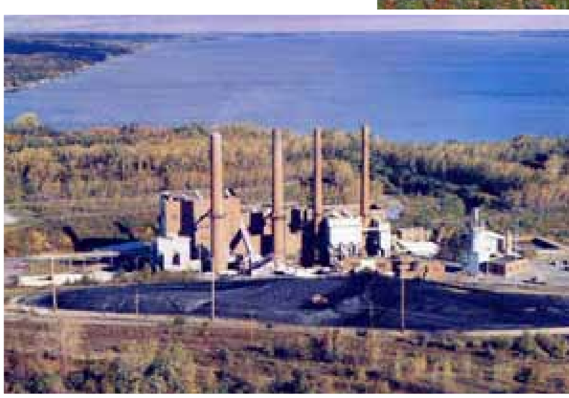
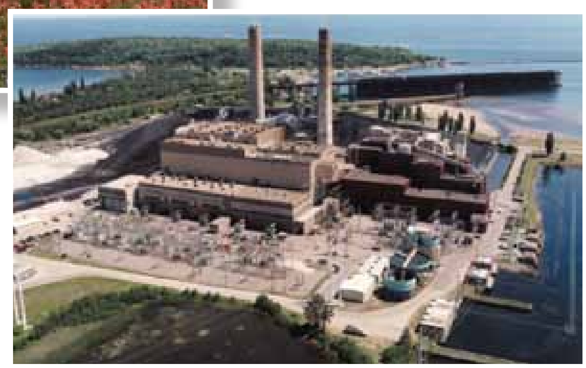
CLEAN COAL TECHNOLOGY





Mercury Control Demonstration Projects

A report on three projects conducted under separate cooperative agreements between the U.S. Department of Energy and:

- Consol Energy
- Pegasus Technologies
- We Energies

Cover Photos:

- Top: Limestone Power Plant
- Bottom left: AES Greenidge Power Plant
- Bottom right: Presque Isle Power Plant

CLEAN COAL TECHNOLOGY

Mercury Control Demonstration Projects

Executive Summary

The Clean Coal Technology Demonstration Program (CCTDP) and two follow-on programs, the Power Plant Improvement Initiative (PPII) and the Clean Coal Power Initiative (CCPI), are government and industry co-funded programs. One goal of these programs is to demonstrate a new generation of innovative coal utilization technologies in a series of projects carried out across the country. These demonstrations are conducted on a commercial scale to prove the technical feasibility of the technologies and to provide technical and financial information for future applications.

Another goal of these programs is to furnish the marketplace with a number of advanced, more efficient coal-based technologies that meet increasingly strict environmental standards. These technologies will mitigate the economic and environmental barriers that limit the full utilization of coal.

To achieve this goal, in 1985, the U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) began administering a multi-phased effort. The earliest program, the CCTDP, comprised five separate solicitations. The PPII had one solicitation, and the CCPI has had two solicitations to date. The projects selected through these solicitations have demonstrated technology options with the potential to meet the needs of the energy markets while satisfying relevant environmental requirements.

In recent years, it has been determined that mercury emitted by coal-fired power plants is detrimental to human health and to the environment. This report describes three projects being conducted under the CCPI and PPII programs that are aimed at demonstrating technologies that primarily remove mercury from coal and reduce other pollutants as well. These projects are listed below:

- Wisconsin Electric Power Company (We Energies) is demonstrating the TOXECON™ process at its Presque Isle Power Plant (PIPP).
- Pegasus Technologies, Inc. (Pegasus) is demonstrating the capability to optimize mercury speciation and control of emissions from an existing power plant using state-of-the art sensors and neural network-based optimization software. This project is being conducted at NRG Texas' Limestone Power Plant.
- CONSOL Energy, Inc. (CONSOL) is demonstrating several technologies on Unit No. 4 at the AES Greenidge Power Plant.

The PIPP power plant comprises nine boilers and nine generation units. The demonstration technology is installed on Units 7, 8, and 9, which are rated at 90 MW each. The TOXECON process installed at PIPP consists of activated carbon injection downstream of the air preheater and a baghouse to remove the activated carbon. A second sorbent system is used to inject a sodium-based sorbent for nitrogen oxide (NO_X) and sulfur dioxide (SO_2) removal. The baghouse also removes most of the remaining particulate matter (PM) that escapes the existing hot-side electrostatic precipitator (ESP).

Pegasus is installing state-of-the-art sensors and neural network-based optimization and control technologies to maximize the proportion of mercury species that are easy to remove from the boiler flue gas. This project will demonstrate how integrating sensors, controls, and advanced analysis techniques into multiple facets of plant operation can lead to effective mercury capture and improved economics.

The CONSOL project at AES Greenidge is demonstrating that several technologies, operating synergistically, provide an economical means to achieve deep emission reductions at smaller plants. The set of technologies being demonstrated comprises a selective non-catalytic reduction (SNCR)/selective catalytic reduction (SCR) hybrid system for NO_X control, a spray dryer for SO_2, mercury and trace pollutant control, a baghouse for particulate control and an activated carbon injection system for additional mercury control.

Mercury Control Demonstration Projects

Topical Report Number 26

Background

A major impediment to the commercialization of new coal-related technology is the final demonstration at the commercial scale. Although laboratory- and pilot-scale development may indicate that the technology shows great promise, the expense of a full-scale demonstration can cause significant delays. Since coal is, by far, the Nation's most plentiful fossil fuel and accounts for more than half of all electric power generation, it is in the national interest to continue to use coal as a major energy source. Uncontrolled coal combustion, however, tends to result in unacceptable levels of emissions. Therefore, if coal is to continue to provide this power, effective, economical emission controls are needed. Even though a number of promising clean coal technologies (CCTs) were developed prior to the 1980s, they were not initially accepted by the utility industry due to the large financial risk involved in employing a new technology at commercial scale. To speed acceptance and deployment of these technologies, Congress established the first of three Department of Energy (DOE)/industry cooperative demonstration programs in the 1980s. The first was the Clean Coal Technology Demonstration Program (CCTDP); two follow-on programs, the Power Plant Improvement Initiative (PPII) and the Clean Coal Power Initiative (CCPI), followed. All three programs are administered by DOE's National Energy Technology Laboratory (NETL). Projects within the programs are cost-shared, with the DOE share limited to a maximum of 50 percent.

CCTDP

The CCTDP was initiated in 1985 as a cost-shared effort among the U.S. government, state agencies, and the private sector. It was originally started in response to concerns over acid rain. Acid rain is formed from the oxides of sulfur and nitrogen, both of which were emitted in large quantities from uncontrolled, coal-fired power plants.

The program's goal was to demonstrate the best, most innovative technologies emerging from the world's engineering laboratories at a scale large enough to enable industry to determine whether the new processes had commercial merit. Projects proposed by industry were selected through a series of five national competitions aimed at attracting promising technologies that had not yet been proven commercially. The commercial-scale projects have included SO_2 control systems, NO_X control technologies, fluidized-bed combustion, gasification, advanced coal-processing technologies, and industrial-process technologies. The CCTDP concluded with a total of 33 projects successfully completed. These projects had a total value of $3.25 billion of which DOE contributed 40 percent. More than 20 of the technologies tested in the original program have achieved commercial success.

PPII

After the blackouts and brownouts of electric power in major regions of the country in 1999 and 2000, Congress directed DOE to issue "a general request for proposals for the commercial-scale demonstration of technologies to assure the reliability of the nation's energy supply from existing and new electric generating facilities...." In February of 2001, DOE issued a solicitation for proposals under the PPII program. By the deadline of April 19, 2001, twenty-four proposals had been submitted for government cost-shared financial assistance, and eight projects were selected for negotiation. Three projects were later withdrawn by their industrial sponsors, while four of the remaining projects have been completed and one is still active.

CCPI

In the last few years there have been increasing concerns about the potential health impacts of trace emissions of mercury, the effects of microscopic particles on people with respiratory problems, and the potential global climate-altering impact of greenhouse gases. With coal likely to remain one of the Nation's lowest-cost fuels for the foreseeable future, the President pledged a new commitment to even more advanced clean coal technologies. Building on the successes of the original CCTDP, the CCPI encompasses a broad spectrum of research and large-scale projects that target the critical environmental challenges of today.

The CCPI is designed to be implemented over 10 years, with a federal investment totaling $2 billion and a minimum industry cost share of 50 percent. Initially, the CCPI is providing government co-financing for new coal technologies that will enable utilities to further reduce greenhouse gases, sulfur, nitrogen, and mercury pollutants from power plants. To date, two rounds of proposals have been received and nine active projects implemented, which comprise the CCPI-1 and the CCPI-2. These projects demonstrate mercury removal, very low sulfur and nitrogen emissions, byproduct utilization, carbon dioxide capture, and improved efficiency. Improved efficiency not only reduces the cost of electricity, but it is also a cost effective way to reduce all emissions, particularly those of carbon dioxide (CO_2), the most common greenhouse gas.

This document describes three projects (one PPII and two CCPI) that focus on the capture of mercury while reducing the emission of other pollutants such as nitrogen oxides (NO_X), sulfur dioxide (SO_2), and particulate matter (PM). All three projects also focus on improved efficiency for both new and existing power plants.

The DOE Clean Coal Technology Program

The DOE commitment to clean coal development has progressed through three phases. The first phase was the Clean Coal Technology Demonstration Program (CCTDP), a model of government and industry cooperation, which advanced DOE's mission to foster a secure and reliable energy system. With 33 projects completed, the CCTDP has yielded technologies that provide a foundation for meeting future energy demands and utilizing the vast U.S. reserves of coal in an environmentally sound manner. Begun in 1985, the CCTDP represents a total investment value of over $3.25 billion. DOE's share of the total cost is estimated at $1.30 billion or approximately 40 percent. The projects' industrial participants (i.e., non-DOE) have provided the remaining share of nearly $2.0 billion or 60 percent.

Two follow-on programs have been developed that build on the successes of the CCTDP. The Power Plant Improvement Initiative (PPII) is a cost-shared program patterned after the CCTDP that is directed toward improved reliability and environmental performance of the Nation's coal-burning power plants. Authorized by the U.S. Congress in 2001, the PPII involves five projects that focus on technologies enabling coal-fired power plants to meet increasingly stringent environmental regulations at the lowest possible cost. Four projects have been completed and one is still active. The total value of these projects is $71.5 million with DOE contributing a share of $31.5 million or 44.6 percent. These projects are the result of a single solicitation.

The second follow-on program is the Clean Coal Power Initiative (CCPI), also patterned on the CCTDP, which was authorized in 2002. The CCPI comprises multiple solicitations over a ten-year period. The goal of the CCPI is to accelerate commercial deployment of advanced technologies that will ensure the Nation has adequate, clean, reliable, and affordable electricity. Total federal funding will be approximately $2 billion; industrial participants will provide a cost share of at least 50 percent. To date, two solicitations have been completed and nine projects have been awarded or are in negotiation. These projects have a total value of approximately $2.68 billion, of which DOE will contribute approximately $533 million (19.9 percent).

Mercury Removal Projects

TOXECON™ Retrofit For Mercury and Multi-Pollutant Control on Three 90-MW Coal-Fired Boilers

Introduction

In addition to concerns about mercury's impact on the environment and on human health, there have been increasing concerns about the impact of very small particulates in the atmosphere. The minute particulates, which also contribute to atmospheric haze, are less than 2.5 µm in diameter and are designated as $PM_{2.5}$. $PM_{2.5}$ is a recognized health hazard since material in this size range is respirable and is small enough to be carried into the lungs where it tends to be deposited. Although flyash contains some $PM_{2.5}$, for the most part, $PM_{2.5}$ is not a primary emission. It is actually formed in the atmosphere from many common and not so common pollutants. For example, in urban areas, nearly 40 percent of the $PM_{2.5}$ mass is comprised of carbonaceous materials. Sulfate and nitrate also comprise appreciable fractions of $PM_{2.5}$. While electrostatic precipitators (ESPs) can remove over 99 percent of particulates, baghouses are much better at capturing the very small particles. Several organizations developed technologies to enhance primary $PM_{2.5}$ capture. One of these technologies, COHPAC®, was developed by Electric Power Research Institute (EPRI). It consists of a baghouse installed as close as possible downstream of an existing ESP to take advantage of residual charge on the particles to enhance collection on the bags. If the plant layout is such that the baghouse can't be installed close enough to the ESP, a discharge electrode can be installed at the entrance to the baghouse. A COHPAC was installed at Alabama Power's E.C. Gaston Unit 3 for particulate control. Beginning in 2001, NETL sponsored a series of powdered activated carbon (PAC) injection tests on this unit to capture mercury. The results led to development of the TOXECON technology. In 2003, NETL selected TOXECON as a CCPI mercury control demonstration project. The demonstration is being carried out at We Energies' Presque Isle Power Plant.

Presque Isle Power Plant

Project Description

In response to the first CCPI solicitation, Wisconsin Electric Power Company (We Energies) submitted a proposal to design, install, operate, and evaluate the TOXECON process on a coal-fired boiler. This project was selected in January 2003 and a cooperative agreement was awarded in March of 2004. The project is located at We Energies' Presque Isle Power Plant (PIPP). Total project cost is $52,978,115. DOE is providing $24,859,578 or 46.9 percent; We Energies is providing the remaining 53.1 percent.

The PIPP consists of nine coal-fired units that were installed between 1955 and 1979. The TOXECON demonstration technology was installed on Units 7, 8, and 9. These units are rated at 90 MW each. The TOXECON technology is being demonstrated on the

Property	Typical Value
Higher Heating Value, Btu/lb	9,052
Analysis, weight percent	
Moisture	25.85
Carbon	52.49
Hydrogen	3.65
Nitrogen	0.75
Sulfur	0.28
Ash	4.64
Oxygen	12.33
Chlorine	0.01

combined flue gas streams from the three boilers. The boilers were installed by Riley Stoker and are Riley Turbo dry bottom opposed-wall-fired boilers. Steam leaving the superheater is at 1625 psig and 1005 °F, and the reheat steam is at 390 psig and 1005 °F. All three units are equipped with hot side ESPs that were designed and built by Joy-Western; each unit is two chambers wide and each chamber has six fields. The ESPs have a design collection efficiency of 99.2 percent. NO_X emissions are reduced with low-NO_X burners and combustion optimization software; SO_2 emission limits are met by burning low sulfur coals.

Boilers 7, 8, and 9 are fueled with low sulfur subbituminous coal from the Powder River Basin (PRB). The coal is obtained from several PRB mines with coal purchases based on price. The coal has a typical Higher Heating Value (HHV) of 9052 Btu/lb, a sulfur content of 0.28 percent, and an average mercury content of 0.13µg/g.

The TOXECON technology was installed downstream of the air preheater at the PIPP. It comprises a sorbent injection system and a baghouse along with the necessary supporting equipment. Supporting equipment for the carbon injection system includes in-duct injection lances, and sorbent receiving, handling, and storage facilities. Supporting equipment for the baghouse includes the ash removal equipment and the air compressor to supply pulse air for cleaning the bags.

In addition to We Energies, the project team includes EPRI, ADA-ES, Inc., Wheelabrator Air Pollution Control (WAPC), and Cummins & Barnard (C&B). We Energies provides and operates the demonstration site. We Energies is also responsible for project management, environmental permitting, and reporting. ADA-ES is responsible for design of the mercury control system, design of the mercury monitoring system, demonstration testing of the entire process, and report preparation. In addition, ADA-ES is also the project management interface with NETL. WAPC was responsible for the design and construction of the baghouse, support for baghouse installation, and start-up under a subcontract with We Energies. EPRI, the developer and patent holder of the TOXECON technology, provides technical advice to We Energies. C&B provides engineering services, construction management, equipment design and specification, equipment installation, and start-up training for plant operators.

Project Goals

The objectives of this project are as follows:

- To demonstrate that the TOXECON multi-pollutant control system can consistently achieve 90 percent mercury removal from flue gas using sorbent injection.
- To evaluate the potential for 70 percent SO_2 removal through the injection of sodium-based sorbents.
- To evaluate the ability of sorbents to provide some degree of NO_X removal.
- To achieve lower particulate emissions with the baghouse.
- To demonstrate an accurate mercury continuous emissions monitor (CEM) that is suitable for use in power plants.

- To integrate and optimize the system for mercury and multi-pollutant control.
- To recover 90 percent of the mercury captured by the PAC.
- To use all of the flyash captured in the existing hot-side ESP.

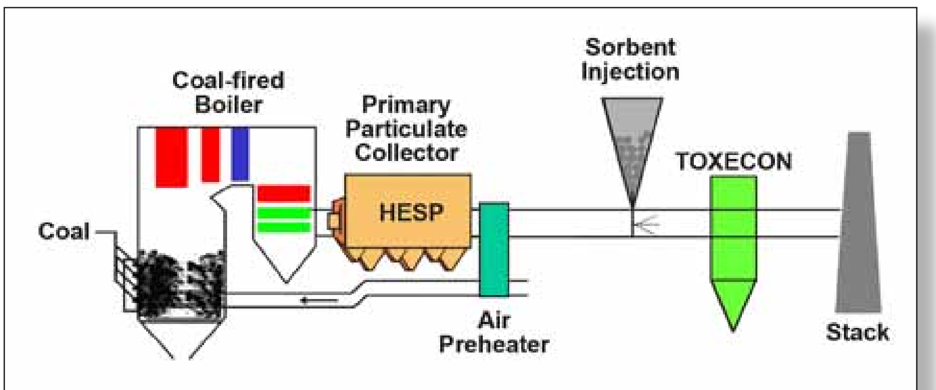
Technology Description

The TOXECON technology is intended primarily for application downstream of an existing ESP. When applied to a boiler that is equipped with a hot-side ESP, the TOXECON system is installed immediately downstream of the air preheater. If the host plant is equipped with a cold-side ESP, the TOXECON system is installed downstream of the ESP. The TOXECON technology as installed at PIPP is a relatively simple process. The PAC system consists of a storage silo, a pneumatic unloading system, and three injection trains. At PIPP, PAC is injected downstream of each air preheater with the placement of the injection lances designed to achieve thorough mixing of the PAC sorbent within the flue gas. The PAC injection system consists of three separate trains. Each train includes a feed hopper, feeder, eductor, injection lance, and blower. Each train is designed to handle 200 lb/hr of sorbent material, although the overall design injection rate is 216 lb/hr. The excess capacity is intended to permit optional reinjection of some PAC/flyash from the baghouse. A similar system was also installed to test the injection of a sodium-based sorbent into the flue gas to determine if 70 percent SO_2 removal is feasible and if some NO_X removal is possible. After the sorbents are injected, the ducts from Units 7, 8, and 9 merge to form a single duct leading to the baghouse.

The entrained PAC captures some of the mercury as it travels with the flue gas to the baghouse. The PAC is removed along with residual flyash in the baghouse. The PAC continues to remove mercury as long as it remains in the dust cake on the bags. Similarly, when sodium-based sorbent is used, SO_2 and NO_X continue to be captured by the dust cake. Therefore the design and/or operation of this baghouse maximize the amount of time the dust remains on the bags while keeping with sound operating practices. The baghouse at PIPP is a conventional pulse-jet baghouse designed for a face velocity of 5.5 ft/min. Normally, pulse-jet baghouses are designed for face velocities in the range of 3 to 5 ft/min with 3.5 to 4.5 ft/min being most common. Since a nominal 99 percent of the PM is removed by the existing hot-side ESPs, the dust load to the baghouse is very low, even after sorbent injection. This low dust load permits operation at higher face velocities while maintaining acceptable pressure drop across the bags. After the flue gas is cleaned of PM and the contaminants captured by the sorbents, the flue gas is split into three streams and is discharged through three separate flues that are enclosed by a single stack.

Results

The data collected to date confirm that the TOXECON system can reliably remove at least 90 percent of the mercury from the flue gas leaving the hot-side ESP. A 48-day run, ending in January 2007, consistently achieved mercury removal rates of at least 90 percent, which was one of the project's major goals. This removal rate was accomplished using either halogenated or



TOXECON™ Process Concept

non-halogenated PAC. Since the 48-day run was completed in January 2007, 90 percent mercury removal has been the norm with the exception of special test periods.

Concurrent SO_2 removal was investigated by injecting a sodium-based sorbent (trona). Trona ($Na_3H(CO_3)_2{\cdot}2H_2O$) was injected for SO_2 and potentially NO_X removal. While the goal of 70 percent SO_2 removal was met, there was no perceptible impact on NO_X emissions. When trona and PAC were injected simultaneously, mercury removal efficiency decreased significantly. Even with adding more PAC it proved difficult to achieve 90 percent mercury removal while maintaining 70 percent SO_2 removal.

The goal of developing a reliable CEM system for mercury has not yet been met, but significant progress has been made and results, to date, have been encouraging and suggest that a viable, reliable system will be available before January 2009.

Operational Problems

Shortly after startup, operators observed glowing embers in the baghouse hoppers that indicated the PAC/ash mixture could ignite. A subsequent inspection of the baghouse found that 200 bags had failed from overheating. Laboratory work identified the circumstances (e.g., temperature, hopper heating, residence time) leading to this potentially dangerous situation. Minor equipment and operational changes have so far eliminated this problem.

PAC/flyash unloading problems continue due to excessive dusting when handling this material. Several redesigns of the system have greatly improved the condition but a final solution still remains to be achieved.

TOXECON® System Installed at PIPP

Economics

The capital cost of the 270 MW TOXECON process was $34.4 million in 2005 dollars or $128/kW. Operating and maintenance (O&M) costs were estimated at a total of $0.81 per MWh. Approximately 75 percent of this total is due to the cost of activated carbon and increased fan power. The remaining balance of the O&M costs is for scheduled maintenance, bag replacement, disposal of the ash/activated carbon waste and miscellaneous costs. Variable operating cost is expected to be $16,000 per pound of mercury removed. The TOXECON system at PIPP is expected to remove 82 pounds per year of mercury from the flue gas.

Benefits

The TOXECON process takes advantage of the inherently high particulate removal efficiency of a baghouse and the proven mercury capture ability of activated carbon. Additional benefits are derived when other sorbents are used to capture other pollutants. The use of a sodium-based (trona) sorbent to capture SO_2 was demonstrated during this CCPI project. Concurrent PAC and trona injection did not demonstrate NO_X removal but did indicate that trona injection greatly reduced the mercury removal efficiency of baseline PAC injection rates. Although 70 percent SO_2 removal was achieved, this level was difficult to sustain. The economic tradeoffs are still under review by the participants.

Adding a baghouse downstream of an existing ESP has two important advantages. It not only removes the injected sorbent and the adsorbed pollutants, but also significantly reduces both $PM_{2.5}$ and $PM_{2.5}$ precursor emissions (e.g., SO_2). The second important benefit is that the bulk of the flyash is captured prior to sorbent injection, thus retaining the potential for constructive use of nearly all of the flyash produced by coal combustion.

This technology is considered suitable for application on 167 GW of coal-fired generating capacity and may well become the standard for mercury control on boilers firing western coals.

If the project goals are met, this project will result in annual emission reductions of 82 pounds of mercury; 4,020 tons of SO_2; 1,470 tons of NO_X; and 32 tons of PM at PIPP. It will also result in an accurate, robust CEM for mercury.

Greenidge Multi-Pollutant Control Project

Introduction

There are about 440 domestic coal-fired generating units with capacities ranging from 50 to 300 MW that currently are not equipped with selective catalytic reduction (SCR), flue gas desulfurization (FGD), or mercury control systems. Collectively, these small plants represent about 60 GW of generating capacity and are an important part of our electric power supply. Many of these plants will eventually need to install systems for mercury, NO_X, and SO_2 control if they are to continue to operate. While SCR and wet scrubbers are viable options for achieving deep NO_X and SO_2 emission reductions for most generating units over 300 MW, they are prohibitively expensive in many cases for these smaller plants due to reverse economies of scale. Furthermore, small units are often space constrained, such that even if the costs were not prohibitive, the installation of a conventional SCR and wet scrubber might be either impractical or impossible. The power industry needs space-saving technologies that are economical for these smaller plants if these plants are to continue to provide electricity to consumers. This project is demonstrating a combination of technologies that is more economical than leading conventional technologies for achieving deep emission reductions from smaller coal-fired units. The technologies are arranged to achieve maximum synergism for the control of mercury, NO_X, and SO_2, with improved $PM_{2.5}$ control. The demonstration is taking place on AES Greenidge Unit No. 4, which primarily fires eastern bituminous coal with up to 10 percent biomass (by heat input).

Project Description

CONSOL Energy Inc. (CONSOL) submitted a proposal in response to the PPII solicitation issued in February of 2001. The Greenidge Multi-Pollutant Control Project was selected for negotiation on September 26, 2001. When the contract was awarded, design and construction work was already underway. CONSOL is the participant (i.e. prime contractor) for this project. The other team members are AES Greenidge LLC, the host site owner; and Babcock Power Environmental Inc. (BPEI), the engineering, procurement, and construction contractor and technology supplier. As with all CCPI and PPII projects, NETL is managing the project. The total project cost is estimated at $32,742,976; DOE is providing $14,341,423 (43.8 percent), and AES Greenidge LLC is providing the remaining balance of $18,401,553 (56.2 percent).

AES Greenidge is a 161-MWe (net) coal-fired electric power plant that sells power to the New York Independent System Operator. It is located in Dresden, New York, in Yates County on the western shore of Seneca Lake. The plant comprises two operational generating units. Unit 3 is a 54 MWe (net) unit, and Unit 4 is rated at 107 MWe (net). Two older units have been removed from the plant, but the stacks are still standing.

Greenidge Project Site

AES Greenidge Power Plant

The demonstration project equipment is being installed on Boiler 6, which provides the steam to Unit 4. Boiler 6 is a Combustion Engineering dry bottom, tangentially-fired pulverized coal boiler designed to produce 1465 psig, 1005 °F steam. The primary fuel for Boiler 6 is eastern U.S. bituminous coal. Boiler 6 is also permitted to fire clean, unadulterated wood (at up to 100 percent by weight of the total fuel) or waste wood from a furniture manufacturing process (at up to 30 percent by weight of the total fuel). AES Greenidge has historically used waste wood to provide up to 10 percent of the heat input to Boiler 6. The waste wood is prepared and fed to the boiler separately from the coal. The boiler is equipped with a natural gas reburn system that is currently not in use.

Prior to this project, the boiler's primary means of NO_X control was a system of separated overfire air (SOFA) ports. AES Greenidge met its SO_2 emission limit by firing a medium sulfur coal and co-firing waste wood. Particulate emissions were controlled with an electrostatic precipitator (ESP). AES Greenidge has upgraded and/or rebuilt several systems outside the scope of this project including the secondary superheater, steam turbine, air preheaters, combustion system, ash handling system, distributed control system, and SOFA system.

The Multi-Pollutant Control Project entails the installation and operation of a set of technologies that will work synergistically to control a number of pollutants. These technologies include a hybrid selective non-catalytic reduction / selective catalytic reduction (SNCR/SCR) system for NO_X control; and a Turbosorp® circulating fluidized bed dry scrubber (CFBDS) system with activated carbon injection and baghouse ash recycling for SO_2, mercury, sulfur trioxide (SO_3), hydrochloric acid (HCl), hydrofluoric acid (HF), and particulate matter control. The importance of this demonstration is that the combination of these technologies is uniquely designed to meet the needs of smaller coal-fired power plants by affording deep emission reduction capabilities, low capital costs, small space requirements, applicability to a wide range of coals, low maintenance requirements, and operational flexibility. As discussed above, there are about 440 coal-fired units rated between 50 and 300 MWe in the United States that are not equipped with SCR, FGD, or mercury control systems, and these plants are an important part of the domestic generating capacity. Rated at 107 MWe, AES Greenidge Unit 4 is representative of these units. Conventional technologies such as wet scrubbers and SCR tend to be prohibitively expensive on smaller units due to reverse economies of scale. In addition, many of the units in this size range are space-constrained. The Multi-Pollutant Control Project will demonstrate an affordable solution for control of multiple pollutants for smaller coal-fired power plants.

Project Goals

The following are the goals of the project:

- Demonstrate that the hybrid SNCR/SCR system can reduce NO_X emissions to 0.10 pounds per million British thermal units (lb/mmBtu) or less, a reduction

Regulatory History

Title III of the 1990 Clean Air Act Amendments (CAAA) identified 189 substances emitted by fossil fuel combustion that may be toxic or hazardous. These 189 substances are usually referred to as hazardous air pollutants (HAPs) or air toxics. The CAAA required the Environmental Protection Agency (EPA) to evaluate their emissions by source as well as their potential harm to human health and the environment. The EPA was also required to determine the need to control the emission of HAPs. DOE's NETL, in collaboration with EPRI, comprehensively addressed the CAAA requirements specific to the electric power industry with a series of projects from 1990 to 1997. These projects provided the majority of the data for two congressionally-mandated EPA Reports to Congress. The first report, the "Mercury Study Report to Congress," was issued in 1997 and found that coal-fired power plants were the largest U.S. source of anthropogenic mercury emissions. The second report, the "Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generating Units–Final Report to Congress" was issued in 1998. This second report concluded that mercury from coal-fired power plants was the HAP of "greatest potential concern" and that additional research and monitoring was warranted.

In 1999 and 2000, the EPA, in cooperation with NETL, issued an Information Collection Request (ICR). The purpose of the ICR was two-fold. One aim was to refine the mercury emission inventory from coal-fired power plants. The other was to determine the mercury control capabilities of existing and new, potentially viable technologies. In the same timeframe, the National Academy of Sciences (NAS) conducted an evaluation of the health impacts of mercury. Based on the ICR and the NAS evaluation, the EPA determined that there was a "plausible link" between emissions of mercury from coal-fired power plants and the bioaccumulation of mercury in fish, as well as animals that eat fish. Since consumption of fish is the primary pathway for human exposure to mercury, the EPA determined that it was necessary to reduce mercury emissions from fossil fuel combustion in power plants. The EPA issued its decision to regulate mercury in December of 2000.

The EPA issued the Clean Air Mercury Rule (CAMR) on March 15, 2005. This was the first regulation to specifically address mercury emissions from coal-fired power plants. The CAMR complements the Clean Air Interstate Rule (CAIR) which was issued to reduce the emissions of NO_X and SO_2, since technologies designed to remove other pollutants often coincidentally remove some mercury. The net effect of these two rules is expected to be a 70 percent reduction in mercury emissions, which are currently estimated at 48 tons per year. The CAMR created a market-based cap-and-trade program to reduce mercury emissions. The reduction will take place in two phases. Mercury emissions are capped at 38 tons per year in 2010. This level of emissions will be achieved by coincidental mercury capture in technologies whose primary purpose is the control of other pollutants. By 2018, total mercury emissions from all coal-fired power plants are limited to 15 tons per year. In addition, new coal-fired units will have to meet New Source Performance Standards.

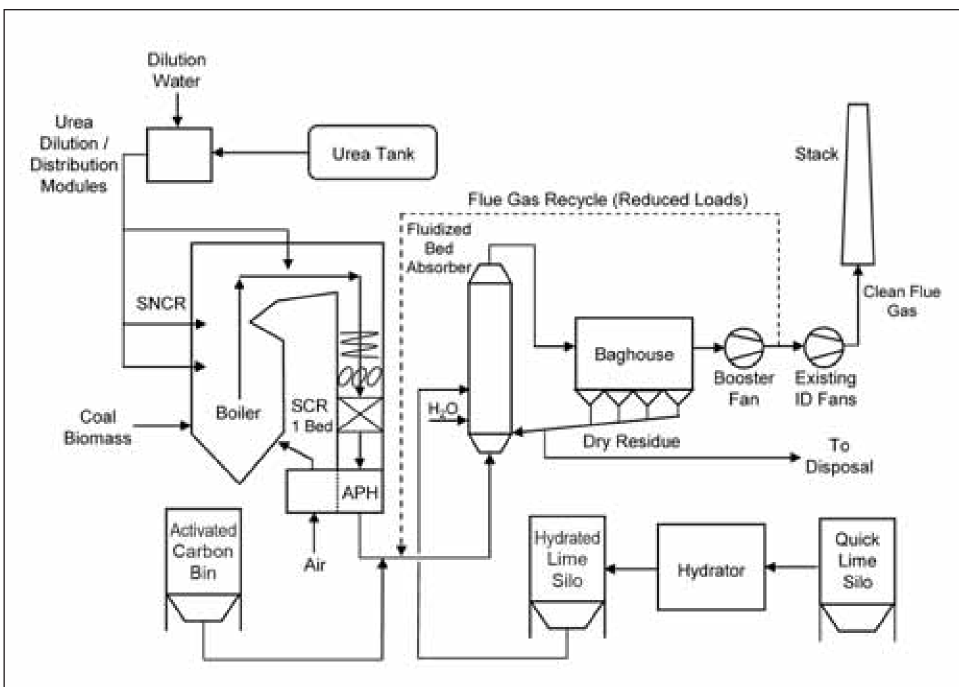
The CAMR is applicable to all coal-fired utility boilers with a heat input of 73 MW (thermal) or 250 million Btu per hour. Industrial cogeneration boilers are also regulated if they sell over 25 MW of electrical power and more than one third of their maximum output to a power distribution system.

The New Source Performance Standards apply to all coal-fired units that start construction after January 20, 2004. This applies to existing units which are modified or rebuilt. The emission limits are based on a twelve-month rolling average and on coal type and technology. Emission limits are specified for six coal/technology combinations: bituminous coal, subbituminous coal with FGD in wet climates, subbituminous coal with FGD in dry climates, lignite, coal refuse, and integrated gasification combined cycle. Unlike the standards for other emissions, mercury standards are based on the gross amount of electricity generated (lb/MWh) rather than on heat input (lb/million Btu).

Compliance with the standards will be based on a twelve-month rolling average. Data must be continuously collected from each affected unit using long-term sorbent traps or continuous emission monitoring systems. Both new and existing units will be subject to the cap-and-trade provisions of the CAMR. This program, which mandates that generating plants must demonstrate compliance by holding one allowance for each ounce of mercury emitted, is similar to the provisions of the Acid Rain Program. Coal-fired power producers will be required to meet the 15 ton cap by 2018. Each state is assigned an annual mercury emission budget which will not change, regardless of any growth in electric power generation. The EPA has established a model cap-and-trade program; however, states may establish more stringent rules. Once a state establishes its program, it must submit a State Implementation Plan to the EPA.

of 60 percent, when the unit is firing coal containing at least 2 percent sulfur and co-firing up to 10 percent biomass. This reduction is to be accomplished in addition to the NO_X reduction already achieved by the combustion modifications that were installed outside of the scope of the DOE-sponsored project.

- Demonstrate that the CFBDS can remove at least 95 percent of the SO_2 from the flue gas while the boiler is firing coal with at least 2 percent sulfur and co-firing up to 10 percent biomass.
- Demonstrate 90 percent mercury removal by the SNCR/SCR and CFBDS/baghouse systems and, if required, carbon injection.
- Demonstrate up to 95 percent removal of SO_3, HF, and HCl by the CFBDS.
- Evaluate the technical and economic performance of the technology to demonstrate the commercial viability of an emission control system that is suitable for meeting the emission limits of boilers in the 50 to 300 MWe range.



Greenidge Process Concept

Technology Description

The technologies that comprise the multi-pollutant control system are the hybrid SNCR/SCR system, the Turbosorp® CFBDS system, an activated carbon injection system, a pulse-jet baghouse, a lime hydration system (used to produce hydrated lime for the CFBDS), and a booster fan (used to overcome the pressure drop created by the SCR, CFBDS, and baghouse). They are arranged to achieve a high degree of synergism. The SNCR reduces the catalyst requirement for the SCR while generating the ammonia required by the SCR. The SCR allows the SNCR to achieve relatively high NO_X reduction since it is designed to consume the excess ammonia slip that is generated as a result of operating the SNCR in this way. The SCR oxidizes the elemental mercury, facilitating its capture by the CFBDS and/or the carbon injection system. The CFBDS and baghouse facilitate mercury capture, reducing the activated carbon injection requirement, and remove the SO_3 that is formed by oxidation of SO_2 across the SCR. It is believed that the removal of SO_3 also promotes the capture of mercury by the native unburned carbon and by the activated carbon, when in use. Low-NO_X burners were installed outside of the scope of the DOE project, but these too work synergistically with the rest of the system by reducing NO_X formation, creating more ideal conditions for SNCR, and increasing the unburned carbon content of the flyash, which aids in mercury removal.

The SNCR system is the first part of the demonstration to interact with the flue gas. An SNCR system consists of injecting urea ($CO(NH_2)_2$) or ammonia (NH_3) into the upper furnace where the flue gas is at the appropriate temperature for NO_X reduction to occur. (These temperatures are normally 1700 to 1900 °F, although the SNCR reaction can take place from 1400 to 2200 °F.) In the system installed at AES Greenidge, an aqueous solution of urea is injected into the furnace. At the high furnace temperature, the urea dissociates into radicals that react with NO_X to form molecular nitrogen (N_2), CO_2, and water vapor. The overall reaction is:

$$CO(NH_2)_2 + 2\ NO + \frac{1}{2}\ O_2 \rightarrow 2\ N_2 + CO_2 + 2\ H_2O$$

Although not shown, ammonia is a minor byproduct of the above reaction. Ammonia production tends to decrease as temperature increases. If SNCR is used in a stand-alone application, the system must be operated so that ammonia production is limited since ammonia emissions (ammonia slip) are generally limited to less than 10 parts per million (ppm) in the flue gas. The optimal temperature range for the above reaction is between 1700 and 1800 °F; however, the reaction is often carried out at somewhat higher temperature to avoid excessive ammonia slip. With the hybrid SCR/SNCR installed at Greenidge, ammonia slip is actually desired since the ammonia is used in the downstream in-duct SCR catalyst bed.

The in-duct SCR consists of a single catalyst bed installed downstream of the SNCR in a modified section of the ductwork. The compact SCR has the advantage of allowing the SNCR to operate at a lower, more favorable temperature by consuming the resultant ammonia slip, and it also provides an incremental reduction in the NO_X that is not removed by the SNCR system. This hybrid SNCR/SCR is expected to provide high levels of NO_X reduction at a lower capital cost than a conventional SCR system. The hybrid system also requires only a minimal footprint. For the compact SCR to operate at maximum effectiveness, the ammonia generated in the SNCR system must be thoroughly mixed with the flue gas. This is accomplished by installing BPEI's Delta Wing® static mixing technology upstream of the SCR reactor.

After the flue gas exits the SCR system, it passes through the air heater. After it leaves the air heater, activated carbon can be injected into the flue gas to remove mercury. The activated carbon remains in the flue gas and enters the CFBDS. The CFBDS used is BPEI's Turbosorp® technology. Hydrated lime, which is produced from pebble lime in the onsite hydrator, is used as the sorbent. The flue gas enters the bottom of the fluidized bed absorber. Dry hydrated lime, dry baghouse solids, and water are added to the flue gas near the base of the absorber. The water is added both to reduce the temperature and to increase the humidity of the flue gas. This is done to enhance the absorption of the impurities. The amount of water added is limited to avoid condensation. The hydrated lime reacts with the SO_2, SO_3, HCl, and HF gases to form benign solids. These solids, along with the flyash and activated carbon, are captured in the baghouse. Most of the solids captured in the baghouse are recycled to the CFBDS via air slides to enhance the utilization of hydrated lime and activated carbon. A small portion of the captured solids are removed from the system for landfill disposal. The performance of the CFBDS when it is operated with high-sulfur (i.e., 2–4 percent sulfur) coals will be evaluated during this project, as will the impact of co-firing up to 10 percent biomass. In general, dry scrubbers similar to the CFBDS have exhibited high levels of mercury removal without activated carbon injection. This project will also determine if mercury removal goals can be achieved without the use of activated carbon.

View of AES Greenidge Showing Demonstration Facility

CFBDS and Baghouse

Results

As of this writing, the multi-pollutant control system has been completely installed and has undergone testing to confirm that it meets the performance guarantees. With one minor exception, the system met all guarantees and demonstrated its ability to meet the emission reduction objectives set forth in the project goals. (The goal of removing at least 95 percent of the HF from the flue gas could not be demonstrated because the HF concentrations at both the inlet and outlet of the CFBDS were below detection limits.) During the guarantee tests NO_X was measured at 0.10lb/mmBtu and ammonia slip was 2 ppm. Hg removal was 94 percent and 95 percent with and without activated carbon injection. SO_2 removal was 96 percent while SO_3 and HCl removal rates were 97 percent. Greenidge Boiler 6 was firing 2.5–3.0 percent sulfur eastern bituminous coal when the guarantee tests were conducted, and the unit was operating at or near full load. As with any new system, there were some initial problems, the most notable being deposition of large ash particles on the SCR catalyst bed, which resulted in increased pressure drop and a reduction in catalyst effectiveness. Screens were installed upstream of the catalyst bed to help alleviate the problem, but further modifications may be required to fully resolve it. The screens are cleaned with sootblowers and the ash particles are removed with a vacuum system. It should also be noted that, although the NO_X emission target was demonstrated during short-term testing, the plant has routinely had to operate at a NO_X emission rate between 0.10 lb/mmBtu and 0.15 lb/mmBtu to maintain acceptable combustion characteristics, steam temperatures, and ammonia slip.

Mercury Specie and Multi-Pollutant Control

Introduction

Implemented under the CCPI, the project at the NRG Texas – formerly Texas Genco – Limestone Power Plant in Jewitt, Texas, is designed to demonstrate the capability to optimize mercury speciation and control emissions from an existing power plant. NRG Texas, with a generating capacity of more than 14,000 MW primarily based on fossil-fueled plants, is an important producer of electricity in Texas. Performed by Pegasus Technologies, Inc. – a division of NeuCo, Inc. – this project demonstration will occur on an 890 MW utility boiler that uses 14,500 tons of coal per day. A goal of the project is to demonstrate that the Pegasus technology package can maximize the oxidation of mercury in the flue gas, which maximizes mercury capture with the particulate matter and in the FGD system. The technology package being demonstrated also provides plant operators with the ability to assess detailed plant operating parameters, which affect mercury capture efficiency as well as overall heat rate, particulate removal, and FGD efficiencies. These data are fed to a neural network optimization system, which controls plant subsystems to provide the lowest possible mercury and other pollutant emissions, the lowest heat rate, and the least risk of environmental non-compliance, all with minimal capital expenditure. This technology, once demonstrated, is expected to have broad application to existing coal-fired boilers and to provide positive impact on the quality of saleable by-products such as flyash. The project began in April 2006, with performance testing targeted for December 2008. This estimated $15.6 million project will be 38 months in duration, with a DOE cost share of 39 percent.

Project Objectives

Pegasus will demonstrate on a large utility coal-fired boiler the ability to affect and optimize mercury speciation and multi-pollutant control using non-intrusive advanced sensor and optimization technologies on a large coal-fired utility boiler. Plant-wide advanced control and optimization systems will be integrated into a coal-fired steam electric power plant in order to minimize mercury emissions, while simultaneously providing improved performance in those systems that were installed to meet the limits of other criteria pollutants. The Pegasus software will also maximize the thermal efficiency and improve the by-product quality of the plant. Advanced solutions utilizing state-of-the-art sensors and neural network-based optimization and control technologies will be used to maximize the portion of the mercury vapor in the boiler flue gas that is oxidized or captured in particle bonds, resulting in lower releases of mercury.

This neural network-based control and optimization system gathers data from coal composition, combustion gas composition, mercury species, feed rates, etc., and uses this information to optimize power plant operations. The greatest power of neural networks in power plants is their ability to generalize from previous information and develop similar patterns for future use. Such intelligent control is expected to improve mercury capture by over 40 percent, NO_X emissions by 10 percent, reduce fuel consumption by 0.5–2.0 percent, and improve operating flexibility.

NRG Texas's Limestone Power Plant in Jewett, Texas

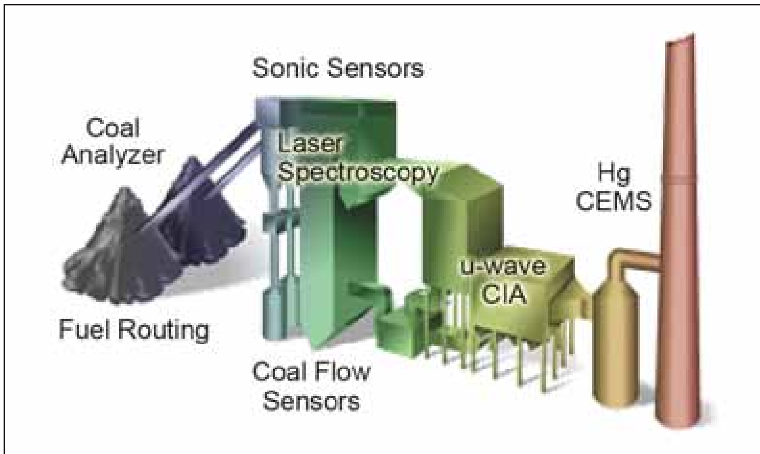
Project Description

The estimated 48 tons of mercury emitted annually by coal-fired power plants in the United States is about one-third of the total amount of mercury released from human activities. Mercury emissions take a number of chemical forms – or species – including as a pure element, as part of a gaseous compound, or bound to particulates in flue gas. While elemental mercury is difficult to remove from flue gas, certain mercury species, such as mercury that is adsorbed onto flyash particles, are relatively easy to remove. Adjustment of certain parameters during combustion can optimize the speciation process, maximizing the mercury captured in particle bonds and the FGD system which preferentially captures oxidized species. The net result is substantially greater capture of mercury and lower mercury emissions.

The NRG Texas demonstration power plant is equipped with a tangentially-fired boiler that fires a blend of 70 percent Texas lignite and 30 percent Powder River Basin (PRB) subbituminous coal, which are known to emit relatively high levels of elemental mercury under routine combustion conditions. Pegasus will apply sensors at key locations to evaluate the mercury species (elemental and oxidized mercury), develop optimization software that results in the best plant conditions to promote mercury oxidation and minimize emissions in general, and use neural networks to determine the optimization conditions.

The unit is also equipped with a cold-side ESP rated at approximately 99.8 percent particulate removal efficiency and a wet limestone FGD system rated at approximately 90 percent SO_2 removal efficiency. Both devices are capable of high mercury capture efficiency if the mercury is in an oxidized solid state rather than an elemental vapor state.

Using a neural network to affect and optimize mercury speciation and multi-pollutant control, the non-intrusive advanced sensor and optimization



Control System Schematic for NRG Texas Limestone Power Plant

technologies will act like a highly trained operator, making decisions on inputs to the process by measuring and learning the outputs. Using the artificial intelligence and simulation technologies, Pegasus will minimize pollutant emissions and the use of raw material resources while simultaneously optimizing the operating capabilities of the plant.

Mercury Specie and Multi-Pollutant Control System

This project involves the installation and demonstration of sensors and optimization software in six separate technology packages. While the modular design is transparent to this project, it is important to the future marketing of this system because of the flexibility needed with utilities to include or exclude a particular module based on either the existing equipment or budget for a specific customer. Many of the sensors and optimizer packages that will be installed are utilized across the modules; therefore, they have been included under the module in which they are most used. The technology packages for this project include the following:

1. **Intelligent Fuel Management System (FMS):** The FMS is composed of the Pegasus Combustion Optimization System, the Ready Engineering Coal Fusion System, and a Sabia elemental analyzer.

2. **Mercury Specie Control System:** The Mercury Specie Control System includes the boiler area optimization, Pegasus Virtual On-line Analyzers (VOAs), and various sensors. Mercury emissions will be measured through Continuous Emission Monitors (CEMs).

3. **Advanced Electrostatic Precipitator (ESP) Optimization System:** The ESP Optimization System is composed of a Carbon-In-Ash (CIA) virtual on-line analyzer, a CIA sensor, and Pegasus ESP Optimization software.

4. **Advanced Intelligent Sootblowing (ISB) System:** The ISB system is composed of Pegasus Intelligent Sootblowing software. This module has been previously demonstrated.

5. **Advanced Flue Gas Desulfurization Optimization System:** The FGD Optimization System is composed of Pegasus FGD Optimization software.

6. **Intelligent Plant (Unit Optimization):** The Pegasus Plant Optimization System will contain a simulator and will arbitrate among the solutions for the above systems. The system will interface with users through a commercially available computer.

Each technology package includes non-intrusive sensors and the appropriate software package needed for data acquisition, optimization, and integration with the overall neural network. In using this approach, all facets of coal-fired power plant operation will be optimized by balancing the inputs and outputs of the plant within a realm of multiple constraints. The intended result is to improve the efficiency of plant operations while operating within regulatory and commercial constraints.

Phase 1 (04/12/06 – 12/14/07)

During the first of three performance phases, sensor installation, software system design, and baseline operating metric testing was achieved. Instruments or instrument technology packages installed include the following: coal elemental analyzer (part of the fuel management system), mercury sensors, coal flow sensors, laser-based furnace gas speciation sensors, on-line carbon-in-ash sensor (located in the ESP), installation of communications links for data acquisition and control, related computers, controllers, and Pegasus optimization products. Baseline testing was performed to establish comparative data for follow-on operational testing in Phase 3. After initial baseline testing, parametric testing was performed to exercise various combinations of control variables to determine their effect on mercury speciation and by-product generation as well as overall plant performance. These data will be used in Phase 2 to adjust the neural network for optimization control.

Phase 2 (12/15/07 – 12/30/08)

Software installation, data communications modification, and Distributed Control System modification will be achieved during Phase 2. The test plan data and historical data (if applicable) will be evaluated to confirm that no irregularities exist prior to model development. After obvious excursions in the data (e.g., calibrations) are eliminated from the data set, operating issues and constraints will be reviewed as part of further model development. Control models will be developed to characterize the effect of control variables on the operational characteristics of the boiler, mercury speciation, and by-product generation. Models will be created which accurately and reliably represent the effects of changes in the unit on the outputs that will be optimized. Before the control models are implemented in an on-line system, an off-line simulation will be performed. The models will then be evaluated and demonstrated to the team and Limestone Power Plant operators and engineers, so their input can be used to finalize the behavior of the models.

Controlling Mercury

While research continues to find better and cheaper ways to remove mercury from the flue gas of coal-fired boilers, electric generating units (EGUs) already have several viable options. The mercury found in flue gas can be found in several physical and/or chemical states. It can be in the form of elemental mercury vapor or in an oxidized state. These chemical states can either be attached to flyash particles or free-floating. No matter which technology is used, elemental mercury is more difficult to remove than oxidized mercury.

The current leading technology specific to mercury removal consists of injecting PAC into the flue gas to adsorb the mercury. In some cases, the system itself is very simple, consisting of equipment to receive, handle, store, and inject the carbon. The carbon is injected into the flue gas between the air heater and the particulate control device. The particulate control device, either a baghouse or an electrostatic precipitator, removes the carbon and adsorbed mercury along with the flyash. Continued use of the existing baghouse or ESP assumes that the existing particulate control device can handle the additional particulate load without degradation of performance. A disadvantage of this simple system is that the flyash is contaminated with activated carbon. In 2004, approximately 40 percent of the flyash was sold for constructive uses. Flyash with high carbon content is difficult to sell, and some EGU operators are reluctant to risk losing their market, since they would incur disposal costs rather than receive payment for the flyash. If the boiler being retrofitted with activated carbon injection (ACI) is equipped with a hot-side ESP, the power plant can install the ACI system downstream of the air heater and install a new particulate removal system to remove the PAC and any residual flyash. A baghouse is generally preferred due to its high efficiency, especially for respirable particulates. This method ensures that the bulk of the flyash removed by the existing ESP is not contaminated with additional carbon.

While ACI is the most effective method of capturing mercury, power plants can often achieve significant coincidental mercury removal with their particulate and SO_2 controls. The effectiveness of achieving adequate mercury removal in equipment intended to control other pollutants varies significantly from plant to plant. As stated above, elemental mercury is less likely to be captured by any removal system, although ACI is less sensitive to the state of the mercury. The state of mercury in flue gas is affected by the type of boiler, the type of coal, and variations in boiler operation. Operators can influence the state of mercury in the boiler by optimizing combustion conditions to maximize oxidation of the mercury while maintaining satisfactory overall operation. By increasing the portion of the mercury that is oxidized, its removal in the ESP, baghouse, or FGD system is enhanced.

Increased oxidation of mercury is also a co-benefit of an SCR system. The SCR catalyst tends to oxidize a portion of the mercury in the flue gas, leading to higher removal rates in the particulate control system and/or the FGD system.

Pegasus uses pre-designed methods for constraining the models under various design and operational limitations. These are dynamic constraints that fluctuate with load, the number of burners in service, rate of change, etc. After the initial modeling is completed, a shorter series of tests will be conducted. This will involve setting up operational parameters to verify the predictive capabilities of the neural network model to assure that the model has been properly trained. During this period, the models will be coarse tuned. In the beginning, control loops will be tested one at a time to determine individual loop characteristics; afterwards, they will be tested in groups to determine interactive characteristics.

At the end of Phase 2, a decision will be made to either (1) initiate work under Phase 3 or (2) conclude the project following the successful demonstration of closed-loop operability for neural networks and controllers.

Phase 3 (01/01/09 – 05/31/10)

Demonstration and validation of all systems will be performed in Phase 3, as well as a comparison of the test results with the project objectives. Extended mercury and multi-pollutant testing will be conducted. The Technology Packages — Fuel Management System, Combustion and Mercury Control System, ESP system, ISB system, FGD system, Intelligent plant (i-Plant) system — will all be demonstrated during closed-loop operation. Operator and engineer training will also be conducted during Phase 3.

Anticipated Benefits

In this project, Pegasus Technologies and NRG Texas are attempting to combine all of the required best-of-class artificial intelligence and simulation technologies to prove that mercury speciation, as well as multi-pollutant benefits, can be measured, optimized, and controlled. If successful, Pegasus will demonstrate the capability of sophisticated control processes and advanced sensor technologies to simultaneously reduce harmful emissions of mercury and increase plant efficiency. Increased control of SO_2, NO_X, and particulate matter should also result, along with a reduction in water usage. Since these technologies are designed to control and optimize all major facets of power plant operations, the demonstration is expected to provide the capability to maximize plant efficiency for electricity production while reducing mercury emissions. This project is also expected to address concerns that higher mercury concentrations in existing by-products such as ash may adversely affect the commercial value of those by-products.

This project should demonstrate an operating environment that simultaneously offers higher average compliance with environmental requirements as well as better control of emissions, resulting in both a smaller risk of non-compliance to the utility and minimization of capital expenditures. In general, the project is expected to demonstrate how integrating sensors and advanced controls into a total plant solution can lead to improved economics while being environmentally compliant. The technologies being demonstrated are expected to have widespread application since they can be directly retrofitted to the existing coal fleet or integrated into future new plant designs.

Conclusions

This Topical Report describes three projects that are demonstrating three different cost-effective ways to remove mercury from the flue gas of coal-fired power plants. Having a portfolio of cost-effective mercury-removal technologies is critical to the continued operation of the nation's existing coal-fired power plants and to the construction of new plants.

The We Energies project is demonstrating the TOXECON process. This process is applicable to all power plants but is most applicable to those units having a hot-side ESP. The existing ESP removes the bulk of the flyash prior to activated carbon injection leaving the flyash uncontaminated with carbon. Since excess carbon reduces the marketability of flyash, this feature is highly desirable. The baghouse also acts as a polishing step for particulate removal by capturing most of the material that passes through the ESP.

CONSOL is demonstrating a set of technologies to effectively and economically control a number of pollutants including mercury, SO_2, SO_3, NO_X, and particulate matter. The technologies that comprise the Greenidge Multi-Pollutant Control Project are arranged in a manner that results in a high degree of synergism. With respect to mercury control, the SCR catalyst increases the amount of mercury in an oxidized state, making it easier to remove by the activated carbon and Turbosorp CFBDS. The Turbosorp system, which is primarily intended to remove SO_2, SO_3, and other acid gases, is also highly effective in removing oxidized mercury. Preliminary results indicate that mercury-removal rates of well over 90 percent are achievable without activated carbon injection. The baghouse associated with the CFBDS effectively removes both the sorbent and the flyash. The technologies being demonstrated at Greenidge are particularly important for units that are 300 MW or smaller since technologies that are economical in larger plants are not economical in smaller plants due to reverse economies of scale.

Pegasus is demonstrating a set of AI software packages that not only improves overall plant operation, but also improves the performance of existing environmental control systems. At the Limestone Plant, the AI systems enable the existing wet scrubbers to effectively remove mercury by increasing the portion of the mercury that is oxidized. This technology is particularly applicable to units that already have systems to control other criteria pollutants.

Although these projects are not complete, their value is demonstrated by recent announcements that some power producers are installing these or similar technologies.

Acronyms and Abbreviations

ACI . . . . activated carbon injection
BPEI . . . . Babcock Power Environmental, Inc.
Btu . . . . British thermal unit
CAAA . . . . 1990 Clean Air Act Amendments
CAIR . . . . Clean Air Interstate Rule
CAMR . . . . Clean Air Mercury Rule
CEMs . . . . continuous emission monitors
CCTDP . . . . Clean Coal Technology Demonstration Program
CCPI . . . . Clean Coal Power Initiative
CFBDS . . . . circulating fluidized bed dry scrubber
CO_2 . . . . carbon dioxide
DOE . . . . U.S. Department of Energy
EGU . . . . electrical generating unit
EPA . . . . U.S. Environmental Protection Agency
EPRI . . . . Electric Power Research Institute
ESP . . . . electrostatic precipitator
FD . . . . forced draft
FGD . . . . flue gas desulfurization
HAPs . . . . hazardous air pollutants
HHV . . . . higher heating value
HF . . . . hydrogen fluoride
Hg . . . . mercury
$HgCl_2$ . . . . mercuric chloride
HgO . . . . mercuric oxide
lb . . . . pound or pounds
µg . . . . micrograms
µm . . . . microns
MW . . . . megawatts
NETL . . . . National Energy Technology Laboratory
NO_X . . . . nitrogen oxides
PAC . . . . powdered activated carbon
PIPP . . . . Presque Isle Power Plant
PPII . . . . Power Plant Improvement Initiative
PM . . . . particulate matter
$PM_{2.5}$ . . . . particulate matter 2.5 microns or smaller diameter
PRB . . . . Powder River Basin
SCR . . . . selective catalytic reduction
SO_2 . . . . sulfur dioxide
SO_3 . . . . sulfur trioxide
SNCR . . . . selective non-catalytic reduction

To Receive Additional Information

To be placed on the Department of Energy's distribution list for future information on the Clean Coal Demonstration Programs, the projects they are financing, or other Fossil Energy Programs, please contact:

John L. Grasser, Director
Office of Communication
FE-5/Forrestal Building
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585
202-586-6803
202-586-5146 fax
john.grasser@hq.doe.gov

David J. Anna
Office of Public Affairs Coordination
U.S. Department of Energy
National Energy Technology Laboratory
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4646
412-386-6195 fax
david.anna@netl.doe.gov

Bibliography

DOE Contacts for CCT Projects

TOXECON™

Michael McMillian,
Project Manager
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4669
michael.mcmillian@netl.doe.gov

Greenidge

Wolfe Huber, Project Manager
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-5747
wolfe.huber@netl.doe.gov

Pegasus

Michael McMillian,
Project Manager
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4669
michael.mcmillian@netl.doe.gov

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Contacts for Participants in CCT Program

David Wroblewski, Senior VP Development
Pegasus Technologies
100 Seventh Avenue, Suite 210Chardon, OH 44024
440-285-7794
dwroblewski@pegasustec.com

D. P. Connell, Principal Investigator
CONSOL Energy Inc.
Research & Development
4000 Brownsville Road
South Park, PA 15129-9566
412-854-6559
danielconnell@consolenergy.com

Steven T. Derenne, Project Manager
Wisconsin Electric Power Company
333 West Everett Street
Milwaukee, WI 53203
414-221-4443
steve.derenne@wepowerllc.com

National Energy Technology Laboratory

1450 Queen Avenue SW
Albany, OR 97321-2198
541-967-5892

2175 University Avenue South, Suite 201
Fairbanks, AK 99709
907-452-2559

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4764

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4687

One West Third Street, Suite 1400
Tulsa, OK 74103-3519
918-699-2000

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Office of Fossil Energy

Printed in the United States on recycled paper

February 2008