

## Boiler and Turbine Steam and Cycle Chemistry - Program 64

### Program Overview

#### Program Description

Safety and availability loss due to failures are two key issues driving R&D on major fossil power plant components, especially in older plants. Operators need to minimize major causes of lost availability and associated maintenance costs related to corrosion and inadequate cycle chemistry, and prevent boiler tube and turbine blade/disc failures and flow-accelerated corrosion (FAC).

The Electric Power Research Institute's (EPRI's) Boiler and Turbine Steam and Cycle Chemistry Program (Program 64) 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.

#### Research Value

Utilities need to balance the risks and costs of the largest, most costly equipment, and focus on using proven technologies to create solutions. By using the results of the R&D in this program, members can:

- Improve overall unit availability — losses due to improper chemistry have a 1% or more effect on unit availability
- Reduce steam turbine efficiency losses — chemical and metallic oxide deposits reduce turbine efficiencies by up to 2%
- Reduce chemistry-related boiler tube failures
- Reduce chemistry-related O&M costs
- Improve world-class or excellent cycle chemistry

#### Approach

Cycle chemistry guidelines, technologies, and training materials 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.

- Cycle chemistry guidelines and technology address the critical aspects of fossil plant cycle chemistry and are applicable to all plant designs. They cover boiler and feedwater treatments, shutdown/startup/layup, condensate polishing, makeup, instrumentation, chemical cleaning, copper, air cooled condensers, and FAC. 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).
- Cycle chemistry and corrosion control in the Phase Transition Zone (PTZ) provides a deterministic model to control the corrosion process of turbine materials in the PTZ. This model is now being developed as an EPRI software code for failure analysis and prediction. The model considers system variables such as the steam environment, liquid film composition, stress, and temperature. Monitoring and treatment of the early condensate environment provide reduction of the active corrosion and opportunities to improve thermodynamic efficiency. 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 or enhance conditions in the PTZ.
- Deposition in water and steam cycles addresses deposition concerns for each major plant component. Scientific and plant-based knowledge, combined with basic laboratory and field studies, provides probabilistic risk models for assessing the impact of deposits and a maintenance cleaning activity model for removing deposited material. Utilities can use the guide to identify the specific actions needed to address deficiencies consistent with individual unit characteristics.

- Feedwater filtration and condensate polishing technology R&D develops user guidelines for assessing, selecting, justifying, and operating condensate polishing and filtration systems used to remove dissolved and suspended solids from feedwater, ensuring continual high purity of the water/steam cycle. Maintenance of high purity is essential for reducing corrosion and deposition in the cycle. Fossil Plant Feedwater Guidelines can be used by members for technical evaluations of polishing and filtration requirements and to appraise system performance.
- Cycle chemistry instrumentation, control, and monitoring develop instrumentation and validate instrumentation results needed for on-line monitoring, which provides the most comprehensive approach to surveillance and control, especially in older plants and plants with reduced staff size and experience. Chemistry surveillance technology can allow members to make knowledgeable decisions about the right chemistry instrumentation and controls to protect various cycle components and improve current plant operations.
- Research involving corrosion in the boiler and water/steam cycle uses scientifically based criteria to determine action levels to prevent boiler corrosion and identifies specific actions needed to address deficiencies leading to flow accelerated corrosion in high energy piping and air-cooled condensers. Members can use the guidelines developed from these activities to identify specific actions needed to address deficiencies consistent with individual unit characteristics.

### Accomplishments

Cycle chemistry guidelines, technologies, and training materials 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. Recent accomplishments include:

- 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
- Advancement in the understanding of high-temperature oxides in supercritical waterwall tubes
- Interim guidelines to address air-cooled condensers
- Benchmarking processes to assess plant or system chemistries

### Current Year Activities

The program R&D for 2010 will focus on reducing corrosion damage associated with FAC and boiler deposits. Specific efforts will include:

- Guidelines and assessment of amine treatment technologies
- Quantitative assessment of boiler, steam turbine, and air-cooled condenser corrosion processes
- Probabilistic risk assessment model of corrosion and deposition environments
- Online and *in situ* instrumentation to monitor the plant cycle
- Management of data quality and validation

### Estimated 2010 Program Funding

\$2.5M

### Program Manager

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## Summary of Projects

Project Number	Project Title	Description
P64.001	Cycle Chemistry Guidelines and Technology	This project provides a comprehensive suite of guidelines addressing the critical aspects of fossil plant cycle chemistry and encompassing boiler and feedwater chemistry treatments, transient operating and outage conditioning, chemical cleaning, condensate polishing, makeup water treatment, instrumentation and control, copper metallurgy, and flow-accelerated corrosion (FAC).
P64.002	Cycle Chemistry and Corrosion Control of Turbine Materials in the Phase Transition Zone	This project develops modeling, technologies, and processes to reduce turbine blade and disc rim cracking due to corrosion fatigue and stress corrosion cracking in the phase transition zone (PTZ).
P64.003	Deposition in the Water/Steam Cycle	This project develops information and technologies to understand and reduce deposition on turbine blades and in feedwater and condensate systems.
P64.004	Feedwater Filtration and Condensate Polishing Technology	This project continues research to develop guidelines for selection of technologies to address the optimization of condensate and feedwater quality and purification.
P64.005	Cycle Chemistry Instrumentation, Control and Monitoring	This project develops new methods and technologies for monitoring of cycle chemistry, corrosion, corrosion product transport, and deposition activity.
P64.006	Corrosion in the Boiler and Water/Steam Cycle	This project examines boiler corrosion under a variety of operating conditions to discover causes and develop methods to prevent corrosion and incorporate them in operating guidelines.

### P64.001 Cycle Chemistry Guidelines and Technology (069176)

#### Key Research Question

Cycle chemistry program deficiencies at the organizational and plant levels directly and negatively affect fossil plant unit availability, reliability, and performance. Flow-accelerated corrosion (FAC) and boiler corrosion fatigue (CF) damage mechanisms from improper chemical control are major safety concerns as well as a source of equipment failures. EPRI surveys indicate guidance in the proper application and the transfer of knowledge of cycle chemistry technologies provide a major benefit to utility operations, chemistry, maintenance, engineering, and management staff in the development of efficient and effective cycle chemistry programs.

#### Approach

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 comprehensive suite of guidelines addresses the critical aspects of fossil plant cycle chemistry and encompass boiler and feedwater chemistry treatments, transient operating and outage conditioning, chemical cleaning, condensate polishing, makeup water treatment, instrumentation and control, copper metallurgy, and flow-accelerated corrosion (FAC). The guidelines are applicable to all fossil plant designs, including 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.

Technology advances address the key damage and failure mechanisms in water-cooled and air-cooled condensers and feedwater heaters. 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, assessing alternative treatments with organic amines, understanding the corrosion processes in air-cooled condensers and developing on-line instrumentation for boiler and turbine corrosion. This project provides training materials to support the development of cycle chemistry programs to specifically address:

- Cycle chemistry improvement: to optimize boiler, feedwater, and steam chemistries.
- Flow-accelerated corrosion (FAC): to mitigate/eliminate this damage mechanism, which is a major safety concern.
- Condenser and heater tube failure control.

This project also supports a tri-annual International Conference on Cycle Chemistry, as well as other conferences, seminars, and member user groups.

### Impact

- Significantly improve fossil unit availability and performance.
- Eliminate chemistry-related damage in boilers and turbines.
- Reduce levels of maintenance activities compared to those required with deficient chemistry.
- 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 specific plants and units using the guidelines and reports provided as resources. 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 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 or other means of unit assessment should be repeated periodically as a means of checking the overall effect of improvements.

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Guidelines for Makeup Water Treatment - Revision 2:</b> The last version of the guidelines for makeup (high-purity demineralized water), produced in 1999, will be reviewed and revised as necessary to reflect research in permeable membrane, ion exchange, chemistry instrumentation and monitoring, and related issues. Rising chemical costs and environmental discharge limitations will be addressed. Pretreatments using ultra-filtration will be discussed as a method to extend reverse osmosis membrane and ion exchange resin performance and service life.	12/31/10	Technical Report

Product Title & Description	Planned Completion Date	Product Type
<p><b>Interim Guidelines - Organic Amine Treatments in Fossil Power Plants:</b> Results of research activities on organic amine assessment for power plant application in 2009 and information from international conferences on organics in steam-water cycles in 2005 and 2008 will serve as the basis for developing interim guidelines, addressing the potential use of organic amines to remediate specific corrosion problems, including first condensate pH in the PTZ of the LP turbine, the pH of condensing steam in air-cooled condensers, and pH conditions at the locations of two-phase FAC. Also addressed will be guidance on the benefit and use of some polyamine or filming amine to provide hydrophobic conditioning of components during a long outage/storage period.</p>	12/31/10	Technical Report

### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<p><b>Guidelines for Control of Steamside Corrosion in Air-cooled Condensers of Fossil Units and Combined Cycle HRSGs:</b> Interim Guidelines for Control of Steamside Corrosion in Air-Cooled Condensers, published in 2008 by Program 64, 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, and to include methodologies to mitigate the corrosion and reduce iron transport. The revised guidelines will also include alternative or specialized chemical treatments, design changes, and mechanical modifications to reduce and control the corrosion activity. Techniques such as slipstream treatment, induced condensing spray systems, and condensate recycle will be investigated.</p>	12/31/11	Technical Report
<p><b>Cycle Chemistry Guidelines for Fossil Plants -Comprehensive Guidelines for All Boiler and Feedwater Treatment Chemistries:</b> EPRI Guidelines for Fossil Plants will be updated to the current state of knowledge of scientifically based information and compiled into a comprehensive guideline, incorporating specific boiler limits and risk assessments based on boiler cleanliness and deposit history. Guidance will be included on online monitoring techniques and in-situ monitoring of corrosion products, early condensate, and corrosion. The core monitoring parameter will be revised to address specific damage mechanisms, including FAC, both single and two phase, turbine environment, and boiler corrosion. Alternative treatments will be covered as optional techniques to address unit-specific concerns.</p>	12/31/11	Technical Report

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

### Key Research Question

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. Understanding of the composition of steam and liquid films in the PTZ is fundamental to both deposition on component surfaces and nucleation of steam in the PTZ. 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. Technology Innovation is closing the gap between pit initiation and crack development. This model is now being developed as an EPRI software code for failure analysis and prediction.

## Approach

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/disc surfaces.

This project supports further development, including derivation of the necessary evolutionary path algorithms for the chemistry and operation, and field testing of EPRI's Steam Sensor or other monitoring devices to supply online 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 will also be incorporated in future versions of the key EPRI Chemistry Guidelines (64.001) and training 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.

## Impact

- 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 can 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.

## 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<p><b>Validation of PTZ Zone Chemistry Monitoring:</b> EPRI developed a steam sensor to monitor chloride, conductivity, oxidation-reduction potential (ORP), and pH of the low-temperature/low-pressure steam, to provide prediction of the early condensate composition using the code developed ORNL as part of EPRI research on the liquid films. Refinements to the steam sensor will be explored to improve sensitivity, and alternative monitoring methods will be examined for <i>in-situ</i> or external monitoring of the early condensate in the PTZ. Field measures will provide the basis for validation of the monitoring techniques. Prediction, simulation, or actual measurement of the chemistry in the liquid films is necessary for optimizing corrosion control and to provide tools for supplying data to the EPRI model for stress corrosion and corrosion fatigue cracking life predictions within the steam turbine PTZ.</p>	12/31/10	Technical Update

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 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.	12/31/10	Technical Report

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Control of Corrosion in the Steam Turbine PTZ - Progress Report:</b> EPRI's Model for Life Predictions within the Steam Turbine PTZ will be used to establish risk assessments of discrete steam environments and operating conditions. Modifying the actual conditions and environments utilizing steam modifying agents (such as organic amines) and EPRI monitoring techniques methodologies will be examined in an effort to control the corrosion mechanism in the PTZ. The initial work will focus the application methods for modifying steam chemistries and monitoring the effect on the early condensate and the corrosion mechanisms within the PTZ. Working with Program 65, pitting monitors or sacrificial test strips will be used to measure the success.	12/31/11	Technical Update
<b>Control of Corrosion in the Steam Turbine PTZ -Final Report:</b> Building on the research for controlling corrosion in the PTZ conducted in 2001, modification of the chemistry of the early condensate and EPRI monitoring techniques will be developed to control the corrosion mechanism in the PTZ. Working with Program 65, pitting monitors or sacrificial test strips will be used to measure the success. The EPRI Model for Life Predictions within the Steam Turbine PTZ will be used to establish risk assessments of discrete steam environments and operating conditions.	12/31/12	Technical Report

## P64.003 Deposition in the Water/Steam Cycle (100509)

### Key Research Question

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 a major 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.

### Approach

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 last four 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 to include risk-based assessment of environmental condition and the impact of deposition on corrosion. Deposition in steam turbines, feedwater, and condensate systems will also 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.

### Impact

- 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.
- Provide scientifically based risk assessment of corrosion and deposition and environmental factors of cycle chemistry

### 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 in 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. Risk analysis can be used to make informed decisions regarding operating damage and cost — for example, cost assessments associated with continued operation with known upset chemistry conditions and corrosive environments.

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<p><b>Final Deposition Model for Waterwalls of Drum Boilers:</b> Following some in-field and laboratory validations, the EPRI model will be finalized. Information from the model will provide the basis for matrix-based operational guidance for the management of boiler deposits. A previously developed Deterministic Model predicts the chemical environment within the deposits and adjacent to the tube surface and the transport of liquid and steam through the changing geometries in the micro-system on the inside of the boiler waterwall tubes. Developed in 2009, the Chemical Equilibria and Corrosion Assessment (CECA) module will take input from the Deterministic Model to predict corrosion rate and provide a Probabilistic Risk Assessment (PRA). A test facility developed specifically to validate the model under environmental conditions that are typical of the chemical and thermal/hydraulic (T/H) conditions of fossil boilers, including supercritical boilers under conditions that are prototypical of heat fluxes and flow rates, will confirm the microscopic structure of deposits in an operating fossil boiler using laboratory tests. The model will contain a set of output conditions that may be represented by tables, graphs, or equations specific to a set of input conditions. The output will be in a form that guides the day-to-day operation of a fossil power plant. The results will be published by EPRI as part of industry guidelines.</p>	12/31/10	Technical Report

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<p><b>Management of Porous Deposits:</b> Development of the EPRI Deposition Model identified the physiochemical behavior and characteristic of boiler waterwall porous deposits. This knowledge and understanding will be used to research techniques and processes to manage the growth, thickness, maturation, and porosity of deposits. A key element is prevention of loss of porosity of the deposit and effective removal of deposit material from the environment to avoid re-entrainment. An interim report will identify the methodologies and treatments having potential to control and reverse porous deposit formations.</p>	12/31/11	Technical Update

### P64.004 Feedwater Filtration and Condensate Polishing Technology (046583)

#### Key Research Question

High-purity feedwater is critical to control of damage-causing deposition and corrosion in the feedwater cycle, boiler and turbine. 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. Ionic contaminants to the feedwater cycle for poor quality or nonoptimized makeup water treatment and in-leakage of cooling water or other sources are the fundamental corrodents leading to boiler tube hydrogen damage and turbine stress corrosion and corrosion fatigue cracking. Existing technologies require innovative approaches to continue optimization of the operating costs and performance of these systems. Issues of concern are operation at elevated temperatures, fouling and pressure drop, premature exhaustion on high pH or high CO<sub>2</sub> levels, and chemical and materials costs.

#### Approach

EPRI reported on the State of Knowledge for Condensate Polishing in 2006 and reviewed innovative designs of separate resin bed in 2007. Feedwater filtration technologies studies were conducted in 2006 through 2008. These studies confirmed that applying polishing and filtration technologies is a means of removing dissolved and suspended solids from the feedwater; however, improvements are needed to optimize the operating costs and performance of these systems. Technical innovation studies have shown the potential application of nanofiltration for supplementing filtration and polishing system performance. Continued research will be used to develop guidelines for selection of technologies to address the optimization of condensate and feedwater quality and purification.

#### Impact

- Eliminate dissolved ionic contamination to the water/steam cycle.
- Facilitate optimization of the cycle chemistry with alternative treatments or higher pH operation.
- 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 Polishing and Filtration Guidelines and Technical Assessments can be used by members for technical evaluations of polishing and filtration requirements, and optional methodologies. Members can assess the needs and benefits from the application and installation of these cleanup systems using Risk Based Technologies (P64.003) and Life Prediction Models (P64.002) in association with Comprehensive Cycle Chemistry Guidelines (P64.001) to appraise system requirements and savings.

## 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<p><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. Nanotechnology-based filtration media will be experimentally investigated for the removal of potentially corrosive impurities such as sodium, chloride, and sulfate from water. Modeling of the nanotube filtration will include permeability and porosity of the filter media and the capability for scaling to operational systems applicable to power plant makeup or feedwater filtration systems.</p>	12/31/10	Technical Update

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<p><b>Innovation in Fossil Plant Filtration: Application of Nanotube Technology:</b> A fluidic test system will be designed and manufactured to measure the permeability and filtration characteristic of experimental samples in comparison with previously predicted models. Collaboration with a number of international centers developing nanomembrane technologies will identify candidate technologies and feasibility characteristics in support of the experimental system. A final report will identify the filtration capability, water purity, permeability/flow rate characteristics, and the ranking and selection of materials for scaleup to power plant applications. The report will provide a recommended route to achieve full scaleup and power plant implementation.</p>	12/31/11	Technical Report

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

### Key Research Question

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.

### Approach

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. A cycle chemistry instrumentation and control state-of-knowledge report was completed in 2007. This project will ensure the quality of the data provided by the instruments.

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. 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.

### Impact

- 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.

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Water Chemistry Instrumentation Data Quality:</b> This project will provide a comprehensive investigation of the methods and practices to ensure water chemistry analyzers are working correctly and providing accurate and reliable data to plant operators. Methods of verifying data including calibration techniques and sensor maintenance will be reported. This report also will provide the necessary charts and tables for making temperature corrections and techniques of known additions and standardizing samples for high-purity calibration of analyzers. A complete set of reference charts and tables will also be provided, showing pH, conductivity, and specific ion relationships for verifying online monitoring conditions.	12/31/10	Technical Report

### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Cycle Chemistry Advisor:</b> The root structure of the PC-based Cycle Chem Expert and the internet-based Combined Cycle HRSG CC-Chem will be reviewed with a team of fossil chemistry users to assess the needs and requirements of a cycle chemistry advisor. This report will detail the logic to be applied for assessing each measured parameter in combination with all other monitored points for early identification of chemistry excursions, prevention of corrosion damage and deposition problems, and evaluation of cycle performance. The report will provide expert advice and corrective operating procedures. Members will use this information to develop internal cycle chemistry advisory systems integrated into a plant's control system, or engage in a supplemental project to develop plant-specific systems with EPRI assistance.	12/31/11	Technical Report

## P64.006 Corrosion in the Boiler and Water/Steam Cycle (058176)

### Key Research Question

Boiler waterwall internal corrosion is the leading corrosion-related cost in the fossil power 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. Scientifically based limits, established to practically eliminate the causative environment and conditions of corrosion, are needed for proper guidance and control of boiler corrosion. Flow-accelerated corrosion (FAC) — both single and two-phase — is still a major damage mechanism occurring too frequently in power plants. Units with air-cooled condensers are displaying corrosion resembling FAC, as detailed in the interim guideline produced in 2008; however, the mechanism is not understood.

### Approach

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). Field and laboratory examination of ACC damage mechanism will provide the basis for new guidelines (P64.001).

### Impact

- 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
- Reduce corrosion and corrosion product transport in air-cooled condensers

### 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.

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<p><b>Corrosion Mechanisms in Air-Cooled Condensers:</b> A campaign of metallurgical examination of air-cooled condenser (ACC) tubes and detailed monitoring at a number of EPRI host sites will be conducted to gather information. Laboratory studies will be developed to simulate and understand the key factors involved in the corrosion/FAC process. Testing of possible chemical treatment solutions (including amines) and physical techniques such as coating or tube inserts will be a parallel effort in the laboratory and in the field. The final product will be a guidance document on the application of field/lab findings.</p>	12/31/10	Technical Report

Product Title & Description	Planned Completion Date	Product Type
<p><b>Boiler Corrosion Guideline Limits:</b> Control curves developed in nondeposition environments will be used to conduct a series of tests in a deposition apparatus, from which EPRI will derive a set of control curves under realistic boiler conditions. 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.</p>	12/31/10	Technical Report

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<p><b>Flow Accelerated Corrosion Mitigation and Monitoring:</b> Using new/improved monitoring techniques such as ORP<sub>T</sub> and online corrosion product monitoring, (P64.005) and alternative treatments, such as amines/polyamine (P64.001), field studies will be conducted to evaluate possible reduction in single-phase and two-phase FAC. <i>In-situ</i> corrosion monitoring or sacrificial electrode techniques will be examined for applicability to monitoring and controlling FAC. Techniques such as offline conditioning (impressed oxide growth or localized copper/chromium enrichment) in FAC- prone locations/material will be evaluated. Research will be initiated to look at the role of copper in the FAC mechanism.</p>	12/31/11	Technical Report
<p><b>In-situ Monitoring of FAC and Corrosion:</b> Research conducted on boiler corrosion developed electrochemical impedance spectroscopy (EIS) probes to monitor corrosion <i>in-situ</i> on a laboratory scale. This project will explore the commercialization of corrosion probes for <i>in-situ</i>/real-time monitoring of corrosion rates in selected environments, including under-deposit corrosion in simulated and actual deposits with artificially induced heat flux to promote concentration of impurities within and beneath the deposit. <i>In-situ</i> monitoring will examine actual or simulated monitoring of FAC activity in corrosion prone materials, environments, and geometries. A report of the findings will provide the basis for revised guidelines on boiler corrosion or FAC in power plants.</p>	12/31/11	Technical Report