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A SMART APPROACH TO INSPECTING FIRED HEATER AND BOILER COILS

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INTRODUCTION

What keeps you up at night? If you are responsible for the integrity of fired heater or boiler coils, it may be an unexpected failure.

Matching the proper inspection techniques to detect specific types of damage of an asset is a critical component for achieving long-term reliability and performance. Universally, smart or intelligent pigging is now a standard practice for the inspection of fired heater and serpentine boiler coils. Its growth in popularity and industry acceptance as a superior method for the inspection of coils prompted the addition of smart pigging into API Recommended Practice (RP) 573, Inspection of Fired Boilers and Heaters, in 2013. The growth in popularity also led to a surge in the number of smart pigging companies in the market, creating additional complexities for asset owners when aligning tool capabilities with inspection needs.

In API RP 573, verification of a provider's intelligent pig operating range is strongly recommended prior to selection, as capabilities may vary among the companies offering this service.

The tool's measurement grid, also known as ultrasonic testing (UT) sample spacing, and the minimum detectable wall thickness should be the main capabilities verified to ensure the various types of damage mechanisms commonly found in fired heater and boiler coils are detectable (see **Figure 1**).

In addition, the tool's probability of detection (POD) capability, which is established by the service provider, should be confirmed. POD is derived from a tool's UT transducer resolution and measurement grid and can be described as the ability to confidently detect a defect based on a minimum defect size. This is usually expressed using a confidence level: for example, a 90% probability of detection of wall loss ½" width x ½" length or larger. In this example, a tool will detect and accurately size a localized area of wall loss that is ½" x ½" or larger nine out of ten times. This provides asset owners with some assurances that a defect, such as localized wall loss, will be detected and quantified with a high degree of confidence.

Since POD is such an important metric for gauging performance acceptability, it is worth taking some time to elaborate on two elements that affect POD: UT transducer resolution and measurement grid density. The UT transducer resolution is the diameter of the UT beam that is projected onto the tube surface and is commonly referred to as the UT "footprint." The diameter of the footprint is governed by the diameter of the transducer and other factors such as transducer frequency and standoff. The measurement grid is the center-to-center spacing between UT readings. If the spacing equals the diameter of the transducer footprint, the resolution and measurement grid are the same. However, if there are gaps between readings, the measurement grid is larger than the transducer footprint, thus effectively reducing detection capabilities. The transducer footprint along with the number of transducers and tool speed establishes the measurement grid or UT sample spacing, which in turn determines the POD.

Uniform & Localized Metal Loss
- Corrosion & Erosion (internal and external)
- Oxidation (external scale)
- Pitting (internal and external)

Deformations
- Creep and Stress Rupture (tube swelling)
- Bulging
- Ovality
- Denting

Mechanical Deterioration
- Fretting (mechanical vibration at tube hangers and supports)
- Dents
- Mechanical Cleaning (improper/over cleaning)

Manufacturing Defects
- Wall thickness below mill tolerances
- Gouges
- Laminations

Figure 1. Fired heater and coiler tube damage mechanisms.

Understanding these principles and how to apply them to an asset can greatly assist with maintenance planning and the prevention of unexpected failures.

Smart pigging providers use immersion-based ultrasonics (UT) to measure a pipe's wall thickness and radius. Most providers use tools that are equipped with multiple fixed UT transducers housed around the exterior of the tool's body to achieve various levels of data sampling density. The density of usable UT readings plays a critical role in determining a tool's ability to reliably and repeatedly detect the various damage mechanisms seen in fired heater and boiler coils. When selecting a smart pigging technology/tool, some important things to consider are:

1. Number and size of ultrasonic transducers
2. Tool speed
3. Tool size
4. Minimum wall thickness detection

All these factors help to determine the probability or certainty that a defect will be detected and accurately sized.

NUMBER AND SIZE OF ULTRASONIC TRANSDUCERS

Many smart pigging service providers have tools designed to inspect 4" piping, among other sizes, with measurement grids (UT sample spacing) ranging from 0.158" width x 0.158" length to 0.790" width x 0.300" length depending on the company. The minimum detectable flaw size and POD for the most common type of smart pigs for fired heater and boiler coil applications are largely determined by the size and number of transducers on the tool.

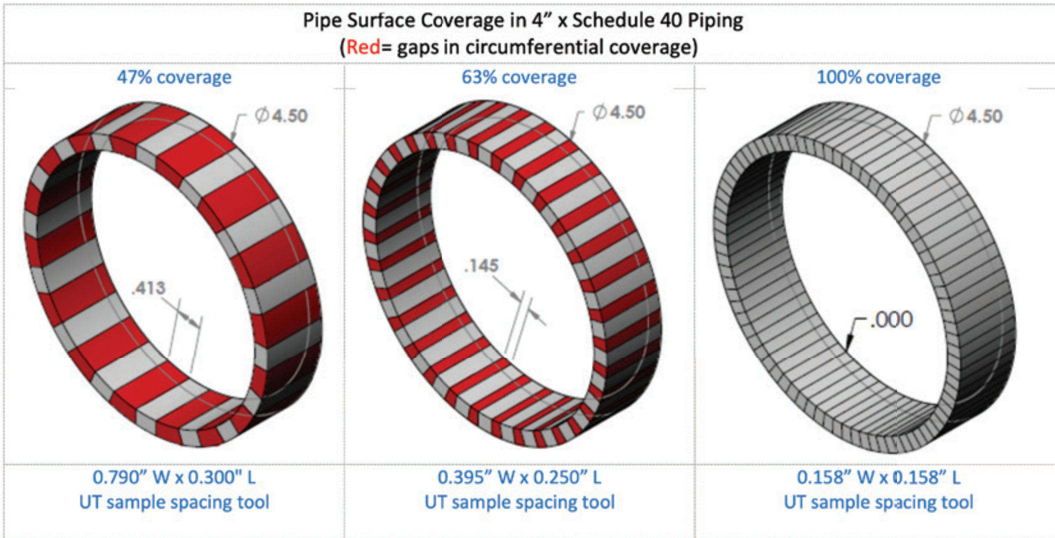

Figure 2. UT sample spacing comparion of pipe cross-section.

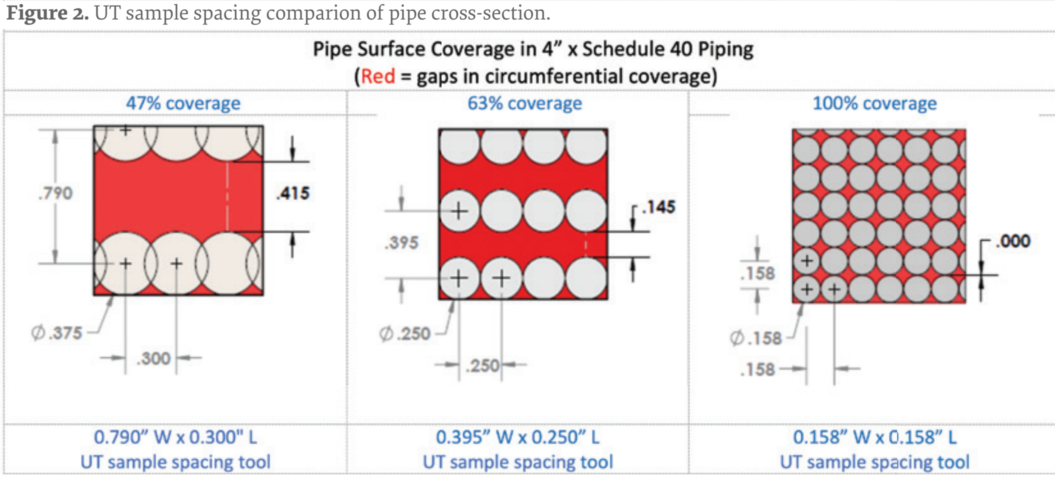

Figure 3. UT sample spacing comparion of 1" x 1" pipe surface grid.

For example, when a tool utilizing 0.375" diameter transducers with a measurement grid of 0.790" width x 0.300" length is used to inspect 4" nominal size schedule 40 piping, approximately 640 wall thickness and radius readings are taken every linear foot. This may seem like a lot at first, but, in reality, the overall internal surface coverage is no better than 47%. This is because gaps in pipe coverage exist circumferentially (the "width" dimension), severely limiting the tool's ability to detect localized metal loss, which is common in fired heater and boiler coils. This diminished detection capability is a result of the limited number of fixed transducers around the body of the tool.

Utilizing a tool with 0.250" diameter transducers and a measurement grid of 0.395" width x 0.250" length provides marginally better metal loss detection capabilities with 1,536 wall thickness and radius readings per linear foot. This equates to a pipe surface coverage of 63%, but there are still large gaps in coverage where localized metal loss can be missed.

Tools containing the highest number of transducers with the smallest transducer diameter provide the best ultrasonic surface coverage and resolution for the detection of localized metal loss. To that point, a high-resolution tool with 100% surface coverage would provide the best detection capabilities (see **Figures 2** and **3**).

TOOL SPEED

Each smart pigging company designs and develops tools with a fixed UT firing rate. This rate is set at an appropriate level to ensure 100% UT surface coverage in the axial direction when the tool is traveling through a coil at the optimal speed. The tool speed is set via a flow meter during smart pigging operations and needs to be at or below the optimal speed for the proper coverage. During pigging operations, tool overspeed conditions can exist if flow meters are not utilized or the pumping equipment that pushes the smart pig is faulty. A good on-site project manager should be able to remedy any in-field issues to establish proper tool speeds and confirm during the post-tool run verification that the complete amount of coverage was obtained.

Another useful indicator of surface coverage is the overall number of UT readings obtained axially and circumferentially. However, this indicator can sometimes be misleading depending on how a company advertises its capabilities. For instance, a company may claim in its specification, or through advertising, a higher number of UT readings per foot than is typically obtained during an inspection. This can be achieved by slowing down the movement of the tool through a pipe well-below the optimal speed, which allows the UT footprints to overlap, effectively reducing the center-to-center axial spacing between readings (see **Figure 4**).

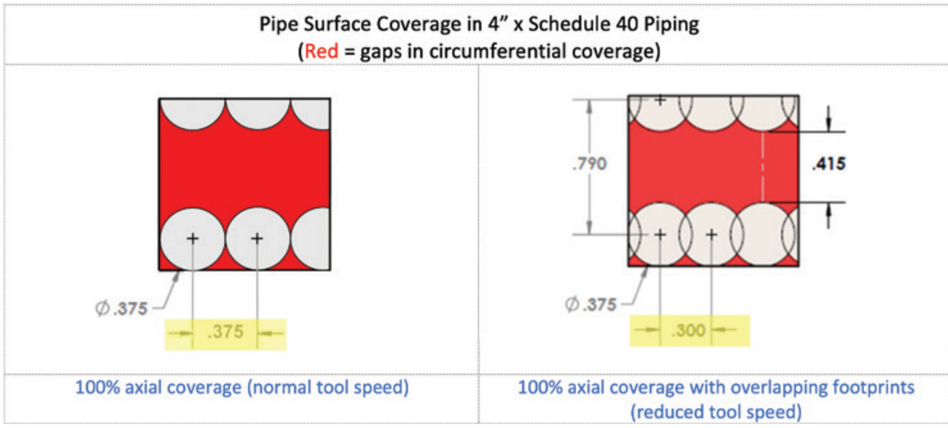

Figure 4. Impact on coverage at or below optimal tool travel speed.

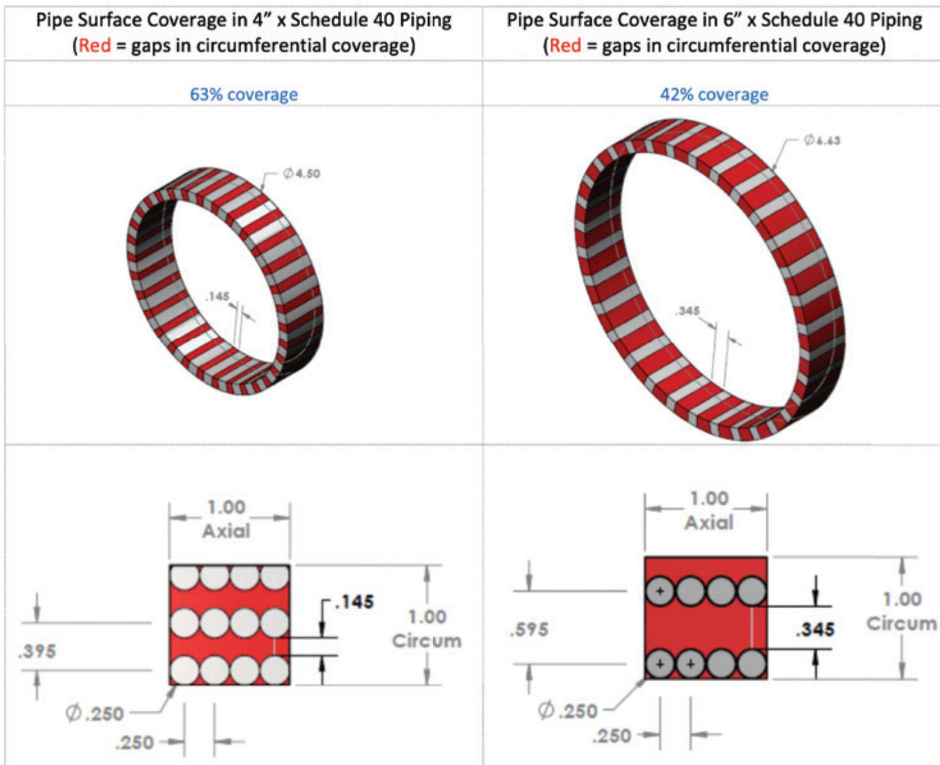

Figure 5. Using one tool for multiple pipe sizes.

However, this method does not improve the overall surface coverage, since 100% axial coverage is already obtained once a tool is operated at the optimal travel speed.

Every smart pigging provider can achieve a smaller or improved axial grid measurement (the "length" dimension) with this approach. However, the benefits are limited since defects smaller than the circumferential grid measurement (the "width" dimension) are not detectable. This is a limiting factor in detection capabilities for tools with less than 100% surface coverage.

TOOL SIZE

Ideally, smart pigging technology companies design ultrasonic tools that provide a consistently high level of coverage and resolution for the full range of pipe sizes found in fired heaters and boilers. With the inspection coverage and surface resolution dependent on the number and size of transducers, multiple tool sizes with a varying number of transducers are necessary to cover the entire pipe size range found in fired heaters and boilers. Essentially, the larger the pipe the more transducers are required to maintain the same level of coverage.

Reduced ultrasonic coverage will occur if an undersized tool is used. For instance, when a tool uniquely sized for 4" piping is used to inspect 6" piping, the UT measurement grid and surface coverage diminishes, as compared to that same tool in 4" piping, since the surface area of a 6" pipe is greater. Given the previous example where a tool with a measurement grid of 0.395" width x 0.250" length is utilized, the coverage drops from 63% to 42%, further reducing flaw detection capabilities (see **Figure 5**).

Achieving as close to 100% high-resolution coverage as possible by "right-sizing" the smart pigging tool for the correct application ensures the greatest level of detection, while preventing missed calls and possible pipe failures.

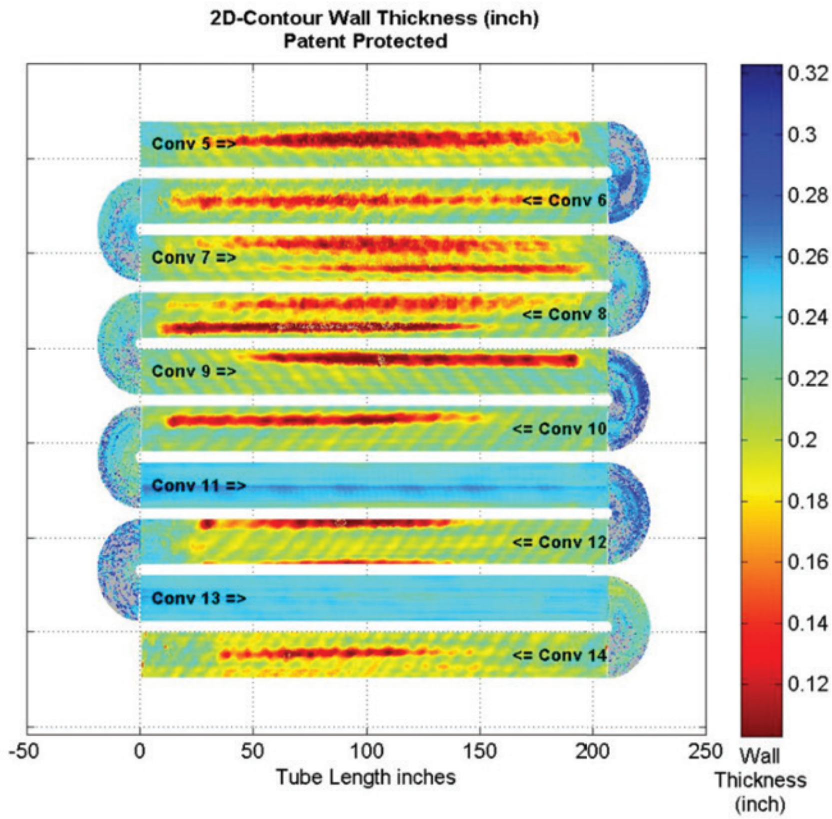

Figure 6. Damaged coil (many areas in Red were missed during hte inital inspection).

MINIMUM WALL THICKNESS DETECTION

The minimum wall thickness that smart pigging tools can detect varies and can impact the outcome of an inspection as much as any of the other previously mentioned factors.

Several years ago, a prominent refining company ruptured a tube during a hydrotest shortly after performing a smart pigging inspection on fired heater coils.[1] Follow-up testing by another smart pigging company revealed numerous areas of wall thinning that were not reported during the first inspection (see **Figure 6**). Upon further investigation, it was discovered that the smart pigging company's tools could not detect wall thickness readings below the refinery's minimum allowable wall thickness (Tmin).

Had the heater been brought back on-line after the repair from the hydrotest failure and without a follow-up inspection, more in-service tube ruptures or leaks would have occurred resulting in another unexpected and costly outage.

UNDERSTANDING INSPECTION LIMITATIONS FOR BETTER INTEGRITY MANAGEMENT

Managing the integrity of heater and boiler coils is made easier with the advent of smart pigging technology. Large amounts of UT data now make it possible to accurately assess the condition of fired heater and boiler coils. However, differences in flaw detection capabilities, such as UT measurement grid, probability of detection, and minimum detectable wall thickness, do exist between companies offering these services. Understanding how these differences can impact the accuracy of an inspection and ability to detect common damage mechanisms found in heaters and boiler coils can help guide better decisions when it comes to ensuring the long-term reliability and performance of an asset.■

For more information on this subject or the author, please email us at inquiries@inspectioneering.com.

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Tim Haugen has been with Quest Integrity for over 15 years. In addition to his corporate responsibilities, he has extensive field and managerial experience, having managed smart pigging inspection operations at client facilities worldwide and having overseen Quest Integrity's Central US, Caribbean and Latin American inspection operations for many years.