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 of 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.
- EPRI has developed a troubleshooting guide that, through a group of 57 questions, can help identify whether and which underlying causes (or both) of thermal transients are present in the operating practices or in the design of the HRSG.
- 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 2012 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 HRSG Tube Failures (HTFs)
- Technology to assess control of steamside deposition
- Case studies and development of HRSG life assessment tools and methodologies
- Further development and demonstration of remote capabilities for external inspection techniques
- Exploration of technology for organics treatment

Estimated 2012 Program Funding

$1.5M

Program Manager

Bill Carson, 704-595-2698, bcarson@epri.com

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 (FAC), underdeposit 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 already has developed guidelines for complete cycle chemistry, shutdown and lay-up, and chemical cleaning. The next steps will address the chemistry during startups and the deposition process in high-pressure evaporator tubing. This effort 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.

2012 Products

Product Title & Description	Planned Completion Date	Product Type
Deposition Processes & Mechanisms in Heat Recovery Steam Generators (HRSGs): The research for this project is anticipated to identify mechanisms contributing to the deposit formation and morphology. It models the deposit growth, maturation, and accumulation of contaminants leading to under-deposit damage, and confirms deposition and mechanics in a simulated environment test autoclave with heated electrochemical corrosion potential (ECP) probe. This project is conducted in conjunction with Program 64 (Boiler and Turbine Steam and Cycle Chemistry).	12/31/12	Technical Update
Additional Research Into 2-Phase FAC: This project uses laboratory simulation to evaluate methods for mitigating two-phase FAC such as steamside of feedwater heaters and drain lines and HRSG low-pressure (LP) economizer evaporator tubes. This project is conducted in conjunction with Program 64.	12/31/12	Technical Update
In-Situ Monitoring: The purpose of the project is to evaluate linear polarization resistance (LPR) corrosion probes as part of alternative layup techniques. This project is conducted in conjunction with Program 64.	12/31/12	Technical Update

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. There is a growing concern, however, that HRSG components will approach end-of-life sooner than expected or seen in conventional boilers. As a result, HRSG owners and operators need to be able to quickly and economically assess the health of major HRSG components.

Approach

The program will begin development of a predictive methodology for HRSG component life assessment. Work will continue on development and validation of research on HRSG pressure-part, thermal transient limits and mitigation, and research will be able to factor in how the operation of the unit affects the life calculation, inspections, and testing requirements.

Impact

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

How to Apply Results

The end-of-life methodology should help HRSG owners determine when inspections should occur, what types of inspection/testing are needed, and how to plan for replacement or repairs. The approach will take into account the previous years' work on thermal transient, cycling, and design issues.

2012 Products

Product Title & Description	Planned Completion Date	Product Type
Development of HRSG Dew-Point Deposition on Back-End Pre-Heater and Economizer Tubing Guideline: Back-end corrosion continues to be a nuisance to the HRSG operator. It has not yet been determined to cause concern, but there is a growing interest in how it affects the performance and what is needed to clean the tubing. This is a follow-up to the work that will be done in 2011 to clean the deposits once formed. The 2012 project will study the long-term effects of the deposits and, if needed, eliminate the formation of the deposits on the tubing. A possible approach could be to coat the tubes with ceramic and examine how effective the coating is for deposit shedding.	12/31/12	Technical Update
Development of HRSG Component Life-Assessment Document: This project is to develop life-management strategies for HRSGs. This will include piping and the specific challenges related to cycling and high-temperature damage (creep). It also looks to provide templates for performing key maintenance activities using either in-house staff or contractors to increase overall awareness of issues and solutions.	12/31/12	Technical Update
"Used" HRSG Purchase Specification: Many companies are looking for “on the ground” HRSGs to supplement their generation portfolios. This oftentimes is an economical alternative to the difficult and time-consuming development, permitting, and construction for a new build. This report will provide the questions to ask when performing due diligence, utilizing the many reports, projects Program 88 has prepared.	12/31/12	Technical Update

Product Title & Description	Planned Completion Date	Product Type
HRSG Material Selection Guideline Update: The existing guidelines provide present an excellent overview of a broad range of HRSG components, but offer limited information on the detailed materials selection process for specific HRSG components, especially for new HRSG designs with steam temperatures approaching 1100 degrees F (590 degrees C). To stay current with the anticipated new advanced materials and operating ranges, this project will update the existing materials guideline.	12/31/12	Technical Update
Guideline for Converting Baseload-Designed HRSG Into Cycling Service: Most HRSG units are operating outside their design. It has been shown that cycling service from economic and environmental issues can expose the baseload-designed units to new damage, affecting the availability of the unit. This project would examine the cost and projects needed to convert a unit from baseload to cycling service.	12/31/12	Technical Report

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Document Formalized Plans for Life-Management Guide to Include Tubes and Larger Components: With the HRSG fleet aging, it becomes necessary to develop a proactive approach for life management. This project is expected to draw on information and technology already developed and apply it to the HRSG fleet.	12/31/13	Technical Update
Inspection Guideline for Life-Assessments of a HRSG: As the HRSG fleet ages, it is important to have a process to determine when to inspect, what to inspect, and how often to stay out in front of an availability loss. This project would help to assess the damage mechanisms before they become detrimental to the availability of the units.	12/31/13	Technical Update

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 technologies 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 continue to explore the 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 procedures to perform and where to perform them. These tools and guidelines are especially useful during HRSG tube failures and outages, because they provide 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 developed through this program most likely will be commercialized through a third-party vendor, increasing opportunities for members to deploy the device.

2012 Products

Product Title & Description	Planned Completion Date	Product Type
Continued Development of Snake Robot Technology: This project will continue the work with Carnegie Mellon University on developing the snake robot technology for inspections in hard-to-reach areas and on attaching additional tooling to the robot.	12/31/12	Hardware
Southwest Research Institute Tube-to-Header Flexible Eddy Current Probe that can be Attached to a Robotic Delivery System.: This project is to attach the technology already available to the industry to a robotic delivery system. Due to the tight tubing arrangement, a remote or robotic delivery system would benefit the industry in proactively identifying internal cracking in areas that currently are inaccessible.	12/31/12	Hardware
Enhanced Development of NDE System for Inspection of Finned Tubing: Although very few failures have been experienced within the finned tube area, it is anticipated that that this problem will grow. Very few tube samples have been taken, due to the complexity and tight arrangement of the HRSG tubing. If corrosion is experienced, there is significant wall reduction in the HRSG tubing, and early detection of wall loss is necessary to achieve maximum availability. This project will assist operators of HRSG in early detection of tube wall loss.	12/31/12	Hardware

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 demonstrate ways that HRSG operators 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.