Heat Recovery Steam Generator (HRSG) Dependability - Program 88

Program Overview

Program Description

Heat recovery steam generators (HRSGs) pose a unique set of operational challenges, due in part to their rapid startup capabilities and high operating efficiencies. Preventing HRSG tube failures (HTFs) is a priority, but complex failure paths, which are influenced by cycle chemistry or thermal transients, are difficult to understand and mitigate. Limited access and other complexities make inspection and repair of HRSGs very difficult.

The Electric Power Research Institute's (EPRI's) Heat Recovery Steam Generator Dependability program (Program 88) provides a complete set of technical tools to improve the performance and reliability of combined-cycle HRSGs.

Research Value

Projects include unit-specific and pressure-circuit-specific chemical treatment methods and limits, optimal approaches to preventing HRSG tube failure, and methods for life assessment, nondestructive evaluation (NDE) options, welding, and other repair methods. Using the R&D from this program, members can:

- Achieve tube failure rates consistent with their risk tolerance and financial models
- Increase reliability through better understanding of HRSG thermal transients
- Increase understanding and control flow-accelerated corrosion (FAC) through an initial predictive code and other technologies
- Optimize HRSG operational and shutdown chemistry through better understanding of the chemistry cycle
- Identify and correct cycling and thermal transient problems through chemistry cycle guidelines and methods
- Optimize HRSG inspection and repair by using new hardware, NDE guidelines, and techniques for improving access

Approach

Operator guidelines help monitor, identify, and minimize the effects of shutdown, startup, and thermal transients on fatigue life, while a diagnostic expert system helps control and maintain optimal chemistry. Regional workshops covering HRSG tube failure, cycle chemistry, inspection, and FAC effectively transfer the knowledge gained through this program.

- HRSG cycle chemistry R&D recently completed a two-year study of an assessment technology for deposition in high-pressure (HP) evaporators that will involve circulation considerations. Additional work will summarize the potential for using organics in HRSGs.
- HRSG tube failures and life assessment research is continuing to develop a comprehensive methodology to assess cycling capability, including optimizing startup in terms of thermal transients. The program also continues to document case studies and develop life assessment tools and methodologies, and complete a model for two-phase FAC to assist in proactive FAC control.
- HRSG NDE and repair R&D includes developing and demonstrating external inspection techniques with remote capability, developing final equipment for HRSG tube elbow replacement near headers, and assessing an internal coating technology to provide protection against FAC.
- EPRI workshops for HRSG dependability are offered regionally to members of the HRSG Tube Failure Reduction/Cycle Chemistry Improvement Program and FAC and NDE programs.

Accomplishments

EPRI's thermal transient and cycle chemistry guidelines provide quantitative, specific suggestions for obtaining the best possible performance from existing HRSGs. The guidelines also provide guidance applicable to new units for appropriate design of pressure parts.

- EPRI has developed comprehensive guidelines on cycle chemistry for all HRSGs, including shutdown/startup chemistry and chemical cleaning.
- EPRI has developed a complete approach to identifying reasons for thermal transients, as well as related analytical tools.
- Unique repair technology has been developed, as well as a revision to the interim NDE guidelines to include case studies of visual techniques and technology transfer materials.

Current Year Activities

Program R&D for 2010 will continue to focus on thermal transients and chemistry directly responsible for damage to HRSG pressure parts. Specific efforts will include:

- Exploration of technologies to address HTFs, including an initial predictive code for two-phase FAC
- Technology to assess deposition in high-pressure (HP) evaporators
- Case studies and development of HRSG life assessment tools and methodologies
- Further development and demonstration of remote capabilities for external inspection techniques
- Delivery of equipment for HRSG tube elbow replacement near headers
- Initial assessment of an internal coating technology for FAC protection

Estimated 2010 Program Funding

$1.6M

Program Manager

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Summary of Projects

Project Number	Project Title	Description
P88.001	HRSG Cycle Chemistry	This project R&D helps reduce HRSG tube failures by providing guidelines to improve cycle chemistry through management of key failure mechanisms.
P88.002	HRSG Tube Failures and Life Assessment	This project provides in-depth investigations and guidelines addressing high-risk component failure root-cause mechanisms. Corrective solutions and damage mitigation techniques are developed, evaluated, and demonstrated.
P88.003	HRSG NDE and Repair	This project develops technologies and techniques to improve internal and external HRSG repairs.
P88.004	EPRI Workshops for HRSG Dependability	Regional workshops provide information and lessons learned in HRSG availability to utility operators, chemistry staff, and maintenance staff.

P88.001 HRSG Cycle Chemistry (051612)

Key Research Question

HRSG tube failures are influenced and controlled by cycle chemistry, which consists of flow-accelerated corrosion, under-deposit corrosion (mainly hydrogen damage), corrosion fatigue, and pitting. EPRI's suite of HRSG cycle chemistry guidelines is designed to manage all of these failure mechanisms.

Approach

Reliable operation of combined-cycle/HRSG units requires careful consideration of cycle chemistry. EPRI has already developed guidelines for complete cycle chemistry, shutdown and layup, and for chemical cleaning. The next steps will address the chemistry during startups and the deposition process in high-pressure evaporator tubing. This will link closely with the nondestructive measurement of internal deposits in P88.003.

Impact

- Significant reduction and improved management of chemistry-related generation losses in HRSGs.
- Improved unit availability and reduced O&M costs through prevention of chemically influenced HTF.
- Control of corrosion damage and deposition problems in HRSGs and steam turbines of combined-cycle plants.

How to Apply Results

Members may benchmark their chemistry programs independently or in collaboration with EPRI staff to identify areas of deficiency and determine approximate costs. The content of the chemistry guidelines can then be used to identify specific actions needed to address those deficiencies in a manner consistent with individual unit characteristics. For example, the chemistry guidelines can be consulted to verify proper selection and optimization of HRSG water chemistry used in individual fossil units. The benchmarking process should be repeated periodically as a means of checking the overall effect of improvements implemented. That way, success can be gauged by measuring progress against a rigorous set of performance metrics consistent with the EPRI guidelines.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Cycle Chemistry Instrumentation for Combined-Cycle Plants: An assessment of special instrumentation for combined-cycle plants, this report will include special tools to assess on-line deposition in HP evaporators, as well as corrosion sensors for each pressure cycle.	12/31/10	Technical Report
Water Treatment Equipment for Combined-Cycle Plants: Makeup Systems: Make-up Treatment Guidelines for Program 64 will be revised in 2010. Special requirements for makeup of combined-cycle plants will be developed in conjunction with the EPRI Cycle Chemistry program (P64).	12/31/10	Technical Report
Monitoring and Controlling Carryover in HRSGs: This report will evaluate techniques used to minimize carryover as well as extract and monitor saturated steam samples in drum evaporator circuits. This information will be used to develop a guidance document for use by plant operators.	12/31/10	Technical Report

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Guidelines for Control of Steamside Corrosion in Air-Cooled Condensers of Fossil Units and Combined Cycle HRSGs: Interim Guidelines for Control of Steamside Corrosion in Air-Cooled Condensers published in 2008 (P64) will be revised and updated to incorporate scientific data on the active corrosion mechanism of the early condensing steam from research conducted in 2009-2010, in addition to methodologies to mitigate the corrosion and reduce iron transport. The revised guideline will include alternative or specialized chemical treatments, design changes, and mechanical modifications to reduce and control corrosion activity. Techniques such as slip-stream treatment, induced condensing spray systems, and condensate recycle will be investigated.		Technical Report
Interim Organics Treatment:		Technical Report

P88.002 HRSG Tube Failures and Life Assessment (051614)

Key Research Question

HRSG tube failures are caused by flow-accelerated corrosion; under-deposit corrosion in evaporator circuits; corrosion and thermal fatigue in economizer, superheater, and reheater circuits; and creep fatigue in superheaters and reheaters. Over the last six years, work within the program has addressed the known fatigue-initiated and chemically influenced failures. Now, two-phase FAC remains the leading HTF cause and needs comprehensive analysis.

Approach

The program will begin development of a predictive model for two-phase FAC. Work will continue on development and validation of research on HRSG pressure part thermal transient limits and mitigation.

Impact

- Achieve significant improvement in HRSG availability.
- Reduce operations and maintenance cost through reduced HRSG tube failure.

How to Apply Results

The FAC model will help HRSG owners determine if and when two-phase FAC will occur. The approach for thermal transient limits will be applied to each pressure cycle. Validation of transient results and models will assist members in recommending design changes or improving specifications.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Flow accelerated corrosion governing document: Flow-accelerated corrosion (FAC) is a complex issue. Interaction includes corrosion, chemistry, materials, in-service inspection, and stress analysis technologies. EPRI Report 1008082, "Guidelines for Controlling FAC in Fossil and Combined-Cycle Plants," provides guidance but does not provide information that ensures commitment to the program. A document that would establish corporate commitment to the program, identify and empower those responsible for the FAC program, identify all FAC tasks, and set long-term goals and strategies could be very beneficial to HRSG dependability.	12/31/10	Technical Report

Product Title & Description	Planned Completion Date	Product Type
Development of Life Assessment for HRSG Superheater/Reheater Tubes: As HRSGs accumulate operating hours, there will be a need for life-assessment techniques and methodologies. Development and use of such techniques will be complicated by tight tube spacing and fins.	12/31/10	Technical Report

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Development of HRSG Dew Point Deposition on Back End Pre-heater and Economizer Tubing Guideline	12/31/11	Technical Report

P88.003 HRSG NDE and Repair (055580)

Key Research Question

Inspection, nondestructive evaluation, and repair of HRSG tubes and tube/header attachments are very difficult due to restricted access. EPRI has developed a series of techniques and technology to conduct repairs from the internal surfaces. NDE developments have been similarly directed to provide internal examination techniques as well as reduce thermal transients and thermal fatigue damage.

Approach

This project will deliver the final tube elbow replacement device described in a 2008 EPRI technical report. Work also will continue to develop an external delivery device that can be used to provide welding, repair, sampling, and NDE on HRSG pressure components. The NDE project will continue to develop and demonstrate external examination techniques to address damage.

Impact

- Enhance unit availability.
- Reduce tube/header examination and repair times.
- Experience fewer HTFs.
- Benefit from validation of damage assessment and models.

How to Apply Results

The NDE Guidelines provide members with tools and guidelines on the performance of nondestructive evaluation of HRSGs, so they know what types of NDE to perform and where to perform them. This is especially useful during HRSG tube failures and outages, as it provides comprehensive information on where HRSG failures occur, which damage mechanism is operative on various components, how to examine the components for damage, and how to establish subsequent re-inspection intervals. The internal examination technique and delivery device will most likely be commercialized through a third-party vendor, increasing opportunities for members to deploy the device.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Delivery Device for NDE: This product consists of an NDE device coupled with an existing robotic repair device. This tooling will be very beneficial because of the compact, rigid design of the HRSG components. The project will deliver hardware associated with the tube elbow replacement device developed in 2008 and couple it with the latest NDE and inspection technology available.	12/31/10	Hardware
Advanced NDE Assessment: Inspection, nondestructive evaluation, and repair of HRSG tubes and tube/header attachments are very difficult due to restricted access. EPRI has developed a series of techniques and technology to conduct repairs from the internal surfaces. NDE developments have been similarly directed to provide internal examination techniques as well as reduce thermal transients and thermal fatigue damage. R&D for advanced NDE to address examination of additional HRSG components identified as potential failures will continue and will be documented in this technical update.	12/31/10	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Revised NDE guidelines to include recent technical updates: The NDE Guidelines provide members with tools and guidelines on the performance of nondestructive evaluation of HRSGs, so they know what types of NDE to perform and where to perform them. This is especially useful during HRSG tube failure and outages, as it provides comprehensive information on where HRSG failures occur, which damage mechanism is operative on various components, how to examine the components for damage, and how to establish subsequent re-inspection intervals. The internal examination technique and delivery device will most likely be commercialized through a third-party vendor, increasing opportunities for members to deploy the device.	12/31/11	Technical Update
Internal NDE coupled to the robotic header to tube repair welder: Continue to pursue the development of tooling and NDE equipment to meet the need for inspection/evaluation and ensure HRSG dependability.	12/31/11	Technical Update

P88.004 EPRI Workshops for HRSG Dependability (051615)

Key Research Question

EPRI surveys indicate that focused workshops offer a significant benefit in HRSG availability to utility operators, chemistry staff, and maintenance staff. Improvements can be realized by understanding the influences of inadequate cycle chemistry, unidentified severe thermal transients, and effective inspections. Each of these areas has been addressed in other projects within the HRSG program.

Approach

This project offers workshops conducted regionally for key personnel involved in the design, operation and maintenance, and NDE of HRSGs. Workshops utilize materials resourced and updated from other program projects. Workshop modules will demonstrate ways that HRSG staff can proactively identify severe thermal transients and optimize cycle chemistry for each pressure cycle.

Impact

- Improve unit availability significantly.
- Reduce operations and maintenance costs via workshops that increase member awareness of the thermal and chemistry factors contributing to HRSG tube failure as well as effective inspection and repair techniques.

How to Apply Results

Attendance at HRSG workshops increases members' knowledge of research results that can meet their specific plant needs. Workshop information can be used to optimize the cycle chemistry in each pressure cycle, establish a monitoring program, or refine an existing program. Members can work with EPRI staff to identify which sections of an HRSG should be monitored and inspected with NDE techniques, and which available repair methods can be applied to mitigate damage.