Overcoming Inspection Challenges Through Advanced Eddy Current Technique for Nuclear Safety Related Heat Exchanger Tubes

Summary

EPRI supported the modification of a probe design for a particular class of heat exchangers that present inspection challenges. Specific inspection and examination technique specification sheets were developed to support the inspections and advanced data processing features were interrogated from the data analysis software for optimal data evaluation and reporting. Training was provided to the inspection vendor, enabling successful application of the inspection and data evaluation techniques.

The first-of-a-kind advanced eddy current combination array and bobbin probe and inspection technique was successfully implemented during two outages at one plant, demonstrating to the regulator that the material condition of the tubing remained satisfactory with no through-wall leakage.

APPLICABILITY

Nuclear plants with air-to-water, safety and non-safety related heat exchangers constructed with conductive external fins.

VALUE

Compliance with regulatory safety requirements related to tube integrity and enhanced awareness of heat exchanger condition.

EPRI PROGRAM

Nondestructive Evaluation

Example – Member Application

For this specific application, the plant owner relied on EPRI guidance and expertise throughout the project. EPRI developed the advanced NDE eddy current technique, collaborated with the inspection vendor to deliver training to personnel responsible for conducting the exams, and hosted a demonstration activity to test and evaluate the proposed technique.

- An existing probe design was specially configured that exhibited minimal or no interference from the external conductive fins. The innovative feature of this probe was that it included 36 total pancake type coils in two bracelets and centering device (petals), which provided uniform eddy current penetration and fit to the expanded and non-expanded tube regions. This was accomplished in a narrow probe body configuration, only 0.535-inch (13.6 mm) in diameter, which provided 360° circumferential coverage of the entire tube wall.
- An examination technique specification sheet (ETSS) following EPRI guidance was developed to describe the necessary steps to acquire and evaluate the eddy current data. To prepare this document, the probe was tested with multiple parameters to determine optimal inspection settings. This included testing with multiple frequencies, gains, probe pull speeds (with and without an encoder), median and low pass filters, and various probe drive and sampling rates.
- Data analysis software with multiple feature functionalities, including data slewing to review bobbin and array coil data in equal flaw location, was interrogated to improve data evaluation. The data slewing feature allowed the data analyst to observe the signal phase angle rotations to determine the origin of the flaw (inside or outside surfaces) and to measure the signal for flaw depth sizing. The eddy current test results when compared to actual flaw “truth” results in the member-supplied mockups were within an acceptable range of +/- 3%.
- Training was developed and conducted in parallel with inspection demonstration activities. Three eddy current data analysts worked with EPRI subject matter experts

to demonstrate the required steps to acquire, evaluate, and report the flaw conditions. EPRI hosted a demonstration activity for the utility and its inspection vendor at the EPRI offices in Charlotte, during which the data analysis technique sheets were reviewed and the utility/vendor team witnessed EPRI's setup of the inspection (data acquisition, data evaluation, flaw depth sizing, and reporting approaches).

The project team also consulted EPRI Product 3002015785, *Assessment of Electromagnetic Methods for Nonferromagnetic Tubes with External Fins: Array Coil Technology for Inspecting Hydrogen and Motor Cooler Tubes with External Fins*, to support this application. The successful results from this work are prompting a revision to the report to further enhance the technology transfer for other members.

Background

Air-to-water heat exchanger tubes serve as the primary containment boundary between containment atmosphere and the open loop service water system at some nuclear plants. In the United States, to ensure sound integrity, these tubes must be inspected to meet the Nuclear Regulatory Commission (NRC) Generic Letter 89-13 and the plant's own heat exchanger nondestructive (NDE) program inspection requirements. Nuclear plants in other countries may have comparable regulatory or company-specific requirements that impose inspection commitments. The current methodology used is pressure testing, which only identifies leaking tubes. The condition of the remaining tubes is unknown.

IMPLEMENTATION GUIDANCE

The technique is broadly applicable across the nuclear power industry. The first-of-a-kind probe and inspection technique can be used to inspect air-to-water, safety and non-safety related heat exchangers constructed with conductive external fins.

Based on the successful demonstration documented here, interested utilities should be able to engage their vendors directly to apply the technique using appropriate probes. Since heat exchanger designs and environmental conditions differ, unique circumstances may arise that require additional evaluation. Early engagement with EPRI can ensure unique or complicated inspection requirements can be met in a timely fashion supported by physical demonstrations where needed. EPRI engagement also ensures that lessons learned from specific applications can be shared with the broader industry.

Utilities can use the examination technique specification sheet (ETSS) developed for this application as a starting point and adapt it as necessary to meet their own situation. EPRI can provide assistance as needed.

Typical balance-of-plant (BOP) heat exchanger and condenser tubes in nuclear power plants are equipped with smooth (prime surface) tubing that can be reliably evaluated with standard bobbin coil eddy current techniques. However,

certain air-to-water safety-related heat exchanger tubes are constructed with external conductive fins (such as copper) with varying tube internal diameter (ID) openings caused by tube expansion. Many nuclear plants contain heat exchangers with these types of tubes. The conductive fins and varying tube IDs pose formidable inspection challenges. Through-wall leaks can be masked from the undesirable background noise generated by the conductive fins, and using a smaller diameter probe to accommodate a range of IDs can cause signal “drifts” in the tube expansion region, which reduces flaw depth sizing accuracies.

EPRI’s Role

EPRI has been involved in improving the use of eddy current for nuclear inspection activities for many years. For this specific application, the plant owner relied on EPRI guidance and expertise throughout the project. EPRI completed the final demonstration and technology transfer four months before the utility’s inspection schedule. This provided sufficient time to secure the probes and equipment needed to complete the inspection task.

Value

The technique has applicability to both safety and non-safety heat exchangers. At one plant, the technique has been applied during two outages and enabled the member to ensure the material condition of the tubing meets the requirements of the Nuclear Regulatory Commission’s (NRC) Generic Letter 89-13 and the plant’s own heat exchanger NDE program. Previous examinations resulted in a "go/no-go" assessment, providing either an acceptable or not acceptable wall loss determination. The innovative eddy current technique provides detailed data that facilitate better monitoring of the health of the heat exchanger, supporting better equipment reliability. Plant owners can make timely and informed decisions to repair and replace damaged tubes before they are returned to service, trend the eddy current data for flaw growth rates, and adjust design and water chemistry to mitigate or eliminate future tubing degradation. Such activities can preclude unplanned power down rates or shutdowns.

Resources

- 3002015785, *Assessment of Electromagnetic Methods for Nonferromagnetic Tubes with External Fins: Array Coil Technology for Inspecting Hydrogen and Motor Cooler Tubes with External Fins*
- EPRI laboratory and NDE qualification capabilities
- Support from EPRI subject matter experts

To support more effective technology transfer, EPRI is tracking implementation of key R&D activities.

Please access this link to provide input on your company’s use of this particular research: https://www.surveymonkey.com/r/QKFZFH2

Access additional Value Guides and examples of EPRI R&D application at: https://interactive.epri.com/nuclear-value/p/1

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