Continuous Emissions Monitoring - Program 77

Program Overview

Program Description

In the United States, consent decrees, state laws, and anticipated federal Maximum Achievable Control Technologies (MACT) standards for coal-fired power plants drive the need for robust, accurate, and certifiable continuous emissions monitors (CEMS) for particulate matter (PM) and a number of gaseous pollutants not currently measured. Under the United Nations' Environmental Program, a growing number of countries or regions internationally, such as Europe, are considering similar regulations and, therefore, face similar compliance monitoring needs. Of particular interest to a number of power companies are instruments that continuously measure solid (filterable) and aerosol (condensable) PM, acid gases (e.g., hydrochloric acid [HCl], hydrofluoric acid [HF], and hydrogen cyanide [HCN]), and ammonia in post-flue gas desulfurization (FGD) stack conditions. 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 SO2 control
- Droplet monitors to measure condensables
- Sampling techniques that lend themselves to the very low pollutant concentrations that may be required by MACT limits.

For mercury, experience with continuous mercury monitors (CMMs) remains limited, and their operation and maintenance (O&M) are labor-intensive. To continue to drive CMMs’ O&M toward levels now achieved with criteria pollutant CEMs, the industry needs assistance harvesting the lessons learned by early CMMs users. 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 hazardous air pollutants (HAPS)
- Obtain credible, non-ash-property-dependent particulate mass emission measurements made in the stack to benefit from particulate capture by the SO2 control
- Optimize NOx and sulfur trioxide (SO3) control operations, or flue gas conditioning for electrostatic precipitator (ESP) performance, via in situ, continuous measurement systems for ammonia (NH3), SO3, 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, with near-term emphasis on continuous particulate mass and acid gases, and for optimizing pollutant control operation. It identifies, develops, and demonstrates innovative measurement systems with the potential to significantly reduce CEMs costs. It also serves as a clearinghouse for sharing early experience with new measurement systems, so all users do not have to go through the same learning curve, and it provides platforms to instrument suppliers (flue gas and reference measurements) to help them 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 very low mercury concentrations.

• 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. A goal is direct measurement of PM mass. 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. The project will continue to collaborate with EPRI’s post-combustion NOx program (Program 73) to demonstrate in situ NH3 monitors. It also will develop an understanding of the accuracy of CO2 measurement at 1% concentration level (for future operations with CO2 capture).

• EPRI’s work on advanced monitors — microsensors, CEMS for hostile environments, and automated diagnostics — will reinvigorate its Tech Watch for other advanced systems (having not had success with the earlier finds), and conduct proof-of-concept tests if any appear promising.

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 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.

• Strong positive response by the host power station and instrument suppliers to the EPRI-organized monitor troubleshooting and development test platform
Current Year Activities

The program R&D for 2011 will focus on advancing continuous PM monitors to become insensitive to fly ash properties and possible to calibrate without unusual processes; enabling the use of digital opacity systems on large stacks; investigating possible CEMS for acid gases; and compiling/synthesizing the state-of-the-art in CEMS technology in one document. Additional efforts may continue the development and demonstration of continuous in situ, spatial measurements of NH$_3$ and SO$_3$ in the boiler back-end for process control and the continuing Tech Watch for concepts that could lead to significantly lower-cost CEMs. Specific efforts will include:

- Updated CEMs guideline, with the latest lessons learned from installation and first few years of operation of mercury and PM monitors, as well as updates on all other aspects of continuous monitoring
- Development and analysis of data that may still be needed to demonstrate the validity of alternate calibration approaches for continuous PM monitors (e.g., to answer EPA questions)
- Exploratory tests of any concepts providing direct measurement of filterable particulate mass emissions (dry or wet stacks) found in a 2010 survey
- Proof-of-concept tests of potential CMMs enhancements that lower detection levels to emission concentrations expected from controlled power plants
- Evaluation and possible proof-of-concept demonstration of potential CEMS for acid gases (hydrochloric/hydrofluoric acid and, maybe, cyanide)
- Initial assessment of approaches to measuring carbon dioxide (CO$_2$) at 1% concentrations, anticipating a future stringent CO$_2$ capture requirement

Estimated 2011 Program Funding

$1.2M

Program Manager

George Offen, 650-855-8942, goffen@epri.com

Summary of Projects

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<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P77.001</td>
<td>Evaluation of Mercury Monitors</td>
<td>By assembling, scrutinizing, and synthesizing early power plant experience with CMMs, EPRI will provide guidelines that plant instrument staff can use to operate their CMMs for best results at lowest operating and maintenance costs.</td>
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<tr>
<td>P77.002</td>
<td>PM Monitor for All Fly Ash and Stack Conditions</td>
<td>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; provide more accurate and consistent visual observations of opacity; or can be used to monitor mist eliminator performance.</td>
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<td>P77.003</td>
<td>Monitors for Process Control, Compliance, and TRI Reporting</td>
<td>CEMs capable of measuring NH$_3$ and SO$_3$ levels &lt;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.</td>
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<tr>
<td>P77.004</td>
<td>Advanced Monitors - Microsensors, CEMS for Hostile Environments, and Automated Diagnostics</td>
<td>This project is intended to determine 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$_2$ levels in plants with CO$_2$ capture systems.</td>
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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 2010, 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 monitors continues to improve as implementation issues are resolved, aided by EPRI’s role as a clearinghouse for sharing experiences and best practices. 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 provide a forum for sorbent trap users to share experience and refine spiking techniques, and operating procedures. As needed, EPRI will seek fixes to problems 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.
2011 Products

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Future Year Products

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<tr>
<td>Continuous Mercury Measurement Guidelines – 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.</td>
<td>12/31/13</td>
<td>Technical Report</td>
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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 the PM collector and SO₂ scrubber. Further, power plants with SO₂ 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) provide instrument calibration for the recently proposed digital opacity methods (calibrated via comparisons with transmissometer readings rather than comparisons with EPA Method 9 charts, which may result in erroneous indication of violations) and enable its use in typical electric generation units, whose stacks mostly are larger than the current 7-foot-diameter limit; b) measure droplet concentrations and size distributions in order to monitor mist eliminator droplet loss and quantify sulfuric acid aerosol formation, and c) provide a direct mass measurement of PM.

Approach

EPRI will complete the development of the Quantitative Aerosol Generator (QAG), a device that challenges a PM monitor with a known mass of particulate, as well as fly ash injection techniques. These technologies are being tested at a power plant where suppliers of up to seven different continuous PM monitors (including Beta gauge, various optical systems, triboelectrostatic, TEOM [tapered element oscillating microbalance], and a hybrid) are troubleshooting and field-hardening their systems and assisting in the checkout of these alternative calibration approaches. In parallel, EPRI also will investigate the availability of droplet monitors, or of concepts that could be used to develop a droplet monitor. EPRI also will begin to evaluate any promising techniques found during a 2010 survey that could provide a direct mass measurement of PM. To overcome the questions on accuracy and stack size limitations placed on the use of the digital opacity method, EPRI will conduct field tests at plants with typical stack diameters (>7 ft), comparing the “readings” provided by the digital opacity instrument and the plant’s transmissometer.
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, saving innumerable hours to obtain the variance and possible penalties or loss of goodwill with the local air regulatory authorities.
- A droplet monitor would help operators maintain the mist eliminator in optimum condition and provide a means to measure actual SO$_3$ 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 at power plants 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$_2$ 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

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<tr>
<td><strong>Particulate Mass Emission Monitoring -- Performance, Calibration, and Validation via Electronic Opacity:</strong> Test results on the ability of the QAG and/or fly ash injection techniques to provide an accurate, repeatable calibration source for continuous mass PM monitors, independent of fly ash properties. Also, report on the accuracy of digital imaging results for power plant-size stacks, based on comparisons with transmissometers (electronic measurements, not human judgment).</td>
<td>12/31/11</td>
<td>Technical Report</td>
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<tr>
<td><strong>Advanced PM Measurement Concepts:</strong> Final report (projected) on availability and performance of an aerosol monitor and a device that measures PM emissions directly.</td>
<td>12/31/13</td>
<td>Technical Report</td>
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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$_3$), SO$_3$, HCl/HF/HCN, selenium, and, potentially, arsenic and organics. When this happens, the plants will be required to install CEMs to prove continuous compliance. Alternatives to current NH$_3$ monitors, primarily NOx chemiluminescence, are needed because the present systems are not accurate enough at the 1-5 ppm emission levels that could be set for boilers as it has been for gas-fired combined cycle combustion turbines. CEMS do not exist or are not widely used and accepted for the other HAPS noted.

Approach
In 2011, EPRI will continue to seek methods to overcome interference by the particulate in the flue gas when using tunable diode lasers (TDL) or Fourier Transform Infra-Red (FTIR) systems to measure NH$_3$ at the SCR outlet. EPRI also will continue to investigate the possibility of using Differential Optical Absorption Spectroscopy (DOAS) to determine if a potential interference by SO$_2$ gases can be overcome.

In 2010, EPRI will search for methods to measure the other HAPS indicated above. Depending on the findings and the emission limitations in EPA’s March 2011 proposed MACT rule, EPRI will survey the literature and CEMS suppliers to determine the state-of-the-art in conducting the required measurements. Research to address any needs in these areas will be planned and initiated following the publication of the proposed MACT and assessment of its measurement requirements.

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 an 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$_3$ concentrations using the controlled condensate method, with the aim of improving accuracy and consistency.

Impact
- Successful demonstration of an NH$_3$ monitor accurate at emission levels consistent with the regulatory limits will prevent exceedances or costly over-control.
- Accurate measurement of SO$_3$ concentrations can minimize the consumption (and cost) of reagents used for SO$_3$ control or, in the case of SO$_3$ injection for ESP performance, the amount of SO$_3$ 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.

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<tr>
<td>New Monitoring Requirements and Technologies -- Tech Watch: Findings from Tech Watch seeking potential new monitoring technologies/concepts or regulatory initiatives in the monitoring area. Will include any significant advances on NH$_3$ and SO$_3$ monitoring beyond the 2010 work.</td>
<td>12/31/11</td>
<td>Technical Update</td>
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Future Year Products

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<tr>
<td><strong>New Monitoring Requirements and Technologies -- Tech Watch:</strong> Findings from Tech Watch and subsequent RD&amp;D on new monitoring technologies/concepts or regulatory initiatives in the monitoring area.</td>
<td>12/31/12</td>
<td>Technical Update</td>
</tr>
<tr>
<td><strong>Ammonia and SO3 Monitors for Ultra-low Emission Levels -- Technology Readiness Report:</strong> Field test results from two to three sites with very low NH₃ emissions and assessment of the technology readiness of the monitor. Field test results from one to two sites of continuous, post-particulate control SO₃ monitors for process control and potential compliance.</td>
<td>12/31/12</td>
<td>Technical Report</td>
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<tr>
<td><strong>New Monitoring Requirements and Technologies -- Tech Watch:</strong> Findings from Tech Watch and subsequent RD&amp;D on new monitoring technologies/concepts or regulatory initiatives in the monitoring area.</td>
<td>12/31/13</td>
<td>Technical Report</td>
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**P77.004 Advanced Monitors - Microsensors, CEMS for Hostile Environments, and Automated Diagnostics (046727)**

**Key Research Question**

As emission limits become stricter, measurement equipment will be challenged to monitor more species and at low concentrations. Significant cost advantages are expected if new multicomponent, lower-detection-level monitoring systems can be 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 CO₂ emission limits in the future, which will require CO₂ measurement at just 1% concentration levels.

**Approach**

Because the long-term, potentially very low-cost multipollutant sensors found and tried in previous years were discovered to be not ready for further development by EPRI, given the industry's higher near-term priorities (mercury, PM, NH₃, and now acid gases and other potential MACT pollutants), EPRI again will revert to a Tech Watch mode and encouragement to developers of next-generation CEMS sensors until the industry's nearer-term needs have been addressed.

As part of the Tech Watch, EPRI also will determine the availability of instruments to measure CO₂ 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 could 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$_3$ consumption for SCRs, SO$_3$ abatement, or flue gas conditioning for ESP performance through low-cost, easy, instantaneous feedback of process outlet species concentrations (ammonia for SCR, SO$_3$ for the other two applications). This work eventually would support the process control effort in P77.003 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.

Future Year Products

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<tr>
<td><strong>Advanced Sensors for Continuous Flue Gas Species Monitoring:</strong> Identification and engineering assessment of microsensors that might be applicable for use in CEMS or for flue gas species monitoring for automated process control (may be combined with a P77.003 report). Lab or field test results if such sensors are found.</td>
<td>12/31/12</td>
<td>Technical Report</td>
</tr>
<tr>
<td><strong>Advanced Sensors for Continuous Flue Gas Species Monitoring:</strong> Update of 2012 report on microsensors that might be applicable for use in CEMS or for flue gas species monitoring for automated process control. Lab or field test results if such sensors are found.</td>
<td>12/31/14</td>
<td>Technical Report</td>
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