DOE/NETL's Mercury Control Technology Research Program for Coal-Fired Power Plants

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Mercury exists in trace amounts in fossil fuels (e.g., natural gas, oil, and coal), vegetation, crustal material, and waste products. Through combustion or natural processes, mercury vapor is released to the atmosphere, where it can drift for a year or more, spreading with air currents across vast regions of the globe. An estimated 4900 tons of mercury are emitted annually into the atmosphere worldwide from both natural and anthropogenic sources.[1] Coal-fired power plants in the United States emit approximately 48 tons of mercury per year, which is only a small fraction, approximately 1%, of total worldwide mercury emissions.

While mercury emissions from other U.S. industrial sources are being regulated, controls have not yet been required for electric utility boilers. However, the U.S. Environmental Protection Agency (EPA) in December 2000 determined a need to regulate mercury emissions from coal-fired plants because of a "plausible link" between emissions of mercury from these plants and the bioaccumulation of mercury in fish. As a result, EPA has begun development of a Maximum Achievable Control Technology (MACT) standard to regulate mercury emissions from power plants. The final MACT regulation is scheduled to be issued by December 2004 and compliance could be required by December 2007. Parallel to the MACT process, the Bush Administration's Clear Skies Initiative and several other versions of multipollutant legislation have been proposed by members of Congress requiring varying degrees of mercury emissions reductions from U.S. power plants.

CHALLENGES OF MERCURY CAPTURE

The Clean Air Act Amendments of 1990 required EPA to conduct a study of mercury emissions from various combustion and other sources. In 1999–2000, EPA carried out an Information Collection Request (ICR) to update the mercury emissions inventory for U.S. coal-fired plants.[2] The outcome of the ICR indicated that some degree of mercury control (co-benefit control) is achieved by existing conventional air pollution control devices (APCDs) installed for removing nitrogen oxides (NO_x), sulfur dioxide (SO_2), and particulate matter (PM). However, the ICR also indicated that the capture of mercury across existing APCDs varies significantly, based on coal properties, fly ash properties (including unburned carbon), specific APCD configurations, and other factors, with the level of control ranging from 0% to more than 90%. Perhaps one of the most significant findings of the ICR was that units burning subbituminous and lignite coals frequently demonstrated significantly lower mercury capture than similarly equipped bituminous-fired units. The lower performance observed for low-rank coals may be linked to the speciation or chemical form of mercury in the flue gas. EPA's analysis indicates that plants that burn bituminous coal typically have higher levels of oxidized mercury than plants that burn lignite or subbituminous coal, possibly due to the higher chlorine and/or sulfur content of bituminous coal. The higher chlorine content may affect speciation and enhance the adsorption of gas-phase mercury onto the surface of activated carbon or fly ash.

The U.S. Department of Energy/National Energy Technology Laboratory (DOE/NETL) is conducting a comprehensive mercury research and development program directed at full-scale field-testing of mercury control technologies, as well as bench- and pilot-scale tests of several novel control concepts. The research also considers characterization of mercury in coal byproducts and the transport of mercury in power plant plumes. This article provides a summary of the status of DOE/NETL's mercury research program, with a focus on the development of advanced emissions control technology.

It is clear that conventional APCD technology, while achieving some degree of co-benefit mercury capture, will not achieve the level of control necessary to meet currently proposed mercury limits. Today, no single technology can cost-effectively provide add-on mercury control suitable for all plant configurations and fuel types. Activated carbon injection (ACI) has shown the most promise as a near-term mercury control technology. Although ACI is considered an accepted technology for use at waste combustors, several challenges need to be addressed before it can be considered a commercial technology for coal-fired power plants. The effect of long-term use of ACI (or any other injected sorbent or additive) on plant operations has yet to be determined. In addition, for plants that sell their ash as a byproduct, an increase in carbon content (or the addition of other chemical compounds) may adversely affect the resale value of the ash and, consequently, may lead to increased costs for disposal.

DOE/NETL'S MERCURY RESEARCH PROGRAM

Recognizing the potential for mercury regulation, the U.S. Department of Energy/National Energy Technology Laboratory (DOE/NETL) has been carrying out comprehensive mercury research under the DOE Office of Fossil Energy's Innovations for Existing Plants (IEP) program. Initial efforts in the early 1990s were directed at characterizing power plant mercury emissions and focused on laboratory- and bench-scale control technology development. The current program is directed at full-scale field-testing of mercury control technologies, as well as continued bench- and pilot-scale tests of a number of novel control concepts. The near-term goal is to develop mercury control technologies that achieve 50–70% mercury capture at less than three-quarters of the baseline cost estimate of $50,000–$70,000/lb of mercury removal for ACI technology. The aim is for these technologies to be available for commercial demonstration by 2005 for bituminous coal plants and by 2007 for lignite and subbituminous plants. The longer-term goal is to develop advanced mercury control technologies that achieve 90% or greater capture at one-half to three-quarters of the cost of current ACI technology and be available for commercial demonstration by 2010.

In September 2000, DOE/NETL awarded funding for the full-scale testing of two approaches to mercury control that could meet the IEP's short-term goals. Then in June 2001, additional funding was provided for six bench- and pilot-scale projects focused on developing novel concepts for mercury control that could meet the IEP's long-term goal. In addition, six new mercury projects were initiated in 2003. The IEP program also includes fundamental research to better understand mercury speciation in power plant plumes, as well as the ultimate fate of mercury in coal byproducts. DOE/NETL also participates with the University of North Dakota's Energy & Environmental Research Center (EERC) in a jointly sponsored research program that includes several mercury control technology projects. The following sections include brief summaries of the various DOE/NETL mercury research and development projects.

Sorbent Injection

Laboratory-, bench-, and pilot-scale studies have shown that sorbent injection could be an effective approach for the control of mercury emissions from coal-fired plants. These studies also suggested that lowering the flue gas temperature using water-spray cooling might aid mercury adsorption and reduce sorbent injection requirements. To evaluate the potential of sorbent injection as a mercury control option, ADA Environmental Solutions (ADA-ES) conducted large-scale field tests at the four coal-fired plants described in Table 1.

Testing included parametric tests using several commercially available powdered activated carbon (PAC) products at various feed rates and operating conditions, followed by a one- to two-week long-term test with one of the PAC products selected from the parametric testing. Figure 1 presents an overall comparison of mercury removal versus carbon injection rate for the tests conducted at the E.C. Gaston, Pleasant Prairie, and

Table 1. Description of plants used for sorbent injection field tests.

Company	Plant	Coal Rank	APCD Configuration	Tests Completed
Alabama Power	E.C. Gaston	Low sulfur bituminous	Hot-side ESP and COHPAC	April 2001
We Energies	Pleasant Prairie	PRB	Cold-side ESP	November 2001
PG&E	Brayton Point	Low sulfur bituminous	Cold-side ESP	August 2002
PG&E	Salem Harbor	Low sulfur bituminous	Cold-side ESP and SNCR	November 2002

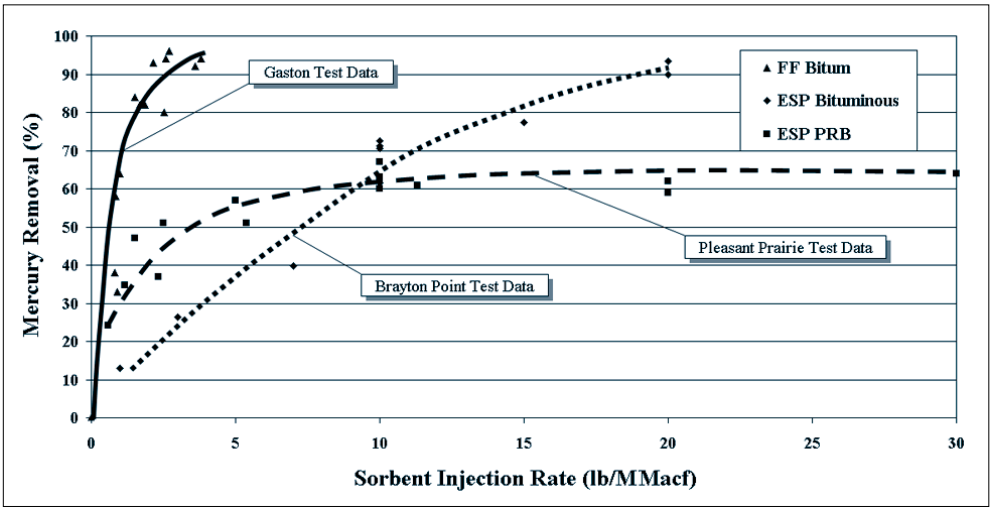

Figure 1. Mercury removal (%) vs. sorbent injection rate (lb/MMacf) for tests at three sites.

Brayton Point plants. As Figure 1 shows, PAC injection can provide some degree of mercury control for existing units. However, the degree of mercury reduction and sorbent requirements vary significantly, based on APCD configuration, coal rank, and the baseline level of mercury reduction co-benefits. The following is a brief summary of the test results.

E.C. Gaston (Unit No. 3). While there was no measurable performance difference between the PACs used during the parametric testing, Norit's Darco FGD activated carbon was selected for the nine-day, long-term tests. Mercury capture averaged 87–90% with a carbon injection rate of 1.5 pounds per million actual cubic feet (lb/MMacf) of flue gas based on three Ontario Hydro test results. However, continuous emissions monitor (CEM) mercury data indicated an average capture of 78% that varied from 36% to 90%. As a result of the increased particulate loading during carbon injection, the required cleaning frequency of the compact hybrid particulate collector (COHPAC) baghouse increased significantly. There was no improvement in mercury capture using the spray cooling system.[3-5]

Pleasant Prairie. Norit's Darco FGD activated carbon was used during three five-day, long-term tests at feed rates of 1.6 and 11.3 lb/MMacf, with mercury capture ranging from 46% to 66%. Although carbon injection did not deteriorate electrostatic precipitator (ESP) performance, the ESP was relatively large and additional testing needs to be conducted on units with smaller ESPs. As in the E.C. Gaston testing, there was no improvement in mercury capture using the spray cooling system.[4,6]

Brayton Point. Norit's Darco FGD was injected between two cold-side ESPs at feed rates of 3 and 20 lb/MMacf, with mercury capture ranging from 25% to 90% across the second ESP. The carbon injection did not deteriorate ESP performance. However, the second ESP was relatively large and additional testing needs to be conducted on units with smaller ESPs.[6]

Salem Harbor. During baseline testing without PAC injection, average mercury capture was 90%. The high baseline mercury removal was attributed to high levels of unburned carbon and low flue gas temperature (approximately 270 °F). Parametric testing was conducted at various flue gas temperatures and PAC injection rates ranging from 5 to 20 lb/MMacf. Without PAC injection, baseline mercury capture decreased from 50–70% at temperatures of 285–325 °F to 5–20% at 345 °F. At 20 lb/MMacf PAC injection, mercury capture was 75–85% at 285–325 °F and 45% at 345 °F. While temperature clearly caused a decrease in baseline mercury capture, the effect that increased temperature has on PAC performance is uncertain.[6]

Enhanced Mercury Control in Wet FGD

There is evidence that a portion of the oxidized mercury captured in a wet flue gas desulfurization (FGD) system can be reduced to elemental mercury and emitted out the stack. A method to prevent the reduction of oxidized mercury would enhance the overall mercury capture across the wet FGD system. Babcock & Wilcox and McDermott Technology Inc. carried out full-scale field tests of a proprietary liquid reagent to enhance mercury capture in coal-fired plants equipped with wet FGD systems. The project was initiated in 2000 and completed in 2002. Testing was conducted at two power plants: Michigan South Central Power Agency's 60-MW Endicott Station and Cinergy's 1300-MW Zimmer Station. Both plants burn high-sulfur bituminous coal and use cold-side ESPs for particulate control. The Endicott Station uses a limestone wet FGD system with in situ forced oxidation and the Zimmer Station uses a magnesium-enhanced lime wet FGD system with ex situ forced oxidation.

Test results were mixed. A favorable outcome was achieved at Endicott in that the reagent was able to suppress mercury reduction across the wet FGD system. Testing at Zimmer did not achieve the desired effect and reduction of oxidized mercury to elemental mercury continued across the wet FGD system. Possible explanations for the poor results at Zimmer include the high sulfite concentration and low liquid-to-gas ratio in the magnesium-enhanced lime wet FGD system, which may have impeded reagent performance. Table 2 presents the baseline and reagent results. The tests conducted at Endicott and Zimmer also included an evaluation of the

mercury concentration in the various byproduct streams. A significant finding was that the mercury in the wet FGD waste slurry from both plants was not bound to the gypsum particles. Therefore, it may be possible to use particle separation techniques to minimize potential mercury contamination of the gypsum.[7]

Low-Temperature Mercury Capture with an ESP

Consol Energy Inc. is conducting tests to demonstrate mercury capture with an ESP operating at low flue gas temperatures. The pilot-scale testing will be carried out at Allegheny Energy's 288-MW Mitchell Power Station, Unit No. 3, which burns a medium-high sulfur eastern bituminous coal. The project was initiated in 2001 and is scheduled for completion in 2004. Previous research conducted by Consol demonstrated that fly ash particles in power plant flue gas could adsorb a significant portion of the mercury if the gas is cooled below typical exhaust temperatures (i.e., 300–200 ºF). However, operating at reduced flue gas temperatures also results in the condensation of sulfur trioxide (SO_3), which can lead to equipment and duct corrosion. To address the corrosion problem, Consol is using an alkaline sorbent injection system to reduce the flue gas SO_3 concentration.

Low-Cost Novel Mercury Sorbents

Apogee Scientific Inc. is conducting pilot tests to assess the mercury capture performance of low-cost novel sorbents. The project was initiated in 2001 and will be completed in 2003. Pilot testing was conducted using a flue gas slipstream in a small-scale pilot system at two power plants: Midwest Generation's Powder River Basin (PRB)-fired Powerton Generating Station and We Energies' low-sulfur bituminous-fired Valley Plant. More than 40 sorbents were tested in a fixed-bed arrangement, including activated carbons, char (mildly activated carbon), unburned carbon from fly ash, and zeolite sorbents. Based on fixed-bed test results, eight sorbents for the PRB application and 17 sorbents for the bituminous application were selected for evaluation. Preliminary analyses show that some of the sorbents being tested cost 15–30% less than the baseline Norit America's Darco FGD activated carbon. Mercury capture performance varies, ranging from 5% to greater than 90% mercury capture, with the iodine-impregnated carbon performing the best at low injection rates. For the sorbents tested at Powerton, flue gas temperatures up to 350 ºF did not significantly affect performance in the baghouse or residence chamber configuration.[8]

Table 2. Mercury removal across wet FGD.

Mercury Species	Endicott		Zimmer	
	Baseline (%)	Reagent (%)	Baseline (%)	Reagent (%)
Total	60	76	45	51
Oxidized	90	93	90	87
Elemental	(40)	20	(20)	(41)

Advanced Hybrid Particulate Collector

EERC is conducting bench-scale and large pilot-scale field demonstration tests to evaluate mercury control performance of sorbent injection used in conjunction with advanced hybrid particulate collector (AHPC) technology, a combination ESP and fabric filter (FF) system designed to optimize fine particulate collection. Design characteristics of the AHPC may allow for equivalent or better mercury capture at lower sorbent feed rates than conventional ESP and FF systems. Large pilot-scale tests are being conducted on PRB coal at Otter Tail Power Company's 450-MW Big Stone Plant. The project was initiated in 2001 and is scheduled for completion in 2004.

Results from the pilot-scale tests indicate a 91–97% total mercury collection efficiency with a sorbent feed rate of 1.5 lb/MMacf, compared to a baseline (no sorbent) mercury collection efficiency of 49%. The relatively high mercury removal rates are somewhat unexpected for low-rank coals and may have occurred because of high levels of chlorine in the flue gas, perhaps due to co-combustion of tire-derived fuel (TDF) in the boiler during the test period. Additional pilot-plant studies were conducted at an ACI rate of 1.5 lb/MMacf and mercury removal ranged from 65% without TDF cofiring to 90% with TDF cofiring. Supplemental injection of hydrogen chloride had little or no effect on mercury removal.[9]

ECO Multipollutant Control Technology

Powerspan Corp. is conducting pilot-scale field tests to optimize the mercury control performance of the electro-catalytic oxidation (ECO) process. This project was initiated in 2001 and is scheduled for completion in 2004. The technology is a nonthermal, plasma-based multipollutant control concept designed for the simultaneous removal of SO_2, NO_x, and fine particulate emissions from the flue gas of coal-fired plants. Previous pilot-scale testing suggested that the ECO process has the potential for significant mercury removal because the reactor can convert elemental mercury to oxidized mercury. The oxidized mercury can then be efficiently captured in the wet FGD. An activated carbon filtration system is also being tested for the removal of captured mercury from the wet FGD discharge prior to crystallization of the ammonium sulfate and nitrate byproducts.

The pilot-scale field-testing is being conducted on a flue gas slipstream at FirstEnergy's eastern bituminous-fired R.E. Burger Plant. Preliminary test results indicate an average mercury removal efficiency of 88% across the plant; however, the effectiveness of the ECO system's ability to oxidize elemental mercury is still being evaluated. Speciated testing has shown that normal inlet flue gas elemental mercury concentration

is extremely low. Therefore, artificial injection of elemental mercury into the pilot plant is being tested to demonstrate ECO's ability to capture elemental mercury.[10,11]

Calcium-Based Sorbents and Oxidizing Agents

The Southern Research Institute (SRI) is conducting bench- and pilot-scale tests to assess the performance of calcium-based sorbents and oxidizing agents that could provide simultaneous removal of both mercury and SO_2 from flue gas. The individual sorbents consist of a proprietary oxidant and either a hydrated lime ($Ca(OH)_2$) or a silica-modified calcium ($CaSiO_3$). The oxidant is intended to oxidize gas-phase elemental mercury. The sorbents are being tested on a variety of coal types and flue gas conditions at SRI's Combustion Research Facility. The project was initiated in 2001 and is scheduled for completion in 2004.

Initial pilot-scale tests of the two sorbents on low-sulfur bituminous coal showed both to be ineffective in enhancing the oxidation and capture of elemental mercury and achieved overall mercury removal of only 25–50%. Follow-up tests with an ordinary hydrated lime sorbent without the oxidant was able to remove 80–90% of the mercury. Subsequent bench-scale tests indicate that the two proprietary sorbents would be more effective in mercury removal with injection at a higher flue gas temperature and lower NO_x concentration compared to the initial pilot-scale test conditions. Additional pilot-scale testing will evaluate the sorbent performance under alternate flue gas conditions.[12]

SRI has also evaluated additional oxidizing agents, including kaolinite and chlorine gas injection into high temperature zones. The kaolinite proved to be ineffective, while the chlorine gas showed promise when injected into the burner, but not when injected upstream of the air heater. When chlorine gas was injected into the burner, the fraction of oxidized mercury in the flue gas was raised from less than 20% to greater than 50%. Coal blending (i.e., 90% PRB and 10% bituminous) resulted in greater than 50% oxidized mercury at the particulate collector inlet, compared to 15% for PRB coal only.[13]

Mercury Oxidation Catalysts

URS Corp. is conducting pilot-scale evaluations of several catalysts for the oxidation of elemental mercury in flue gas. The project was initiated in 2001 and is scheduled for completion in 2004. This project is necessary to demonstrate the long-term effectiveness of four previously tested catalysts on honeycomb substrates that could be used in full-scale commercial applications. The pilot-scale testing is being conducted at Great River Energy's North Dakota lignite-fired Coal Creek Station and City Public Service of San Antonio's PRB-fired J.K. Spruce Plant.

Initial tests demonstrated varying degrees of mercury oxidation, ranging from 53% to 93% across three catalysts. However, two catalysts demonstrated early activity that decreased significantly after 60 days in service. Subsequent inspection indicated that a buildup of fly ash in the pilot test chamber likely caused the drop in oxidation rather than a loss of catalyst activity. A sonic horn is being tested to prevent the buildup of fly ash and testing of the fourth catalyst has been postponed until the problem is corrected.[14-16]

Mercury Speciation at Plants Using SCR and SNCR

EERC is conducting tests at several coal-fired plants equipped with selective catalytic reduction (SCR) or selective noncatalytic reduction (SNCR) NO_x control technologies. Prior EERC testing indicated that the catalyst and/or ammonia (NH_3) reagent associated with SCR and SNCR might convert some of the elemental mercury to oxidized and particulate mercury in the flue gas. The project was initiated in 2001 and is scheduled for completion in 2003.

Field studies were conducted at six unnamed coal-fired plants in 2001. Four of the plants were equipped with SCR controls, one plant used SNCR; and one plant used NH_3 and SO_3 for ash conditioning to improve particulate control. Follow-up field tests were conducted in 2002 at two of the 2001 SCR-equipped plants and two additional plants with SCRs.

The results from the 2001 field tests are mixed and indicate that, while oxidation of mercury across SCR systems can occur, the oxidation is a complex process that may be dependent on several variables, such as coal properties, furnace conditions, and catalyst factors, including type, size/gas space velocity, and age. Significant oxidation was shown to occur across the SCR for two of the four plants. Of the two plants that did not show significant oxidation across the SCR, one burned PRB coal in a cyclone furnace and the other used a relatively small SCR control compared to the other test sites. Testing at three of the four plants with SCR and two plants using SNCR and flue gas conditioning indicated that NH_3 injection did not significantly improve mercury oxidation. Furthermore, during operation of the SCR at one plant without NH_3 feed, the oxidized mercury further increased from 64% to 82% at the SCR outlet.

Follow-up field tests at the two sites tested in 2001 yielded mixed results. While oxidation across the catalyst (measured at the SCR outlet) appears to have decreased from that observed in 2001, the flue gas fraction of oxidized mercury at the inlet to the particulate control device was unchanged, approximately 97% and 95%, respectively, at the two sites. Contrary to the performance observed at the site with the small SCR tested in 2001, tests in 2002 at two additional bituminous-fired units with similar-sized SCRs demonstrated improved oxidation due to SCR operations.[17-19]

Mercury Control Technologies for Utilities Burning Lignite Coal

EERC is conducting a two-phase project to develop and test sorbent injection technologies for utilities that burn lignite coal. The first phase of the project is to conduct bench- and pilot-scale evaluations for the screening of potential sorbents, and

the second phase of the project is to conduct full-scale field tests of the selected sorbents at a lignite-fired power plant. The project was initiated in 2001 and is scheduled for completion in 2003.

The pilot-scale testing, using two different lignite coals, is being conducted to compare the mercury capture effectiveness of sorbent injection into an ESP, FF, and AHPC. Norit FGD and a char-derived sorbent were selected for pilot-scale testing. Initial tests indicated that mercury capture using carbon sorbents could be highly dependent on carbon activation temperatures. In addition, hydrogen chloride in the flue gas appears to act as a conditioning agent for the sorbents.[20] Pilot-scale testing demonstrated 70% mercury capture at sorbent injection rates ranging from 2.9 lb/MMacf for the AHPC to 17.1 lb/MMacf for the ESP. Mercury capture efficiency of the sorbents was different for the two lignites, while increasing flue gas temperatures, from 300 °F to 400 °F, caused equally lower mercury capture efficiency for both coals.[21]

Advanced Particulate Collector

Under its particulate control program, DOE/NETL is sponsoring the pilot-scale development of LSR Technologies' particulate control technology known as ElectroCore. ElectroCore is an electrically enhanced mechanical separator designed to be retrofitted downstream of an existing ESP to optimize fine particulate collection. This project was initiated in 2000 and completed in 2002. The pilot-scale testing was conducted at Alabama Power Company's bituminous coal-fired E.C. Gaston, Unit No. 4. In addition to particulate removal, the mercury removal performance of the ElectroCore process was evaluated in conjunction with PAC injection. Preliminary test results indicate that the ElectroCore process captures approximately 90% of the total mercury at a PAC injection rate of 7 lb/MMacf.[22]

IN-HOUSE RESEARCH ACTIVITIES

An important component of DOE/NETL's mercury research program is its in-house research and development activities. Laboratory experimentation, modeling, and pilot-scale testing is being carried out in support of the overall goal of developing low-cost mercury control technology. In the laboratory-scale work, novel sorbents and techniques for the removal of mercury from flue gas are being investigated using a small packed-bed reactor. In the pilot-scale work, a 500-lb/hr pulverized coal-fired combustion system, which includes a furnace, air preheater, spray dryer, ductwork, and a pulse-jet FF, has been characterized with respect to the distribution and fate of hazardous air pollutants in flue gas, with an emphasis on mercury. Investigations with this unit have entailed evaluation of various activated carbons and novel sorbents, as well as comparisons of various sampling techniques for the determination of total and speciated forms of mercury while burning a low-sulfur bituminous coal. To provide insight into the data obtained from the pilot-scale system, a two-stage mathematical model using PAC has been developed. The model accounts for in-flight mercury removal in the ductwork with additional removal in the FF.[23,24] In addition, a computational fluid dynamics modeling effort was initiated in 2002 by DOE/NETL's in-house staff.

As a result of the in-house research, the following two novel DOE/NETL processes show promise as cost-effective methods for mercury control.

In Situ Sorbent Removal of Mercury

The Thief Process (U.S. Patent No. 6,521,021)[25] removes mercury from coal combustion flue gas by adsorption/absorption onto thermally activated sorbent produced in situ. The sorbent consists of semicombusted coal, which is extracted from the furnace, injected into the flue gas downstream of the air

preheater, and then captured in a particulate control device. The in situ-produced sorbent is not always as reactive as commercially available activated carbon, but pilot-scale tests indicate that mercury removal efficiencies of up to 90% are achievable. Continued testing of the Thief Process will be carried out in the 500-lb/hr combustor burning different coals.[26]

Photochemical Removal of Mercury

A new method developed by DOE/NETL, called the GP-254 Process (U.S. Patent No. 6,576,092),[27] may enhance mercury removal from coal-fired plant combustion flue gas in existing APCDs. Irradiation with 253.7-nm ultraviolet radiation can induce many components of flue gas to react with elemental mercury and subsequently cause an increase in the fraction of oxidized mercury. The oxidized mercury species can then be captured near the radiation zone or in downstream particulate control or wet FGD pollution control equipment. A preliminary cost analysis suggests that annual operating costs for the GP-254 Process could compete with current ACI systems.[28]

IMPACT OF MERCURY CAPTURE ON COAL UTILIZATION BYPRODUCTS

There is concern that mercury captured in coal utilization byproducts (CUB) could be reemitted into the environment during disposal or use. DOE/NETL is sponsoring a number of projects that focus on the evaluation of potential leaching and volatilization of mercury and other trace metals from CUBs. DOE/NETL in-house researchers, the DOE/NETL-sponsored Combustion By-Products Recycling Consortium, industry, and other research organizations are assessing potential mercury releases from CUBs and products manufactured from CUBs, such as cement, gypsum wallboard, and manufactured aggregates. Preliminary results of testing conducted by Consol indicate that a minimal amount of mercury is leached from CUBs, with less than 1 ppb of mercury detected in all of the leachate samples collected from 14 coal-fired plants.[29] Additionally, leachate sampling and testing will be conducted by EPRI at approximately 25 active or closed CUB disposal sites. The EPRI project was initiated in 2002 and is scheduled for completion in 2005.

TRANSPORT AND FATE OF MERCURY EMISSIONS

The majority of DOE/NETL mercury research is directed at the development of control technologies and the evaluation of the environmental impacts of captured mercury in CUBs. However, DOE/NETL is also sponsoring research to evaluate the transport and fate of mercury emissions from coal-fired plants. For example, DOE/NETL is supporting a wet deposition monitor located near Holbrook, PA, as part of the National Atmospheric Deposition Program–Mercury Deposition Network.[30] DOE/NETL and EPRI are cosponsoring two projects to characterize the speciation and reactions of mercury in the stack plumes of coal-fired plants. In addition, Ohio University is conducting an evaluation of the emissions, transport, and deposition of mercury, arsenic, and fine PM from coal-fired plants in the Ohio River Valley region. The atmospheric behavior of gaseous speciated mercury may influence local deposition patterns. If the sponsored research indicates that local deposition "hot spots" are unlikely, proposed mercury emissions trading programs could offer additional compliance options for units that may require costly retrofit technologies.

NEW MERCURY PROJECTS

Several new mercury control technology research and development projects were initiated in 2003 and are described below.

- ADA-ES will conduct a one-year long-term performance evaluation of the impact of ACI on the COHPAC FF particulate collection system at Alabama Power's E.C. Gaston Plant.
- General Electric Energy and Environmental Research Corp. will conduct a two-year field evaluation using a combination of overfire air and coal reburn to achieve multipollutant control of NO_x and mercury at Western Kentucky Energy's R.D. Green Power Station.
- Consol will conduct mercury speciation field-testing at 10 bituminous coal-fired plants equipped with both SCR and FGD systems.
- Reaction Engineering will conduct a six-month pilot-scale mercury speciation test for several NO_x SCR catalysts using a flue gas slipstream at AEP's PRB-fired Rockport Power Plant.

As a follow-on to current projects, DOE/NETL has issued a new competitive solicitation to conduct a second phase of full-scale mercury control technology field tests. The scope of this solicitation is to conduct long-term field tests of advanced mercury control technologies over a broad range of coal types and APCD configurations, with a particular emphasis on low-rank coals. The overall goal is to provide cost and performance data to facilitate the design and operation of commercial demonstration projects. Project awards are to be announced by the end of 2003.

CONCLUSIONS

While our knowledge of the formation, distribution, and capture of mercury from coal-fired power plants has greatly advanced over the past decade, many uncertainties and challenges still remain. Moreover, the technology to cost-effectively remove mercury from the diverse population of coal-fired plants currently in operation is not yet commercially available. Therefore, as regulators move toward regulating mercury emissions from the electric-utility sector, it is critical that research continues to address these challenges.

In response, DOE/NETL is continuing to partner with industry and other key stakeholders in carrying out its comprehensive mercury control technology research program. This effort is being carried out through extramural and in-house research

focused on enhancing the capture of mercury across existing APCDs, and developing novel stand-alone control concepts to achieve high levels of mercury removal at costs considerably lower than currently available technology. In addition, the program includes more fundamental research directed at understanding the fate of mercury in CUBs, as well the emissions, transformation, and transport of mercury from coal-fired plants. The results from the DOE/NETL mercury research program will provide much needed data to further characterize the emissions from coal-fired plants. For more information, visit the Web site: *www.netl.doe.gov/coalpower/environment/index.html*.

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DISCLAIMER

Reference in this article to any specific commercial product or service is to facilitate understanding and does not imply endorsement by the U.S. Department of Energy.

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