EFFECTIVE & RELIABLE INSPECTION OF FIN-FAN COOLER TUBES

ANDREAS BOENISCH & ABDUL RAHMAN TAQATEQ
- Short overview Fin Fan Cooler & Tube Types, Tube corrosion Issues

- NDT techniques for Fin Fan Cooler Tube inspection, MagBiased Eddy Current Operational information & in combination with Iris follow up

- Case studies

- Summary
FIN FAN COOLER & TUBE SET UP

Air Cooler tube banks installed with fin fan tubes

Desktop analysis using computational fluid dynamics to model any potential problem areas in the bundle in relation to flow and distribution.

Reference:
http://www.calgavin.com/engineering-services/air-cooler-trouble-shooting/#ixzz3lItlY5Ce

Typical CS Tubes
1” OD x 2.11mm, 2.77mm

Headers either end
Fin Fan Cooler tube - Fin types

- Extruded Fins
- Embedded Fins
- Footed Tension (Wrap On)

Typical Cleaning
- Air Cooler tube cleaning from inside
- Fins cleaning externally

Majority fin fan cooler tubes base material Carbon steel, (exception: Stainless Steel, Duplex, ...)
Fins Typically Aluminium
Dimensions typically 1” x 2,11mm (1,65mm: 2,77mm; 3.0mm etc.)
FIN FAN COOLER TUBE CORROSION ISSUES

Example Fin Fan Cooler tube defect

External Corrosion

Internal Corrosion
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## FIN FAN TUBE INSPECTION TECHNIQUES

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<th>PRE-PARATION</th>
<th>SPEED</th>
<th>SIZING</th>
<th>OTHER INFO</th>
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<tr>
<td>RFET</td>
<td>larger size int. defects, ext. defects limited</td>
<td>Tubes well cleaned</td>
<td>Medium</td>
<td>Average</td>
<td>Fins causing field absorption. Very limited use</td>
</tr>
<tr>
<td></td>
<td>Internal defects only</td>
<td>Tubes well cleaned</td>
<td>High</td>
<td>Average</td>
<td>missing external corrosion</td>
</tr>
<tr>
<td></td>
<td>External and internal defects</td>
<td>Tubes well cleaned</td>
<td>High</td>
<td>Average</td>
<td>Limited analysis separation defect/others Limited to lower WT</td>
</tr>
<tr>
<td>MFL</td>
<td>External and internal defects</td>
<td>Tubes very well cleaned</td>
<td>Low</td>
<td>Very good</td>
<td>Very well cleaning required, water require, slow, excellent sizing</td>
</tr>
<tr>
<td>IRIS</td>
<td>External and internal defects</td>
<td>Tubes cleaned</td>
<td>High</td>
<td>Good / average</td>
<td>fast, excellent sensitivity ext/int pit detection, limited cleaning, sizing on volume</td>
</tr>
<tr>
<td>Magnetic Biased ET</td>
<td>External and internal defects</td>
<td>Tubes cleaned</td>
<td>High</td>
<td>Good / average</td>
<td>fast, excellent sensitivity ext/int pit detection, limited cleaning, sizing on volume</td>
</tr>
<tr>
<td>Acoustic Pulse Reflectometry (APR)</td>
<td>Internal defects only</td>
<td>T very well cleaned</td>
<td>Very high</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
FIN FAN TUBE INSPECTION - MagBiased ET

- **Materials:** Non Ferromagnetic
  - Carbon Steel (also FINNED !), Duplex

- **Typical Sizes:**
  - Tube Sizes: > ID 10mm
  - WT: up to 8 mm
  - Length: up to 30m
  - U-bends radius: -

- **Probes:** Fill factor 85%-95%

- **Production:** average 350 tubes/shift

- **Detection:** External & Internal Defects as
  - localised def. e.g. pitting
    - from >10%/ wall loss / ø 2-3mm
  - gradual def. e.g. Erosion/ thinning
    - limited
  - Cracking (probe dep.) > 10%
**FIN FAN TUBE INSPECTION - MagBiased ET**

**Signal Analysis**

- Differential Channel (Very Sensitive for localised defect detection)
- Low influence through variation of Frequency
- Limited Signal Phase spread
- Defect analysis on Signal Amplitude
- Signal Amplitude has influence of Defect Volume
**FIN FAN TUBE INSPECTION - MagBiased ET**

**Calibration**

Typical Fin FanCooler Calibration Tubes – original fin fan cooler tubes, fins baked in resin.

Defects typically:
4 x 20% wall loss – 5mm diameter
40 %, 60%, 80% wall loss – 10mm diameter
100% TWH – 2.5mm diameter
Ultrasonic immersion pulse echo technique

Transducer must be centered in the heat exchanger tube.

A rotating 45-degree mirror reflects ultrasound pulses directed radially onto the tube wall.

Reflections from the inner and outer walls of the tube can be used to represent the tube wall thickness.

Each successive pulse is mapped out as a horizontal scan line on the UT equipment screen.

There are ~150 readings per revolution and 2400 revolutions per minute.
18 flat bottom holes on the OD of a calibration tube. Nominal wall: 2.55 mm, tube OD: 1 inch.

Good definition of ID surface and OD FBH
Typical Inspection Strategy:

- Standard cleaning allowing MagBiased Eddy Current Tube Inspection
  - Probe Through passing tested with dummy (fill factor 90% to 95%)

- 100% of Tubes inspected with Magnetic Biased Eddy Current
  - Detection external or internal pitting corrosion, general corrosion,
  - Analyzing wall loss integral in 10% steps with accuracy +/- 10%

- Decide selected tubes for sizing accuracy Iris inspection at dedicated position
  (selected tube : with Magnetic Biased ET detected >XX % wall loss)
  - Additional cleaning allowing Iris Tube Inspection at dedicated tubes only
  - Iris verification and improved sizing inspection

ADVANTAGES:
limited cleaning necessary , fast overview of ext./internal defects, sizing where relevant
## FIN FAN TUBE INSPECTION TECHNIQUES

Experienced comparison / follow up Magnetic Biased ET & Iris

<table>
<thead>
<tr>
<th>Indication No.</th>
<th>Magnetic Biased ET Finding</th>
<th>Iris Finding</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vertical indication, correct run, 4x 20% FBH @60° defect indication</td>
<td>20% wall loss</td>
</tr>
<tr>
<td>2</td>
<td>Vertical indication, correct run, 40% FBH defect indication</td>
<td>36% wall loss</td>
</tr>
<tr>
<td>3</td>
<td>Vertical indication, correct run, 60% FBH defect indication</td>
<td>50% wall loss</td>
</tr>
<tr>
<td>4</td>
<td>Vertical indication, correct run, 80% FBH defect indication</td>
<td>78% wall loss</td>
</tr>
<tr>
<td>5</td>
<td>Vertical indication, correct run, 100% defect indication</td>
<td>No Signal</td>
</tr>
<tr>
<td>6</td>
<td></td>
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Automatic Online-Signal analysis and Transfer of Results to the Documentation-Software

Final Report
Protected Place for Computer Operation (tent/habitat) near Heat Exchangers

Deskplace:
place for computerized ET System

Supply:
- Power AC 110V

Tube Inspection Assistant in headset (on cable) connection with operator.

Requirements:
- Scaffold
- Light
(- Habitat / Tent around Tube Sheet)
- Short overview Fin Fan Cooler & Tube Types, Tube corrosion Issues

- NDT techniques for Fin Fan Cooler Tube inspection, MagBiased Eddy Current Operational information & in combination with Iris follow up

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- Summary
Severe external corroded Fin Fan Cooler tube. Corrosion as well below the aluminum fins. Refinery site near coast.

Tubes: 1” x 2.11mm, standard CS.

Wall loss up General wall loss ~ 30%
Localized wall loss to 100%
**FIN FAN TUBE INSPECTION - CASE STUDY**

**External corroded Fin Fan Cooler Tubes**

**Mag Biased ET inspection data followed up by Iris**

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### Magnetic Biased Signal Review:

14.0mm - Diameter Bobbin Probe = Successful.

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### Iris Area Review:

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### Remarks / Result:

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<th>Magnetic Biased ET Finding</th>
<th>Iris Finding</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vertical indication 30-39% according to calibration - Max Mag -B signal found (30-33% wall loss) - Max IRIS signal found</td>
<td>Remaining wall 1.62mm due to final verification with Iris</td>
<td>30-40% wall loss</td>
</tr>
</tbody>
</table>

**OVERALL RESULT (WALL LOSS)**

Re-Analysis – 30-39% Wall Loss

**Comments**

<table>
<thead>
<tr>
<th></th>
<th>Magnetic Biased</th>
<th>IRIS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Signal noise 1-2 divisions</td>
<td>Minor loss of backwall echo noted</td>
</tr>
</tbody>
</table>
External corroded Fin Fan Cooler Tubes closed to header tube sheet (crevice corrosion)

Analysis of detectability by RFET, Mag Biased ET, Iris

Main area of tube inspection interest at the fin fan coolers
External corroded Fin Fan Cooler Tubes closed to header tube sheet (crevice corrosion)
Analysis of detectability by RFET, Mag Biased ET, Iris

RFET field distribution

Mag Biased ET inspection data of defect close to header tube sheet:

Mag Biased ET field distribution

Differential Chart
Absolute Chart
Impedance - Focus Differential Chart
Impedance - Focus Absolute Chart
External corroded Fin Fan Cooler Tubes closed to header tube sheet (crevice corrosion) detectability areas of Mag Biased ET
FIN FAN TUBE INSPECTION - CASE STUDY

External corroded Fin Fan Cooler Tubes closed to header tube sheet
Analysis of detectability by Iris

The Magnetic Biased Eddy Current Technique is excellent for localised defect detection at fin fan cooler detection – however the dead zone of the Magnetic Biased Focused probe close to the tube sheet up to around 10mm required.

A special built Focused Iris probe to detect the defects very close to the tube sheet.
The possibility of the remaining wall thickness analysis of deeper defects may look advantageous with a 15MHz probe compared to a 5MHz probe.
FIN FAN TUBE INSPECTION - CASE STUDY

External corroded Fin Fan Cooler Tubes closed to header tube sheet

Iris detectability

UT Tube Signal Mapping with Special Focused Iris probe

Defect No. 1 behind Tube Sheet of Fin Fan cooler tube 1” x 2.11mm
FIN FAN TUBE INSPECTION - CASE STUDY

External corroded Fin Fan Cooler Tubes closed to header tube sheet
Iris detectability

UT Tube Signal Mapping with Special Focused Iris probe
Defect No. 2 behind Tube Sheet of Fin Fan cooler tube 1” x 2.11mm

UT Tube Signal Mapping with Special Focused Iris probe using 5MHz probe
Defect No. 2

UT Tube Signal Mapping with Special Focused Iris probe using 15MHz probe
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SUMMARY - EFFECTIVE & RELIABLE INSPECTION OF FIN-FAN COOLER TUBES

-Magnetic Biased Eddy Current has recognisable advantages as:
  - No influence of external fins to the electromagnetic field
  - External and internal pitting & general corrosion detection
  - Signal Phase separation defects vs non defects
  - Fast scanning
  - High POD
  - Reasonable defect sizing & accuracy
  - Limited cleaning requirements

-Iris has recognisable advantages as:
  - Excellent defect analysis resolution
  - Good sizing
  - Limited influence of header tube sheet for near defect detection

-Combining MagBiased ET increases Efficiency by keeping high defect detection capabilities and defect sizing where necessary.
THANK YOU FOR YOUR ATTENTION

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