

A NEW ERA OF CRACK INSPECTION IN GAS PIPELINES

Matthias Hilvert and Thomas Beuker, ROSEN Group, introduce the new RoCD EMAT-C Ultra Service, which is built on proven EMAT-C technology.

Effective pipeline integrity management relies on a broad spectrum of inline inspection (ILI) technologies that enable operators to confidently detect, classify, and size anomalies. These tools form the core of modern integrity management programmes, supporting informed decisions regarding maintenance activities, such as hydrotesting and excavation planning. As pipeline networks grow in complexity, the need for optimised inspection approaches becomes increasingly critical.

The introduction of EMAT-C Ultra technology represents a major step forward in addressing crack-related threats. Based on the proven EMAT-C technology, the new system seamlessly integrates into established operational workflows, while providing substantial performance enhancements. Its doubled sensor coverage and dual sound-path methodology – capturing signals clockwise (cw) and counterclockwise (ccw) – significantly strengthen the reliability of crack detection for critical dimensions, achieving 95% probability of detection (POD) and surpassing current industry expectations.

This article compares the performance of EMAT-C Ultra with industry benchmarks that validate its effectiveness in advancing pipeline integrity management.

The electro-magnetic acoustic transducer (EMAT) technology

EMAT technology is a well-established and further growing method for detecting cracks and crack-like defects in pipelines. Since its commercial introduction in 2006, EMAT has steadily become an essential tool in pipeline integrity management, thanks to its ability to generate and analyse ultrasonic sound waves without requiring a coupling medium.

EMAT operates using two physical phenomena: the Lorentz force and magnetostriction. These effects are produced by alternating currents interacting with a static magnetic field, allowing the system to generate ultrasonic waves.¹ When these waves encounter cracks or defects in the base material or longitudinal seam welds, they reflect back, and the tool's echo channel records these signals (Figure 1). A large number of overlapping transducers are arranged on the inspection tool to generate a high-resolution image of the pipeline. Due to the short propagation distance of the waves between the measuring elements, this design ensures high signal quality, forming the basis for accurately determining the position and dimensions of flaws.² Unlike traditional piezoelectric ultrasound, which captures only a single frequency, EMAT

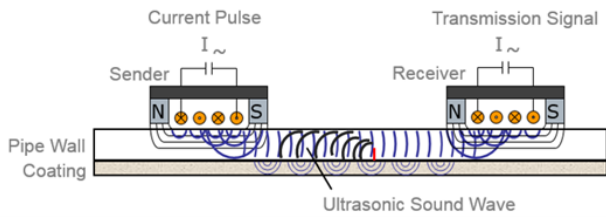


Figure 1. Schematic explanation of the EMAT soundwave propagation.

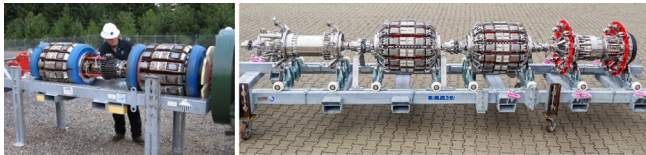


Figure 2. Comparison between EMAT-C tools from around 2006 (left) and 2023 (right).



Figure 3. Picture of an EMAT-C Ultra tool at job site before launching.

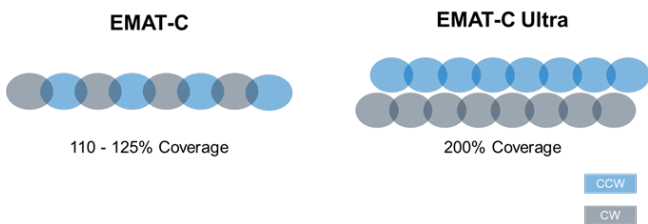


Figure 4. Comparison between EMAT-C sensor coverage (left) and EMAT-C Ultra sensor coverage (right) at full performance specification.

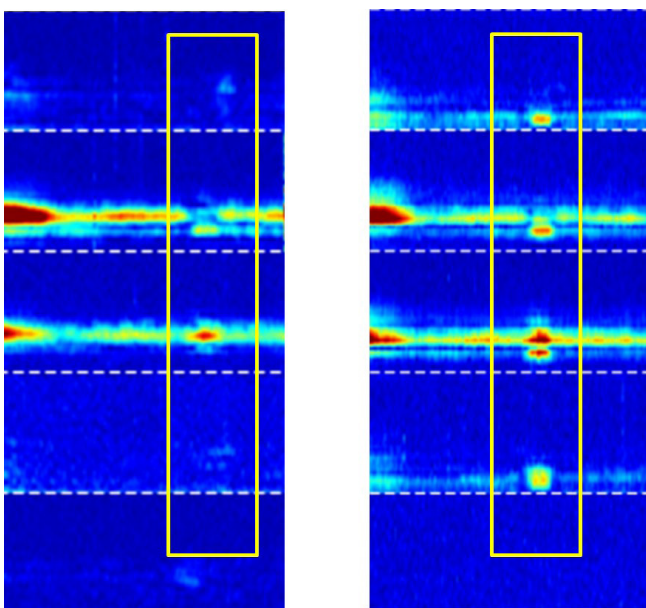


Figure 5. Comparison of EMAT-C (left) and EMAT-C Ultra (right) longitudinal weld data with a crack indication (yellow box).

records the entire frequency spectrum. This broader dataset allows for more detailed analysis, enabling accurate identification and sizing of linear anomalies.

This highly versatile technology can inspect a wide range of pipeline diameters (10 - 48 in.). Its performance has been rigorously validated through numerous industry pull tests and case studies, ensuring consistent and reliable results in the field.

Over the past two decades, more than 136 000 miles (220 000 km) of pipeline data have been analysed, highlighting its critical role in pipeline integrity. This large volume of inspected pipeline miles is accompanied by a large number of field verification results, which are invaluable for improving and further developing the technology. ROSEN has a treasure trove of over 10 000 reported anomalies that have been verified in the field. This information is an important source for using modern artificial intelligence (AI) technologies for the continuous development and optimisation of data analysis.³

RoCD EMAT-C Ultra

For nearly 20 years, ROSEN's RoCD EMAT-C tools have been essential to pipeline integrity management. They have evolved from early Cup-Tool designs (Figure 2) with integrated EMAT sensors into robust systems that address challenges such as high gas flow conditions with a speed control valve and wheel supported sensor suspension.

Today, modern EMAT-C tools provide low-noise data, improved run behaviour, advanced electronics, and durable sensors capable of operating over hundreds of kilometres (Figure 3).

Similar to earlier versions, today's tools use two measurement segments, each covering slightly over 50% of the circumference. This achieves an overlap of 110 - 125%, depending on the tool size, ensuring full coverage even with rotation. The newest generation, EMAT-C Ultra, builds on this foundation with further optimised capabilities, including a further optimised sensor system. One of the key enhancements is the increased coverage to 200%.

This is achieved through a new sensor arrangement that ensures every point on the pipeline is inspected in both clockwise and counterclockwise directions (Figure 4). This dual-directional inspection method enhances the detection of smaller, more complex flaws that other technologies may miss.

Another critical advancement is the separation of sender and receiver sensors onto independent carriers. This configuration allows each channel to move freely and maintain optimal contact with the pipe wall, even in challenging areas such as long seam welds. Dual-sided scanning ensures that, even if a sensor carrier is momentarily influenced by the geometry of the longitudinal weld, crack-like indications are still captured by multiple sensor channels (Figure 5). This redundancy enables the detection and identification of smaller flaws in the pipe body and longitudinal welds.

The RoCD EMAT-C Ultra Service represents a significant evolution of the well-established and reliable RoCD EMAT-C Service. It incorporates advanced sensor technology to achieve enhanced crack detection and resolution (Figure 6). These improvements enable the detection of shorter and shallower linear indications, bringing the service's resolution and

detection thresholds close to those offered by state-of-the-art UTCD technologies.

One of the key advancements of the RoCD EMAT-C Ultra Service is its enhanced detection reliability for linear indications (Figure 7). The POD has been improved by up to 95%, exceeding current industry standards. The combination of higher sensitivity and dual-direction coverage (clockwise

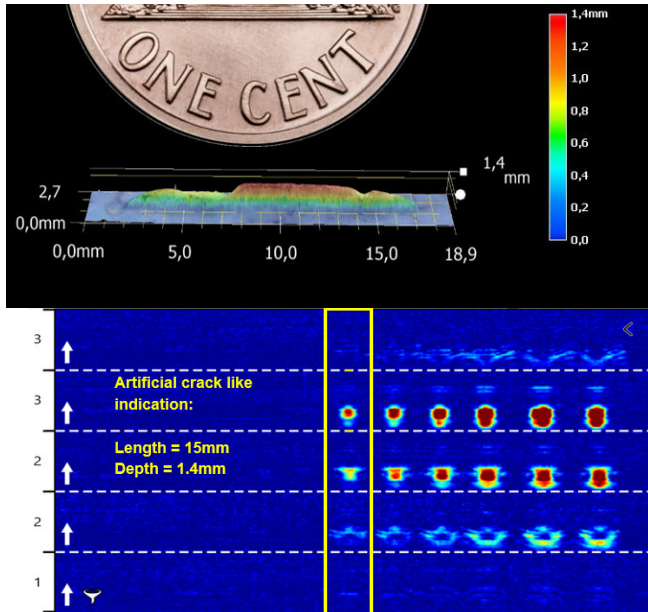


Figure 6. Example of a short and shallow feature detected by EMAT-C Ultra. The channels alternate between cw and ccw orientation.

and counterclockwise) significantly increases the probability of identifying all common types of internal and external axial cracks and crack-like defects.

Another advantage of the application's dual sound path is improved detection of tilted cracks. These cracks do not follow a radial direction, rather, they are tilted away from the surface into the pipe wall (Figure 8).

Tilted cracks usually reflect better on one side than the other. This makes a tilted or inclined crack that is only addressed from one side more difficult to detect and/or identify. Detecting the crack from both sides provides a more complete picture and improves identification and depth sizing capabilities. Figure 9 shows data from a series of artificial cracks with increasing inclination from left to right. While the signal from one channel (clockwise in this case) becomes slightly weaker, the signal from the other channel remains stable.

The RoCD EMAT-C Ultra Service ensures seamless compatibility with existing RoCD EMAT-C workflows, enabling operators to integrate the enhanced capabilities without disruption. The consistent advancement of sensor technology and methodology solidifies EMAT-C Ultra as a practical solution for pipeline crack detection and continues the history of collected EMAT-C data for a safe and reliable pipeline assessment.

EMAT-C Ultra performance verification

EMAT-C Ultra is a fully operational technology that has already been used for pipeline inspections of various diameters from 10 to 42 in. Before any new ROSEN technology enters service, it undergoes a comprehensive validation process aligned with API 1163 to ensure safe operation and compliance with all performance requirements.

This validation was carried out at the ROSEN Test Centre in Lingen, Germany (Figure 10), which is one of the world's largest testing facilities, spanning 108 000 m² and containing over 9300 m of test pipelines ranging from 3 to 56 in. in diameter. It is equipped to simulate a wide range of pipeline anomalies.

For the EMAT-C Ultra validation, eight fully operational tools (10 - 42 in.) were used, and pull tests were performed across all diameters, covering wall thicknesses ranging from 3.9 mm (0.154 in.) to 13.1 mm (0.516 in.).

Planar flaws were machined as narrow, rectangular EDM notches in test spools of all diameters to assess the RoCD EMAT-C Ultra Service. The inspection tool was pulled

Table 1. Statistics according to Clopper Pearson of the pull test results analysis for pipe body (PB) and long seam (LS)

Wall thickness cluster (mm)	Number of samples evaluated	Minimum detectable feature in pipe body (20 mm x 2 mm)		Minimum detectable feature in long seam (40 mm x 2 mm)	
		POD _{CP}	POI _{CP}	POD _{CP}	POI _{CP}
3.9 - 4.3	2759	90.8%	90.8%	99.6%	99.6%
4.4 - 5.9	12 391	99.6%	99.6%	92.9%	99.4%
6.0 - 7.5	34 201	99.4%	99.7%	99.9%	99.9%
7.6 - 9.1	33 532	99.5%	99.9%	99.6%	99.7%
9.2 - 10.7	36 832	95.7%	96.1%	95.3%	96.4%
10.8 - 12.3	5443	97.4%	97.4%	95%	95%
12.4 - 13.1	2772	90.2%	90.2%	90.2%	90.2%

Table 2. Excerpt of the EMAT-C Ultra specification for isolated radial cracks

POD	Isolated radial cracks w/ axial orientation				
	In pipe body and SCC colonies		In longitudinal weld area		
	90%	95%	90%	95%	
Minimum length	20 mm (0.79 in.)	40 mm (1.57 in.)	60 mm (2.36 in.)	40 mm (1.57 in.)	60 mm (2.36 in.)
Minimum depth	2 mm (0.08 in.)	1 mm (0.04 in.)	2 mm (0.08 in.)	2 mm (0.08 in.)	3 mm (0.12 in.)
Size certainty	80%				
Depth sizing accuracy for t < 10 mm	+/- 0.2 t	+/- 0.15 t		+/- 0.15 t	
Depth sizing accuracy for t > 10 mm	+/- 0.25 t	+/- 0.2 t		+/- 0.2 t	
Length sizing accuracy	+/- 20 mm (0.79 in.)				

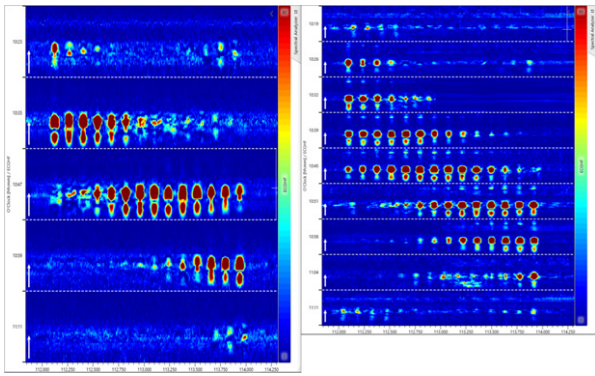


Figure 7. Comparison of EMAT-C (left) and EMAT-C Ultra (right) data of the same anomalies. The channels alternate between cw and ccw orientation.



Figure 8. Illustration of tilted cracks.

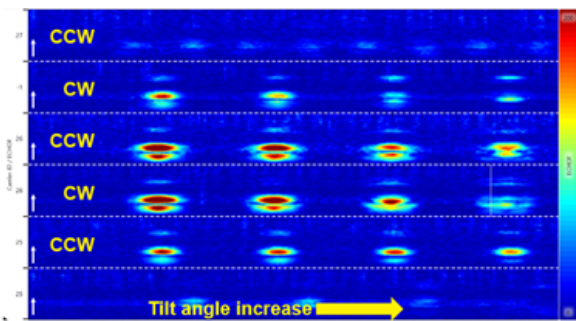


Figure 9. Data example for tilted cracks.



Figure 10. Aerial view of the ROSEN Test Centre in Lingen, Germany.



Figure 11. Example of a synthetic crack (made visible by MPI) and a synthetic sharp-edged corrosion.

through the pipe multiple times to ensure measurement repeatability. In addition to these classic notches, modern test spools can also contain synthetic anomalies with precisely defined morphology, size, and orientation. For EMAT-C Ultra evaluations, synthetic planar and volumetric flaws were included, such as those mimicking sharp edged or general corrosion defects (Figure 11).

To verify EMAT-C Ultra, 512 pull tests were performed across multiple pipeline diameters. The large number of anomalies in the test pipes generated 127 930 anomaly signals, providing a robust dataset for evaluation. This extensive dataset enabled statistically solid conclusions and confirmed the tool's reliability and performance across diverse operational conditions.


The data were analysed using a workflow similar to that of a standard pipeline evaluation to ensure the results reflect realistic inspection conditions.

For the calculation of the POD and POI, one-sided Clopper-Pearson binomial proportion confidence intervals were chosen as the statistical approach. This ensured statistically significant results with a guaranteed confidence level.⁴

Table 1, for example, shows the statistics for POD and POI in the pipe body and long seam according to Clopper-Pearson for the minimal detectable feature.

Based on a dataset comprising over 127 930 anomaly signals, this analysis derives a conservative and reliable specification for the new EMAT-C Ultra technology (Table 2). The specification is applicable to wall thicknesses ranging from 3.9 mm (0.154 in.) to 13.1 mm (0.516 in.) and has a POI of 90% for all common types of radial and longitudinal cracks, terminating on internal or external wall surfaces, including the weld bead.

Conclusion

Managing pipeline integrity is essential for safety and operational reliability. RoCD EMAT-C Ultra is a major advancement, that overcomes the limitations of previous inspection methods. It features 200% sensor coverage and dual sound-path detection. With its higher sensitivity and POD of up to 95%, as well as its ability to seamlessly integrate into existing integrity workflows, RoCD EMAT-C Ultra not only meets, but exceeds, industry expectations. The results presented here confirm RoCD EMAT-C Ultra's capability to enhance pipeline inspection practices and promote safer, more efficient operations. 

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