

# *Advanced Emissions Control Development Program*

## *Quarterly Technical Progress Report*

*For the period: October 1 to December 31, 2000*

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## **Overview**

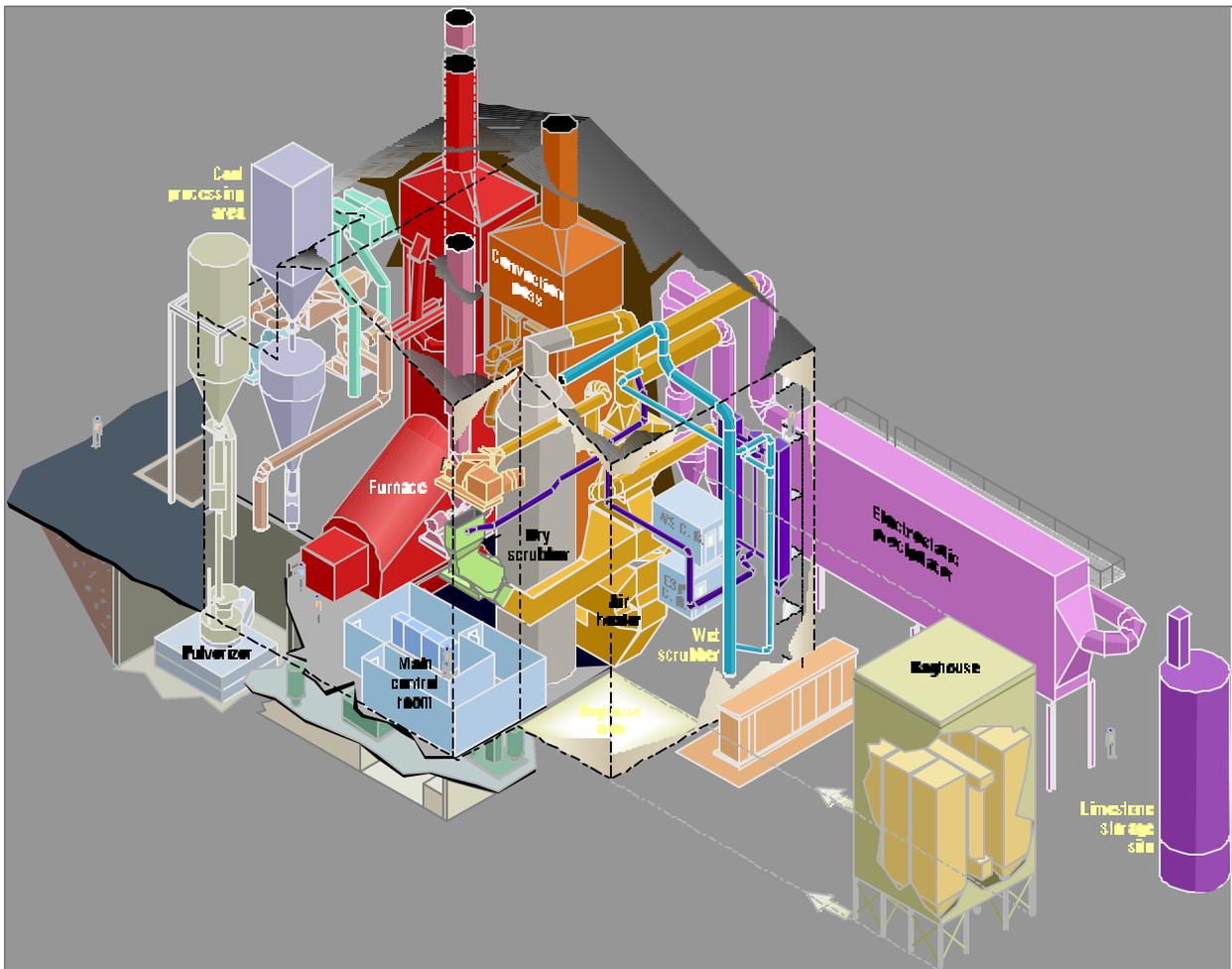
The primary objective of the Advanced Emissions Control Development Program (AECDP) is to develop practical, cost-effective strategies for reducing the emissions of hazardous air pollutants (HAPs, or air toxics) from coal-fired boilers. The project goal is to effectively control air toxic emissions through the use of conventional flue gas cleanup equipment such as electrostatic precipitators (ESPs), fabric filters (baghouses), and wet flue gas desulfurization (WFGD) systems. Development work initially concentrated on the capture of trace metals, fine particulate, hydrogen chloride, and hydrogen fluoride. Recent work has focused almost exclusively on the control of mercury emissions.

Work is currently being conducted by McDermott Technology, Inc. (MTI), under an amendment (addition) to the original project workscope to permit a more thorough evaluation of mercury control concepts developed earlier in the project. The original project workscope was conducted under three phases and was completed in July, 1999. The original three phases were jointly funded by the United States Department of Energy's National Energy Technology Laboratory (DOE), the Ohio Coal Development Office within the Ohio Department of Development (OCDO), and Babcock & Wilcox – a McDermott company (B&W). The additional workscope being conducted under the amendment is funded by the U.S. DOE-NETL. Detailed descriptions of the work completed under Phases I, II, and III are contained in the final reports for each of the phases.

## **Previous Work**

Phase I (Facility Modification and Benchmarking) was aimed at providing a reliable, representative test facility to study air toxics. A full-flow ESP and partial-flow baghouse and wet scrubber were added to the existing complement of flue gas treatment systems installed at the B&W Clean Environment Development Facility (CEDF). A schematic of the CEDF and project test equipment is provided in Figure 1. The CEDF is a one-of-a-kind testing facility with

a rated capacity of 100 MBtu/hr (about the equivalent of a 10 MW<sub>e</sub> electric plant). It simulates a large commercial generating station from the coal pile to the stack. For the added equipment, the general design philosophy was to install systems that would be representative of existing commercial systems, yet provide a high degree of flexibility in both operation and configuration. Other activities completed in Phase I included equipment verification, air toxics benchmarking and the establishment of an emissions database.



**Figure 1 – Clean Environment Development Facility**

Air toxic benchmarking measurements were performed to quantify the air toxics emissions from the boiler and back-end flue gas cleanup equipment. Air toxics emissions were verified through comparison of the emissions from the CEDF with the emissions predicted by the trace element content of the coal and the draft emission modification factors (EMFs) established by the U.S. EPA. The EMFs were developed using data gathered at a number of commercial plant sites. The similarity between the predicted and measured emissions indicated that the air toxics emitted from the CEDF are representative of commercial units firing bituminous coal.

Three test campaigns were conducted in Phase II (Optimization of Conventional Systems). The first two campaigns were directed at the development of air toxics control strategies based on the use of conventional particulate and SO<sub>2</sub> control equipment. Campaign 1 focused on mercury speciation measurements, particulate- and vapor-phase trace metal emissions, and fine particulate emissions. Emphasis was placed on characterization of ESP and baghouse trace element emissions control performance. The control of mercury emissions with a wet limestone scrubber was broadly characterized during Campaign 2 at conditions representative of a range of commercial scrubber operation. Campaign 3 provided data on the impacts of coal properties on mercury emissions for several Ohio steam coals. The impact of coal cleaning on mercury emissions was investigated through characterization of commercially-cleaned coals and their associated parent (uncleaned) coals. Two advanced measurement systems, a mercury monitor and a Fourier transform infrared spectrometry analyzer (FTIR), were also evaluated in Phase II.

Phase III (Advanced Concepts and Coal Comparisons) included investigations of advanced emissions control concepts, primarily for the purpose of reducing vapor-phase mercury emissions. Two different approaches were taken to address the two major segments of the coal-fired utility market:

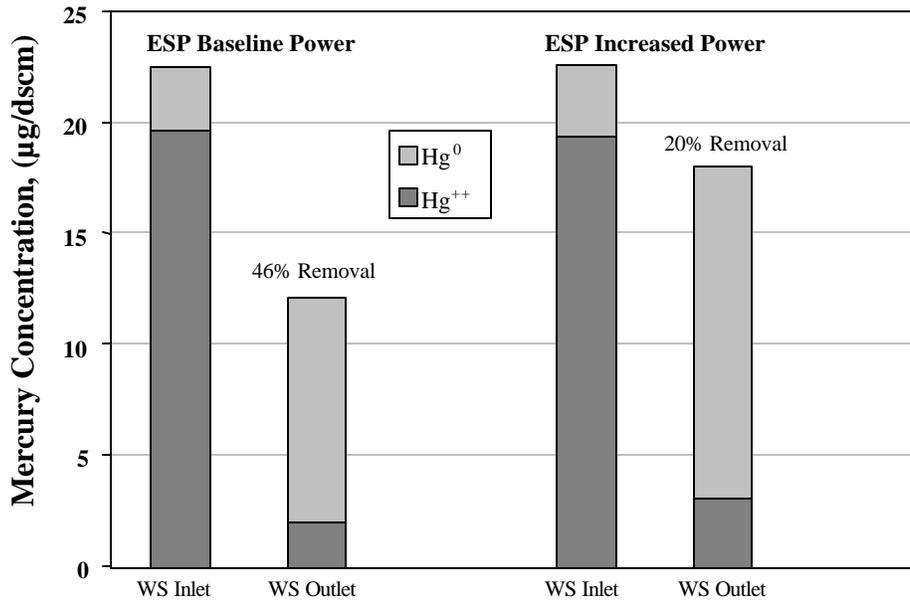
- Scrubbed systems (primarily wet flue gas desulfurization) which represent about 25% of the coal-fired utility market. The majority of these scrubbed systems consist of an ESP followed by a wet scrubber
- Unscrubbed systems which represent about 75% of the utility coal market. The majority of these systems consist of ESPs only.

Mercury species were tracked through the entire coal-utilization process including pre-combustion, combustion, and post-combustion processes for several Ohio coals. Commercial coal cleaning, which is used on the majority of coals fired east of the Mississippi, provided average mercury emission reductions of 42% compared to the raw coal. Particulate control devices (ESPs and baghouses) effectively removed the particulate-phase mercury, but the particulate-phase mercury was only a small fraction of the total mercury for the coals tested. A baghouse, which provided negligible control of vapor-phase mercury, apparently impacted the speciation of the vapor-phase mercury in the flue, resulting in a modest conversion of the elemental mercury to the oxidized form.

Control of mercury by an ESP with upstream sorbent injection was demonstrated for two sorbents during Phase III testing. Testing focused on sorbents of low cost relative to commercial activated carbons. Carbon injection is a commercially-proven technology for the control of mercury emissions from municipal solid waste incinerators. However, application of carbon injection technology to coal-fired utility boilers would be very expensive due to the low utilization of carbon expected for those systems. One low-cost sorbent tested during Phase III provided 45 % and 56 % removal of total mercury at two cost-competitive stoichiometries, compared to an 18% average removal for baseline conditions with no sorbent injection. Carbon injection likewise provided improved control of mercury by an ESP, removing 56% of the total mercury in the flue gas at an activated carbon to mercury mass ratio of 9000 to 1.

Phase III testing related to FGD systems focused on enhancing control of mercury across wet scrubbers when operated downstream of an ESP. Testing during Phase II had consistently indicated less mercury removal for an ESP/WFGD system as compared to a baghouse/WFGD system – *even though there was no significant difference in mercury removal or speciation across the particulate collectors*. Also, elemental mercury levels increased across the *scrubber* when an ESP was used upstream. Causes for these observations were hypothesized at the beginning of Phase III and corresponding methods for enhancing mercury control in the wet scrubber were tested. The hypotheses were based on the belief that the ESP can destroy gas-

phase species that would otherwise react with the mercury in the scrubber and thereby sequester the mercury in a solid precipitate, preventing the subsequent conversion of the oxidized mercury to the elemental form. Figure 2 illustrates the observed conversion of oxidized mercury species to the elemental form in a wet scrubber operating downstream of an ESP. This phenomenon is not observed in the scrubber when operating downstream of a baghouse. Figure 2 further illustrates the fact that the effect is dependent on the operating conditions in the ESP.



**Figure 2. Effect of ESP Power on Mercury Removal in Wet Scrubber**

Several enhancements were identified to improve control of mercury in a wet FGD system downstream of an ESP. The baseline data used for comparison with the enhancements showed 46% removal across the scrubber when preceded by an ESP when firing a blend of Ohio 5, 6, & 7 coals. Three enhancements were evaluated to determine their potential for eliminating the effect of the ESP on mercury control in the scrubber. All three of the enhancements significantly improved mercury control across the wet scrubber and prevented increases in elemental mercury. Mercury removal increased to 80, 71, and 73% for the three enhancements, respectively.

## **Current Work**

The Babcock and Wilcox Company and McDermott Technology, Inc., consider the mercury control concepts developed during the three phases of the AECDP, and described in the previous section, to have the potential to permit U.S. utilities to reduce mercury emissions from their coal-fired units in a very cost-effective manner. B&W expects to move these concepts to the commercial demonstration stage in 1-3 years – consistent with U.S. EPA’s regulatory timeframe for utility mercury emissions. However, there are a variety of issues that need to be addressed before a detailed commercialization plan can be developed. These issues are being addressed under the aforementioned additional workscope added to the AECDP by way of a contract amendment. The following sections describe these additions to the AECDP contract workscope. They fall under two main activities or tasks: 1) Concept Evaluation and 2) Fate of Mercury.

### **Task 1 – Concept Evaluation**

The objective of this task is to further evaluate the mercury emissions control concepts developed under Phase III. The enhanced WFGD and sorbent injection technologies will be evaluated both technically and economically for potential application to coal-fired utility boilers. The evaluations will comprise the following activities:

***Preliminary Assessment of the Market.*** This activity will be a follow-on to the preliminary boiler population study conducted previously. The evaluation will focus on the status and potential form of mercury regulations and their impacts on the electric utility industry. It will also include evaluation of near-term utility needs for mercury control including an updated utility boiler population survey, an assessment of existing environmental control equipment, and the potential for mercury emissions reductions using the MTI/B&W concepts.

***Engineering Study / Conceptual Design.*** Preliminary (conceptual) process designs will be developed for each of the mercury control concepts. These designs will be based on the application of the technologies to representative commercial boilers, and will be used to identify

design uncertainties, as well to quantify the sensitivity of performance and cost on design specifications. For each concept this activity will include the preparation of a process flow diagram, material balance, major equipment list and budgetary equipment cost estimate.

For the enhanced WFGD concepts, this activity will be used to better define which approach or combination of approaches makes the most sense from performance, cost, environmental, and operational points of view. For the sorbent injection system a thorough analysis of the installation costs, sorbent costs, and boiler performance impacts will be done to permit a cost comparison with activated carbon injection systems. Key factors in this analysis include sorbent type, injection location/temperature, and solid byproduct considerations such as the stability of the mercury and solubility of the flyash.

***Cost Analysis.*** Based on the preliminary designs, budgetary capital and operating costs will be developed for each mercury control concept. These costs will then be compared with other mercury control concepts such as activated carbon injection, carbon beds, etc.

### **Task 2 – Fate of Mercury**

A key consideration in the commercial viability of any mercury removal process is the fate of the captured mercury. To be an effective control technology, the captured mercury must remain sequestered in the solid byproduct permanently. This is an important consideration for both the gypsum or sludge produced by the enhanced WFGD process, and for the spent sorbent/flyash byproduct produced by the sorbent injection process. Work will be done under this subtask to characterize the properties and stability of the byproducts produced by the mercury control concepts. This work will involve chemical analysis of baseline, aged, and treated samples of byproduct materials. Some of this work will make use of samples archived during earlier phases of the project. Consideration will also be given to the collection of samples from representative field sites.

A testing plan will be developed prior to actual testing. Chemical analysis procedures and sample aging and/or treatment schemes will be chosen based on discussions with U.S. DOE, U.S. EPA, and others. Preliminary discussions with U.S. EPA personnel indicate that they are planning to hold a working group meeting to discuss characterization methods in the near future. MTI will participate in these discussions in order to ensure that data collected during this project can be compared with work being done at other laboratories.

For the enhanced WFGD system, particular attention will be paid to the stability of the captured mercury during the types of processing unit operations necessary to produce gypsum wallboard. Key considerations for the limestone sorbent process include the long-term stability and/or leachability of the captured mercury, and the impacts of the process on the salability of the flyash.

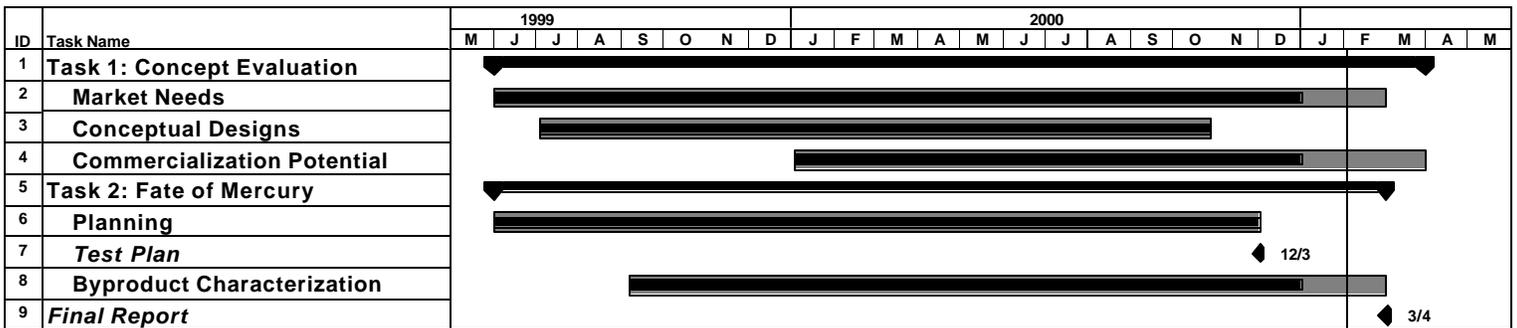


Figure 3. Schedule of Activities

## **Work Conducted During Reporting Period**

### **Budget and Schedule Issues**

The schedule status of the project is summarized in Figure 3. The schedule reflects the approval of a no-cost extension of the project period of performance through March 31, 2001.

### **Task 1 – Concept Evaluation**

Work under Task 1 primarily consisted of the development of capital and operating costs for the scrubbed and unscrubbed systems. Preparation of the final report also began.

### **Task 2 – Fate of Mercury**

Much of our work during the reporting period centered on evaluating the feasibility of using the PSA mercury analyzer to perform thermal stability tests. The basic concept is to heat solid samples at a controlled rate and to follow the evolution of mercury species by routing the carrier gases through the PSA analyzer. Extensive trials were conducted using various pure mercury compounds such as HgO, HgS, etc. We feel that the method yields repeatable results which will allow us to assess the stability of the captured mercury under conditions of commercial thermal treatment processes used in the production of gypsum wall board or cement.

A representative of the American Coal Ash Association was kind enough to supply representative samples of byproduct streams from various commercial sites. These samples include ash from both eastern and western coals, as well as scrubbed and unscrubbed systems. Each of these samples was characterized using our thermal stability method which makes use of the PSA mercury analyzer. Work on the final report began.

## **Work Planned for the Next Reporting Period**

### **Task 1 – Concept Evaluation**

Process economics will be evaluated relative to competing technologies (carbon injection).

The final report will be issued.

### **Task 2 – Fate of Mercury**

The final report will be issued.