Refineries at Risk

The Critical Link between Reliability and Safety Drives Global Acceptance of New Inspection Technologies for Fired Heaters

State of Refining

- Refinery infrastructure is aging
- Refineries operating at as high as 99.4%
- Overuse increases the potential for failure
- Recent failures are understandable given the aging infrastructure and overuse

Paraphrased from - Larry Chorn, PhD, Chief Economist, Platts Analytics
(Dec. 2006)
Rapid/Global Change

- Refiners around the world have been re-defining entire heater reliability programs around ongoing monitoring programs and "New Inspection Technologies" for fired heater – FTIS™ & LOTIS®. These programs coupled with engineering assessment (RLA and FFS) allow refiners to manage risk of operations. Nowhere in the refinery is this more important than in the Coker Unit.

Ongoing Heater Monitoring Program

1. Identify Key Reliability/Safety Parameters
2. Reliability Measurement Tools
3. Routine Monitoring Program
4. Detect Potential Failures
Key Reliability Parameters

1. Tube Metal Temperature
2. Process Fluid Temperature
3. Heat Flux Rate
4. Excess Oxygen
5. Fuel Gas Pressure
6. Process Feed Characteristics
7. Process Charge Rate
8. Flue Gas Temperature
9. Draft
10. Environmental Emissions
11. Process Fluid Pressure
12. Structural Component Temperature

Why is Temperature Important?

- Controls availability
- Determines reliability
- Allows an assessment of risk
Measuring Tube Metal Temperatures

Flir Systems
ThermaCam SC1000

- Handheld portable radiometer camera
- Electrically cooled FPA imager
- Temperature range: 14 to 2732 deg F
- Color LCD Display
- Digital Video Output
- ThermaCam Reporter Software

Coker Charge Heater During Steam-Air Decoke

Temperature Range: 947.8°F to 1287.5°F
Observe Heat Distribution Pattern

Crude Charge Heater

- heat distribution
- tube temperatures
- burner signature

Flue Gas Analyzer

Testo 300 M Analyzer

- Handheld portable flue gas analyzer
- Measures O2, CO, NOx and SOx emissions, draft and flue gas temperature
Flue Gas Analysis

- Burner performance (flame quality, emissions)
- Heater efficiency monitoring

Routine IR/Heater Monitoring Program

- Determine who will perform monitoring (Internal Resources/External Resources/Shared)
- Establish heater baseline performance
- Determine monitoring frequency per heater:
  - weekly, monthly, quarterly, as needed
- Data collection and analysis
- Determine action plan forward
Step 4: Detect Potential Failures

Can you identify the performance problems?
Which heater would you choose?

Before

After

Inspection Technologies Defined

- FTIS™ - (Furnace Tube Inspection System)
  - Untethered intelligent pig utilizing Ultrasonics (UT) to rapidly inspect both the radiant & convection section as well as other piping configurations.

Inlet/Outlet piping modifications may be necessary in order to "pig" a furnace in the most efficient and effective manner.
Inspection Technologies Defined

- **FTIS™** - *(Furnace Tube Inspection System)*
  - Untethered intelligent pig utilizing Ultrasonics (UT) to rapidly inspect both the radiant & convection section as well as other piping configurations.

- **LOTIS®** - *(Laser Optic Tube Inspection System)*
  - Laser based system designed to internally inspect tubes of many services (Boilers, Steam Reformers, Heaters, etc.)

Reiners Applying FTIS™ & LOTIS® Today

- ConocoPhillips
- Esso
- ExxonMobil
- Agip
- Marathon Oil Corporation
- bp
- CITGO
- Saudi Aramco
- PetroCanada
- Shell
- Valero Energy Corporation
- Chevron
- SK Corporation
- CHEP
- Syncrude
- ChevronTexaco
- Suncor
- Orion
- Coastal
- Flint Hills Resources
- Nefco
- QuestTruTec
- QuestReliability
Applications

- Furnaces Piping / Tubing
  - Numerous Furnace Types (Coker, Vacuum, Crude, UOP Platforming Heaters (CCR), Can, Cabin, etc.)
  - Various Coil Configurations (Vertical, Horizontal, U-Shape, etc.)
  - Changing Diameter Coils (4" Ø 5" Ø 6" Ø 8")
  - Non-piggable furnaces in some cases (i.e. Common Headers) (Common Header Delivery Systems*)

- Pipelines
  - Underground / Buried / Road Crossings
  - Insulated (i.e. Asbestos)
  - Overhead (i.e. Congested Pipe Racks)
  - In Plant / Between Plants / Wharf Lines

*Common Header Delivery System only available in Europe at this time.

FTIS™ Detectable Failure Mechanisms

- Pipe/Tube Wall Loss
  - Corrosion (Int. or Ext.)
  - Erosion (Int. or Ext.)
  - Pitting (Int. or Ext.)
  - Mechanical Damage (Int. or Ext.)

- Deformation
  - Bulging (i.e. Flame Impingement)
  - Swelling (i.e. Creep Strain)
  - Denting
  - Ovality
3D Modeling of FULL Serpentine Coil

100% of the Ultrasonic (UT) Data Utilized to Generate This Image

3D modeling and reporting options allow operations and inspection to easily interpret data for immediate and accurate corrective actions.

3D Modeling of FULL Serpentine Coil

Radiant Section 3D-Outer Radius (Inch)

Creep Damage is clearly evident in this example utilizing FTIS™.
“Gray Scale” Decoking Assurance

Gross coke remaining in tubes after cleaning

External Studded or Finned Surfaces

3D View

2D View

New Pipe

Sample Convection Pipe

New Pipe

Quest TruTec Proprietary Information

Quest TruTec

QUEST

Reliability
FTIS™ Current Limitations

- Current Design can handle minimum ID of 3.862" (6th Generation will reduce this minimum)
- Requires use of couplet (water) to push FTIS™ through piping coil and couple ultrasonic transducers.
- For Mule Ear (Plugged) Headers, the use of LOTIS® technology is recommended.

LOTIS® Detectable Failure Mechanisms

- Internal Pipe/Tube Wall Loss
  - Corrosion
  - Erosion
  - Pitting
  - Mechanical Damage

- Deformation
  - Bulging (i.e. Flame Impingement)
  - Swelling (i.e. Creep Strain)
  - Denting
  - Ovality
Internal LOTIS™ System, Model - 400M

0.460" to 5.64" (11mm to 143mm) ID
Accuracy of plus/minus 0.002" (0.05mm)

Tube by Tube Analysis
Creep Damage (Flame Impingement)

LifeQuest™ Heater Overview

- Clients demanded the ability to use FTIS™ and LOTIS® data to make decisions concerning safe and reliable operations.
- What clients asked for:
  - Remaining Life Assessment within 24 hours
  - Utilization historical data
  - Compare data sets
  - Assess risk versus time to help with turn-around planning
  - In-house control over the process
Utilizes 100% of the FTIS™ or LOTIS® Data for side by side comparison with past inspections.

LifeQuest™ allows you to manually input or automatically import past Operating Conditions, Inspection Histories, and Materials Information. This is preferably done before the turn-around occurs for quick assessment.
Operating Conditions, Materials, Corrosion, and FTIS™ data is in so it is time to calculate the Deterministic Remaining Life on a foot by foot basis using API(579).

Output is in hours

The final output is a “System Risk Curve” output of Remaining Life in hours versus Probability of Failure. Acceptable level of risk is determined and additional tubes removed or T/A’s planned based on results.
Case Study #2

VACUUM HEATER

- Number of Coils / Passes = 8
- Pipe Material = 5Cr (5", 6" & 8" x Sch-80)
- Plant had modified heater convection section
- During mechanical pig cleaning process water was observed coming from Convection Section
- Plant elected to have FTIS™ Intelligent Pig inspection carried out rather than start cutting off return bends to find damage
- A FTIS™ Inspection was carried out on all 8 coils/passes (Inspection encompassed "both" Radiant and Convection sections)
- FTIS™ Intelligent Pig revealed only 8 pipe sections were damaged and localized to one end. All damage was "external"
- Plant stated that FTIS™ saved them over $1M in coil replacement cost

Case Study #2: Pigging Set-Up

Launcher/ Receivers into the convection section of the furnace

Two passes being examined at the same time

Typical Launcher / Receiver Set-up
Case Study #2: FTIS™ External Damage

2D plot showing isolated areas of EXTERNAL corrosion damage within the studded region.

Case Study #2: “External” Corrosion

Soot blowers caused damage on OD of pipe.

Note that the external studs are corroded away.

Through wall hole in pipe where water was leaking from convection section.
Case Study #2: Removed Piping

Problem was isolated to 8 tubes and they were removed from heater for repairs.

Case Study #2: Tube Repairs (\( \frac{1}{2} \) New - \( \frac{1}{2} \) Old Material)

New Pipe was welded to the Old Pipe to get heater back online.
Case Study #3

ATMOSPHERIC HEATER

- Number of Coils / Passes = 4
- Pipe Material = 347 Stainless (4", 5" & 6" x Sch-40/80)
- Plant expected some damage, however, not severe
- FTIS™ Inspection revealed substantial damage in both Radiant and Convection section of the coil
- Plant cut out sections to confirm data. When the results matched perfectly, they then elected to expand scope of work and inspect a total of three (3) heaters
- FTIS™ Data clearly showed two types of damage patterns
- Plant cut out all damaged areas above threshold and confirmed accuracy of FTIS™. FTIS™ data matched destructive testing perfectly.
- Plant is now using FTIS™ data to better understand why damage is occurring.

Case Study #3: (3D Plot) Corrosion in Radiant Section Piping

- Plant cut out coupons and confirmed FTIS™ accuracy
- Corrosion is clearly evident and localized to a few tubes
- Picture shows contour of internal corrosion damage
Case Study #3: (2D Plot) Corrosion in Radiant Section Piping

Photos show cross section views of coupons cut out by client
Notice that damage is isolated to all 4 tubes on the right.

Case Study #3: Destructive Test Results

<table>
<thead>
<tr>
<th>PIPING COIL</th>
<th>INSPECTION RESULTS CONFIRMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.) PIPE #11 - 150&quot;-200&quot; AREA</td>
<td>FTIS™ REPORT ---- 0.095- INCH</td>
</tr>
<tr>
<td></td>
<td>MANUAL UT ---- 0.095- INCH</td>
</tr>
<tr>
<td></td>
<td>DRILLED HOLE w/CALIPER ---- 0.096- INCH</td>
</tr>
<tr>
<td>PIPE# 11-   400&quot;- 450&quot; AREA</td>
<td>FTIS™ REPORT ---- 0.095- INCH</td>
</tr>
<tr>
<td></td>
<td>MANUAL UT ---- 0.110- INCH</td>
</tr>
<tr>
<td></td>
<td>DRILLED HOLE w/CALIPER ---- 0.088- INCH</td>
</tr>
<tr>
<td>2.) PIPE #28- 400&quot; AREA</td>
<td>FTIS™ REPORT ---- 0.247- INCH</td>
</tr>
<tr>
<td></td>
<td>DRILLED HOLE w/CALIPER ---- 0.249- INCH</td>
</tr>
<tr>
<td>3.) PIPE #29 - 200&quot; AREA</td>
<td>FTIS™ REPORT---- 0.185- INCH</td>
</tr>
<tr>
<td></td>
<td>DRILLED HOLE w/CALIPER ---- 0.198- INCH</td>
</tr>
</tbody>
</table>

- Thickness checks were initially performed by FTIS™
- Manual UT thickness were taken on exterior after removal
- Samples were cut out / hole drilled and measured with a micrometer - all readings were very close to the same.
- The areas showing localized thinning in the FTIS™ report have erosion areas throughout entire pipe length, with scattered deeper pitting.
Case Study #4

VACUUM FURNACE

- Number of Coils / Passes = 2
- Pipe Material = ASTM A335 - P5 (6-inch x Sch.40)
- Heater Vintage = 1976
- FTIS™ was applied to inspect both process coils.
- FTIS™ inspection results detected extensive "external" corrosion damage in the radiant.
- Visual inspection found tightly adhered scale on piping exterior surface.
- FTIS™ results were not impacted by tightly adhered scale
- Large broad areas with 56% "external" wall loss was noted.
- Plant engineers utilized FTIS™ test results to make decision for replacement of several pipe sections
Summary

- Aging infrastructures, PSM concerns, and capacity requirements are driving refiners globally to re-examine and redefine their entire inspection and reliability programs for Fired Heaters.