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 economics.

Research Value

The industry needs 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 incidence of FAC damage and failures — FAC is both a personnel safety and component availability concern
- 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.

- The project on cycle chemistry guidelines and technology addresses the critical aspects of fossil plant cycle chemistry and is applicable to all plant designs. Research in this area covers 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).
- The project on 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 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.
- The project on 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. Members can use these models to identify the specific actions needed to address deficiencies consistent with individual unit characteristics. Application of risk assessments provides managers with the tools to evaluate conditional situations in an informed and cost-effective manner.

- 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. Members can use the Fossil Plant Feedwater Guidelines for technical evaluations of polishing and filtration requirements and to appraise system performance.
- R&D for cycle chemistry instrumentation, control, and monitoring develops instrumentation and validates 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. Data validation methodology provides techniques for correlation and interpretation of data in a meaningful manner to assess both the plant conditions and the accuracy of monitoring data.
- Research involving corrosion in the boiler and water/steam cycle uses scientifically based criteria to determine action levels needed 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 and deposition process in boiler waterwalls
- Advancement in the understanding of high-temperature oxides in supercritical waterwall tubes
- Solvent evaluation and interim guidelines for chemical cleaning of supercritical steam generators
- Interim guidelines to address air-cooled condensers
- Assessment and interim guidance for the application of amine chemistries in fossil plants
- Modeling of corrosion product transport in the feedwater cycle
- Guidelines for make-up water treatment
- Cycle chemistry instrumentation selection and data validation
- Interim research on two-phase FAC in feedwater heaters and heater drains
- Benchmarking processes to assess plant or system chemistries

Current Year Activities

The program R&D for 2012 will focus on reducing corrosion damage associated with FAC and boiler deposits. Specific efforts will include:

- *Comprehensive Chemistry Guidelines for all Fossil Plant Boiler and Feedwater Treatment* report
- *Management of Porous Deposits for Reducing Deposit-Related Corrosion* report
- *Flow-Accelerated Corrosion Mitigation and Monitoring* report
- *Chemistry Guidelines for Open Cooling Water Systems* report
- Online and *in situ* instrumentation to monitor corrosion and FAC in the plant cycle

- Corrosion and the role of acetates and formates in the PTZ
- *Enhanced Chemical Instrumentation Monitoring* report
- *Management of Boiler Chemical Cleaning Wastes* report

Estimated 2012 Program Funding

$3.0M

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 and water/steam cycle 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 plant 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 encompasses boiler and feedwater chemistry treatments, transient operating and outage conditioning, chemical cleaning, condensate polishing, makeup water treatment, instrumentation and control, copper metallurgy, and 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 EPRI Technology Innovation (TI) activities, and experience of the program members. Major planned activities include updated guidance on all chemistry treatment practices, deriving methodologies for managing and controlling corrosion product transport and boiler deposits, validation of chemistry monitoring and liquid film conditions in the early condensate of the steam turbine PTZ, assessing nanofiltration technologies for feedwater applications, and developing on-line instrumentation and enhanced instrumentation techniques 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.
- Turbine steam chemistry and PTZ corrosion control

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

Impact

- Establishes the *de facto* standard of worldwide chemistry practices
- Can be used to significantly improve fossil unit availability and performance
- Eliminates chemistry-related damage in high-pressure piping, boilers, and turbines
- Reduces levels of maintenance activities compared to those required with deficient chemistry
- Provides 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 impact of improvements.

2012 Products

Product Title & Description	Planned Completion Date	Product Type
Open Cooling System Chemistry Guidelines: This project will develop a revised guideline in collaboration with the Nuclear Water Chemistry Group on the Chemistry in Open Cooling Systems. The Guidelines for Fossil and Nuclear Plants will be updated to the current state of knowledge of scientifically based information and compiled into a comprehensive guideline, incorporating best practices, guidance on using chemicals to treat microbiological growth, macrobiological growth, corrosion, and suspended solids fouling and scaling in service water and cooling systems. Monitoring and control methodologies as well as specific chemical treatment regimes will be covered.	12/31/12	Technical Report
10th International Conference on Cycle Chemistry in Fossil and Combined Cycle Plants with Heat Recovery Steam Generators: This international conference will be held in Seattle, WA. June 25-29, 2012. The conference will provide the industry with the latest information, developments, and field experience in all aspects of fossil plant chemistry. In addition to presentations from world experts and utility experience reports, this conference will provide access to at least two technology transfer workshops.	12/31/12	Workshop, Training, or Conference

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Guidelines for Chemical Cleaning of Fossil and HRSG Plant Equipment: This project will develop revised guidelines, reflecting the spectrum of technology and best practices for chemical cleaning of plant equipment. Specifically, the guidelines will focus on methodologies to assess the need to chemically clean the boilers and evaporators of HRSGs, as well as high-pressure turbines, water-cooled generator stators, water-cooled condenser tubes, and other ancillary systems. This revision will include the latest information and research on solvent selection, specifically for removal of high-temperature oxides and water-borne oxides in supercritical units, and methods of waste disposal to meet the increasingly stringent water and air quality standards. The final report will provide the station chemist, maintenance engineer, environmentalist, and plant management with a complete guide to chemically cleaning plant process equipment, determining when cleaning is required, and details of the chemicals and processes for a safe, effective, and environmentally responsible cleaning.	12/31/13	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 significant increases in plant maintenance costs. 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 (TI) work and six years of work in Program 64, a deterministic model of the corrosion process in the PTZ was developed. TI R&D is closing the gap between pit initiation and crack development. A state-of-knowledge document on corrosion fatigue and stress corrosion cracking in the turbine environment has been developed.

Approach

The model of the corrosion process in the PTZ 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 monitoring devices to supply or supplement 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 also will 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 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 amine treatments to optimize pH control during operation and 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 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 neutralizing amines and polyamines, could realize substantial improvement in corrosion protection and efficiency, if not power production, in the LP region of the steam turbine.

2012 Products

Product Title & Description	Planned Completion Date	Product Type
Control of Corrosion in the Steam Turbine PTZ - Progress Report: EPRI's Life Predictions within the Steam Turbine PTZ will be used to establish risk assessments of discrete steam environments and operating conditions. To control the corrosion mechanism in the PTZ, researchers will evaluate the potential for modifying the actual conditions and environments utilizing steam-modifying agents (such as amines), and will assess the efficacy of EPRI monitoring techniques. The initial work will focus on 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, the project will use pitting monitors or sacrificial test strips to measure success.	12/31/12	Technical Update
Technical Update: State of Knowledge of Acetate and Formate Corrosion Behavior in the Turbine Phase Transition Zone: This project will provide an update of current knowledge and identify gaps in the understanding of the transport behavior of acetate and formate and similar weakly acidic compounds in the turbine steam environment. It will outline the current understanding of the chemistry, transport, distribution, volatility and solubility, concentrating mechanisms, and the influence of accumulation and concentration in the liquid films in the turbine phase transition zone on turbine corrosion fatigue and stress corrosion cracking. The project will seek to address gaps and/or deficiencies in the current knowledge with supplemental research on the role of acetate and formate in turbine damage mechanisms, as well as to determine the appropriate limits for the individual species. The update will provide the power plant chemist and turbine engineer with a guide for establishing steam limits specific to applications of alternative chemical treatments such as volatile amines.	12/31/12	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Control of Corrosion in the Steam Turbine PTZ -Final Report: Building on the research conducted in 2012 on controlling corrosion in the PTZ, 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, the project will use pitting monitors or sacrificial test strips 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.	12/31/13	Technical Report
State of Knowledge: Turbine Steam Chemistry and Control: This project will outline the fundamental bases for EPRI Turbine Steam Chemistry Control, and the current knowledge on the transport and behavior of impurities in the turbine steam environment. It will outline the current understanding of the chemistry of water and steam, steam quality and impurity transport, chemical distribution, volatility and solubility, deposition mechanisms, influence of deposits, and turbine corrosion. The report will include the new understandings from recent research on inhibition of crevice and pitting corrosion, the influence and behavior of acetate and formate on corrosion mechanisms, and the control of corrosion in the phase transition zone. The final report will provide the power plant chemist and turbine engineer with a guide to the fundamental chemistry mechanisms that occur across the turbine steam flow path of fossil power plant cycles. The project also will identify potential future research needs in the field of turbine steam chemistry and control.	12/31/13	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. Maintenance cleaning activities to remove deposited material increase unit operating costs and extend the interval of unit outages. EPRI has compiled scientific and plant-based knowledge, and conducted initial basic laboratory and field studies, to understand and reduce deposition on turbine blades.

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 five years, work has been conducted to better understand the structure of drum boiler waterwall deposits, and to support ongoing efforts to construct a deterministic model, including a risk-based assessment of the environmental condition and the impact of deposition on corrosion.

With the culmination of understanding of the deposition mechanics and influences on corrosion, this project will continue to assess methodologies and chemistry practices to manage deposits and lower their impact on unit performance and material damage.

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.

Impact

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

2012 Products

Product Title & Description	Planned Completion Date	Product Type
Management of Porous Deposits: Field Demonstration: The methodologies and treatments with potential to control and reverse porous deposit formations will be applied in field demonstration project(s). This project will evaluate the effectiveness of the techniques developed to manage the growth, thickness, maturation, and porosity of deposits in actual field applications on operating fossil power units. It will assess the pre-application condition of porous deposits present in the field unit; the application and monitoring of the deposit management techniques; and the quantification of the effectiveness of the technique to control and/or reverse deposition based on subsequent porous deposit condition assessment. The final report will provide refined guidance on the application of the methodologies and treatment based on actual field experience, as well as an assessment of the effectiveness of the various techniques for management of porous deposits.	12/31/12	Technical Report
Management of Boiler Chemical Cleaning Waste: This project will review and summarize the current chemical cleaning treatment formulations and disposal options available. This project will provide a revision to the EPRI *Boiler Chemical Cleaning Waste Management Manual*, 1992, TR-101095. Significant changes in the practices and solvent used for boiler cleanings, as well as the waste management practices, necessitate a timely revision of the waste management manual. The continued evolution of air, water, and solid waste regulations have greatly altered the choices available for boiler cleaning waste management options. Environmental concerns are resulting from the disposal of chemical cleaning waste, which is becoming more difficult and expensive to achieve. The project also will investigate new treatment formulations/ technologies and their impact on future disposal practices.	12/31/12	Technical Report

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

Key Research Question

High-purity feedwater is critical to control damage-causing deposition and corrosion in the feedwater cycle, boiler, and turbine. Boiler waterwall deposits primarily consist 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 from 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_2 levels; and chemical and materials costs.

Approach

EPRI research studies on condensate polishing and feedwater filtration confirm that applying these 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. In 2008 and 2010, Technology Innovation (TI) projects focused on assessing the current state of carbon nanotube water filtration technologies, which 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 established and emerging 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.

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

Key Research Question

Long-term fossil unit availability requires effective control of cycle chemistry. Online 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 the instruments used 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 full suite of instrumentation indicated in current guidelines, core instrumentation is essential to meet the plant chemistry needs. A cycle chemistry instrumentation and control state-of-knowledge report was completed in 2007, with a complementary instrumentation data validation report completed in 2010. This project will ensure the quality of the data provided by the instruments.

Current 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 R&D 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, including methods for managing and utilizing the data generated.

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 cycle components and improve current plant operations.

2012 Products

Product Title & Description	Planned Completion Date	Product Type
Online Chemistry Data Management System: This project will review online data management systems with a team of fossil chemistry users to assess the needs and requirements of cycle chemistry. 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.	12/31/12	Technical Update
In-situ Monitoring or Indicating Flow Accelerated Corrosion: This project will continue the two-year exploration of the use of *in-situ/ex-situ* techniques for real-time monitoring of corrosion rates, and specifically single-phase FAC, in selected environments. *In-situ* monitoring techniques, including the use of electrochemical corrosion potential and corrosion resistance probes, will examine actual or simulated FAC activity in corrosion-prone materials, environments, and geometries. *Ex-situ* monitoring techniques will be examined in parallel for comparison of these methods. A report of the findings will provide an evaluation of the potential use of these methods in power plant applications for monitoring FAC.	12/31/12	Technical Report

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
In-situ Monitoring or Indicating Flow Accelerated Corrosion: This project will complete the two-year exploration of the use of *in-situ/ex-situ* techniques for real-time monitoring of corrosion rates, and specifically single-phase FAC, in selected environments. *In-situ* monitoring techniques, including the use of electrochemical corrosion potential, and corrosion resistance probes, will examine actual or simulated FAC activity in corrosion-prone materials, environments, and geometries. *Ex-situ* monitoring technique(s) will be examined in parallel for comparison of these methods. A report of the findings will provide an evaluation of the potential use of these methods in power plant applications for monitoring FAC. This result of the project will provide a basis for a field evaluation of the techniques identified by the laboratory research.	07/31/13	Technical Report

Product Title & Description	Planned Completion Date	Product Type
Field Evaluation of In-situ Side Steam Monitoring for Flow Accelerated Corrosion: This project will conduct field studies using the *in-situ/ex-situ* techniques developed for real-time monitoring of single-phase FAC. Side-stream studies of fossil and HRSG power plant systems susceptible to single-phase FAC will be conducted to examine actual FAC activity in corrosion-prone materials, environments, and geometries. The findings of the field evaluation will be compared with NDE measurement and system operating chemistries as well as *ex-situ* monitoring techniques. A report of the findings will provide an evaluation of the potential use and benefit in power plant applications for monitoring and controlling FAC.	12/31/14	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 treatment guidelines provide boiler water corrosion control based on cation conductivity, which has 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, provide for proper guidance and control of boiler corrosion. Flow-accelerated corrosion (FAC) — both single- and two-phase — still is 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 has sought to define the limits in a simulated deposit medium using electrochemical corrosion potential measures. For the first time, EPRI established 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 was to use the limits derived in this project in the final deposition rig tests (P64.003).

To address conditions of two-phase FAC, simulated models will evaluate the conditions of influencing FAC and provide information on conditions for stifling the mechanism. The findings will be invaluable in establishing control methodologies to mitigate and/eliminate two-phase FAC as it is occurring in feedwater heater steamside drains, low-pressure HRSG evaporators, and air-cooled condensers.

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 the occurrence of two-phase FAC in all prone areas in fossil plants and HRSGs
- 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. Control methodologies can be applied to minimize two-phase FAC in feedwater heater drains.

2012 Products

Product Title & Description	Planned Completion Date	Product Type
Investigation of Flow-Accelerated Corrosion Under Two-Phase Flow Conditions: This project continues a three-year research effort involving two-phase FAC conditions in a simulated test loop and will provide details and greater understanding of the mechanism and control factors. Using a simulated laboratory environment, this work will evaluate methods for mitigating two-phase flow-accelerated corrosion typically found in the steamside of feedwater heaters and associated drain lines of conventional fossil fired units, and in HRSG low-pressure (LP) economizer evaporator tubes. The focus of the work will be to quantify the effectiveness of varying methods to control/mitigate two-phase FAC in the test loop with the goal of developing mitigation methods for implementation in field trials.	12/31/12	Technical Report

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Field Validation of Two-Phase Flow Accelerated Corrosion Control: This project will apply techniques and methodologies, identified through laboratory research to mitigate two-phase flow accelerated corrosion in critical areas of the power plant or HRSG, to actual plant equipment in the field. Monitoring techniques in the susceptible two-phase FAC areas will be utilized to measure the rate of material wastage compared with nonoptimized treatment methods. A successful study will demonstrate a marked reduction or elimination of the FAC mechanisms, thereby improving reliability of equipment, increasing service life, and increasing personnel safety.	12/31/13	Technical Update
State of Knowledge: Corrosion Mechanisms in Water and Steam Cycles of Fossil Plants: This project will be a concise summary of the current knowledge and understanding of corrosion mechanisms present in water and steam cycles of fossil plants. It will review the current state of knowledge of boiler, feedwater, condensate, and steam corrosion, including all the steamside/waterside corrosion-influenced failure modes. It will discuss the latest understanding of general corrosion mechanisms, such as single-phase and two-phase FAC, first-formed condensate corrosion (FCC), and low- and high-temperature corrosion phenomena. The final report will provide the station chemist and plant management with a complete guide to corrosion processes in fossil plants. In addition, the project will identify the limits of understanding for each corrosion mechanism and possible needs for future research efforts.	12/31/13	Technical Report

Supplemental Projects

Corrosion Mechanisms in Air Cooled Condensers (071854)

Background, Objectives, and New Learnings

Air-cooled condensers (ACCs) increasingly are being installed to reduce water use in power plants. Unfortunately, significant iron corrosion product transport has been exhibited in ACCs on numerous units, which is not unique to any specific design. EPRI established interim guidelines for control of steamside corrosion in air-cooled condensers. This work (detailed in EPRI document 1015655) found that the active corrosion mechanisms in the ACC requires further study to establish effective comprehensive chemistry control guidelines. This project will explore additional techniques for mitigating corrosion product concurrent with research of the corrosion mechanism(s).

Project Approach and Summary

This project will research the mechanisms of corrosion observed in the air-cooled condenser and evaluate treatment strategies to mitigate damage and reduce iron transport. Research laboratory studies will be developed to simulate and understand the key factors involved in the corrosion process. The project at host utilities will evaluate treatment technologies and monitoring tools such as nondestructive evaluation (NDE), analysis of corrosion product transport (CPT), along with wet chemistry, and visual inspections. The project will monitor corrosion transport throughout the water and steam cycle to determine the improvement benefit in other key unit components such as in-line polishers and condensate filtration systems.

Benefits

Improved understanding and control of the active corrosion mechanisms in the ACC can result in longer component life and reduced losses due to downstream impacts of corrosion products transported from the ACC. This project will provide utilities with improved techniques to control and manage these conditions. Mitigation of the corrosion mechanisms in the ACC will reduce the impact of deposition on heat exchange surfaces throughout the cycle. Improved performance, reduced damage, and reduced O&M cost are direct benefits. Extended filtration and polisher service periods with lower operating cost also are anticipated.