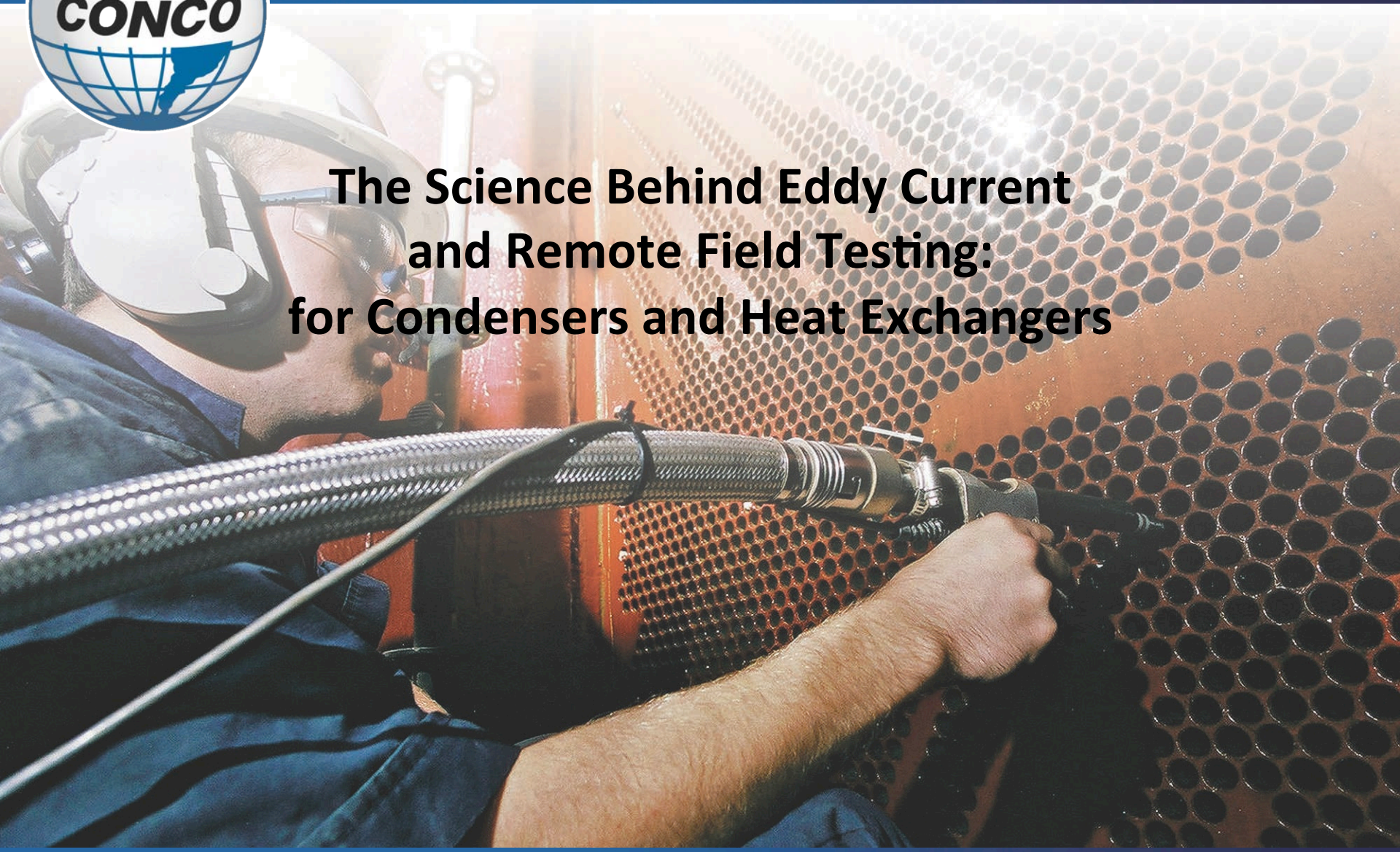
Conco Services Corporation



The Science Behind Eddy Current and Remote Field Testing: for Condensers and Heat Exchangers

Introduction

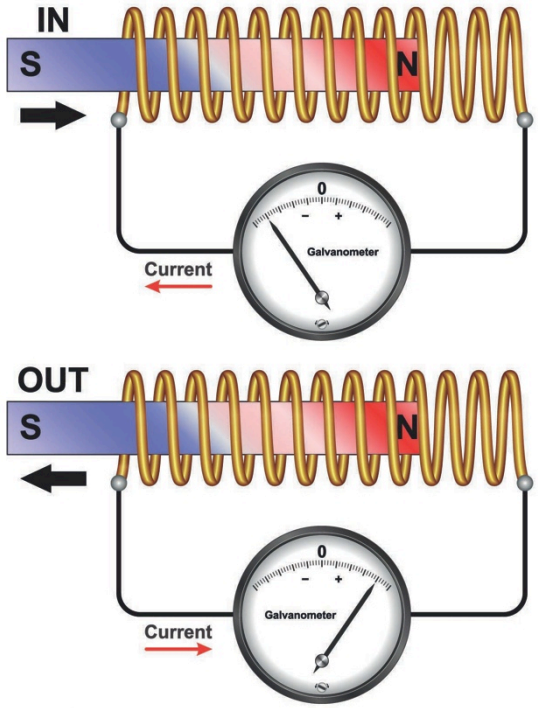
- What Is Eddy Current Testing (ECT) and Remote Field Testing (RFT)?
- What has Driven the Advancement of ECT and RFT Technology?
- Probe Construction
- Fill Factor
- Applications
- Calibration
- Single vs. Multi-Frequency
- Conclusions

What is ECT and RFT?

- Non-destructive inspection techniques.
- Based on inducing electrical currents in materials being inspected and observing the interaction between those currents and the materials.
- Used to monitor condenser and heat exchanger tube integrity.

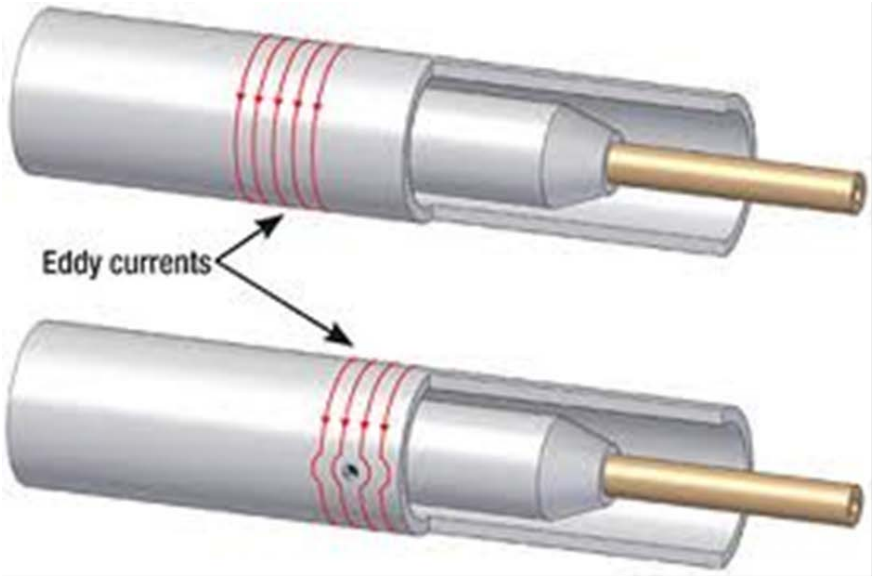
What is ECT and RFT?

- ECT and RFT technology can trace its roots back to Michael Faraday.
- Modern electromagnetic techniques rely on the experiments performed by Faraday in the mid 1800s.



What is ECT and RFT?

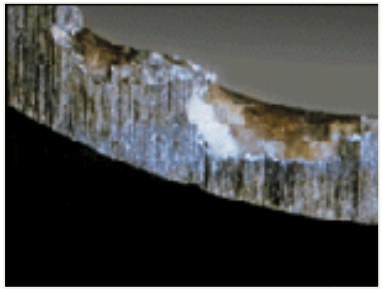
- Eddy currents are generated by electromagnetic coils in a test probe.
- As the probe moves through the tube, defects in the tube wall will interrupt or alter the amplitude and pattern of the eddy current, changing its magnetic field and causing a variance in the coils electrical impedance.

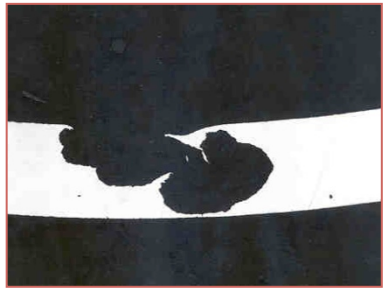


Flaw Disturbs Eddy Current Flow Path

What is ECT and RFT?

- By measuring the probe electrical impedance, a trained technician can “see” defects in the tube wall, such as pitting, cracking, erosion, corrosion, grooving, dents and changes in wall thickness.

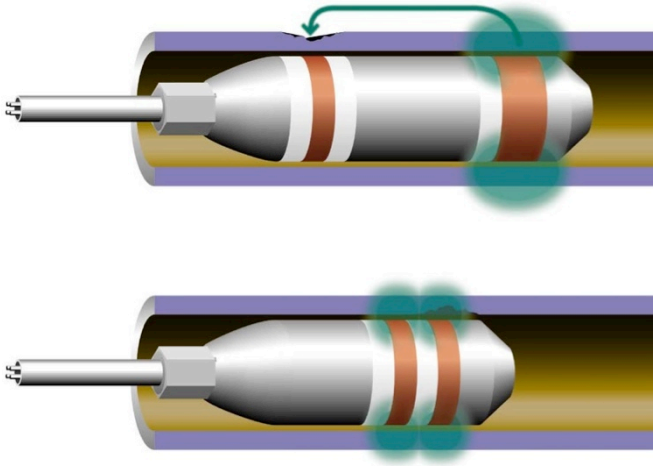




What has Driven The Advancement of ECT and RFT Technology?

- World wide increase in the demand for power.
- Increased focus on power plant equipment reliability and efficiency.
- Need to find smaller and smaller defects that can lead to tube failure, causing a drop in MW output or triggering a forced outage.

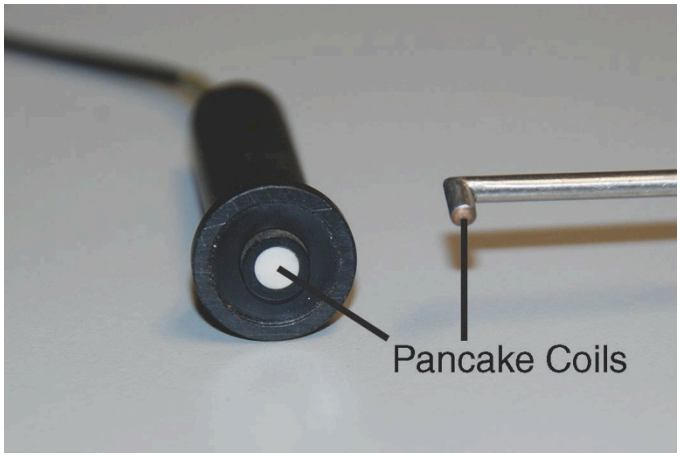
Probe Construction

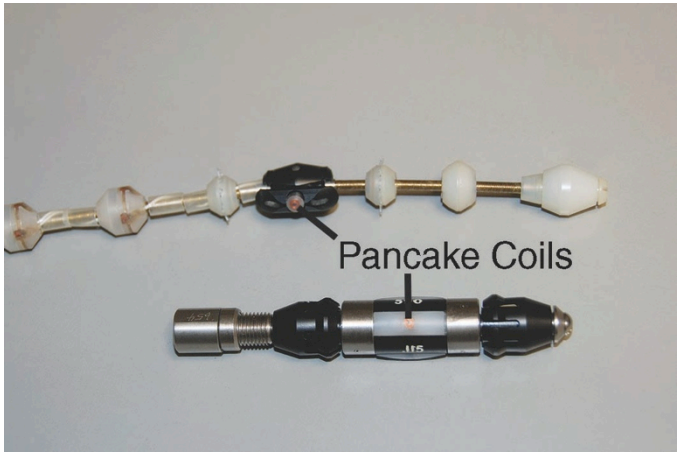


- ECT and RFT Probes consist of a coil or coils wrapped around a structure.
- Design will determine how the eddy currents are induced and how flaws are detected.
- Built on a non conductive body (air core) or using ferrite cores and conductive shielding to help shape the eddy current field for special applications.

Probe (Pancake) Coils

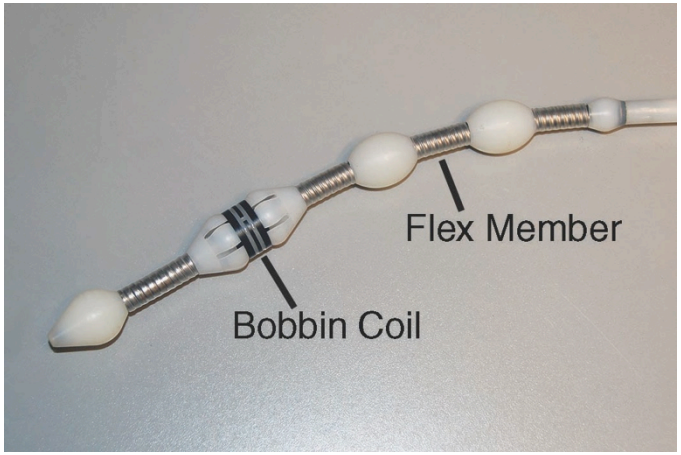
- Designed to test the surface of materials.
- Can be applied effectively to plates and welds.
- When fixed to a spinning device it is called a Motorized Rotating Pancake Coil (MRPC) and is very effective on tubes, but is time consuming and expensive to operate.





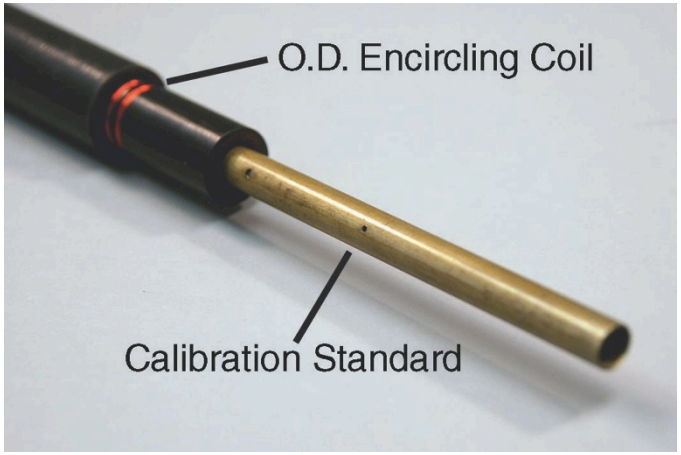
Bobbin Coils

- Allow for the inspection of installed tubes from the ID.
- Interrogates the entire circumference of a tube.
- The most widely used coil.
- Considered the “workhorse” of the tube testing industry.



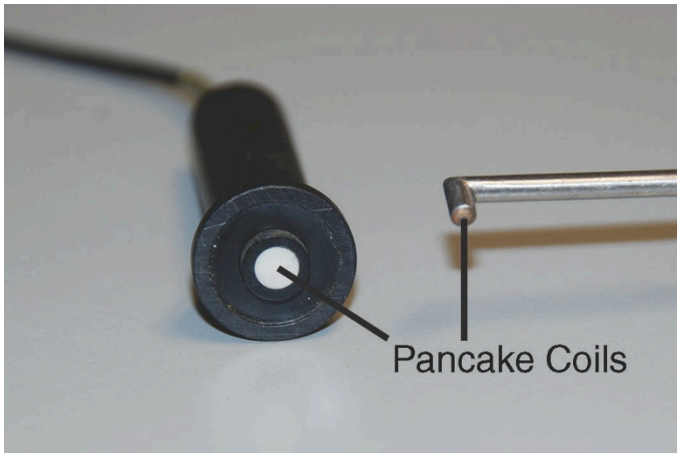
Encircling (Feedthrough) Coils

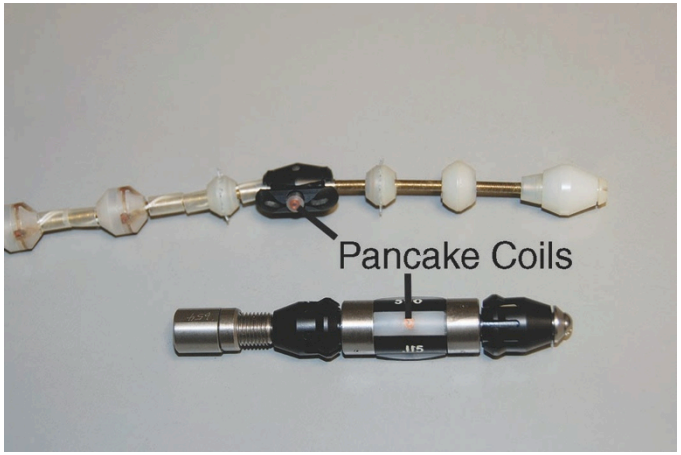
- Allow for the inspection of round objects such as tubes, wires and rods from the OD.
- Interrogate the entire circumference of the material.
- Used mostly in production monitoring activities.



Absolute Arrangement

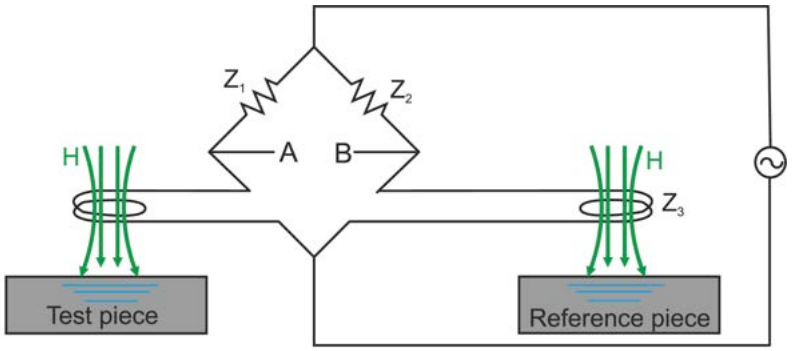
- Coil works independently, making no reference to any other coil, and is affected by all changes in the material.
- Usually limited to use by conductivity testers, coating thickness gauges and small surface riding pancake coils for surface scanning.





Differential Arrangement

- Two or more coils electrically connected to oppose each other and look for an imbalance or “difference” between the two coil impedances when a flaw is encountered.
- Sub categorized into two types:
  - Self Comparison.
  - External Reference.



Self Comparison Differential

- Two or more coils electrically connected, placed in close proximity to each other and wound in opposition.
- Very sensitive to small volume flaws.
- Minimize noise due to probe motion (wobble), temperature variations and deposits.
- Effective in detecting abrupt changes in wall thickness.
- Cannot detect gradual wall loss associated with steam erosion or tube-to-tube wear.

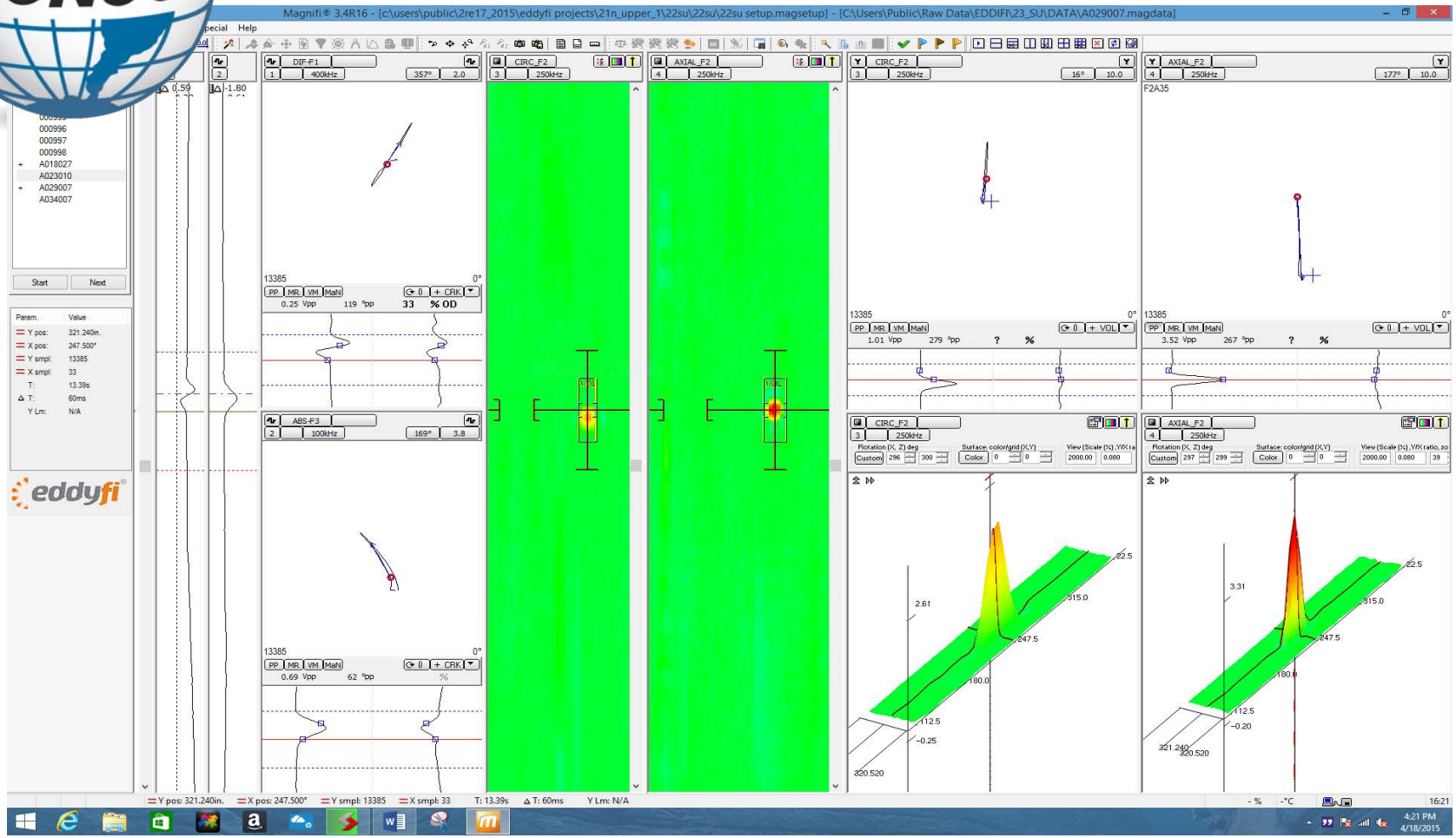
External Reference Differential

- Two or more coils electrically connected.
- Coils can be on the same test part separated by a distance to avoid direct coupling between the two coils.
- One coil can be on the test part while the other coil sits in a fixed location on a reference sample that represents nominal material conditions.
- Sensitive to all measurable changes similar to absolute coils.
- Data can be erratic – much like absolute coils.
- Typically reserved for defect confirmation against the self comparison differential channels and for detection of specific damage like erosion and tube-to-tube wear.

Hybrid Coils
Driver Pickup / Reflection

- Have the widest range of configurations.
- Basic configuration utilizes an excitation coil and an independent sensing (pick-up) coil or set of sensing coils.
- The excitation and sensing coils can be incorporated into each other or separated by certain distance.
- Hybrid coils have endless configurations to meet special needs of the inspection industry, but are not necessarily the most affordable breeds.

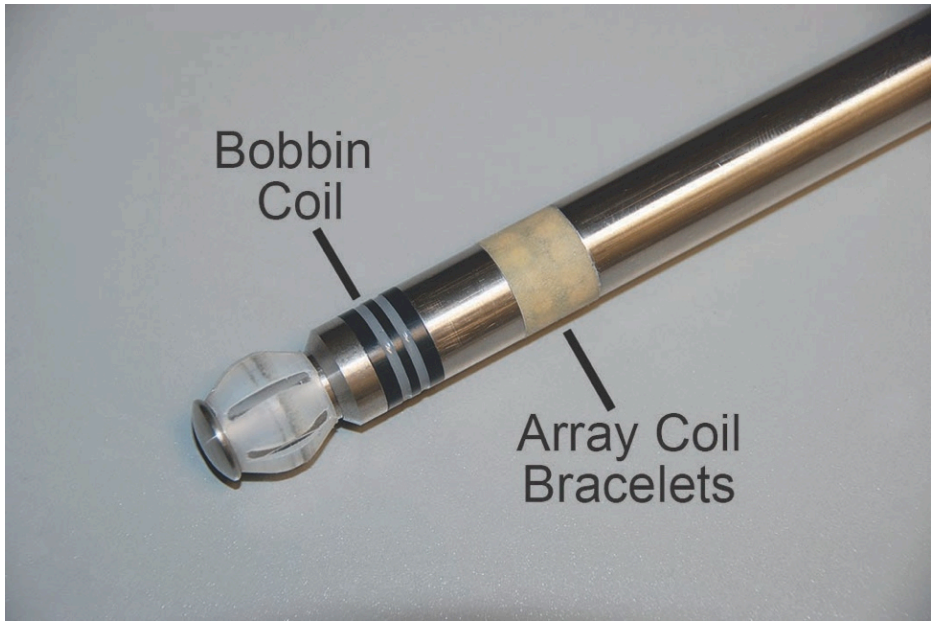
Hybrid Coils
Array Probes



Advanced Array Technology - Detailed Display

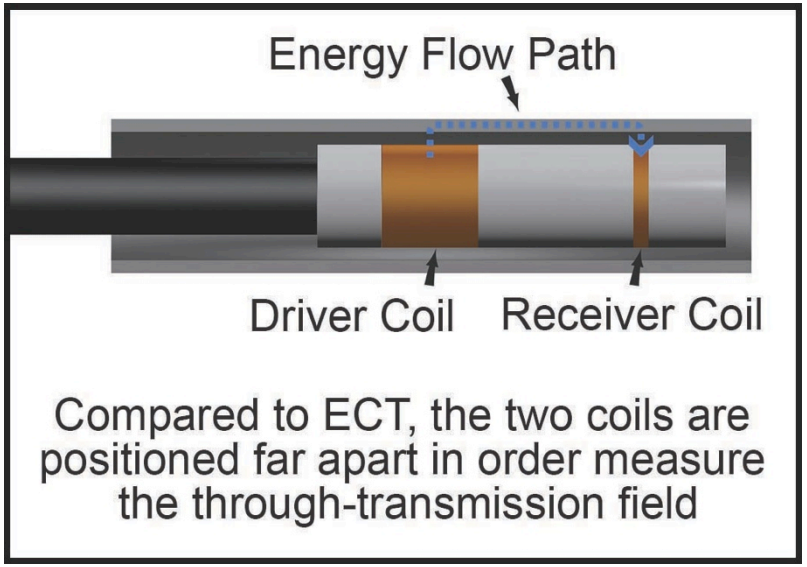
ECT vs RFT Probes

- Most ECT Probes are Bobbin Probes operating in the differential modes, self comparison and external reference.
- Some ECT Probes fall into the Hybrid category for specialized configurations. However, as sensitivity is gained for one specific damage mechanism, other mechanisms may be missed.



ECT vs RFT Probes

- RFT Probes are Hybrid Probes, (Driver/Pickup).
- RFT Probes feature a large excitation coil to generate the magnetic field and a pickup coil located two to three tube diameters from the exciter coil to detect the changes in field strength.



Fill Factor

- Fill Factor (FF) is the percentage the tube ID filled by the probe for tubing inspections from the ID.
- When calculating fill factor, use the formula: $FF = d^2/D^2$ where d is the outside diameter of the coil and D is the inside diameter of the tube.
- ECT preferred to have a FF of 85% or better.
- RFT preferred to have a minimum FF of 70%.
- Smaller FF values may be acceptable based on signal response from a calibration standard.
- Same formula for OD encircling coils, reverse the values.

ECT Applications

- Ideal for non-ferromagnetic materials such as copper, brass, copper-nickel, austenitic stainless steels and similar alloys.
- Relies on direct coupling between the inspection coil and the test material.
- Can be used on mildly permeable tubes like Monel and ferritic stainless steels with the use of magnetic bias probes, to “zero” out the permeability effects and let the eddy current alternating magnetic fields run free to do their job.

RFT Applications

- Ideal for permeable and highly permeable materials like ferritic stainless steel, carbon steel and similar alloys.
- Designed to overcome the permeability effects in ferromagnetic tubing.
- Coupling takes place indirectly through the generation of eddy currents and their resulting magnetic field.
- RFT can work on non permeable materials but it is not as accurate or effective as conventional ECT.

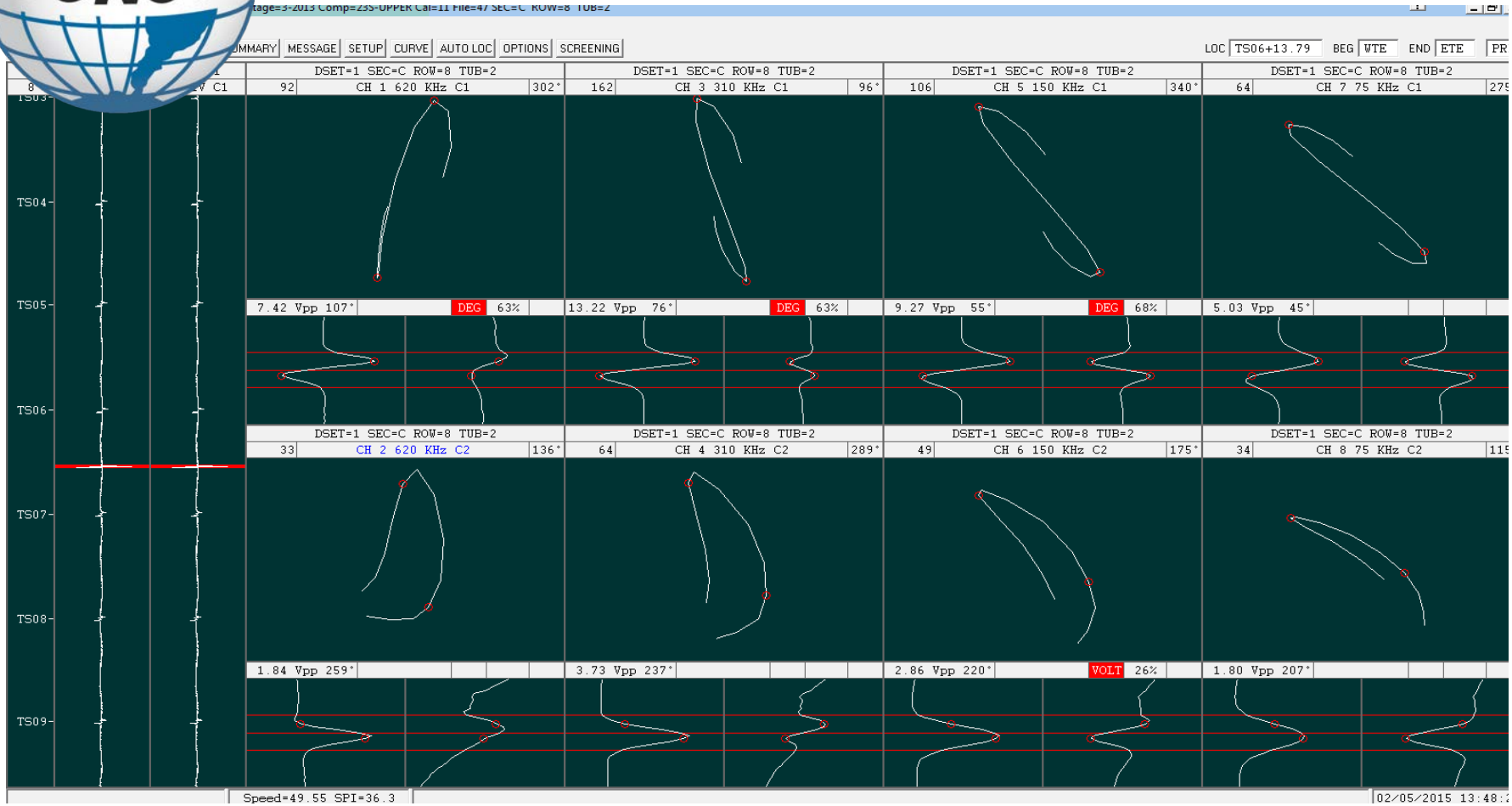
Calibration

- All ECT and RFT equipment must be calibrated on a regular basis to ensure functionality and sensitivity are adequate for the intended inspection.
- The ASME Boiler and Pressure Vessel Code, Section V, article 8 and article 17 specify the requirements for Eddy Current Testing and Remote Field Testing.
- ASME section V also defines certification requirements for inspection personnel.

Single Frequency vs Multi Frequency Testing

- For ECT, the more frequencies the better.
  - Each frequency has its strength for detection and allows for signal mixing to eliminate unwanted interference like tube support plate signals.
  - Use of both differential and absolute modes is also recommended.
  - The variety of a number of eddy current channels and mode combinations allows an extensive analysis of defect (flaw) depth and characterization.

Single Frequency vs Multi Frequency Testing



More channels of data ensure the analyst is making a valid defect call, not identifying and plugging false indications.

Single Frequency vs Multi Frequency Testing

- RFT, fewer frequencies than ECT.
  - RFT does not easily lend itself to multi frequency inspection and signal mixing.
  - Due to the characteristic low frequency operation, one or two test frequencies are typical for a RFT inspection.
  - Adding too many low frequencies has an impact on production by reducing the sample rate and in turn forces slower scanning speeds.

Conclusions

- ECT and RFT are effective tools for measuring tube integrity.
- ECT with multiple frequencies for non-ferromagnetic tubes.
- RFT with one or two frequencies for ferromagnetic tubes.
- Armed with detailed information about a HTX's tube integrity, plant managers can take proactive steps to either repair, replace or plug damaged tubes before they fail, preventing a forced outage.

Questions

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