

Steam Generator Management

Program Overview

Program Description

The Steam Generator Management Program (SGMP) conducts research to ensure the safe and economic operation of steam generators in pressurized water reactor plants. Research activities target identification and mitigation of various forms of steam generator degradation, replacement steam generator specifications, water chemistry guidelines, in-service inspections, and tube integrity.

Industry Needs and Issues Addressed

- Greater consistency in managing steam generator issues across the nuclear fleet
- Integrated approach for managing steam generator materials degradation in pressurized water reactors
- Improved understanding of how multiple variables impact steam generator operation and maintenance, including thermal-hydraulics, water chemistry, tubing materials, inspection techniques, and tube-plugging/repair criteria

Impact

- Reduced potential for steam generator tube ruptures and forced leakage outages, which can cost \$5 to \$20 million per event
- Better tools for integrity assessments, reducing unnecessary examinations that can cost \$1 to \$2 million per plant
- Chemistry controls that can delay the onset of corrosion effects and mitigate steam generator fouling

Key Accomplishments

- Guidelines to implement the requirements of Nuclear Energy Institute (NEI) 97-06, a self-imposed industry requirements document that describes fundamental elements of a nuclear plant's steam generator program
- Regulatory acceptance of the generic license change package, Technical Specification Task Force (TSTF)-449, which describes inspection frequency recommendations for maintaining steam generator tube integrity
- Field demonstrations of chemistry control and dispersants to mitigate steam generator corrosion and fouling
- Field demonstrations of automated eddy current analysis software
- Development and maintenance of the Steam Generator Degradation Database (SGDD), which tracks steam generator degradation experience across the nuclear fleet

Current Year Objectives

- Array Probe Auto Data Analysis Software, Version 5.0
- Pressurized water reactor primary to secondary leakage guidelines
- Pressurized water reactor secondary chemistry guidelines
- Foreign Object Handbook
- Steam generator engineer training course
- Report on improved leak rate modeling

Industry Involvement

- Estimated 2009 funding: \$6.6

Program Technical Lead

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Summary of Projects

Project Number	Project Title	Value
	SGMP Emerging Issues	To address unanticipated technical and regulatory issues that affect the operation of steam generators
	SG Regulatory Issues	The principal focus of the nondestructive examination (NDE) and Engineering and Regulatory (E&R) Issue Resolution Groups (IRGs) is to ensure steam generator (SG) tube integrity. The cornerstone product is support for NEI 97-06 reference documents: in particular, the <i>SG Examination Guidelines</i> and its qualification program, the <i>SG Integrity Assessment Guidelines</i> , and the <i>SG In Situ Pressure Test Guidelines</i> .
	SGMP Advanced Water Chemistry	Improved water chemistry control to 1) minimize corrosion product transport into the SGs, where it can foul tube surfaces and create crevice environments for the concentration of corrosive impurities; 2) minimize fouling within the SGs; and 3) minimize corrosion damage of SG tubes
	SGMP Tech Transfer	Maintenance and update of a database of worldwide SG information, SG Degradation Database (SGDD), that has been developed and placed on an internet site. The database provides utility engineers with the experiences of other utilities as a basis for making decisions that affect the SG program at their plants.
	Improved SG ISI/NDE	Development of automated methods for examination of SG tubes to accurately assess the condition of tubes, sleeves, plugs, and tube support structures. Automated data analysis reduces utility reliance on human analysts and would result in more reliable and consistent data.
	SGMP Materials and Thermal Hydraulics	Alloys 600 and 690 can be susceptible to stress corrosion cracking (SCC) in lead (Pb) environments. SCC testing and Pb behavior studies are conducted to determine if an inhibitor or remedial action can be identified to retard or eliminate effects of Pb. Thermal hydraulics studies are conducted to evaluate conditions in operating SGs that affect mechanical degradations.
	SGMP Supplemental Programs and User Groups	Co-funded projects on outside diameter stress corrosion cracking (ODSCC) at the tube support plate (TSP), generic review for use of dispersants, and Analysis of the Thermal-Hydraulics of a Steam Generator (ATHOS) code for thermal hydraulic calculations in SGs

Project Descriptions

SGMP Emerging Issues (058768)

Issue

Not all steam generator operational and regulatory issues can be anticipated to be included in annual plans. Emerging issues of high priority must be addressed in a timely manner and not be hampered by fiscal constraints. In addition, set-aside funds are now a requirement of the Materials Executive Oversight Group (MEOG).

Description

An Emerging Issues fund is set up to address unanticipated and emerging issues of high priority throughout the year. The SGMP Issues Integration Group evaluates and determines candidate emerging issues to be addressed by this fund.

Value

- Ability to address emerging technical and regulatory issues in a timely manner
- Set aside fund to eliminate/reduce impact on ongoing planned projects

How to Apply Results

Information developed will be distributed to Steam Generator Management Program (SGMP) members via SGMP Information Letters, Interim Guidance, Technical Reports, and Workshops.

SG Regulatory Issues (061426)

Issue

Management of degradation in steam generators with original Alloy 600 MA tubes, which are challenging the capability and resources of steam generator owners, as well as taking proactive steps in early and reliable detection of degradation in steam generators with the more corrosion-resistant Alloys 600 TT and 690 TT tubes. This project provides the vehicle for a collaborative means of addressing the issues in an efficient, cost-effective, and consistent manner.

Description

This project is conducted under two separate technical advisory groups, namely the Nondestructive Evaluation Issues Resolution Group and the Engineering and Regulatory Issues Resolution Group. The principal focus of these groups is to ensure steam generator tube integrity through condition monitoring and operational assessments. The cornerstone product is support for NEI 97-06 reference documents, in particular, *the SG Examination Guidelines* and its qualification program, *the SG Integrity Assessment Guideline*, and *the SG In Situ Pressure Test Guidelines*.

Value

- Minimize the potential for steam generator tube ruptures and forced leakage outages that can cost \$5 to \$20 million per event.
- Better tools for integrity assessments that can result in reduction in unnecessary examinations costing \$1 to \$2 million per plant.

How to Apply Results

Information is detailed in the related SGMP Guidelines, whose implementation is mandated by NEI 97-06 and NEI 03-08. Members use this information to develop in-house procedures in compliance with Technical Specifications and NEI 97-06 requirements.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Updates of Examination Technique Specification Sheets (ETSS's) for performance demonstration: This task includes maintaining eddy current and ultrasonic equipment, calibration standards, probe pushers, cables, testers, probes, hardware, and software. This task also includes maintenance of the Techquals database and updates to the EPRIQ website for posting of techniques for industry use.	12/23/2009	Technical Resource
Revision 2 of Flaw Handbook: This technical report provides guidance for determining the burst pressure of degraded steam generator tubing. This product provides calculations that assist the steam generator engineer or vendor in performing condition monitoring and operational assessments.	12/31/2009	Technical Report
Conduct EPRI SG NDE Workshop: This workshop provides a forum for the steam generator nondestructive evaluation community to share information on nondestructive evaluation research developments, industry experience, and regulatory issues.	7/31/2009	Technical Resource
Revision 3 of the Integrity Assessment Guidelines: This technical report provides guidance for evaluating the condition of steam generator tubing based on nondestructive examination or in situ pressure testing. This document is a required document for those plants that have adopted NEI 97-06 and new steam generator technical specifications.	12/31/2009	Technical Report
Conduct EPRI SG Engineering Training Workshop: This workshop familiarizes new steam generator engineers with design information and program requirements. This workshop also is useful for engineers who have responsibility for multiple plant systems and perform steam generator outages once every four years.	12/31/2009	Workshop, Training, or Conference
Thermal Hydraulics and Flow Induced Vibration Analysis of a Model F Steam Generator: Comprehensive thermal hydraulic analysis and a flow-induced vibration analysis of a model F steam generator	12/31/2009	Technical Report

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Revision 1 of Foreign Object Handbook: Update of the Foreign Object Handbook will include results of thermal/hydraulic work performed in 2008 and 2009 to better predict wear from foreign objects in steam generator tube bundles.	2010	Technical Report
Rev. 4 of In Situ Pressure Test Guidelines: Guideline document that provides requirements for performing in situ pressure testing of steam generator tubes. This document is a required guideline for implementation of NEI 97-06.	2011	Technical Report
Rev. 8 of SG Examination Guidelines: Guideline document that supports requirements of NEI 97-06 and NEI 03-08 for nondestructive evaluation of steam generator tubing.	2011	Technical Report
Conduct EPRI SG Engineering Training Workshop: Training for new steam generator engineers.	2010	Workshop, Training, or Conference

SGMP Advanced Water Chemistry (052334)

Issue

Improved water chemistry control is essential to minimize corrosion product transport into the steam generators, where it can foul tube surfaces and create crevice environments for the concentration of corrosive impurities; minimize fouling within the steam generators; and minimize corrosion damage within the steam generators.

Description

Secondary and primary water chemistry guidelines are developed and periodically reviewed and revised as needed to reflect technology developments and industry experience. Advanced technology developments are incorporated in application sourcebooks, which provide assistance to the plant chemists on water chemistry control, including improved amines, molar ratio control, and integranular stress corrosion cracking inhibition (boric acid and TiO₂ addition). Studies on the use of elevated hydrazine have been focused on its influence on flow-accelerated corrosion (FAC). The influence of amines and dispersants on corrosion product deposition and removal from SGs is continuing to be investigated, as well as the role of lead in stress corrosion cracking.

Value

- Industry guidance in primary chemistry, secondary chemistry, SG lay-up, and hideout return
- Improved understanding of the oxygen-hydrazine reaction in carbon steel systems to better model oxygen levels (and change in electrochemical potential) to mitigate FAC
- Improved understanding of high-temperature lead chemistry as a means to develop remedial strategies against lead-induced stress corrosion cracking

How to Apply Results

Plant chemists will include the guidance provided in the EPRI chemistry documents in their plant operating procedures to ensure that steam generator tube corrosion and steam generator tube fouling conditions are minimized. In addition, plant chemists will review the results of EPRI studies on various additives for controlling steam generator tube corrosion and fouling to determine if application at their plants would be advantageous.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Effects of Different pH Control Agents on PWR Plant Systems and Components: Provides a single source document to the industry utilizing the most current information to assess the role of amines on plant chemistry, polishers, FAC, steam generator fouling, and thermal-hydraulics	9/30/2009	Technical Report
Evaluation of Pb Transport to Crack Tips: This work will quantitatively evaluate a number of potentially viable lead transport mechanisms, including liquid phase diffusion, electrochemically driven diffusion, surface diffusion, solid state diffusion, and transport as anions.	12/31/2009	Technical Report
A Technical Bases Evaluation of Chemistry Effects on the SCC Behavior of Different SG Tube Alloys: Comprehensive technical bases for continued development of the water chemistry guidelines for steam generators of improved design	12/31/2009	Technical Report

Product Title & Description	Planned Completion Date	Product Type
Laboratory Testing to Validate pH and Conductivity MULTEQ Calculations: Experimental program to establish the validation of the pH and conductivity MULTEQ (MULTiple EQUilibrium) calculations using a matrix of test solutions with and without lead	12/31/2009	Technical Report

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Development of Predictive Models for Deposit Accumulation and Corrosion on the Secondary Side of Steam Generators: Experienced-based empirical models for predicting the probable rates of deposit accumulation and tube corrosion at support intersections and at top of tube sheet areas of steam generators. This will take advantage of completed work on a quantitative model characterizing line contact support plate fouling, which was funded by the EPRI Technology Innovation program	2011	Technical Report

SGMP Tech Transfer (052592)

Issue

Utility management and steam generator engineers require information pertaining to industry steam generator operating experience. A common source of up-to-date and easily retrieved steam generator information is needed.

The EPRI *Primary to Secondary (P/S) Leak Guidelines* is a directive document in NEI 97-06., which requires that an industry committee be convened every one to two years to review this guideline document and determine the need for revision.

Description

A database of worldwide steam generator information, Steam Generator Degradation Database (SGDD), has been developed and placed on an internet site accessible to all EPRI members. Maintaining this database with complete and accurate data, reported in a consistent manner, is essential for meeting utility information needs.

The EPRI *Primary to Secondary Leak Guidelines* document is reviewed on a periodic basis and revised when recommended by an industry guidelines review committee.

Value

- SGDD helps to ensure the safe and reliable operation of steam generators by providing data to plant engineers to help in determining inspection scope, planning for tube repair activities, and determining the effectiveness of various steam generator corrective action programs (for example, chemical cleaning).
- The *Primary to Secondary Leak Guidelines* help ensure the safe and reliable operation of the steam generators by providing information on leak detection methods and defining actions based on leak rate.

How to Apply Results

SGDD information assists plant engineers in preparing various steam generator assessment documents. SGDD information on industry steam generator experience is essential in determining if negative industry events could occur at their plant and in taking a proactive approach to address potential events that affect steam generator safety or operation.

The *Primary to Secondary Leak Guidelines* enable plant operations staff to ensure that leakage does not exceed allowed leakage values.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Steam Generator Degradation Database Maintenance: Provide SGDD program support, software corrections, server maintenance and monitoring, database administration tasks, and resolution of items identified through user experience	12/31/2009	Software

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Steam Generator Degradation Database Maintenance: Provide SGDD program support, software corrections, server maintenance and monitoring, database administration tasks, and resolution of items identified through user experience	2009	Technical Resource

Improved SG ISI/NDE (061427)

Issue

Current inspection methods for steam generator tubes are limited in their ability to detect and size tube degradation. For utilities that have replacement steam generators, inspection limitations may limit the length of the inspection interval, thereby eliminating the cost savings associated with skipping inspections. In addition, inherent errors and inconsistencies associated with manual data analysis can potentially be eliminated through the development and qualification of automatic data analysis algorithms.

Description

Tools will be developed to improve the accuracy and efficiency of steam generator inspections. Tools may include software algorithms for automatic analysis of inspection data, creation of a database library for documenting the performance of automatic data analysis software, development of procedures for determining examination technique equivalency, development of guidelines for improved data analysis, and development of improved inspection techniques.

Value

- Reduce steam generator inspection costs
- Reduce steam generator inspection duration
- Improve steam generator flaw detection and sizing accuracy to justify longer inspection intervals

How to Apply Results

The automatic data analysis algorithms developed by this project would be used by nondestructive evaluation vendors when performing a steam generator inspection at a client's facility. As a result of improved flaw detection and improved flaw-sizing accuracy, the increased probability of flaw detection and decreased sizing errors would be incorporated into the client's operational assessment to justify longer operating intervals.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Automatic Data Analysis Software, Version 5.0: This project will result in the development of software algorithms that will allow steam generator eddy current data from both rotating probes and array probes to be automatically analyzed at rates that are faster and results that are more consistent than manual data analysis.	3/31/2009	Software
Automatic Analysis of Rotating Probe Eddy Current Data: This technical report describes details of the rotating probe eddy current data analysis algorithms that were developed and documents the accuracy of the automatic analysis algorithms for detection and sizing of SG tube degradation.	3/31/2009	Technical Report
Standardized Process for Determining Examination Technique Equivalency: This technical update report provides a consistent and cost-effective method to evaluate system performance, evaluate technique performance, and demonstrate substitute component equivalency.	3/31/2009	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Standardized Process for Determining Examination Technique Equivalency: Technical report providing a consistent and cost-effective method to evaluate system performance, evaluate technique performance and to demonstrate substitute component equivalency.	2010	Technical Report

SGMP Materials and Thermal Hydraulics (061428)

Issue

Foreign objects and tube wear provide some of the biggest threats to safe and reliable steam generator operation. An understanding of these phenomena is needed so that predictive tools can be developed and actions can be taken to minimize the potential for degradation that exceeds tube structural limits. Corrosion studies on current and planned steam generator tubing materials also are needed to determine the effect of various steam generator environments on the rate of tube degradation, form a basis for recommendations to reduce the potential for degradation, and allow accurate long-term predictions on the initiation and growth of tube degradation.

Description

Enhance existing EPRI thermal hydraulic codes and fatigue and wear codes to provide more accurate estimates of secondary side flow, foreign object movements, and tube wear rates from both steam generator support structures and foreign objects.

Perform electrochemical polarization and controlled potential stress corrosion cracking tests in various environments to estimate steam generator tube degradation and growth in typical steam generator environments.

Value

- Determine maximum inspection intervals based on predictions of tube wear depths
- Determine the possibility of fatigue crack initiation in tubes due to flow-induced vibration
- Guidance on long-term tube repair decisions and strategies
- Plant-specific method for quantifying the risk of stress corrosion cracking in higher-stress tube regions

How to Apply Results

The plant engineer will be able to use EPRI-developed codes and apply experimentally verified methodologies to evaluate potential wear damage from foreign objects. The new method for more accurately predicting stress corrosion cracking will allow the plant engineer to better plan for the application of mitigating methods.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Deposit Chemistry and PWR Secondary-Side IGA/SCC: The objective of this project is to collect a uniform deposit characterization data set for deposits from a limited number of plants so that correlations between deposit chemistry and intergranular attack/stress corrosion cracking rates can be fully explored. The deposit characterization will be limited to the elemental composition of tube scale flakes and sludge pile collars, but will include additional elements besides lead.	12/31/2009	Technical Report
Thermal-Hydraulics and Studies of Foreign Objects in a PWR Steam Generator: The objective of this project is to develop experimental studies of the motion of a foreign object in a steam generator for triangular pitched steam generator tube bundles.	12/31/2009	Technical Report

SGMP Supplemental Programs and User Groups (055086)

Issue

The products resulting from base-funded projects sometimes lead to further research that addresses a specific issue for a subset of the original funding group. Issues addressed may include development of additional capabilities to available software products, development of a database to support alternate tube repair criteria, generic review of newly developed chemical additives, and review of new industry issues that may have generic implications.

Description

EPRI software codes have been developed to assess the thermal hydraulic conditions present in steam generators and to determine the rate of tube wear from both steam generator support structures and foreign objects. Although the basic code was developed and validated, a user group was created to identify and fund the development of new code features.

Value

- Ability to address plant-specific steam generator research needs
- Ability to address research needs for a subset of utilities that have a common issue

How to Apply Results

Research results will be provided to those companies that funded the work. The method of applying the research would depend on the specific product.