water was pumped into the pipeline at a flowrate of 175 dm3/s (630 m3/h) for nearly 7.5 hours. The following head loss components had to be compensated by the pumps' discharge pressure reaching up to 20 bar – elevation difference of the pipeline route, UT ILI tool's friction loss, air backpressure and hydraulic loss.

ILI tool velocity was recorded and is presented in fig. 9, which explicitly shows that the tool's velocity was stable and in an optimal operation range as recommended by the ILI tool supplier

After the ILI tool run the pig traps were removed and the inspection data were downloaded. An initial data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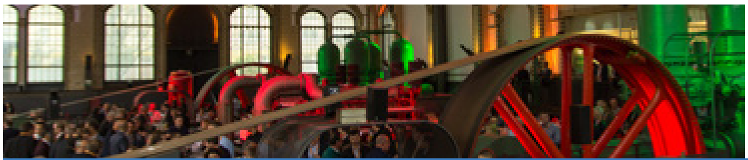

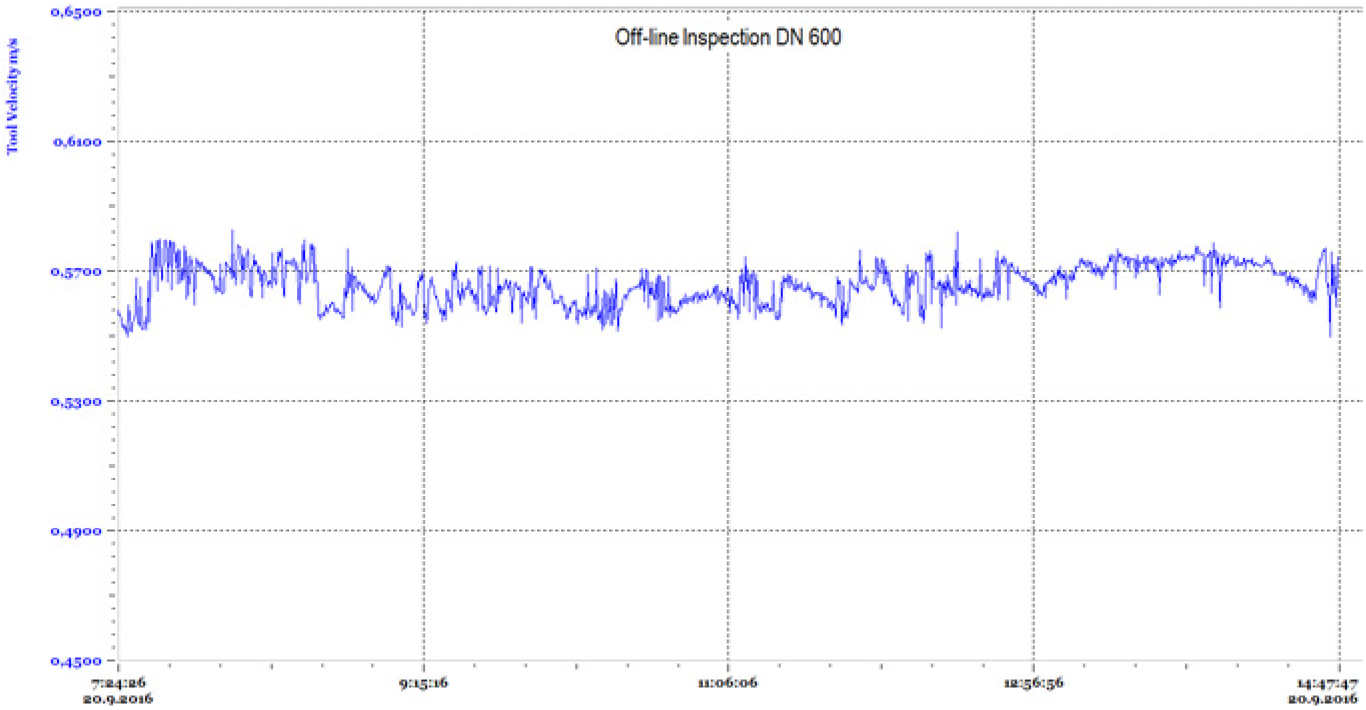

Figure 9: UT tool's velocity record

screening showed that the quality of the dataset was high enough for further processing and interpretation.

The first run of the ILI tool was, therefore, successful.

Figure 11: a photograph of the defect before the sleeve installation

PUTTING THE PIPELINE BACK INTO SERVICE

Twelve hours after the inspection tool run the water from the pipeline was drained back into the Otava River and pipeline drying was initiated. The drying was terminated when the dew point of water in air at the pipeline section outlet stabilized at -20 °C. The whole drying job took two days. The drying air was produced by a drying unit with an output flowrate of 3600 m3/h. The dry pipeline segment was re-connected to the pipeline network, filled with nitrogen inerting mixture and put into service

ILI DATA INTERPRETATION

After the inspection tool run, the downloaded data was analysed and interpreted. Corrosion defects already repaired with steel sleeves were not further considered as defects.

The results in the final report were compared to records of

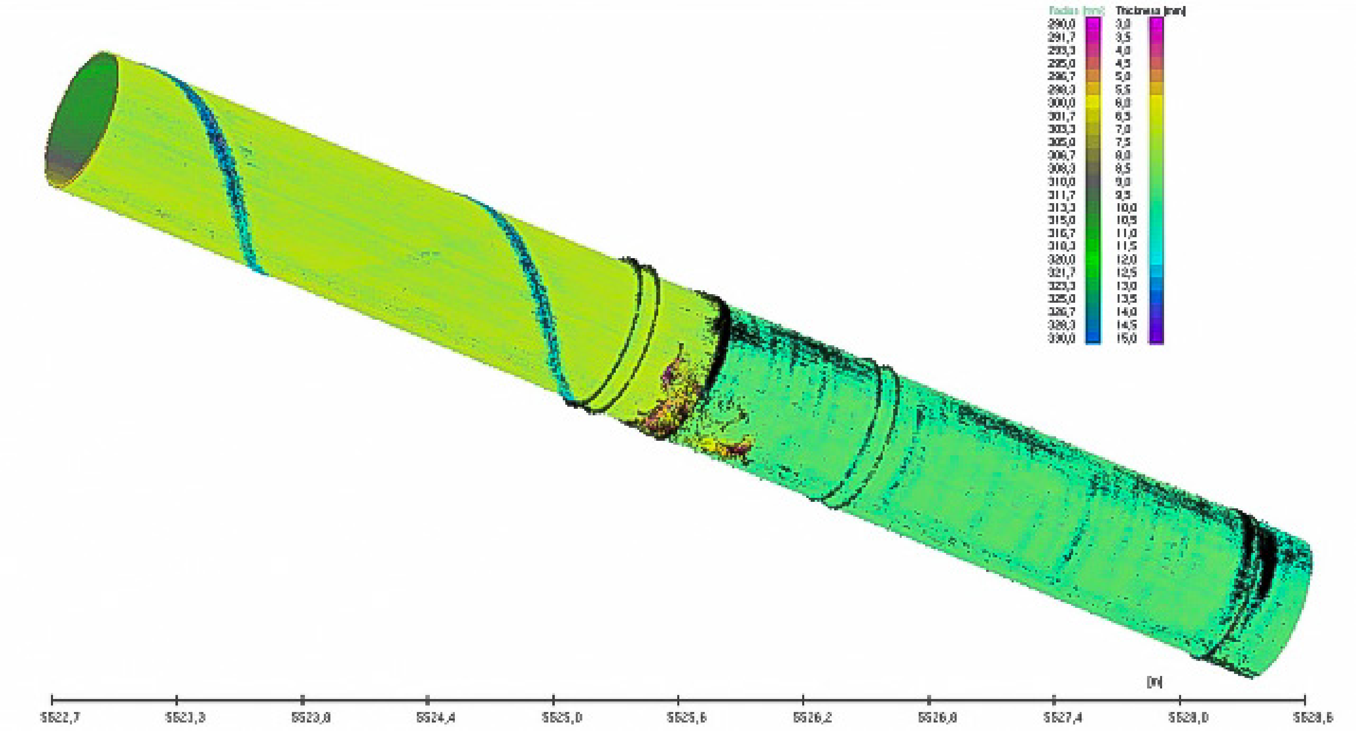

Figure 10: Visualisation of a defect repaired by a sleeve based on ILI data

past repairs of the pipeline section near village Čížová. As shown in fig. 10 and fig. 11 the defects detected by the UT tool matched the real pipe condition very well.

The operator might have thought that the situation was very critical based on the first look at the whole list of defects. In total, 525 defects were detected. However, a more detailed analysis revealed mainly minor manufacturing defects were present. Only 65 notable defects were filtered out and only 11 defects were recommended to be dealt with promptly. The critical defects were located mainly in the sections where the pipeline coating was installed manually during construction. Without considering several substantial dents from the pipeline construction, the pipeline segment was in relatively good condition and was evaluated to be suitable for repairs.

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CATHODIC CORROSION SURVEY

The corrosion survey, conducted by Pearson method, revealed 43 coating defects at the segment between Sedlice and Borečnice. The locations of the coating defects and the significant corrosion defects corresponded with each other only near the village Čížová. Based on this finding it was concluded that except that location the cathodic protection was sufficient along the rest of the pipeline.

CONCLUSION

The ILI results revealed severe general corrosion defects mainly in the location near the village Čížová. The rest of the pipeline was not significantly corroded. The operator obtained insightful answers regarding the actual pipeline condition, specifically, regarding class, number, severity and location of defects. In addition to that, exact locations of circumferential welds, off-takes, bends and sockets were obtained. Also a detailed pipe tally book was generated based on the ILI data. Based on the MAPPING unit data both vertical and horizontal pipeline profiles were calculated including exact geographical coordinates. According to the ILI data, corrosion survey and material tests a list of recommended urgent repairs was proposed. Also operation recommendations report was issued. By following the proposed practice, the pipeline section's operation lifetime should not be limited.

CONVERSION OF DN 400 OPATOVAC-SLOBODNICA OIL PIPELINE TO NATURAL GAS PIPELINE

Ivan Fugaš > Plinacro

ABSTRACT

Pipeline DN 400 Opatovac-Slobodnica of the total length of 105 km, was constructed in 1968 and its original purpose was to transport oil from Opatovac terminal to an oil refinery near Slavonski Brod, Croatia. When it was constructed it was made in five sections. Four of them was already converted to pipeline for natural gas transmission but the last and the most demanding section, of the total length of 5,5 km must be converted to a pipeline for natural gas transmission by the end of the year 2018.

The problems with this last section is that it is not in operation since the 1990, additionally it was damaged during the war for independence in Croatia, it is not cathodic protected and it's unpiggable so general conditions of pipeline is unknown, including the condition of coating. Also these section is not connected to Croatia natural gas transmission network and on pipeline route there is a river crossing, five road crossings and forest area of about 20.000 square meters grown on pipeline route over last 27 years.

In normal operation, the gas pipeline is a closed system that has no environmental impact. Gas quantities at the controlled discharge of an individual pipeline section are considerably reduced compared to the classic discharge method, so that the impact of gas on the environment has been reduced to a minimum.

INTRODUCTION

The pipeline DN 400 Opatovac-Slobodnica, was made of welded steel pipes material API 5L X52, diameter 406 mm, wall thickness of 7,1 mm. Since this is a short section there is only one block station (gate valve) near the river crossing and the valve is severely damaged so it needs to be replaced. The procedure for the conversion of pipeline is:

- determining the actual wall thickness of the pipeline
- determining the condition of the coating
- inspecting the pipeline for leakage and replacing damaged valve and all parts of the gas pipeline through which cleaning tools and intelligent inspection tools can't pass (miter bends).
- preparing pipeline for cleaning and intelligent inspection
- repairing all damaged parts of the gas pipeline established by IN-LINE inspection
- installation of cathodic protection
- clean the pipeline after all necessary pipeline repairs
- connecting the revitalized section of DN 400 Opatovac-Slobodnica pipeline to the Croatian natural gas transmission system.

The gas pipeline is designed in accordance with the applicable domestic laws and technical regulations and in accordance with the relevant domestic and foreign standards.

- Regulatory for technical conditions and standards for the safe transport of liquid and gaseous hydrocarbons by oil and gas pipelines and oil and gas pipelines for international transport (Croatian OG 53/91)
- ASME B31.8 – Gas Transmission and Distribution Piping Systems
- API 5L – Specification for line pipes
- API 6D – Specification for pipeline valves

PREPARING PIPELINE FOR IN-LINE INSPECTION

WALL THICKNESS AND PIPELINE COATING

In August 2017., there was excavations at 9 locations to determine the actual wall thickness of the pipeline. Locations are determined by at specific locations as nearby residential buildings, corrosive environment, river crossings, waterways, roads, and places of more intensive destruction during the war. We used ultrasonic technologies as a non-destructive testing to measure wall thickness. Every location was tested in four points on the pipe, mutually spaced by 90 °. Three measurements were made for each point, and the result is taken for the lowest measured value. Measured wall thickness ranges from 6.8 to 7.1 mm, and the average value in all points is 6.97 mm. This is 1.85% less than the rated wall thickness, and the lowest measured value is 4.2% lower than the nominal wall thickness.

The permissible tolerance for the built-in pipes is -12.5%. This would fit the wall thickness of 6.2 mm.

Since all the measured points of the wall thickness are considerably greater than the minimum permissible, it is to be expected that the gas pipeline at the full length of the wall thickness meets the conditions for a design pressure of 50 bar.

$$t = \frac{P \times D \times s}{20 \times k \times V \times T}$$

Formula 1: Wall thickness formula

t – wall thickness
P – design pressure
D - nominal outside diameter
s - design factor
k - specified minimum yield strength, for material API 5L X52 - 358 N/mm2
V - longitudinal joint factor
T - temperature derating factor

Figure 2: Holiday detector coating inspection

We measure corrosion depth (Figure 1) and a condition of coating with Holiday detector (Figure 2) Parallel with the wall thickness on the same location.

Figure 1: Measurement of corrosion depth

The next step was to inspect the pipeline for possible leakage. Considering the age of pipeline, all the bombing during the war and the fact that the pipeline is not been working for 18 years, a test pressure was set to 4 bar and a nitrogen was chosen as a testing media. During 8 hours of the testing, pipeline route was observed by foot to detect any possible leakage and to find possible locations where cleaning tools and intelligent inspection tools could not pass (miter bend). 8 locations were found for possible miter bends and we checked all of them excavation and 6 of them was positive for miter bend.

Since no pressure drop was detected during 8 hours, no leakage was found on the pipeline route and conclusion was that pipeline is ready for all preparation for pipeline cleaning; installation of pig traps, removal of miter bends and replacement of block valve.

MECHANICAL WORKS ON THE PIPELINE (PIG TRAPS, MITER BENDS AND BLOCK VALVE)

Pig traps on both ends of pipeline, launcher and receiver are design to have quick opening-closures, and to be operated by maximum two persons without using special tools. Pig traps had all standards equipment like open/closed door, drain, gas vent and pressure relief, kicker line, pressure gauge… and the size of pig trap was 100 mm (4") bigger than the rest of the pipeline. Both traps were fabricated in local factory and installed on site (Figure 3).

Figure 3: Installation of pig trap

Parallel with works on pig traps all 6 found miter bends are replaced with 5D bends and on that replaced sections recoating was done. Also all preparation for cathodic protection was done.

The pipes were ordered and replaced with API 5L X52, all the welding was done in accordance to HRN EN 12732:2014 (Gas infrastructure -- Welding steel pipework -- Functional requirements) and all welds were inspected radiographically under HRN EN ISO 17636-1:2014 (Non-destructive testing of welds -- Radiographic testing -- Part 1: X- and gamma-ray techniques with film).

Damaged block gate valve located right before the pipeline river crossing was also replaced with new above the ground block ball valve (in accordance with API 6D - Specification for pipeline valves), Figure 4.

Figure 4: Installation of ball block valve

With pig traps installed, all the miter bends remove and damage block valve replaced cleaning procedure of pipeline can finally start.

PIPELINE CLEANING

Before the IN-LINE inspection or inspection with smart tools, it was necessary to clean the pipeline from all impurities that could possibly damage the smart tool, or disable the tool inspection through the pipeline. Since the pipeline is not connected to the Croatian natural gas transmission network the cleaning and inspection was done with nitrogen. In the end, the pipeline was connected to a drain tank for all possible liquid impurities and oil products. The first few cleanings were done with foam pigs that brought a lot of impurities, such as pieces of wood, debris and pieces of steel and refinery oil. Each passage of the cleaning tools through the gas pipeline lasted for about 3 hours, and was performed at intervals of 4 times per week (Figure 5).

Figure 5: Spongy cleaner with impurities

CONCLUSION

In order to ensure safe and reliable natural gas transmission it was necessary to check a general condition of DN 400 Opatovac – Slobodnica gas pipeline. This was done by preparing the pipeline for the inspection with smart tools.

After IN-LINE inspection based on the given results Fitness for Purpose assessment will be made to quickly assess the results of the inspection and to identify and prioritize any features which may be an immediate threat to the integrity of the pipeline for remedial action.

After the foam pigs, cleaning process continued with classic BiDi scraping tool with magnets and tracking locator. As seen in the picture 6 tools brought liquid impurities and large pieces of steel tubes and rods. BiDi scraper was sent 15 times during cleaning operation. Also we did calibration of the pipeline with aluminium caliper plates, with a diameter of which equals 95% of the internal diameter of the pipeline pipe.

Figure 6: Impurities after BiDi cleaning

IN-LINE inspection is planned for April 2018 but from all the works and inspection that have been done so far, it is considered that there should be no major feature on this pipeline that could endanger project completion and prevent connection of pipeline DN 400 Opatovac – Slobodnica to Croatia natural gas transmission network and supply of natural gas to consumers.

With all the previous work and inspections that were very challenging, the 50 years old oil pipeline will be converted to natural gas pipeline. With the relevant re-assessment Company will save time and money otherwise it would be necessary to construct a new pipeline.

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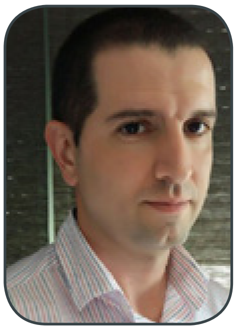


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Thank you for all your submissions!
The winner will be announced on the ptc at wednesday in
Room ECC1 from 10:00 to 10:30 and on the Ptc Website

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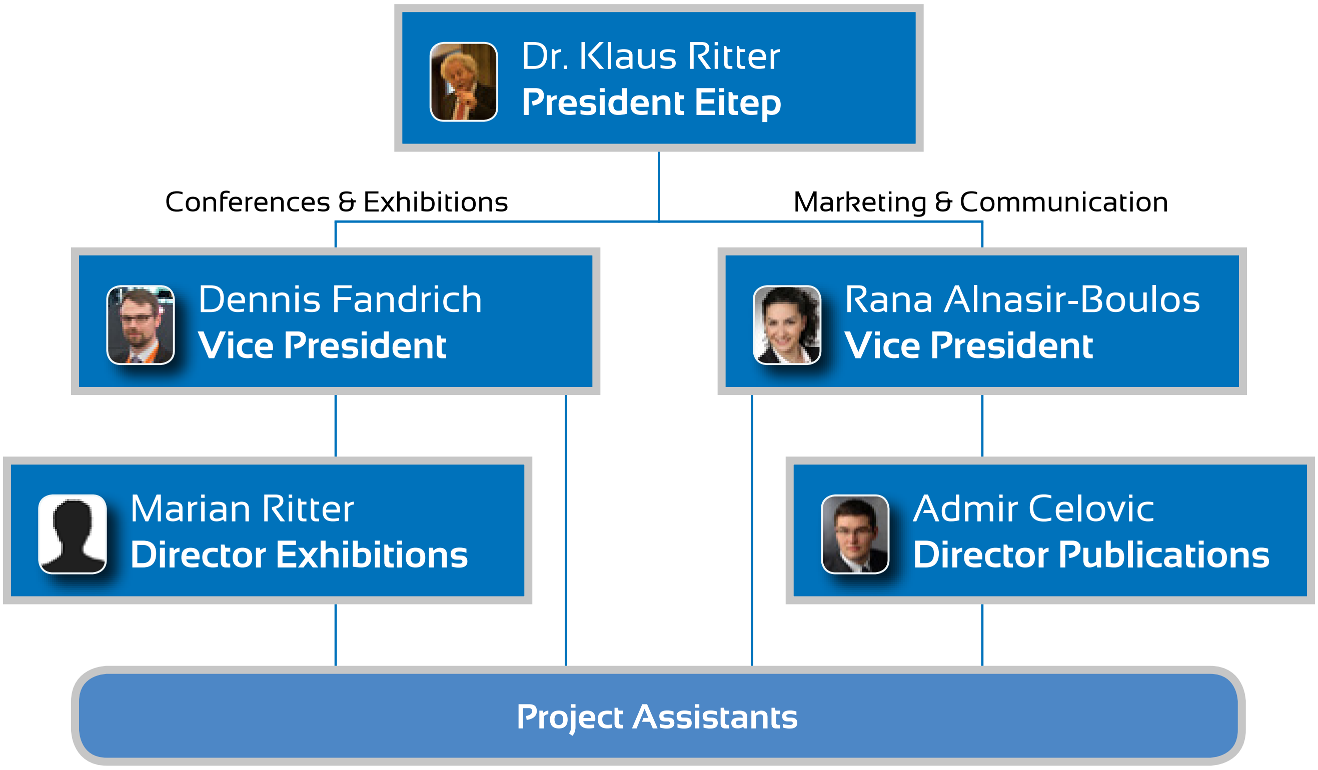

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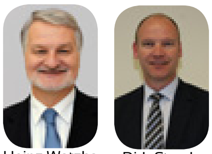

Heinz Watzka Dirk Strack

Monday, 12 March 2018 *(09:00 – 18:30)*

Welcome Coffee & Registration
(Exhibition Hall)

Opening Ceremony

Keynote Speech

Opening Panel Discussion
"Safety"

Lunch Break & Poster Session
(Exhibition Hall)

Technical Sessions

1.1 Inline Inspection	*2.1 Cyber Security*	*3.1 Materials*	*4.1 Maintenance & Repair*	*5.1 Asset Management*

Get-Together
(Exhibition Hall)

Exhibition

Tuesday, 13 March 2018 *(09:00 – 17:00)*

Technical Sessions

1.2 Challenging Pipelines	*2.2 Operational Improvements*	*3.2 Materials*	*4.2 Trenchless Technologies*	*5.2 Supply Networks*

Coffee Break
(Exhibition Hall)

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Technical Sessions

1.5 Integrity Management	*2.5 Offshore (Inspection)*	*3.5 Monitoring / Internet of Things*	*4.5 Planning & Design*	

Reception "Old Berlin"
(Brauhaus am Alex)

Exhibition

Wednesday, 14 March 2018 *(09:00 – 13:30)*

Plenary Session
"Remarkable Projects"

Coffee Breaks
(Exhibition Hall)

Closing Panel Discussion
"Public Perception / Social Acceptance"

Closing Remarks

Lunch Break
(Exhibition Hall)

Exhibition

Wednesday, 14 March 2018 *(14:00)*

Workshop: Pipeline Leak Detection
Organized and held by KROHNE

KROHNE

Wednesday, 14 March 2018 *(14:00)*

Workshop: Hydrogen
Organized and held by DNV-GL

DNV·GL

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Monday, 12 March 2018 *(16:30)*

Get-together
(Exhibition Hall)
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15-16 March 2018

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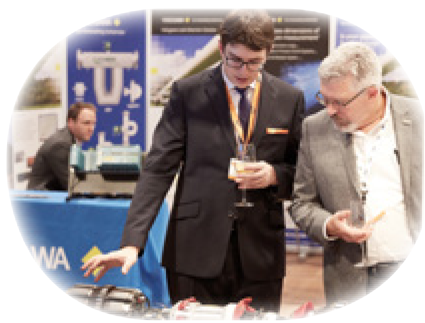

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- Pipeline Transport Institute (PTI LLC)
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- Polyguard Products
- PPSA - Pigging Products and Services Association
- Premier Coatings
- PSI Software
- Rädlinger Primus Line
- RAM-100 International
- Reinhart Hydrocleaning
- ROMSTARGROUP
- ROSEN Group
- sebaKMT
- Shawcor
- Siemens
- SolAres (Solgeo / Aresys)
- T.D. Williamson
- TDC International
- TIB Chemicals
- TNO
- TÜV SÜD Industrie Service
- VACUWORX
- Vlentec
- World Pipelines
- Worldwide Group
- Yokogawa
- Zwick Armaturen

50 DIFFERENT NATIONS

DELEGATIONS FROM 50 DIFFERENT PIPELINE OPERATORS FROM ALL AROUND THE WORLD

600+ DELEGATES

70+ EXHIBITORS

80 PRESENTATIONS

20 TECHNICAL SESSIONS

ACCOMPANYING SCIENTIFIC POSTER SHOW

THEMATIC FOCUS:
COATING
CONSTRUCTION
CYBER SECURITY
INLINE INSPECTION
INTEGRITY MANAGEMENT
LEAK DETECTION
MANAGEMENT + QUALIFICATION
MATERIALS
OFFSHORE TECHNOLOGIES
OPERATIONAL IMPROVEMENTS
PLANNING & DESIGN
PUBLIC PERCEPTION
REPAIR
SAFETY
TRENCHLESS TECHNOLOGIES

WE PROVIDE SOLUTIONS FOR THE NEEDS OF A SAFE AND RELIABLE PIPELINE INDUSTRY

PUBLICATIONS

PTJ-E-JOURNAL

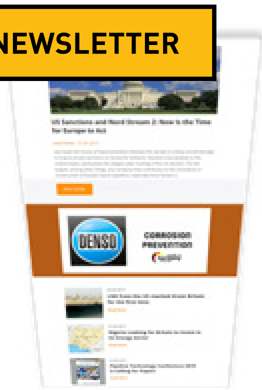
PIPELINE TECHNOLOGY JOURNAL (PTJ)

- DISTRIBUTED ONLINE TO 50.000 RECIPIENTS WORLDWIDE
- FOCUS ON PIPELINE TECHNOLOGIES, PRODUCTS & SOLUTIONS
- FREE OF CHARGE PUBLICATION

PIPELINE TECHNOLOGY JOURNAL NEWSLETTER

- PROVIDING THE PIPELINE INDUSTRY WITH GLOBAL PIPELINE NEWS
- SEND OUT TO 50.000 RECIPIENTS
- IS PUBLISHED BIWEEKLY
- FREE OF CHARGE DIGITAL OUTLET

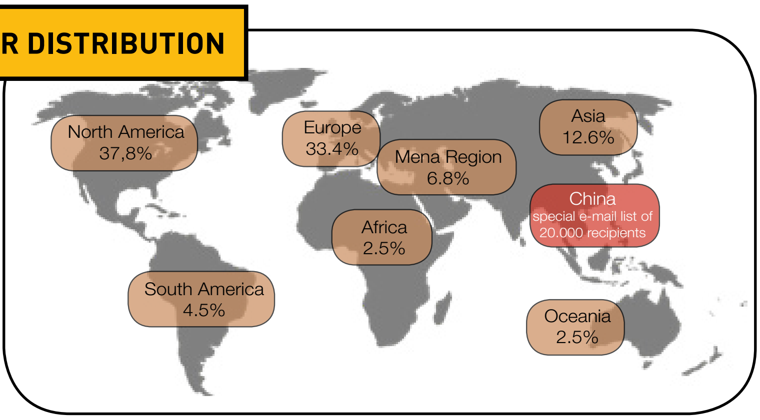
PTJ-NEWSLETTER



PIPELINE TECHNOLOGY CONFERENCE NEWSLETTER

- FOCUS ON UPDATES ABOUT PIPELINE TECHNOLOGY CONFERENCES
- IS PUBLISHED REGULARY
- FREE OF CHARGE DIGITAL OUTLET

USER DISTRIBUTION



PTJ-WEBSITE

CONFERENCES & EXHIBITIONS

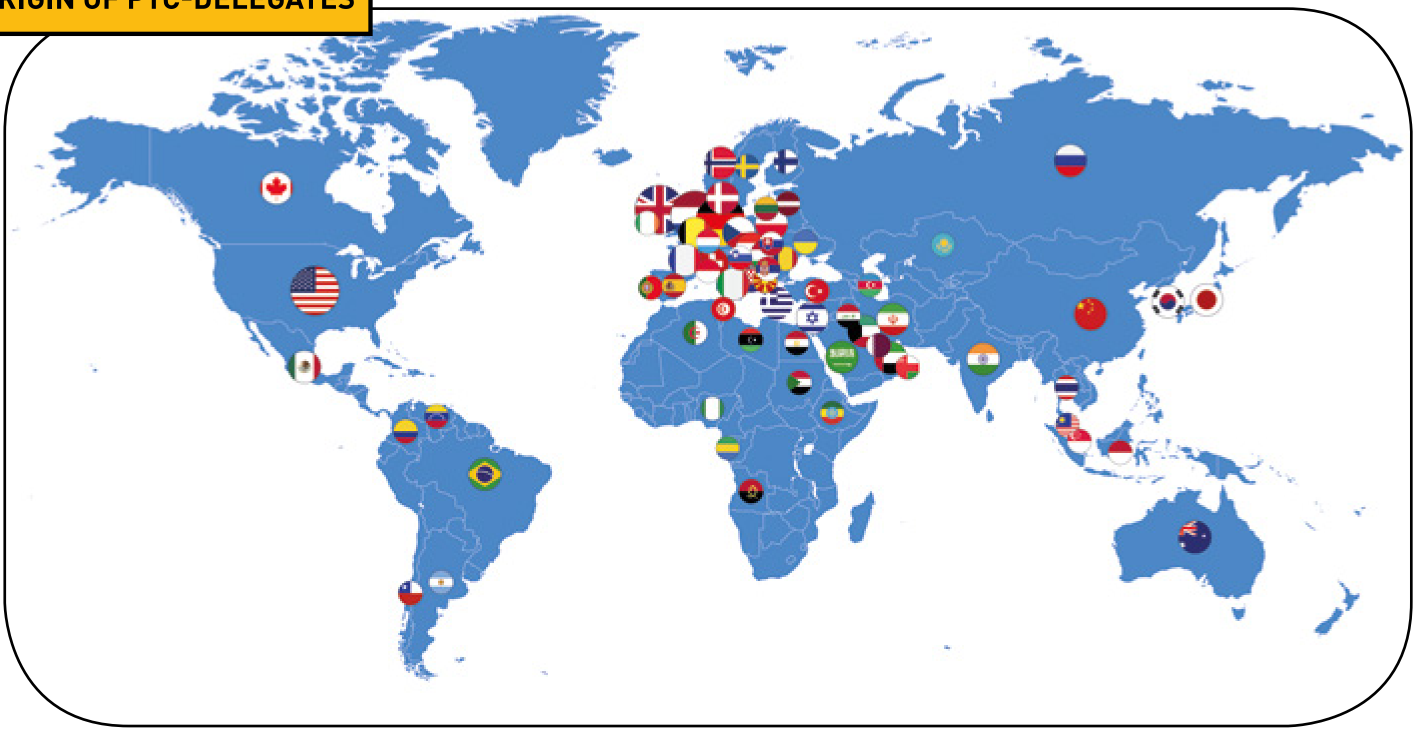
PIPELINE TECHNOLOGY CONFERENCE (PTC)

- **EUROPE'S LEADING AND BIGGEST PIPELINE EVENT:**
  600+ DELEGATES, 70+ EXHIBITORS, 80+ CONFERENCE SPEAKERS, 20+ TECHNICAL SESSIONS.
- **HIGHLY INTERNATIONAL: DELEGATES FROM 50+ DIFFERENT COUNTRIES:**
  33% GERMANY / 33% REST OF EUROPE / 34% REST OF THE WORLD.
- **ATTRACTS PIPELINE OPERATORS FROM ALL OVER THE WORLD:**
  EACH YEAR DELEGATIONS FROM 50+ DIFFERENT PIPELINE OPERATORS ATTEND THE PTC.
- **WIDELY SUPPORTED:**
  44-MEMBER ADVISORY COMMITTEE, 16 SUPPORTING ASSOCIATIONS, 27 MEDIA PARTNER, ETC.

CONFERENCE ON MANAGEMENT & QUALIFICATION

23.10.2018 - CITY CUBE, BERLIN, GERMANY

ORIGIN OF PTC-DELEGATES



QUALIFICATION & RECRUITMENT

AS PART OF THE PIPELINE TECHNOLOGY CONFERENCE
- PRESENTATIONS
- PANEL DISCUSSIONS
- PIPELINE JOB & CAREER MARKET

AS PART OF THE PTJ & PTJ NEWSLETTER
- DIGITAL CAREER MARKET TRANSPORTED INTO THE PIPELINE COMMUNITY AND PRESENTED TO SCHOOLS AND UNIVERSITIES

THROUGH SEMINARS ...
- ... FOR MANAGEMENT
- ... FOR TECHNICAL STAFF
- ... FOR STARTERS AND CAREER CHANGERS

LOBBYING / RECRUITMENT

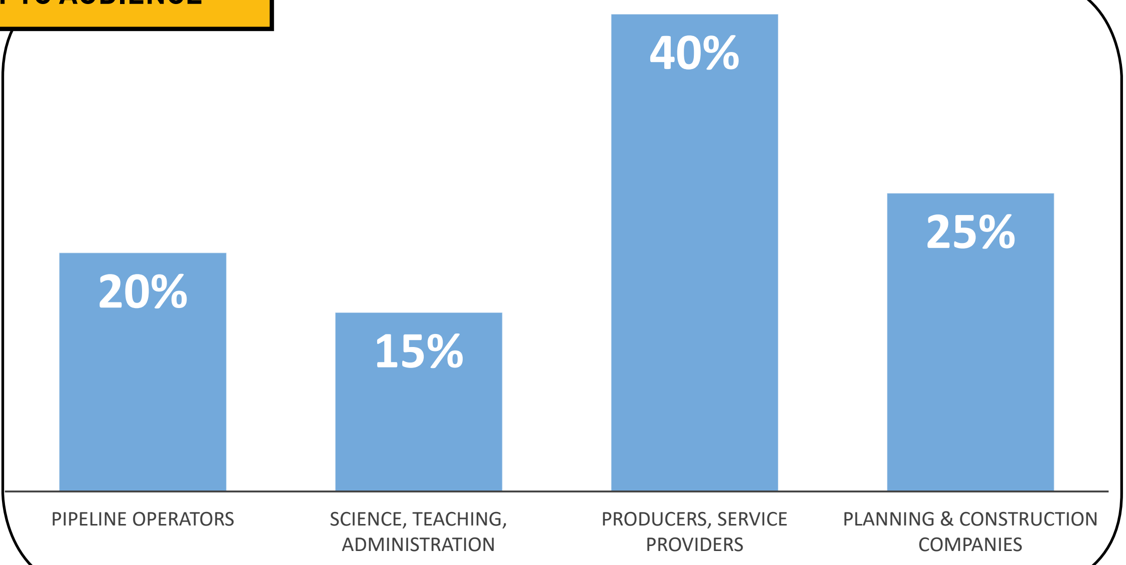
EITEP SEMINAR OFFERS

FOR MANAGEMENT
- LIFE CYCLE EXTENSION STRATEGIES
- NEW INSPECTION AND SAFETY TECHNOLOGIES
- RISK ASSESSMENT
- PUBLIC PERCEPTION

FOR TECHNICAL STAFF
- INTERNATIONAL PIPELINE PLANNING
- SAFETY & MONITORING OF CONSTRUCTION SITES
- INLINE INSPECTION
- LEAD DETECTION
- CORROSION PROTECTION

FOR STARTERS AND CAREER CHANGERS
- NEEDS OF PEOPLE / MATERIALS / TECHNOLOGIES
- PIPELINES IN THE FIELD OF TENSION

PTC AUDIENCE



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CHAIRMEN

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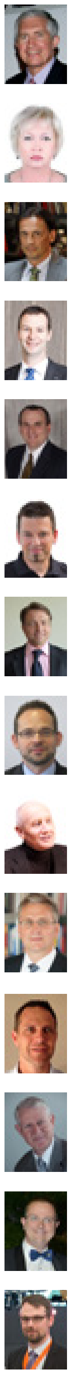
Dirk Strack, Technical Director, TAL - Deutsche Transalpine Oelleitung

MEMBERS



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Juan Arzuaga, Executive Secretary, IPLOCA

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Filippo Cinelli, Senior Marketing Manager, GE Oil & Gas

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Ulrich Schneider, Business Development Manager Continental Europe, KTN

Guntram Schnotz, Expert / Pipeline, TÜV SÜD Industrie Service

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Herbert Willems, Global ILI Technology Support, NDT Global

Conference Management
Dennis Fandrich, Director Conferences, EITEP Institute

Automation

Siemens
Germany
www.siemens.com

Yokogawa
Japan
www.yokogawa.com

Certification

Bureau Veritas
Germany
www.bureauveritas.de

Cleaning

Reinhart Hydrocleaning
Switzerland
eee.rhc-sa.ch

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Premier Coatings
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Denso
Germany
www.denso.de

Shawcor
United States
www.shawcor.com

Kebulin-gesellschaft Kettler
Germany
www.kebu.de

Polyguard Products
United States
www.polyguard.com

TDC International
Switzerland
www.tdc-int.com

TIB Chemicals
Germany
www.tib-chemicals.com

Construction

Herrenknecht
Germany
www.herrenknecht.com

IPLOCA - International Pipe Line & Offshore Contractors Association
Switzerland
www.iploca.com

MAX STREICHER
Germany
www.streicher.de/en/topmenu/home

Petro IT
Ireland
www.petroit.com

VACUWORX
Netherlands
www.vacuworx.com

Vlentec
The Netherlands
www.vlentec.com

Construction Machinery

Maats
Netherlands
www.maats.com

Worldwide Group
Germany
www.worldwidemachinery.com

Corrosion Protection

TPA KKS
Austria
www.tpa-kks.at

Engineering

ILF Consulting Engineers
Germany
www.ilf.com

KÖTTER Consulting Engineers
Germany
www.koetter-consulting.com

Inline Inspection

3P Pipeline, Petroleum & Precision Services
Germany
www.3p-services.com

A.Hak Industrial Services
Netherlands
www.a-hak-is.com

KTN AS
Norway
www.ktn.no

LIN SCAN
United Arab Emirates
www.linscaninspection.com

NDT Global
Germany
www.ndt-global.com

Pipesurvey International
Netherlands
www.pipesurveyinternational.com

PPSA - Pigging Products and Services Association
United Kingdom
www.ppsa-online.com

Romstar
Malaysia
www.romstargroup.com

Rosen
Switzerland
www.rosen-group.com

Inspection

Ametek – Division Creaform
Germany
www.creaform3d.com

Applus RTD
Germany
www.applusrtd.com

EMPIT
Germany
www.empit.com

Integrity Management

Metegrity
Canada
www.metegrity.com

Pipeline Innovations
United Kingdom
www.pipeline-innovations.com

Leak Detection

Asel-Tech
Brazil
www.asel-tech.com

Atmos International
United Kingdom
www.atmosi.com

Direct-C
Canada
www.direct-c.ca

Entegra
United States
www.entegrasolutions.com

GOTTSBERG Leak Detection
Germany
www.leak-detection.de

MSA
Germany
www.MSAsafety.com/detection

OptaSense
United Kingdom
www.optasense.com

Pergam Suisse
Switzerland
www.pergam-suisse.ch

PSI Software
Germany
www.psioilandgas.com

sebaKMT
Germany
www.sebakmt.com

SolAres (Solgeo / Aresys)
Italy
www.solaresweb.com

Materials

egeplast international
Germany
www.egeplast.de

Monitoring

Krohne Messtechnik
Germany
www.krohne.com

Pump and Compressor Stations

TNO
The Netherlands
www.pulsim.tno.nl

Repair

CITADEL TECHNOLOGIES
United States
www.cittech.com

Clock Spring
United States
www.clockspring.com

RAM-100
United States
www.ram100intl.com

T.D. Williamson
United States
www.tdwilliamson.com

Research & Development

Pipeline Transport Institute (PTI LLC)
Russia
www.en.niitn.transneft.ru

Safety

DEHN & SÖHNE
Germany
www.dehn-international.com/en

HIMA
Germany
www.hima.de

TÜV SÜD Indutrie Service
Germany
www.tuev-sued.de/is

Standards & Regulations

DNV GL
Norway
www.dnvgl.com

DVGW - German Technical and Scientific Association for Gas and Water
Germany
www.dvgw.de

Surface Preparation

MONTI - Werkzeuge GmbH
Germany
www.monti.de

Trenchless Technologies

GSTT - German Society for Trenchless Technology
Germany
www.gstt.de

Rädlinger Primus Line
Germany
www.primusline.com

Valves & Fittings

AUMA
Germany
www.auma.com

IMI Precision Engineering
Germany
www.imi-precision.com

Zwick Armaturen
Germany
www.zwick-armaturen.de

14TH PIPELINE TECHNOLOGY CONFERENCE

18-20 MARCH 2019, ESTREL CONVENTION CENTER, BERLIN, GERMANY

ptc

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www.pipeline-conference.com

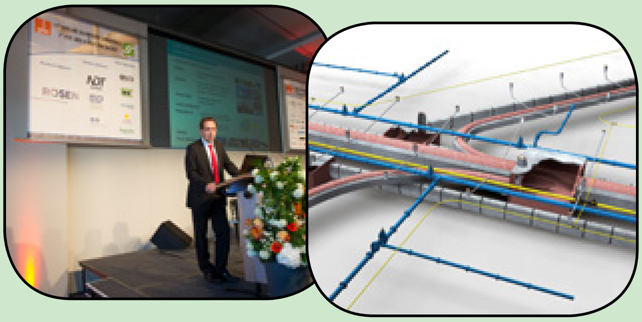
In conjunction

3RD PIPE AND SEWER CONFERENCE

18-20 MARCH 2019, ESTREL CONVENTION CENTER, BERLIN, GERMANY

International Conference and Exhibition on Pipe and Sewer Technologies, taking place at the Estrel Berlin, Berlin, Germany

www.pipeandsewer.com



ptj

Next Issue: April 2018

Pipeline Technology Journal

In the next Edition of ptj:

Management & Qualification

www.pipeline-journal.net

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Midstream Oil and Gas Congress 2018	26 - 27 March 2018	Copenhagen, Denmark
Pumps, Valves, Pipes and Compressor Industrial Exhibition (PVPC)	28 - 29 March 2018	Abu Dhabi, UAE
Pipeline + Energy Expo	03 - 05 April 2018	Tulsa, OK / United States
EITEP Conference on Management and Communication	**23 October 2018**	**Berlin, Germany**
14th Pipeline Technology Conference (ptc)	**18 - 20 March 2019**	**Berlin, Germany**
3rd Pipe and Sewer Conference (PASC)	**18 - 20 March 2019**	**Berlin, Germany**

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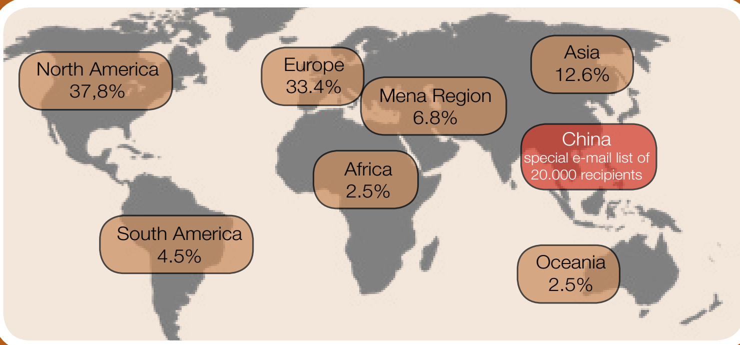

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ptj-brand-audiences

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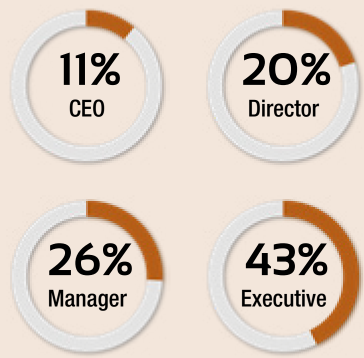
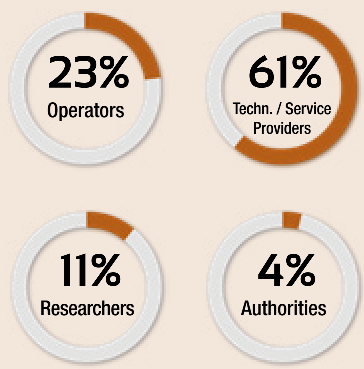


Company types



A manifold database

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