A full-page background image showing a worker in a blue uniform and white helmet climbing a dark grey wall. The worker is seen from the side, facing right, and is secured by ropes and safety harnesses. The wall has a vertical seam. The lighting is bright, casting a long shadow of the worker onto the wall.

ACFM[®] Sets the Standard for Surface Inspection

For over 30 years, ACFM[®] has earned an undisputed reputation for accurately detecting and sizing surface-breaking cracks.

This eBook presents *Alternating Current Field Measurement (ACFM[®])*, the electromagnetic testing technique that offers compelling advantages over other Non-Destructive Testing (NDT) methods for surface crack detection.

It's time to acknowledge how *ACFM[®]* raised the bar and set the standard for a robust solution, providing production efficiency and peace of mind.

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How Alternating Current Field Measurement Surfaced

The beginning of the Alternating Current Field Measurement or **ACFM®** electromagnetic testing technique took place in the 1980s when a group of oil companies based in the United Kingdom required a more reliable Non-Destructive Testing (NDT) solution for inspecting subsea structural welds.

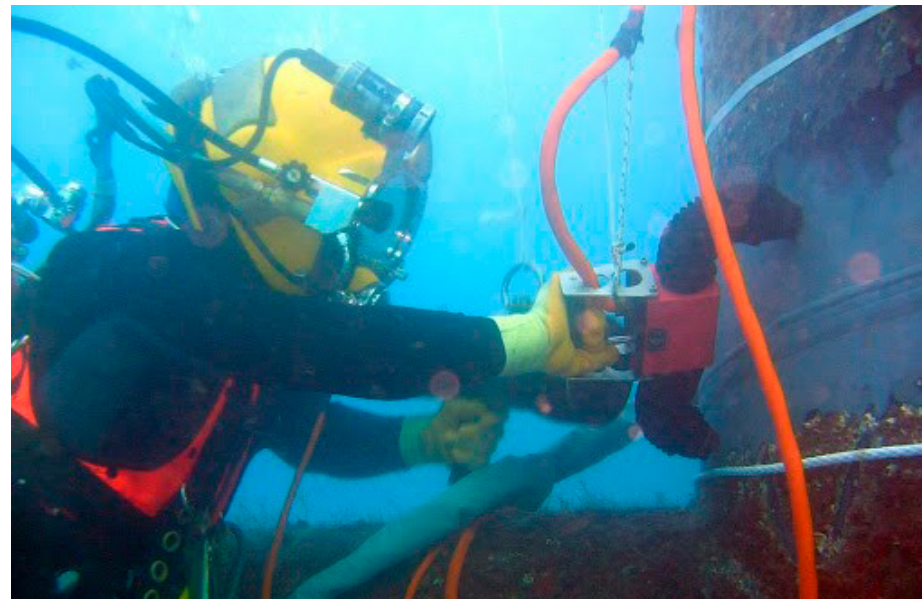
Prior to ACFM®, in the offshore sector, Magnetic Particle Inspection (MPI or MT) was typically used to locate surface breaking defects in underwater welded intersections. This method required a level of cleaning that resulted in bare metal with removal of any coatings present. While the surface length of any indications could be measured by MPI, it could not provide defect depth—the most relevant parameter in ultimately determining the remaining life of the structure.

Conventional Eddy Current Testing (ECT or ET) was also employed, but it faced challenges with reliably detecting some flaws in carbon steel welds due to their electromagnetic complexity. Furthermore, ECT was limited to estimating a maximum crack depth of five millimeters or 0.2 inches and had a high degree of error.

Finally, Alternating Current Potential Drop or ACPD was a technique that was also sometimes used to predict the depth of surface breaking fatigue cracks. The process was difficult and slow to use underwater because the technique demanded good electrical contact between the voltage probe and the steel surface. A non-contact equivalent to ACPD was needed.

Oil companies working in the North Sea contacted the mechanical engineering department at University College London (UCL) who had extensive experience in both theoretical and practical developments in ACPD. This led to the development of the new technique which would become known as **Alternating Current Field Measurement**. ACFM® provided offshore operators the ability to detect surface cracking in welds, without the level of cleaning necessary for MPI or ACPD, and then accurately predict the length and depth of those flaws with a single, effective technique. Since the first commercial instrument produced in 1991, ACFM® has grown worldwide as a valuable addition to the NDT toolbox, especially for examining painted or coated welded steel structures.

RELATED BLOG: <https://eddyfi.com/en/blog/how-acfm-changed-the-subsea-crack-detection-game>



How the Technique Works

The way ACFM® works is that it locally induces a uniform electromagnetic current into the asset under review and measures the density of the magnetic flux across its surface. The probe does not require electrical contact with the component which translates into not having to remove any paint, coatings, or grime. Currents are contained in a thin layer on the face of the carbon steel material. Any surface breaking defects disturb the induced current and therefore the magnetic flux density.

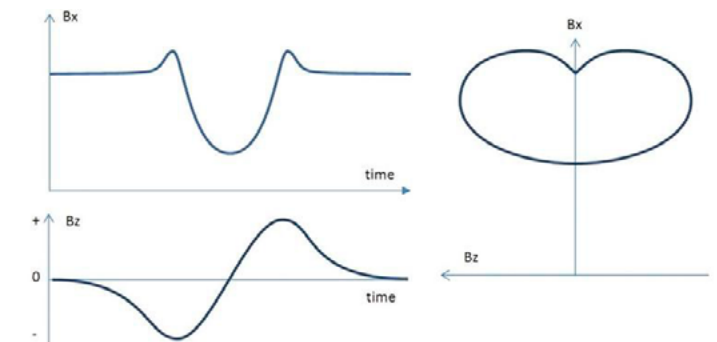
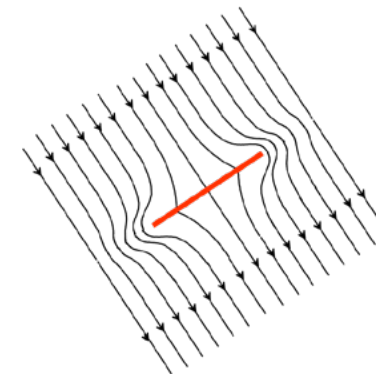
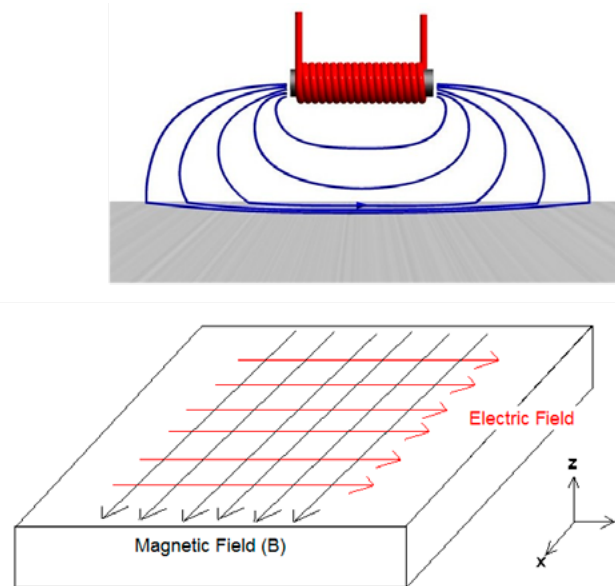
This density provides information in conjunction with a sizing algorithm to determine a defect's length and depth. The mathematical model eliminates the need for calibration using mock defects like slots in order to estimate a defect's size; calibration with slots is known to be prone to errors as a result of human mistakes, differences in slot behavior to real cracks, mismatched geometry and lack of length diversity.

The primary course of induced currents is recognized as the Y axis (typically across a weld), and the direction of the associated magnetic field in and near the surface represents the X axis (typically parallel to a weld). When no defects are present, the current travels along the Y axis and the magnetic field along the X axis. The magnetic field's Y and Z components, B_y and B_z , are zero while the X component, B_x , matches the electric current's magnitude.

Linear surface breaking defects on the X axis force the electric current to flow around and under a defect's tips. This reduces the magnetic field's strength in the middle of the defect and increases it at the ends, resulting in a B_x response which forms a trough in the middle and peaks slightly at the tips. The magnitude of this trough is related to the depth of the defect. The partly circular flow of current around the crack ends creates a measurable non-zero B_z response which forms a peak at one end and a trough at the other. The distance between these is related to the surface length of the defect. A third trace called

the butterfly plot consists of the B_x and B_z sensor data plotted against each other. The vertical axis maps the B_x amplitude and the horizontal axis marks the B_z . This display eliminates the time element from the scan and scan speed variation effects and provides an effective discriminator between crack indications and spurious signals.

This uniquely displayed ACFM® data is stored by the instrument and available for further analysis post-inspection for audit and reporting purposes. When it comes to equipment, a standard ACFM® probe contains a magnetic field inducer and one magnetic sensor each to measure flux density along the X and Z-axis. To cover a larger area in a single pass, array ACFM® probes are designed to contain many sensor pairs adjacent to each other to accommodate multiple configurations. This data can be viewed as traditional trace plots or C-scans.



BENEFITS OF ACFM®

ACFM® was designed so that it doesn't require extensive cleaning or bare metal on which to operate which dramatically reduces the preparation time and cost. ACFM® is designed around a uniform field input which leads to important advantages over some other techniques: the probes don't require onsite calibration, the probe scan patterns are simple as the probe is scanned along the line of the weld, and the liftoff response is reduced so that the inspection is relatively insensitive to changes in probe handling and surface irregularities. Another important advantage is that ACFM® can size much deeper defects, up to 25 millimeters, or 1 inch, in depth, which can be valuable information in thick walled structures.

The performance capabilities of ACFM® have been extensively tested through independent trials which in turn have led to the acceptance of the technique by many classification and verification bodies including Lloyds Register, ABS, DNV and BV.

■ Standards for the inspection of welds using the ACFM® technique are also published by ASTM and API, among others.

- ◆ No extensive cleaning or buffing required
- ◆ No onsite calibration necessary
- ◆ Simple, intuitive, scan patterns
- ◆ Suitable to detect and size deep defects (up to 1 in)
- ◆ Technique accepted by many certification and verification bodies

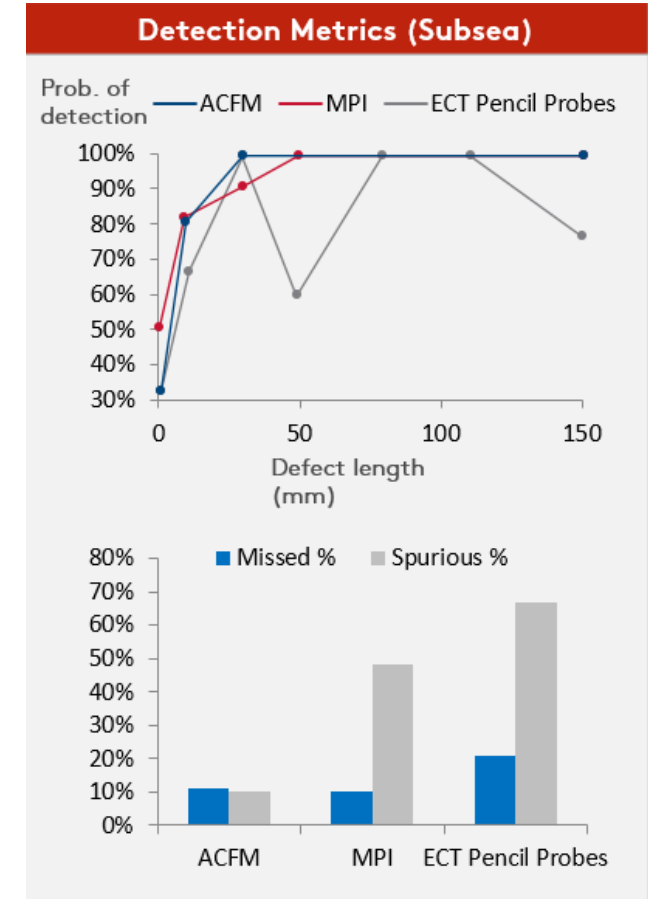
SEE EXACTLY HOW ACFM® STACKS UP COMPARED TO OTHER CONVENTIONAL METHODS.

PROPERTY	ACFM®	MPI
Crack Detection and Location	Yes	Yes
Crack Length Measurement	Yes	Yes
Crack Depth Measurement	Yes	No
Storage of Inspection Data for Later Analysis	Yes	No
Ability to Automate Inspection and Analysis	Yes	No
Operator Skill Required	Medium-High	Low-Medium
Dependency on Operator	Low	High
Suitability for Audit	Good	Poor
Cleaning Requirements	Minimal	High

ACFM® compared to MPI

PROPERTY	ACFM®	ECT Pencil Probe
Crack Depth Measurement Without Calibration	Yes	No
Maximum Depth	About 30 mm	About 5 mm
Crack Length Measurement	Yes	Yes
Crack Detection and Location	Yes	Yes
Spurious Signals	Low (Bx only)	High
Operator Skill Required	Medium-High	High
Easy Deployment in Transition Region (e.g. Weld)	Yes	No
Easy Extension to Array Probes	Yes	No

ACFM® compared to ECT Pencil Probes



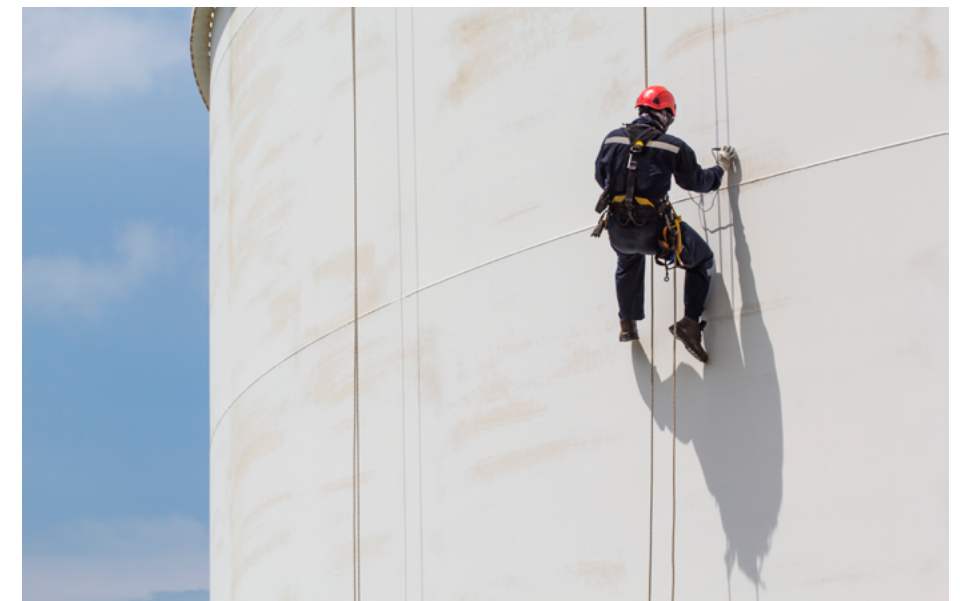
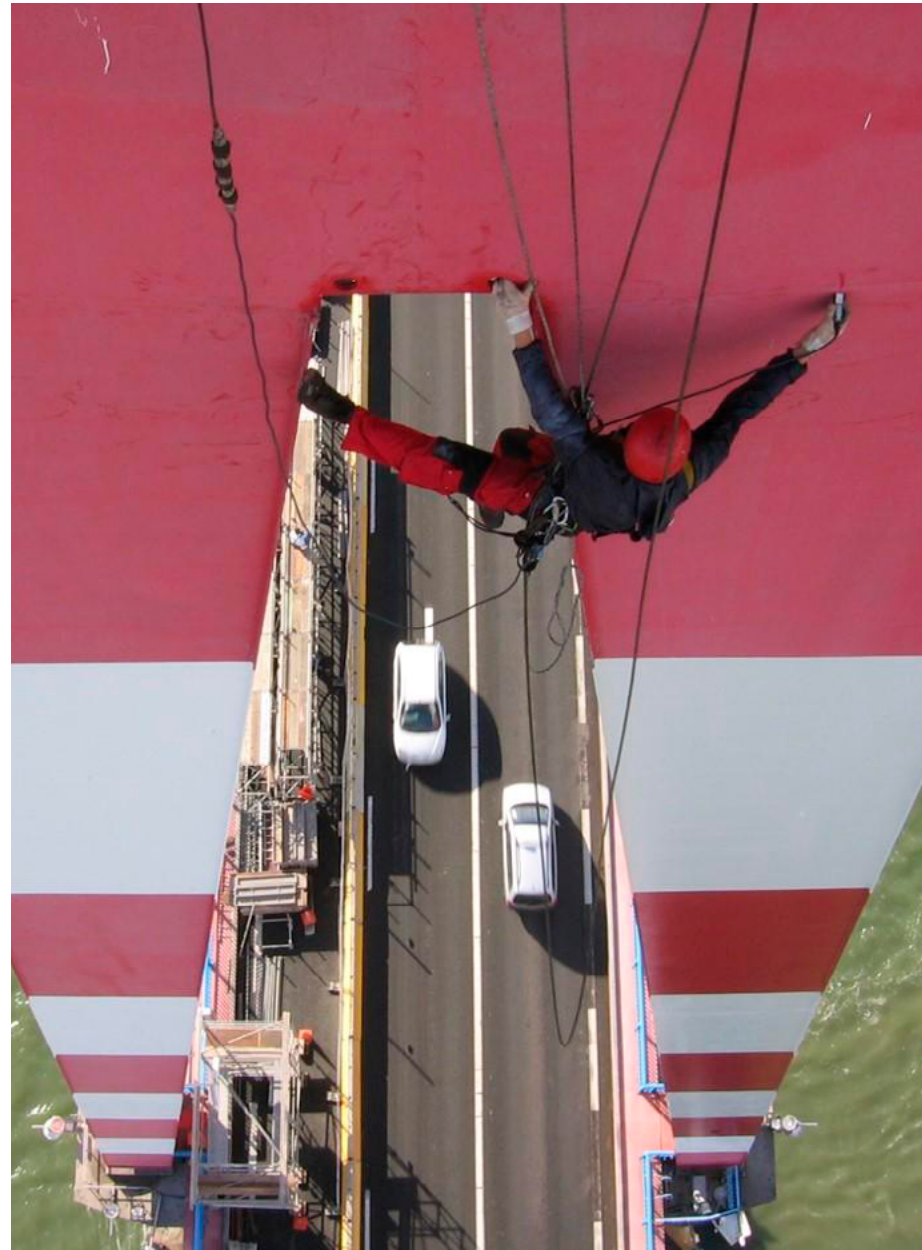
Where ACFM® Raised Standards

ACFM® is typically used on ferromagnetic materials where it has the highest sensitivity, but it has also been implemented on non-ferromagnetic materials including austenitic stainless steel in nuclear storage tank pools, titanium offshore risers, and Inconel threaded connections on downhole motors—all with great success.

With the first application for ACFM® being subsea weld inspection in the offshore oil and gas industry, the advantages of this technique have increasingly been realized by other sectors. The technique is widely accepted by key players in energy, chemical, transportation and other industries. In the oil and gas space, many certification authorities have approved ACFM® to inspect offshore installations.

■ As the following use cases will demonstrate, adopting the Alternating Current Field Measurement technique is advantageous in a range of environments.

ACFM® IS APPROVED BY MANY CERTIFICATION AUTHORITIES SUCH AS NACE, ASME, ASTM, COFREND, ISO, AND MANY MORE...



TANK INSPECTION

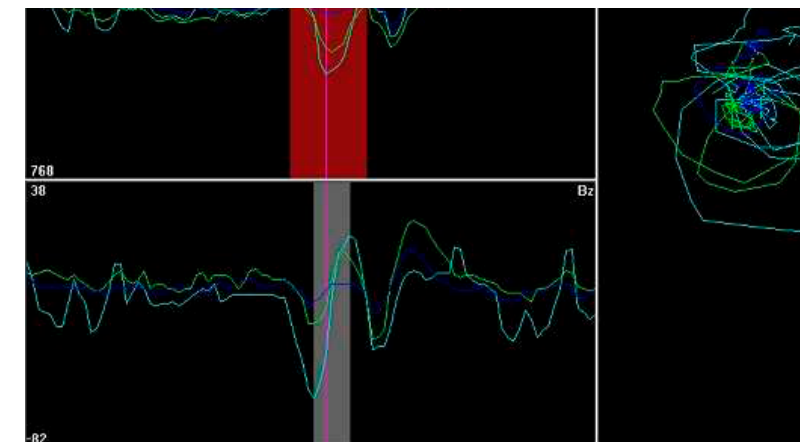
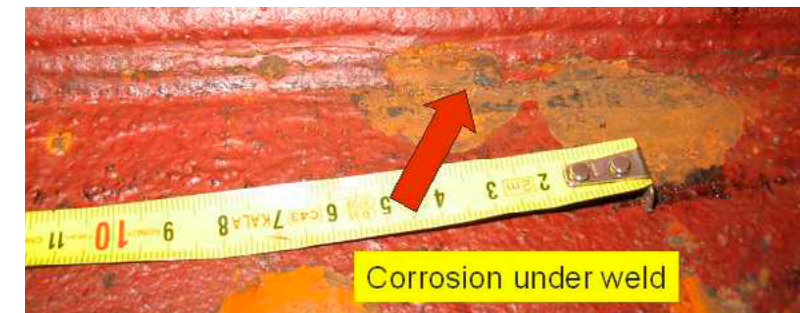
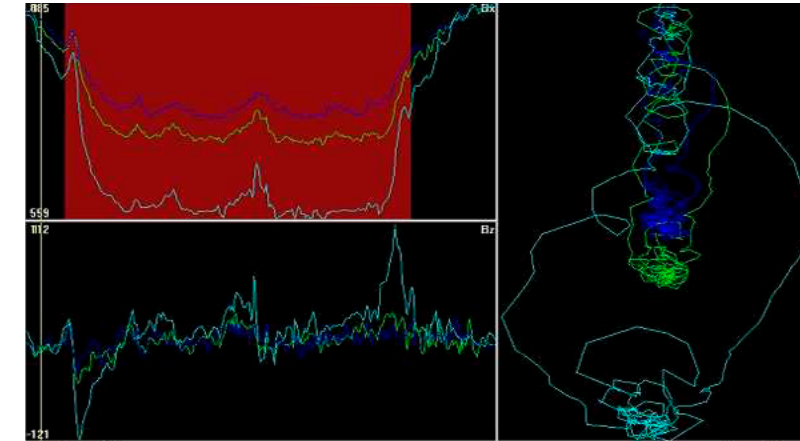
For land-based operations, ACFM® has been effectively applied to oil, gas and petrochemical storage tanks commonly containing diverse liquids including crude and processed hydrocarbons. These tanks are manufactured by welding steel plates together and feature complex floor plate layouts with butt and lap welds, although the weld between the wall and floor is generally a simple fillet weld.

Select refinery failure analysis investigations indicate that cracking at the weld between the wall and tank floor plates have previously resulted in leakage. The cyclic stresses incurred from loading and unloading in addition to the base slab condition can encourage cracks at the weld toe of internal fillet welds on the tank floor plate side. Unfortunately, floor scanners used to monitor corrosion thickness are unable to detect cracks in welds given the noise level.

Conventional crack detection processes have employed vacuum boxes and MPI—time consuming processes that require cleaning and surface preparation. Thick epoxy coatings are typical of petrochemical tank floors and represent another obstacle for MPI as it must be removed before the technique can be applied.

Given the benefits in terms of cost and time savings plus reliable results, the ACFM® technique was selected for crack detection on internal fillet weld connections between the wall and floor of oil storage tanks based in France. With a requirement to only detect deep defects or through cracks, normal scan speed limitations were relaxed; when a defect was detected, an additional scan would be performed locally for sizing details. This method enabled weld toe scanning speeds of about 100 meters, or 330 feet, per hour. To put this into perspective, **MPI typically takes one hour to cover 10 meters** without taking prior cleaning and preparation time into account.

Moreover, ACFM® with array probes revealed surface corrosion under coatings and caustic stress corrosion cracking in carbon steel tank floors. These damage mechanisms were neither detected by vacuum box nor color contrast dye Penetrant Testing (PT). The large ACFM® signal resulting from branched multiple shallow cracks was later confirmed by fluorescent MPI.



DRILLSTRING THREAD INSPECTION

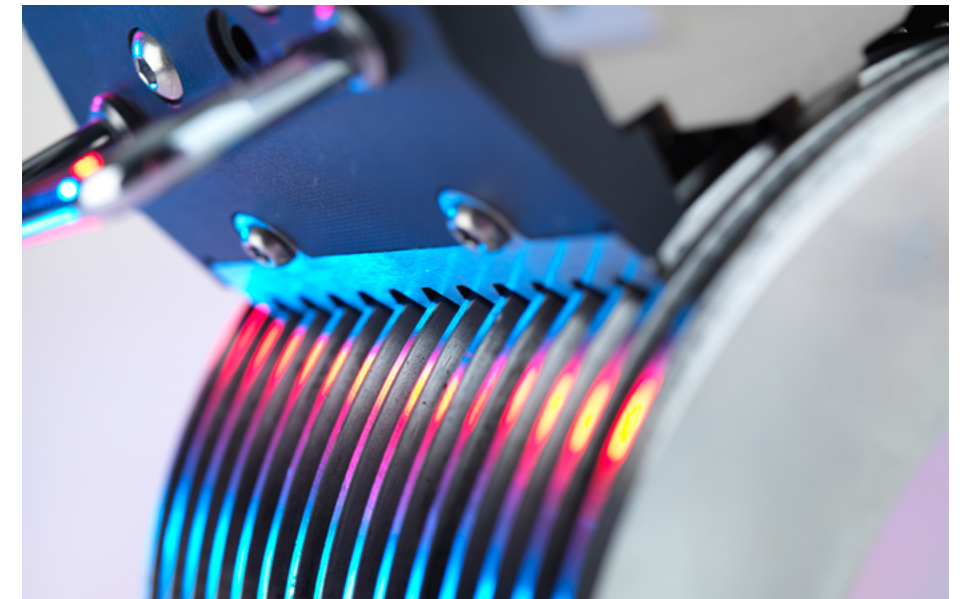
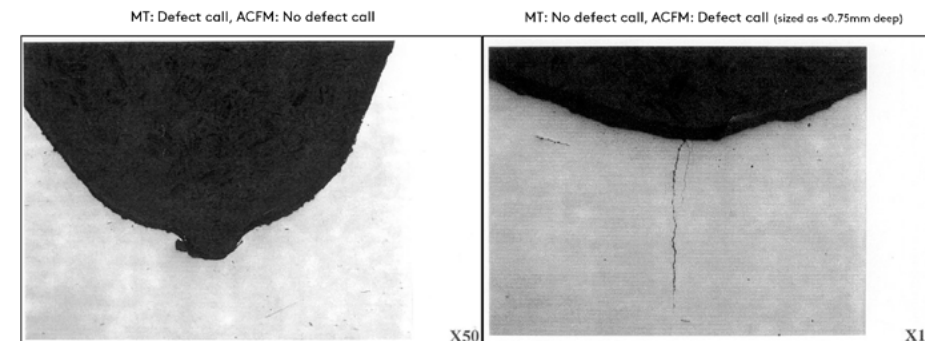
When it comes to drilling operations, maintaining the integrity of a drillstring is mandatory. The threaded connections on drill pipe and other drillstring components endure substantial cyclic loading, unsurprising given the intense task at hand. These threaded connections between components, exposed to fatigue damage, commonly represent the most vulnerable part for drillstring and bottom hole assemblies.

Scheduled inspections of downhole components help identify any cracking and allow operators to effectively plan repair or replacement activities. This has conventionally been performed with enhanced optical methods, namely magnetic particle or dye penetrant testing. Under both circumstances, interpretation of results relies on the technician who usually provides a handwritten record of any defect indications. Besides the human factor, these methods present other drawbacks including requirements for extensive pre-cleaning and degreasing of components as well as low light conditions for dyes and inks to be effectively used. With visual access required, the drillstring component must be rotated during assessment.

ACFM® is a welcome replacement for the efficient and reliable inspection of drillstring threads. The electromagnetic technique eliminates the need for considerable cleaning and visual entry to the area under examination while providing an objective record of inspection results. These results can be used to monitor downhole threaded components based on quantitative data for any defects found including length, depth, and location. A robust ACFM® instrument contributes to cost effective inspection resources, and reduced risk of cracks being missed resulting in a downhole failure.

■ Halliburton performed trials to compare MT to ACFM® on downhole motor components normally retired at the end of their recommended operating life. There were 140 threaded ends inspected with magnetic particle testing. Results showed approximately 10% surface indications without any positive crack indications. When the inspection was performed using ACFM®, **23 defects were found**. With the additional information offered by ACFM®, nine of the components were able to be reworked with the rest scrapped. Two of the scrapped parts contained substantial defects that were not picked up by MT. Following independently witnessed trials, ACFM® technology has been included as an acceptable method in the North Sea Drillstring Inspection Standard NS-2.

RELATED BLOG: <https://eddyfi.com/en/blog/cut-costs-not-corners-using-alternating-current-field-measurement-ACFM-for-drillstring-thread-inspection>



RAILWAY ASSET INSPECTION

Operators in the rail industry regularly investigate bogies, wheelsets, and rails for surface cracking. The traditional technique used, MPI, required extensive cleaning, stripping of paint and subsequent restoration of the protective paint coating which created a slow and expensive process. The subjectivity of the test and lack of any permanent record were also areas of concern. Rigorous, independent trials were carried out comparing ACFM® with MPI on bogies and wheelsets and concluded that ACFM® offered an equivalent or higher probability of detection than MPI along with an electronic record of the test, all completed without removal of the paint.

- The success of ACFM®, especially for consistency in results, made it a ***strong candidate for the inspection of Rolling Contact Fatigue (RCF) cracks on rails.***

WITH AN EXCELLENT PoD, ACFM® CAN BE DEPLOYED WITHOUT THE REMOVAL OF PAINT OR COATINGS.



Back in the 1990s, rail break from RCF cracking was a major problem in the United Kingdom. Bends were particularly prone to failure. At the time, rail inspection was performed visually. The obvious deficiency with visual testing is the lack of indication for the depth of any defects spotted. Ultrasonic “walking stick” probes were employed but the multiple cracking that typifies RCF damage scattered the ultrasound and rendered the stretch of rail untestable. Even deep defects could not be seen due to the obscuring nature of the shallower surrounding cracks.

ACFM® is not prone to this effect as the response is driven by defect depth and so an ACFM® sensor can detect the deep RCF defects even among many shallow cracks. An ACFM® array was created with multiple sensors which covers the area of the rail head most prone to RCF damage.

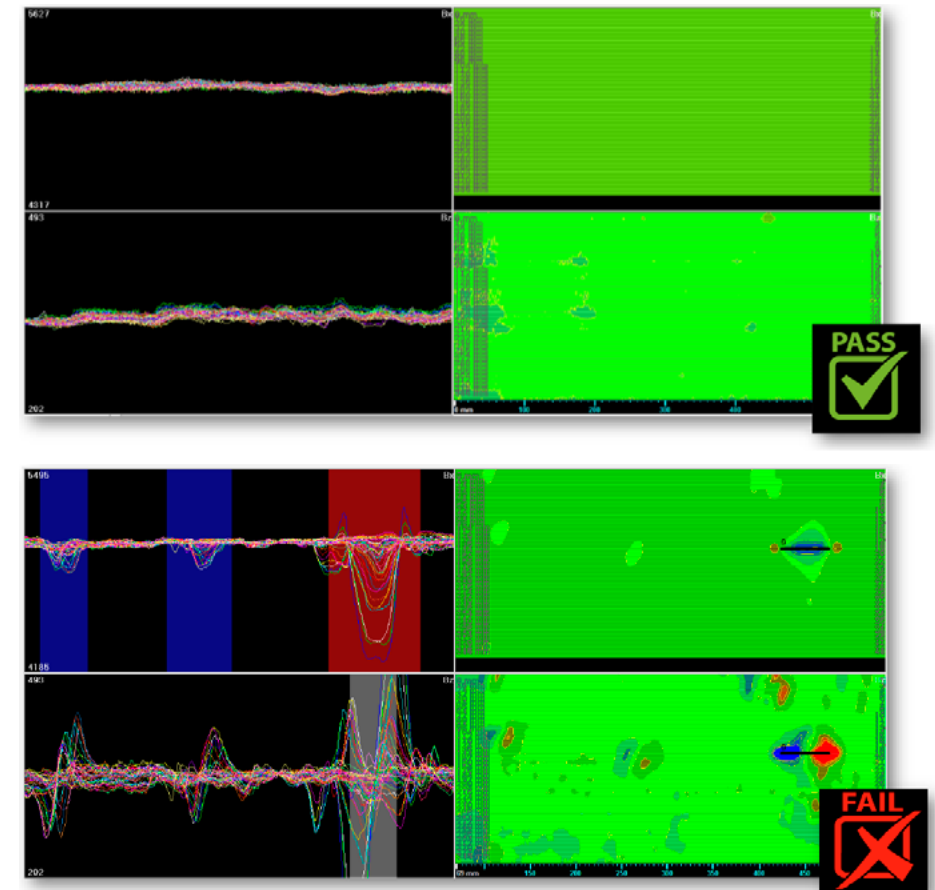
The standard fatigue cracks that ACFM® was designed for are considerably different than RCF defects. In most cases, rolling contact fatigue cracks are inclined at 30 degrees from the surface. They can either spread towards the surface resulting in a loss of part of the rail surface or they can travel down towards the rail developing into a rail break. Furthermore, the front of a crack is often wider under the surface than the length of the surface while the crack depth is larger compared to the surface length.

The ACFM® theoretical sizing model developed in the 1980s therefore does not apply to RCF cracks. After comprehensive calibration trials utilizing rails with true RCF cracks, a new calibration procedure was developed for sizing defective rails. The new sizing algorithm has been incorporated in special software also capable of automated detection and reporting of the deepest defect for a given length of rail. ACFM® can detect gauge corner cracking on the surface of a rail head which can be responsible for rail break. With the ability to accurately measure crack propagation, ACFM® assists operators with making decisions to grind or re-rail the track section in question.

RELATED BLOG: <https://eddyfi.com/en/blog/the-rolling-momentum-of-ACFM-in-the-rail-industry>



“ACFM® assists operators with making important integrity decisions.”



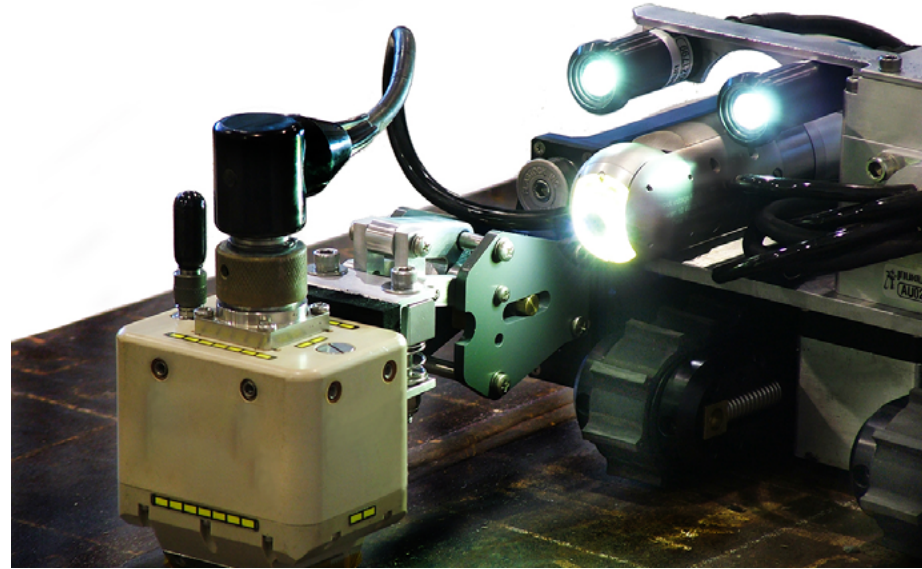
ROBOTIC DEPLOYMENT OF ACFM®

There are some applications that require more sophisticated deployment of ACFM® probes. Many of these circumstances accommodate remotely operated vehicles in place of divers in the inhospitable offshore environment. Moreover, there is an obligation for topside inspections where it is simply too costly or dangerous for direct human intervention. As an example, ACFM® has been robotically deployed for the inspection of nuclear waste storage tanks as well as the internal walls of coke drums.

In the case of the coke drum, its walls were made from carbon steel with stainless steel cladding, joined by Inconel welding. A long articulating arm on the inspection system was able to access the coke drum either by being lowered from the top or raised up from the bottom. Onboard cameras and lasers integrated in the arm were used to record dimensional measurements of the drum surface and any distortion.

The remotely operated arm then unfolds to place a motorized scanner featuring magnetic wheels against the drum wall. An ACFM® array probe is attached to the scanner to identify signs of corrosion or other damage along the wall. These inspections were performed while the wall was at 100° Celsius, successful in part to a forced-air cooling system built in to keep the electronics at operating temperatures.

■ Opportunities for **robotic implementation of the Alternating Current Field Measurement technique are rapidly increasing with Industry 4.0.**



How to Stay Beyond Current

ACFM® technology offered by Eddyfi Technologies has developed an undisputed reputation for accurately detecting and sizing surface breaking cracks through paint and coatings, for over 30 years.

Our **true ACFM® technology** offers a uniform field inducer, constant current drive, orthogonal sensors, discrete phase sampling with no onsite calibration ever required.

RELATED BLOG: <https://eddyfi.com/en/blog/next-generation-alternating-current-field-measurement-ACFM-technology-for-surface-breaking-crack-detection>

True ACFM®

- ◆ No onsite calibration
- ◆ Uniform field inducer
- ◆ Constant current drive
- ◆ Orthogonal sensors designed for optimized crack detection and sizing



AMIGO™ 2: THE NEXT STEP IN ACFM® EVOLUTION

The TSC Amigo™ 2 ACFM® instrument offers the rugged, reliable, and user-friendly interface that industry demands with expectations for increased performance in speed, signal quality and portability.

As its name implies, this is the second-generation Amigo, engineered around a highly advanced signal acquisition and processing system. It is up to 10 times faster for a data range that is 14 times better. This translates into smoother, higher resolution indications of even the smallest defects under thick coatings.

The self-contained ACFM® tool incorporates the electronics, multi-touch display, and storage in one rugged package; while this setup favors transportability, operators have the option to use a remote computer if desired. Amigo 2 supports up to eight digital inputs for high-speed, large array ACFM® probes. It is backwards compatible with all standard manual or array Amigo probes. The onboard software, Assist™, allows conveniently switching between different connected probes.

DISCOVER THE NEXT STEP IN ACFM® EVOLUTION: <https://eddyfi.com/en/product/amigo-2>



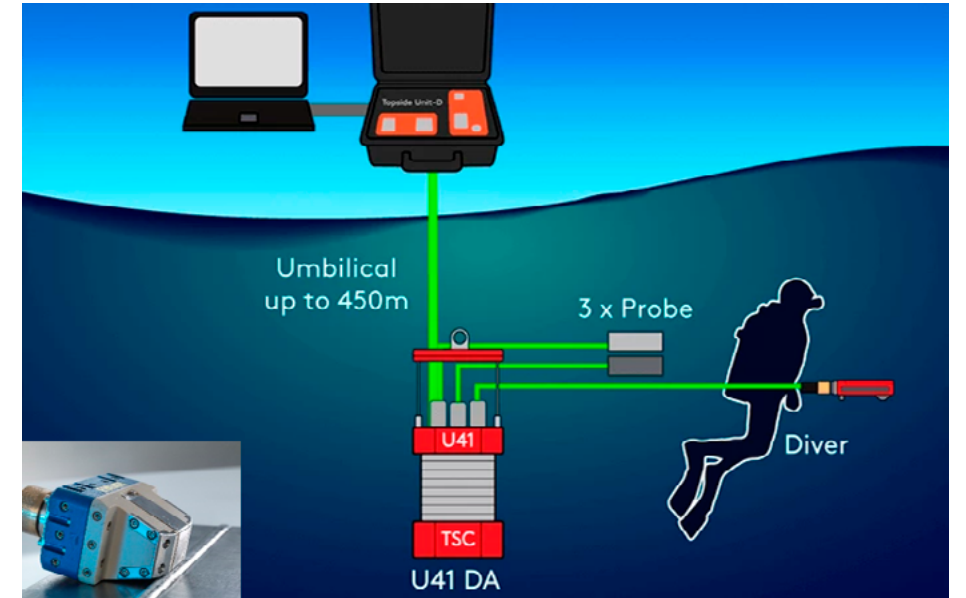
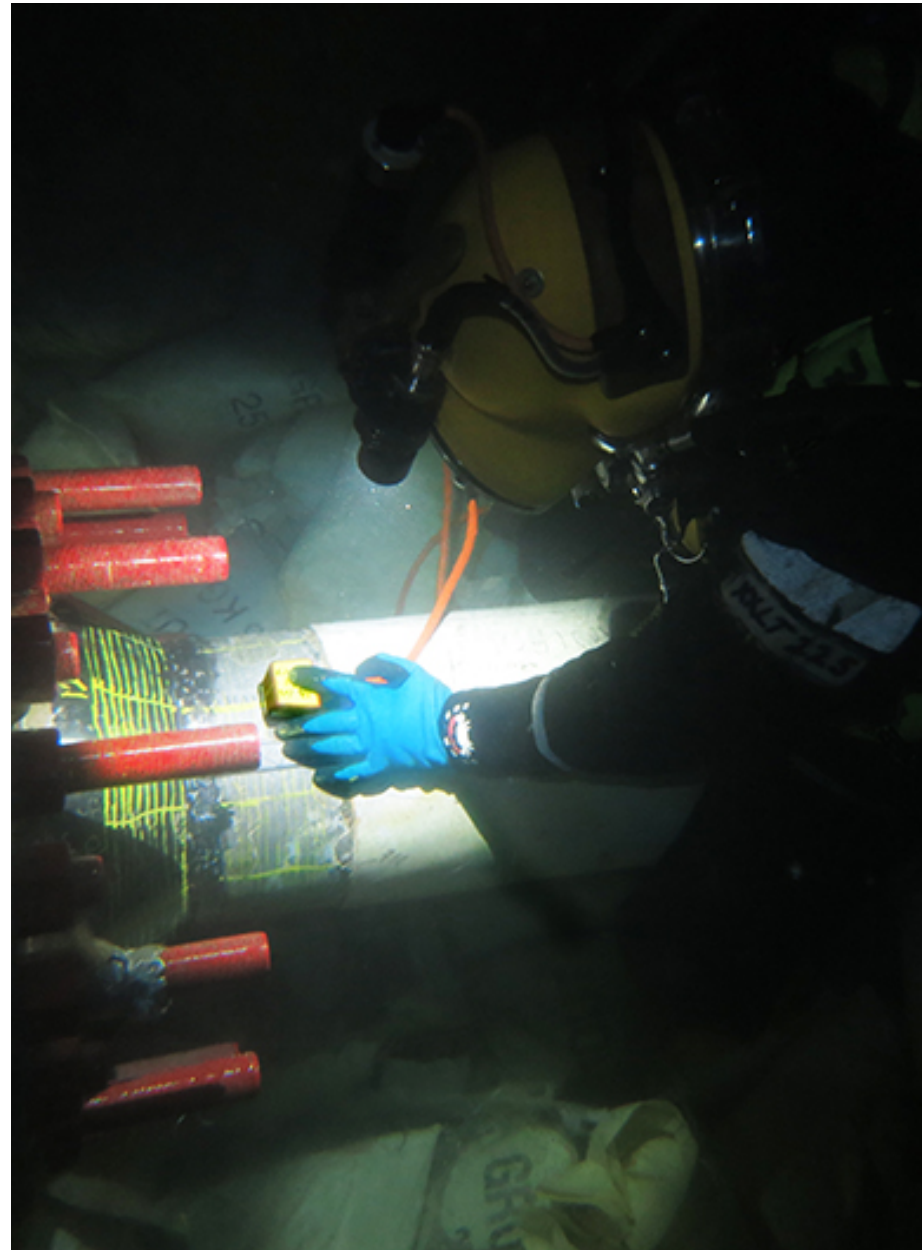
U41: MODERNIZING SUBSEA ACFM®

The TSC U41™ ACFM® instrument has redefined and modernized subsea crack inspection.

The subsea bottle is lowered to a diver who uses simple Bx/Bz pair or mini (4-row) array probes connected through a 5-meter, or 16.4-foot, long cable. Another 150-meter, 492-foot, long cable responsible for power and communication is connected from the bottle to the topside unit. A laptop connected to the topside unit is used to control operations. Multiple umbilical cables may be connected together to enable the diver to travel up to 450 meters, 1476 feet, away from the topside unit on deck.

Typical applications include inspection of structural node welds on jackets, caisson inspection, pipeline damage assessment, and mooring chain and system evaluation.

DELVE INTO THE ADVANCED SUBSEA SURFACE BREAKING CRACK DETECTION TOOL:
<https://eddyfi.com/en/product/u41>



SUBSEA CRACK INSPECTION HAS BEEN MODERNIZED AND REDEFINED, THANKS TO ACFM®.

ACFM® for Better Inspections Today and Tomorrow

The Alternating Current Field Measurement, or ACFM®, technique changed the NDT world with its introduction of a powerful mechanism for repeatable, actionable, meaningful, and preventative data results for subsea weld inspection and beyond.

With advantages including testing through paint and coatings without extensive surface preparation or cleaning, the time efficiencies of ACFM® just can't be ignored. It has effectively replaced magnetic particle inspection and other techniques in instances where confidence in data matters.

- At the end of the day, ACFM® contributes to the crucial role of ensuring asset integrity to safeguard humans and the environment today... and tomorrow.

Trust ACFM® to see beyond the surface.

**CONTACT EDDYFI TECHNOLOGIES
FOR THE BEYOND CURRENT ACFM® SOLUTION**

info@eddyfi.com | eddyfitechnologies.com

