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# INCREASED RELIABILITY / REDUCED RISK BY APPLYING INTELLIGENT PIGGING TECHNOLOGY TO INSPECT COILS IN PROCESS HEATERS

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## Abstract

Reliable "intelligent pig technology" is now readily available to the refining industry which can provide quick/comprehensive inspection to both "convection" and "radiant" sections in process furnace piping coils. Both tabular data formats along with two-dimensional / three-dimensional high-resolution color graphics of the test results are immediately produced on site showing tube/pipe wall thinning, bulging, swelling, and ovality.

## Introduction

Furnace coils in petroleum and chemical plants present a significant challenge for the Non-Destructive Evaluation (NDE) inspector when applying conventional Non-Destructive Testing (NDT) methods. The coil's significant length (occasionally 5,000' [+1,524m] per coil), extended surfaces (i.e. studs, fins), multiple short radius (one-dimensional) 180° return bends, and difficult access make furnace coils extremely difficult to inspect when applying conventional NDT methods. Development of remotely operated, autonomous inspection tools (intelligent pigs), were developed which allows the inspection to be carried out in both the convection section and radiant sections without the need to access the furnace box. During a typical operation, the intelligent pig is transported through the interior of the serpentine piping coil via a column of water, which provides propulsion and coupling for the ultrasonic transducers. The inspection data is processed and stored on board the intelligent pig, applying high-speed digital signal processing to enable instantaneous results upon retrieval of the intelligent pig from the furnace coil. At the conclusion of an inspection run, the field engineer immediately downloads the data from the intelligent pig to a laptop computer providing immediate access to both visual and quantitative results. Features such as internal or external corrosion, erosion, pitting, bulging, swelling, and other deformation are easily located, quantified, and reported. Custom software provides the ability to view the entire coil in both two-dimensional and three-dimensional graphics. Over the last ten years, intelligent pigging has significantly improved both the quality of inspection data and overall safety in the operation of refinery furnaces.

## Market Demands for Intelligent Pigging Technology for Process Heater Coil Inspections

Typical conventional inspection practices utilized by refiners in the past to inspect furnace coil piping are very time consuming and costly. The total cost of lost production, scaffold erection, gaining pipe access, and inspection labor varies widely. Furnace down times of 2-7 days can also be expected

when carrying out an inspection utilizing conventional inspection practices. Additionally, these procedures only provide "limited" inspection coverage and/or nonquantitative test results.

Conventional NDE inspections typically carried out on furnace piping coils consist of manually collected ultrasonic thickness (UT) readings at given increments (i.e., 2', 4', 6' [0.6m, 1.22m, 1.82m]) along the pipe and at four 90° intervals around the circumference (i.e. top, fire side, bottom, and refractory side), if access permits. The general strategy is to return to these "exact" locations each year, assuming the inspector can find the same spot. In addition, the sparse amount of data collected is then applied to calculate very crude corrosion rates. However, in most cases, ultrasonic inspection from the piping exterior can only be performed in the radiant portion of the pipe. In the convection section, where extended surfaces in the form of studs or fins are attached, the "external" ultrasonic contact method cannot be applied due to lack of access to the pipe's surface. At best, this results in only limited inspection of a typical furnace piping coil.

Less frequently, a furnace coil inspection will be complemented with radiography (X-ray). X-ray inspection could provide 100% coil coverage in the radiant section; however, if this option were selected it would be economically cost prohibitive and timely. X-ray results will only provide qualitative information, which is also limiting. Like current manual ultrasonic methods, X-ray inspection is labor intensive and requires direct access to the exterior of the heater piping coil.

The development goal of the FTIS™ intelligent pig was to develop a tool capable of rapid in situ measurement of an entire furnace piping coil, without entering the heater, and in only a few minutes per coil. Today a typical FTIS™ coil inspection takes under 30 minutes to collect the inspection data in both the convection and radiant sections. This has significantly reduced the cost and time associated with periodic furnace coil inspections.

## Theory of Operation

The FTIS™ technology relies on proprietary designed ultrasonic (UT) technology to acquire wall thickness, diametrical dimensions, and shape information throughout the furnace piping coil. The UT module houses dozens of ultrasonic transducers to transmit ultra-high frequency acoustic energy into the water between the intelligent pig housing and the inner surface of the piping. The flush water serves as the couplant between the transducer and the piping wall. Upon arrival at the piping wall, a portion of the pulse energy reflects back towards the transducer while a fraction of the pulse energy propagates onto the steel pipe wall. At the outer pipe surface a similar reflection occurs, sending energy back in the direction of the inner wall and UT transducer. Onboard high-speed digital signal processing of the returned echoes determines the time of flight in the piping wall. Time of flight is then used to compute the piping wall thickness, diametrical, and shape dimensions based on the known acoustic propagation properties of the water and piping material.

## FTIS™ Intelligent Pig System Description

The FTIS™ intelligent pig was developed to detect and measure wall thickness and changes in internal/external diameter dimensions caused by pitting, corrosion, bulging, swelling, and general deformation. The FTIS™ intelligent pig is comprised of multiple modules (see Figure 1), and is

propelled with water throughout the length of a furnace piping coil. The use of custom ultrasonic sensor technologies combined with a powerful graphical data analysis package results in high-resolution, digital, quantitative inspection data for the entire piping coil. Data can be obtained in a matter of minutes after being collected without removing return bends or entering the furnace firebox. Today's designs are capable of inspecting coils with nominal diameter dimensions between 4" and 8" (101.6mm and 203.2mm), Schedule 40 - 80. Other smaller size designs are currently under development. Future designs are expected to have inspection capabilities in piping with diameters between 2.5"-8.0", and should negotiate most Mule Ear (Plugged Header) returns.

The modules shown in Figure 1 provide specific functionality to the system. The ultrasonic sensor modules contain the primary sensor components as described previously. This module has an adjacent processor module that contains a dedicated high-speed digital signal-processing unit, which

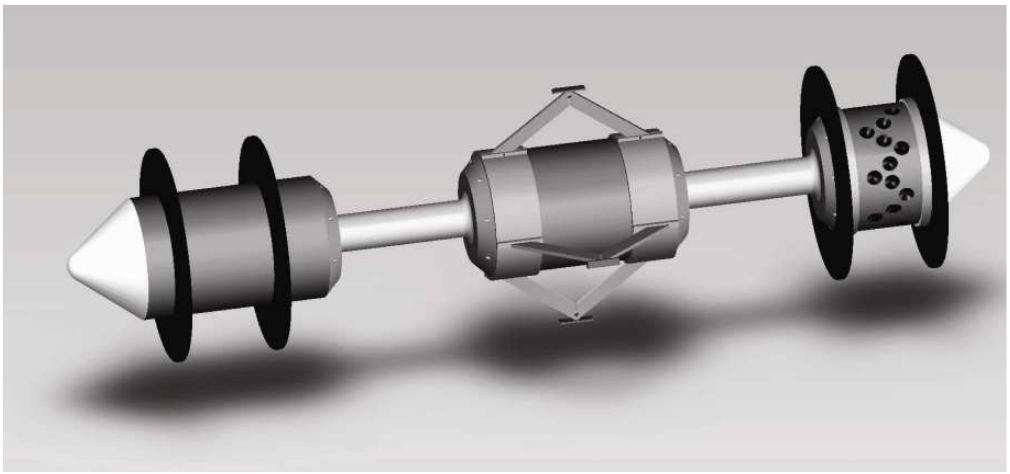

**Figure 1. FTIS Intelligent Pig**

digitizes, preprocesses, and stores the recorded measurements in nonvolatile memory. The processor module currently can store inspection data with up to +5,400' (1,646m) of pipe length. Longer pipe lengths (i.e. pipelines) can be inspected by simply programming the FTIS™ with a start up delay and running several tools right behind one another. An additional module records axial position via two independent encoder wheels that track the inner pipe surface and record the linear travel of the intelligent pig. System power is provided by a final battery module. The modules are connected using custom flexible connectors to allow the intelligent pig to navigate the close radius bends found in furnace systems. The durable inter-module connectors provide robust mechanical linkage allowing data and positioning signals to pass between the individual modules. One very important feature of the FTIS™ intelligent pig is that it does not have an umbilical cord or tether following behind it which potentially could break, causing unreliability in the inspection.

The FTIS™ intelligent pig operates autonomously and is propelled through the furnace with ordinary water. This typically takes place immediately after a mechanical decoking has been carried out. In order to minimize cost and redundancy, Quest TruTec works with several qualified mechanical pig decoking companies globally. The mechanical pigging contractor provides the necessary launcher/receiver, pumps, hoses, and trained pump operators. If the furnace consists of a header-type manifold at the inlet or outlet, custom launching and receiving systems are applied to render the furnace piggable.

The FTIS™ intelligent pig is designed to negotiate short radius one-diameter (one-dimensional) return bends or larger traveling at a speed of 1-2' (0.30-0.61m)/second, which enables a typical coil inspection to be completed in about 10-15 minutes. Once a scan has been completed and the intelligent pig is retrieved from the receiver, the intelligent pig is connected via USB to the laptop computer to recharge the battery and download the recorded measurement data. Software running on the laptop computer is utilized to download and archive the recorded inspection data.

## Data Analysis

Once the inspection data is downloaded to the laptop computer, the custom application software can be used to process and view the inspection results in several graphical formats (i.e. two-dimensional, three-dimensional, etc.). The software is a robust Windows™-based application that takes full advantage of the Windows graphical user interface capabilities. The software automatically identifies the return bends and breaks the coil down into segments allowing easy pinpoint flaw location when deep into the coil.

The two-dimensional coil layout graphic (See Figure 2) enables the data analyst to view the "entire coil" on one page. The coil is presented in a rolled out format which provides a 360° view of the pipe's circumference as if it was shaped like a flat plate instead of a round tube. This ensures that no flaws are left undetected. In the Figure 2 plot it is quite easy to identify an entire portion of the furnace coil which is experiencing wall thickness loss.

The two-dimensional coil layout graphic also allows the data analyst to zoom in on specific flaws, if necessary. As Figure 4 demonstrates, small features such as isolated pitting can be easily identified and quantified with this type of high resolution graphic data capability.

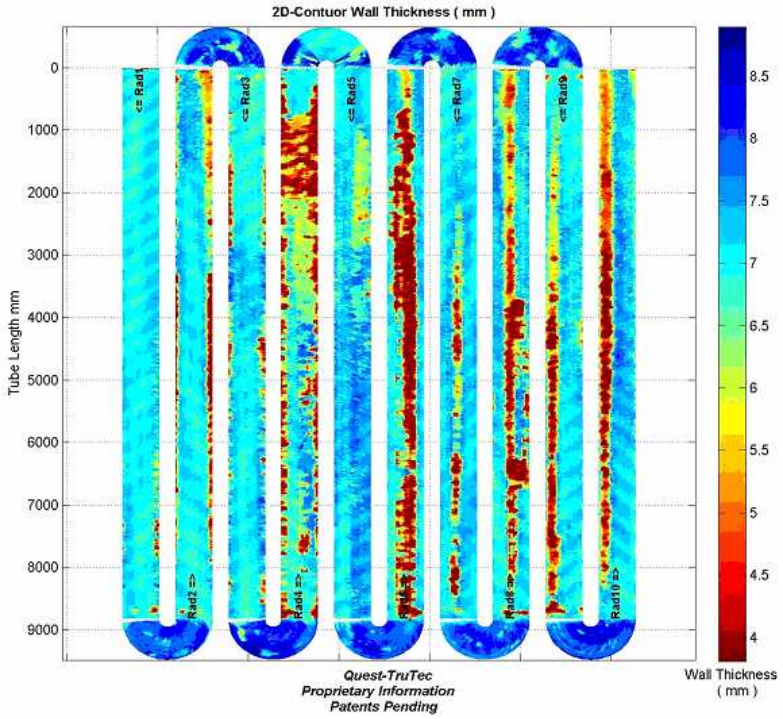


**Figure 2. Two-Dimensional Coil Layout**

The three-dimensional coil layout graphic (see Figure 3) enables the data analyst to take the two-dimensional graphics and roll them back into their original cylindrical shape. This furthers the ability to graphically present overall patterns of damage occurring in the furnace, which allows plant engineers to make sound engineering decisions on modifications to the operation or mechanics of the heater.

## Inspection Report

The custom FTIS™ intelligent pig data analysis software package was designed such that it can provide almost instant results when the furnace inspection is completed. Immediate access to inspection results regarding the condition of the furnace is extremely important when the plant is relying upon this type of detailed information to make "on the fly" repairs or design modifications during the narrow window of a plant turn-a-round.

## Conclusion

Inspection services carried out with the FTIS™ intelligent pig technology are key to a complete and comprehensive inspection data collection process. Inspections can be completed quickly, minimizing furnace down time. Preliminary results can be available within minutes after the data is downloaded from the intelligent pig, enabling engineers to make real-time decisions concerning the return of the furnace to service.

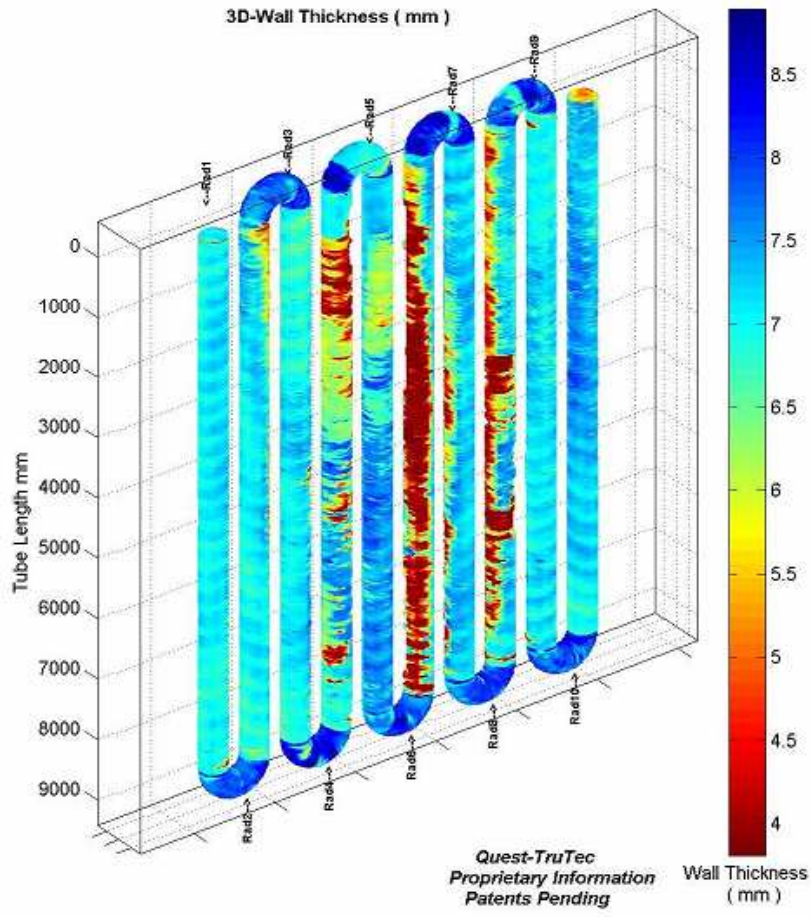


**Figure 3. Three-Dimensional View of Partial Radiant Coil**

Utilization of this system will enable refineries to determine corrosion rates more accurately than ever before. The data are easily archived for direct comparison with future inspection data. Accurate corrosion rate information is expected to improve extended run time, which translates into increased plant throughput, efficiency, and reliability.

The major benefit to the refinery is increased production because the down time associated with current inspection methods is greatly reduced. Additionally, FTIS™ does not require the erection of scaffolding, entry into the heater box, or removal of return bends, saving significant time and cost. The service only requires a single entry point into the furnace, a single exit point from the loop, and an available supply of water.

## Case Studies

### *Case Study #1*

### CRUDE HEATER

- Number of Coils / Passes = 12.
- Pipe Material = 9Cr – MO (A335-P9) (6” x Sch-80).
- Plant had several sections in which partial sections of piping coil had been replaced with new material.
- Plant Engineers did not expect any damage in new coil sections; however, they were concerned with older coil sections.
- Manual Ultrasonic inspection had not found any damage in previous year’s inspections (inspection limited to “only” Radiant section).
- A FTIS™ Inspection was carried out on all 12 coils/passes (inspection encompassed “both” Radiant and Convection sections).
- FTIS™ data showed severe corrosion damage in “both” new and old coil sections (see Figure 4).
- Plant now has reconsidered use of conventional NDE inspection methods.

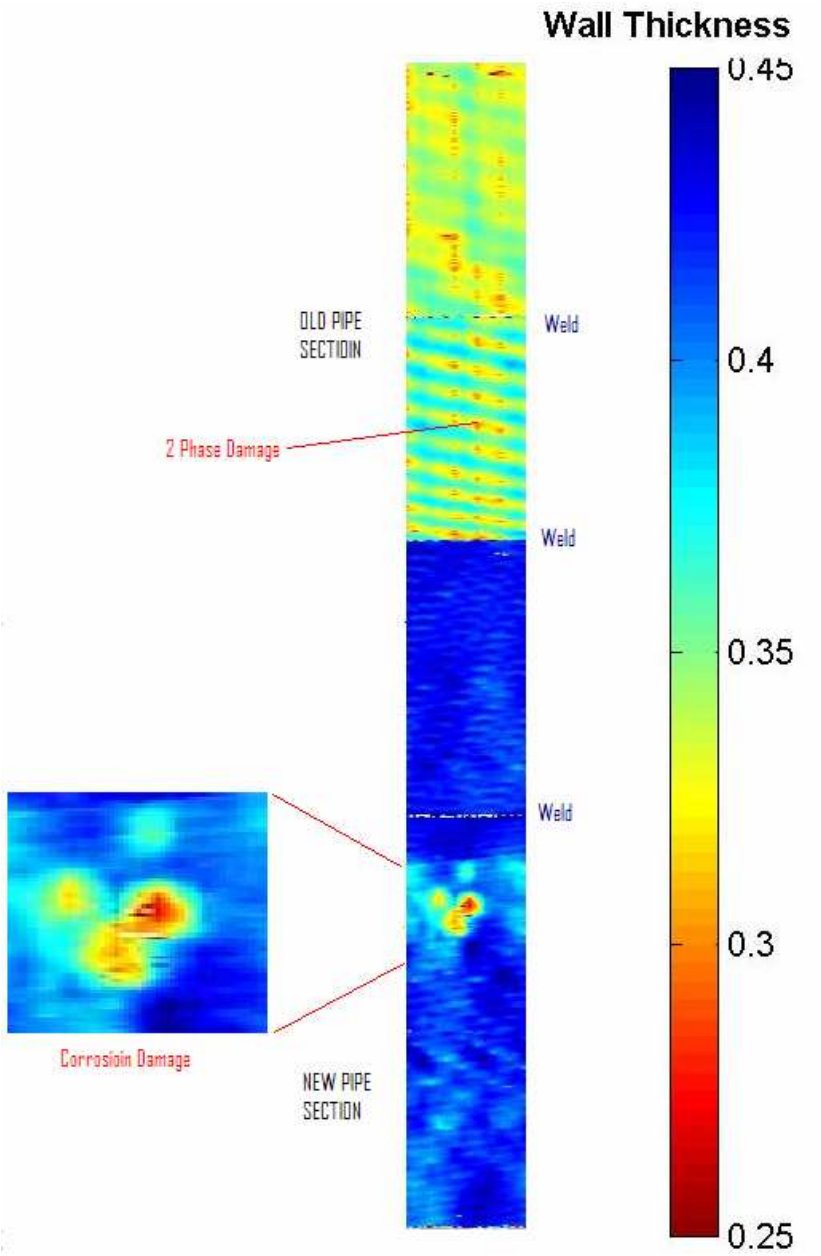


**Figure 4. FTIS Inspection Results**

*Case Study #2*

**VACUUM HEATER**

- Number of Coils / Passes = 8.
- Pipe Material = 5Cr (5”, 6”, and 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 (see Figure 5). All damage was “external”. Plant stated that FTIS™ saved them over one million dollars in coil replacement costs.

**Additional Case Studies Available at**
**www.questtrutec.com**

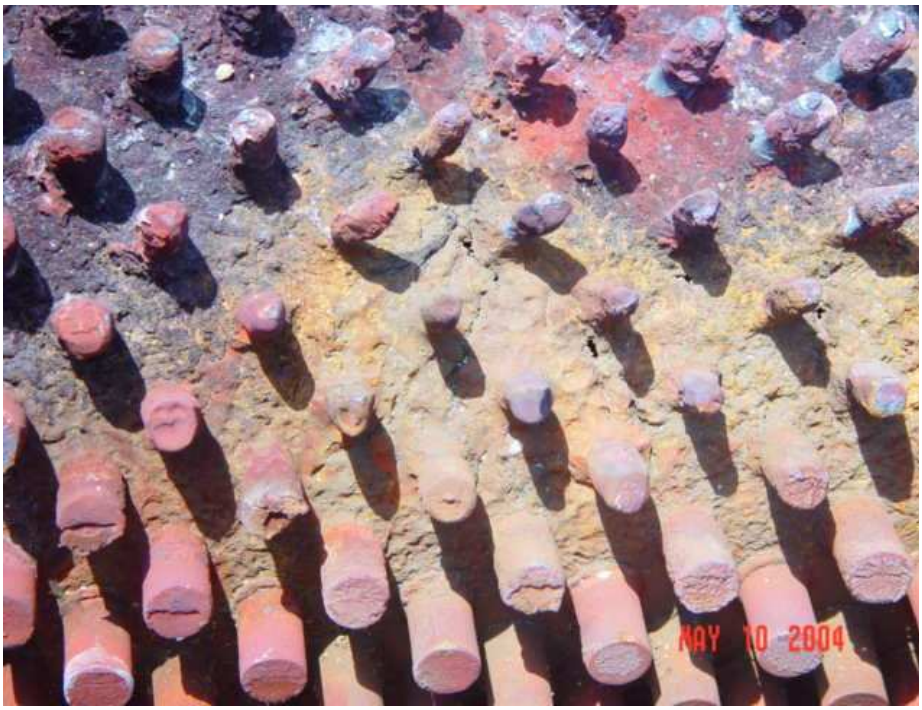


**Figure 5. Convection Pipe With External Corrosion**