

# Continuous Emissions Monitoring - Program 77

## Program Overview

### Program Description

State and anticipated revised federal regulations limiting mercury (Hg) emissions from coal-fired power plants continue the need for robust, accurate, and certifiable continuous mercury monitoring (CMM) technology. Experience with the technology is limited, and operation and maintenance (O&M) of monitors are labor-intensive. To drive CMMs O&M toward the levels now achieved with criteria pollutant continuous emissions monitors (CEMs), the industry needs an assessment of best practices and of the performance of sorbent trap technology, a simplified CMMs system. The potential for limits on other hazardous air pollutants (HAPS) under a Maximum Achievable Control Technology (MACT) regulation also drives a need to measure both solid (filterable) and aerosol (condensable) particulate matter (PM) continuously. Enabling technology needs include:

- Direct measurement of mass emissions to overcome the uncertainty of indirect measurements as PM characteristics change
- Acceptable ways to calibrate PM monitors at plants with wet stacks without having to disrupt the operation of the wet SO<sub>2</sub> control
- Droplet monitors to measure condensables.

Longer term, to remain competitive and be able to demonstrate compliance with potentially very low emission limits, industry needs advanced, microchip- or laser-based CEMs, which hold the promise of 10–25% of the cost of current technology.

The Electric Power Research Institute's (EPRI's) Continuous Emissions Monitoring program (Program 77) develops, enhances, and evaluates CEM systems that measure chemical species of regulatory and operational interest.

### Research Value

This R&D helps utilities objectively evaluate and implement monitoring options to achieve their measurement needs with robust, accurate, and easy-to-operate instruments. Benefits include:

- Save months of plant instrument technician and environmental engineer time needed to make newly procured CMMs work
- Prepare for new regulations that may require mercury measurements below today's detection levels, as well as PM measurements as surrogates for nonmercury metal HAPS
- Collect credible, non-ash-dependent particulate mass emission measurements made in the stack to benefit from particulate capture by the SO<sub>2</sub> control
- Optimize NO<sub>x</sub> and sulfur trioxide (SO<sub>3</sub>) control operations, or flue gas conditioning for electrostatic precipitator (ESP) performance, via *in situ*, continuous measurement systems for ammonia (NH<sub>3</sub>), SO<sub>3</sub>, and sulfuric acid
- Learn about new developments and avoid mistakes by using EPRI's periodically updated CEMs Guidelines
- Potentially save hundreds of thousands of dollars per stack if advanced "sensors-on-a-chip" are developed and accepted for power plant applications

### Approach

This program promotes the development and validation of accurate, robust, and low-maintenance CEMs for compliance with new reporting requirements, such as mercury and continuous particulate mass, and for optimizing pollutant control operation. It identifies, develops, and demonstrates innovative measurement

systems with the potential to significantly reduce CEMs costs. It also guides vendors on ways to improve their products for greater accuracy and functionality in commercial applications.

- R&D focusing on evaluations of mercury monitors provides a forum for dynamic interaction among power companies during the first years of implementing CMMs. It assists members with issues, documents lessons learned, and seeks and tests methods for accurate measurements at lower levels.
- Research involving PM monitors for all fly ash and stack conditions develops and demonstrates continuous PM monitors that can operate in a wet stack and retain their calibration with changes in fly ash properties, with a focus on direct measurements of PM mass. It also demonstrates proposed calibration approaches for filterable PM monitors that do not require plant operation at higher-than-normal PM emissions. In addition, it will seek or develop and evaluate instruments to measure aerosols (droplets) as a means of understanding and monitoring sulfuric acid formation and emissions.
- R&D on monitors for process control, compliance, and TRI (Toxics Release Inventory) reporting continues to identify and conduct field tests of continuous monitors for chemical species whose measurement may be required in the future, could help in operating air pollution controls, or could improve the credibility of TRI emission estimates. These monitors include Fourier Transformed Infrared (FTIR), tunable diode laser, and Differential Optical Absorption Spectroscopy (DOAS) instruments. The project will continue to collaborate with EPRI's post-combustion NO<sub>x</sub> program to demonstrate *in situ* NH<sub>3</sub> monitors, with a focus on the application of cavity ringdown spectroscopy, a novel system being demonstrated in the laboratory in 2009.
- EPRI's work on advanced monitors — microsensors, CEMS for hostile environments, and automated diagnostics — will complete proof-of-concept tests of a quantum cascade laser monitor for multiple pollutants, and design a complete CEM package around this analyzer, including calibration. It also continues its Tech Watch for other advanced systems, and initiates proof-of-concept tests if any appear promising. And it seeks to understand the accuracy of CO<sub>2</sub> measurement at 1% concentration level (for future operations with CO<sub>2</sub> capture).

### Accomplishments

EPRI's leadership in identifying and resolving performance and O&M issues with continuous monitors is recognized by the power industry, CEMs equipment suppliers, and regulatory agencies, especially the U.S. Environmental Protection Agency (EPA). This has been demonstrated in recent years by the number of EPA decisions on mercury monitors that have relied on EPRI findings, as presented to the EPA by industry.

Examples include:

- EPA approval of the sorbent trap method for continuous mercury monitoring and use as a reference method
- EPA approval to use an instrumental reference method in lieu of the complex, costly, slow-turnaround-time Ontario Hydro batch method
- Accelerated development of National Institute of Standards and Technology (NIST)-traceable calibration procedures for CMMs
- Proposed methodology for calibrating particulate mass emission monitors that avoids need to exceed emission limits for other pollutants.
- Identification of at least two promising next-generation, multipollutant CEMs — the quantum cascade laser and cavity ringdown spectroscopy.

### Current Year Activities

The program R&D for 2010 will focus on bringing the development of CMMs to closure, including documentation and resolution of lessons learned during the initial installations; advancing continuous PM monitors to become insensitive to fly ash properties and possible to calibrate without unusual processes; and showing the potential and benefits of dramatically lower-cost micro-sensor-based technologies. Specific efforts will include:

- Updated CMMs guideline, with lessons learned from installation and first one to two years of operation

- Proof-of-concept tests of potential CMMs enhancements that lower detection levels to emission concentrations expected from controlled power plants
- Exploratory tests of direct measurements for filterable particulate mass emissions in either dry or wet stacks and of calibration using new spiking technologies
- Proof-of-concept demonstration of multipollutant (criteria pollutants, NH<sub>3</sub>, SO<sub>3</sub>, hydrochloric/hydrofluoric acid, and Hg) laser-based system
- Initial assessment of approaches to measuring carbon dioxide (CO<sub>2</sub>) at 1% concentrations, anticipating a future stringent CO<sub>2</sub> capture requirement

### Estimated 2010 Program Funding

\$1.3M

### Program Manager

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## Summary of Projects

Project Number	Project Title	Description
P77.001	Evaluation of Mercury Monitors	By assembling, scrutinizing, and synthesizing early power plant experience with CMMs, EPRI will provide a Guidelines that plant instrument staff can use to operate their CMMs for best results at lowest operating and maintenance costs.
P77.002	PM Monitor for All Fly Ash and Stack Conditions	This project responds to regulatory pressure to install particulate mass emission monitors by developing a more workable calibration approach than currently used. Longer term, it develops instruments that measure PM emissions directly, independent of fuel, and that can be used to monitor mist eliminator performance.
P77.003	Monitors for Process Control, Compliance, and TRI Reporting	Ammonia CEMs capable of measuring NH <sub>3</sub> and SO <sub>3</sub> levels <5 ppm accurately will be identified and validated for the locations in the flue gas path where these measurements are needed. A Technology and Regulatory Watch will give members advanced notice of changes in available technology or monitoring requirements.
P77.004	Advanced Monitors - Microsensors, CEMS for Hostile Environments, and Automated Diagnostics	This project determines the technical merit of advanced sensors that promise up to 75-90% cost reductions for monitoring the full suite of pollutants and are accurate at the lowered emission limits expected in the future. It includes measurement of flue gas CO <sub>2</sub> levels in plants with CO <sub>2</sub> capture systems.

### P77.001 Evaluation of Mercury Monitors (051775)

#### Key Research Question

Federal requirements for monitoring mercury emissions from coal-fired boilers are uncertain (as of early April 2009) due to a February 2008 court action vacating the Clean Air Mercury Rule (CAMR). However, it is certain such monitoring will be required in the near future by the federal government. States with independent mercury regulations still require continuous mercury monitors (CMMs), presumably those satisfying the requirements promulgated in support of CAMR. With some states requiring high removal percentages, and EPA having announced its intent to propose Maximum Achievable Control Technology (MACT) limits, the need exists for CMMs that measure accurately at very low emission rates. Ongoing work is expected, by the end of 2009, to lead to instrumental monitors that can pass current accuracy requirements, are reliable, and

are readily calibrated and audited. The robustness of the sorbent trap monitor will still need to be proven. Once these goals are achieved, the industry will need guidelines to operate and maintain these complex instruments to achieve their required performance with acceptable effort. Further, because CMMs are new to the power industry, the suppliers, QA/QC contractors, and regulatory authorities, many issues are certain to arise during the first few years of implementation. The learning curve for all parties needs to be shortened.

### Approach

EPRI will maintain the web-based forum created in 2008 for members to share their experiences and for EPRI or others to suggest solutions. By tracking the dialogue and contacting members of the program, EPRI will assemble the industry's lessons learned in a Guideline that suggests best practices, which EPRI will publish annually. To ensure that the sorbent trap method remains viable, EPRI will continue its ongoing efforts to test various sorbent materials, spiking techniques, and operating procedures. As needed, EPRI will seek fixes to problems such as SO<sub>x</sub> interference, or provide guidelines on this method's suitability for particular applications. EPRI also will investigate the feasibility of using advanced technologies (e.g., cascade lasers) as CMMs, to reduce cost and complexity and to measure lower emission rates (see P77.004).

### Impact

By facilitating the sharing of experiences among early adopters and incorporating this information in a Guideline document, power plant operators can use the Guideline to:

- Avoid noncompliance and over-compliance costs due solely to inaccurate or incorrectly certified continuous mercury monitors.
- Save months of time of plant instrument technicians and plant and corporate environmental compliance engineers during system shakedown.
- Prepare for future mercury measurement challenges, such as lower emission limits.

Demonstration of the wide applicability of the sorbent trap method (30B) will enable more plants to use this lower-cost CMM, especially for plants that do not need instantaneous measurements as a feedback signal to a mercury control.

### How to Apply Results

Plant instrument technicians and plant and corporate environmental compliance engineers can obtain information about CMMs through the EPRI website and staff technical support. They also will be able to compare their operations to best practices documented by EPRI and use the report to determine if improvements to their systems or procedures are warranted. Those seeking to use the sorbent trap method (30B) as their CMM will be able to determine if it is an option, given the fuel that they burn.

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Continuous Mercury Measurement Guidelines – Annual Update:</b> Update of 2009 report, with additional experience documented and explained. Progress reports on advanced technologies for lower emission levels or simpler systems. Definition of flue gases in which sorbent traps can be used reliably.	12/31/10	Technical Report

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Continuous Mercury Measurement Guidelines – Update:</b> Update of 2010 report with additional field experience.	12/31/11	Technical Update
<b>Continuous Mercury Measurement Guidelines – Final Report:</b> Final report, with guidance based on up to four years experience, as well as newer developments/advances. Similar to well-known periodic CEMS Guideline updates.	12/31/12	Technical Report

## P77.002 PM Monitor for All Fly Ash and Stack Conditions (069168)

### Key Research Question

Regulators increasingly require coal-fired power plants to install continuous particulate mass (PM) emission monitors and to use an unwieldy calibration approach that can involve detuning of the PM collector and SO<sub>2</sub> scrubber. Further, power plants with SO<sub>2</sub> scrubbers desire to measure their PM in the wet stack following the scrubber in order to obtain a true measure of the emissions leaving the plant — i.e., to receive credit for the PM captured in the scrubber. But not all PM monitors are capable of measuring in that environment due to the optical interference of the water droplets. Power plant operators need a more straightforward calibration approach and one that works in both dry and wet stacks. They also need a better understanding of how well different monitor types perform in wet stacks.

Also needed by industry in the near future are systems that can (a) measure droplet concentrations and sizes distributions in order to monitor mist eliminator droplet loss and quantify sulfuric acid aerosol formation, and (b) provide a direct mass measurement of PM. Recently proposed digital opacity methods rely on comparisons with EPA Method 9 observations; such techniques do not substantially improve the state of the art of opacity measurements and may result in erroneous violations.

### Approach

EPRI will continue the development and demonstration of the Quantitative Aerosol Generator (QAG), a device that challenges a PM monitor with a known mass of particulate. Following the successful demonstration of a laboratory prototype in 2009, it will be taken to the field at a site that is willing to serve as a host for a test program involving several different types of PM monitors — Beta gauge and various optical systems. These tests will determine the QAG's ability to serve as a calibration source for each of these instruments. In parallel, EPRI also will begin to investigate the availability of droplet monitors, or of concepts that could be used to develop a droplet monitor, and other techniques such as tapered element oscillating microbalance (TEOM) that could provide a direct mass measurement of PM. To address the challenge posed by EPA's proposed digital opacity method, EPRI will develop a test protocol to determine if there is a direct link between digital imaging results, stack opacity monitors, and Method 9 observations.

### Impact

- Successful demonstration of the QAG calibration system will eliminate the need for variances to detune air pollution controls in order to generate the range of PM levels required for a calibration.
- A droplet monitor would help operators maintain the mist eliminator in optimum condition and provide a means to measure actual SO<sub>3</sub> emissions leaving the FGD.
- A direct mass measurement of PM emissions would ensure a consistent measurement of PM emissions independent of fly ash properties, potentially avoiding the need to recalibrate the monitor every time the fuel changes (which could be an issue with biomass cofiring if the biofuel source or the percent of cofired fuel changes often).

- Successful demonstration of digital imaging standards for stack opacity measurements would reduce or eliminate erroneous opacity violations.

### How to Apply Results

Power plant environmental engineers could use the instruments and calibration systems developed in this project to:

- Calibrate their PM mass emission monitors with a level of effort comparable to that required for current CEMs
- Monitor the effectiveness of their SO<sub>2</sub> scrubber mist eliminators in real time, reducing water loss and possible emissions of absorbed species
- Obtain more consistent measurements of PM emissions despite frequent fuel changes

### 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Direct Calibration of Particulate Mass Emission Monitors -- Field Test Report:</b> Initial test results on the ability of the QAG to provide an accurate, repeatable calibration source for Beta gauge PM monitors.	12/31/10	Technical Update

### Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Direct Calibration of Particulate Mass Emission Monitors -- Final Report:</b> Test results on the ability of the QAG to provide an accurate, repeatable calibration source for Beta gauge and opacity-based PM monitors. Also, report on methods to relate digital imaging results with other measures of opacity.	12/31/11	Technical Report
<b>Advanced PM Measurement Concepts:</b> Status report on availability and performance of an aerosol monitor and a device that measures PM emissions directly.	12/31/11	Technical Update
<b>Advanced PM Measurement Concepts:</b> Final report (projected) on availability and performance of an aerosol monitor and a device that measures PM emissions directly.	12/31/13	Technical Report

## P77.003 Monitors for Process Control, Compliance, and TRI Reporting (069169)

### Key Research Question

As emission limits become more strict, it is expected that power plants will be subject to limits on ammonia (NH<sub>3</sub>), SO<sub>3</sub>, and potentially HCl, and will be required to install CEMs to prove continuous compliance. Alternatives to current NH<sub>3</sub> monitors, primarily NO<sub>x</sub> chemiluminescence, are needed because the present systems are not accurate enough at the 1-5 ppm emission levels set for gas-fired combined cycle combustion turbines. Measuring to comparable levels could also be required for selective catalytic reduction (SCR)-equipped coal-fired boilers in the future. Emission limits and corresponding measurement requirements may be promulgated for other species, and the industry needs to be prepared.

## Approach

EPRI has been looking for alternatives to the chemiluminescence measurement system for NH<sub>3</sub> at the SCR outlet. Field tests of TDL and FTIR systems have shown promise, but the tests also identified engineering issues (interference by the particulate in the flue gas) that EPRI intends to address in 2009-2011. EPRI also will continue to investigate the possibility of using Differential Optical Absorption Spectroscopy (DOAS) to determine if a potential interference by SO<sub>2</sub> gases can be overcome. Presuming success in proof-of-concept tests on a prototype cavity ring-down spectroscopy (CRDS), an advanced sensor being evaluated under P77.004 during 2009, EPRI will conduct field tests in 2010-11 on process control applications under this project. Surveys of the literature and monitoring of EPA's regulatory calendar will continue in order to stay abreast of any new, field-tested technologies (in other applications) that may be applicable to stack monitoring or new monitoring requirements. EPRI will follow-up, as appropriate, to determine if a R&D activity is needed as a response and will document its findings for the membership. EPRI will continue to provide technical input to the ASTM International committee developing new standard procedures for measuring SO<sub>3</sub> concentrations using the controlled condensate method, with the aim of improving accuracy and consistency.

## Impact

- Successful demonstration of an NH<sub>3</sub> monitor accurate at emission levels consistent with the regulatory limits will prevent exceedances or costly over-control.
- Accurate measurement of SO<sub>3</sub> concentrations can minimize the consumption (and cost) of reagents used for SO<sub>3</sub> control or, in the case of SO<sub>3</sub> injection for ESP performance, the amount of SO<sub>3</sub> injected.
- Advanced knowledge of potential new monitoring requirements will give the industry time to prepare, lessening the chances of being saddled with unnecessarily costly instruments.

## How to Apply Results

Engineers responsible for CEMs procurement and compliant operation can use the performance data generated under this project to determine if instruments are ready for commercial operation, how they need to be installed and operated, and what to require in a bid package for such devices.

## 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Ammonia and SO<sub>3</sub> Monitors for Ultra-low Emission Levels -- Status Report:</b> Status report on lab and early field tests on at least one alternative to current NH <sub>3</sub> monitoring technology for post-SCR locations, and one candidate for continuous SO <sub>3</sub> monitoring following the particulate control.	12/31/10	Technical Update
<b>New Monitoring Requirements and Technologies -- Tech Watch:</b> Findings from Tech Watch seeking potential new monitoring technologies/concepts or regulatory initiatives in the monitoring area.	12/31/10	Technical Update

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>New Monitoring Requirements and Technologies -- Tech Watch:</b> Findings from Tech Watch seeking potential new monitoring technologies/concepts or regulatory initiatives in the monitoring area.	12/31/11	Technical Update
<b>New Monitoring Requirements and Technologies -- Tech Watch:</b> Findings from Tech Watch seeking potential new monitoring technologies/concepts or regulatory initiatives in the monitoring area.	12/31/12	Technical Update

Product Title & Description	Planned Completion Date	Product Type
<b>Ammonia and SO<sub>3</sub> Monitors for Ultra-low Emission Levels -- Technology Readiness Report:</b> Field test results from two to three sites with very low NH <sub>3</sub> emissions and assessment of the technology readiness of the monitor. Field test results from one to two sites of continuous, post-particulate control SO <sub>3</sub> monitors for process control and potential compliance.	12/31/12	Technical Report

## P77.004 Advanced Monitors - Microsensors, CEMS for Hostile Environments, and Automated Diagnostics (046727)

### Key Research Question

As emission limits become more strict, measurement equipment will be challenged to monitor more species and at low concentrations. Significant cost advantages are expected as new multicomponent, lower-detection-level monitoring systems are developed. Recent advances in microchip and nanotechnology offer the promise of drastic reductions in CEMs costs, both through miniaturization and multipollutant measurement capabilities in a single system, as well as greater sensitivity. However, given the small market size of the power industry relative to other industries that use microsensors, developers are not devoting resources to flue gas measurements; hence, the power industry needs to lead the effort to gain the benefits. The industry also needs to prepare for probable CO<sub>2</sub> emission limits in the future, which will require CO<sub>2</sub> measurement at just 1% concentration levels.

### Approach

EPRI continues to look for promising analytical techniques that can be applied to flue gas measurements and conducts proof-of-concept testing of such techniques under this project. Once the concept has been proven, further development and field demonstrations are conducted under P77.003. Previous studies have identified Cavity Ring-Down Spectroscopy (CRDS) and Quantum Cascade Lasers (QCL) technologies.

For CRDS, EPRI expects to complete proof-of-concept tests for NH<sub>3</sub> measurements in 2009, to be followed by engineering and field demonstration of applicability for NH<sub>3</sub> monitoring in 2010-11 (P77.003). Additional laboratory development efforts to expand the application of CRDS for other species (CO<sub>2</sub>, CO, HCHO, CH<sub>4</sub>) will continue in 2010-11. For QCL, EPRI plans to complete proof-of-concept testing for SO<sub>2</sub>, NO, NO<sub>2</sub>, CO<sub>2</sub> in 2010, followed by field demonstrations in 2011 and beyond (P77.003). Laboratory tests of additional species (primarily Hg and SO<sub>3</sub>) will begin in 2011.

Under the Tech Watch function of this project, EPRI also will determine the availability of instruments to measure CO<sub>2</sub> at flue gas concentrations of 1–2% (range of presumed concentrations in the flue gas of power plants equipped in the future with carbon capture technology) or determine the steps needed to obtain and qualify such instruments.

### Impact

Successful deployment of emerging measurement technologies will lower capital and operating costs and improve accuracy at the anticipated future lower emission limits.

- Reduce the capital and operating labor costs of CEMs to as little as 10–25% of those of current systems, with equal or superior performance.
- Reduce ammonia, alkali sorbent, or SO<sub>3</sub> consumption for SCRs, SO<sub>3</sub> abatement, or flue gas conditioning for ESP performance through low-cost, easy, instantaneous feedback of process outlet species concentrations (ammonia for SCR, SO<sub>3</sub> for other two applications). (Supports the process control effort in P77.002 by providing the microsensor technology.)

## How to Apply Results

Planners considering the next round of CEMs replacements will be able to anticipate significantly advanced monitors with greater confidence.

## 2010 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Microsensors for Continuous Flue Gas Species Monitoring -- Status Report:</b> Update of 2009 report, presumably with final results on proof-of-concept demonstration of a fully operational QCL system for SO <sub>2</sub> NO, NO <sub>2</sub> , and CO <sub>2</sub> . Also includes initial proof-of-concept testing of any other promising new sensor types for emissions compliance or process control.	12/31/10	Technical Update

## Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<b>Strategies for Monitoring Low-level CO<sub>2</sub> Emissions:</b> Demonstration tests of CO <sub>2</sub> CEMS measuring at levels around 1-2% CO <sub>2</sub> . May be prototype or commercial unit, depending on supplier offerings.	09/30/11	Technical Report
<b>Microsensors for Continuous Flue Gas Species Monitoring -- Status Report:</b> Update of 2010 report, presumably with proof-of-concept tests on additional sensors or on additional pollutants measured by previously tested sensors.	12/31/11	Technical Update
<b>Guideline on Advanced Sensors for Continuous Flue Gas Species Monitoring:</b> Guidance on the selection, procurement, operation, and use of microsensors for emissions compliance monitoring and for flue gas species monitoring for automated process control (combined P77.003 and P77.004 report).	12/31/12	Technical Report