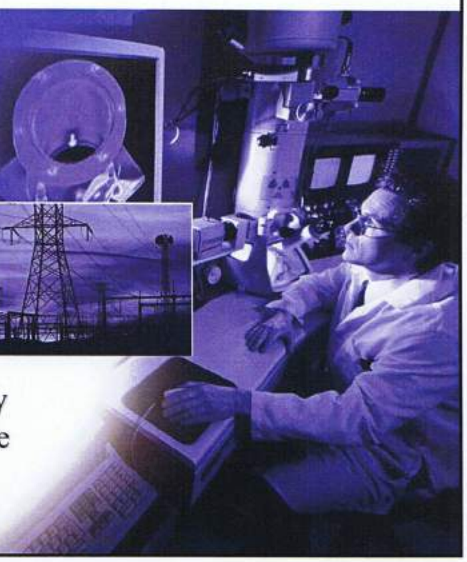
Refineries at Risk



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

QUEST RELIABILITY — Asset Longevity | Plant Performance

QUESTTRUTEC

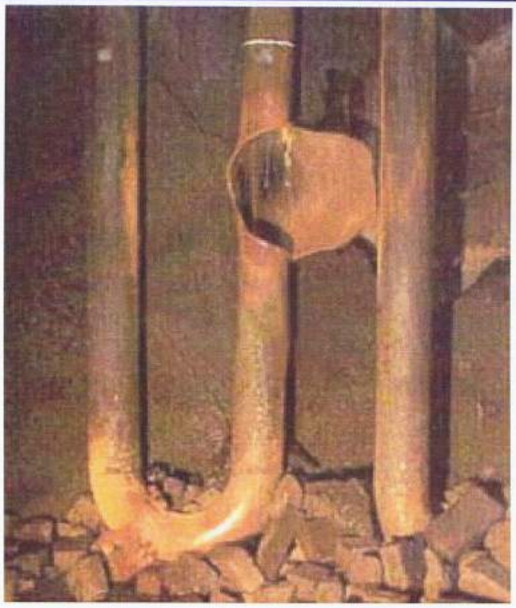
State of Refining

- 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)

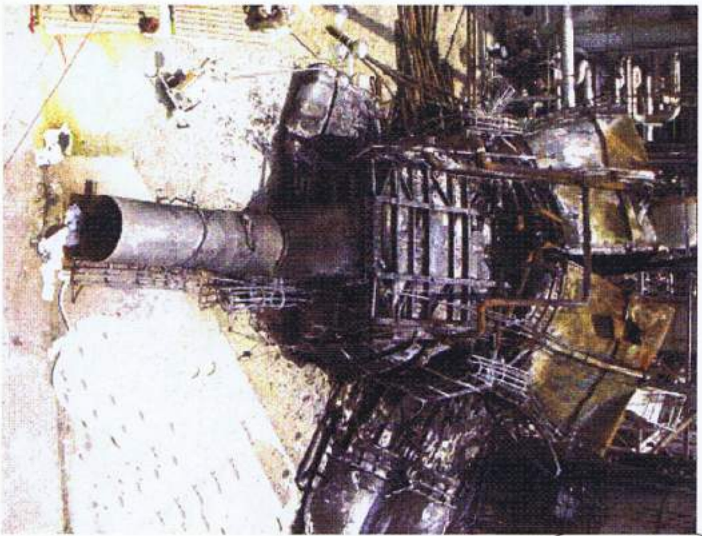
QUESTTRUTEC QUEST RELIABILITY

Catastrophic Heater Failures



QUESTTRUTEC QUEST RELIABILITY

Catastrophic Heater Failures



QUESTTRUTEC QUEST RELIABILITY

Catastrophic Heater Failures

QUESTTRUTEC QUEST RELIABILITY

Catastrophic Heater Failures

QUESTTRUTEC QUEST RELIABILITY

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.

QuestTruTec · Quest Reliability

Ongoing Heater Monitoring Program

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

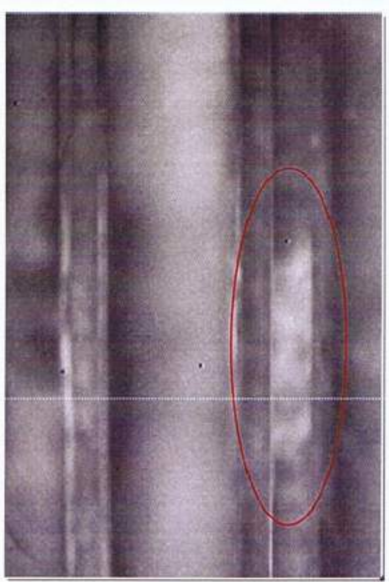
QuestTruTec · Quest Reliability

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

QuestTruTec · Quest Reliability

Why is Temperature Important?



- Controls availability
- Determines reliability
- Allows an assessment of risk

QuestTruTec · Quest Reliability

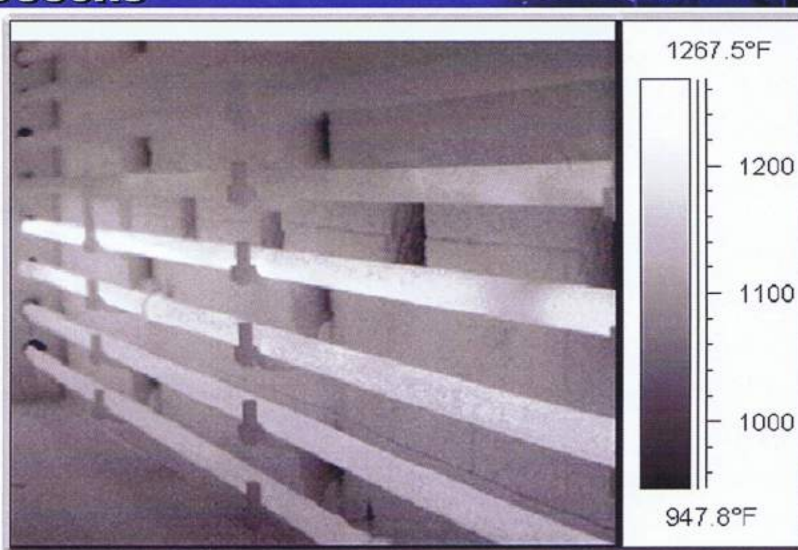
Measuring Tube Metal Temperatures

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

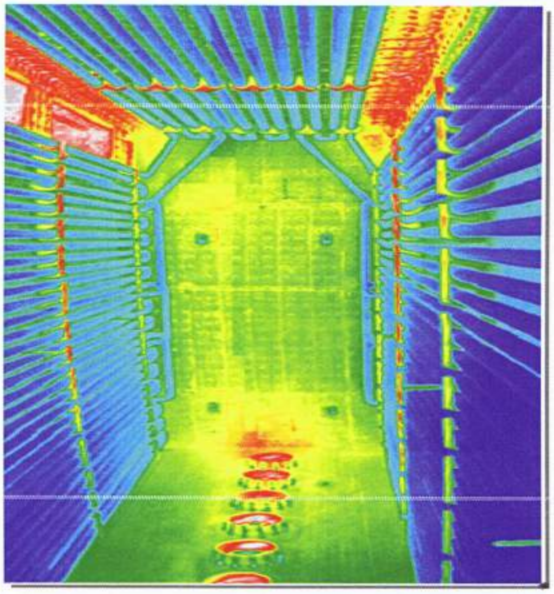
QuestTruTec QUEST RELIABILITY

Coker Charge Heater During Steam-Air Decoke



QuestTruTec QUEST RELIABILITY

Observe Heat Distribution Pattern



Crude Charge Heater

- heat distribution
- tube temperatures
- burner signature

QUESTTRUTEC QUEST RELIABILITY

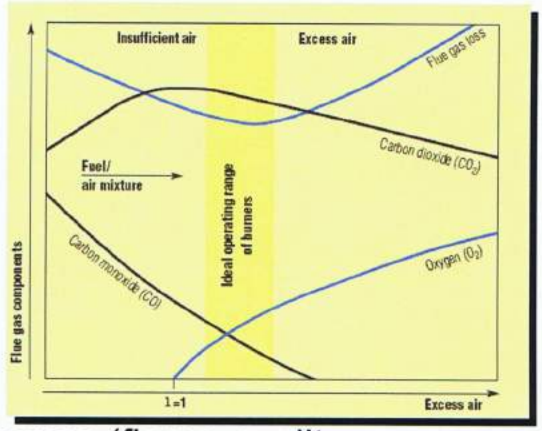
Flue Gas Analyzer

Testo 300 M Analyzer

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

QUESTTRUTEC QUEST RELIABILITY

Flue Gas Analysis



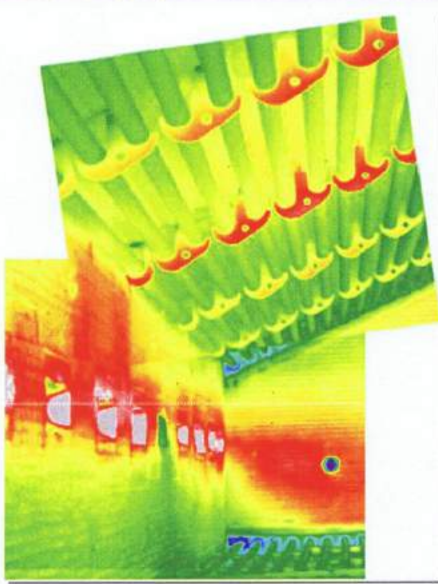
- Burner performance (flame quality, emissions)
- Heater efficiency monitoring

Routine IR/Heater Monitoring Program

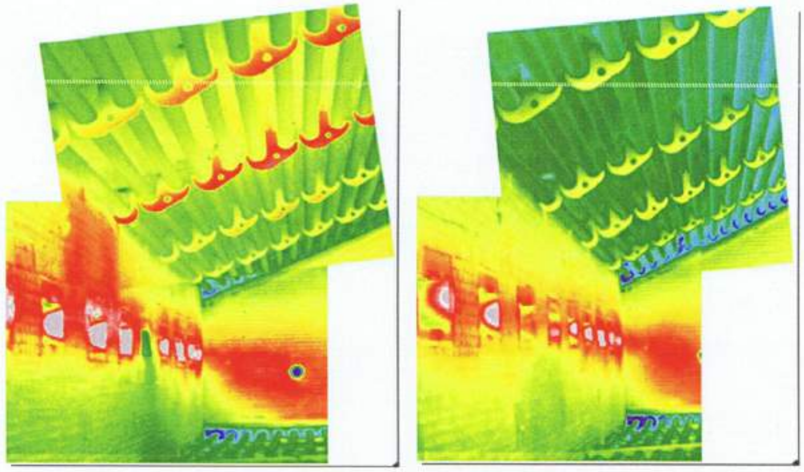
- Determine who will perform monitoring (Internal Resources/External Resources/Shared)
- Establish heater baseline performance
- Determine monitoring frequency per heater:
  - weekly, monthly, quarterly, as needed
- Data collection and analysis
- Determine action plan forward

Step 4: Detect Potential Failures

Can you identify the performance problems?



Which heater would you choose?



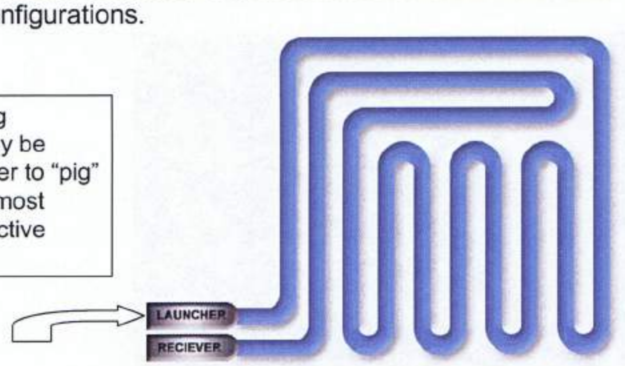
Before **After**

QUESTTRUTEC QUEST RELIABILITY

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.



QUESTTRUTEC QUEST RELIABILITY

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.)

QUESTTRUTEC QUEST RELIABILITY

Refiners Applying FTIS™ & LOTIS® Today

ConocoPhillips
Esso
ExxonMobil
Agip
Marathon Oil Corporation
bp
CITGO
Saudi Aramco
PETRO-CANADA
Shell
VALERO ENERGY CORPORATION
Chevron
TEXACO
SK Corporation
CHS
Syncrude
Securing Canada's Energy Future
ChevronTexaco
Orion
REFINING CORPORATION
COASTAL
SUNCOR ENERGY
elpaso
Nerefco
CO-OP
FLINT HILLS RESOURCES

QUESTTRUTEC QUEST RELIABILITY

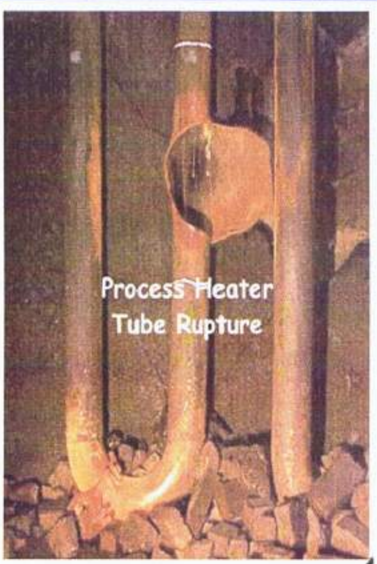
Applications

- **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" ◊ 5" ◊ 6" ◊ 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

QuestTruTec QUEST RELIABILITY

FTIS™ Detectable Failure Mechanisms

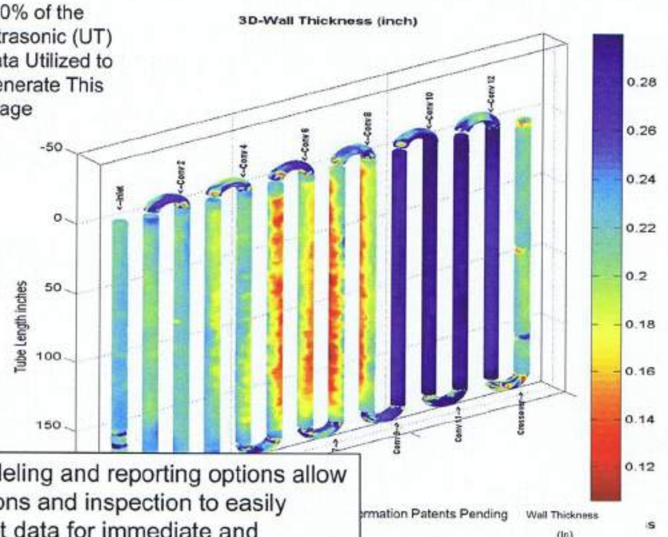


- Pipe/Tube Wall Loss
  - Corrosion *(Int. or Ext.)*
  - Erosion *(Int. or Ext.)*
  - Pitting *(Int. or Ext.)*
  - Mechanical Damage *(Int. or Ext.)*
- Deformation
  - Bulging *(i.e. Flame Impingement)*
  - Swelling *(i.e. Creep Strain)*
  - Denting
  - Ovality

QuestTruTec QUEST RELIABILITY

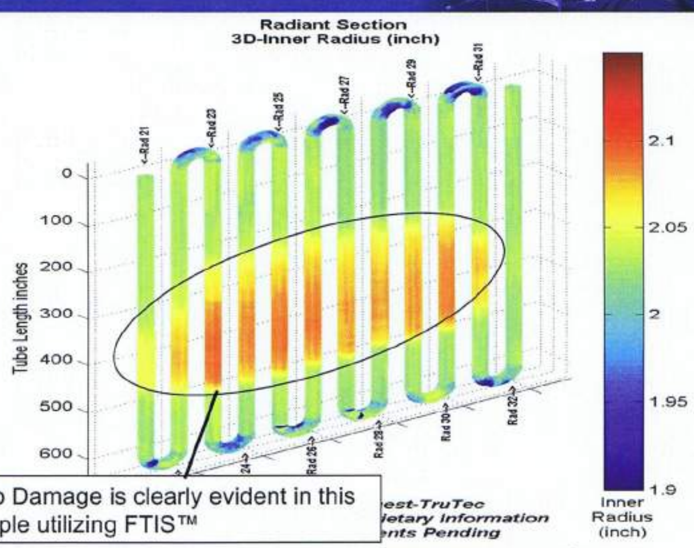
3D Modeling of FULL Serpentine Coil

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



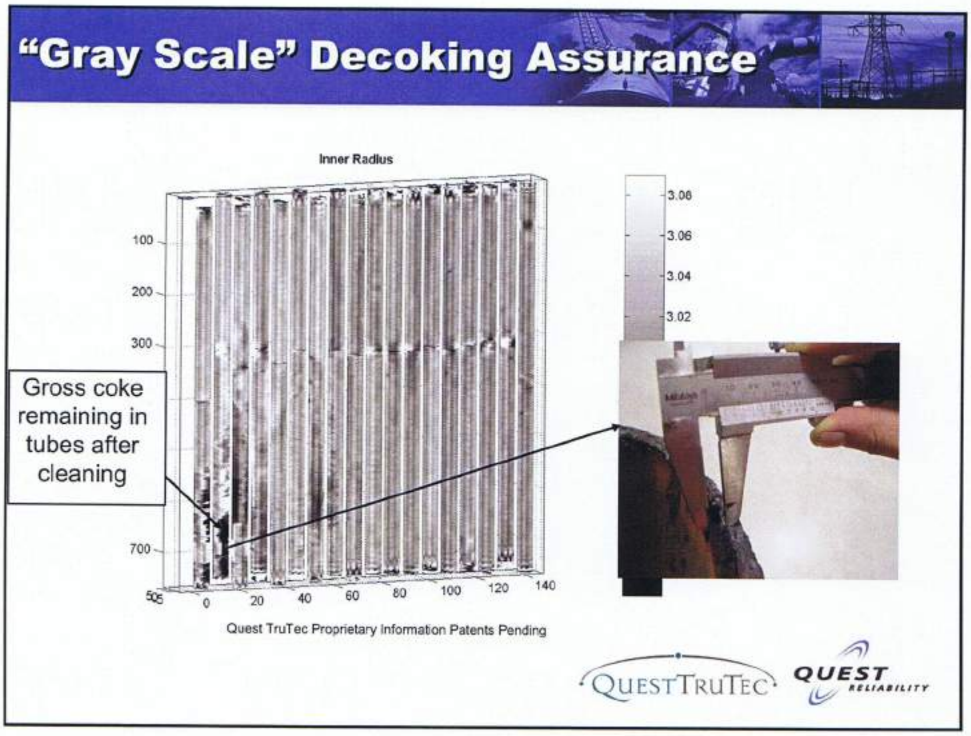
3D modeling and reporting options allow operations and inspection to easily interpret data for immediate and accurate corrective actions

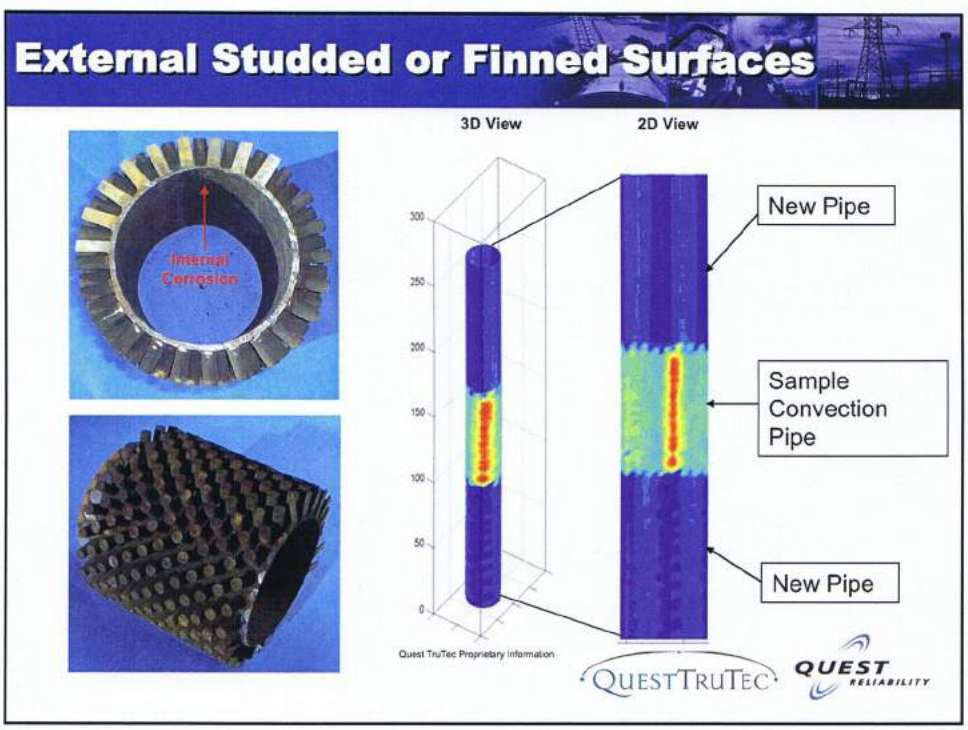
3D Modeling of FULL Serpentine Coil



Creep Damage is clearly evident in this example utilizing FTIS™

QUEST TRUTEC · QUEST RELIABILITY


"Gray Scale" Decoking Assurance
Inner Radius
100
200
300
700
505
0
20
40
60
80
100
120
140
3.08
3.06
3.04
3.02
Gross coke remaining in tubes after cleaning
Quest TruTec Proprietary Information Patents Pending
QUESTTRUTEC
QUEST RELIABILITY

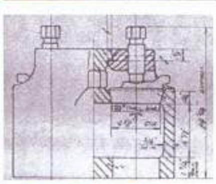

External Studded or Finned Surfaces
Internal Corrosion
3D View
2D View
300
250
200
150
100
50
0
New Pipe
Sample Convection Pipe
New Pipe
Quest TruTec Proprietary Information
QUESTTRUTEC
QUEST RELIABILITY

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.

QUESTTRUTEC QUEST RELIABILITY

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

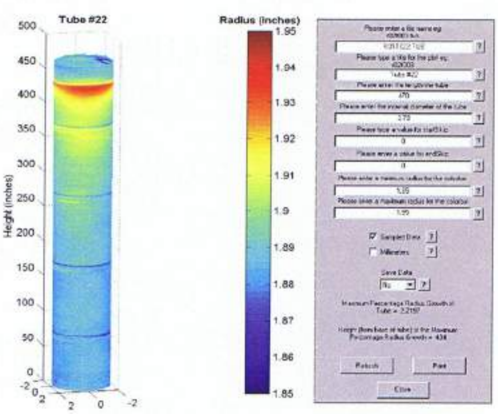
QUESTTRUTEC QUEST RELIABILITY

Internal LOTIS™ System, Model - 400M

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

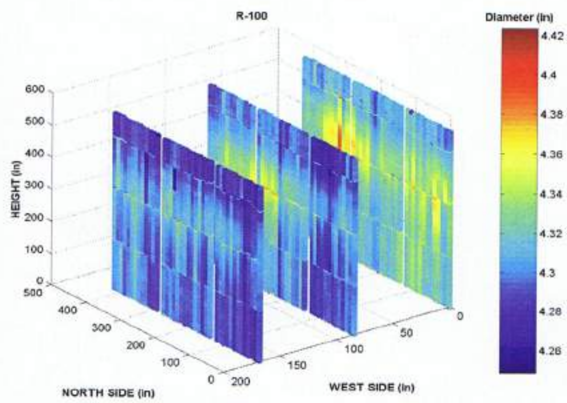
QUESTTRUTEC QUEST RELIABILITY

Tube by Tube Analysis



QUESTTRUTEC QUEST RELIABILITY

Creep Damage (Flame Impingement)

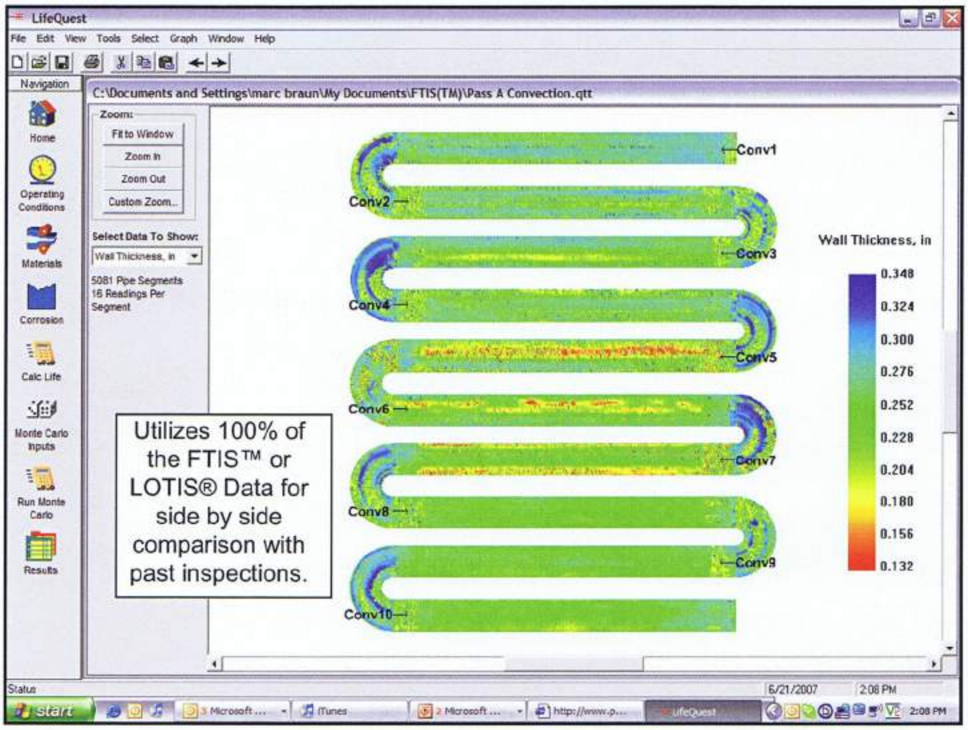


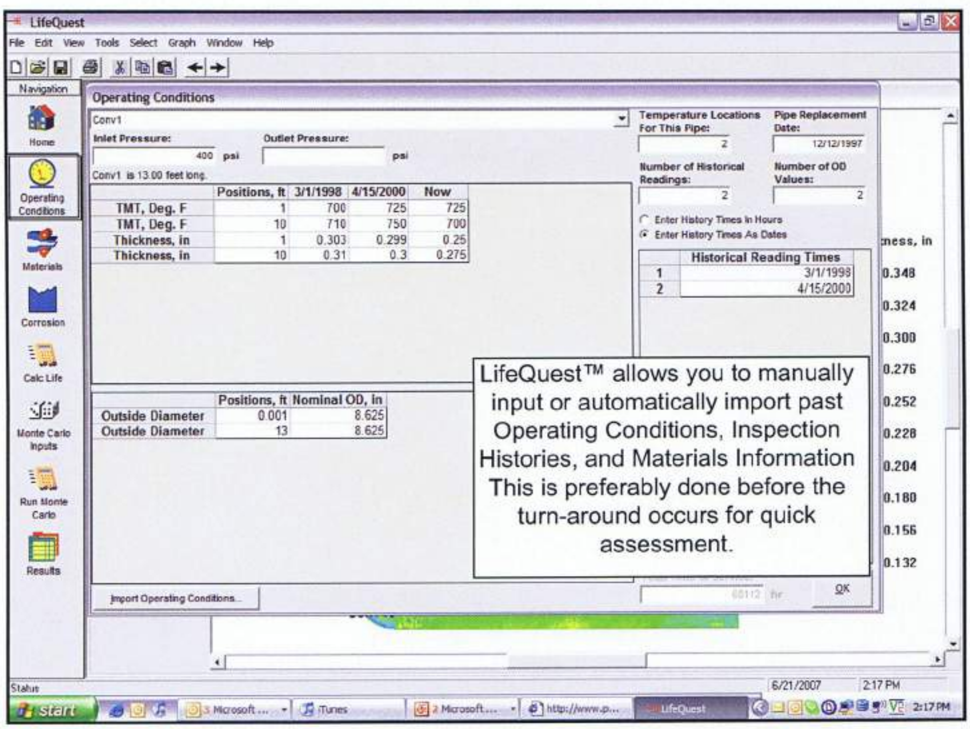
QUESTTRUTEC QUEST RELIABILITY

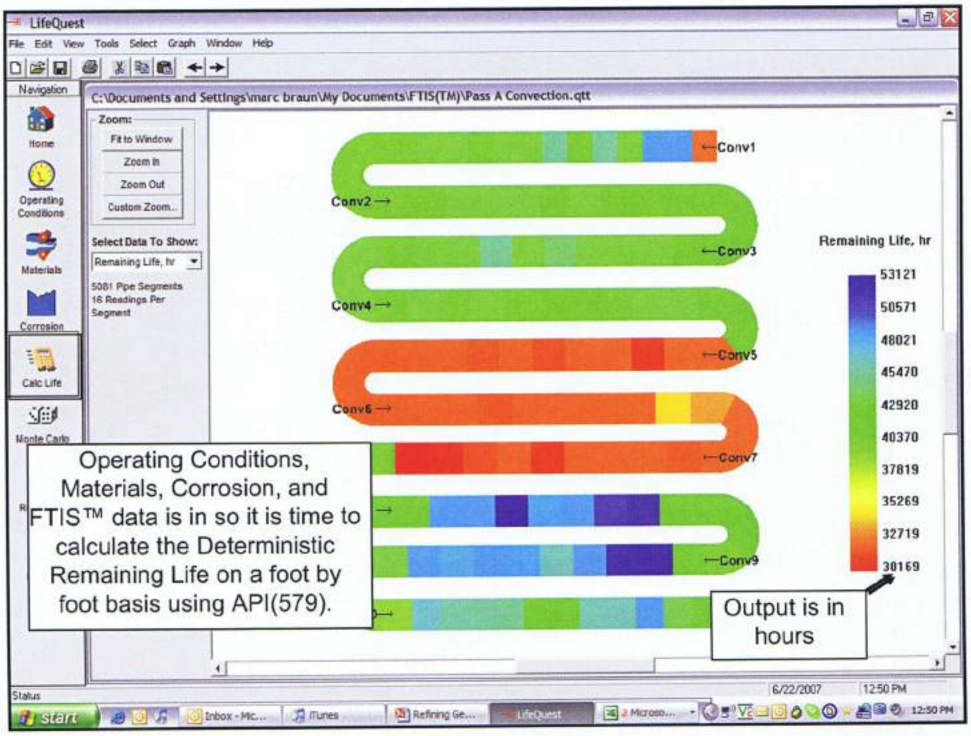
LifeQuest™ Heater Overview

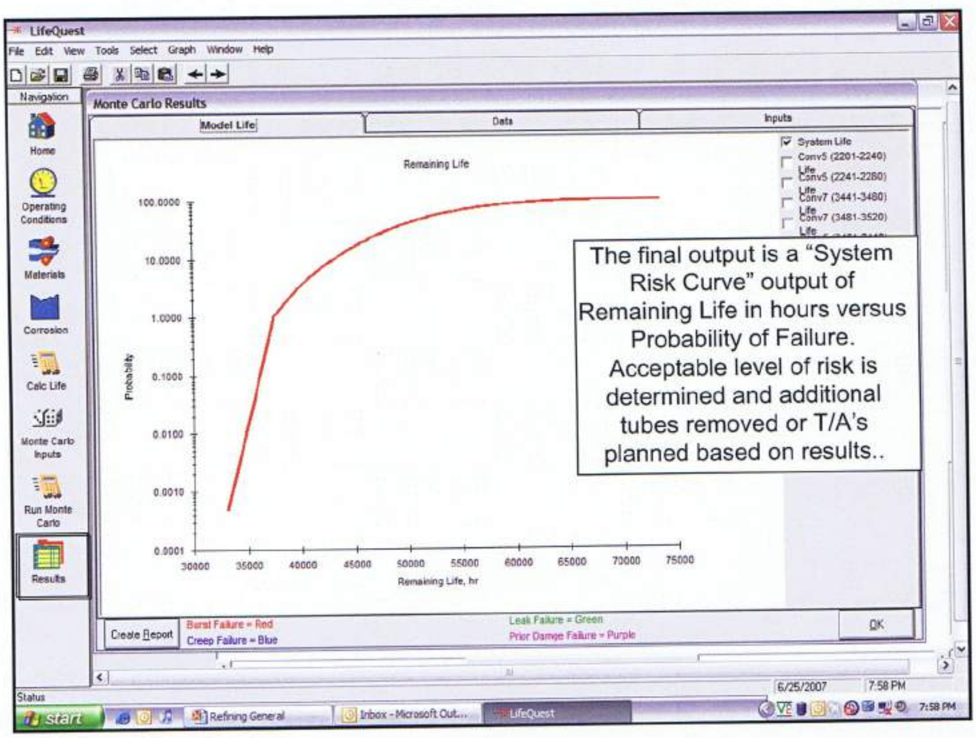
- Clients demanded the ability to use FTIS™ and LOTIS® data to make decisions concerning safe and reliable operations.
- What clients asked for:
  - Remaining Life Assessment within 24 hours
  - Utilization historical data
  - Compare data sets
  - Assess risk versus time to help with turn-around planning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

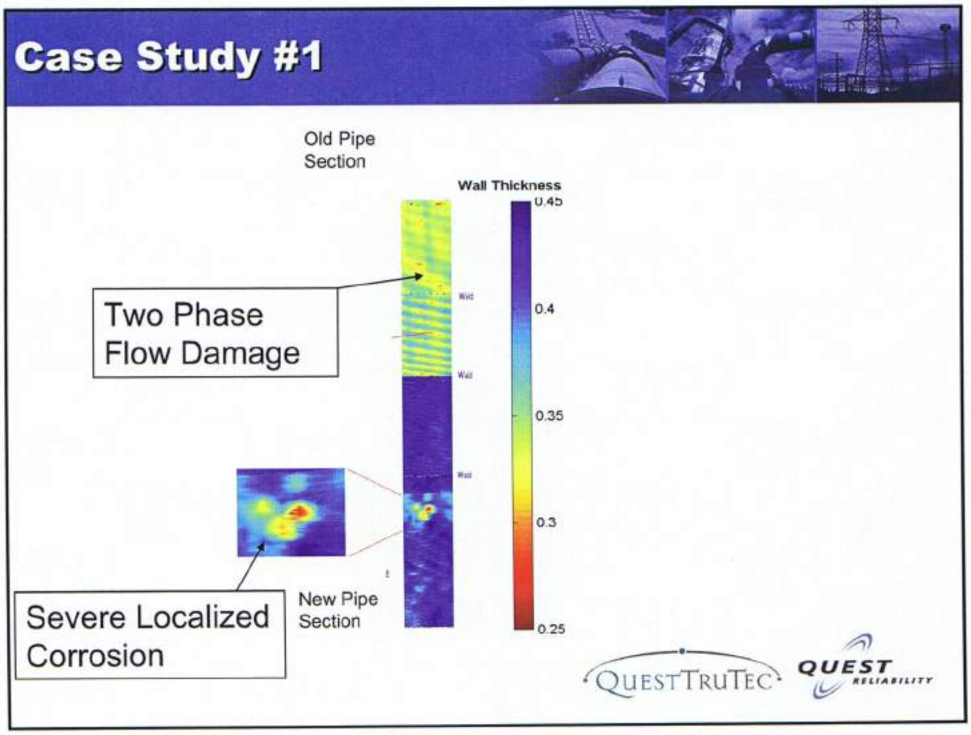
QUESTTRUTEC QUEST RELIABILITY

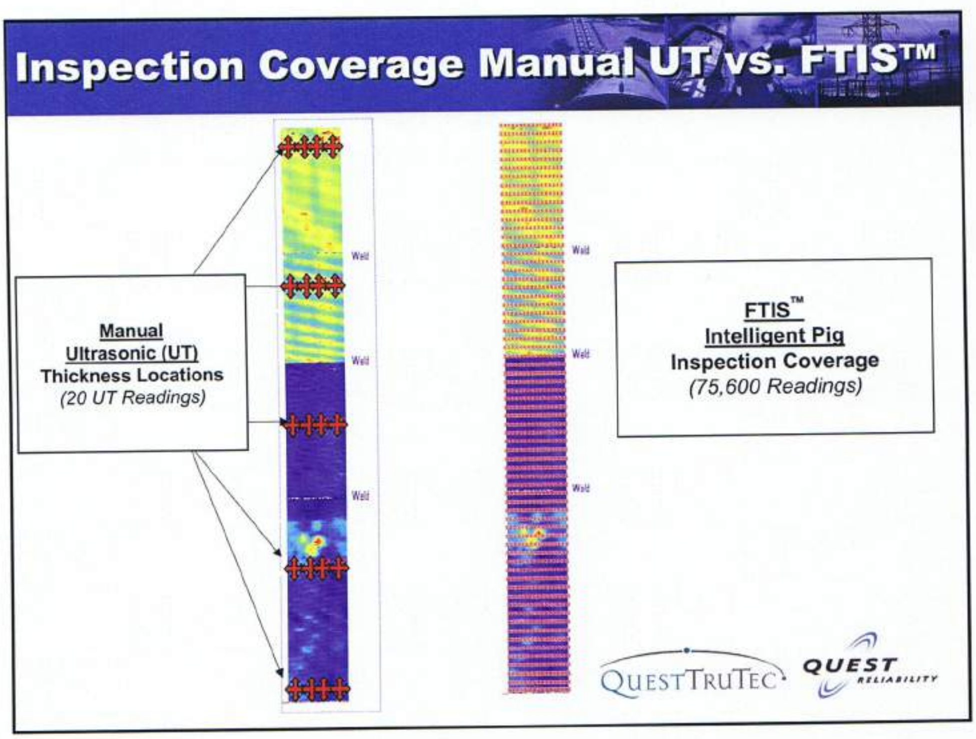

LifeQuest
File Edit View Tools Select Graph Window Help
Navigation
C:\Documents and Settings\marc braun\My Documents\FTIS(TM)\Pass A Convection.qtt
Zoom:
Fit to Window
Zoom In
Zoom Out
Custom Zoom...
Select Data To Show:
Wall Thickness, in
5081 Pipe Segments
16 Readings Per Segment
Home
Operating Conditions
Materials
Corrosion
Calc Life
Monte Carlo Inputs
Run Monte Carlo
Results
Conv1
Conv2
Conv3
Conv4
Conv5
Conv6
Conv7
Conv8
Conv9
Conv10
Wall Thickness, in
0.348
0.324
0.300
0.276
0.252
0.228
0.204
0.180
0.156
0.132
Utilizes 100% of the FTIS™ or LOTIS® Data for side by side comparison with past inspections.
Status
6/21/2007
2:08 PM


LifeQuest
File Edit View Tools Select Graph Window Help
Navigation
Operating Conditions
Conv1
Inlet Pressure:
400 psi
Outlet Pressure:
psi
Conv1 is 13.00 feet long.
Positions, ft 3/1/1998 4/15/2000 Now
TMT, Deg. F 1 700 725 725
TMT, Deg. F 10 710 750 700
Thickness, in 1 0.303 0.299 0.25
Thickness, in 10 0.31 0.3 0.275
Positions, ft Nominal OD, in
Outside Diameter 0.001 8.625
Outside Diameter 13 8.625
Import Operating Conditions...
Temperature Locations For This Pipe: 2
Pipe Replacement Date: 12/12/1997
Number of Historical Readings: 2
Number of OD Values: 2
Enter History Times in Hours
Enter History Times As Dates
Historical Reading Times
1 3/1/1998
2 4/15/2000
OK
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.
Status
6/21/2007
2:17 PM


LifeQuest
File Edit View Tools Select Graph Window Help
Navigation
C:\Documents and Settings\marc braun\My Documents\FTIS(TM)\Pass A Convection.qtt
Zoom:
Fit to Window
Zoom In
Zoom Out
Custom Zoom...
Select Data To Show:
Remaining Life, hr
5081 Pipe Segments
16 Readings Per Segment
Home
Operating Conditions
Materials
Corrosion
Calc Life
Monte Carlo
Conv1
Conv2
Conv3
Conv4
Conv5
Conv6
Conv7
Conv9
Remaining Life, hr
53121
50571
48021
45470
42920
40370
37819
35269
32719
30169
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
Status
6/22/2007
12:50 PM


LifeQuest
File Edit View Tools Select Graph Window Help
Navigation
Monte Carlo Results
Model Life
Data
Inputs
System Life
Remaining Life
100.0000
10.0000
1.0000
0.1000
0.0100
0.0010
0.0001
Probability
30000
35000
40000
45000
50000
55000
60000
65000
70000
75000
Remaining Life, hr
Home
Operating Conditions
Materials
Corrosion
Calc Life
Monte Carlo Inputs
Run Monte Carlo
Results
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..
Create Report
Burst Failure = Red
Creep Failure = Blue
Leak Failure = Green
Prior Damge Failure = Purple
OK
Status
6/25/2007
7:58 PM


Case Study #1
Old Pipe Section
Wall Thickness
0.45
0.4
0.35
0.3
0.25
Two Phase Flow Damage
Severe Localized Corrosion
New Pipe Section
QUESTTRUTEC
QUEST RELIABILITY


Inspection Coverage Manual UT vs. FTIS™
Manual Ultrasonic (UT) Thickness Locations
(20 UT Readings)
FTIS™ Intelligent Pig Inspection Coverage
(75,600 Readings)
QUESTTRUTEC
QUEST RELIABILITY

Case Study #2

VACUUM HEATER

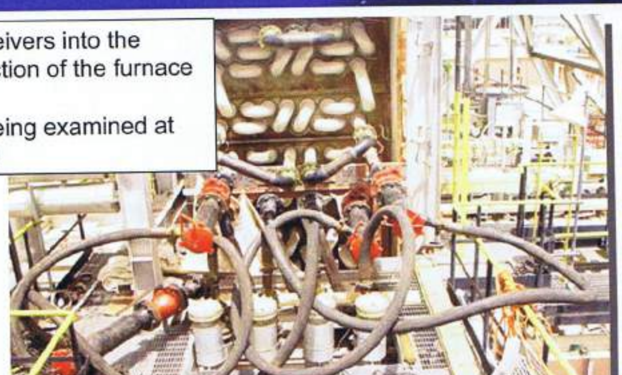
- Number of Coils / Passes = 8
- Pipe Material = 5Cr (5", 6" & 8" x Sch-80)
- Plant had modified heater convection section
- During mechanical pig cleaning process **water** was observed coming from Convection Section
- Plant elected to have FTIS™ Intelligent Pig inspection carried out rather than start 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

QUESTTRUTEC QUEST RELIABILITY

Case Study #2: Pigging Set-Up

Launcher/Receivers into the convection section of the furnace

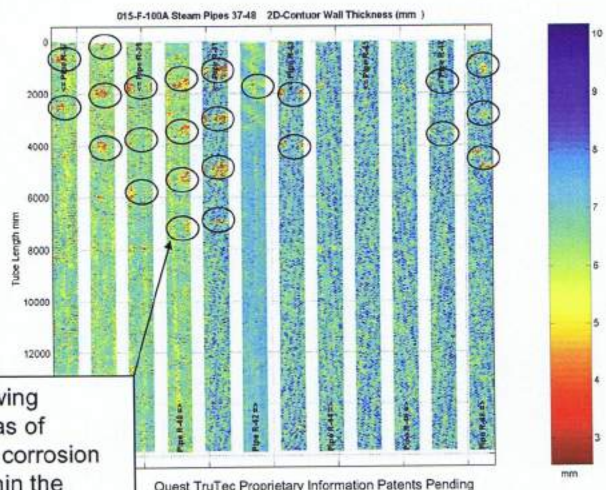
Two passes being examined at the same time



Typical Launcher / Receiver Set-up

QUESTTRUTEC QUEST RELIABILITY

Case Study #2: FTIS™ External Damage

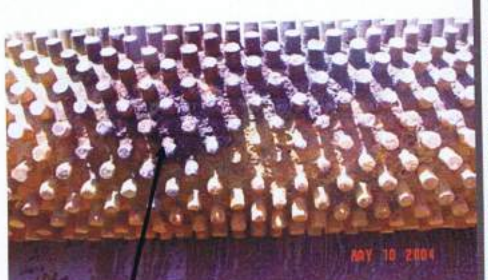


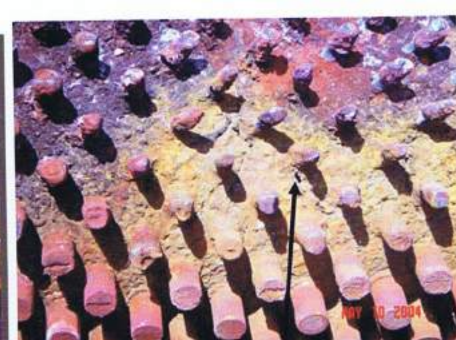
2D plot showing isolated areas of EXTERNAL corrosion damage within the studded region

Quest TruTec Proprietary Information Patents Pending

QUESTTRUTEC · QUEST RELIABILITY

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

QUESTTRUTEC · QUEST RELIABILITY

Case Study #2: Removed Piping

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

QUESTTRUTEC QUEST RELIABILITY

Case Study #2: Tube Repairs (½ New – ½ Old Material)

New Pipe was welded to the Old Pipe to get heater back online

QUESTTRUTEC QUEST RELIABILITY

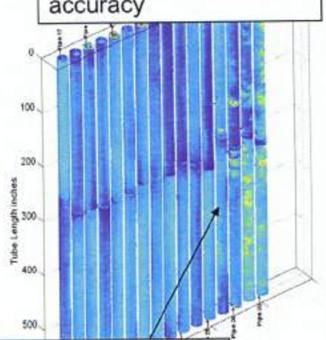
Case Study #3

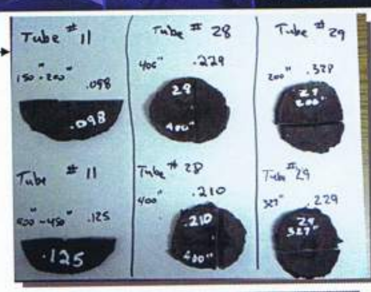
ATMOSPHERIC HEATER

- Number of Coils / Passes = 4
- Pipe Material = 347Stainless (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

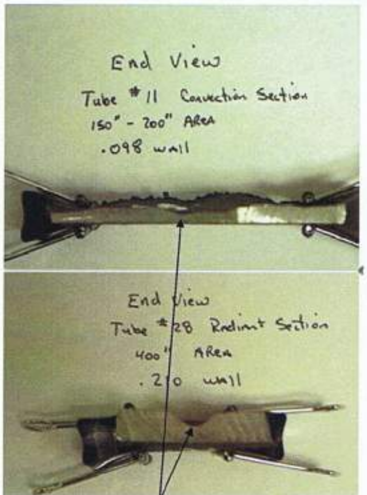


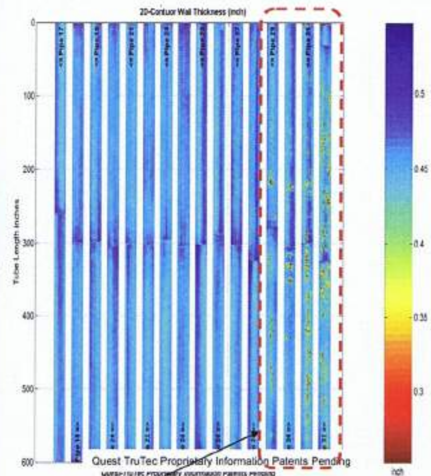


Corrosion is clearly evident and localized to a few tubes

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.

QUESTTRUTEC QUEST RELIABILITY

Case Study #3: Destructive Test Results

PIPING COIL
INSPECTION RESULTS CONFIRMATION

1.) PIPE # 11 - 150"-200"AREA ----	**FTIS™ REPORT ----**	**0.095- INCH**
	MANUAL UT ----	**0.095- INCH**
	DRILLED HOLE w/CALIPER –	**0.098- INCH**
PIPE# 11- 400"- 450" AREA----	**FTIS™ REPORT ----**	**0.095- INCH**
	MANUAL UT ----	**0.110- INCH**
	DRILLED HOLE w/CALIPER --	**0.098- INCH**
2.) PIPE # 28- 400" AREA ----	**FTIS™ REPORT ----**	**0.247- INCH**
	DRILLED HOLE w/CALIPER --	**0.248- INCH**
3.) PIPE # 29 - 200" AREA ----	**FTIS™ REPORT---**	**0.185- INCH**
	DRILLED HOLE w/CALIPER -	**0.188- INCH**

- **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.**

QUESTTRUTEC QUEST RELIABILITY

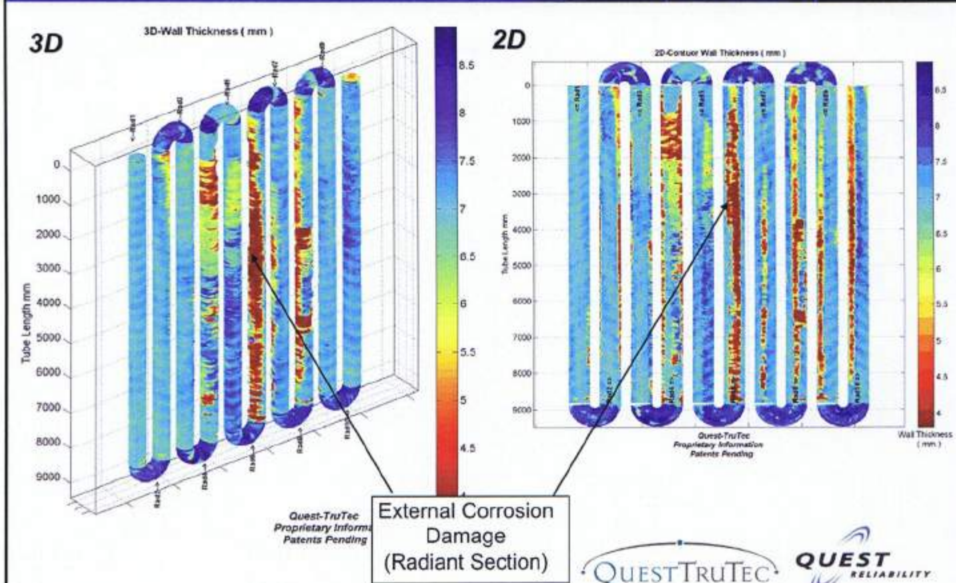
Case Study #4

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

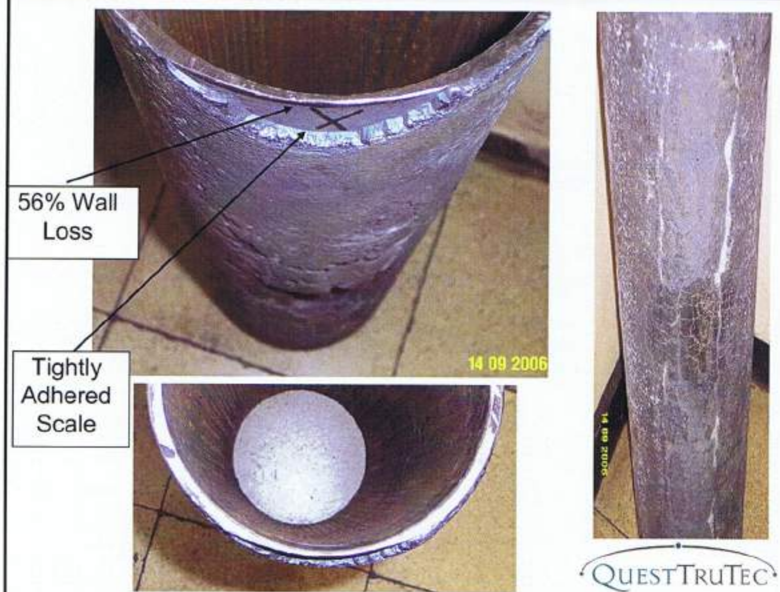
QUESTTRUTEC QUEST RELIABILITY

Case Study #4 Radiant Section Corrosion



QUESTTRUTEC QUEST RELIABILITY

Case Study #4

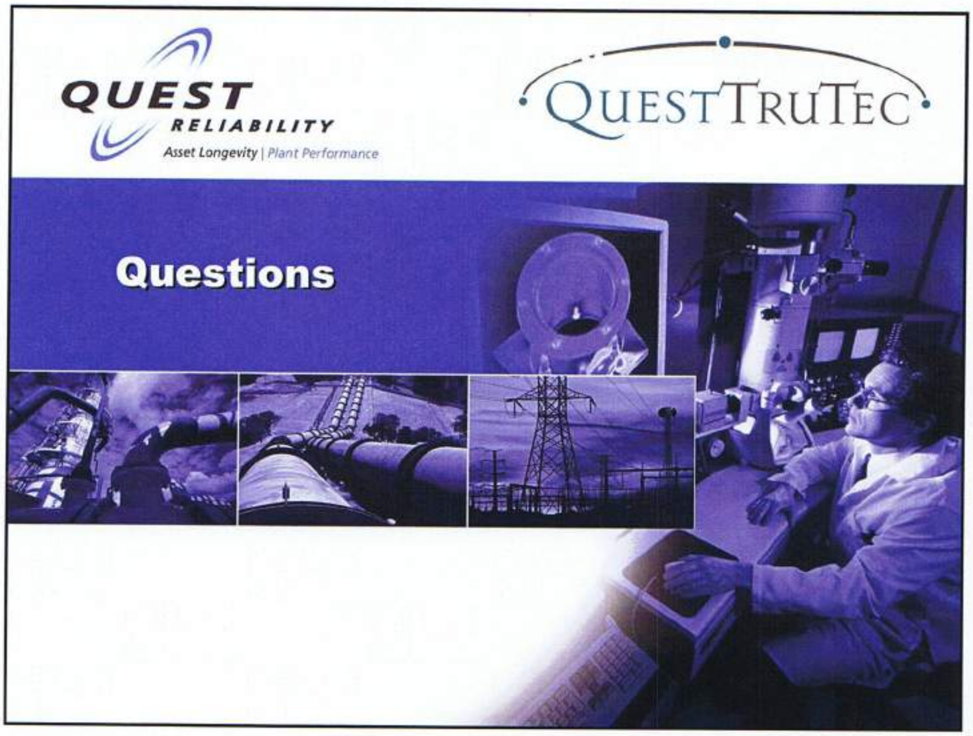


QUESTTRUTEC QUEST RELIABILITY

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.

QUESTTRUTEC QUEST RELIABILITY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