Heat exchangers (Hx) are devices used to transfer heat from one fluid to another. Most commonly, Hx are constructed of hundreds to thousands of tubes in parallel, encased in a metal shell. One fluid is found inside the tubes, and another fluid on the outside, enclosed by the shell. A very common example for the use of heat exchangers is in fossil-fueled power plants, where they cool and condense steam (on the shell side), pumping cooling water, such as sea/lake/river water through the tubes. In general, heat exchangers are found in a very large variety of industries such as power plants, refineries, paper mills, HVAC, food and beverage, chemicals, and many more. Operating 24/7 over long periods, Hx are subject to eventual degradation or failure through many mechanisms: erosion, corrosion, abrasion (caused by support plates rubbing against the tubes), thermal shock, sedimentation, fouling etc. Plant operators are aware of these inevitable issues and act to inspect their Hx periodically, both to ensure their efficiency and prevent catastrophic failures, which can be very costly.

Conventional Non-Destructive Testing (NDT) methods have mostly been around for ages and fall far short of delivering the ideal desired inspection method which is fast, accurate and easy to use.

The most well-known inspection method is Eddy-current Testing (ET). In this method, a probe is physically pushed through each tube and pulled back. The probe contains one or several coils, whose electrical impedance is affected by the surrounding tube. Different configurations of coils and driving frequencies can be used to detect various flaws, and distinguish whether they are on the external or internal surface of the tubes. ET is relatively accurate, with the ability to inspect 30-60 tubes per hour, depending somewhat on their length and condition. Deposits in the tube can cause probes to jam which can hold up the inspection and even damage probes. ET is heavily dependent on tube wall material, which is a twofold limitation: it cannot be used to inspect ferromagnetic materials at all, and requires a “calibration standard” for any tube it can be used on. ET variants such as Full/Partial Saturation Eddy Current (FSEC/PSEC), Remote Field Testing (RFT) and Magnetic Flux Leakage Testing (MFLT) have further drawbacks. Though they can be used for ferromagnetic materials, they are generally slower than ET and less accurate.

Finally, ET depends heavily on the subjective interpretation by the technician. A Study conducted by MTI and EPRI, for example, showed that a skilled technician detected 87% of the faults in a Hx mockup, whereas another technician detected only 50% of the faults on the same tubes.

Another well-known NDT method is based on ultrasound. Ultrasound is a form of reflectometry: sending a wave through a medium, and recording any reflections from discontinuities in the medium. Adapting this method to tube inspection is quite involved: once more, a probe is invasively inserted down the tube. The probe creates an ultrasonic beam parallel to the tube axis, which hits a spinning 45
degree mirror. As the probe moves down the tube it scans the tube wall in a spiral. This method is known as IRIS – Internal Rotating Inspection System.

IRIS, although accurate poses great difficulty in the inspection procedure. The need for good resolution dictates a narrow beam, which in turn entails a very slow pull rate so that the spiral scan of the tube provides full coverage. Filling the tubes with water, without air bubbles is messy and time consuming. IRIS also requires cleaning the tubes down to the metal, which is another time-consuming and costly procedure that must take place before inspection even begins. Finally, the accuracy of IRIS reduces with the thickness of the tube walls, and it cannot be used below a thickness of 0.9mm.

A new acoustic-based technology is changing the industry and enabling companies to accurately and rapidly perform comprehensive inspections, drastically reducing the chance of catastrophic failures. APR: Acoustic Pulse Reflectometry, a technology found in the newly-introduced AcousticEye Dolphin G3™ Tube Inspection System, meets the markets demand for speed, accuracy and objective report generation.

This breakthrough tube inspection system promises to make sampling a thing of the past. The technology is not tube material or configuration dependent. It is non-invasive and the report generation is objective and independent of a highly trained professional therefore the entire inspection procedure is much faster than conventional methods.

The core technology of APR encompasses an acoustic pulse traveling down the air enclosed in the tube. As long as the pulse does not encounter any changes in the tube cross-section, the pulse continues to propagate, with some attenuation due mainly to friction between the molecules of air and the tube wall. If however any discontinuity is encountered, reflected waves are created, which propagate back up the tube. The more abrupt the changes in cross section, the stronger these reflections are. These reflections are then recorded and analyzed by the software to determine what kind of discontinuity caused them. Discontinuities diagnosed include defects such as holes, corrosion, wall loss and tube bulges.

The primary limitations of APR are:

- The discontinuity must be present on the tube surface ID
- ID deposits will also appear and may be interpreted as an inward bulge, etc.
- It may be difficult to differentiate between a bulge and deposits, depending upon the configuration of the deposit

Today’s emphasis on saving the environment brings the importance of well maintained tubes, integrity testing and inspection to a new meaning. Industry should closely examine its energy consumption and efficiency and increase the need to quickly and efficiently maintain, inspect and refurbish facilities. Use of APR technology is enabling both small and large enterprises alike to increase efficiency, safety and inspection speed. By eliminating sampling, costly downtime of mission critical equipment is avoided.
With APR no longer will it be necessary to judge the integrity of 100% of the tubes based on a choice lot of tested tubes and 100% of the tubes will be tested at a fraction of the time and cost.

**Sidebar**

**Case Study: Expander/Compressor Discharge Cooler**

In Jan 2011, International Oil Company performed a shutdown for scheduled maintenance in one of their off shore facilities. The APR Tube inspection system was brought in to perform inspection of several tube banks in the heat exchangers.

The operators were seeking to detect any defective tubes and were specifically seeking defects of the nature of corrosion, wall loss and pinhole leaks. Several defects were found in the tubes inspected by APR.

APR inspection results:

- 18 wall loss areas (pitting) were found
- 8 tubes showed blockages.
- 4 tubes were found with holes

Further to the APR the defected tubes found were then inspected by two additional inspection techniques in order to compare and verify findings. The inspection technologies, boroscope inspection and Eddy Current inspection verified the findings, however the Eddy Current did not reveal the defects found.
Each U-tube was inspected in a single measurement for complete length including U-bend.

Fault analysis for 100% of all 1180 tubes of top and bottom coolers (590 tubes each) was done and submitted.

Cleaning validation report was provided.

Thresholds of 5% blockage, 10% erosion, 20% pitting and all holes, were included in fault analysis. Report provides for exact size of fault and location.

2 measurements required per each U-tube.

Only 13% of total of 1180 tubes for top and bottom coolers (78 tubes each) at random and an extrapolated report for all 1180 tubes was submitted.

Cleaning validation report was provided.

Report provides for 20-39%, 40-59% and > 60% of wall reduction/corrosion in steps (without location of fault). ET did not provide any information for blockages.
APR inspection indicated faults in U-bends of tube with exact locations-4 holes.

APR can quickly report medium to major faults which are more important and crucial for plant/site personnel to take corrective operation and equipment/plant turn around

As ET did not inspect the U-bends of tubes hence their reporting of faults in U-bends is open for further examination and confirmation.

ET could not find holes in their first analysis. The inspection report is based on a 13% sample of tubes and indicates many small wall losses of 20-39% (without giving exact % of fault or location) which may not be of immediate concern of plant/site personnel.

**Conclusion**

- 100% of tubes were tested with APR in a fraction of the time
- Defects were detected with APR that were not found with other technologies
- APR is particularly sensitive to the areas in the u-tube that other inspection technologies do not reach

**Images**