Heat Exchanger & Boiler Tube Inspection Techniques

Overview

For the in-service inspection of ferromagnetic, non-ferromagnetic and fin-fan tubes, the following advanced techniques offer high defect detection capabilities and accurate defect analysis:

- **Multiple Frequency Eddy Current**
- **Magnetic Biased Eddy Current**
- **Remote Field Eddy Current**
- **Rotating Eddy Current**
- **IRIS (Rotational Ultrasonic System)**

The Multiple Frequency Eddy Current technique offers a reliable inspection of non-ferromagnetic tubes with high defect detection capabilities.

For the inspection of ferromagnetic tubes, the Magnetic Biased Eddy Current technique offers fast and reliable screening while the Remote Field Eddy Current technique is used to detect thinning, large volumetric defects and as a verification to Magnetic Biased Eddy Current. IRIS offers high resolution results and is also used as a verification tool.

The Rotating Eddy Current technique is applied for the detection and analysis of cracks.

With high inspection speed and low cleaning requirements, these are cost effective inspection technologies.

Documentation & Reporting

The advanced and comprehensive Eddy Current Computer System and Reporting Software provides a precise and accurate condition overview and enables the automatic signal analysis of the individual tubes in real time while the inspection is in progress.

Innospection's EddyMax system uses a multiple frequency operation in simultaneous modes for defect detection and analysis. Multiple Frequencies enable the best signal to noise ratio in order to reach an optimum sensitivity on the internal and external tube wall.

Differential Modes are very sensitive in the detection of local defects such as corrosion, pitting, vibration damages and cracks while Absolute Modes are sensitive in the detection of gradual-type defects such as thinning, erosion and material characteristic changes. Mixing Channels are used to subtract unwanted signal influence. Low / High Gain Channels enable the system to run in additional channels with duplicated standard settings but with choices of increased or decreased amplitudes to accommodate a variety of different defect types and volumes.

The results are transferred to the documentation software which generates not only a precise and accurate condition overview but also the specific inspection results for the individual tubes as well as accurate client-defined plugging plans.

Multiple Frequency Eddy Current

TECHNIQUE DESCRIPTION	
Typical Inspected Materials	Non-ferromagnetic and electric conductive materials (plain wall or with fins) E.g. Stainless Steel, Brass, Copper, Copper Nickel Alloys, Titanium, Monel, Hastelloy
Frequency Settings	Reaching sufficient sensitivity on both sides of the tube walls. Standard penetration depth depends on the conductivity of tube wall E.g. Titanium ~ 200 kHz, Stainless Steel ~ 100 kHz, Brass ~ 50 kHz, Copper ~ 10 kHz
Standard Sensitivity	Ø 1.5 Through Wall Hole (TWH)
Typical Analysis	From 10% wall loss onwards
Accuracy	± 5% to ± 10% of defect depth analysis Reasons for accuracy tolerance include centring of probe, accuracy of calibration defect depth, tolerance band of calibration curve (material, defect volume), analysis capability of operator / inspection equipment
Sensitive To	Any type of material heterogeneity such as corrosion, erosion, localised pitting, vibration damages and material changes Pitting : > Ø 1 - 2.0mm (Ø 0.5mm), depth >20% Holes : > Ø 0.7 - 1.0mm (Ø 0.3mm), surface dependant Vibration Damage : > 20% loss (mixing required) Cracking : High detectability with field-crack orientation 90° (> 10%) Thinning : Internal > 10%, External > 20% Local Defects : Internal and External > 20% / Ø 2-3mm
INSPECTION DETAILS	
Speed	35 – 60 tubes/hour (approx. 500 – 600 tubes / team / shift)
Wall Thickness	Typical 0mm to 8mm (higher with special sensors)
Internal Diameter	From Ø 5mm (max. experience 170mm)
Length	Standard cable up to 30m
Bends	With U-Bend probes - beds with radius > 10 x ID
Preparation	Generally cleaned tubes and free of electric conductive deposits. Probes of Ø 1.0 to Ø 1.5mm below tube nominal internal diameter in order to pass through
Probes	Fill factor 85-95%
Detection	Differential Mode for localised defects Absolute Mode for gradual defects and thinning

Innospection Limited
Unit 1, Howemoss Avenue, Kirkhill Industrial Estate, Dyce, AB21 0GP, Aberdeen, United Kingdom
Tel : +44 (0)1224-724744 Email : info@innospection.com
Web : www.innospection-technologies.com Web : www.innospection.com

Magnetic Biased Eddy Current

TECHNIQUE DESCRIPTION	
Typical Inspected Materials	Ferromagnetic material (plain wall or with fins) E.g. Carbon Steel, Monel, Duplex
Frequency Settings	Relatively independent
Standard Sensitivity	Ø 1.5mm to Ø 2.5mm Through Wall Hole (TWH)
Typical Analysis	From 20% wall loss onwards (depth analysis by signal amplitude in comparison to calibration defects)
Accuracy	± 10% to 15% of defect depth analysis Reasons for accuracy tolerance include centring of probe, accuracy of calibration (defect volume difference of calibration / tubes), analysis capability of operator / inspection equipment
Sensitive To	Local defects : Highly sensitive to corrosion, pits and vibration defects as only Differential Mode is being usable Cracks : Best detection when Eddy Current or magnetic field is broken and in perpendicular direction to crack-field Thinning : Not sensitive to thinning due to no Absolute Mode
INSPECTION DETAILS	
Speed	25 – 40 tubes/hour (approx. 350 to 400 tubes / team / shift)
Wall Thickness	Typical 0mm to 4mm (higher with special sensors)
Internal Diameter	From Ø 10mm (max. experience 130mm)
Length	Standard cable up to 30m
Bends	Only large radius bends
Preparation	Generally cleaned tubes and free of electric conductive deposits. Probes of Ø 1.0 to Ø 1.5mm below tube nominal internal diameter in order to pass through
Probes	Fill factor 85-95%
Detection	Only Differential Mode for localised defects pitting, vibration defects

Remote Field Eddy Current

TECHNIQUE DESCRIPTION	
Typical Inspected Materials	Ferromagnetic material (plain wall or with fins) E.g. Carbon Steel, Monel, Duplex
Frequency Settings	Typical signal noise ratio between 50 Hz to 1 KHz for optimum penetration / sensitivity
Standard Sensitivity	Ø 2.5mm Through Wall Hole (TWH)
Typical Analysis	From 20% wall loss onwards
Accuracy	± 10% to 15% of defect depth analysis Reasons for accuracy tolerance include centring of probe, accuracy of calibration (defect volume difference of calibration / tubes), analysis capability of operator / inspection equipment
Sensitive To	Local defects : Sensitive to corrosion, pits and vibration defects from certain volume e.g. Ø 10mm / 20% Cracks : Best detection when Eddy Current or magnetic field is broken and in perpendicular direction to crack-field Thinning : Very sensitive to thinning (erosion)
INSPECTION DETAILS	
Speed	20 – 30 tubes/hour (approx. 250 tubes / team / shift)
Wall Thickness	typical 0mm to 4mm (higher with special sensors)
Internal Diameter	from Ø 10mm (max. experience 80mm)
Length	Standard cable up to 30m
Bends	With use of flexible U-Bend probes - beds with radius > 15 x ID
Preparation	Generally cleaned tubes and free of electric conductive deposits. Probes of Ø 1.0 to Ø 1.5mm below tube nominal internal diameter in order to pass through
Probes	Fill factor 85-95%
Detection	Differential Mode for localised defects Absolute Mode for gradual defects and thinning

Innospection Limited
Unit 1, Howemoss Avenue, Kirkhill Industrial Estate, Dyce, AB21 0GP, Aberdeen, United Kingdom
Tel : +44 (0)1224-724744 Email : info@innospection.com
Web : www.innospection-technologies.com Web : www.innospection.com

Rotating Eddy Current (Rotoscan)

TECHNIQUE DESCRIPTION	
Typical Inspected Materials	Ferromagnetic material E.g. Carbon Steel, Monel, Duplex. (Plain wall, limited to finned tubes)
Typical Usage	Detection of defects at tube expanded zones
Sensitive To	Local defects : External and internal defects like pitting and corrosion in tube material and tube entrance Cracks : From 0.5mm depth (longitudinal and circumferential) in tube expansion zone, back side welded tubes and circumferential tube cracking due to wrong expansion
INSPECTION DETAILS	
Speed	500 – 700 tube expanded zones per shift
Probes	Fill factor up to 100% (with flexible sensors)
Detection	Differential Mode for localised defects Absolute Mode for gradual defects and thinning

Innospection Limited
Unit 1, Howemoss Avenue, Kirkhill Industrial Estate, Dyce, AB21 0GP, Aberdeen, United Kingdom
Tel : +44 (0)1224-724744 Email : info@innospection.com
Web : www.innospection-technologies.com Web : www.innospection.com

IRIS (Rotational Ultrasonic System)

TECHNIQUE DESCRIPTION	
Typical Inspected Materials	Ferromagnetic and non-ferromagnetic material
Typical Analysis	From 20% wall loss onwards
Accuracy	Very accurate in defect detection (a three dimensional picture showing the defect profile and depth can be obtained)
Sensitive To	Local defects : Highly sensitive to volumetric defects, good resolution at tube circumference Cracks : Not sensitive to cracking Thinning : Sensitive to thinning (erosion)
INSPECTION DETAILS	
Speed	Slow technique (approx. 80 tubes / team / shift) Actual inspection speed depends on a number of factors but is generally approx. 2.4m/sec to achieve a 100% coverage
Bends	Not inspectable
Preparation	Water must be introduced into the tube to act as a couplant. Tubes must be absolutely cleaned down to the bare metal (unlike other techniques which tolerate some degree of scaling)
Probes	Must be centralised within the tube or the signals will be lost. A dead zone could occur due to the effect of "probe ringing"
Detection	Only volumetric defects are detected. Not sensitive to cracking
Operator	Very experienced operators are required for successful IRIS inspections

Innospection Limited
Unit 1, Howemoss Avenue, Kirkhill Industrial Estate, Dyce, AB21 0GP, Aberdeen, United Kingdom
Tel : +44 (0)1224-724744 Email : info@innospection.com
Web : www.innospection-technologies.com Web : www.innospection.com