ADAPTIVE ENERGY TECHNICAL BRIEF

Inspecting Heat Exchanger Tube Welds with High-Speed Ultrasonic Scanning

The AHS-1 ultrasonic unit uses a multi-probe spiral scanner to provide fast, accurate inspection of critical tube welds in refinery, petrochemical and power plant heat exchanger systems, helping minimize maintenance downtime and prevent critical failure

Industrial Heat Exchanger Systems

Industrial plants such as oil refineries, petrochemical processors and power plants typically use large heat exchangers in their operations. A heat exchanger allows heat from a fluid (a liquid or a gas) to pass to a second fluid (another liquid or gas) without mixing the two. Typically, one fluid passes through a vessel or tube, while the second fluid passes through an adjoining vessel or fills an enclosure shell. The temperature of the fluids is altered by conduction through the metal of the vessels or tubes without the two fluids ever coming into direct contact.

Tube-to-tube sheet inspection in a heat exchanger using the AHS-1 unit

Heat exchangers can be used to heat or cool fluids in a single phase, to heat liquid to evaporate (or boil) it, or as condensers to cool a vapor into liquid form. For example, in fossil-fueled power plants, heat exchangers are used to cool and condense steam (on the shell side) by pumping cold water, such as sea water, through the tubes. In chemical plants and refineries, heat exchangers are sometimes used as re-boilers to heat incoming feed for distillation towers. In nuclear power plants— called pressurized water reactors—special large heat exchangers pass heat from the primary (reactor plant) system to the secondary (steam plant) system, producing steam from water in the process.

Shell & Tube Exchangers

The most common class of heat exchangers used in these industrial settings is the shell and tube design, which is well suited for these high-pressure applications. This type of heat exchanger consists of a shell (a large pressure vessel) that encloses a bundle of tubes. One fluid runs through the tubes, and another fluid flows over the tubes inside the outer shell, transferring heat between the two fluids. The set of tubes is called a tube bundle.

For the heat exchange process to be effective, the tube material must provide good thermal conductivity. To minimize corrosion, the material needs to be compatible with both the shell-side and tube-side fluids under expected operating conditions (e.g., temperatures, pressures, pH). Materials that offer strength, thermal conductivity and corrosion resistance are metals including copper alloy, stainless steel, carbon steel, non-ferrous copper alloy, brass, nickel, titanium and special alloys such as Inconel® and Hastelloy®.

Heat Exchanger Operating Considerations

Because energy is transferred through the tube walls in both directions, temperature differentials cause the tube material to expand and contract. Additionally, the tubes are under pressure from the fluids themselves. When heat exchangers are in operation 24 x 7 over long periods of time, they are subject to eventual degradation or failure through mechanisms such as corrosion, cracking and thinning. At a large industrial plant, there can be 50 of these exchangers connected into a large production system. If even one exchanger fails, the whole system shuts down until necessary repairs can be made.

Plant operators need to inspect heat exchangers periodically to ensure efficiency, detect potential weaknesses and prevent catastrophic failures. Inspection typically requires stopping production for the entire plant for a designated period of time, so operators try to keep these stoppages—called turnarounds—as short as possible. To do this some plants have used a "sampling" approach, where only a portion (e.g., 10 percent) of the tubes in each exchanger are inspected.

The sampling approach can be problematic, however, because if even one uninspected tube has developed a defect that is overlooked, it can later cause a catastrophic failure, thus the entire inspection process would have been useless. Industrial plants need a reliable and accurate method for inspecting the entire installation of heat exchanger tubes to prevent unplanned downtime. Yet, any inspection technique also needs to be fast, so that the system will be offline for testing for only the minimal amount of time.

Heat Exchanger Tube Inspection Methods

Two of the most common methods of inspecting heat exchangers in industrial settings are eddy current testing (ECT) and ultrasonic testing. Eddy current testing works by inserting a probe through each tube that emits an electrical current. The probe contains an electrical coil or coils and measures impedence of the electrical current to identify defects in the tubes. Different coil configurations and current frequencies allow test engineers to identify various types of flaws and distinguish whether they are on the internal or external surface of a tube.

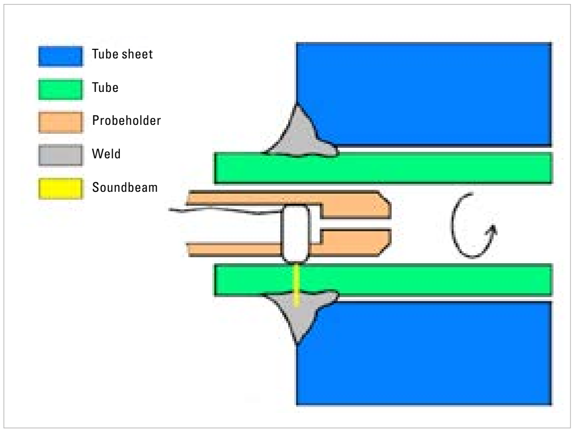
The drawback of eddy current testing is that it can only be used on non-ferrous metals such as brass or copper-nickel. Some variants of ECT are available for ferrous metals, for example remote field ECT, used for inspection of carbon steel tubing. However, these methods are slow and less accurate.

The ultrasonic testing method uses sound wave reflections to measure discontinuities in a medium. To use this method for tube inspection involves sending an ultrasonic probe into the tube, emitting a beam parallel to the tube axis, which is reflected in a spiral configuration by a spinning mirror set at a 45 degree angle. This method is known as internal rotating inspection system (IRIS), and requires that the tubes be filled with water to act as a couplant. Ultrasonic IRIS produces a helical scan, and is reflected from both the interior dimension and outer dimension of the tube. The time difference of the wave reflections is used to calculate the thickness of the tube wall.

High-Speed Ultrasonic Inspection Solution for Tube Welds

Heat exchanger tube bundles are made up of individual segments of tubing welded together. These weld points are subject to the same pressures and temperature fluctuations as the tubes themselves and can be critical points of failure if not property inspected and maintained.

Adaptive Energy works in partnership with FORCE Technology, a Danish research institute specializing in non-destructive testing innovation, to deploy a specialized scanner system, the AHS-1, designed specifically for inspecting the tube-to-tube sheet welds. The AHS-1 offers pulse-echo (ultrasonic) scanning capabilities for tube-to-tube welds, optimized for speed. The unit can scan three welds simultaneously, and three scan units can be attached for simultaneous use, providing scanning speeds of up to 300 welds per hour.



Inspection principle for using the probe to inspect a heat exchanger tube weld

The AHS-1 system works by shooting an ultrasonic probe 20-50 feet into the exchanger tubes. The probe picks up information about the condition and structure of the tube that allows test engineers to identify which tubes are showing signs of cracking or thinning and need to be repaired or replaced. The AHS-1 is based on a measurement principle using a dual-crystal, zero degree probe scan to inspect tube welds. The transducer revolves, resulting in a spiral shaped scan pattern. Additionally, the probe units are adaptable to fit variations in heat exchanger geometry from plant to plant.

Features of the AHS-1 Heat Exchanger Tube Inspection Scanner

- Versions with one to three scanning units available
- Integrated remote control unit with status LEDs
- Up to three welds can be scanned simultaneously
- Inspection rate: up to 300 welds per hour
- The probe holder system is tailored to the actual tube geometry
- Four Standard interior dimension (ID) ranges:
  - 19 – 25 mm
  - 25 – 30 mm
  - 30 – 40 mm
  - 40 – 50 mm
  - Other sizes available on request
- Automatic rewind of transducer
- Automatic Job name generation
- Automatic Job selection during data analysis

Benefits of Ultrasonic Heat Exchanger Tube Weld Inspection

Adaptive Energy customers in the petrochemical, refinery and power plant industries who have used the AHS-1 system have experienced myriad benefits including:

- Early detection of damaged components, allowing for cost-effective preventive maintenance
- The ability to schedule repairs to minimize costly turnaround time
- Maximizing component lifetime through pro-active repairs
- Avoiding decline in production quality or output
- Preventing unexpected plant shutdowns due to damaged components
- Achieving better analysis of production- or process-caused damages for future prevention
- Preventing secondary damage to high-value components
- Preventing environmental damage and avoid negative company publicity
- Increasing operational safety and adherence to regulatory requirements

With effective inspection regimens in place that include fast, accurate scanning of heat exchanger tubes, industrial refineries and power plants are able to perform efficiently and safely, protecting the public and providing the oil, materials and energy that global industries and communities rely on.

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About Adaptive Energy

Adaptive Energy creates customized, non-destructive material evaluation solutions to address mission-critical, time-sensitive testing needs. By combining the latest digital radiography, computed tomography, and ultrasonic imaging technologies with innovative mechanical and robotic assemblies, Adaptive Energy's integrated systems offer rapid deployment, are easy to learn and maintain, and perform reliably under pressure.

Working collaboratively with organizations in the aerospace, automotive, energy, petro-chemical, defense, infrastructure, and materials industries, our experts develop optimized solutions for flaw and crack detection, composite delamination, weld inspection, hardness testing, custom radiation enclosures and overhead gantry systems, and more.

Adaptive Energy is also the exclusive distributor in the U.S. and Canada of FORCE Technology's P-Scan ultrasonic scanners, including the P-Scan Stack with Phased Array, a next generation automated inspection system.

For more information about FORCE Technology and the P-Scan product line visit www.forcetechnology.com, and for details about the P-Scan Stack with Phased Array visit www.p-scan.com.

CONTACT

+1.253.284.0825

Email info@adaptiveenergy.com

Mailing address
Adaptive Energy
1640 Marine View Drive, Suite B
Tacoma, WA 98422

www.adaptiveenergy.com