



# SLOFEC™

***FAST CORROSION  
SCREENING TECHNIQUE***



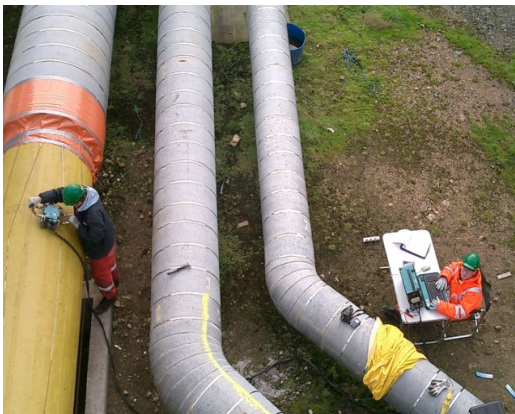
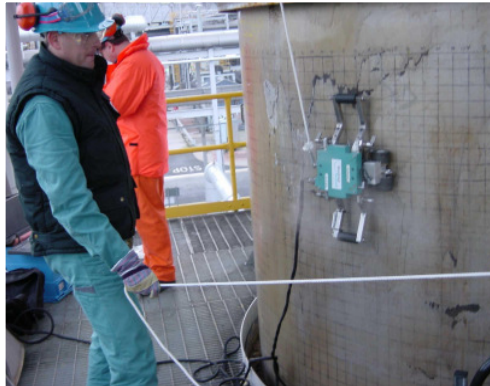
# SLOFEC™ Technique



SLOFEC™ refers to Saturated Low Frequency Eddy Current.

Innospection Ltd is the main provider of the SLOFEC™ inspection services and is the sole licensed SLOFEC operator in the United Kingdom, Australia, Middle East, South Africa, Malaysia etc.

The SLOFEC technique is the world's leading technology for fast scanning and has the exceptional capabilities to deliver unmatched high quality defect reports. The main applications of this technique are the inspection of storage tanks, pipelines, vessels and other type of steel constructions.



## Principle of the SLOFEC™ Technique

The SLOFEC inspection technique uses the eddy current principle in combination with a magnetic field. Utilising superimposed DC-magnetisation, the depth of penetration of the eddy current field lines in the ferromagnetic material is increased.

In case of a defect, the magnetic field lines have a higher density in the remaining wall thickness, which consequently changes the relative permeability in the area, which again changes the eddy current field lines, as shown in Diagram 1.

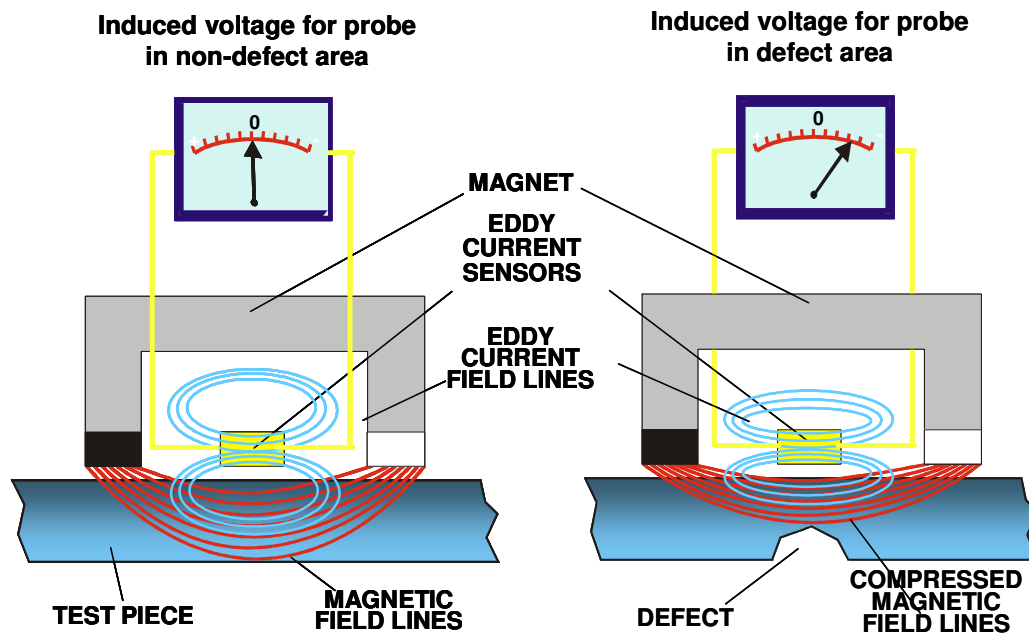


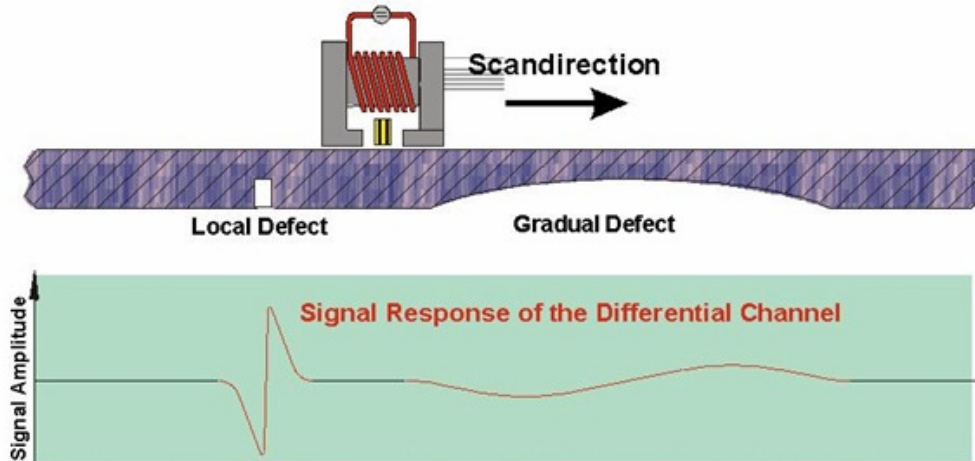
Diagram 1

The changes of the eddy current field lines are measured and analysed in comparison to its calibration in difference of the signal amplitude and the signal phase.

The individual analysis capabilities of the signal phase, signal amplitude and signal shape provides the substantial advantage for the evaluation of:

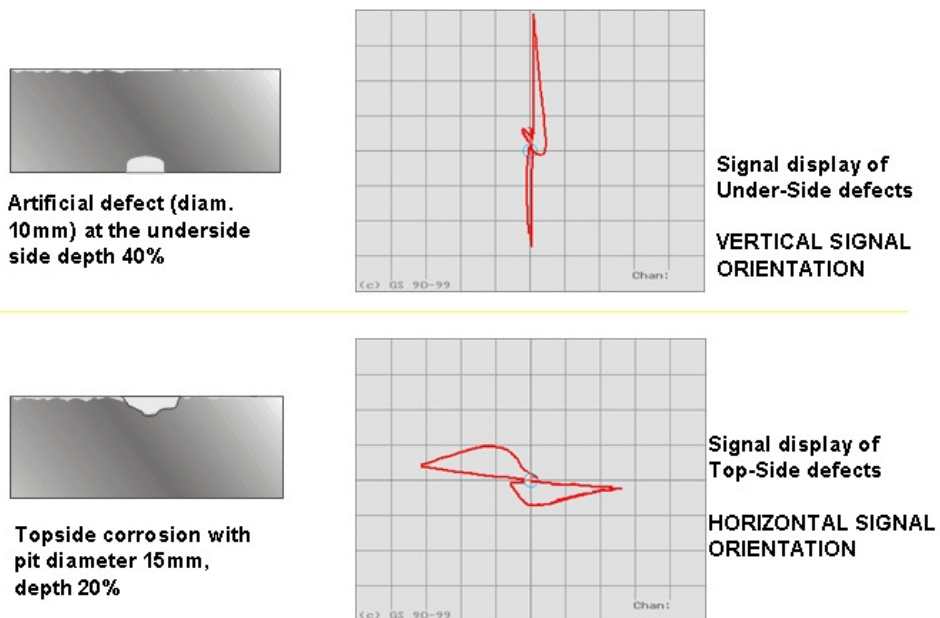
- defect severity in wall loss
- distinguishing top side from underside defects
- analysing the volume of the defect
- distinguishing defects of false calls or laminations or inclusions
- adapting frequency to higher lift off
- allowing separating noise signals from defect signals

The SLOFEC inspection makes use of Eddy Current Differential Channel for the detection of localised material changes i.e. defects. Diagram 2 shows the signal response to a local and gradual defect.



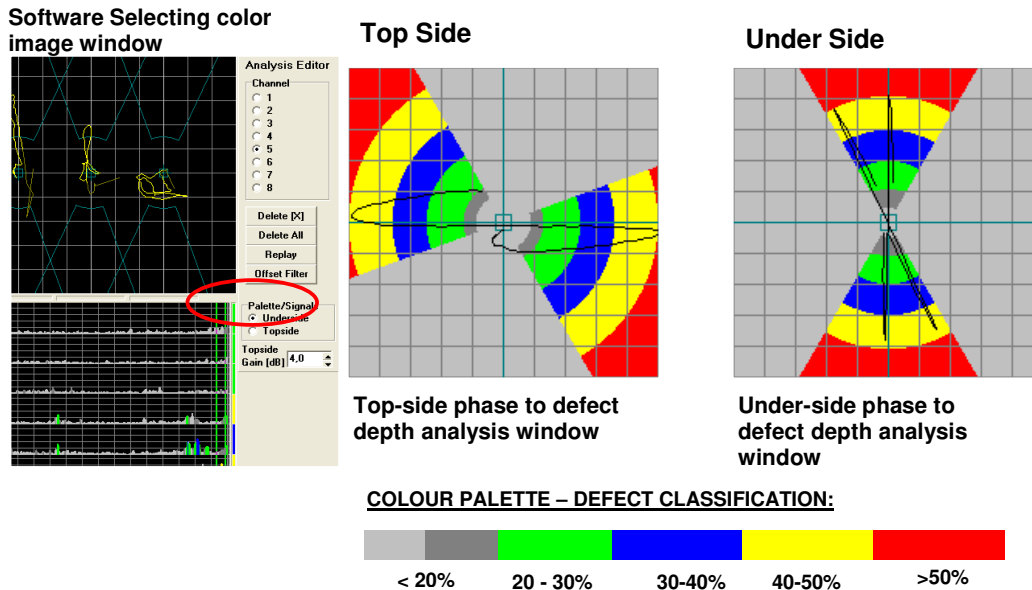
**Diagram 2:  
Signal response to defects**

The scan results are shown with the internal defects on the underside having a vertical signal orientation while the external defects on the topside will have a horizontal signal orientation. Diagram 3 shows the signal phase separation between the external and internal defects.



**Diagram 3:  
Signal phase separation between external and internal defects**

In the inspection software, the analysis capabilities of signal phase separation and amplitude analysis is used with calibrated amplitude / phase to colour palettes, thus allowing the simultaneous evaluation of top side and under side defects, as shown in Diagram 4.



**Diagram 4: Simultaneous Signal Phase and Amplitude analysis (depth in 10% steps)**

Due to the possibilities of adapting the eddy current frequency and reacting on the magnetic field line changes inside the material, SLOFEC can be used for the inspection of materials from low to high wall thicknesses as well as the inspection on top of the coatings.

Our inspection experience is up to 33mm material wall thickness and coating thickness of up to 10mm. Innospection’s Riser Tool can inspect up to a coating thickness of 15mm.

Because SLOFEC is an electromagnetic technique, direct surface coupling is not necessary.

And as with all electromagnetic based techniques, the SLOFEC Technique is not an absolute wall thickness measurement technique like the Ultrasonic Testing and is to be considered as a comparison technique, which means that a calibration with reference to a sample as close as possible in material properties and geometry is required for the inspection. Innospection has set up a wide range of calibration sample stock, which covers typical required reference samples.

## Key Features and Technical Advantages of the SLOFEC Technique

### 1) **Capability of inspecting ferromagnetic and non-ferromagnetic materials**

The SLOFEC technique is regarded as a fully accepted Non Destructive Testing (NDT) technique in an increasing number of industries. The Oil & Gas industry recognises the advantages of this technique for the inspection of ferromagnetic and non-ferromagnetic materials such as carbon steel, stainless steel, duplex and super duplex materials.

This technique has also been proven in the fields as a high speed and reliable method for the detection of local corrosion in pipelines, pressure vessels, storage tanks, caissons and risers as well as other types of steel constructions

### 2) **High inspection speed**

The SLOFEC technique allows the fast screening of large areas with low surface preparations prior to the inspection.

### 3) **High inspection temperature range**

The SLOFEC technique allows the Inspection at high temperatures, with up to date experience of up to 150°C.

### 4) **High defect detection sensitivity and reliability**

The ability of the SLOFEC technique to inspect through different coatings and cladding types, under high temperatures and through thick wall components provides the advantages of using the SLOFEC technique not only for risk based inspection but also as a Non Intrusive Inspection (NII) strategy.

The SLOFEC technique is highly sensitive in the detection of corrosion within a large wall thickness range, with the up-to-date experience from 0mm to 33mm.

The extended thickness capability allows this technique to be suitable not only for the inspection of thick wall components but also for thinner walls covered with thick non-metallic protection layers such as glass fibre reinforced epoxy coatings on floors of (oil) storage tanks. Our experience in inspection through thick coatings is up to 10mm.

The SLOFEC technique is also capable of scanning welds covered by very thick linings, e.g. shell-to-annular welds in lined tanks.

### 5) **Distinction between external and internal defects**

The SLOFEC technique has the unique and useful feature of differentiating between the defects on the Top-Side, Under-side and through holes. It is also very sensitive in the detection of smaller volumetric defects.

In the detection of corrosion, this technique is able to detect the different types of defect profiles, such as:

- single isolated pits
- groups of corrosion attack
- small shallow and narrow pits in their early stage of defect development (to be noted as an early warning sign)
- shallow rounded pits with different diameters that are particularly difficult to detect with conventional manual ultrasonic
- Microbiological Induced Corrosion (MIC)

### 6) **Capability of real time scan results with coloured defect mapping**

The SLOFEC scan results are mapped out in real time which allows for speedy indications of defects in the inspected materials.

The coloured reporting capability of the SLOFEC technique for the corrosion mapping provides an overview on the condition of the inspected component which allows for the evaluation, determination of corrective actions and modifications to future maintenance and inspection strategies.

## Reporting Software of SLOFEC™

The SLOFEC scan results are mapped out in real time which allows for speedy indications of defects in the inspected materials. The coloured reporting software of SLOFEC for corrosion mapping provides not only a condition overview but displays as well the condition of the individual sections of the inspected object.

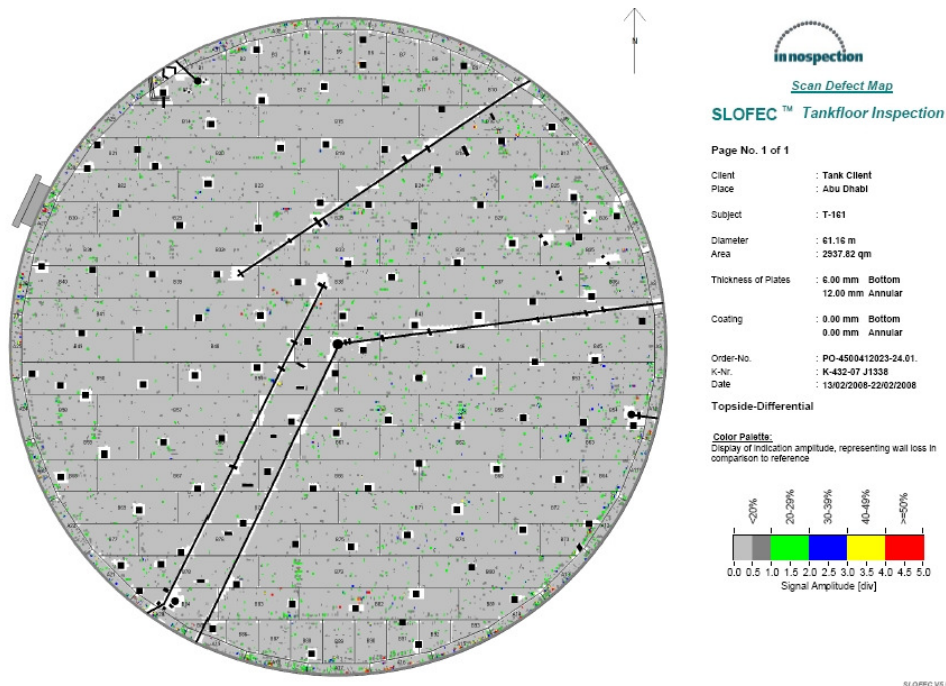
The easy handling of the reporting software enables the setting up of the required colour levels for the defect severity display. As with no other inspection techniques, it also allows the separate reporting of the top side condition from the under side condition, which makes this software highly interesting for storage tanks inspections.

The software has also the additional feature of including individual defect analysis, statistical analysis of defects, repair plate modes, as well as for adding other results as Ultrasonic verifications and more.

This allows the evaluation and determination of corrective actions and modifications to future maintenance and inspection strategies.

In the reporting layout, the inspection data is precisely added and an easy coloured condition overview is displayed. The colour criteria and threshold can be set up to the required criteria.

The diagram below shows an example of the topside condition of a tank floor scan sample coloured map report.



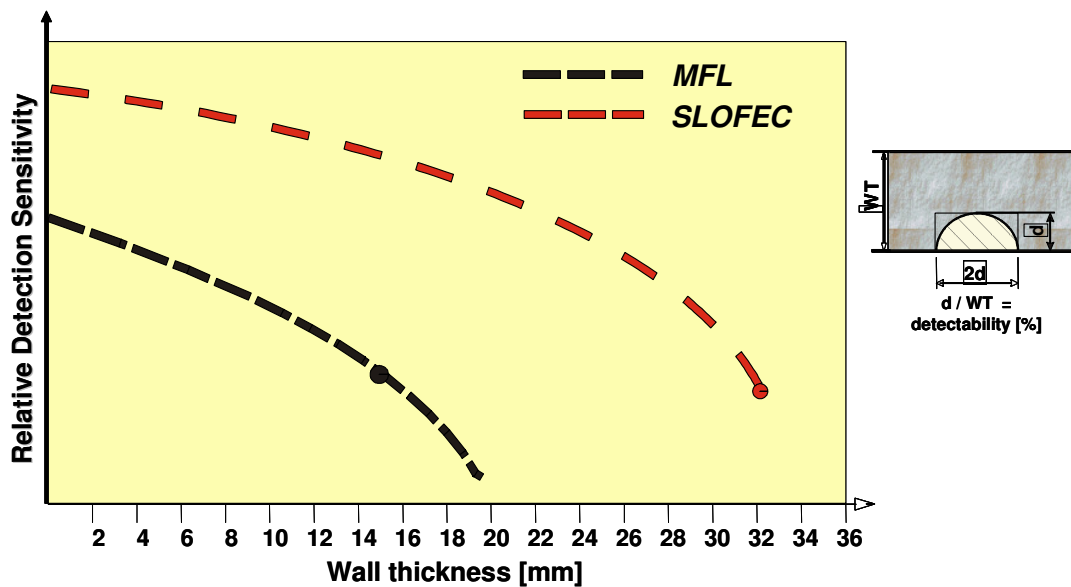
**Diagram 5:**  
**Top-side scan sample coloured map report**

## Comparison between SLOFEC and MFL techniques

Due to its electromagnetic technical background, the SLOFEC Technique is often compared to the Magnetic Flux Leakage (MFL) technique. However the advantages of the SLOFEC technique against MFL are proven to be multiple.

A study was conducted by an independent party to compare the relative defect detection sensitivity and wall thickness range of the SLOFEC technique for tank floor inspection with the typical MFL floor scanning technique. The detection tests were performed with the use of spherical test defects of different plates. The result was set up in the relative detection sensitivity versus wall thickness graph.

The results in Diagram 6 clearly identified the substantial detection and wall thickness range advantage of the SLOFEC technique i.e. SLOFEC has a better defect detection sensitivity than the MFL technique.



**Diagram 6:**  
**Floorscan “Relative Detection Capability versus Wall Thickness”**  
**SLOFEC™ versus MFL**

In comparison with other technologies like the MFL technique, the SLOFEC technique is capable of scanning in excess of 3 times the material thicknesses and scanning through coatings in excess of 5 times the thicknesses. It has also the powerful capabilities of detecting defects less than half the size of that which can be detected with the MFL technique.

Qualification tests conducted by various Oil & Gas organizations showed detection sensitivity of even the smallest diameter defects (pits). Below is an example for the qualification for an international storage tank floor inspection work.

The results showed detection capabilities of the following small defects in the plates with different thickness (with and without coating):

9mm thick plate	defect detected from Ø 2mm, depth 20%
12mm thick plate	defect detected from Ø 2mm, depth 20%
21mm thick plate	defect detected from Ø 4mm, depth 20%

An inspection through coatings of up to 10mm on tank floors and up to 6mm on pipes was performed. The scanners were equipped with multiple sensor arrays which allowed a sufficient resolution while scanning. All scanners were connected to the same Eddy Current Multiple Channel system operated online, allowing the inspection operator to view and analyse online each individual indication.

The signal distinction between the defect and non defect analysis by eddy current signal phase and shape prevents colour reporting of false calls such as inclusions, laminations or surface deposits. Due to this fact, the surface preparation for the SLOFEC inspection is lower than for other techniques like MFL.

In different applications and analysis with major oil & gas operators, the following key features and capabilities were identified with the SLOFEC technique:

- Good detection capabilities for corrosion defects such as Microbiological Induced Corrosion (MIC or RSB)
- Relative equal defect depth analysis of different defect top shapes (flat bottom, spherical or conical top shape)
- Very good signal noise ratio on higher temperatures
- Corrosion detection even along the welds

Over the past years, this technique has not only developed into a much used technique in the oil & gas and petrochemical industry, it has also become an important inspection part of Risk Based Inspection Strategies and Non Intrusive Inspection Strategies. More importantly, it is used as a fast and reliable general corrosion detection tool.