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Recent Technological Advances in Ultrasonic-Based Intelligent Pig Technology for Fired Heater Coils

Advancements Provide Refinery and Chemical Plant Operators with an Option for Obtaining High Quality Inspection Data in 3" Fired Heater Coils

By Richard D. Roberts
Quest Integrity Group, LLC

E-mail questions or comments to tij@gte.net

INTRODUCTION

For years refinery and chemical plant operators have utilized ultrasonic-based intelligent pig technology to inspect coils in convection and radiant sections of fired heaters. This proven technology provides accurate inspection data which allows reliability engineers to make critical decisions about the operation and maintenance of fired heaters. Recent advances have increased the capabilities of these tools and extended these benefits to coker heaters containing 3" (76.2mm) nominal piping size and plug headers with radial inserts.

HISTORY

Accurately assessing the condition of fired heater coils has proven challenging due to several factors. Conventional Non-Destructive Testing (NDT) methods, such as manual ultrasonics (UT), are ineffective in accurately assessing 100% of the internal condition of fired heater coils. The process is further complicated by coil lengths in excess of 1,524m (5,000'), raised surfaces such as studs and fins, multiple short radius 1D x 180° return bends, and inaccessibility.

Remotely operated autonomous internal inspection tools, commonly referred to as intelligent pigs, were developed well over a decade ago to resolve these challenges. This innovative technology enables complete inspection in the convection and radiant sections without the need to access the furnace box. The use of UT based intelligent pigs has significantly improved inspection data quality and coverage area. This innovative inspection practice has also significantly reduced safety risks attributable to refinery fired heaters.

THE TECHNOLOGY

During a typical operation, the intelligent pig is transported through the interior of the serpentine piping coil via a column of liquid (i.e. water, diesel, glycol, etc.), which provides both propulsion and coupling for the ultrasonic transducers. The inspection data is stored electronically in onboard memory as the un-tethered intelligent pig rapidly travels through the piping coil. At the conclusion of an inspection run, the data is immediately downloaded onto a laptop computer via USB cable. This provides immediate access to high resolution graphical images and quantitative test results. Anomalies such as internal or external corrosion, erosion, pitting, bulging, swelling, and other deformation are easily located and quantified. Custom software provides the ability to view the entire coil in both two-dimensional (2D) and three-dimensional (3D) graphics.

MARKET DEMAND

Conventional inspection practices previously utilized by refiners to determine condition assessment of furnace coil piping have proven time-consuming and costly, while providing only minimal inspection coverage. The combined cost of lost production, scaffold erection, inaccessibility, piping surface preparation, and inspection labor quality varies widely. Furnace down times of two to seven days can be expected when conducting a typical coil inspection utilizing manual inspection practices. Additionally, these practices provide limited inspection coverage and/or non-quantitative test results.

Conventional NDT inspection methods for furnace piping coils consist of manually collecting UT spot readings at given increments (i.e., 0.6m, 1.22m, 1.82m [2', 4', 6'], respectively) along the piping coil, typically at four 90° intervals around the circumference (i.e. top, fire side, bottom, and refractory side), if access permits. In most cases, the convection section of fired heater coils is not inspected due to complete inaccessibility. On the rare occasion when the convection section of the coil is accessible, raised surfaces such as fins and studs prohibit the application of any external surface NDT inspection technique. The typical strategy for bare surfaced accessible piping requires the Non-Destructive Evaluation (NDE) technician to return to these exact locations year after year to gather comparison data. Repeatedly identifying these exact locations is difficult, inaccurate, and inefficient. The sparse amount of thickness data collected is then applied to insufficiently calculate corrosion rates, which the plant reliability engineers rely upon to make critical decisions involving current piping condition and remnant life.
Although radiography (RT) inspection of furnace coils can theoretically provide full inspection coverage in the radiant section, this approach would be cost prohibitive and time-consuming. RT results are also limiting in that they provide only qualitative test results. Much like manual UT inspection methods, the application of RT is labor intensive and requires direct access to the exterior of the heater piping coil. Therefore most convection sections would not be a candidate for inspection using this approach.

These challenges led to the development of FIIST™, a robust intelligent pig capable of 100% in-situ inspection of the entire furnace piping coil, without entering the heater, and in only a few minutes per coil. This advanced inspection methodology captures as many as 48 ultrasonic ¼” diameter data points circumferentially on 76mm (3”) diameter piping and up to 168 ultrasonic ¼” diameter data points circumferentially on 305mm (12”) diameter piping, with overlapping inspection coverage of greater than 100% of the entire surface. Today a typical coil inspection requires less than thirty minutes, collecting the inspection data in both the convection and radiant sections. This has significantly reduced the cost and time associated with periodic furnace coil inspections, while dramatically increasing data quality and accuracy.

**INSPECTION DATA DISPLAY**

This inspection technology utilizes proprietary, specially-designed UT sensors and electronic controls to rapidly acquire remaining wall thickness, diametrical dimensions, and shape data throughout the entire furnace coil length. The UT module houses between 48 and 168 individual UT transducers which transmit ultra-high frequency (MHz) acoustic energy into the liquid medium (i.e. water, diesel, glycol, etc.) between the intelligent pig housing and the inner surface of the piping coil. The UT sensors capture coil integrity data utilizing a 6mm x 6mm (¼” x ¼”) footprint, which enables very small flaws (6mm²) to be detected and quantified. The ultrasonic sensors are electronically pulsed at high sampling rates to ensure 100% axial data collection densities. The liquid medium propels the intelligent pig through the coil while providing a couplant between the ultrasonic transducer and the piping wall.

The intelligent pig is comprised of multiple modules and is designed to negotiate multiple short radius 180° 1D return bends while traveling at speeds between 0.30m to 0.61m per second (12" to 24" per second).

Custom software processes and displays the inspection results in two-dimensional (2D) and three-dimensional (3D) graphical formats (see Figures 1 and 2, respectively). The software recognizes and displays return bends and breaks the coil down into individual pipe segments, allowing for easy identification of flaw location. This is particularly important when flaws are located deep within the coil’s length.

The 2D coil layout graphic (see Figure 1) 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 1 plot it is easy to identify an entire portion of the furnace coil which is experiencing wall thickness loss.

The 2D coil layout graphic also allows the data analyst to zoom in on specific flaws as necessary. As Figure 1 demonstrates, small features such as isolated pitting can be easily identified and quantified.

The 3D coil layout graphic (see Figure 2) enables the data analyst to take the 2D graphics and roll them back into their original cylindrical shape. This further enhances the ability to graphically present overall patterns of damage occurring in the furnace, which allows plant engineers to make sound and timely engineering decisions on modifications to the operation or mechanics of the heater.

**Figure 1.** Two-Dimensional (2D) Coil Data Layout

**Figure 2.** Three-Dimensional (3D) Coil Data Layout
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TECHNOLOGY ADVANCEMENTS

Coker heaters are particularly vulnerable to the fouling mechanisms and anomalies detected with this inspection methodology. This is due to more aggressive operating parameters, which push coker heaters to run harder and at higher temperatures. On a positive note, coker heaters are brought down more frequently for maintenance and cleaning than other types of heaters. This affords refinery and plant managers with valuable opportunities to both clean the coils and perform FTIS™ inspections in order to gather comparison data. This is especially critical for coker heaters as they are often considered the workhorse heaters within a refinery. It is therefore important and advantageous to have available an abundance of high quality data in order to make timely decisions about the operation and maintenance of these critical assets.

Prior to late-2008, the market was unable to overcome a major challenge – navigating intelligent pigs through plug headers. Globally, many heaters are outfitted with these cast fittings mounted at the ends of serpentine pipeline coils. Also called mule ear returns (see example in Figure 3), these fittings are either welded or rolled onto the end of two parallel pipe segments in order to create one continuous coil. The original intent of this fitting was to allow access into the heater coil in the event it was to become plugged with coke buildup. The plugs within the cast header could be moved to facilitate the use of high pressure water jet, necessary to remove a portion of the hardened coke, enabling flow of either steam or mechanical decoking pigs.

The interior of the original plug header fittings was squared off, thereby resembling a rectangular box on the interior. Intelligent pigs were often destroyed during data collection because they were unable to negotiate the square interior profiles of the fittings. Heater manufacturers commonly install radial or contoured plugs instead of the flat plugs within new heater designs. Older designs can have these contoured plugs installed as an after-market item. Once the contoured plugs are installed the intelligent pigs are then able to navigate the fitting, thus inspect the adjacent coil.

This is particularly important because many coker heaters still contain plug headers. Couple this with small furnace coil diameters between 3” (76.2mm) and 4” (101.6mm) and one can begin to understand the need for an inspection methodology for these unique heaters.

In recent months, Quest Integrity Group has successfully completed intelligent pig inspections of coker heaters containing 3” (76.2mm) nominal diameter piping and plug headers with radial inserts. The introduction of this smaller tool to the market, and its ability to easily negotiate plug headers with radial inserts (see Figure 4), now provides inspection options as well as data quality and quantity never before available to coker unit inspectors and engineers.

REMAINING LIFE ASSESSMENT

It is possible to import 100% of the data to perform Fitness for Service (FFS) and Remaining Life Assessment (RLA) calculations in accordance with the most widely used national standard, API-579 with this program. This information provides refinery and plant managers with the confidence necessary to make critical operating decisions regarding asset repairs or extending run times.

CASE STUDY #1

A refiner requested UT intelligent pig inspection of a four-pass fired heater radiant section with 3” (76.2mm) nominal pipe size. The piping material was carbon steel 2.25Cr-1Mo (SA 200 T22). The inspection consisted of forty sections of pipe, each 24.6 feet in length (7.5m). The refinery at some point modified the heater coils by adding external thermocouples at the upper studded-to-bare surface transition. The top section of piping contained raised studs. Refinery management was interested in detecting and quantifying coke buildup on the inner diameter of the coils in the studded-to-bare transition area. The inspection data clearly identified the thermocouples and previously removed studs.
CASE STUDY #2

A major refiner requested UT intelligent pig coil inspection in one of its crude furnaces. Both the radiant and convection section coils were inspected. General wall thinning caused by internal erosion/corrosion was detected throughout. The material of the convection and radiant coil sections was fabricated with A-106B / A-335-P9 and A-335-P9, respectively. The diameter of the coil was 6” nominal piping size. The piping has been in service since 1994 and was identified as Schedule 40. The coils contained plug headers with radial inserts which the intelligent pig successfully navigated. One of the pipe segments contained an area with 32% wall loss (see Figure 5). Refinery personnel indicated this coil had never been inspected due to the challenge presented by the plug headers.

CONCLUSION

Intelligent pig technology is key to a complete and comprehensive inspection data collection process. Recent technological advancements provide greater capability to refinery and chemical plant engineers, particularly those working in coker units. 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.

Utilization of this system enables plant engineers to determine corrosion rates more accurately than ever before. The data is easily archived for direct comparison with future inspection data. Accurate corrosion rate information can improve run times, which results in increased plant throughput, efficiency, and reliability, as well as decreased risk of unplanned shutdowns and safety risks.

REFERENCES


2. API-573 (2003) Inspection of Fired Heaters and Boilers, Washington DC USA


Figure 5. 3D view of data gathered during Case Study #2.