

## **64 Boiler and Turbine Steam and Cycle Chemistry**

### **Program Overview**

#### **Program Description**

This program offers guidelines, technology, and training materials to help plant operators manage water-steam chemistry, reduce unplanned outages and operations and maintenance (O&M) costs, and improve unit profitability. Cycle chemistry guidelines, technologies, and workshops support efforts to minimize operating risks associated with corrosion and deposition. Technical tools developed through this program include unit-specific chemical treatment methods, operating limits, and monitoring guidelines to improve plant availability, efficiency, and startup times.

#### **Industry Needs and Issues Addressed**

- Minimize major causes of availability and associated maintenance costs related to corrosion and inadequate cycle chemistry
- Prevent boiler tube and turbine blade/disc failures and flow-accelerated corrosion (FAC)

#### **Impact**

- Improve overall unit availability by 1% or more
- Reduce steam turbine efficiency losses due to deposits by up to 2%
- Reduce chemistry-related boiler tube failures
- Reduce chemistry-related O&M costs
- Improve world-class or excellent cycle chemistry

#### **Key Accomplishments**

- Complete set of cycle chemistry guidelines for all fossil plants and cycle chemistry treatments
- Model for the corrosion processes in the phase transition zone (PTZ) of steam turbines
- Model for the corrosion and deposition process in boiler waterwalls
- Benchmarking processes to assess plant or system chemistries

#### **Current Year Objectives**

- Chemistry management guidelines, technologies, and workshop materials for plant owners and operators
- Quantitative assessment of boiler and steam turbine corrosion processes
- On-line in situ instrumentation to monitor the plant cycle

#### **Industry Involvement**

- Estimated 2009 funding: \$4.0M

#### **Program Technical Lead**

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## Summary of Projects

Project Number	Project Title	Value
P64.001	Updated Guidelines for All Cycle Chemistries	Comprehensive guidelines for chemists and operators that address every aspect of fossil plant cycle chemistry, identify important decision factors, define treatment operating parameters, provide cost-benefit evaluation methodologies, and detail methods for customizing treatments for specific units.
P64.002	Cycle Chemistry Guides to Control Corrosion of Turbine Materials in the Phase Transition Zone	Effective solutions to prevent blade and disc rim cracking in the phase transition zone (PTZ) of steam turbines, plus the associated monitoring instrumentation.
P64.003	Guide to Reduce Deposition Around the Cycle	Information about deposition processes in fossil cycles to improve unit availability and efficiency, reduce risk of corrosion, and minimize maintenance cleaning activity.
P64.004	Feedwater Filtration Technology	Expansion and improvement of options available for purification of feedwater in fossil plant cycles, including simplifying designs and minimizing costs and wastes to broaden and optimize its application in fossil plants.
P64.005	Cycle Chemistry Instrumentation, Control and Monitoring	Improved cycle chemistry methods that allow direct measurement of corrosion activity throughout the steam-water cycles of fossil units.
P64.006	Guides to Control Boiler Corrosion	Determination of precise chemistry environment under which waterside corrosion initiates, to develop improved chemistry guidelines and prevention strategies as well as actions needed to avoid contamination of boiler water.
P64.007	EPRI Workshops for Cycle Chemistry Improvement (CCIP), Condensate Polishing, FAC Control and Condenser Tube Failure Prevention	Enhanced understanding and optimal plant use of key EPRI products through technology transfer activities conducted by EPRI staff at member facilities.

## Project Descriptions

### P64.001 Updated Guidelines for All Cycle Chemistries (100505)

#### Issue

Cycle chemistry program deficiencies at the organizational and plant levels directly and negatively affect fossil plant unit availability, reliability, and performance.

#### Description

This project is dedicated to establishing state-of-the-art guidelines for use by fossil plant chemists and operators worldwide. EPRI benchmarking activities have demonstrated the value of good chemistry to those plants and organizations with programs rated as world-class or very good. This suite of guidelines addresses the critical aspects of fossil plant cycle chemistry and encompasses five boiler chemistry treatments, three feedwater treatments, shutdown/startup/layup, condensate polishing, makeup, instrumentation and control, chemical cleaning, copper, and flow-accelerated corrosion (FAC). The guidelines are applicable to all fossil plant designs. A new guideline produced in 2007 provides chemistry guidance for designing and operating new fossil plants for high reliability by incorporating essential

features needed to avoid chemistry-related boiler tube failure (BTF) and corrosion failures in the PTZ of steam turbines and FAC. The key chemistry guidelines are continuously improved using the results from other program projects, findings of Technology Innovation activities, and experience of the program members. Major planned activities include deriving boiler corrosion control limits, understanding deposition in the boiler, and developing on-line instrumentation for boiler and turbine corrosion.

#### Value

- Improve fossil unit availability.
- Eliminate chemistry-related damage in boilers and turbines.
- Reduce levels of maintenance activities compared to those required with deficient chemistry.

#### How to Apply Results

Members can benchmark their chemistry programs independently or in collaboration with EPRI staff to identify areas of deficiency and determine the approximate costs (lost value). The content of the various guidelines then can be used to identify specific actions needed to address these deficiencies. For example, the chemistry guidelines can be consulted to verify proper selection and optimization of feedwater and boiler water chemistry used in individual fossil units. The benchmarking process should be repeated periodically as a means of checking the overall effect of improvements.

#### 2009 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Assessment of Organics in the Fossil Plant:</b> International conferences on organics in steam-water cycles in 2005 and 2008 identified a number of concerns as well as many potentially beneficial uses of organic-based treatment. Research activity will make preliminary technical assessments of selected generic organic chemicals, including polyamines, for beneficial use.	12/31/2009	Technical Report
<b>Chemical Cleaning of Supercritical Boilers:</b> Research conducted in 2007 and 2008 will be the basis for development of an assessment methodology of the oxides that grow on the internal diameter of supercritical walls. A new chemical cleaning procedure will be developed for the efficient, safe, and economic removal of these oxides.	12/31/2009	Technical Report
<b>Feedwater Heater Tube Failure Manual:</b> A feedwater heater tube failure manual will be developed in the format of other EPRI manuals on boiler tube failures and condenser tube failures. This is a joint project with Program 88.	12/31/2009	Technical Report

#### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Short-Term Protection for Fossil Plant Components:</b> The last version of the guidelines for all-volatile treatment (AVT), produced in 2002, will be reviewed and revised as necessary to reflect research in boiler corrosion, steam turbine corrosion, deposition, chemistry instrumentation and monitoring, and related issues.	2010	Technical Report

Product Title & Description	Planned Completion Date	Product Type
<b>Revised AVT Guidelines:</b> Findings of ongoing and future work in fossil plant shutdown, including measures for protection of various water- and steam-touched components, will be reviewed, and a guidance document developed for use by plant technical, operations, and maintenance personnel.	2010	Technical Report

## P64.002 Cycle Chemistry Guides to Control Corrosion of Turbine Materials in the Phase Transition Zone (100508)

### Issue

Since the early 1990s, incidents of turbine blade and disc rim cracking due to corrosion fatigue and stress corrosion cracking in the phase transition zone (PTZ) have increased, causing unit availability losses and plant maintenance costs to rise significantly. Based on a decade of EPRI Technology Innovation work and six years of work through Program 64, a deterministic model of the corrosion process in the PTZ was developed. This model now is being developed as an EPRI software code for failure analysis and prediction.

### Description

The model considers system variables such as the steam chemistry environment, liquid film composition and electrochemical properties, stress, temperature, and conductivity. In 2006, additional project activity sponsored by Programs 64 and 65 began to develop a new EPRI code for "Corrosion in the PTZ." This work involves validating the interim model with case studies, then fine-tuning it using the results of corrosion tests conducted in liquid films and crevice environments to determine the pitting potential on the blade/disk surfaces.

This work involves further development, including derivation of the necessary evolutionary path algorithms for the chemistry and operation, and field testing of EPRI's Steam Sensor to supply on-line information for the PTZ code. Data resulting from this work will be used to refine the model and provide plant owners, engineers, operators, and chemists with the guidance and tools to optimize the turbine operation and steam environment, control corrosion of the turbine material in the PTZ, and assess life predictions and maintenance schedules. Important research findings also will be incorporated in future versions of the key EPRI Chemistry Guidelines (64.001) and Workshop (64.007) materials.

EPRI international conferences on organics in 2005 and 2008 identified two areas that will be addressed in this project: 1) assessment of new organic/amine chemicals that, according to earlier EPRI studies, could improve steam condensation and liquid film processes in low-pressure (LP) turbine exhausts, thereby boosting efficiency; and 2) assessment of organic treatments for shutdown and layup protection.

### Value

- Minimize the risk of stress corrosion cracking and corrosion fatigue damage to steam turbines.
- Improve steam turbine availability.
- Reduce future steam turbine maintenance costs by avoiding chemistry-related damage and failures.
- Improve LP turbine efficiency.

### How to Apply Results

Members can apply the turbine damage model development work to assess risk levels in all steam turbines and identify actions needed to reduce or prevent further increases in risk levels. Data pertaining to past failure incidents could be reviewed in collaboration with EPRI for possible uploading to the model. Installation of the instrumentation now under development on working steam turbines can provide real-time indications of environmental conditions in which turbine damage is active and significant. Members using the application of new chemical treatment processes or chemicals such as polyamines might realize substantial improvement in efficiency, if not power production, in the LP region of the steam turbine.

### 2009 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Corrosion Control and Life Predictions within the Steam Turbine PTZ:</b> The EPRI model and PTZ sensor validation will be used to describe the conditions and control environment necessary for optimizing corrosion control and to provide tools for scheduling equipment inspections and maintenance.	12/31/2009	Technical Update

### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Assessment of Organics/Amines in Increasing Turbine Efficiency:</b> A technical report describing findings of primary research directed at assessing the application of selected generic organic amines to improve steam turbine efficiency, as well as other amine properties that could affect other aspects of cycle chemistry.	2010	Technical Report

## P64.003 Guide to Reduce Deposition Around the Cycle (100509)

### Issue

Despite its critical influence on plant efficiency and availability, deposition of oxides and impurities around the fossil plant fluid cycle is not completely understood. Better knowledge of deposition on boiler waterwalls and steam turbines could improve fossil unit availability and performance. This is of concern because deposits are a precursor to a number of chemistry-related damage mechanisms. Deposits also have a detrimental impact on component efficiency and performance. Deposition information is required for each major plant component around the cycle. EPRI has compiled scientific and plant-based knowledge, and conducted initial basic laboratory and field studies, to understand and reduce deposition on turbine blades. Maintenance cleaning activity to remove deposited material increases unit operating costs and extends the interval of unit outages.

### Description

This project has conducted laboratory studies on a high heat flux deposition rig to simulate boiler water containing iron and copper oxides under oxidizing and reducing conditions. Over the past two years, work has been conducted to better understand the structure of drum boiler waterwall deposits to support ongoing efforts to construct a deterministic model.

Planned work will evaluate, validate, and revise the model. Deposition in steam turbines, feedwater, and condensate systems also will be addressed, and local material solutions developed. Copper deposition in some high-pressure turbines remains a problem, which will continue to be addressed in case studies as requested by members.

### Value

- Improve cycle chemistry guidelines through a better scientific understanding of corrosion and deposition in fossil units.
- Improve guidelines for determining when to chemically clean boilers.
- Apply improved guidance to avoiding deposition-related performance losses in steam turbines.
- Apply scientifically sound approach to defining boiler chemistry and deposition limits.

### How to Apply Results

The results of this work will be incorporated into the next series of EPRI guidelines, which utilities can use to identify the specific actions needed to address deficiencies consistent with individual unit characteristics. For example, the chemistry guidelines can be consulted to verify proper selection and optimization of feedwater and boiler water chemistry used in individual fossil units.

### 2009 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Chemical Environment within Porous Deposits:</b> The EPRI Boiler Deposition Model will be used to evaluate expected chemical conditions of the fluid within porous deposits. This evaluation will define conditions under which the following will develop: corrosion of tube metal and infilling of deposit pores due to precipitation of solids. Conditional changes identified would be unique to each set of individual unit deposit and chemistry conditions.	12/31/2009	Technical Report
<b>Deposition Rig Studies to Validate EPRI Model:</b> Deposition experiments will be conducted using a deposition facility used previously in the EPRI studies to validate the predictions of the EPRI model.	12/31/2009	Technical Report

### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Final Deposition Model for Waterwalls of Drum Boilers:</b> The EPRI model will be finalized following in-field and laboratory validations. Information from the model will provide the basis for matrix-based operational guidance for the management of boiler deposits.	2010	Technical Report

## P64.004 Feedwater Filtration Technology (046583)

### Issue

Essentially all of the material in boiler waterwall deposits consists of particulates in the form of metal oxides transported from the feedwater. Oxide transport is of particular concern in units that cycle or in which the cycle chemistry has not been fully optimized. A scoping study of feedwater filtration technology was conducted as a Technology Innovation activity in 2006. An assessment of field experience with

condensate filters in fossil plants was conducted in 2007. These studies confirmed that applying filtration technology is a means of removing solids from feedwater before it reaches the boiler, but the knowledge base available to end-users is deficient. Planned studies in 2008 identify filtration performance and assessment of the value of filtration.

**Description**

The ultimate goal of the project is to develop user guidelines for assessing, selecting, justifying, and operating filtration systems. To produce the guidelines, filter particulate removal must be evaluated in the context of the feedwater present in fossil units; economic justification of filters needs to be evaluated, and a methodology must be developed for users to determine the value of a filtration system consistent with their technical and financial requirements.

**Value**

- Reduce metal oxide transport to boilers.
- Extend time interval between boiler cleanings.
- Reduce efficiency losses associated with boiler tube deposits.
- Eliminate boiler corrosion and boiler tube failures associated with boiler tube deposits.

**How to Apply Results**

The Fossil Plant Feedwater Guidelines can be used by members for technical evaluations of filtration requirements and to appraise system performance. Value assessment methodologies then can be applied to project the savings from system installation.

**2009 Products**

Product Title & Description	Planned Completion Date	Product Type
<b>Fossil Plant Feedwater Guidelines:</b> The guidelines will provide comprehensive information of interest to end users on fossil plant feedwater filtration. Topics to be covered include technology options, performance characteristics, field experience, costs, and benefits.	12/31/2009	Technical Report

**Future Year Products**

Product Title & Description	Planned Completion Date	Product Type
<b>Innovation in Fossil Plant Filtration: Application of Nanotube Technology:</b> Carbon nanotube technology provides filtration of water at the molecular level, eliminating particulate and chemical contaminants. The filtration rate, low pressure drop, and the high temperature tolerance of carbon nanotubes are attractive for application to feedwater cycles. This project will explore innovative techniques to incorporate the technology in power plant applications.	2010	Technical Report

## P64.005 Cycle Chemistry Instrumentation, Control and Monitoring (062000)

### Issue

Long-term fossil unit availability requires effective control of cycle chemistry. On-line monitoring provides the most comprehensive approach to surveillance and control. Automated approaches to chemistry control are increasingly important in older plants and plants with reduced staff size and experience. Water chemistry analyzers typically require care and attention to ensure that suitably conditioned samples are provided and that precision and bias errors associated with instrument use are recognized and minimized. Instrumentation provides a characterization of the chemistry environment of bulk fluid conditions. Comparison of measured chemistry readings to target values and action levels provides a useful—though indirect—assessment of the risk of damage to components touched by water and steam. Research is needed for the development of both instrumentation and validation of instrumentation results that provide direct indications to operators of the impacts of the chemistry.

### Description

EPRI's designated core level of instrumentation provides adequate surveillance and control, although it is recognized that many organizations find it difficult to provide and maintain the levels of instrumentation indicated in current guidelines. This project will ensure the quality of the data provided by the instruments.

Available monitoring methods provide only indirect indications of corrosion, corrosion product transport, and deposition activity. Methods that could provide direct assessments of chemical activity and could be used to help plan inspection, sampling, and maintenance activities such as chemical cleaning would be more useful tools. A cycle chemistry instrumentation and control state-of-knowledge report was completed in 2007. This follow-up will examine research for chemistry surveillance technology advances consistent with plant needs. Future work will address chemistry instrumentation and control needs for protection of various cycle components.

### Value

- Ensure reliable operation of existing chemistry instrumentation.
- Provide validation for new and existing monitoring methods.
- Understand instrumentation requirements to support future chemistry guidelines.
- Improve the basis for chemistry control instrumentation improvements.

### How to Apply Results

Chemistry surveillance technology development can allow members to make knowledgeable decisions about the right chemistry instrumentation and controls to protect various cycle components and improve current plant operations.

### 2009 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Corrosion Product Transport Monitoring:</b> This project will assess available methods for determining corrosion product transport. The focus will be on methods to continuously monitor the transport activity and validation of the accuracy of the information provided. Methods will be compared with existing methodology and simulated and actual field tests. The project will assess available and other potentially useful methods for monitoring corrosion and deposition in fossil units. Work will concentrate on components such as condensers, feedwater heaters, deaerators, and piping.	12/31/2009	Technical Report

Product Title & Description	Planned Completion Date	Product Type
<b>Water Chemistry Instrumentation Data Quality:</b> Plant operators need reliable data to ensure that water chemistry analyzers are working correctly. This project would provide a comprehensive investigation of the subject.	12/31/2009	Technical Report

### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Water Chemistry Instrumentation Data Quality:</b> Plant operators need reliable data to ensure that water chemistry analyzers are working correctly. This project would provide a comprehensive investigation of the subject.	2010	Technical Report

## P64.006 Guides to Control Boiler Corrosion (058176)

### Issue

Boiler waterwall internal corrosion is the leading corrosion-related cost in the fossil industry. EPRI issued a revised set of treatment guidelines in 2002 and 2005. In each of these, boiler water corrosion control was based on cation conductivity, which has pragmatically been shown to minimize corrosion without providing a direct indicator of the corrosion process.

### Description

Since 2006, this project has measured boiler corrosion under simulated boiler corrosion conditions using all-volatile treatment (AVT) and phosphate continuum (PC) with levels of chloride contamination. Continuing work will address caustic treatment (CT) and oxygenated treatment (OT). For the first time, EPRI will determine action levels to prevent corrosion and incorporate them in the next revisions of the operating guidelines (P64.001). The final step in developing more realistic boiler water contaminant control curves will be to use the limits derived in this project in the final deposition rig tests (P64.003).

### Value

- Reduce major O&M costs.
- Establish probabilistic risk associated with boiler waterwall corrosion.
- Improve reliability by minimizing or eliminating internal boiler waterwall corrosion in drum boilers.
- Apply scientific basis to boiler chemistry control guidelines.

### How to Apply Results

Members can use the guidelines to identify specific actions needed to address deficiencies consistent with individual unit characteristics. For example, the guides to control boiler corrosion will help members improve reliability by using suggested actions to minimize or eliminate internal boiler waterwall corrosion in drum boilers.

## 2009 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Interim Boiler Corrosion in Deposition Environments:</b> Once the control curves have been developed in nondeposition environments, a series of tests will be conducted in a deposition apparatus, from which EPRI will derive a set of control curves under realistic boiler conditions.	12/31/2009	Technical Report

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Boiler Corrosion Guideline Limits:</b> A new set of EPRI guideline limits will be derived for boiler water under all the chemistry treatments, once the results are available from the deposition rig.	2010	Technical Report

## P64.007 EPRI Workshops for Cycle Chemistry Improvement (CCIP), Condensate Polishing, FAC Control and Condenser Tube Failure Prevention (060369)

### Issue

EPRI surveys indicate workshops provide a major benefit in cycle chemistry technology transfer of knowledge and practical application experience with developing cycle chemistry programs to utility operations, chemistry, maintenance, and management staff.

### Description

This project offers four workshops that can be conducted regionally in association with EPRI Program User's or Interest Group Meetings, or others based on interest. Each workshop includes the EPRI benchmarking processes to document on-going improvements:

- Cycle Chemistry Improvement—to optimize boiler water, feedwater, and steam.
- Condensate Polishing—to provide the basic and advanced topics of polishing.
- Flow-Accelerated Corrosion (FAC): Conducted in conjunction with Programs 63 and 88—to develop a complete, management-supported FAC program, nondestructive examination (NDE) techniques, and predictive tools.
- Condenser Tube Failure Control: Joint activity with Program 87—provides improved management of condenser tubes.

This project also supports a tri-annual International Conference on Cycle Chemistry.

### Value

- Significantly improve unit availability and performance through optimization of cycle chemistry, condensate polishing, FAC, boiler and condenser tube failures.
- Receive unparalleled practical knowledge and understanding of the scientific basis of significant cycle chemistry processes and corrosion mechanisms.

### How to Apply Results

Each member will customize the EPRI approach to its plant using the guidelines and reports provided as workshop resources.

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**2009 Products**

Product Title & Description	Planned Completion Date	Product Type
<b>Condensate Polishing Improvement Program:</b> Workshops on condensate polishing will be conducted regionally in association with EPRI program user or interest group meetings, or others based on interest.	12/31/2009	Workshop, Training, or Conference
<b>Cycle Chemistry Improvement Program:</b> Workshops on cycle chemistry will be conducted regionally in association with EPRI program user or interest group meetings, or others based on interest. One-day workshops are held in classroom format.	12/31/2009	Workshop, Training, or Conference
<b>FAC Training Program:</b> Workshops on flow-accelerated corrosion (FAC) will be conducted regionally in association with EPRI program user or interest group meetings, or others based on interest. One to one-and-one-half-day workshops are held in classroom format.	12/31/2009	Workshop, Training, or Conference
<b>Condenser Tube Failure Control Program:</b> Workshops on Condenser Tube Failure will be conducted regionally in association with EPRI Program User's or Interest Group Meetings, or others based on interest. One to one-and-one-half-day workshops are held in classroom format.	12/31/2009	Workshop, Training, or Conference
<b>International Conference on Cycle Chemistry:</b> The 9 <sup>th</sup> International Conference on Cycle Chemistry in Fossil and Combined Cycle Plants with Heat Recovery Steam Generation is open to EPRI members and international participants. Topics of technological interest are presented over three days, with one-day workshops preceding and following the conference.	7/31/2009	Workshop, Training, or Conference

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