Generic ACFM® Inspection Procedure for Amigo2™

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1 Introduction

1.1 Scope

This document describes the procedures to be used when conducting Alternating Current Field Measurement (ACFM®) inspections of welds and areas in both ferritic and non-ferritic metals with the AMIGO2™ ACFM equipment using standard manually deployed probes.

These procedures have been developed to enable inspection of most geometry generally encountered in civil structures, such as process plant, bridges, pipework etc.

A number of certifying authorities, including ABS, DNV-GL and Lloyd's Register have accepted the ACFM technique for the inspection of metal structures and components (refer to document TSC/FL/2240).

In addition, documents of recommended practice (or procedures for use) for (or including) ACFM have been issued by a number of organisations including:

- ASTM, "Standard Practice for Examination of Welds using the Alternating Current Field Measurement Technique" (E2261-03), latest revision: E2261-12
- ASME BPVC Section V ARTICLE 15, "Alternating Current Field Measurement Technique (ACFMT)", 2017.

1.2 Description of Method

1. ACFM is an electromagnetic inspection technique that induces an alternating current into the surface of the component using a variety of probes, including simple weld, pencil and multi-field array probes. The return signal is instantaneously converted by advanced mathematical techniques using specially written ACFM software and displayed and stored on the instrument. The presence of a discontinuity disturbs the electromagnetic field and thus the return signal to form indications characteristic of the type of discontinuity discovered.
2. All indications are not necessarily related to mechanical discontinuities, since certain metallurgical variations and magnetic permeability variations may also produce defect-like signals, which are not relevant to the detection of unacceptable discontinuities.
3. The ACFM technique is restricted to the detection of surface breaking discontinuities.
4. The ACFM technique does not require electrical contact between the probe and inspection surface.

1.3 Referenced Documents

- Amigo2 User Guide
- TSC/FL/2255, "ACFM® Inspection Considerations and Signal Interpretation"
- TSC/FL/2240, "Acceptance of the TSC ACFM® Inspection Technique"
- TSC/FL/2254, "Supplementary ACFM® Inspection Procedure for Array Probes"

For inspection using special-purpose probes, or inspection of geometries or materials not covered in the above documentation, please refer to TSC for further information.

Background information regarding ACFM equipment can be found in TSC's introductory literature and at www.tscndt.com.

1.4 New in this Issue

- Logo changed
- Typos removed and tidying of document references

2 Equipment and Setup

2.1 Overview

This procedure is intended for use with the following equipment (Figure 1):

- Amigo2™ Portable Crack Micro Gauge.
- Battery charger and / or optional spare battery.
- ACFM probes for the specified material types (see section 2.2).
- Function check plate (see section 2.5.1).

The Amigo2 can also be operated using a remote PC connected to the LAN port. The remote PC will run a desktop version of the ASSIST 3 software which will operate in a similar manner to the instrument version.

Refer to the Amigo2 User's Guide for further information regarding the Amigo2 instrument operation.

Figure 1 Amigo2™ ACFM® Instrument

2.2 ACFM Probes

2.2.1 Probe Selection

The Amigo2 is compatible with all previous generations of ACFM probes, including legacy Amigo1 probes, all array probes, SENSU probes and the generation 2 SENSU2 probes.

Error! Reference source not found. lists the most commonly used types, which are selected according to the application. Consult TSC for further information about standard and specialist ACFM® probes and probe selection.

Probe Name	Type	Frequency	Specification
Standard Weld Probe	256 (topside) 293A (underwater)	5 kHz	Routine inspection of carbon steel welds, plate and tubulars. Highly stable, 3 points of contact with inspection surface. Good compromise between sensitivity, coverage and rejection of noise due to probe handling.
Straight Mini Pencil Probe	250 (topside) 336A (underwater)	5 kHz	Inspection of restricted areas and areas of weld associated with rat holes in structures. Similar sensitivity to the standard weld probe. In comparison to the standard weld probe: • Less stable, 1 point of contact with inspection surface • Less prone to signal variations near plate edges • Less accurate for depth sizing of deep defects (>5mm (0.2”) deep)
Right Angle Mini Pencil Probe, parallel nose	251 (topside) 337A (underwater)		
Right Angle Mini Pencil Probe, transverse nose	252 (topside) 352A (underwater)		
Straight Micro Pencil Probe	255 (topside) 353A (underwater)	50 kHz	Inspection of shallow defects (<1mm (0.04”) deep) in carbon steel. Inspection of materials with low permeability (e.g. stainless steels, aluminium and titanium). In comparison to 5 kHz probes: • more sensitive • narrower area of sensitivity, requiring more scans to cover the same width of weld • more susceptible to probe handling noise
Right Angle Micro Pencil Probe, parallel nose	253 (topside) 354A (underwater)		
Right Angle Micro Pencil Probe, transverse nose	254 (topside) 355A (underwater)		

Table 1 Overview of ACFM® probes

2.2.2 Probe Care

- If a probe is to be used in an environment where the cable could be damaged by dragging along sharp objects, the cable shall be protected using additional sheathing.
- The ceramic nose containing the sensor coils is hard wearing, providing the probe is used correctly. The pencil probe nose can be protected further with a single strip of electrical insulation tape over the end of the nose followed by a wraparound to hold it in place.
- Underwater probes shall be cleaned after use by rinsing with fresh water.

2.2.3 Probe Files

SENSU probes differ from previous ACFM probe generations in that the probe configuration information is stored in the probe itself, not in a data file stored on the controlling PC. This means that the correct and most up to date probe file will always be available whichever instrument the probe is connected to. The configuration files for older ACFM probes are issued on USB mass storage devices and must be imported into the Amigo2 before the probe can be used (see user guide).

If, after checking instrument settings etc., it is found that the issued probe file is unsuitable for a particular application (for example the inspection is not on ferritic steel or the readings are saturating), refer to TSC.

2.3 Connection Procedure

1. Connect the probe to be used to the Amigo2.
2. Switch on the instrument and allow to boot to the main screen.
3. Check that the battery level is sufficient for the required use. The battery level can also be checked with the unit turned off by opening the battery cover and reading the LCD bar on the battery. If necessary, plug in the battery charger and connect to mains power. **Note that the charger is not rated for outdoor use.**

2.4 Enter Inspection Data

Before an inspection, the site, component, sub-component reference and operator's name should be entered. See user's manual.

2.5 Function Check

At the start and end of an inspection session a function check shall be performed with all the equipment used during the actual inspection. This is to ensure that the equipment is functioning correctly and to familiarise the operator with the relative levels of noise and defect signal. This is to be done with the full thickness (181) steel block plate. Additional checks can be performed mid-inspection with the lightweight function check plate.

2.5.1 Function Check Plate

Two types of function check plate are available:

- A lightweight function check plate, with a single through slot in a thin steel shim set into a plastic body, useful to confirm the general functioning of the probes and equipment.
- A full thickness steel block with a central weld and, usually, two semi-elliptical spark eroded slots of controlled size and shape. These mimic fatigue crack profiles and can be used to check the sensitivity. One slot is normally 50mm (2") long x 5mm (0.2") deep and is used to check normal probes; the other is normally 20mm (0.8") long x 2mm (0.08") deep and is used to check probes with micro sensors (unless indicated otherwise in manufacturer's notes accompanying the probe). Note that all SENSU pencil probes should be function checked using the larger slot.

The ASTM and ASME standards, referenced in 1.1, contain different specifications for the function check plate.

For inspections of materials which are not ferritic steel, a test sample of the same material type as that to be inspected shall be used (refer to TSC for details).

2.5.2 Function Check Procedure

1. Select or create the appropriate site and components for the next series of inspections.
2. Check the probe serial number is correct.
3. Select Function Check from the Home Ribbon.
4. Inspect the function check plate. Scan speed shall be approximately 50mm (2") / sec.
    i) If using the lightweight function check plate, scan along the marked line across the centre of the plate.

ii) If using the metal block, then scan along the weld toe over one or other of the slots depending on the probe type (see section 2.5.1).

5. Confirm correct defect response signals and check that the butterfly loop is produced in the correct manner, coinciding with the probe direction. Signals such as that shown in Figure 2 may be displayed.

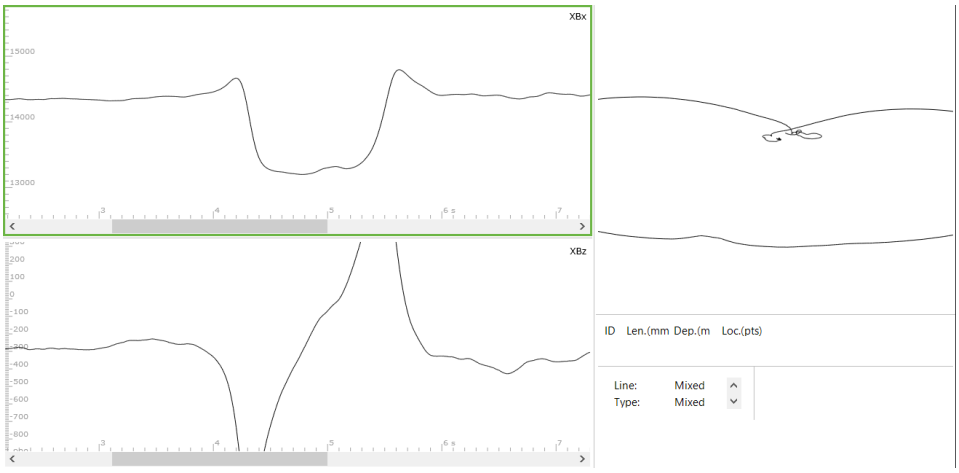

Figure 2 Typical plots for function check on a single defect

If the display is well off the screen, check that the correct configuration was chosen for the material of the function check plate, and that the serial number of the probe displayed by the software matches that marked on the probe.

If a display similar to Figure 2 cannot be produced, seek specialist advice before proceeding.

6. Repeat these steps for each probe to be used in the session.

2.6 Manufacturer Contact Details

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UNITED KINGDOM
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3 Inspection Requirements

3.1 Personnel Required

The AMIGO™ system is typically used by a sole operator or a two-person team with one deploying a probe while the second operates the instrument or connected laptop.

ACFM Operator	Experienced operator with Level 2 pass certificate from a CSWIP, PCN or other recognised ACFM training scheme which conforms to ISO9712 (or previously EN473). An operator with an SNT-TC-1A certificate may be used, provided the training was provided by a TSC-approved training organisation. A Level 1 operator may be used, provided they have access to a Level 2 operator for guidance if complex welds or interpretation difficulties are encountered.
Probe Operator	A technician who has been briefed by the ACFM® operator on probe handling and scanning procedures.

Operators holding certification from other recognised Qualification / Certification schemes than the above may be considered suitably qualified; contact the qualification body responsible for the inspection site for official approval.

Prior to carrying out the inspection, the operator or supervisor shall be fully familiar with the Amigo2™ User's Guide (document number TSC/BB/2470).

Whenever remote probe operators are used, continuous audio communication is required to enable the ACFM® operator to direct the inspection and for the probe operator to be able to report back on any local factors influencing the inspection. Continuous video feedback is also recommended but not essential.

3.2 Safety

1. Personnel shall always comply with the safe system of work put in place on the client's site.
2. The equipment has few potential hazards as it operates from internal batteries and has no easily accessible moving parts while in use. Normal electrical safety care shall be taken if charging the equipment from the 240V or 110V AC supply.
3. The instrument shall only be charged indoors as the charger is NOT designed for outdoor use.
4. The operator shall take care to avoid creating trip hazards with probe and communications cables. These shall be routed tidily and not laid across walkways.

3.3 Surface Preparation

1. Prior to the inspection any features that may inhibit the inspection, hamper probe travel or mask unacceptable discontinuities, shall be removed by grinding, machining or other methods from the area to be inspected and at least 50mm (2") either side. These may include, but are not limited to, debris, loose flaking paint, excessive corrosion, slag, spatter and rough surface.
2. De-magnetisation of the inspection area may be required if magnetic hot spots are suspected, for instance after Magnetic Particle Inspection (MPI) or heavy grinding. The method to be employed shall be subject to agreement with the client.
3. When using standard ACFM probes, the temperature of the inspection surface shall not exceed 80°C. Contact TSC for advice on how to use probes for the ACFM inspection of surfaces where the temperature exceeds 80°C.
4. Standard ACFM probes may be used through paint and coatings with a thickness of up to 4mm (0.16"), as long as the coating is of good condition and generally uniform thickness. If it has a thickness of 1mm (0.04") or more, the nominal coating thickness (lift-off) to the nearest

millimetre shall be entered into the software. Please contact TSC if the coating thickness exceeds 4mm (0.16”) for advice.

3.4 Non-Conformance

- In the event that any of the provisions of this procedure, as relevant, cannot be complied with, the inspection shall be suspended, and the non-conformance reported immediately to the appropriate supervisor and/or ACFM Level 3.
- The inspection shall not be resumed until a satisfactory resolution to the non-conformance has been implemented and the ACFM operator instructed, in writing, to do so.

4 Inspection Procedure for Welds

4.1 Introduction

This procedure covers the use of ACFM probes for the ACFM® inspection of welds and the associated heat affected zones and parent material in ferritic and non-ferritic metals, whether in the as welded or dressed condition.

Refer to TSC/FL/2255 for more information regarding inspection considerations and signal interpretation, e.g.:

- The number of scans required for different types of weld
- Locating the plane of a discontinuity
- Sizing longitudinal discontinuities
- Sizing transverse discontinuities
- Inspection through conducting and non-conducting coatings
- Inspection of other materials than ferritic steel

4.2 Preparation

1. The ACFM operator, if certified to Level 2, shall determine the scans required and select the probe(s) to be used. If the ACFM operator is certified to Level 1, a Written Instruction provided by an ACFM L2 operator shall be followed to determine scan patterns and select the probe(s) to be used.
2. The inspection area shall be prepared as per section 3.3.
3. The inspection area may be marked up to aid quick location of any indications identified in the data. Typically, for flat plate and T-butt geometries, mark positions at 100mm (4") intervals; for cylindrical geometries, mark clock positions or 100mm (4") markers as appropriate.
4. The equipment shall be connected as per section 2.3.
5. An inspection shall be initiated by selecting the appropriate site, component and sub-component and the appropriate probe configuration according to material type.
6. A function check of all the selected probes shall be carried out as per section 2.4 using the slotted metal test block of the correct material for the intended inspection scans. An appropriate “site” and “component” field should be used to identify the plate and inspection location.
7. The extent of the inspection area shall be identified and a datum point established for any positional measurements and noted. A visual inspection of the inspection area shall be carried out and any abnormalities which may cause spurious ACFM signals (e.g. weld spatter, seam welds, grinding marks or stop-start) shall be reported.

4.3 Detection Scans

1. A scan (often referred to as ‘ops check’ scan) shall be carried out on each weld toe to check for cracking that could run the full length of the weld. The probe shall be placed approximately 50mm (2”) away from the weld toe and 10mm (0.04”) in from any plate edge and pushed towards the weld in T (transverse) scanning direction.
2. A number of detection scans, determined by the ACFM operator, shall be carried out to ensure full coverage of each weld (HAZ, weld toe and weld cap). The sensitive width of scan of a typical ACFM probe is 15mm (0.6”) – 7.5mm (0.3”) either side of the probe centreline. If using markers, each position shall be entered into the software. Un-numbered markers may be added to log any visual indications and occasions when the probe is lifted off from the surface.

3. The scan speed may vary according to conditions and probe type but shall not exceed 50mm/sec (2”/sec). A speed of 20-25mm/sec (1”/sec) is typical.
4. Ensure in all scans that the probe remains in contact with the surface.
5. Repeat the above steps to cover the complete weld area under inspection, ensuring an overlap between inspected areas of at least 100mm (4") or one clock position.
6. If a relevant indication is seen on a weld toe, a parallel scan 10mm (0.4”) away (followed by one 20mm (0.8”) away if needed) from the toe, shall be conducted to rule out indications caused by ‘area’ features like a seam weld, grind patch or weld repair.
7. The data of each detection scan shall be analysed. Spurious indications and non-relevant indications, attributed to a geometric or probe handling cause, do not need to be investigated further. Relevant indications are those due to unacceptable discontinuities and are to be noted, located and sized for length and depth.

4.4 Sizing Scans

1. When a discontinuity is detected, a scan to confirm the plane of the discontinuity (often referred to as ‘zig zag scan’) shall be carried out.
2. A scan or series of scans to locate and confirm the position of the ACFM crack ends (often referred to as ‘sizing scan’ and ‘stop-start scan’ or ‘sizing check scan’) shall be carried out.
3. A final, slow, scan over the discontinuity to enable optimum depth sizing (often referred to as ‘depth scan’) shall be carried out. The scanning speed shall not exceed 20mm/sec (0.8”/sec).
4. Using the ACFM crack length obtained in 2, the discontinuity shall be sized for length and depth using the software sizing algorithm.
5. All relevant information, e.g. length, depth, location, distance from the datum (see also section 6.1) shall be recorded in the software.

4.5 Post Inspection

1. A function check of all the probes used during the inspection shall be carried out as per section 2.4 using the same site and components.
2. All files created in the inspection shift shall be backed up.

5 Inspection Procedure for Areas

5.1 Introduction

This procedure covers the ACFM inspection of general areas of structures and components in both ferritic and non-ferritic metals. This is usually required when discontinuities may lie at any location rather than simply along a stress raiser such as a weld line. Typical applications include vessel surfaces, pipes, blades, axles, etc.

Refer to TSC/FL/2255 for more information regarding inspection considerations and signal interpretation, e.g.:

- Locating the plane of a discontinuity
- Sizing longitudinal discontinuities
- Inspection through conducting and non-conducting coatings
- Inspection of other materials than ferritic steel

5.2 Preparation

1. The ACFM operator, if certified to Level 2, shall determine the scans required and select the probe(s) to be used. If the ACFM operator is certified to Level 1, a Written Instruction provided by an ACFM L2 operator shall be followed to determine scan patterns and select the probe(s) to be used.

   If the expected direction of cracking is known, e.g. orthogonal to a principal stress axis, then the inspection direction and grid shall be oriented in this direction.

   If the direction of cracking is not known then the surface shall be scanned in two orthogonal directions (see Figure 3).

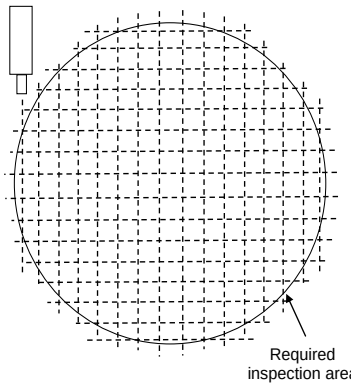

Figure 3 Scan pattern for area inspection

   The spacing between the parallel scans shall be a maximum of 15mm (0.6”), which is the sensitive width of the probe.

2. The inspection area shall be prepared as per section 3.3.
3. The inspection area shall be marked up by drawing the lines of the scan pattern onto the surface or onto a thin acetate sheet fixed onto the surface.
4. The equipment shall be connected as per section 2.3.
5. An inspection shall be initiated by selecting the appropriate site, component and sub-component and the appropriate probe configuration according to material type.
6. A function check of all the selected probes shall be carried out as per section 2.4 using the slotted metal test block of the correct material for the intended inspection scans.

7. The extent of the inspection area shall be identified, and a datum point established for any positional measurements and noted. A visual inspection of the inspection area shall be carried out and any abnormalities which may cause spurious ACFM signals (e.g. weld spatter, seam welds, grinding marks or stop-start) shall be reported.

5.3 Detection Scans

1. Starting at the extremity of the area, a number of detection scans, determined by the ACFM operator in section 5.2, shall be carried out to ensure full coverage of the area, including the orthogonal scans if required. Un-numbered markers may be added to log any visual indications and occasions when the probe is lifted off from the surface.
2. The scan speed may vary according to conditions and probe type but shall not exceed 50mm/sec (2”/sec) for manual probes. A speed of 20mm/sec (0.8”/sec) is often typical.
3. Ensure in all scans that the probe remains in contact with the surface.
4. The data of each detection scan shall be analysed, paying particular notice to adjacent scans when suspected indications are noted. Spurious indications and non-relevant indications, attributed to a geometric or probe handling cause, do not need to be investigated. Relevant indications are those due to unacceptable discontinuities and are to be noted, located and sized for length and depth.

5.4 Sizing Scans

1. If a relevant indication is seen, a scan to confirm the plane of the discontinuity (often referred to as ‘zig zag scan’) shall be carried out.
2. A scan or series of scans to locate and confirm the position of the ACFM crack ends (often referred to as ‘sizing scan’ and ‘stop-start scan’ or ‘sizing check scan’) shall be carried out.
3. A final, slow, scan over the discontinuity to enable optimum depth sizing (often referred to as ‘depth scan’) shall be carried out. The scanning speed shall not exceed 20mm/sec (0.8”/sec).
4. Using the ACFM crack length obtained in 2, the discontinuity shall be sized for length and depth.
5. All relevant information, e.g. length, depth, location, distance from the datum (see also section 6.1) shall be recorded in the software.

5.5 Post Inspection

1. A function check of all the probes used during the inspection shall be carried out as per section 2.4.
2. All files created in the inspection shift shall be backed up.

6 Reporting

6.1 Notes

1. During the inspection it is important that the operator notes general aspects of the job in order to be able to prepare a complete inspection report. Information required may include:
    - Client name and representative name
    - Official name of the site
    - Job reference (if part of a larger scheme of work)
    - Description of the inspection sites including location, ID, type of inspection required, material types
    - Any restrictions on access including percentage of actual coverage
    - Any action taken at the time of inspection
2. Amigo2 records a great deal of inspection information automatically, e.g. date and time of inspection, component name or ID, probe ID and direction of movement. The operator shall record details of the scan in the notes section of each data page to complete this information.

   Typically this information will be the start location, description of scan path and any inspection factors that could affect data interpretation. An example of this might be:

   Start: 12o/c on girth weld, South toe, seam weld at 2 o/c and lift-off at 3:30
3. Discontinuities and anomalies shall be thoroughly documented with enough detail to allow third party review. Start from datum (specify datum), length, location and orientation of any relevant discontinuity shall be included.

6.2 Final Report

1. A final report shall be prepared, as agreed with the client or contractor, detailing the results of the examination.
2. If an acceptance standard has been agreed with the client or contractor, a statement of acceptability against the acceptance standard shall be made.
3. The report shall contain sufficient information to enable full assessment of quality and to ensure that any non-acceptable discontinuities can be accurately located.
4. Any datums used shall be unambiguous.
5. Any restrictions to the test shall be noted.

7 Glossary of Terms

ACFM®	Alternating Current Field Measurement. Non-contacting electromagnetic inspection technique utilising a uniform field and modelled crack sizing
Amigo2™	Topside Portable ACFM system
SENSU®	ACFM probes for use with the Amigo2 system
HAZ	Heat Affected Zone
MPI	Magnetic Particle Inspection
TSC	TSC Inspection Systems, part of Eddyfi Technologies. The developers of the ACFM technique and equipment.