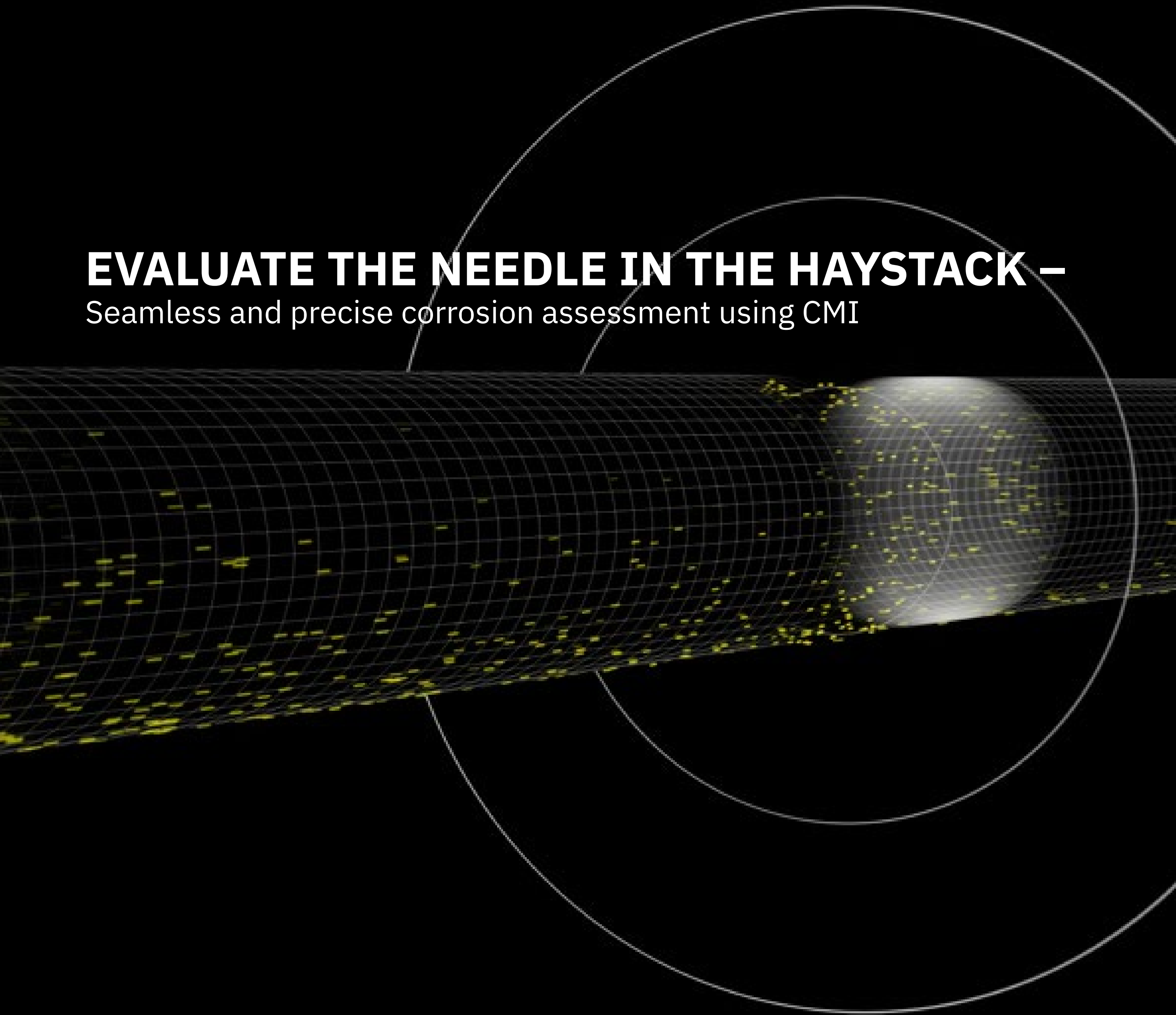
EVALUATE THE NEEDLE IN THE HAYSTACK –

Seamless and precise corrosion assessment using CMI



EMPIT

Introduction

Roughly half of buried distribution and older transmission pipelines worldwide lack the launch-and-receive infrastructure required for inline inspection (ILI) tools. To ensure also the integrity of these pipelines, EMPIT developed the Current Magnetometry Inspection (CMI). CMI is an above-ground inspection technique that enables detection of coating defects down to 1 mm² with pinpoint accuracy, while combining it with insights into local risk for active external corrosion at the steel surface at the located defects. Thus, from CMI also conclusions can be drawn on the local CP efficiency, and it does it with a much higher sensitivity and reliability compared to conventional over the line surveys; confirmed in direct comparisons in research projects.

The typical protection against external corrosion of pipelines consists of a combination of coating and cathodic corrosion protection (CCP). To ensure continuous safe operation, recurring inspections are essential and become increasingly important as the pipelines age. Currently the most reliable method for assessing the condition and corrosion status – and therefore the operational safety – of buried pipelines is inline inspection (ILI) using "intelligent pigs." These devices are equipped with ultrasonic (UT), magnetic flux leakage (MFL), or eddy current (EC) sensors and travel through the pipeline carried by the transported medium.

Based on the wall thickness measurements recorded along the inspected sections, areas with wall loss – and thus locations with potentially active corrosion – can be identified. However, ILI technology can only provide a snapshot of the material condition at the time of inspection – without accounting for the environmental conditions at the respective location and without the ability to differentiate between active corrosion and passive conditions. Modern long-distance transmission pipelines generally have the necessary launch and receiving infrastructure for pigging operations. However, worldwide, approximately half of the existing pipeline networks are considered unpiggable [1].

[1] A. Blackley et al., Pigging Previously Unpiggable Pipelines, PPIM Conference (2024)

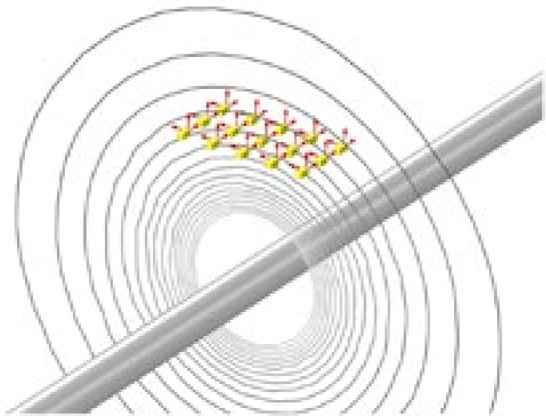


Figure 2: Schematic representation of the magnetic field around the conductor and the arrangement of the sensors for detecting the magnetic field in all three spatial directions.

Conventional over-the-line technology, such as Direct Current Voltage Gradient (DCVG) and Close Interval Potential Survey (CIPS) detect and assess coating defects by measuring pipe to soil potentials along the pipeline, and by measuring voltage gradients between CP off and on potential in the ground respectively. For certain defects, CIPS can determine the IR-free potential (EIR-free) which – according to DIN EN ISO 15589-1 – can be used as a direct verification of CP effectiveness.
However, this method is only suitable for evaluating larger coating defects where a sufficient potential gradient (≥ 150 mV) is present. In addition, the EIR-free does not allow conclusions to be drawn at defects where the effectiveness of the CP system cannot be normatively confirmed. According to reports from several network operators, numerous excavated coating defects at which the CP effectiveness could not be confirmed by the EIR-free were nevertheless found to be sufficiently protected. Consequently, using CIPS only enables the assessment of larger defects, while assessing CP effectiveness solely based on EIR-free potential has led to significant effort and unnecessary costs due to avoidable excavations.

Figure 3: The Current Mapper system during inspection

The Current Magnetometry Inspection (CMI) method – developed by EMPIT – measures a self-applied magnetic field around buried pipelines from above ground. Deep-fusion AI-based machine learning enables localization and advanced 3D mapping of any conductive pipelines and combines it with detection of coating defects down to a size of 1 mm² and direct local corrosion assessment. As the inspection along the pipeline is performed without any direct contact with the pipe, it is suitable even for challenging geometries, complex structures, and unpiggable pipelines.

As the first ever technology CMI defines a new criterium for corrosion assessment – the presence of a surface layer. It can be determined for each detected coating defect, no matter the size and is used to determine whether steel at a coating defect is passivated – indicating effective CP – or whether active corrosion is present – resulting from insufficient CP. Thus, CMI precisely quantifies local CP effectiveness and allows direct and actionable conclusions about material condition at all relevant pipe locations.

Principles of the CMI Technology

During CMI, a multi-frequency alternating current is applied to longitudinally conductive pipelines, resulting in a magnetic field around it. Because this inspection current is self-generated, the resulting field is precisely known and controllable, and unaffected by external or geographic factors. The frequencies between 2 and 2,000 Hz penetrate soil layers with minimal attenuation and, by spanning a range of frequencies, enable clear separation of the pipeline signal from adjacent metallic or structural objects.

The magnetic field is detected and evaluated from the air, ground, or water surface using up to 20,000 measurement points per second with up to 70 sensors. The spatially distributed arrangement of the sensors enables the magnetic field to be vectorially captured in all three spatial directions. From this measurement data, it is possible to determine the current in the pipeline, direction of current flow and the distance of the pipeline from the inspection system at any given moment.

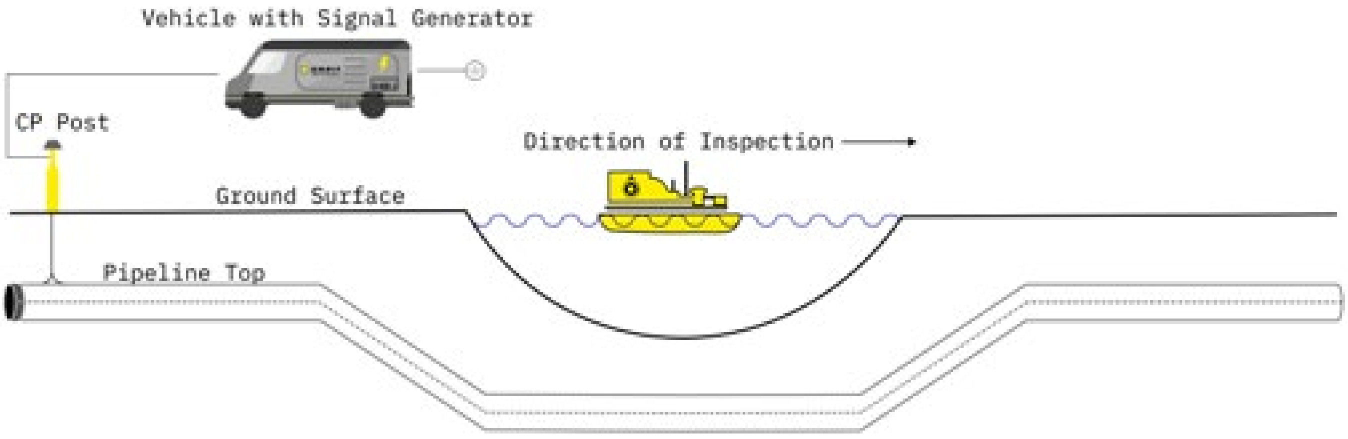


Figure 4 : Schematic represenation of the inspection set up

Combined with additional information from LiDAR, sonar, or radar, and the system's orientation, it makes CMI the world's most accurate method for absolute 3D pipeline positioning – even for complex structures and unpiggable pipelines. This advanced precise mapping is the foundation for the other services, such as bend detection, bending strain assessment and precise locali-zation of coating defects.

The detection of coating defects is based on the current transmission from the pipeline into the ground. This leakage current results on the one hand in an AC attenuation within the pipe and the other hand in a measurable resulting potential gradient. This position of leaking current and the shape and size of the potential gradient is used for the determination of conductive pipeline to soil contact and the accurate positioning of the coating defect.

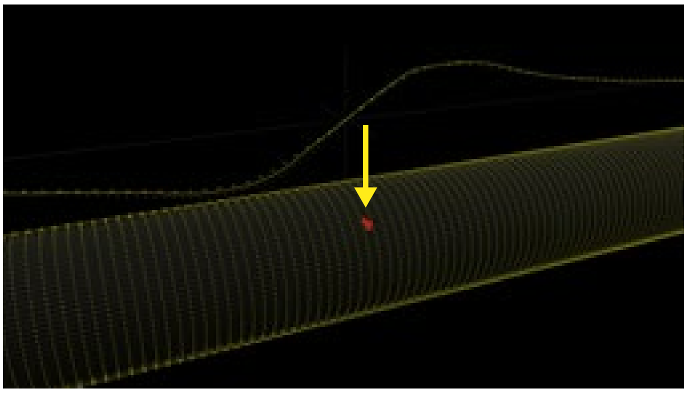


Figure 5: schematic visualization of a coating defect

Temporal correlation of the injected and measured signal, complete cross-correlation and normalization are enabled. This in turn allows for further evaluations, such as the determination of EIR-free or local spread resistances.

Using deep-fusion AI based algorithms further analyze the current flow in its complex form, allowing the resistive (ohmic) component to be separated from the capacitive component. Physically, the capacitance becomes measurable, reflecting whether a protective surface film has formed. Capacitive effects reveal the presence of a surface layer at the coating defect, indicating passivating conditions and a sufficiently working CP.

Non-capacitive behavior reveals the bare contact of steel with the surrounding soil, confirming high risk for an active corrosion process. By evaluating the presence of a surface layer on the pipeline at all coating defect locations, EMPIT has developed a new criterium that enables corrosion assessment of each defect, independent of soil bedding, defect size, or geometrical characteristics. The applicability and reliability of the method was confirmed during the DVGW research project "NEMEK" as well as it is field proven during inspections for pipeline operators around the globe.

Figure 6: Excavation and verification of active corrosion using CMI

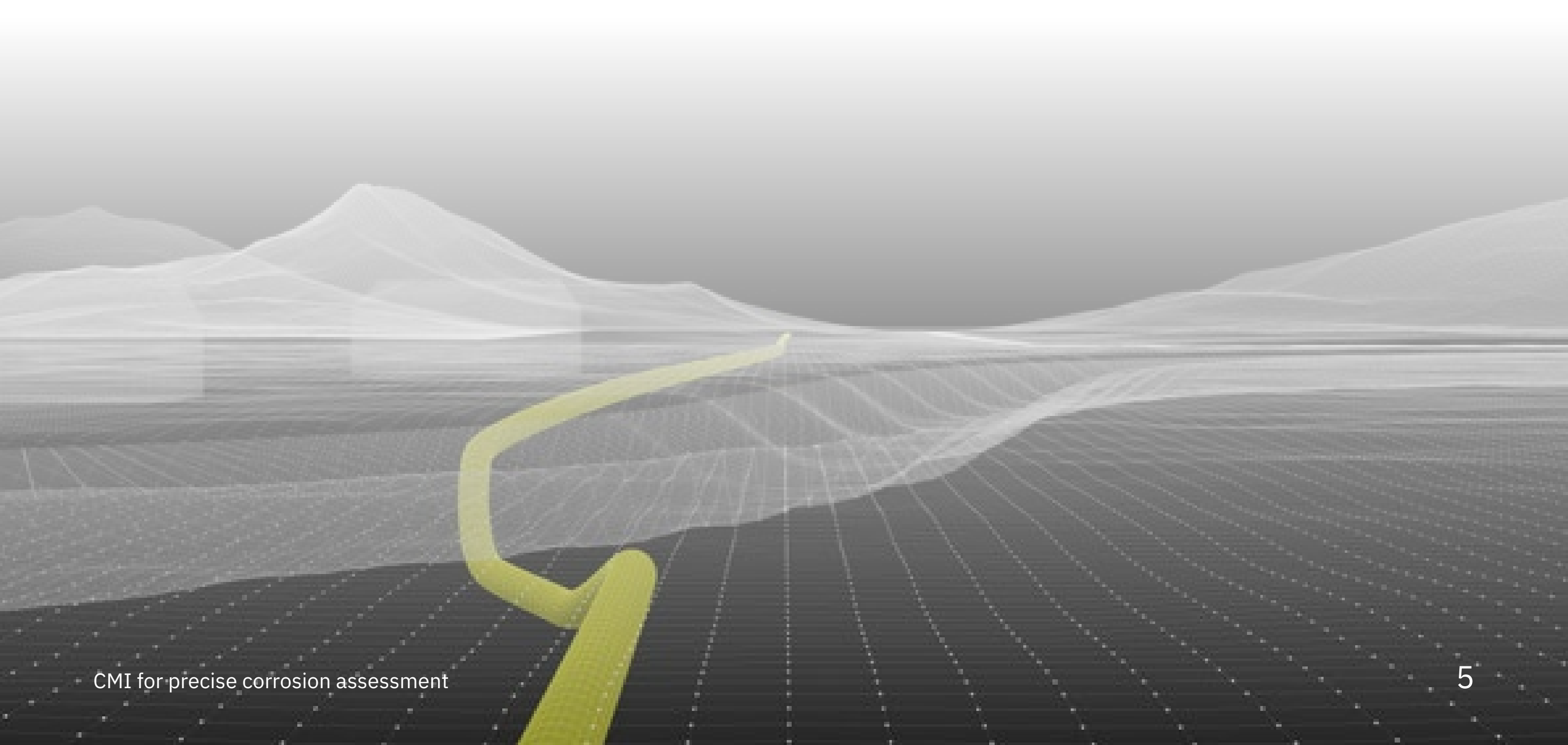
Summary

As first the inspection method worldwide, CMI provides a reliable over-the-line inspection technology to detect coating defects down to sizes of 1mm² and directly assess their corrosion risks. The use of a self-applied AC eliminates operational downtime, without affecting general operations like CP systems. It can be either integrated in existing integrity management procedures and periodic programs but can also be deployed flexible and short-term if required. That minimizes planning, effort and preparation on the Operator‘s side.

The presence of a surface layer allows for direct conclusions on the efficiency of CP systems and actual corrosion hazards, instead of a momentous snapshot of the pipeline condition. And that for every defect – unrelated to defect size, bedding, environmental conditions or pipeline geometry. Thus, CMI is designed to create insights for informed decision making, to minimize unnecessary excavations.

Overall, CMI provides groundbreaking insights for a reliable and action-based integrity management to protect pipelines around the globe and to make every dig count.

Figure 8: left: Excavated pipeline, where coating defects were detected and assessed; middle: defect under passivating conditions with calcerous deposits (circle); right: detected defect with active corrosion



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