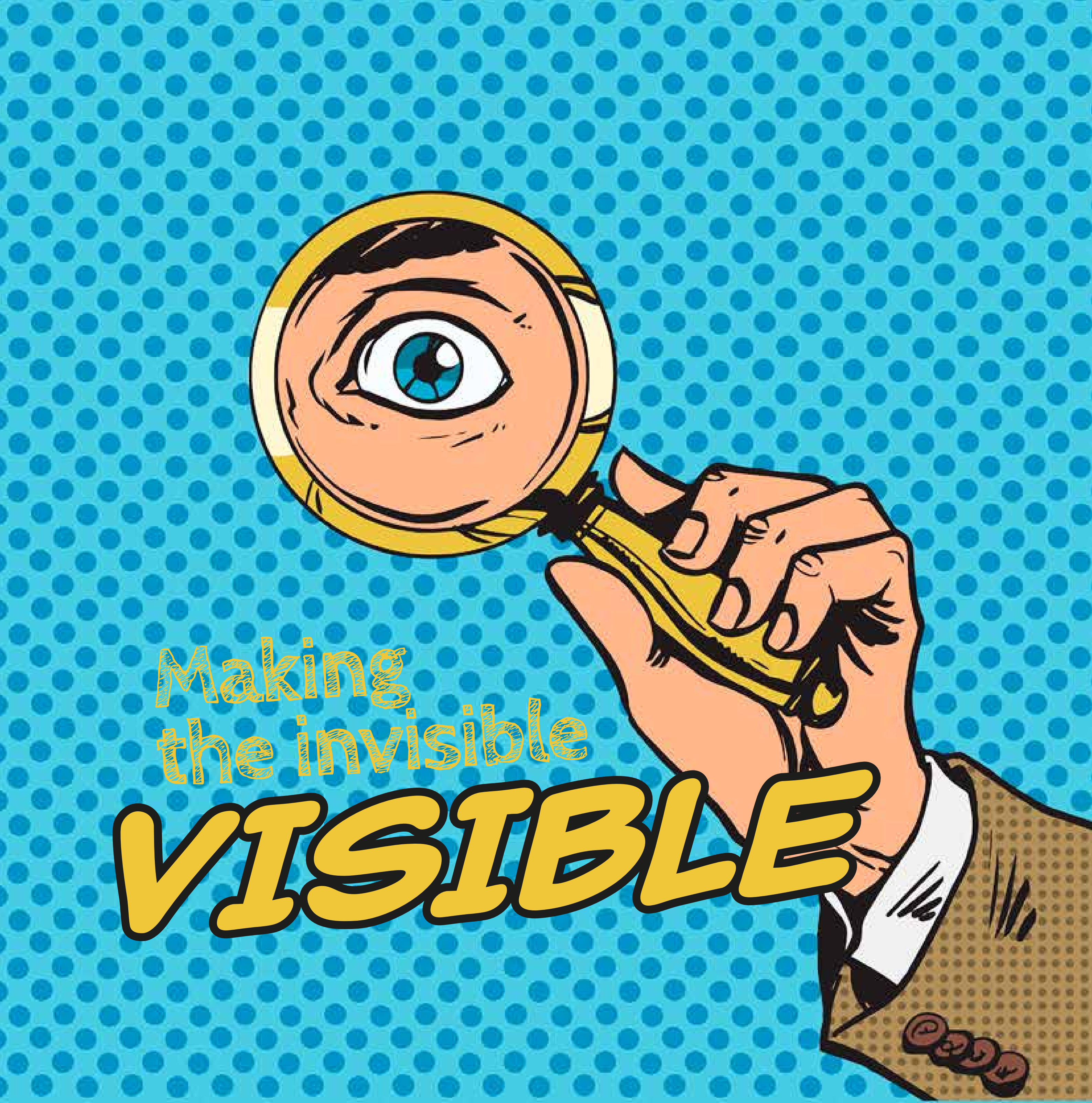

# Making the invisible VISIBLE

**Michael Rapp, ROSEN Group, Germany,** explores a magnetic flux leakage technology that provides laser-like results.



An innovation does not always need to be something completely new. Sometimes it involves revisiting reliable systems of past and present and reinventing them. This was the case with the development of MFL-A Ultra technology.

Magnetic flux leakage (MFL) has proven to be a dependable bedrock for the pipeline inspection industry. Giving this technology a revamp has created powerful new possibilities, while also staying true to its reliable reputation.

Research and development projects always face difficulties. When the maiden voyage is a success, however, teams can

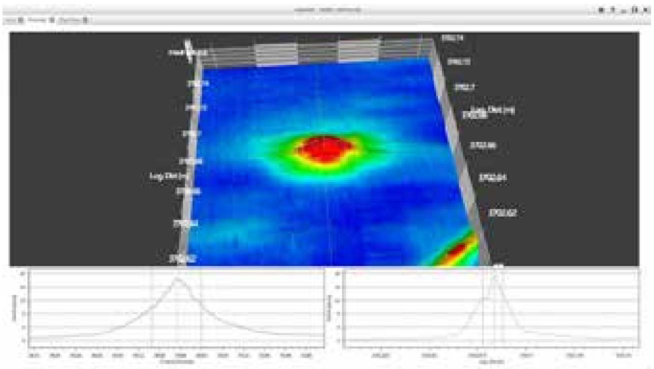

Figure 1. Example of 3D MFL-A Ultra data visualisation.

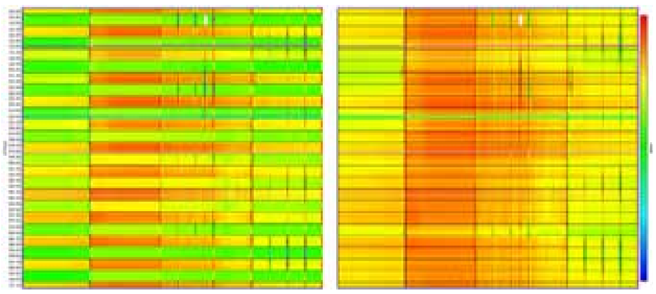

Figure 2. Before (left) and after (right) the normalisation of data sets from both sensor rings.

breathe easy. The development of ultra high definition axial magnetic flux leakage (MFL-A) technology has introduced a step change to inline inspection (ILI). This new technology allows operators to reliably assess heavily corroded pipelines and detect even very small pinholes. Its capability leads to significantly less conservative integrity assessments and, ultimately, saves cost and time by reducing field verifications.

## Delivering results

Investing heavily in research and development allows companies to create sustainable and innovative technologies based on current and future market needs. Given today's market and growing public awareness of the oil and gas industry, the need to invest in the integrity of existing assets is becoming ever greater. This requires the industry to not only focus on regularly inspecting assets, but to also find effective and reliable ways of performing the most accurate integrity calculations possible.

In the past, the resolution of pipeline inspection data has simply not been high enough to evaluate certain 'difficult to assess' defect types, such as highly corroded pipelines, pinholes of 1 mm (0.04 in.) and less in diameter, complex corrosion, microbiologically induced corrosion (MIC), top of the line corrosion (TOLC) and certain girth weld defects. In addition, the evaluation of data has relied primarily on the human eye, impacting the repeatability of results, as well as the ability to truly understand large amounts of data.

These factors, along with a commitment to safety, have resulted in very conservative integrity assessments. This has, ultimately, led to numerous costly field verifications, which the introduction of the RoCorr MFL-A Ultra inspection service can help with.

Many innovations begin as research projects. In this case, the key aim was essentially to build an MFL tool with the highest technically feasible spatial resolution. To make this ambitious target possible, three things had to take place: new sensors had to be engineered and developed, the mechanical properties of the ILI tool had to be enhanced to ensure perfect sensor positioning across the entire pipeline, and new algorithms for both tool calibration and data evaluation had to be created.

The first item that needed to be addressed in order to deliver laser scan-like results was the sensor elements. These were optimised for a 1 mm (0.04 in.) axial resolution and 1.6 mm (0.063 in.) circumferential resolution. This has more than doubled the resolution of current standard MFL technologies and essentially moving from individual data points to true Pipeline Imaging™, an example of which can be seen in Figure 1. During this process, there was hope that simply improving the sensitivity and resolution of the sensors would be sufficient. Unfortunately, that was not the case.

## Attention to detail

Many hurdles had to be overcome to make pipeline imaging possible. The mechanics and electronics of the new sensor elements now needed to be adapted to create optimal conditions for the sensor's data capture capabilities, even in the girth weld area, and to drive accuracy to the next level.

It soon became clear that a track pitch of less than 2 mm (0.08 in.) would be required to deliver the required resolution. This created various challenges for the development team. Traditionally, sensor carriers are placed on one sensor ring and are located at least 2 mm apart due to mechanical constraints. To achieve the desired resolution, two sensor rings had to be mounted beside one another with the carriers attached in a slightly offset fashion, as can be seen in Figure 2. However, during an extensive research and development process, it became clear that this in itself would present a challenge due to the ultra-high resolution and elevated sensitivity of the individual sensor elements.

These elements are affected by their physical location within the magnetic field of the yoke, in other words the displacement of the width of the sensor rings already had a significant influence on the measurement results. In response to this, two data sets are generated – one measuring closer to the front and one closer to the back of the magnetic field. Using image processing algorithms, these sets are normalised in order to create one triaxial magnetic image for the pipeline. Figure 2 shows the data sets both before and after normalisation; the separated data sets from each sensor ring is on the left and the combined image is on the right. In summary, only a


**Figure 3.** Effective area reduction through MFL-A Ultra.

dual sensor ring approach ensures full ultra-resolution circumferential coverage in all operational situations.

These developments enabled the creation of a successfully field-tested 8 in. prototype tool. Using this tool, the team achieved detection of pinholes down to 1 mm dia. To further test and develop the new technology, a second tool was built. In 24 in., with a speed control unit (SCU) and XYZ mapping capabilities, the second tool is now to be ready for commercial applications.

Validating technologies in real life scenarios is vital for measuring the success of any research and development project. Therefore, the updated technology was field-tested in April 2016 by taking a journey of approximately 300 km (180 miles) through North America. The tool performed within the required specifications along the entire pipeline and was successfully retrieved. It delivered a complete data set of 2.5 terabytes in size.

## Ultra-resolution means big data

Of course, collecting ultra-resolution data with consistent quality is only the beginning of the journey to a complete service. What to do with the enormous amounts of data will be the real test. Following on from the real life application in April, after a successful data quality check on site, the data was brought into a ROSEN facility for processing. While the detailed check graphs were proven to be completely successful, the first sighs of relief were short-lived. In order to get the most out of the 2.5 terabytes of data gathered, new algorithms and processes that could handle the volume of potentially integrity-relevant indications had to be developed.

To achieve the performance specifications of this service, machine-learning based adaptive algorithms are fed 3D high resolution laser scans from pipeline defects. This AutoData™ algorithm suite is engineered to ensure consistent automated data management across the entire service, spanning from service calibration and data preparation to defect detection, classification and sizing. It is geared towards delivering Pipeline Imaging on all defects, not only on a certain selection of features per kilometre or mile.

When deciphering raw pipeline data, irregularities may occur that do not necessarily influence the integrity of the pipeline. These include various installations that can potentially take quite some time to identify, which is amplified when working with 2.5 terabytes of data. Consequently, the AutoData system has been designed to classify these installations by following a few simple steps. First, the algorithms need to detect the installation (or installation clusters), then extract a description for each installation type, correct the data for artifacts to avoid false calls and, finally, classify the installations as valves, tees, off-takes etc. The automated machine learning-based process ensures continuous improvement with each completed inspection so that the system gets better every time it is used.

## What's the big deal?

This new technology is a great leap forward to a reliable and dependable system. It provides the highest ILI resolution available to date and the data collected delivers highly accurate Pipeline Imaging, ensuring that no integrity-relevant defects are missed. In turn, this delivers a detailed yet solid foundation for more accurate feature boxing and river bottom profiles (RBP), allowing for less conservative failure pressure calculations and estimated repair factors (ERF).

Ultra-resolution provides increased accuracy and hence smaller error bars. It also delivers more features (including many smaller ones) and breaks down some larger features into several smaller ones. The latter often have a smaller effective area.

Subsequently, there are fewer features above the critical repair threshold, meaning less field verifications and a reduction in repair cost, while making no compromises on safety and compliance. One of the most important benefits of the detailed imaging that the features will provide is better diagnosis of the cause of features. As in medical imaging, the more detailed the view an integrity engineer has of the features, the better he or she is able to diagnose the cause. For example, in precommissioning damage or MIC, whether they are benign or active can be clarified. Once the 'disease' is known, the appropriate 'treatment' – be it repair, inhibition, biocide treatment, cathodic protection upgrade, recoating, enhanced cleaning or monitoring by repeat inspection – can be prescribed.

The first application of this technology was the first step in delivering real Pipeline Imaging rather than mere line plots and C-scans, while running in common MFL operating conditions in terms of velocity, passage, temperature, pressure etc. The technology is geared for both the detection of very small pinholes and structural analysis of heavily corroded pipelines with pit-in-pit/complex corrosion, MIC, TOLC and girth weld defects.

Looking beyond what is possible now, it is foreseeable that selected improvements developed for the MFL-A Ultra technology will also benefit traditional high resolution MFL technologies in the mid term.