**ISSUE STATEMENT**

Corrosion was the dominant tube degradation mode for steam generators manufactured with Alloy 600MA tubing. Most steam generators with Alloy 600MA tubing have been replaced with steam generators that have more corrosion resistant tubing such as Alloy 600TT, 690TT or 800NG. As a result, corrosion of steam generator tubing is decreasing and other degradation modes are becoming more important.

Foreign objects on the secondary side of steam generators cause tube wear that can challenge tube integrity and can lead to primary-to-secondary leakage and unplanned outages. This is currently the number one cause of steam generator forced outages. Foreign objects include material that is accidentally left in the secondary system during installation or repairs, and material from degraded components in the secondary system. Although foreign material exclusion programs are in place at plants to minimize the number of foreign objects in the secondary system, it is not possible to eliminate all foreign objects. As such, a strategy to manage foreign objects and the associated degradation on the secondary side of a steam generator is needed.

**DRIVERS**

*Operational Drivers*

In the worst cases, tube degradation from foreign objects can lead to unplanned outages due to primary-to-secondary leakage. From a more practical standpoint, foreign objects and associated tube wear may lead to an unplanned expanded eddy current inspection scope, an unplanned tube plugging campaign, and/or an inability to operate multiple cycles between inspections. In addition, inability to accurately size foreign object wear leads to unnecessary in-situ pressure tests to demonstrate tube integrity. These activities can significantly increase worker radiation exposure, outage costs and schedule.

*Regulatory Drivers*

Regulators are concerned that existing eddy current inspection practices may not adequately identify foreign objects or foreign object tube wear indications. Undetected foreign objects or tube indications that are missed or inaccurately sized during inspection may lead to a degraded tube that causes a primary-to-secondary leak.

**RESULTS IMPLEMENTATION**

Upon completion of this work, it is expected that:

- Improved eddy current inspection techniques and new secondary side wear sizing techniques will be integrated into vendor services that are provided to the utilities. These techniques will better identify and size tube wear, and locate foreign objects.
- EPRI’s Foreign Object Handbook (EPRI Product 1014981 and subsequent revisions) will serve as the basis for utilities and steam generator vendors to implement a plant-specific strategy for managing foreign objects. This document will include a method to prioritize the order in which objects should be removed from the steam generator, an industry accepted method to predict tube wear, and a summary of relevant operating experience.
- Utility foreign materials exclusion program managers in conjunction with utility steam generator engineers will maintain a foreign materials exclusion program that is based on EPRI’s Nuclear Maintenance Applications Center: Foreign Material Exclusion (EPRI Product 1016315 and subsequent revisions) and INPO’s Achieving Excellence in Foreign Material Exclusion (INPO 07-008 and subsequent revisions).
- NEI 03-08 steam generator guideline documents will be updated by EPRI and implemented by the utilities to address research results and operating experience related to foreign objects.

**PROJECT PLAN**

This work is divided into three essential areas. These areas are needed in conjunction with each other to adequately manage the issues and the associated consequences related to foreign objects within steam generators.

*Effective Inspection*

Existing primary side eddy current techniques for managing foreign objects are limited. The goals of the research are to improve foreign object primary side eddy current detection and sizing capabilities, to evaluate ultrasonic testing for part identification and wear scar sizing, and to develop a secondary side inspection method that can assess tube damage from a foreign object. The secondary side inspection technique will enable utilities to size wear without accessing the primary side. This will be useful if tube wear is observed...
from a visual inspection on the secondary side during an outage when primary side inspections are not conducted or after primary side inspections are complete.

Development of new primary side inspection techniques requires experienced eddy current analysts to propose and test innovative methods to acquire and analyze eddy current data. The eddy current data will be collected in a laboratory with tubes that have tube wear and with parts in locations that are expected in the steam generators. This will be done using several different probe designs. Each successful method will be added to the library of accepted eddy current inspection methods that are used by the inspection vendors. Considering many plants use automated data analysis, advanced algorithms for the detection of loose parts will be developed. The performance demonstration for automated data analysis (AAPDD) will be updated with foreign object data for detection.

A promising secondary side sizing technique based on optical depth measurement will be developed and evaluated for its ability to measure tube wear on the secondary side of a steam generator. Upon completion, the technology will be transferred to a vendor for commercialization and then it will be offered as a service to the utilities.

**Evaluation**

During an outage, many foreign objects can be located in the steam generator. A structured process (prioritization scheme) will enable the steam generator engineer to decide the action needed when foreign objects are detected and assist with the prioritization of foreign object retrieval. EPRI will develop a first-principled based method to predict potential wear from a foreign object and will qualitatively confirm the results using experimental data. This method will be applied generically to develop a prioritization scheme for removal of foreign objects (size and mass) that are located in a steam generator. Prediction of potential foreign object wear using this methodology will be used for tube integrity assessments.

**Foreign Object Handbook**

EPRI will maintain and update the Foreign Object Handbook which provides an overall strategy for managing foreign objects. This handbook will capture operational experience, recommended inspection practices, foreign materials exclusion practices, prioritization schemes, and tube wear prediction methods.

**RISKS**

The industry recognizes the importance of this proactive work to manage foreign objects in steam generators. Risks associated with completion of this work include:

- Development of new eddy current techniques requires a trial-and-error process where analysts propose and test new methods to collect and analyze the data. It is possible that the proposed techniques will not be better than current techniques for wear sizing and for locating foreign objects.
- Vendors are needed to commercialize the new secondary side sizing technique. Vendor interest is unclear at this point in time. Upon transfer of the technique to the field, the challenging conditions in the steam generator may limit the usefulness of the technology.

**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: August 2011  
Roadmap Owner: Heather Feldman |
| 1 | Revision Issued: December 2011  
Roadmap Owner: Heather Feldman  
Changes: Updated flowchart |
| 2 | Revision Issued: August 2012  
Roadmap Owner: Heather Feldman  
Changes: Updated flowchart and included milestones |