Post-Combustion NOx Control - Program 73

Program Overview

Program Description
Selective catalytic reduction (SCR) is the technology of choice for meeting stringent nitrogen oxides (NOx) emission limits for coal-fired electricity generating plants. More than 150 gigawatts (GW) of SCR capacity has been installed in the United States, and significantly more is planned for compliance with anticipated NOx mandates in the coming years, such as the U.S. Environmental Protection Agency’s (EPA’s) Cross State Air Pollution Rule (CSAPR).

The Electric Power Research Institute’s (EPRI’s) Post-Combustion NOx Control program (Program 73) focuses on minimizing total costs and maximizing reliability and performance of SCR and other post-combustion NOx control systems.

Research Value
EPRI’s Environmental Controls programs develop technologies that minimize the impacts of environmental controls on power plant operations and performance. EPRI helps members evaluate and implement technology options to achieve their environmental performance goals at least cost. Post-Combustion NOx Control R&D provides:

- Development and implementation of best practices and operational improvements for SCR systems.
- Lowered O&M expenditures, optimized operation, and reduced downtime for units equipped with SCRs.
- Enhancements to existing SCR systems, which will allow members to operate more efficiently, extend operating time between catalyst replacement cycles, or increase NOx reduction levels to profit from the NOx credit market.
- Strategies to oxidize mercury across SCR systems to improve capture in downstream FGDs (in conjunction with EPRI Program 75).
- Objective, long-term catalyst performance data to support catalyst management decisions (i.e., regeneration effects, flues and operating impacts on catalyst life, and SO3 reduction).
- Detailed evaluations of emerging NOx control technologies.

Approach
The program develops operating and maintenance (O&M) guidelines and documents best practices and procedures consistent with optimal SCR operation. Assessments, methodologies, and databases provide plant owners and operators with the tools to make informed choices, comply with regulatory mandates, and capitalize on NOx credit markets. Interest groups and workshops serve as forums to share best practices in all aspects of SCR operation and performance.

- R&D develops tools, guidelines, and best practices critical to optimum SCR operation, including catalyst management considerations, catalyst reconditioning options, SCR test protocols, and resolution of critical operability issues, including low-load operation, LPA and fine ash deposition, ammonia/NOx uniformity, and catalyst deactivation.
- Evaluations of advanced SCR and emerging post-combustion NOx control technologies allow members to significantly lower NOx emissions with existing SCR systems through improved ammonia/NOx mixing technologies and the latest advanced catalysts (offering higher efficiency and lower costs), and to find cost advantages for the most promising emerging NOx control technologies through compliance with near-term regulations and probable future regulations.
Accomplishments

For more than two decades, EPRI has led the power industry in developing, advancing, and demonstrating cost-effective NOx control technologies and best operating practices consistent with compliance achievement at minimal cost and maximum reliability. Accomplishments include:

- EPRI’s database of long-term regenerated catalyst performance evaluations has provided users with independent data, facilitating their assessment of regeneration.
- Protocols for laboratory testing of SCR catalyst samples.
- SCR forums on key issues.
- Assessments of improved performance achieved through enhanced ammonia/NOx SCR O&M guidelines, updated annually.
- Laboratory and field assessments of continuous ammonia monitors.
- Catalyst management software and best practices for minimization of total cost of operation.
- Predictive tool for deposition of ammonium bisulfate (ABS) and subsequent fouling of air heater surfaces.
- Case studies of impacts of fuel quality considerations (e.g., Powder River Basin and lignite coals) on catalyst performance and longevity.
- Field testing programs to determine catalyst deactivation rates.
- Assessments of near-commercial NOx control technologies and advanced SCR concepts (i.e., new catalyst formulations).
- Progress in understanding flue gas conditions and SCR catalyst effects on mercury oxidation to improve capture in downstream FGD systems.

Current Year Activities

The program R&D for 2013 will continue to focus on optimization of SCR performance and reliability, with the goal of minimization of NOx emissions at least cost. Specific efforts will include:

- Assessments of reconditioned catalysts (including activity, mercury oxidation, and SO2 oxidation).
- Low-load, load-following, and cycling operation.
- Boiler/SCR optimization of NOx levels.
- Catalyst management techniques and options for lowest overall cost of SCR operation.
- Understanding and mitigation of large particle ash (LPA) impacts and fine ash deposition issues.
- Development of technologies and practices with the goal of trouble-free year-round SCR operation.
- Evaluation of advanced SCR technologies such as instrumentation for monitoring NH3, NOx, and SO3, new catalyst formulations, and assessments of other emerging post-combustion NOx control technologies.
- Fuel, boiler, and SCR operating effects on catalyst life.
- SCR guideline updates.
- Webcasts that focus on key SCR-related topics.
- Assessment of catalyst management as an option to enhance SCR mercury oxidation.

Estimated 2013 Program Funding

$3.0M

Program Manager

Anthony Facchiano, 650-855-2494, afacchia@epri.com
Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P73.001</td>
<td>Post-Combustion NOx Controls</td>
<td>This project develops and demonstrates a variety of deliverables and services to promote identification of optimal post-combustion NOx levels, minimize operating costs, and document best practices for SCR performance monitoring and improvement. Emerging advanced SCR concepts are evaluated, along with the effects of increased cycling and load-following operation. Conferences and workshops focused on key topics prioritized by participants are provided for technology transfer and staff development.</td>
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**P73.001 Post-Combustion NOx Controls (070556)**

**Key Research Question**

The industry needs reliable SCR O&M guidelines, documentation of best practices, and resolution of critical operability issues to minimize costs and maximize SCR system performance. In addition, in anticipation of more stringent NOx limits, methods of lowering SCR outlet NOx levels from both existing and new SCR systems — such as improved reagent/NOx mixing upstream of the catalyst, advanced instrumentation and control, or improved catalyst formulations — need to be developed and demonstrated. Finally, in anticipation of impending mercury and other hazardous air pollutants (HAPS) regulations such as the EPA Maximum Achievable Control Technology (MACT), SCR duties will be expanded to include co-benefits achieved from maximizing mercury oxidation while concurrently minimizing SO3 formation.

**Approach**

This project will produce guidelines, technical reports, webcasts, and conferences aimed at minimizing costs and maximizing performance of SCR and other post-combustion NOx control systems. Development and demonstration of advanced concepts geared towards minimizing NOx levels and maximizing mercury oxidation will be undertaken. Specific efforts will include:

- Assessments of reconditioned catalysts (including activity, mercury oxidation, and SO2 oxidation).
- Low-load, load-following, and cycling operation.
- Boiler/SCR optimization of NOx levels.
- Catalyst management techniques and options for lowest overall cost of SCR operation.
- Understanding and mitigation of large particle ash (LPA) impacts and fine ash deposition issues.
- Development of technologies and practices with the goal of trouble-free year-round SCR operation.
- Evaluation of advanced SCR technologies such as instrumentation for monitoring NH3, NOx, and SO3; new catalyst formulations; and assessments of other emerging post-combustion NOx control technologies.
- Catalyst disposal and recycling alternatives.
- Prediction and resolution of air heater fouling, consequential to deposition of ammonium bisulfate.
- Determination of fuels, SCR additives (e.g., SO3 mitigation, bromides), and boiler operating effects on catalyst life.
- SCR guideline updates.
- Webcasts will focus on key SCR topics pertinent to improved SCR operation and performance, and “SCR 101” training webcasts will provide a refresher course on the fundamentals of SCR operation.
- Assessments of catalyst properties, layer replacement cycles, and SCR and air pre-heater operating effects on mercury oxidation.
- Revision of existing catalyst testing protocol (including mercury oxidation) and round-robin testing among bench and micro-scale reactors.
Impact

- Substantial reduction in the cost of SCR operation, achieved through best O&M practices and resolution of critical operability issues, such as those issues associated with load-following or low-load SCR operation.
- Compliance with anticipated regulations, such as the EPA Cross State Air Pollution Rule (CSAPR), the Large Combustion Plant Directive (in Europe), and the EPA’s Mercury and Air Toxics Standards (MATS).
- Minimization of system costs through selection of the optimal SCR catalyst management strategies.
- Information about new advanced SCR concepts through independent evaluations on performance, costs, and operational issues.
- Independent reconditioned catalyst performance evaluations to guide procurement of cost-effective, least-impact options.
- Member information exchanges on best practices through program interest groups, SCR workshops, and webcasts.
- Minimization of SCR downtime.

How to Apply Results

Staff responsible for SCR operation and performance can use the tools, project reports, services, meetings, and webcasts developed through this project to optimize their SCR system O&M practices, auxiliary hardware choices, testing procedures and protocols, and catalyst management strategies.

2013 Products

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<thead>
<tr>
<th>Product Title &amp; Description</th>
<th>Planned Completion Date</th>
<th>Product Type</th>
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<tr>
<td><strong>SCR Reconditioning Guidelines</strong>: A report will be issued on field experience with regenerated catalyst, including deactivation rates, impacts on SO\textsubscript{2} conversion, mercury oxidation, and mechanical strength. Continued efforts are expected to yield information associated with multiple regenerations. Industry experience will be documented in comprehensive case studies and applied to a wide range of fuels, catalyst types, and SCR operating conditions. Site-specific quantification of cost benefits or disadvantages will be included.</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<td><strong>Load-Following and Low-Load Issues for SCR Operation</strong>: Economic conditions, the relative cost of gas vs. coal, and the proliferation of renewable dispatch have caused many SCR systems to operate in a load-following mode, or operate for extended time periods at low loads. This project will examine the issues associated with load-following and low load, including:</td>
<td>12/31/13</td>
<td>Technical Update</td>
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<td>• Lab tests that document catalyst deactivation rates for new and used catalyst as a function of catalyst type when operating below recommended minimum operating temperature and explore potential benefits associated with catalyst regeneration through ABS deposition and vaporization.</td>
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<td>• Options to alleviate temperature impacts at lower loads (e.g., economizer bypass or mods, feedwater temperature control).</td>
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<td>• Ash dropout issues at lower loads.</td>
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<td>• Ammonium bisulfate and SO\textsubscript{3} issues.</td>
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<td>• Reagent controllability to minimize excessive slip levels while maintaining NO\textsubscript{3} levels.</td>
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<td>• Unit-specific case studies to assess real-world operational constraints and to evaluate options to cost-effectively alleviate constraints.</td>
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**Boiler/SCR Optimization:** Based on selected case studies and field tests conducted in support of the development of cost models, a methodology will be developed to enable operators to better optimize SCR performance. Tools will be developed to quantify potential cost tradeoffs between:

- SCR inlet NOx level that results in the optimum combination of boiler- and SCR-related NOx control with respect to operating and maintenance expenses.
- Hg oxidation and NO reduction.
- Changes in boiler SO3 emissions over the load range relative to SCR outlet emissions.

This project will be conducted in coordination with EPRI Program 71.

**SCR O&M Guideline Update:** Key topics to be added in the SCR O&M guidelines will include:

- Methods for benchmarking unit-specific SCR performance with respect to the U.S. fleet of SCRs.
- State-of-the-art practices for mitigating ash deposition on catalyst modules, turning vanes, reactor inlet ducts, and NH3 injection nozzles.
- Maintenance issues with static mixers.
- Overview of best practices for low-load operation of SCR systems.
- Techniques for reducing outage time for catalyst removal and replacement.

**Catalyst Management Issues:** Enhancements to the first edition of the Catalyst Management Handbook, issued in 2012 may include:

- Elements of the catalyst management decision-making process.
- Assessing actual catalyst performance vs. the specification.
- Interpreting laboratory test results.
- Using test results to predict catalyst life.
- SCR co-benefits.
- Example scenarios of catalyst management decisions.

**Fuel Impacts on SCR Catalyst Deactivation Database:** SCR catalyst deactivation rates will be quantified for various applications and as a function of fuel (and other SO3 and Hg mitigation reagents) properties, boiler design, and boiler and SCR operating conditions. Tools such as thermochemical equilibrium calculations will be used to predict the transformation and speciation of catalyst poisons at the SCR. In addition, a database of industry catalyst performance, fuel properties, and full-scale data will be developed in support of efforts to characterize the deactivation mechanism.

**Advanced SCR Concepts and Emerging Technologies:** The website of post-combustion NOx control process will continue to be updated as new technologies are identified or new information on existing processes is available. Further independent assessment of selected NOx control emerging technologies will include (1) chemistry evaluation, (2) capital and operating costs projections, and (3) balance of plant impacts. This project also will evaluate new SCR concepts such as newer catalyst formulation (mercury oxidation, ultra low SO2 conversion, etc.).
### Lab Testing of New Monitors:

With the deployment of SCR and SNCR post-combustion NOx control systems, a growing need has developed for the continuous monitoring of ammonia slip as well as the NH3/NOx ratio in the flue gas of coal-fired boilers. The current project evaluates the accuracy and response of commercially available monitors. The objective of the current project is to establish the response of vendor-provided tunable diode laser monitors in EPRI’s test lab under highly controlled operating conditions to changes in concentration, moisture level, and temperature, and to establish their accuracy and detection limit characteristics. Additional field tests will be conducted to establish monitor operability, reliability, and maintainability characteristics.

**Planned Completion Date:** 12/31/13  
**Product Type:** Technical Update

### Testing of Enhanced SCR Control Approaches:

Current SCR process control approaches typically rely exclusively on inlet/outlet NOx measurements. By incorporating inlet/outlet ammonia measurements, control approaches could better optimize and maintain NH3/NOx uniformity at the SCR inlet, with corresponding improvements to catalyst life while maintaining similar NOx reduction levels, or overall NOx reduction potential while maintaining similar ammonia slip levels. The current project will conduct case studies to document potential benefits of enhanced SCR control approaches relative to existing controls via side-by-side comparisons.

**Planned Completion Date:** 12/31/13  
**Product Type:** Technical Update

### Effects of Catalyst Test Conditions on Performance Data:

The conditions under which laboratory testing is performed are known to affect measured performance parameters, such as activity and SO2 conversion. Because catalyst management depends heavily on the accurate determination of these parameters, inaccuracies can have a dramatic effect on the resulting life-cycle costs associated with the installation. This project will investigate the effects of catalyst test conditions on activity and SO2 conversion (linear velocity, catalyst length, NH3/NOx ratio, inlet NOx, etc.). Round-robin tests will be conducted between micro and bench-scale reactors.

**Planned Completion Date:** 12/31/13  
**Product Type:** Technical Update

### Disposal and Recycling of Spent SCR Catalyst:

As more spent SCR catalyst is generated, options to minimize economic and environmental impacts are increasingly of interest. Previous EPRI studies have identified potential options for the recycling and re-use of spent SCR catalyst. This project will demonstrate potential cost-effective alternatives to catalyst disposal, including the utilization of spent catalyst material in cement, concrete, steel-making, and metal recovery industries.

**Planned Completion Date:** 12/31/13  
**Product Type:** Technical Update

### Future Year Products

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<tr>
<td><strong>SCR Catalyst Reconditioning Database:</strong> Summary of site-specific case studies will be combined in a final report.</td>
<td>12/31/14</td>
<td>Technical Report</td>
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<td><strong>Advanced SCR Concepts and Emerging Technologies Evaluations:</strong> Update on the status of advanced SCR catalysts, reagent/NOx mixing methods, and developing post-combustion NOx control technologies and detailed cost assessments for selected processes.</td>
<td>12/31/14</td>
<td>Technical Update</td>
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<td><strong>Assessment of Fuels on SCR Catalyst Life:</strong> Data generated between 2012 and 2013 will serve to develop a correlation-based model to estimate SCR catalyst deactivation rates based on fuel analysis and boiler/SCR operating conditions.</td>
<td>12/31/14</td>
<td>Technical Update</td>
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Supplemental Projects

Selective Non-Catalytic Reduction Performance Optimization (060642)

Background, Objectives, and New Learnings
Legislative mandates for additional NOx reductions have necessitated installation of post-combustion NOx control technologies on many coal-fired boilers. Current post-combustion NOx control technologies applied on coal-fired boilers have been limited either to selective non-catalytic reduction (SNCR) or selective catalytic reduction (SCR) systems. Although SCR provides higher levels of NOx reduction, capital and operating costs are very high. SNCR provides nominal NOx reduction levels of 20% – 30%, at relatively low capital costs, and with operational costs proportional to urea reagent consumption rates. As a result, SNCR systems have been broadly employed over the last decade on smaller-capacity boilers or older units with limited remaining life, where it is difficult to cost-justify an SCR retrofit, yet incremental NOx reductions still are required.

Project Approach and Summary
Project meetings and webcasts discuss SNCR operational issues and research project results. Potential areas of focus of the SNCR Performance Optimization Group include exploration of operational and performance improvements through group-funded demonstration projects. Potential projects include:

- Improved NOx reduction with existing SNCR systems
- Implementation and testing of improved SNCR process control approaches
- Further testing of continuous spatially resolved ammonia slip monitors
- Testing of continuous furnace exit temperature monitors for optimization of reagent injection
- Characterization of new reagent injectors
- Reagent dilution approaches that minimize system impacts
- Additional projects will be conducted to address needs and issues as identified by group participants.

Benefits
By demonstrating the broader applicability of the SNCR technology with improved process control approaches, value can be realized through reduced operating costs and improved NOx reduction performance, as well as reduced balance-of-plant impacts due to lower ammonia slip levels. Information acquired by participating organizations also can pay off in reduced NOx compliance costs compared to commercially available alternatives.