

ALTERNATING CURRENT FIELD MEASUREMENT (ACFM®)

TECHNOLOGY OVERVIEW OF ADVANCING SURFACE CRACK INSPECTIONS

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TOTAL CONTROL



AGENDA

- Introduction to ACFM technology
- Working principles
- Tools & applications
- Specific solutions for underwater inspections
- Training

INTRODUCTION TO ACFM

ALTERNATING CURRENT FIELD MEASUREMENT (ACFM)

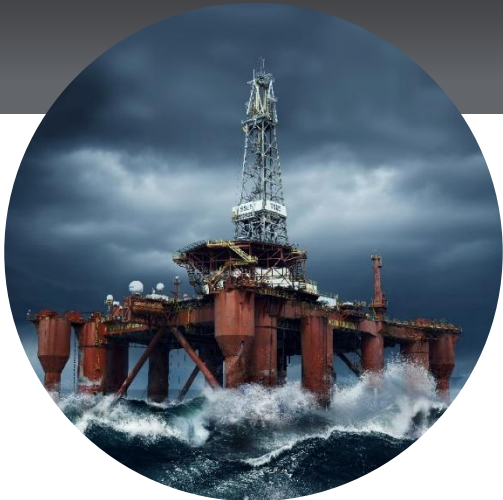
CONTEXT

Fatigue cracking in structural welds:

- **Is a major cause of failures**
- **Impacts public safety and industrial operations**
- **Is difficult to detect and labor-intensive with visual techniques**

ACFM is a proven, efficient, and reliable option to:

- **Minimize surface preparation and recoating**
- **Improve probability of detection**
- **Reduce inspection time and labor**



ACFM HISTORICAL HIGHLIGHTS



**OFFSHORE
O&G ISSUES**
Early 1980's

1

ACFM dev. UCL
Early 1990's

2

**Validation /
ICON + reg.
acceptance**
Throughout 1990's

3

**FIRST WIDELY
COMMERCIALIZED
INSTRUMENT**
~ 2000

4

**Various
application
specific dev.**
~ 2000's – 2010's

5

**New generation
ACFM
instruments**
~ 2018-2019

6

**Application
specific sensor
development**
2020-2023

7

**Connected tools:
OneDrive
Zoom
&
Eddyfi app.**

8

1980

1990

2000

2010

2020

ACFM[®]

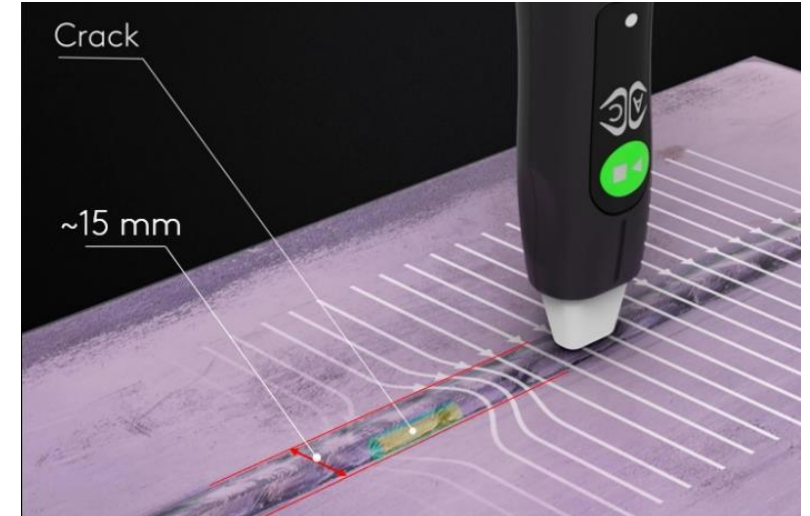


WORKING PRINCIPLES

ACFM CAPABILITIES

Surface-breaking crack detection with sizing in ferrous & non-ferrous materials

- Detect cracks at an early development stage
- Fast acquisition speed at up to 150mm/s (6in/s)
- Forgiving scans with large probe coverage
 - Single element probes: 15mm (0.6in)
 - Array probes: up to 90mm (3.5in)
- Work through coatings of up to 10mm (0.4in) thick
- Size flaw down to 25mm (1.0in) deep



MAIN BENEFITS

Efficient, safe and cost effective:

- Standard ACFM provides a 60% gain in productivity vs MPI
- Using array probes can improve those figures by ~ 3x
- Sizing capability enables cost effective remedies
- No health risks associated with handling chemicals
- No waste chemicals or aggregate management

Credibility and reliability:

- Field-proven reliability and high POD (on rough and coated welds)
- Approved by several regulatory bodies
- Offers streamlined and structured inspection planning and reporting
- Reduced inspection and record-keeping errors



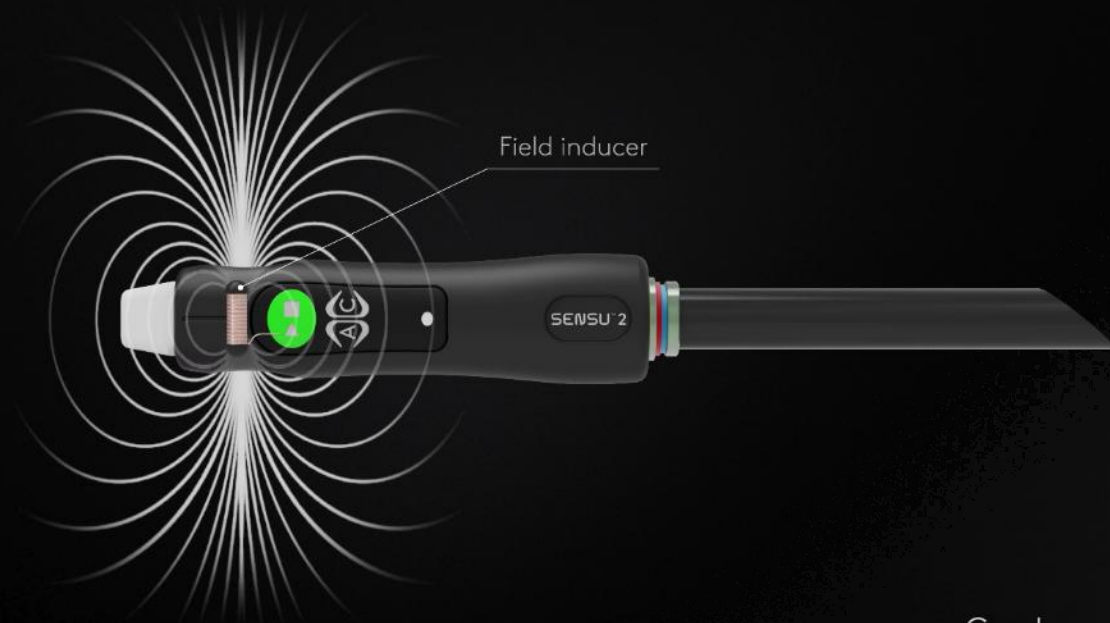
KEY ELEMENTS FOR TRUE ACFM

Uniform
fields

Butterfly
signal

Sizing
method

ACFM WORKING PRINCIPLES: THE UNIFORM FIELDS



Crack

Uniform fields induced



ACFM WORKING PRINCIPLES: THE BUTTERFLY



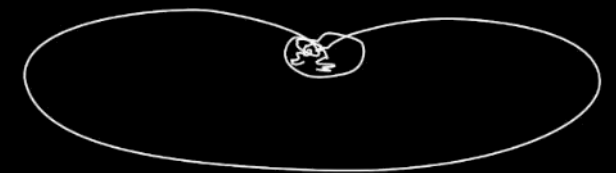
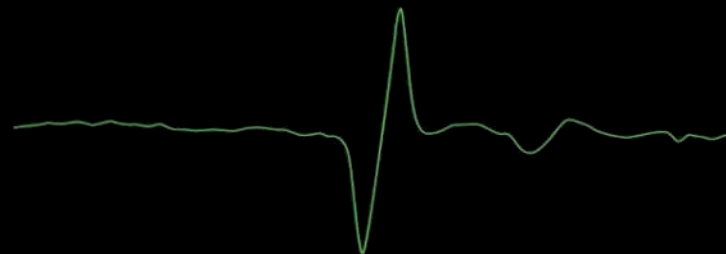
Bx signal



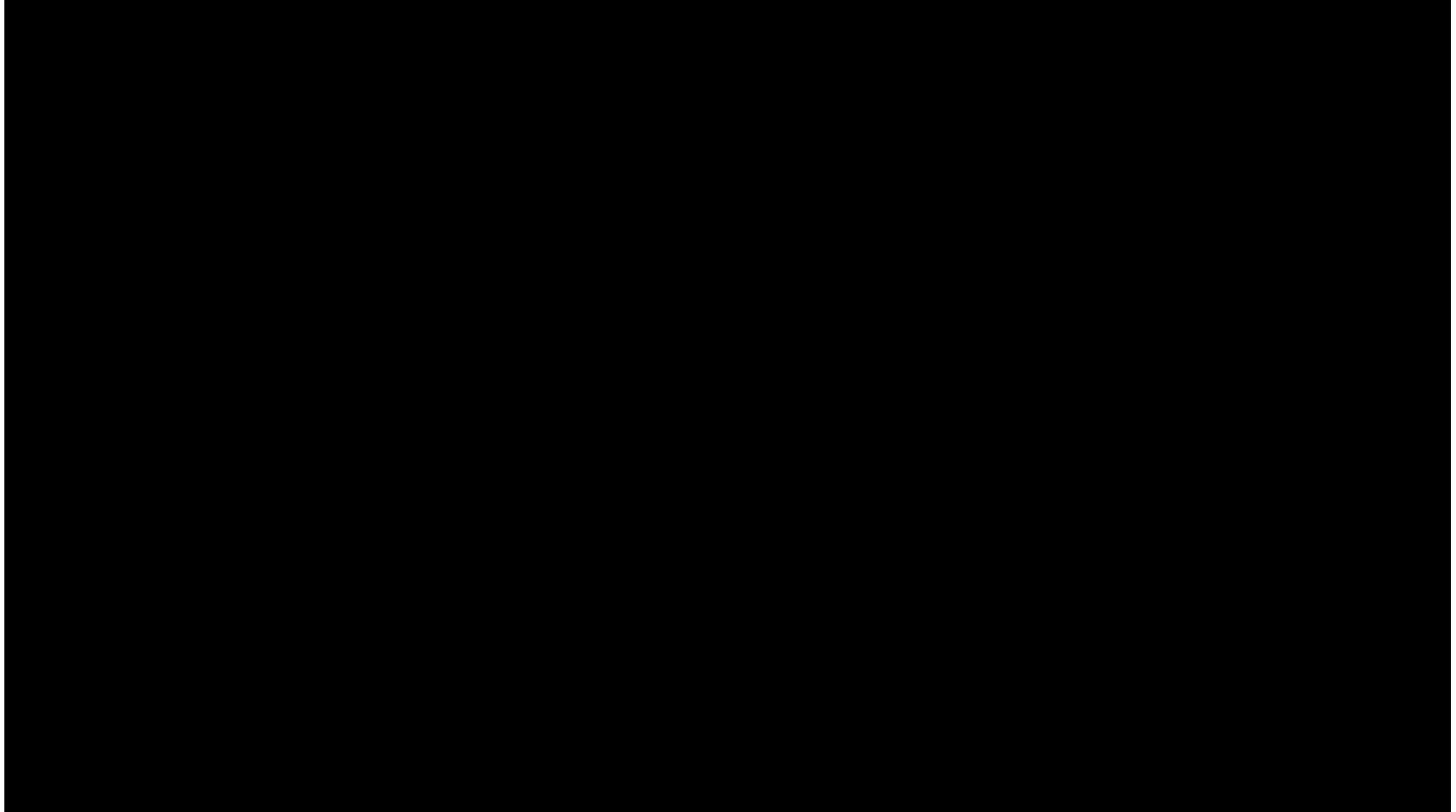
Bz signal



Bx + Bz signal

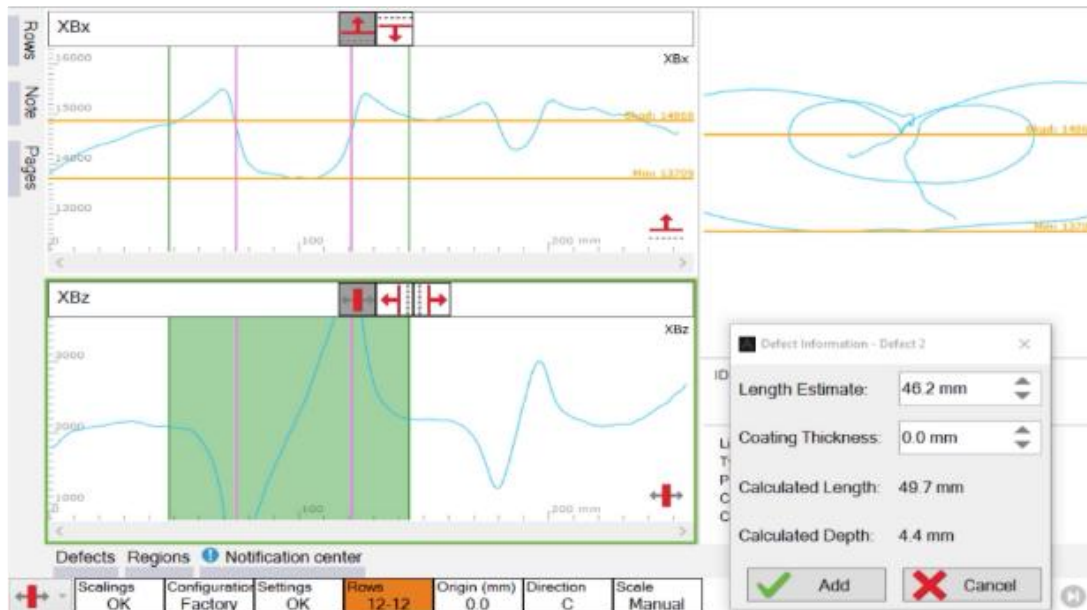


ACFM WORKING PRINCIPLES VIDEO



ACFM WORKING PRINCIPLES: CRACK SIZING

- No onsite calibration required
- Depth sizing range: 0.5mm <> 25mm (0.02 <> 1in)
- complete report generated in one click

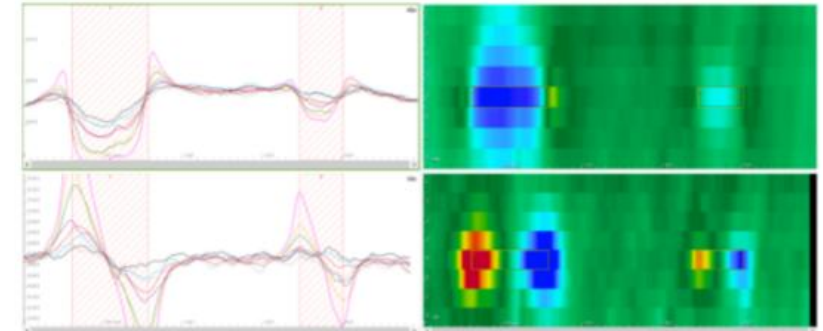


ACFM Test Report

Report on ACFM non-destructive testing

GENERAL INSPECTION PAGE REPORT

Site: ExampleFiles Component: ArrayProbe2 Test Date: 24 Sep 2018 15:38
 Filename: C:\Users\msmith\Documents\Assist\Sites\Sample\ArrayProbe2\SZ6_G_MIX_001.assistdata
 Part ID: SZ6 Operator: Bruce
 Line: Mixed Scan Type: Mixed



Defects

	Length (mm)	Depth (mm)	Rows	Location (mm)	Coat (mm)	CF
1:	53.6	5.5	5	-79.0 .. -31.2	0.0	1.2
2:	31.1	1.5	5	-201.0 .. -173.7	0.0	1.2

Notes

Array probe over longitudinal defect

Settings

Gain	Frequency (kHz)	Phase Angle (°)	Direction	Start Posn (mm)	Scalings
17.0	4.9	-97.8	Anticlockwise	0.0	OK

Probe

Probe:	40mm Array
Serial Number:	1988
Configuration:	Ferritic Steel
Factory Configured:	Yes
Deployment:	Internal Encoder

Operator:	Bruce
Prepared by Signature:	
Date:	

ACFM[®]



TOOLS AND APPLICATIONS

ACFM IN CODES AND STANDARDS



Recommends the control of welds using ACFM

Standard Practice for Examination of Welds using the ACFM Technique (E2261-03), latest revision E2261-12



Standard Practice for Examination of Drill String Threads using the ACFM Technique (E2928-13)



"Nondestructive Testing Handbook, Electromagnetic Testing": Alternating Current Field Measurement Testing.



ASME V, Boiler and Pressure Vessel Code (BPVC). Article 15 about the ACFM technique

Article 31: SE-2261/SE-2261M Standard Practice for Examination of Welds Using the Alternating Current Field Measurement Technique



North Sea standards (NS-2): Accepted alternative to MPI for drill string thread **inspection**



HIGH PERFORMANCE ACFM MADE PORTABLE

- User friendly and easy setup
- True ACFM combining fast scans and high data quality
- Large single-pass array probe coverage up to 90mm (3.5in)

Rugged, easy-to-use keypads



10.4", non-reflective, backlit, high-resolution multi-touch display

Heavy-duty bumpers, hooked for harnessing

Portable, rugged casing designed for IP-65

Protective doors



Quick Copy: Transfer all inspection files to USB at the touch of a button

Remote control capabilities

Battery life (typical): 6-8 hours

“Amigo2 is the reference ACFM system on the market with hundreds of systems sold worldwide”

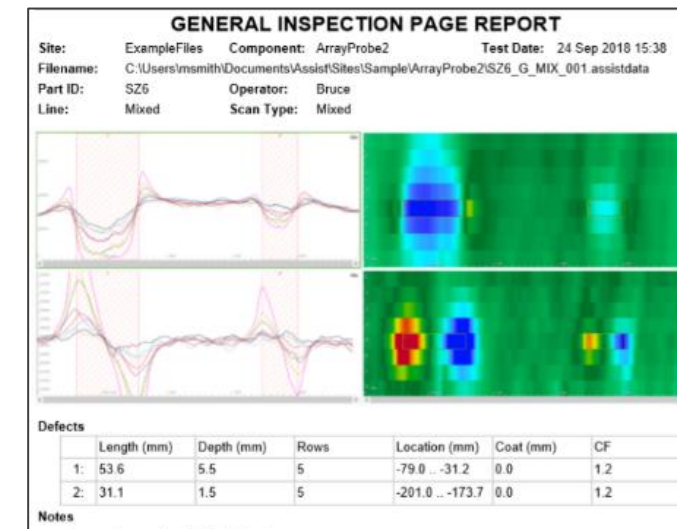
ACFM TOPSIDE INSTRUMENTS

Amigo2



High-end ACFM instrument. Adds support for:

- Compliant array probes for butt welds and lap joints
- Fillet weld array probe featuring 3BZ sizing technology
- High temperature component inspections featuring 3BZ sizing technology (Up to 500°C (932°F))
- Diver array probe



Amigo2 SE



Single element ACFM technology. Supports:

- Fast scanning, wide coverage pencil probes
- Generic weld inspections
- Underwater inspections
- OCTG drill string thread inspections






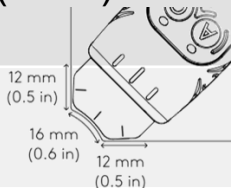


SENSU 2 GENERIC WELD INSPECTION PROBES

All Sensu 2 topside probes feature:

- Field ruggedness: IP65 rating / Connectorized to 5, 20, or 50m cables (16, 65, 164ft)
- Performance: Fast acquisition / High SNR
- Convenience: Configurations stored in probe memory / buttons and LED indicators / ergonomic designs

SENSU 2 GENERIC WELD INSPECTION PROBES

	Pencil probes 	Weld probe 	Compliant array probes 	Fillet weld array probe 
Geometry	Right angle, Straight, Transverse	Stable 3 contact points / butt welds	Butt welds / Lap joints. 8 or 16 element options. Fingers travel: 12mm (0.5in)	Fillet welds with approx. 16mm (5/8in) wide weld caps 
Coverage	15mm (0.6in)	15mm (0.6in)	16 element version: 90mm (3.5in) 8 element version: 45mm (1.75in)	
Features	Versatile, light, simple	Wider field / deep crack measurements (25mm (1.0in))	Integrated encoder, dual axis crack detection / sizing in a single pass	3BZ crack sizing technology, simple and rugged Monoblock design

THE EDDYFI SOFTWARE MODEL

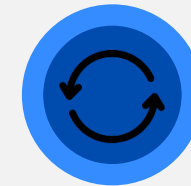
All portable instruments include their embedded software.



All software sold are perpetual : they will never stop working.



New software purchases grant unlimited access to all minor updates.



ASSIST[®] SOFTWARE

Assist[®] GO: Embedded software

- Inspection planning
- Acquisition setup and controls
- Data acquisition and Analysis
- Report creation



Assist[®] CPN/PRO/PRO Diver: PC software

- Facilitates inspection planning, data analysis and reporting
- **PRO adds** Amigo2 remote control (RDAU)
- **PRO Diver adds** U41 remote control (RDAU)



A COMPREHENSIVE AND CONNECTED SOFTWARE SUITE



Zoom Integration

Facilitate Team Collaboration and Troubleshooting:

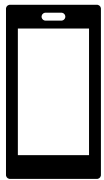
- Initiate Zoom Meetings directly from Amigo2.
- Enable Screen Sharing and Remote Control.



OneDrive Integration

Sync inspection data to OneDrive:

- Consolidate inspection data for improved management.
- Facilitate collaboration by easily sharing data with teammates.



Mobile App

Connect to Amigo2 using the Eddyfi app on your mobile:

- Add pictures and notes to inspection reports
- Contextualize ACFM data for improved analysis.



PROCESS PLANT & REFINERY INSPECTION

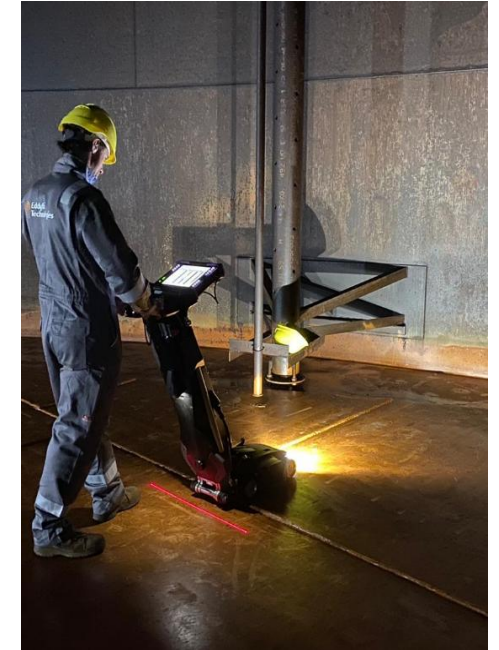
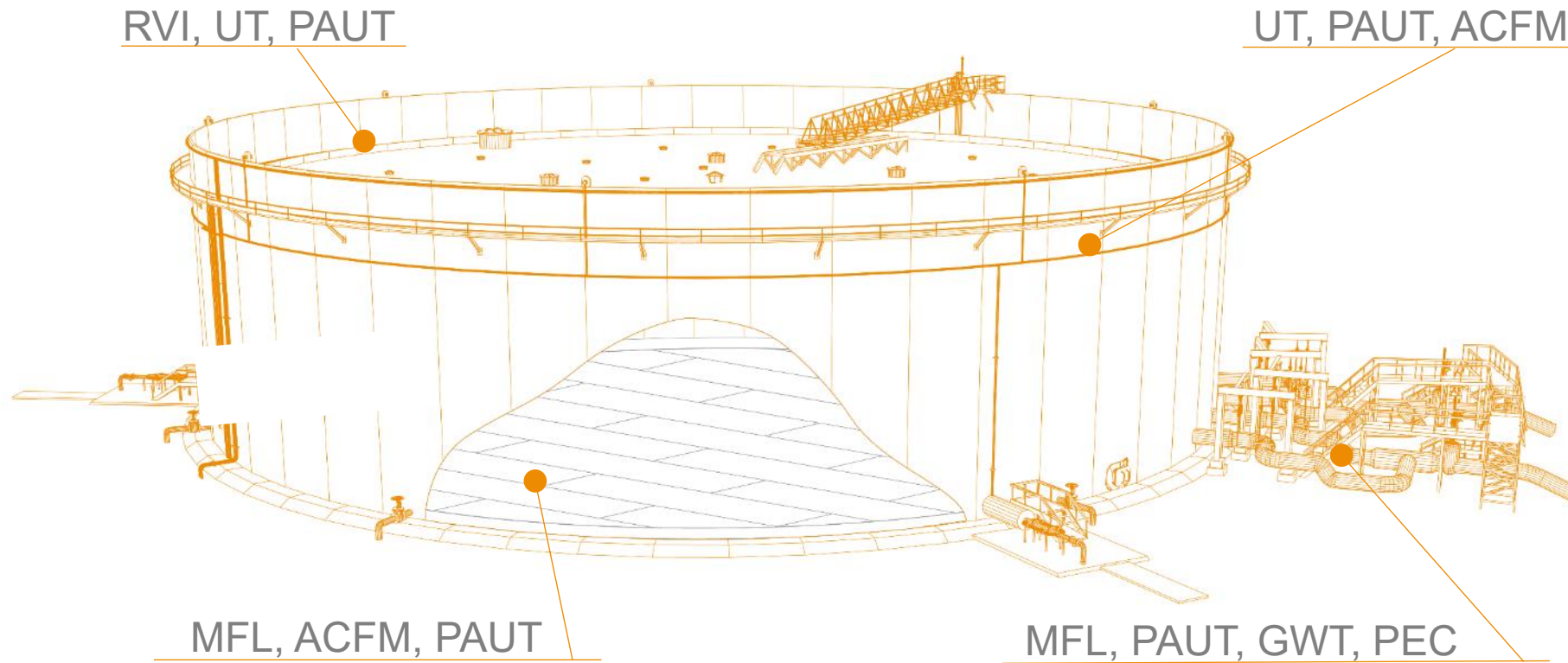
Crack detection and sizing through coatings on:

- Pipework
- Pressure vessels
- Attachment welds
- Nozzles

Ref. ASME V, Boiler and Pressure Vessel Code (BPVC) articles 15 and 31



STORAGE TANK INTEGRITY INSPECTION



STORAGE TANK WELD INSPECTION

Crack detection and sizing with minimal cleaning and no coating removal

Annular welds with the fillet weld array probe:

- Single pass, full weld coverage
- Coverage extends 12mm (0.5in) in the HAZ
- Features the 3BZ crack sizing technology

Fast array probe scans:

- Generic butt welds inspection in one pass
- Lap joints up to 10mm (0.4in) high
- Encoded + Dual fields

VS MPI:

- Substantial cost savings
- increased productivity



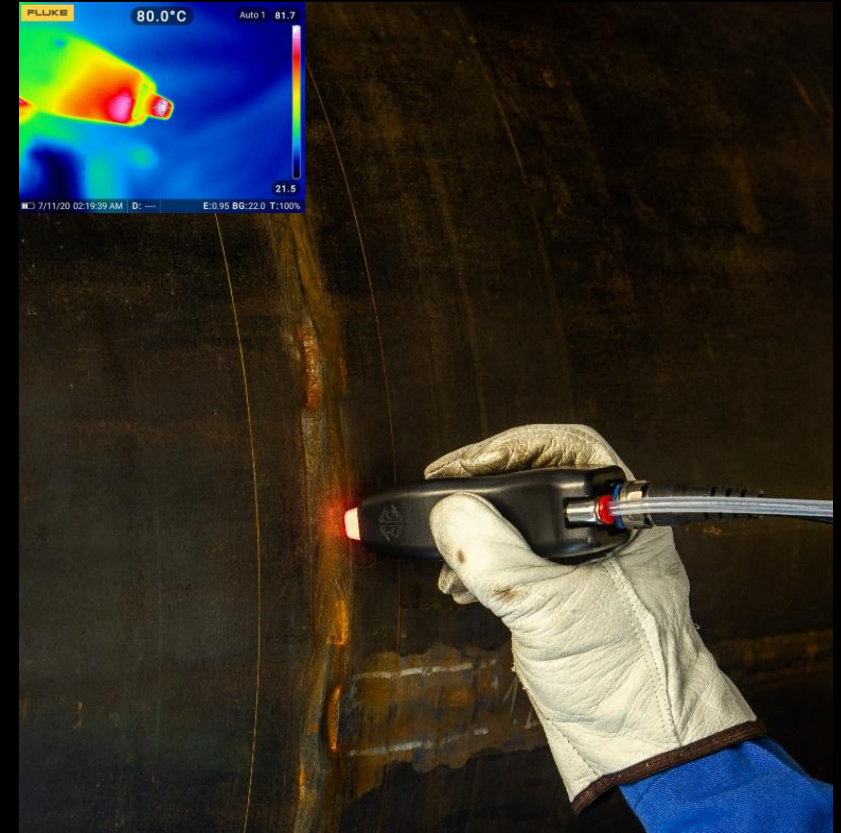
HIGH TEMPERATURE COMPONENTS INSPECTION

Main Applications:

- Hot pipework, Vessels, Pressure vessels
- Emulsion pipelines
- Pre / post-inspection of hot tapped weldolets and split tees
- Welding inter-pass inspection...

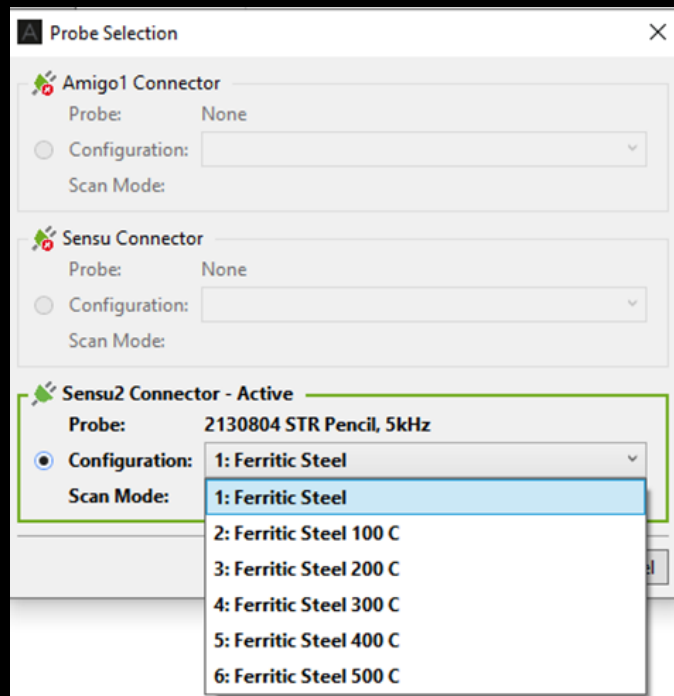
Heat-resistant ACFM probe:

- Inspection of components up to 500°C (932°F)
- Integrated air-cooling system
- Overheating warning LED for real-time visual alerts
- 3Bz crack sizing technology for single pass crack sizing



INSPECTING WITH THE HIGH TEMPERATURE ACFM PROBE

- 1 Pre-loaded probe configuration, no on-site calibration required



- 2 Integrated 3Bz crack sizing technology for single pass sizing



- 3 Probe nose lights up red when cooling is required



Inspections at 500°C (932°F):

- Scan time ~ 12 seconds
- Duty cycle ~ 50%

ACFM FOR IN-SERVICE STRUCTURAL WELD INSPECTION



A few applications:

- Amusement parks
- Cranes
- Bridges
- Communication towers
- Wind turbines
- etc.



ACFM APPLICATIONS FOR CIVIL INFRASTRUCTURE

A few examples:

- Underwater welds
- Lamp post welds
- Deck plates
- Box section girder joints
- Gussets, stiffeners, braces, etc.

ACFM is qualified by the National Highways* (UK)

- New solution for galvanized steel inspection...



* Formerly "Highways agency for roads"

GALVANIZED STEEL STRUCTURES INSPECTION

About hot-dip galvanization:

- Provides corrosion protection but fatigue cracking remains
- Typical zinc coating thickness below 200-250 μm (ASTM / AGA recommendation)
- EC, UT and MPI struggle with the Zinc layer

An ACFM solution to tackle the challenge:

- Detects cracks that breaks through the conductive zinc coating or not
- Crack sizing facilitates decisions on asset integrity and optimizes repairs
- Compatible with standard ACFM hardware



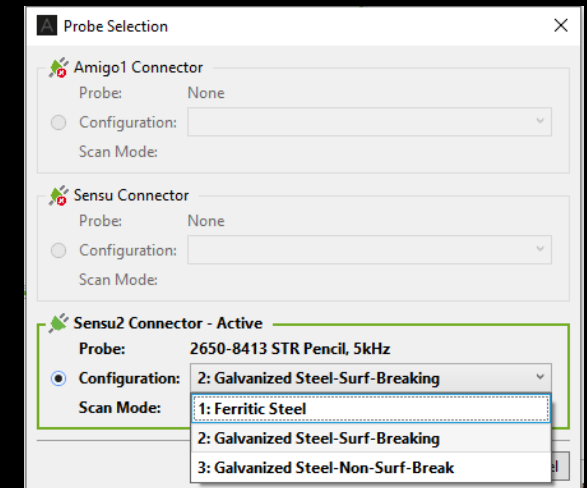
GALVANIZED STEEL INSPECTION SOLUTION

An option for new or existing Sensu 2, 5KHz single-element probes:

- Adds 2 configurations to the standard “Ferritic Steel”
- One for surface-breaking crack detection and sizing
- One for non-surface breaking crack detection

Optimal accuracy on Zinc coatings of up to 300 μm thick

Non-surface breaking crack sizing requires local coating removal



OCTG DRILL STRING THREAD INSPECTION

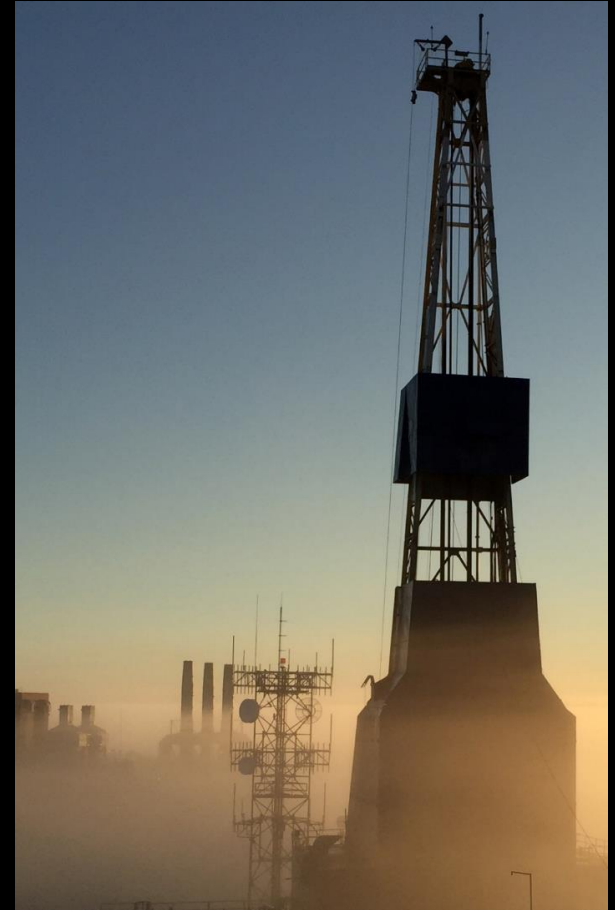
Threaded connections sustain heavy stress / fatigue cracking

Lost BHA (Bottom Hole Assemblies) ~400K USD

Conventional NDT (MT, PT):

- Careful cleaning / expensive waste management
- Slow process / low productivity
- Difficult geometry and bad visibility compromises detection
- No depth sizing: No cost-effective remedy

ACFM offers a reliable and cost-effective alternative!



PROVEN SUPERIORITY FOR DRILL STRING THREAD INSPECTION

On drill string threads, MT POD is not as good as usually expected.

Halliburton trial over 140 threads:

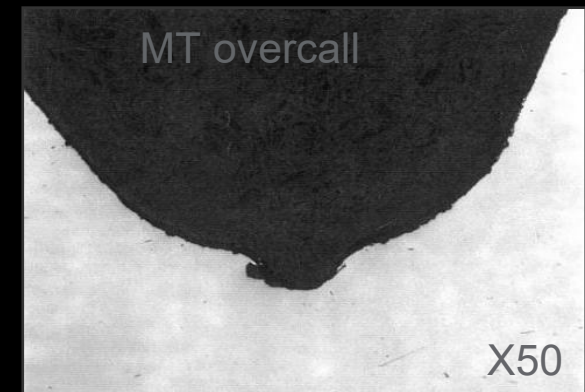
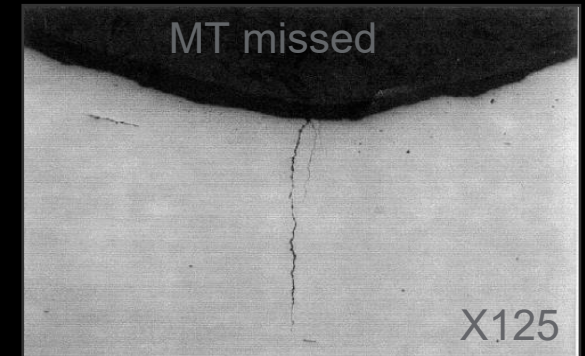
- ACFM identified 23 defects with depth information
- 9 could be reworked and returned to service
- 2 were missed with MT

Shell trial over 20 drill collars:

- 2 discrepancies between ACFM and MT were re-inspected and sectioned...
- MT missed a 0.4mm (0.016in) deep crack found with ACFM
- MT produced one false call

Based on our user experience, ACFM finds flaws on 1-2% of threads previously inspected and missed by MT

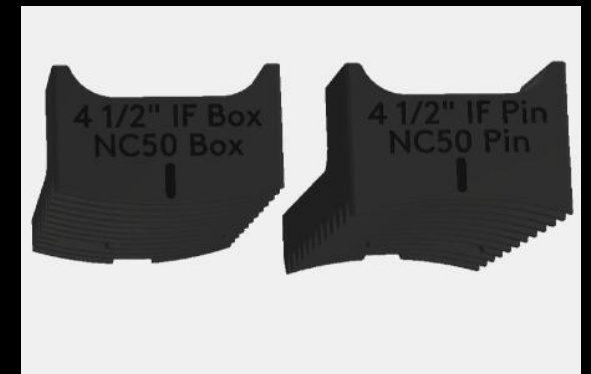
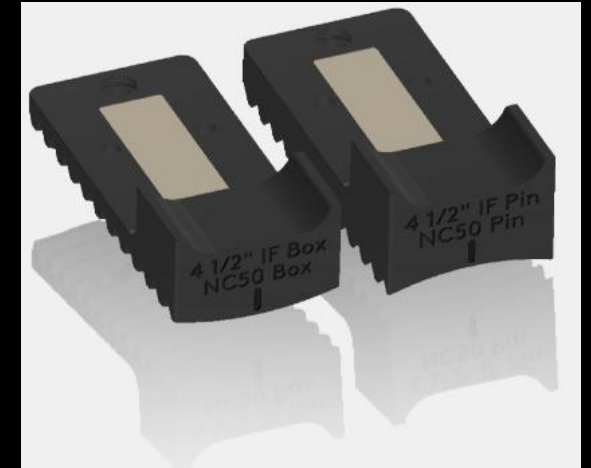
ACFM is approved by NS2 and ASTM international for this application



OCTG DRILL STRING THREAD INSPECTION SOLUTION

ACFM Universal Thread Probe:

- One probe for all thread profiles
- 3D printed shoes to adapt to various thread profiles
- Supports Box ID from 2.3" IF, 2.3" Reg., NC23 and up
- Up to 4 TPI. 5 TPI with slight sensitivity loss
- Fast, reliable and field proven...



ACFM RAILWAY APPLICATIONS

ACFM a railway proven inspection technique for ~20 years

Axle and wheelset inspection:

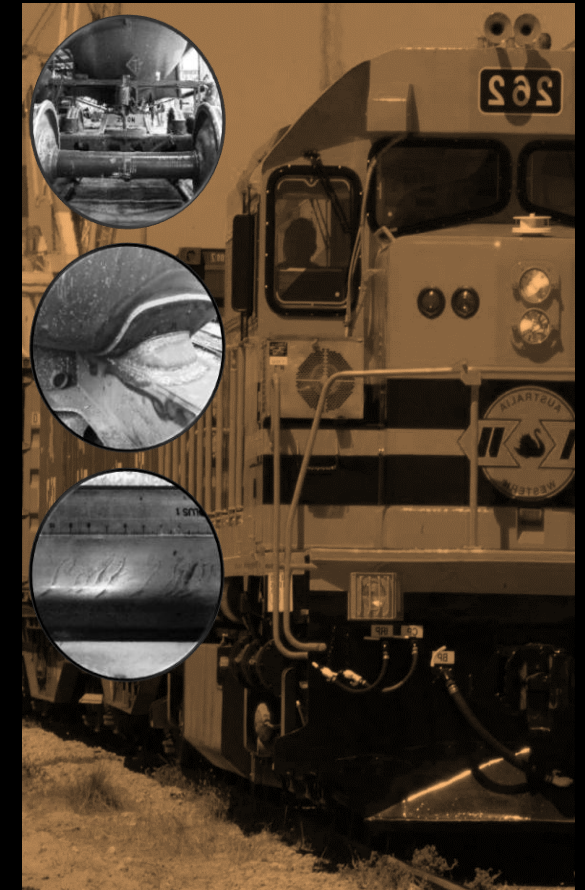
- Fatigue cracking detection and sizing
- An independent blind trial on 15 failed axles proved ACFM superior to ECT and MPI

Structural welds inspection:

- Tank car welds
- Bogie frame welds
- Attachment welds

Rail inspection:

- Fast and reliable detection of Rolling Contact Fatigue (RCF) cracks
- Approved by UK railways, Corus Rail Technologies (on behalf of Network Rail), Balfour Beatty Rail Technologies and York EMC Services, UK.



ACFM RAILCAR AXLE INSPECTION

ACFM was proven during an independent blind trial*:

- 15 axles with known failures
- ACFM has the highest POD and lowest false calls
- ACFM adds the depth sizing capability on top of detection

Perfect match for the Amigo 2 / Sensu 2 array probes

	Experimental POD	Potential POD	Axles flagged as “Failed”
MT/MPI	44%	59%	5
ECT	80%	85%	11
ACFM	84%	95%	15



TANK CAR INSPECTION WITH ACFM IN LIEU OF MPI

Proven reliability: Trials / POD studies on over 100 tank cars

Increased efficiency enable economical gains:

- Inspection time per car going from 8 hours to 30 minutes using Amigo 2
- No more wasted coatings and inspection chemicals
- Potential savings in several million USD industry wide

Other benefits:

- Increased asset utilization
- Reduced health risks to workers
- Less human error / record-keeping errors
- No management of waste chemicals or aggregate



FILLET WELD ARRAY PROBE WITH 3BZ CRACK SIZING

Designed for tank car inspections

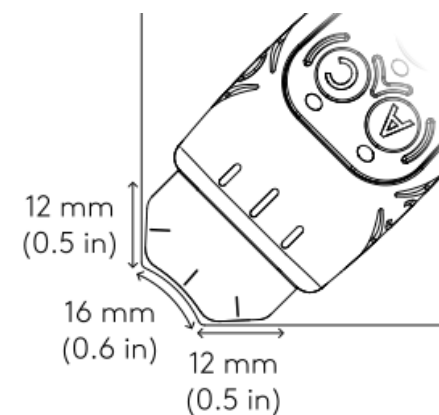
Single pass detection scans

Productivity vs conventional methods (MPI):

- Up to 60% in cost reduction using single element ACFM
- Array probe boosts inspection productivity by 3x

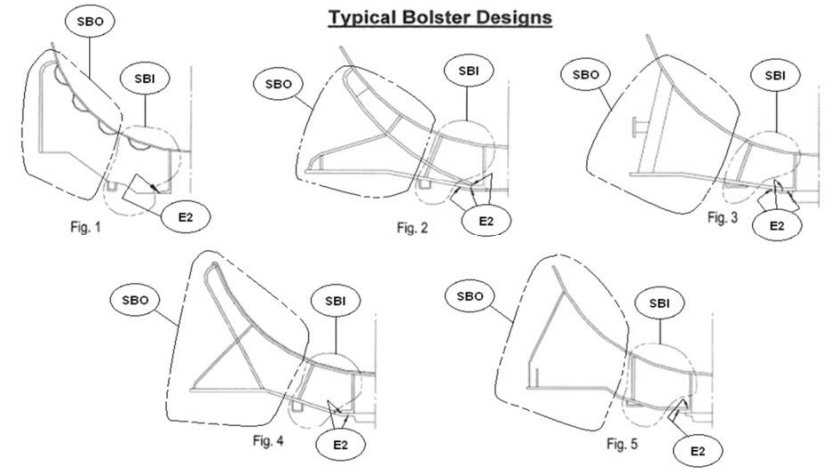
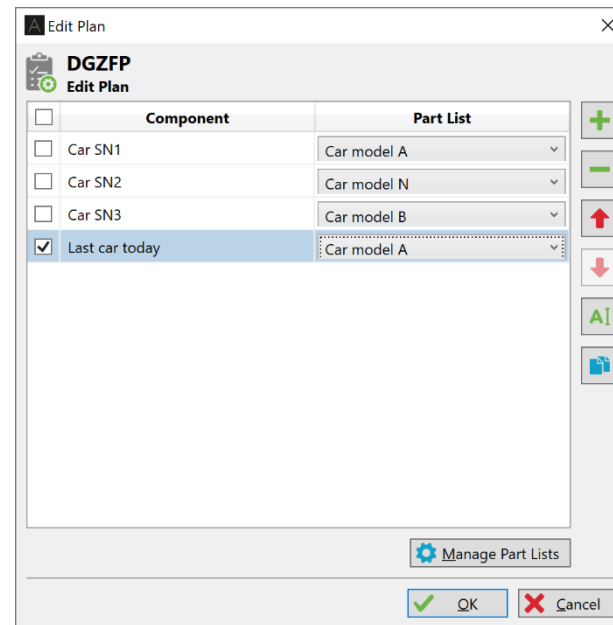
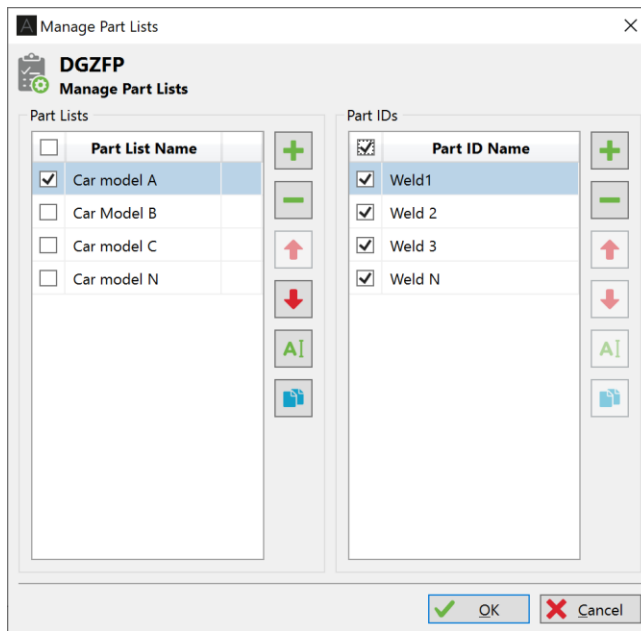
On-probe buttons control the inspection process

3Bz sizing: Crack length and depth sizing without encoders nor surface markings



INSPECTION PLANNING AND CONTROL

- Pre-programmed inspection of complex geometries in an optimized sequence
- Promotes complete and error-free inspections

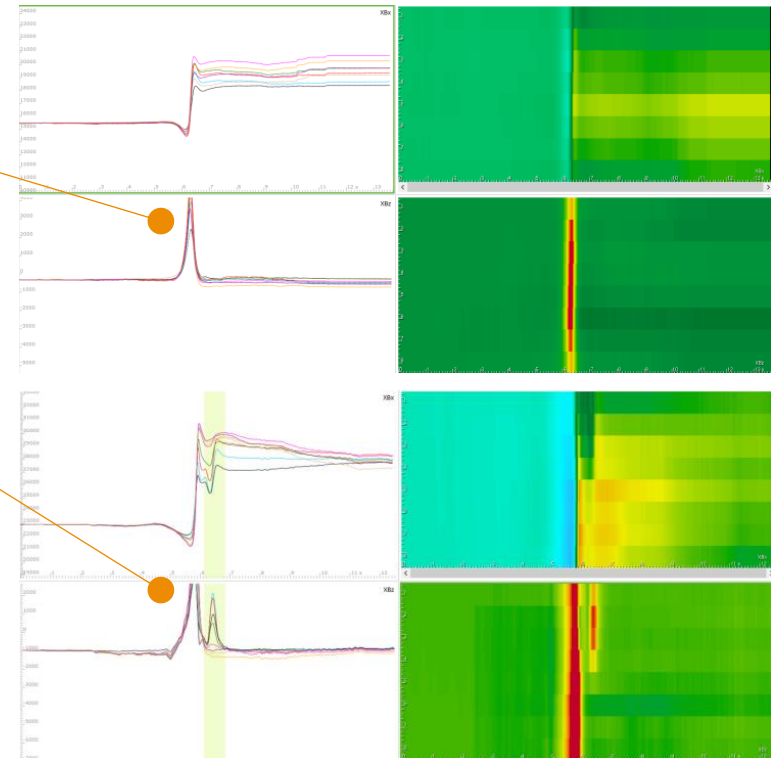


RAIL CROSSING INSPECTION

Rail to manganese crossing dissimilar material fusion flaws

ACFM performance proven in trials Using an ACFM dual field array probe:

- A sound fusion line: Consistent pattern across the joint
- A flawed fusion line: Anomalies on the Y field



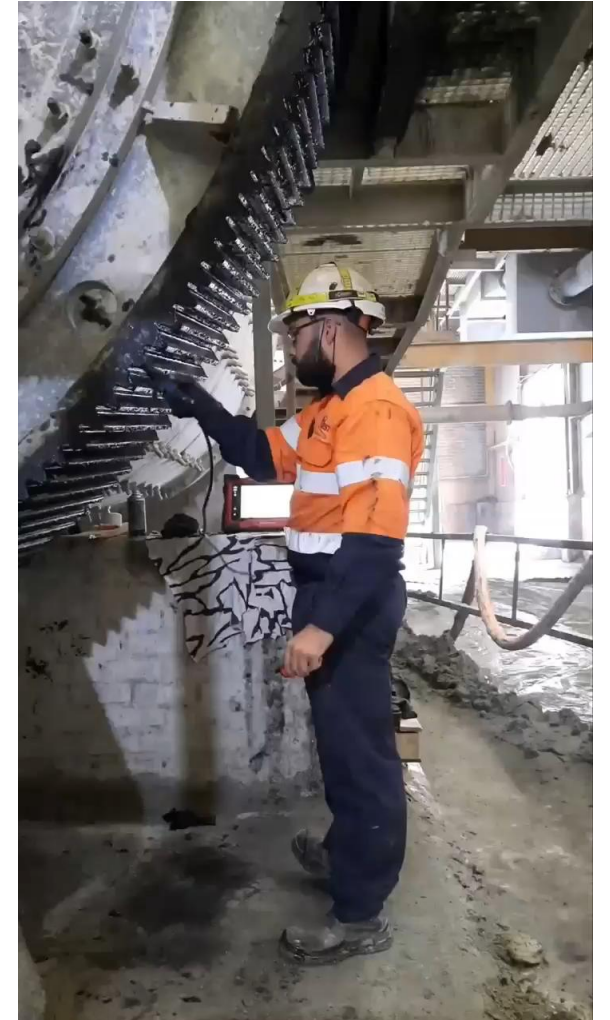
ACFM MINING APPLICATIONS

ACFM is ideal for mining applications:

- Difficult environments, dirty/greasy/worn components
- Large defects in big components
- Frequent fatigue cracking requiring depth sizing

Typical applications:

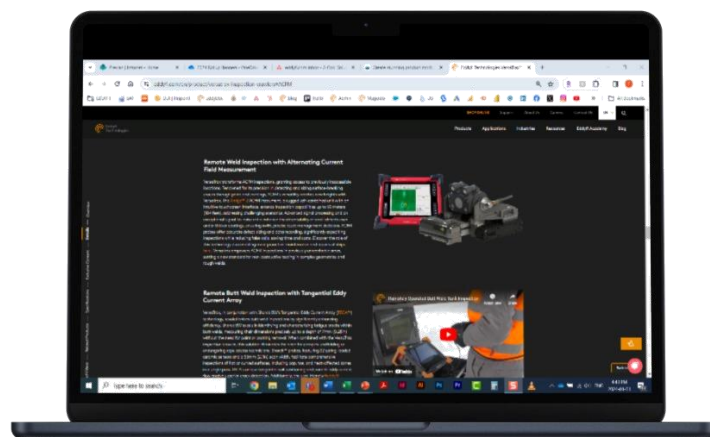
- Welds in large structural components
- Gear teeth inspection (Specified in ASTM E2905)



ROBOTIC DEPLOYMENT

Applications:

- Tank inspection
- Bridge inspection
- Wind turbine inspection
- Ship hulls
- Etc...



SUBSEA SPECIFIC TOOLS AND APPLICATIONS



ACFM SUBSEA APPROVALS



Non-Destructive Testing of Hull Welds, February 2014. Section 6, ACFM Technique



Specified in DNV-RU-OU-0300 (Fleet in service), DNV-RU-OU-0503 (Offshore fish farming units and installations), DNVGL-CG-0051 (Non-destructive testing)



Accepted for in-service examination of structural welds
TSC Subsea is an LR certified ACFM Inspection Services Provider



BS EN ISO 19902: Petroleum and natural gas industries. Fixed steel offshore structures



Approved technique surface breaking crack detection



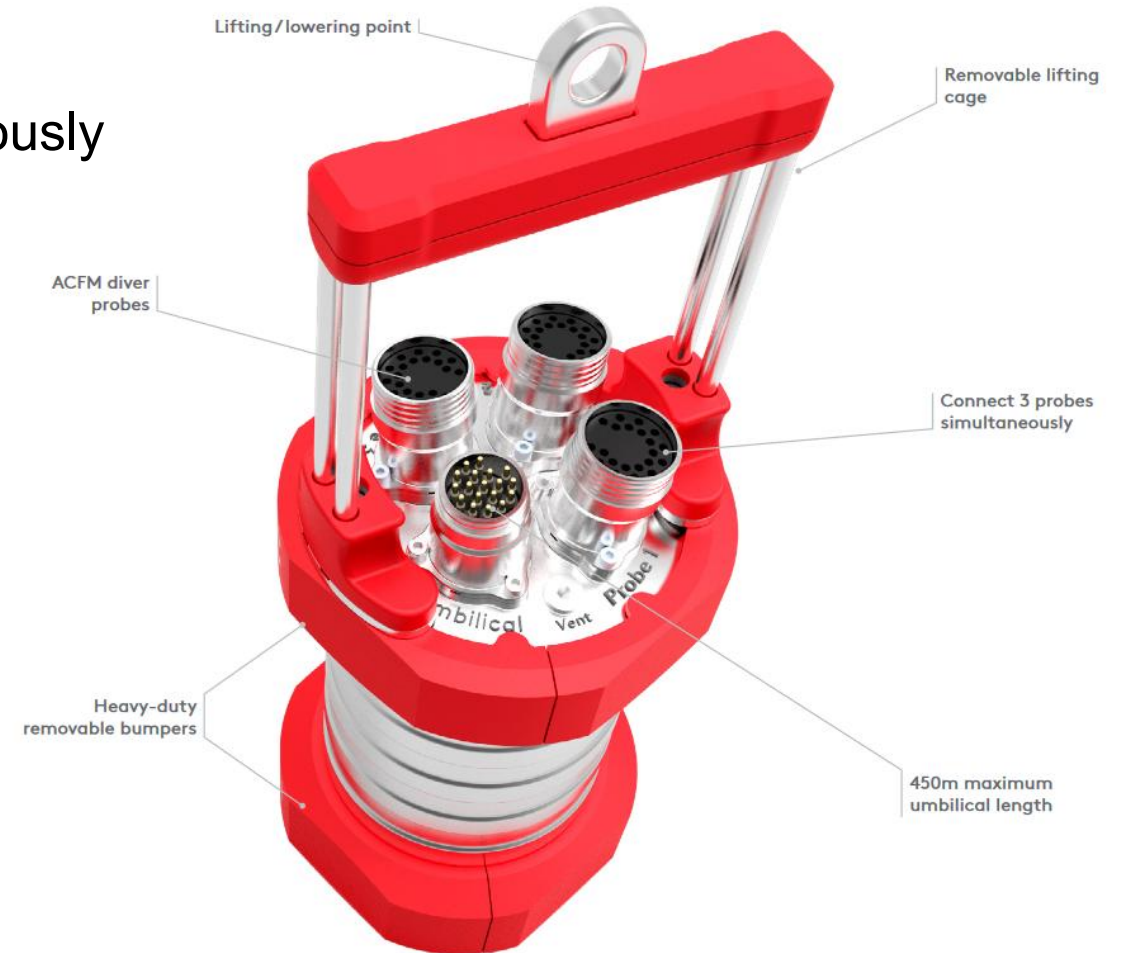
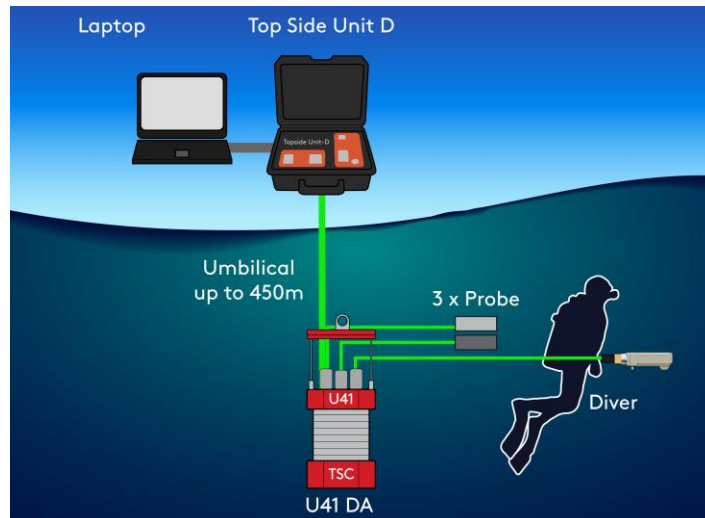
U41: FOR THE DEEP

Diver inspection down to 300m (984ft)

Connects with up to 3x Sensu 2 UW probes simultaneously

Array probe support:

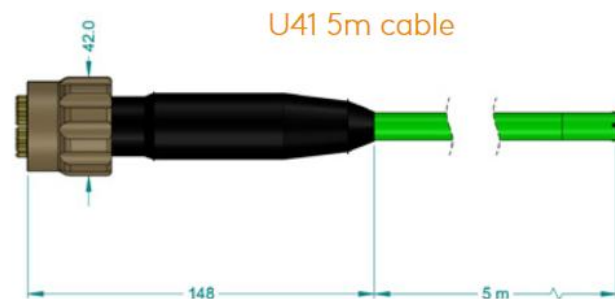
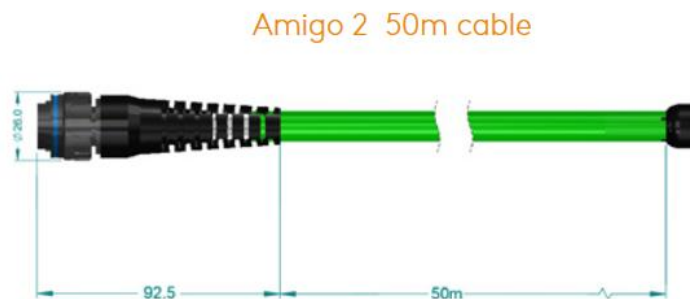
- Diver mini-array probe with 36mm (1.4in) wide coverage
- Reduced number of scans
- Faster recognition and characterization of defects



AMIGO2: FOR SHALLOWER WATERS

Amigo2 supports subsea applications

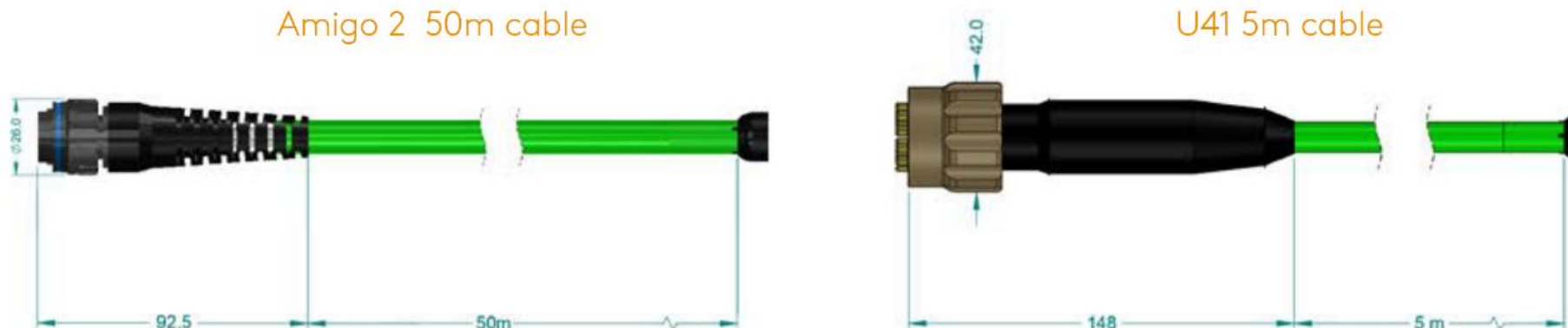
Uses the same probe heads as the U41 but fitted with 50m cables instead:




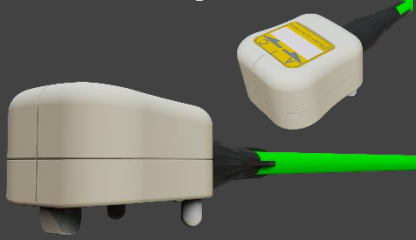
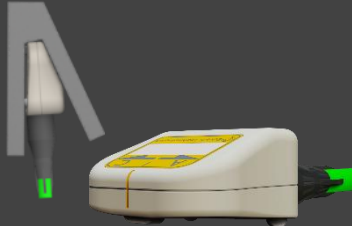

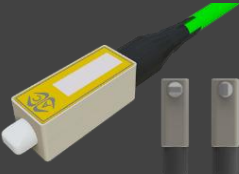
SENSU 2 UNDERWATER PROBES

Sensu 2 underwater probes characteristics:

- IP68 rating (Down to 300m (990ft) underwater)
- Configurations stored in probe memory
- Comes with 50m (165ft) cables for Amigo2, 5m (16ft) cables for U41D/DA



SENSU 2 UNDERWATER PROBES

Probe type	 <p>Diver array</p>	 <p>Weld probe</p>	 <p>Tight access</p>	 <p>Ground weld</p>	 <p>Pencil</p>
Geometry	Flat rigid, 4 element array probe	Stable probe with 3 contact points	Tapered weld probe	Long slender nose to fit into weld repair grinds	Right angle, Straight, Transverse
Coverage	36mm (1.4in)	15mm (0.6in)	15mm (0.6in)	15mm (0.6in)	15mm (0.6in)
Application	Rapid scan of butt welds	Stable butt weld inspection. Deep crack measurements: 25mm (1.0in)	Hard to reach fillet welds / areas	Crack monitoring throughout the repair process	Various geometries, fillet and butt welds

OFFSHORE O&G APPLICATIONS

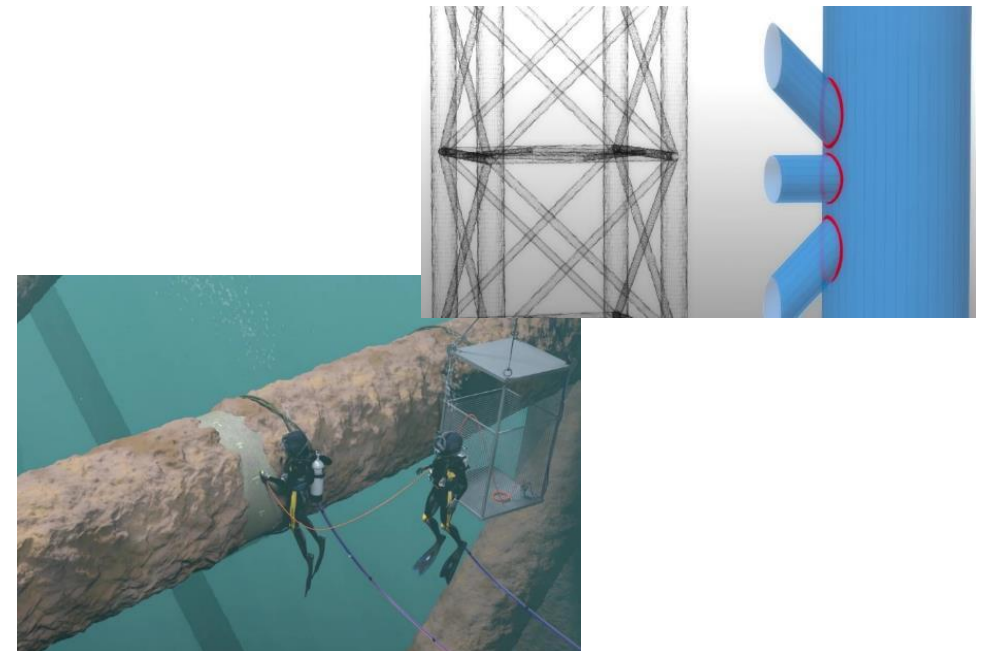
Generic structural weld inspection

Through coatings:

- Jackets (Structural nodes / Attachments / Flooded member investigation)
- Jack-ups (Leg node / Spud can / Hull)
- Semi-subs leg and hull UWILD inspection

Others:

- FPSO hull
- Pipeline damage investigation (anchor, drag...)
- Mooring systems (Chains, etc.)



SHIP / NAVAL APPLICATIONS

Structural weld inspection:

- Hull welds through coatings
- Internal structural welds

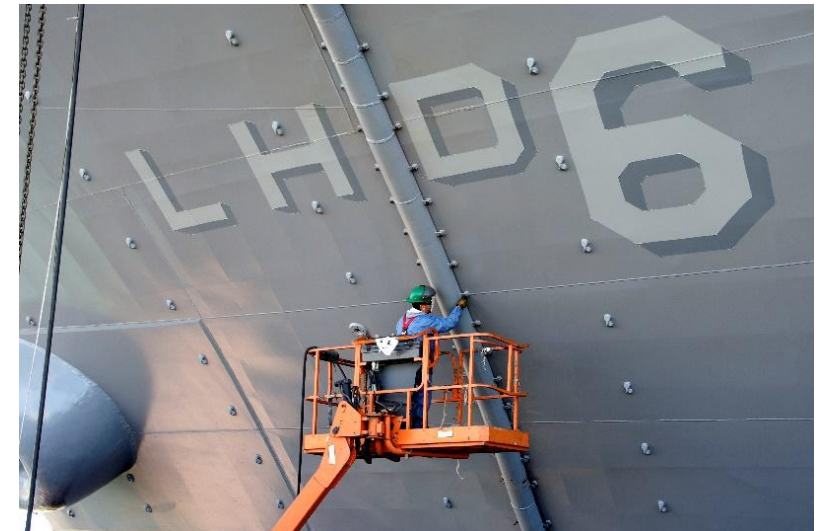


Propulsion system:

- Propeller generic inspection
- Propeller damage investigation
- Driveshaft weld inspection

Done UWILD or drydock

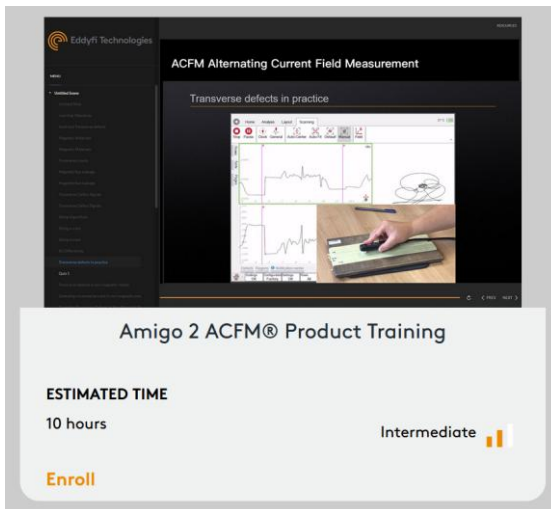
Crawler deployable



ACFM TRAINING

Eddyfi Academy:

- Free e-learning introduction on ACFM and ACFM array
- Paid e-learning: * SNT-TC-1A compliant, includes theory and modules about the inspection of welds using standard probes, array probes and the fillet weld array probe
- Blended option: includes theory online and practical session with an Eddyfi technical expert




Amigo 2 ACFM® Product Training

ESTIMATED TIME
10 hours

Intermediate

[Enroll](#)


Introduction to ACFM@Array

ACFM is an efficient way to inspect carbon steel welds for surface breaking cracks. ACFM Array brings the method to a whole new level of efficiency. This training will explain how ACFM array works and how it can be used to make your inspection much faster and more reliable.

FREE

ESTIMATED TIME
30 min

Beginner



Introduction to ACFM®

This course will introduce you to the physics behind the Alternating Current Field Measurement (ACFM) technique. ACFM utilizes electromagnetic to detect and size surface-breaking cracks in steel structures and welds without requiring the removal of coatings or marine growth.

FREE

ESTIMATED TIME
30 min

Beginner

* For personnel certification, please inquire about our local partners

MAIN ONLINE RESOURCES FOR ACFM

Online webinars provide comprehensive product demonstrations:

- Amigo2: Evolving ACFM Webinar ([Link](#))
- Modernizing Subsea ACFM Inspection with TSC U41 ([Link](#))

Easily accessible info on the web:

- Web page branches out to everything you need
- Probe catalog, solution pages, online store, etc.
- Use these links to explore:
 - <https://www.eddyfi.com/en/product/amigo-2>
 - <https://www.eddyfi.com/doc/ProductsDownloadables/ACFM-Probe-Catalog-01.pdf>
 - <https://store.eddyfi.com/amigo2-instrument-build-configure.html>

OTHER USEFUL RESOURCES AND INFORMATION

Eddyfi literature page:

- Go to page for everything you need to know, in depth
- Catalogs, application notes, product manuals, product notifications, etc.

YouTube + various social networks:

- Please register for latest news and notifications
- Regular new publications, videos, and product launches
- A few interesting coffee break examples:
 - <https://www.youtube.com/watch?v=dwOTO6eJv2Q>
 - <https://www.youtube.com/watch?v=H4WCGgXQwBM>
 - <https://www.youtube.com/watch?v=tp6oTvDDm2M&t=1765s>

Conclusion

**Vetsatile &
high-
performance
platform**

Proven, reliable
and **productive**
inspection
method

Advancing
**Efficiency &
Safety**
Worldwide

THANK YOU

—
HOW CAN WE HELP?

www.eddyfi.com

