IN USE: STEAM GENERATOR TUBE INTEGRITY ASSESSMENT

ISSUE

More than 50% of the PWR reactor coolant pressure boundary is comprised of the heat transfer tubes in the steam generators. Ineffective or inaccurate tube integrity assessments and eddy current inspections of degraded steam generator tubing may enable conditions to persist that can lead to primary-to-secondary leakage, steam generator tube rupture, or a reduction in margin against design basis accidents.

Utilities use eddy current inspection results and tube integrity assessments to compare the condition of the tubing to the tube integrity performance criteria, to determine the scope and time for the next inspection, and to identify the need for long lead time actions. Long lead time actions include sleeving, inspection and repair relief through regulation changes, and/or steam generator replacement. Important inputs to tube integrity assessments are not available for many eddy current techniques. Standardized and more accurate tube integrity assessments and eddy current inspections are needed to maximize steam generator life while maintaining safe and economic steam generator operation.

DRIVERS

Regulatory

Regulators worldwide maintain oversight of tube integrity and have published generic communications that document tube integrity concerns. Since 2002, the U.S. NRC has issued seven Information Notices regarding tube integrity. For example, the U.S. Nuclear Regulatory Commission published Information Notice 2010-21, which states that plants with Alloy 600 thermally treated tubing may not be inspecting the most susceptible tubes in the U-Bend region and Information Notice 2013-11, discussing their concerns with cracking at dents and freespan in Alloy 600TT tubing.

Inspection

1) Existing eddy current techniques do not adequately account for all steam generator tubing variables, including tube material, wall thickness, and cable length. Technique extension without technically sound qualification could lead to less accurate tube integrity inputs; 2) For many degradation mechanisms, the number of mockups available to develop an inspection technique is not sufficient to meet the qualification protocol for system uncertainties; 3) New single pass automated analysis software is unproven and requires industry guidance and assessment of performance capabilities with respect to traditional two party data analysis.

Integrity Assessment

1) Eddy current technique qualification documents do not reflect total system performance and do not provide all the information needed for performing tube integrity assessments; 2) Eddy current noise could mask a flaw that would inadvertently be left in service or cause inaccuracies in sizing the flaw. The effect of eddy current noise on probability of detection and sizing of flaws is not quantified and an industry standard for measuring and monitoring noise is not available.

Workforce

As steam generators are replaced with advanced materials and as time between inspections increases, steam generator engineers and nondestructive evaluation (NDE) analysts may not be involved with steam generator activities for several years. In addition, the steam generator workforce is transient, as many experienced personnel are retiring and newer engineers are rotating into these roles.

RESULTS IMPLEMENTATION

Upon completion of this work, inspection and assessment techniques and procedures will be available to help safely and economically manage the steam generator assets at the lowest possible dose. Key deliverables and stakeholder responsibilities that will be the primary vehicles for implementing the results of this work are:

1. Eddy current and ultrasonic examination technique specification sheets (ETSS) will be developed for all applicable probe types, for use by utilities and inspection vendors

2. Steam generator guideline documents (Pressurized Water Reactor Steam Generator Examination Guidelines and Steam Generator Integrity Assessment Guidelines) will be updated to address new issues and to enable more effective management of steam generators

3. The Automated Analysis Performance Demonstration Database (AAPDD) will be available to demonstrate and qualify automated eddy current analysis algorithms and associated vendor software

4. The Performance Demonstration Database/Qualified Data Analyst (PDD/QDA) will be available for training and qualification of eddy current inspection personnel
5. Vendors will update procedures and processes related to performing tube integrity assessments
6. Nuclear plants will update steam generator programs and plant procedures to reflect research results
7. Utilities and vendors will utilize EPRI training products to maintain an effective workforce

PROJECT PLAN

The work is divided into four areas.

**Inspection Technique Qualification for Tube Integrity Assessments**

Realistic eddy current signals that correspond to a known degradation mechanism are the most critical element for the development of eddy current techniques, the documentation of technique performance, and site-specific validation. Eddy current signals will be collected using both traditional methods (mockup specimens) and innovative methods: 1) flaw injection software to simulate signals and 2) modeling the response of the probe to a flaw using finite element analysis.

The eddy current signals will be used to develop eddy current technique qualifications and quantify the probability of detection as described below.

**Eddy Current**

Research on the effect of essential variables such as tubing material (Alloy 600, Alloy 690, and Alloy 800), expansion transitions, tube support material, and cable length on eddy current response will expand existing eddy current technique qualifications and assist utilities with site validation and technique extension.

There are three main eddy current probe types in use in the industry: bobbin, rotating, and array. Array probes are gaining wider acceptance due to improved detection capability over bobbin probes and improved acquisition speed over rotating probes. As such, additional research is needed on array probe sizing performance to develop additional examination technique specification sheets for wear mechanisms such as structure wear and loose part wear.

EPRI will update and maintain the written and practical data in the Performance Demonstration Database (PDD) to enable the qualification of data analysts. As vendors introduce new eddy current equipment and software, the PDD will be updated to remain compatible with industry practices.

**Tube Integrity Assessment**

Degradation assessments, condition monitoring and operational assessments are required by regulation. These assessments rely on information from the NDE system, such as probability of detection (POD) of flaws, sizing, growth, and associated uncertainties and confidence levels. Existing eddy current technique sheets will be updated to include system probability of detection and sizing uncertainties. Growth rates for advanced alloys (i.e. 600TT) and default growth rates will be developed for use in operational assessments. EPRI’s Flaw Handbook Calculator will be updated and maintained to assist in performing assessments in-house or for validating vendor assessments.

There is evidence that deposits and manufacturing anomalies of the support structure can lead to steam generator tube fatigue failures. Research will provide guidance for identifying unsupported tubes susceptible to flow-induced vibration that could lead to fatigue cracking and will provide tools for predicting deposit loading that could lead to tube integrity issues.

**Automated Eddy Current Analysis**

Probability of detection for automated analysis systems will be developed using realistic eddy current signals with steam generators incorporating advanced materials. Single pass automated analysis systems (the result from a single analysis is considered equivalent to that of the combination of two independent analyses) are emerging in the marketplace. An industry standard for single pass automated analysis and associated probability of detection will be developed. EPRI will also provide a dataset, protocol and examination for automated data analysis systems via the Automated Analysis Performance Demonstration Database as required by the EPRI Pressurized Water Reactor Steam Generator Examination Guidelines.

Additional research on automated analysis algorithms and signal processing should lead to improved performance for detection and sizing of flaws in steam generator tubing. A key element needed for improved automated analysis is application of the appropriate algorithm at applicable locations. To ensure that the automated analysis programs identify the applicable location correctly, additional research on landmark detection is needed.

**Eddy Current Noise**

Guidance will be developed for measuring and monitoring eddy current noise and accounting for the effect of noise on detection and sizing. Quantification of noise is important to ensure that flawed tubes are not masked and are properly detected. A technique to monitor and trend noise during an inspection is needed to enable tube integrity assessments to account for changing conditions.
**Training**

EPRI will develop and maintain current training material and provide routine workshops to educate steam generator engineers and eddy current analysts. Training workshops and on-line training will help ensure new engineers and analysts are qualified and will also help refresh more experienced engineers and analysts who are involved with the processes on an increasingly infrequent basis due to lengthening inspection intervals.

**RISKS**

*Eddy Current Signal Development:* Sufficient realistic eddy current signals may not be collected and the innovative technologies may not be able to develop flaw samples for all applicable damage mechanisms.

*Acceptance of New Technology:* The use of a single pass automated data analysis system may not be accepted by the industry and the regulators.

**RECORD OF REVISION**

This record of revision will provide a high level summary of the major changes in the document and identify the Roadmap Owner.

<table>
<thead>
<tr>
<th>Revision</th>
<th>Description of Change</th>
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| 0        | Original Issue: December 2011  
Roadmap Owner: Heather Feldman |
| 1        | Revision Issued: August 2012  
Roadmap Owner: Heather Feldman  
Changes: Updated flowchart and revised flowchart to include milestones. |
| 2        | Revision Issued: December 2012  
Roadmap Owner: Heather Feldman  
Changes: Updated flowchart. |
| 3        | Revision Issued: August 2013  
Roadmap Owner: Helen Cothron  
Changes: Updated Regulatory Drivers and Flowchart. |