

88 Heat Recovery Steam Generator (HRSG) Dependability

Program Overview

Program Description

This program provides a complete set of technical tools to improve the performance and reliability of combined-cycle HRSGs. 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, NDE options, welding, and other repair methods. Operator guidelines help monitor, identify, and minimize the effects of shutdown, startup, and thermal transients on fatigue life, and a diagnostic expert system helps control and maintain optimal chemistry. Regional workshops covering HRSG tube failure, cycle chemistry, inspection and flow-accelerated corrosion (FAC) effectively transfer the knowledge gained from this program.

Industry Needs and Issues Addressed

- 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 the cycle chemistry or thermal transients, are difficult to understand and mitigate.
- Limited access and other complexities make inspection and repair of HRSGs very difficult.

Impact

- Achieve tube failure rates consistent with a utility's 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

Key Accomplishments

- 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 the reasons for thermal transients and related analytical tools.
- Unique repair technology has been developed, as well as a revision to the interim nondestructive evaluation (NDE) guidelines to include case studies of visual techniques and technology transfer materials.

Current Year Objectives

- 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
- Development and demonstration of remote capabilities for internal inspection techniques
- Delivery of equipment for HRSG tube elbow replacement near headers
- Initial assessment of an internal coating technology for FAC protection

Industry Involvement

- Estimated 2009 funding: \$1.6M

Program Technical Lead

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Summary of Projects

Project Number	Project Title	Value
P88.001	HRSG Cycle Chemistry	Completion of a two-year study of an assessment technology for deposition in the high-pressure (HP) evaporators, which will involve circulation considerations. Additional work will summarize the potential for the use of organics in HRSGs.
P88.002	HRSG Tube Failures and Life Assessment	Continuation of six years of development of a comprehensive methodology to assess cycling capability. This includes optimizing startup in terms of thermal transients. The program will continue 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.
P88.003	HRSG NDE and Repair	Development and demonstration of internal inspection techniques with remote capability. The final equipment for HRSG tube elbow replacement near headers will be completed. An initial assessment of an internal coating technology will be made to provide protection against FAC.
P88.004	EPRI Workshops for HRSG Dependability	Technical transfer will be offered regionally to members of the HRSG Tube Failure Reduction/Cycle Chemistry Improvement Program and FAC and NDE programs.

Project Descriptions

P88.001 HRSG Cycle Chemistry (051612)

Issue

Heat recovery steam generator (HRSG) tube failures (HTF) are influenced/controlled by the cycle chemistry, which consists of flow-accelerated corrosion (FAC), 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.

Description

Reliable operation of combined cycle/HRSG units requires careful consideration of the cycle chemistry. EPRI already has 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 the high-pressure (HP) evaporator tubing. This will link closely with the nondestructive measurement of internal deposits in P88.003.

Value

- Significant reduction or management of chemistry-related generation losses in HRSGs.
- Improved unit availability and reduced operations and maintenance (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 the approximate costs. The content of the chemistry guidelines then can be used to identify specific actions needed to address these deficiencies, 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 measured by measuring progress against a rigorous set of performance metrics, consistent with the EPRI guidelines.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Final Assessment of Deposition in the HP Evaporator: The final assessment methodology for HP evaporators, this work will describe corrosion product transport from lower-pressure circuits and the effects of circulation ratio and geometry.	12/31/2009	Technical Report
Assessment of Organics in Combined Cycle HRSGs: International conferences in 2005 and 2008 on organics in steam-water cycles identified a number of concerns, as well as many potentially beneficial uses of organic-based treatment. Research will provide preliminary technical assessments of selected generic organic chemicals, focusing on single- and two-phase FAC, turbine performance, and corrosion in air-cooled condensers.	12/31/2009	Technical Report

Future Year 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 will include special tools to assess on-line deposition in HP evaporators, as well as corrosion sensors for each pressure cycle.	2010	Technical Report
Water Treatment Equipment for Combined-Cycle Plants: Makeup Systems: Development of special requirements for makeup of combined-cycle plants, in conjunction with EPRI Cycle Chemistry Program (P64).	2010	Technical Report
Monitoring and Controlling Carryover in HRSGs: Evaluation of the techniques used to minimize carryover and to 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.	2010	Technical Report

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

Issue

Heat recovery steam generator (HRSG) tube failures (HTF) are caused by flow-accelerated corrosion (FAC), 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.

Description

The program will complete 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.

Value

- Significant improvement in HRSG availability
- Operations and maintenance (O&M) cost reduction through reduced HTF

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 utilities in recommending design changes or improving specifications.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Final Model for Two-Phase FAC: The final model description for two-phase FAC, it will be sufficiently detailed to enable further development of EPRI software.	12/31/2009	Technical Report
Continuation of Drains Report: This technical update will address the effectiveness of drains system recommendations in preventing thermal fatigue damage of reheaters and superheaters.	12/31/2009	Technical Update
Guidelines for Automation of Controls: This technology update will assess the effectiveness of HRSG control systems and the impact of control systems on the thermal fatigue of major components. It will include a recommendation for additional research required to specify or design the automation of controls.	12/31/2009	Technical Update

Future Year Products

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 the tight tube spacing and fins.	2010	Technical Report

P88.003 HRSG NDE and Repair (055580)

Issue

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

Description

This project will deliver the final tube elbow replacement device described in a 2007 technical report. Work also will continue to develop an internal diameter delivery device that can be used to provide welding, repair, sampling, and NDE at distances up to 30 feet from the header. The NDE project will continue to develop and demonstrate internal examination techniques to address incipient damage.

Value

- Enhanced unit availability
- Reduced tube/header examination and repair times
- Fewer HTF
- Validation of damage assessment and models

How to Apply Results

The NDE Guidelines provide members with the tools and guidelines on the performance of nondestructive evaluation (NDE) 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 most likely will be commercialized through a third-party vendor, increasing the opportunity for members to deploy the device.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Prototype Internal Delivery Device for NDE and Deposit Assessment: The prototype will be built and tested in a laboratory HRSG mock-up and in a field HRSG.	12/31/2009	Hardware
Initial Results on Internal Coating: The feasibility of using magnetron sputtering will be tested on HRSG tube and elbow sections. This technique should be able to provide a high chromium layer to resist FAC.	12/31/2009	Technical Update
Revision 2. HRSG NDE Guideline: Revision 2 of the HRSG NDE Guideline will incorporate information from the 2008 Technical Update on NDE of drains and other HRSG components that have experienced premature failure.	12/31/2009	Technical Report

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Delivery Device for NDE and Deposit Assessment: This report will document the capabilities and functionality of the Internal Delivery Device developed in 2009.	2010	Technical Update
Advanced NDE Assessment: R&D for advanced NDE to address examination of additional HRSG components identified as potential failures will continue and be documented in this Technical Update report.	2010	Technical Update

P88.004 EPRI Workshops for HRSG Dependability (051615)

Issue

EPRI surveys indicate focused workshops offer a major benefit in heat recovery steam generators (HRSGs) availability to utility operators, chemistry, and maintenance staffs. Improvements can be realized by understanding the influences of inadequate cycle chemistry, non-identified severe thermal transients, and effective inspections. Each of these areas has been addressed in the other projects of the HRSG program.

Description

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 the other program projects. The workshop modules will demonstrate ways HRSG staff can proactively identify severe thermal transients and optimize the cycle chemistry for each pressure cycle.

Value

- Significant unit availability improvements
- Operations and maintenance (O&M) cost reductions via workshops that increase member awareness of the thermal and chemistry factors contributing to HRSG tube failure (HTF) and effective inspection and repair techniques.

How to Apply Results

Attendance at the HRSG workshops increases members' knowledge of the research results that can meet their own, specific plant needs. Workshop information can be used to optimize the cycle chemistry in each pressure cycle, establish a monitoring program, or make refinements to 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.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
HRSG Tube Failure Reduction/Cycle Chemistry Improvement Program (HTFRP/CCIP): The HTFRP/CCIP workshops are provided to members on a regional basis, optimizing resources and exposing larger audiences to the workshop materials.	12/31/2009	Technical Resource

Product Title & Description	Planned Completion Date	Product Type
Workshop for NDE and Repair: Workshops for NDE and repair are available to members on a regional basis, optimizing resources and exposing larger audiences to the workshop materials. This workshop can be offered as or as part of the HTFRP/CCIP regional workshop.	12/31/2009	Workshop, Training, or Conference
