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AXISS™: In-line inspection axial strain measurement service

Proactive condition assessment and monitoring to ensure pipeline safety

In-line inspection (ILI) based axial strain measurement is the solution needed to mitigate more severe axial strains before they develop, causing pipeline failure. Proactive, cost-effective axial strain measurement means you can detect small changes in strain conditions, which can be crucial to the life and safety of the pipeline.

Baker Hughes, Process & Pipeline Services' AXISS™ service is the only way to measure axial strain with an ILI tool — providing a complete understanding of the entire pipeline without needing costly intervention.

Maximum insight with minimal disruption

Previously, axial strain could only be estimated using strain gauges or by making cut-outs from the section under investigation. While strain gauges measure axial strain starting from the time of installation on the pipeline, AXISS specifically detects and monitors areas of increased axial strain through the life of the pipeline, including those left during manufacturing.

When combined with the bending strain data provided by an inertial measurement unit (IMU), you can be confident in the integrity of your pipeline with a more complete picture of the total strain condition.

While dedicated axial strain inspections can be performed, the AXISS measurement system is retrofitted to our suite of Magnetic Flux Leakage (MFL) tools (VECTRA™, VECTRA™ GEMINI and New MagneScan™) for operationally efficient and cost-effective inspections conducted during scheduled corrosion inspection surveys.

The science of best in class axial strain detection

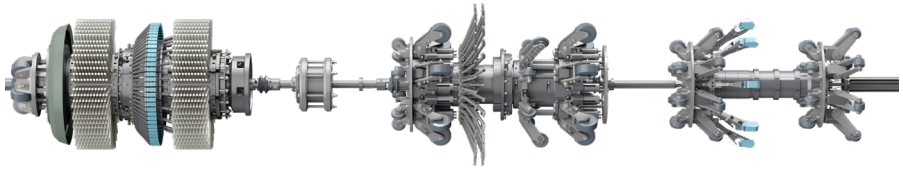
Axial strain detection and measurement are achieved through an electromagnetic sensor technology that measures the strain in a thin surface layer of the pipe material. Absolute strain is delivered when using a calibration factor which is based on a representative pipeline sample of the inspected section or predicted by a Baker Hughes proprietary analytical calibration model.

Features and benefits

- Delivers absolute axial strain to support fit for service decisions
- Deployed on standard MFL tools to efficiently collect strain data during standard scheduled MFL inspections
- Detect strain following external events to support geohazard management programs and identify new threat locations
- Understand total strain history from construction and monitor condition throughout pipeline service life
- Validate strain levels following strain relief activities
- Provides a more comprehensive view of pipeline strain than standard IMU bending strain surveys

Additional solutions:

- Total longitudinal strain integrity engineering report



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AXISS configurations and tool sizes:

Number of probes	MFL Platform	Tool size range
8	MagneScan™	12″ to 36″
	New MagneScan™	
	VECTRA™	12″, 16″, 20″
	VECTRA™ GEMINI	20″, 30″, 36″
4	VECTRA™	24″ to 42″
	VECTRA™ GEMINI	24″ to 42″

AXISS specifications:

Axial strain	MicroStrain	Percent
Axial strain at POD = 90%	200με	0.02%
Standard axial strain accuracy at 80% certainty when samples are provided	±100με	±0.01%
Axial strain accuracy at 80% certainty when using analytical calibration model	± (100με + 15% of reported strain)	± (0.01% + 15% of reported strain)

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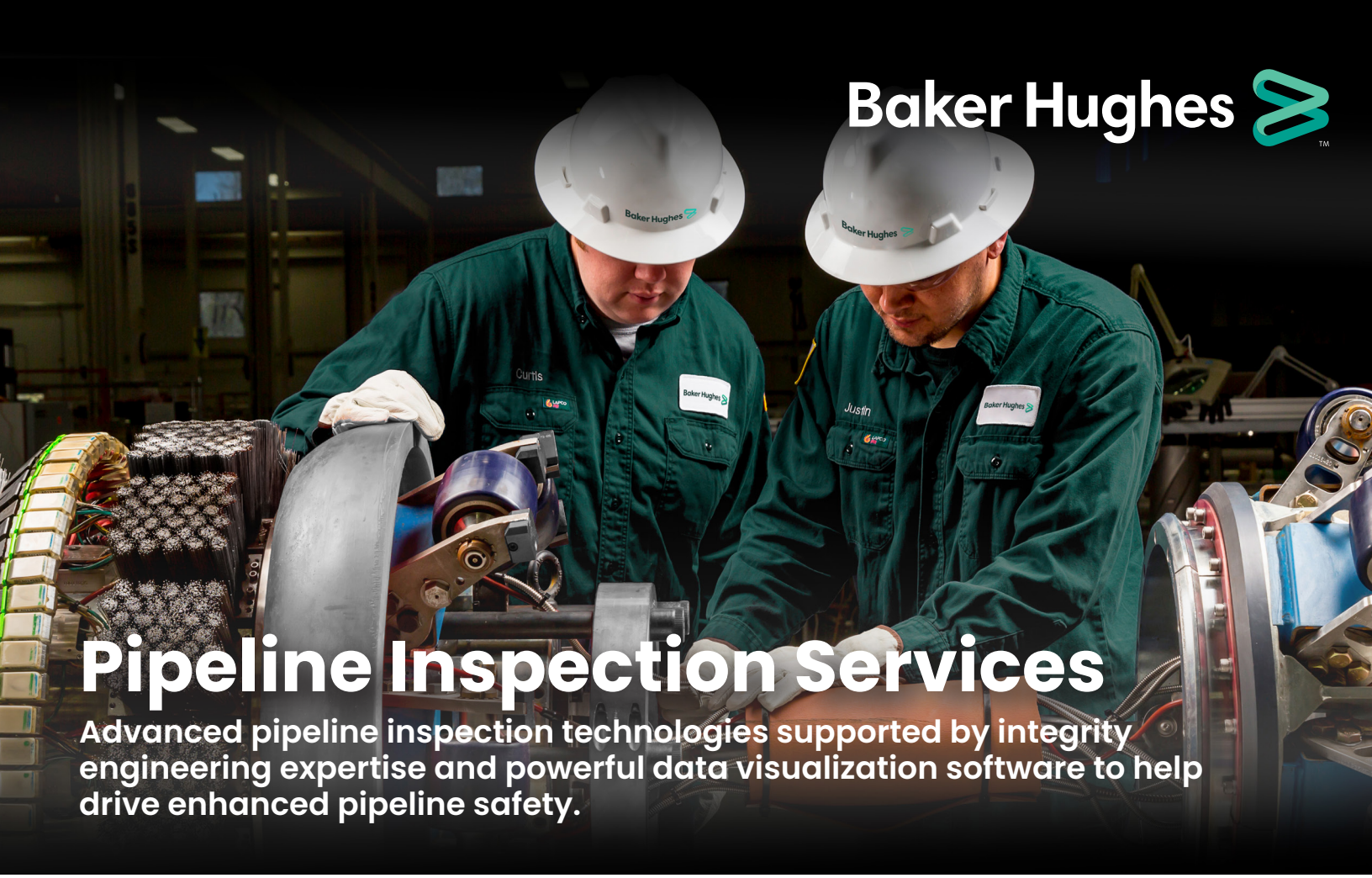
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Pipeline Inspection Services

Advanced pipeline inspection technologies supported by integrity engineering expertise and powerful data visualization software to help drive enhanced pipeline safety.

With over 40 years of experience and expert data analysis, Baker Hughes, Process & Pipeline Services (PPS), enable you to more confidently manage pipeline integrity threats. Whether your pipeline is onshore or offshore, or if it transports liquid or gas, our in-line inspection (ILI) service technologies help you meet your integrity program objectives.

Our ILI services identify threats, such as corrosion, cracks, mechanical damage, and stress and strain from construction or due to movement. Our extensive and diverse range of inspection technologies provide the accurate information you need to most efficiently plan your maintenance programs.

Corrosion Inspection

We have an unrivaled suite of market leading Magnetic Flux Leakage (MFL) technologies for corrosion detection and measurement so you can rest assured we have the right tool in the box.

If you need to maintain high flow rates for optimum product throughput we have active gas bypass tools to maximize flow and optimize data quality. Baker Hughes set the benchmark for accurate metal loss sizing when we introduced triaxial sensor MFL technology. If your dig costs are escalating then this is the choice to make for improved confidence.

When axially oriented corrosion is a risk or you need a second view of the line condition, axial flaw inspection tools provide you the solution.

Applications

- Gas
- Liquid
- Petrochemical (LNG, propane, olefins)
- Energy transition (H2, CO2)

Benefits

- Confirm integrity with in-line inspection services including:
  - VECTRA™, VECTRA™ GEMINI and MagneScan™ combination magnetic flux leakage (MFL) inspection services
  - TranScan™ inspection services for axial flaws and seam weld defects
  - EMATScan™ and UltraScan™ CD Plus inspection services for crack measurement
- Obtain accurate pipeline geometry and mapping data
  - CalScan™ and GEOPIG™ high resolution caliper and mapping services
  - AXISS™ ILI axial strain measurement services
- Supported by an industry leading portfolio of integrity engineering services including:
  - Corrosion assessment
  - Crack assessment
  - Dent and strain assessments
  - Risk and other threat management

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Crack detection inspection

PPS invests in and develops technologies that can inspect older pipelines, with a propensity for weld seam cracks and hook cracks. We have solutions that allow operators to accurately locate and highlight pipeline cracks. Our pipeline inspection capabilities can identify stress corrosion cracking (SCC) and cracks of unknown gestation. We can also employ recognized engineering techniques to predict rupture pressure when adjacent crack(s) interact if extensive SCC crack fields are populated with critical and sub-critical cracks.

Our crack inspection tool portfolio utilizes Electro Magnetic Acoustic Transducer (EMAT); ultrasonic; and axially-orientated magnetic flux technology to detect and measure a full range of cracking defects.

Pipeline movement monitoring and mapping

We introduced inertial mapping to in-line inspection in the 1980s and we still lead in inspection technologies specifically designed for pipeline movement and strain assessment caused by geohazards, 3rd party interference, or resulting from construction. In 2016 we introduced another breakthrough technology for axial strain monitoring. Add this to our ability to provide bending strain, movement monitoring, and mapping with most of our ILI tools and you've got it covered.

Deformation inspection

When it comes to validating or identifying deformations you need the right tool for the job. Whether you are running with low pressure, line proving while de-watering, conducting a pre-inspection verification, or a proactive check for 3rd party damage, each task has unique challenges to collect great data, first time. With a full range of construction caliper to high resolution inertial geometry tools, our fleet is up to any job.

Analysis services

The strength of PPS and what separates us from our competition, is our analysis and integrity engineering capabilities, performance, and responsiveness. Our ability to interpret the data collected by our tools is unmatched in the industry. Our secret, the best data quality, most advanced algorithms, rigorous process, and commitment to comprehensive training and competency systems fully aligned with ANSI ILI PQ 2010.

We offer proven, industry-accepted pipeline integrity engineering solutions that support a pragmatic approach without jeopardizing pipeline safety. This comprehensive range of assessment techniques evaluates anomalies critically and enables us to recommend control measures, repair processes, or changes to the system process to promote long-term pipeline integrity. Rest assured, no matter where you are in the world, we will have an expert on hand to help you make the right decisions with your data.

Contact Baker Hughes or visit bakerhughes.com/process-pipeline-services to find out how you can more confidently maintain pipeline integrity and confirm compliance with our pipeline inspection services.

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RunCom™

Perform reliable, direct comparisons of corrosion growth between inspection runs

The ability to calculate accurate corrosion growth rates will be a key determinant in the success of your corrosion management strategy and, consequently, the future integrity of your pipeline.

Increase the value of your data

RunCom™ is Baker Hughes' suite of run comparison software designed to analyze data from multiple in-line inspections. It performs a direct, quantitative comparison to provide your decision makers with actionable information.

Our highly skilled analysts use RunCom to compare data from our MagneScan™, VECTRA™ GEMINI, as well as data from other vendors' tools. Importantly, in the event that successive inspection runs utilize different technologies, our MagneScan and VECTRA GEMINI inspections can be compared.

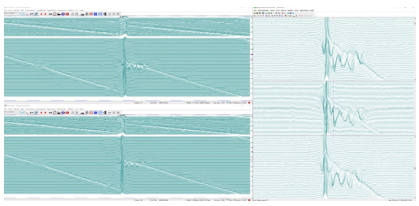
The software details the corrosion activity along an entire pipeline, confirms the effectiveness of past remedial measures, and provides the technical basis for safe and cost-effective remediation and operating plans.

Perform 'pure' comparisons

While less advanced comparison methods can indicate extreme corrosion growth between inspection runs, they cannot reliably quantify the precise extent or location of active corrosion. But this is exactly the level of detail needed to properly prioritize corrosion sites and develop successful, economical remediation strategies. In fact, it is for this reason that operators are advised to select a high-resolution inspection tool for their ILI activities.

RunCom provides a superior solution because it does not rely on previously processed data or second-hand information. One of the most common sources of error is the incorrect matching of corrosion sites. RunCom minimizes this possibility performing a direct and quantitative comparison of the raw inspection signals. This enables very high accuracy in matching corrosion sites. Through its signal scaling tools, RunCom adjusts for tool repeatability and maintains consistent sizing methods to minimize other error sources. This approach has proven to be up to three times more accurate than feature comparisons without RunCom.

Since its introduction in 1999, RunCom has proven to customers worldwide that it determines corrosion growth rates with greater confidence and higher accuracy than other methods.



RunCom performs side-by-side matching of raw signal data from various inspection tools to deliver 100% data matching accuracy and identify corrosion growth sites.

Features and benefits

- Detection of internal and external corrosion growth
- Quantification of corrosion growth throughout the pipeline
- Identification of new corrosion sites and any other new features (e.g. dents, touching metal objects, etc.)
- Signal to signal comparisons across different inspection technologies e.g. MagneScan vs VECTRA GEMINI inspections
- Provides visibility of corrosion activity (and any other changes) along an entire pipeline
- Gives early warning of active corrosion which enables cost-effective, early intervention
- Confirms where remedial measures have been effective, thus avoiding costly future excavations and repairs
- Provides a segmentation of the pipeline based on corrosion activity
- Enables better informed integrity and remediation planning decisions

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The information provided in a RunCom analysis is invaluable in the decision-making process and prioritization of the remedial measures necessary to limit future corrosion growth.

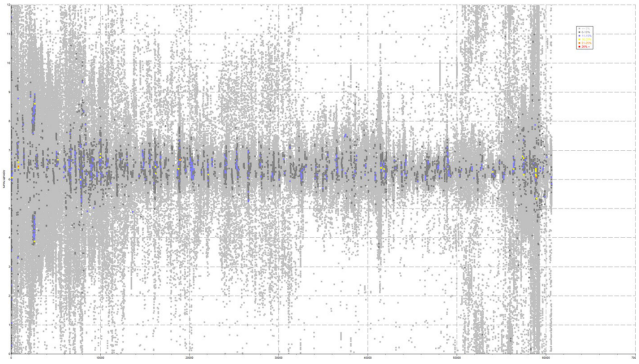
This information, together with an advanced integrity evaluation, will optimize future repair and re-inspection needs—resulting in significant cost savings—when compared with estimated rates and codified corrosion assessment methods.

RunCom Reporting Options

There is the option of a short RunCom Screening report which identifies a selection of the highest corrosion growth rates in the pipeline, recommending, if appropriate, a full RunCom assessment to be performed.

Standard RunCom reporting comprises signal matching for the full line followed by a manual assessment of a large sample of features.

An additional RunCom spool-based report can be provided following the Standard RunCom service. This includes a detailed listing of the external and internal corrosion growth rates along the entire pipeline on a spool-by-spool, feature-by-feature, and box-by-box basis, corrosion growth rate summary statistics, and charts showing the corrosion growth trends for the pipeline.



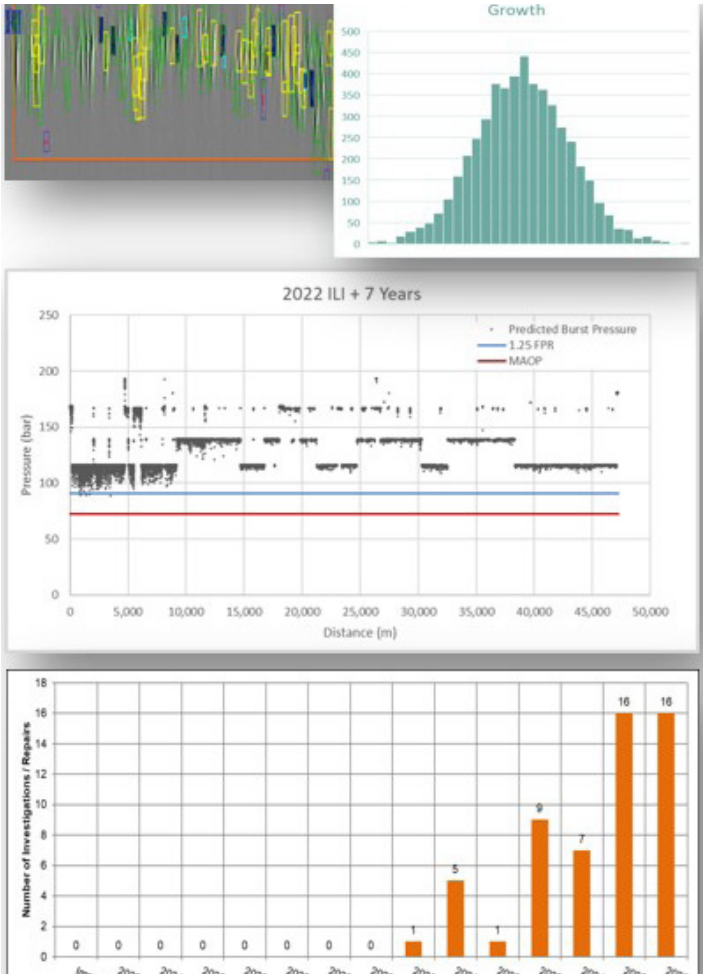
MFL RunCom typically delivers at least three times the accuracy of other box or feature comparisons methods available.

Related Integrity Assessments

A RunCom Plus assessment is available, which applies individual spool growth rates in a future integrity assessment of the metal loss in the pipeline to determine a time-based optimized repair plan.

The new RunCom Cluster Growth 3D assessment can be offered (with or after a RunCom assessment) to account for growth in all three dimensions (depth, length, and width). This most advanced assessment models the more complex interaction between nearby areas of corrosion to identify the corrosion areas that are most likely to require monitoring or intervention between inspections. This new approach:

- Uses a probabilistic simulation model to select rates from local distributions (groups) to account for variability of growth rate over time.
- Accounts for growth in depth, length and width dimensions and uses the LAPA (RSTRENG) burst pressure algorithm for assessing Cluster severity vs time.
- Models the potential for future interaction between nearby areas of corrosion via a machine learning neural net model to predict plausible sites and patterns of new defect initiation.
- Produces two growth scenarios (worst case and expected) to provide flexibility for evaluating future repair needs and optimising reinspection intervals.



A cluster severity assessment is provided (at 50th & 95th percentile scenarios), using the RSTRENG assessment method, which provides cluster dig predictions vs time.

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CO_2 gathering network services

Supporting energy transition

As the globe targets significant reductions in carbon emissions, the energy industry is adapting at an ever-increasing pace. And, as more operators turn to processes such as sequestration and tertiary recovery to meet energy transition goals, concerns around the pipelines transporting CO_2 have increased.

Because CO_2 is heavier than air, as well as colorless and odorless, a leak could go undetected, allowing the CO_2 to spread low along the ground or in confined spaces, displacing oxygen and creating numerous health and safety risks.

Pipeline threats exist everywhere, and they are ever present. Whether it's an external threat like nearby excavation, or an internal threat like the very product the pipeline carries, or coating on the pipeline itself, maintaining pipelines and the ability to predict potential problems with pipeline stability has never been more important than it is now.

Repurposing decommissioned lines

Operators are now faced with the need to recommission previously decommissioned pipelines, which raises concerns around understanding the condition and worthiness of these dormant lines.

To meet approaching environmental requirement deadlines, Baker Hughes, Process & Pipeline Services (PPS) is prepared to partner with operators to reduce concerns around the safe operation of those pipelines with our **fitness for service** solutions.

One source; complete solutions for years to come

Our Carbon Capture Services leverage the MagneScan super high resolution MFL4 tool, along side strain-based integrity assessment, to provide the right solution for your business.

Baker Hughes' MagneScan MFL4 tool sets the standard for reliable metal loss inspection results. Designed to withstand harsh operating conditions, it has proven its versatility in a wide range of applications in every type of pipeline – dry or liquid, overland or subsea.

Super high resolution detection/sizing of smallest defects (pinholes) improves accuracy of sizing, drawing on Baker Hughes' unparalleled inspection experience to bring the highest levels of accuracy to data analysis and interpretation. MagneScan detects:

- internal and external pitting
- general corrosion
- hard spots in the pipe wall
- metal loss associated with dents and under casings
- repair shells
- metal object
- girth weld anomalies

Our magnet brush design results in a higher magnetic field introduced into the pipe wall, and an increased magnetic response from defects. Furthermore, the tri-axial sensors on all

Features and benefits

- Corrosion management and response planning
- Our highest-definition tools have the capability to detect pinhole-sized features, seeing the most minute areas of metal loss
- Detect and assess girth weld cracking, assisted by our extensive database of actual and known manufactured defects
- Detect bending strain and axial strain following external events to support geohazard management programs and identify new threat locations
- Revalidate pipeline integrity
- Cleaning to prepare for CO_2
- Inert system prior to commissioning
- Clean new or existing compressors

Additional services

- Flooding, cleaning, gauging and testing (FCGT)
- Pigging and gauging
- Dewatering and drying
- Pipeline conditioning
- ThreatScan — real time impact detection

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of our MFL4 tools:

- Discriminate axial features compared to single axis MFL
- Generate distinguishable signals for pin-holes on a reliable and repeatable basis
- Allow the overlay of data streams to ensure complexity is understood and accounted for in sizing methodology
- Eliminate the need for supplementary Transverse or 45-degree inspection data for metal loss features
- Provide sizing methodologies based on 100,000's of defect morphologies
- Has confirmed specification based on 150,000 plus dig results, of which 50,000 plus LaserScan signals have been correlated to the inspection signals

Baker Hughes' AXISS™ technology measures axial strain in pipelines. It is the solution needed to mitigate axial strains prior to developing into injurious values that may cause pipeline failures. AXISS offers a number of key advantages for axial strain monitoring:

- Enables cost-effective and continuous measurement of axial strain along the entire pipeline's length;
- Measures small changes in strain conditions over the lifetime of the pipeline;
- Provides proactive risk management by detecting critical strain conditions due to areas of known and unknown geohazards or other causes of pipeline axial loading.

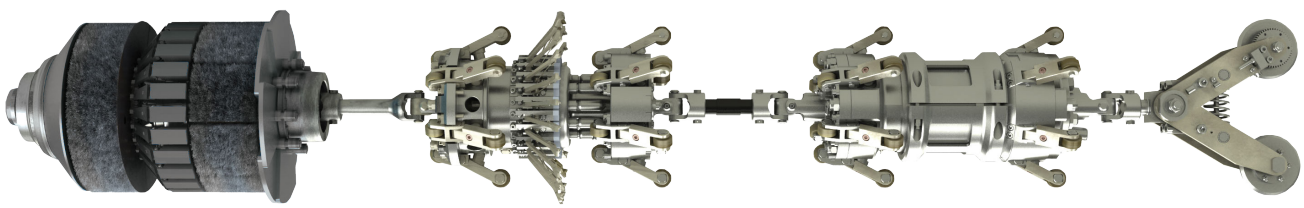
Previously, this type of detection required localized strain monitoring at known high-risk sites. AXISS can be run simultaneously with our MagneScan MFL4 tool, enabling cost-effective and continuous measurement of axial strain along the entire length of the pipeline. Together these two technologies deliver the the detailed data and high confidence levels essential for a productive integrity management program.

Using industry leading technology like RunCom™, the PPS suite of run-comparison software, we can analyze data from multiple in-line inspections, performing a direct and quantitative comparison to help operators understand and mitigate threats, providing your decision makers with actionable information.

PPS has a long history of providing accurate and reliable data on pipeline conditions and complete pipeline integrity solutions. That means you have one source providing information on the current condition of a pipeline, reducing risk and minimizing costs by avoiding unnecessary repairs to achieve regulatory compliance.

ILI data (along with other data points) not only gives you a clear picture of current conditions of a pipeline, it can also be used to predict the future condition. This process can take into account the pipeline remaining in its current mode of operation, or changes to its future operation — age, weather conditions, pipeline coating, or the product within.

Contact a PPS team member and let us customize a solution to meet your particular needs.



MagneScan SHR+ (super high resolution) tool

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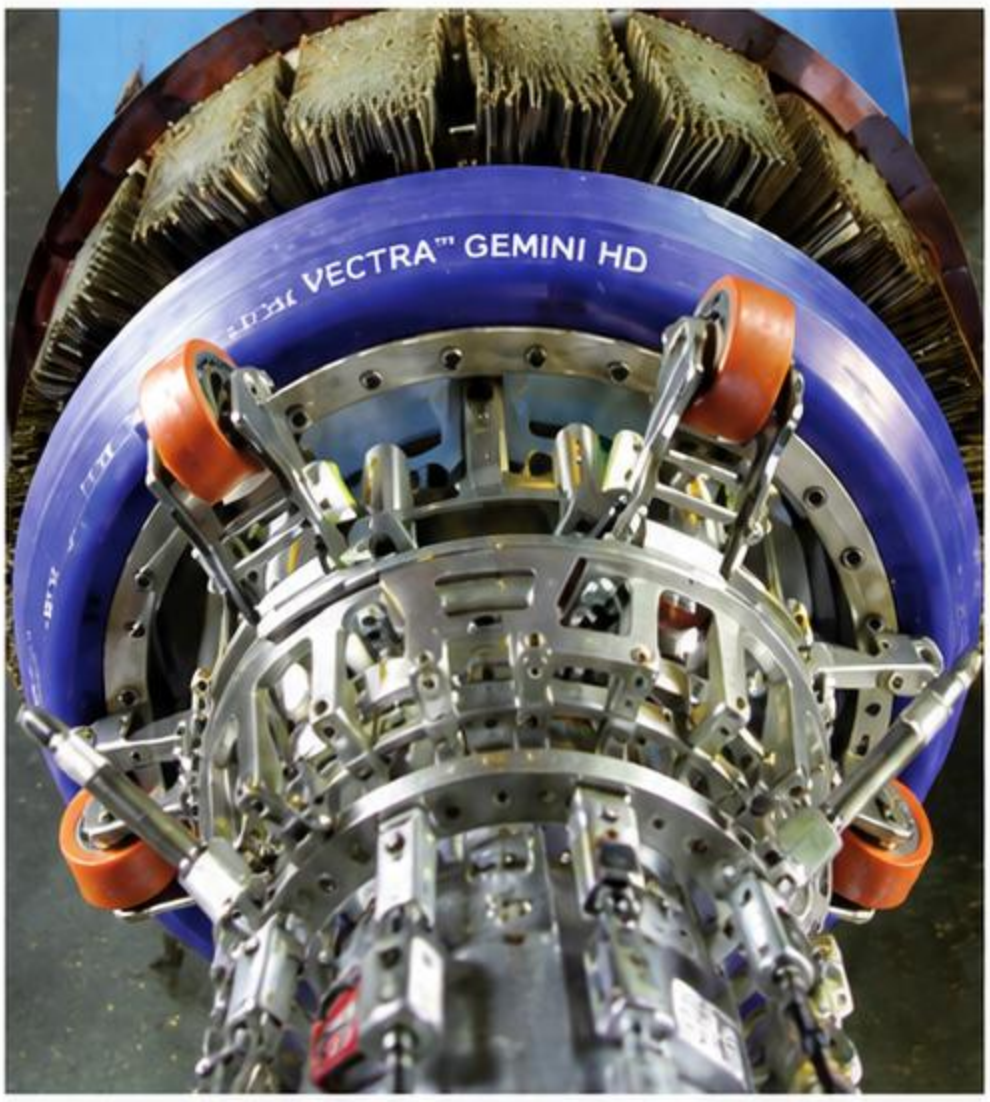
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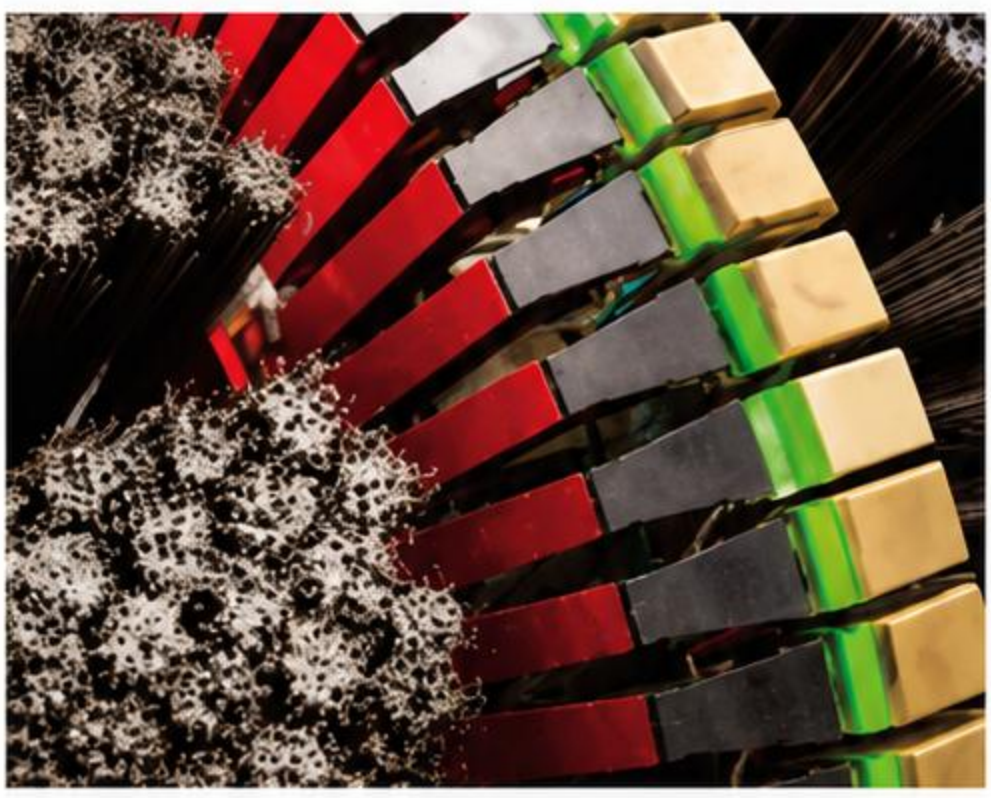
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Technology spotlight



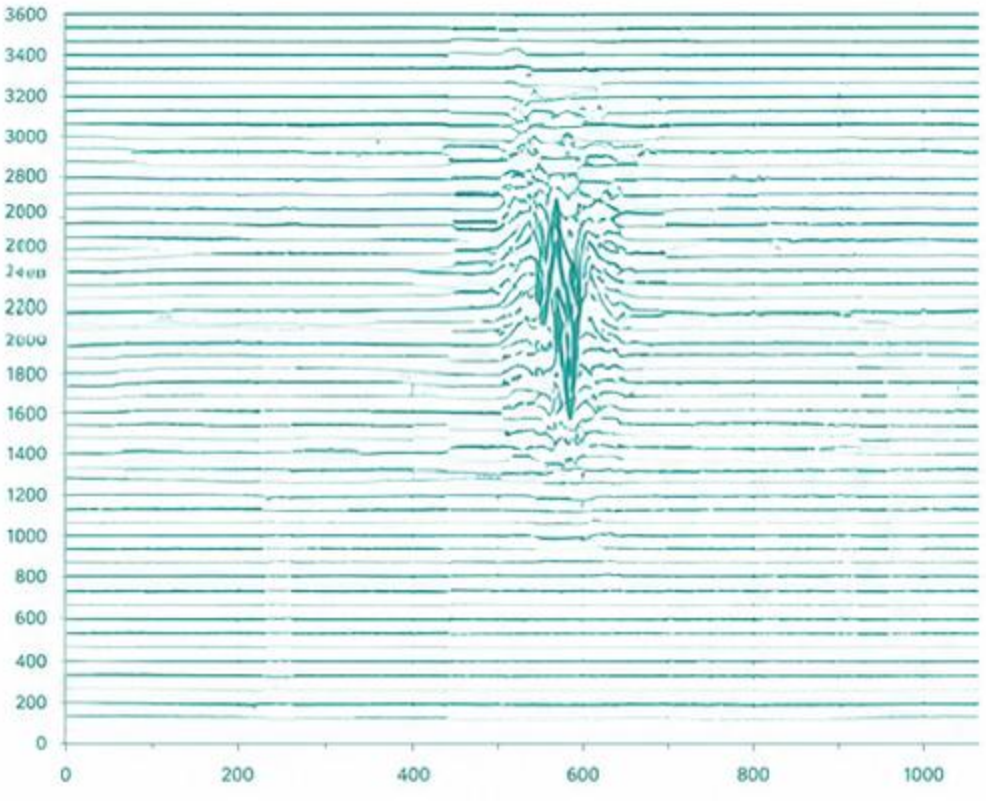
Heavily corroded and difficult-to-access pipelines

VECTRA™ GEMINI HD and **MagneScan™ S1R Plus** are our highest-specification in-line inspection tools. They deliver the best possible information to address your most complex challenges—enabling more reliable decision-making, ultra-high confidence, and significantly fewer digs. VECTRA HD has twice as many sensors as other MFL tools. The result is a more accurate picture than ever before—one that enables early detection and pinpoint accuracy of even the smallest instances of metal loss and complex corrosion. MagneScan S1R Plus has 4-in-1 sensor technology that makes it possible to identify linkages between individual pits/pinholes and the formation of axial CC and ILC circunferential pitting and grooving. These tools deliver extremely high accuracy for depth, length, and width—making them particularly well suited to lines with extensive, complex corrosion, high failure consequences, or the likely presence of axial defects or pinholes. The end result is the high confidence needed to only dig and repair what is absolutely necessary—the savings here significantly outweigh the incremental cost of the higher-specification inspection.



Pinhole corrosion

Very small pinholes can cause major problems—leaks. Whether caused by external microbe-induced corrosion or internal pitting, pinholes are always extremely difficult to detect. Our highest-definition tools have the capability of detecting pinhole-sized features, and seeing the most minute areas of metal loss. VECTRA HD, for example, has industry-leading sensors resulting in early fields multiple data frames a single run—resulting in a sharper view that more accurately locates, identifies, and sizes complex anomalies such as pinholes. On top of inspection tool capabilities, we're constantly improving our algorithms and models so our analysts can more accurately quantify these difficult features. All in all, your advantage are reduced maintenance costs and less lost revenue. In exchange for increased uptime, fewer digs, and improved safety.



Pilferage and illegal tapping

When two illegal taps were discovered in a European refined product pipeline (along with a tank holding 30,000 liters of stolen product), we quickly mobilized a MagneScan tool to assess the unknown risks. We compared the results to another MagneScan inspection we completed several years earlier. Within a week, we produced a highly practical Change Report that gave precise location details about new anomalies, we identified nine illegal taps along nearly 200 km of pipeline. Six months later, we ran the process again and found several new illegal taps. Not only has this helped the customer minimize its losses, but it's raised industry awareness and vigilance around this critical financial and safety issue. We now offer the Change Report with our MagneScan S1R Plus and VECTRA GEMINI HD inspection services.

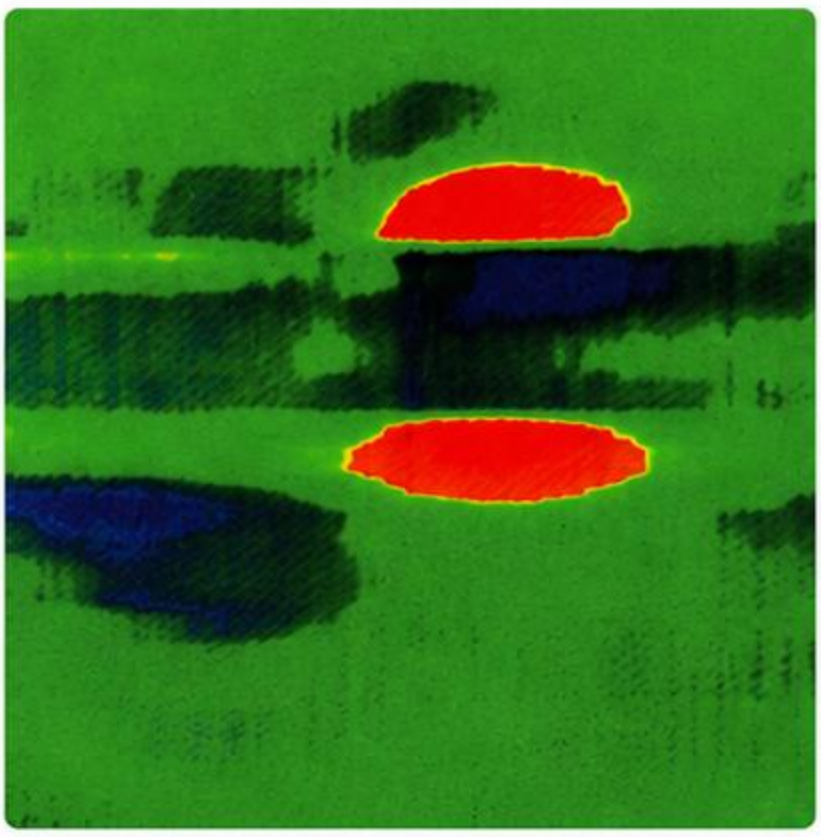
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Girth weld cracking

Cracks in girth and spiral welds have been causing operators concerns for a number of years; but finding a reliable inspection solution has been challenging. Advancements in our MagneScan and VECTRA technologies have led to increased confidence levels in detection and sizing of these features with MFL technology. We've gathered a large database of actual pipeline defects, alongside manufactured defects, to develop a bespoke analysis process and associated report specifically for girth and spirat welds. This is now proven to be a reliable solution for operators who know they have pipeline construction concerns, and need to better focus their integrity and maintenance budgets.



Axially oriented seam corrosion

For over 20 years, our TranScan inspection fleet has been the industry go-to for detecting seam-weld defects, axial flaws, and third-party damage. TranScan's transverse field inspection (TFI) technology ensures that axial flaws (cracks and elongated metal loss) present their largest dimension to the magnetic flow, creating a strong signal from flaws that are invisible to other magnetic tools. TranScan tools are very robust, and equally at home in gas or oil pipelines. They can inspect up to 4 m/s and have a high tolerance to dirt and wax. They have even been used to detect flaws in seam welds as narrow as 0.1 mm. TranScan has become the tool of choice among operators and regulators for the detection of hook cracks and lack-of-fusion in pre-1970 ERW gas pipe. Its sensitivity to dents, associated cracking, and metal loss also makes it ideal for the detection and classification of third-party damage.



Corrosion management and response planning

It's industry standard to compare data from different inspections to determine corrosion joinrces rate, but the application of the resulting information is not well understood. By contrast, our RunCom™ product provides a range of corrosion-growth and integrity-assessment services that support response-planning decisions. By moving away from fixed corrosion rates to instead use joint-based and cluster rates, we leverage the real power of RunCom's signal-level data analysis—this significantly increases the precision of growth-rate calculations, and improves decision-making about re-inspection intervals and repair initiatives. With excavation and repair costs typically $100,000, RunCom's ability to avoid unnecessary digs has very clear value.



Complete project management and execution

Our precommissioning and maintenance (P&M), and in-line inspection (ILI) teams regularly join forces to provide a single point of responsibility for complex projects. One example of a successful combined effort was for a German operator with a 22-day shutdown planned to inspect two oxygen lines. ILI in a water batch would be the easiest option, but with a high cost. We instead proposed a nitrogen batch, which was more complex—but faster and less expensive.

Bringing extensive nitrogen experience to the table, we worked closely with the customer and three suppliers to manage everything from pre-engineering to ILI and N, execution, infield troubleshooting, and fast-track reporting. The team worked like a well-oiled machine, and the inspection was a huge success with high accuracy from our MagneScan SHR Plus tool.

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