Ultra High Efficiency ESP Development for Air Toxics Control

Final Technical Report, Phase II

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ABSTRACT

Because more than 90 percent of U.S. coal-fired utility boilers are equipped with electrostatic precipitators (ESPs), retrofitable ESP technologies represent a logical approach towards achieving the Department of Energy's (DOE) goal of a major reduction in fine particulate and mercury emissions (air toxics) from coal based power systems. EPA's recent issuance of significantly tightened ambient air standards for particles smaller than 2.5 μm ($PM_{2.5}$) creates a new urgency for developing cost-effective means to control fine particulate emissions. This challenge is compounded by the on-going switch in the utility industry to low-sulfur Powder River Basin (PRB) coals, that generate higher resistivity and difficult-to-collect fly ash. Particulate emissions can increase by a factor of ten when a utility switches to a low-sulfur coal. Numerous power plants are presently limited in operation by the inability of their ESPs to control opacity at high loads.

In Phase I of this program, ABB investigated five technologies to improve the collection of fine particulate and trace metals in ESPs. These included: (i) flue-gas cooling, (ii) flue-gas humidification, (iii) pulsed energization, (iv) wet ESP and precharger modules, and (v) sorbent injection for mercury control. Tests were conducted with an Eastern bituminous coal and a Powder River Basin sub-bituminous low-sulfur coal in an integrated pilot-scale combustor and ESP test facility. The impacts of the different retrofit technologies on ESP performance, individually and in combination, were evaluated in-depth through advanced sampling and measurement techniques.

In Phase II, the most promising concepts identified from Phase I testing, flue-gas cooling and humidification, pulsed energization, and sorbent injection at low flue-gas

temperatures for mercury control, were integrated into a commercially oriented sub-scale system for field testing at Commonwealth Edison's Waukegan Unit No. 8. The main objective of the proposed Phase II testing was to determine longer term ESP performance and mercury capture improvements with the above enhancements for a range of low-sulfur coals currently fired by utilities.

Unanticipated cost growth in readying the Pilot Plant for shipment and during slipstream construction at the utility host site resulted in the issuance of a preemptive stop work order from ABB until a detailed technical and budgetary review of the project could be completed. Four program recovery scenarios were developed and presented to the DOE. After careful review of these options, it was decided to terminate the program and although the Pilot Plant installation was essentially completed, no testing was performed. The Pilot Plant was subsequently decommissioned and the host site returned to its preprogram condition.

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EXECUTIVE SUMMARY

Since more than 90 percent of U.S. coal-fired utility boilers are already equipped with electrostatic precipitators (ESPs), retrofitable ESP technologies are a logical approach towards achieving the Department of Energy's (DOE) goal of a major reduction in fine particulate and mercury emissions (air toxics) from coal-fired power systems. EPA's recent issuance of significantly tightened ambient air standards for particles smaller than 2.5 μm ($PM_{2.5}$) creates a new urgency for developing cost-effective means to control fine particulate emissions. This challenge is compounded because many utilities have switched to low-sulfur Powder River Basin (PRB) coals that generate high resistivity and difficult-to-collect fly ash. Particulate emissions can increase by a factor of ten when a utility switches to a low-sulfur coal. Numerous power plants are presently limited in operation by the inability of their ESPs to control opacity at high loads.

In Phase I of this program, ABB investigated five technologies to improve the collection of fine particulate and trace metals in ESPs. These included: (i) flue-gas cooling, (ii) flue-gas humidification, (iii) pulsed energization, (iv) wet ESP and precharger modules, and (v) sorbent injection for mercury control. Tests were conducted with an Eastern bituminous coal and a Powder River Basin sub-bituminous low sulfur coal in an integrated pilot-scale combustor and ESP test facility. The impacts of the different retrofit technologies on ESP performance, individually and in combination, were evaluated in depth through advanced sampling and measurement techniques.

Significant findings from the Phase I ABB/DOE project included:

- Reduction in particulate emissions by a factor of 10 to 20 for both low-sulfur coals tested, to a value below 10 mg/Nm^3 (< 0.01 lbs/MMBtu) when flue-gas temperature was reduced from a typical industry value of 170°C to 100°C. Ultra-low emissions were achieved for a relatively small ESP collecting area [36 m^2/(m^3/s) or 180 ft^2/kacfm] for the Powder River Basin coal.
- Reduction in particulate emissions from 45 mg/Nm^3 to less than 5 mg/Nm^3 (< 0.005 lbs/MMBtu) at a gas temperature of 150°C from a combination of flue-gas humidification and pulsed energization
- Lower fine particulate (< 2.5 μm) emission, by a factor of 10 to 20, in above tests versus baseline operation
- Reduced trace metal emissions, by a factor of up to 10, due to fine particulate emission reduction
- Greater than 90% mercury capture at 100^{o}C with activated carbon injection; promotion of mercury capture with low flue-gas temperature, for both the native ash (no sorbent) and the sorbent
- ESP collection efficiencies ranged from 96 to 99.9% during the course of the Phase I tests

Phase I testing clearly showed that controlling ESP inlet temperature and humidity, in combination with pulsing, was key to effective collection of fine particulates and mercury from low-sulfur coals.

Flue-gas humidification, cooling, pulsed energization and sorbent injection were selected for more thorough evaluation in Phase II where ABB proposed the installation of a pilot ESP in a slipstream at a full-scale utility boiler. This would have allowed:

- Long-term testing to verify that positive effects of cooling, humidification, and pulsing on particulate emissions and trace-metal capture do not deteriorate, and that fouling and corrosion do not occur
- Evaluation of ABB's proprietary spray cooling system performance versus conventional systems
- Evaluation of mercury control with a combination of cooling and sorbent injection
- Acquisition of performance data for commercial design with full-scale flue-gas and ash
- Evaluation of a range of flue-gas velocities and specific collection areas typical of full-scale ESPs
- Testing with additional low-sulfur coals, on-line comparison of pilot and full-scale ESP performance, and more detailed characterization of the impacts of ESP operation on the emitted size distribution ($PM_{2.5}$)

Commonwealth Edison (ComEd), one of the top ten U.S. utilities and a significant consumer of PRB coals, welcomed the opportunity to work with ABB and DOE in Phase II and offered it's Waukegan Unit No. 8 in Waukegan, IL as a host site.

In Phase II, the most promising concepts identified from Phase I testing, flue-gas cooling and humidification, pulsed energization, and sorbent injection at low flue-gas temperatures for mercury control, were integrated into a commercially oriented sub-scale system for field testing at a utility site slipstream. The main objectives of the Phase II testing were to determine longer term ESP performance (i.e., if any degradation occurs) and assess the risk of corrosion and plugging due to acid condensation with operation at low temperature and high humidity. A secondary objective was to evaluate mercury capture improvements with the above enhancements for a range of low-sulfur coals currently fired by utilities.

Acquisition of field performance data is critical not only for the reasons presented above, but also for effective commercialization of the technologies developed under this program. Slipstream field testing in the ABB pilot unit was designed to provide the following key elements necessary for successful commercialization efforts:

- Sizing guidelines for achieving low flue-gas temperatures, and the corresponding ESP designs
- Data base for selection of flue-gas cooling/humidification balance, as a function of the level of performance improvements required, physical space limitations, and the design of existing equipment
- Benchmarked comparison of the ABB proprietary spray cooling system with conventional humidification systems, in terms of droplet-size distributions, power consumption, and long-term performance
- Verification and documentation of the improved effectiveness of carbon sorbents for mercury capture during low-temperature ESP operation; field data to support use of this technology for coal-fired applications

- Data base of field performance improvements with SIR operation in the various pulsing modes, extended for a broader range of fuels; further exploration and documentation of the synergies between SIR operation and flue-gas humidification

The ABB Pilot ESP was modified for long term slipstream testing and delivered to Commonwealth Edison's Waukegan Unit No. 8. Slipstream construction and pilot installation began in May of 1998. Construction continued until July 1998 when unanticipated cost growth resulted in the issuance of a preemptive stop-work order from ABB until a detailed technical and budgetary review of the project could be completed. Four program recovery scenarios were developed and presented to the DOE in October of 1998. After careful review of these options, the DOE decided to terminate the program and no field-testing was performed. The Pilot Plant was subsequently decommissioned and the site restored to its preprogram condition.

1.0 Introduction

This report summarizes the results of Phase II of the Ultra High Efficiency ESP Development for Air Toxics Control program. The main objective of this program was to evaluate the long-term effectiveness of the ESP enhancements concepts developed under Phase I. Unanticipated cost growth associated with Pilot Plant modification and field installation at the utility host site ultimately lead to the termination of the program before any testing was performed. This report summarizes the proposed Phase II activities and documents the progress made prior to the cancellation of the project.

2.0 Technical Background

Nearly ninety percent of U.S. coal-fired utility boilers are equipped with electrostatic precipitators (ESP). Cost-effective retrofit ESP technologies are a viable means to accomplish Department of Energy's (DOE) goal of a major reduction in fine particulate and air toxic emissions from coal-fired power plants.

Particles in the size range of 0.1 to 5 μm typically escape precipitators. Although their total mass is relatively small, metals, such as arsenic, cadmium, lead, molybdenum and antimony, can concentrate on these particles. This is the main driver for improved fine-particulate control. Vapor-phase emissions of mercury, selenium, and arsenic are also of major concern. Current dry ESPs, which operate at temperatures greater than 140^{o}C, provide little control for vapor-phase toxics.

The need for improvements in precipitators performance is driven by environmental concerns and the current trend towards the use of low sulfur coals. Switching to low-sulfur coals is the dominant approach for SO_2 emission reduction in the utility industry. Low-sulfur coals generate high-resistivity ash, that can cause an undesirable phenomenon called “back corona.” Higher particulate emissions occur if there is back corona in the ESP.

2.1 Technical Issues

Given this background, the primary technical areas that needed to be addressed to improve collection of fine particulate and vapor-phase metals (for example, mercury) include the following:

High-ash resistivity: ESP performance is strongly influenced by the properties of the collected dust cake (resistivity and cohesivity). High dust cake resistivity decreases particle migration velocities and lowers collection efficiency. In most cases, an increased amount of sulfur trioxide (SO_3) and higher relative humidity in the flue-gas decrease the resistivity of the fly ash and increase its cohesivity. Higher sulfur coals typically produce low-resistivity ash and are easier to collect in an ESP compared to low-sulfur coals.

In the United States, utilities are switching to low-sulfur coals mainly from the sub-bituminous class mined in the Powder River Basin (PRB). These coals have lower heating values than the bituminous, higher-sulfur coals that they are replacing. Switching to PRB fuels increases the flue-gas flow and lowers heat extraction in the boiler and convective sections compared to design specifications. The decreased heat removal increases the temperature of the flue-gas entering the ESP and further exacerbates the problem of high resistivity ash. Additionally, the increased flue-gas flow through the ESP exceeds the original high design velocity, increasing reentrainment and lowering collection efficiencies. Several plants are limited in the load (MW) at which they can operate, because they cannot meet particulate emission limits. The particulate emission limits also restrict the choice of the fuel that the utilities can burn, typically increasing their fuel cost and the cost of electricity generation.

Particulate emissions can increase by a factor of ten when a utility burning a medium- or high-sulfur coal switches to a low-sulfur coal. Flue-gas conditioning with SO_3 is currently the most widely used technique for solving resistivity related problems caused by low-sulfur coals. This conditioning technique requires an ongoing operating expense.

Power supply system: In an ESP, the precipitation of particles is enhanced by increasing the electrical-field strength (i.e., high voltage) between the electrodes, while ensuring minimum back corona. The ESP is therefore operated with the maximum power input, but just below the sparking level or back corona limit. The back corona limit is usually reached first for high resistivity ashes.

Back corona can be controlled by regulating the production of ions (charges) at the discharge electrode by methods such as pulsing. Flexibility in implementing various pulsing scenarios is important to control back corona.

Conventional ESP power supplies transform and rectify at normal frequency (60 Hz). These transformer/rectifier (T/R) sets generate a substantial ripple on the high voltage due to the fact that charging takes place only once per half period. The corona current between these "voltage peaks" can discharge the ESP as much as 50 percent. Thus, a ripple decreases the upper limit on the operating voltage. Power supplies that can eliminate ripples can enable operation at higher voltages and higher collection efficiencies for ash with moderate or low resistivity.

Vapor phase control: Some of the metallic hazardous air pollutants (HAPs) such as mercury and selenium are present in the vapor phase at ESP operation temperatures. Current dry ESPs have very low capture efficiencies for these vapor phase HAPs. Vapor-phase-toxics control is a critical challenge for ESP advancements.

In summary, the control of fine particulate and air toxics by ESPs can be improved by:

- reducing fly ash resistivity
- agglomerating small particles and increasing cohesivity
- advanced pulsed energization when back corona is present
- reducing reentrainment
- increasing the condensation and adsorption of vapor phase species (e.g., Hg) on the surfaces of ash or sorbent particles

Retrofitting existing ESPs to achieve ultra-high particulate collection efficiencies, hence a dramatic decrease in trace-toxic emissions, is an extreme challenge for the technology developer. Ultra-high efficiency is defined by ABB to mean an outlet particulate emission below 10 mg/Nm^3 (0.028 lb/Mmbtu @3% O_2). Another challenge is to achieve the performance requirement with low-sulfur coals in cases where the original design is for mid-to-high sulfur coals. Finally, any retrofit or new technology must be cost effective and reliable in order to be accepted by the utility community. Each of the above challenges was addressed in the approach described below.

2.2 Technical Approach

The ABB team's approach was to focus on four retrofit ESP elements that have high probabilities of achieving the ultra-high particulate collection efficiency goal, as well as a high likelihood of gaining acceptance in the utility industry. The three elements selected for evaluation and development for the advanced ESP were:

- Gas cooling upstream of ESP
- Gas humidification upstream of ESP
- A new transformer-rectifier set - Switched Integrated Rectifier (SIR)

A fourth element was added to the ABB program, as mercury control became a more important issue during the course of the Phase I project. This technical element involved:

- Flue-gas cooling with activated sorbent injection for mercury capture

Each of the technical elements, and how they address the outstanding technical issues, is discussed further below.

Gas Cooling And Humidification: Current precipitators in the United States are mainly operating in the temperature range from 140 to 170^{o}C. Dust-cake resistivity for most types of coal ash peaks around 170^{o}C. Significant benefits can, therefore, be derived from flue-gas cooling. One of the advantages of gas cooling and humidification is the increased surface adsorption of SO_3 and moisture, which decreases dust cake resistivity. Also, lower gas velocity, resulting from reduced flue-gas temperature, reduces reentrainment of ash from the ESP collection plates. Gas cooling also fosters condensation and collection of vapor-phase mercury, arsenic and selenium species. Thus, an ESP with a cooling and humidification system addresses all the technical issues identified earlier.

Switched Integrated Rectifier (SIR): SIR is a new transformer/rectifier (T/R) set developed by ABB that allows more flexible, higher-voltage operation without sparkover. The SIR unit also has a built-in microprocessor that is capable of intermittent energization with any desired charging frequency. For high-resistivity fly ashes, the varying voltage, if correctly applied, can substantially reduce both power consumption and emissions.

Mercury Control: The extent of capture of trace metals, especially vapor-phase species such as mercury, was determined for the various ESP performance enhancement techniques described above. In addition, ABB examined the possibility of augmenting activated carbon injection, a technique being investigated by several researchers for mercury control. The unique aspect of the ABB approach was to combine activated carbon injection with flue-gas cooling. This synergistic approach decreased the carbon requirements for achieving a prescribed mercury capture efficiency, thus lowering operating costs for mercury control. Phase I of the program targeted whether flue-gas cooling improves the performance of the activated carbon for mercury capture. Under Phase II of this program, long-term testing of this concept was planned.

3.0 Facilities Description

3.1 Pilot ESP

The advanced ESP test facility consists of the ABB mobile pilot-scale ESP, Figure 3.1-1, configured with the advanced ESP performance enhancement modules, and fitted to a slipstream of flue-gas at a full-scale host site utility. The advanced modules are the flue-gas cooler, the flue-gas humidification system, advanced energization (SIR), and sorbent injection for mercury capture. The ABB pilot ESP was designed to provide extremely high collection efficiencies while effectively modeling full-scale operation. The ESP had three electrical fields, each equipped with mechanical rappers. The discharge electrodes were of the spiral wire variety, affixed to rigid frames. A schematic of the pilot ESP internal arrangement is shown in Figure 3.1-2. An ash conveyor screw system removed the ash from the collection hoppers located beneath each collection plate. The range of specific collection areas (SCA), the electrode-to-plate spacing, and the 3-field configuration of the pilot ESP all contributed to a realistic simulation of full-scale ESP phenomena during the Phase I test program.

Figure 3.1-1 ABB Mobile Pilot ESP

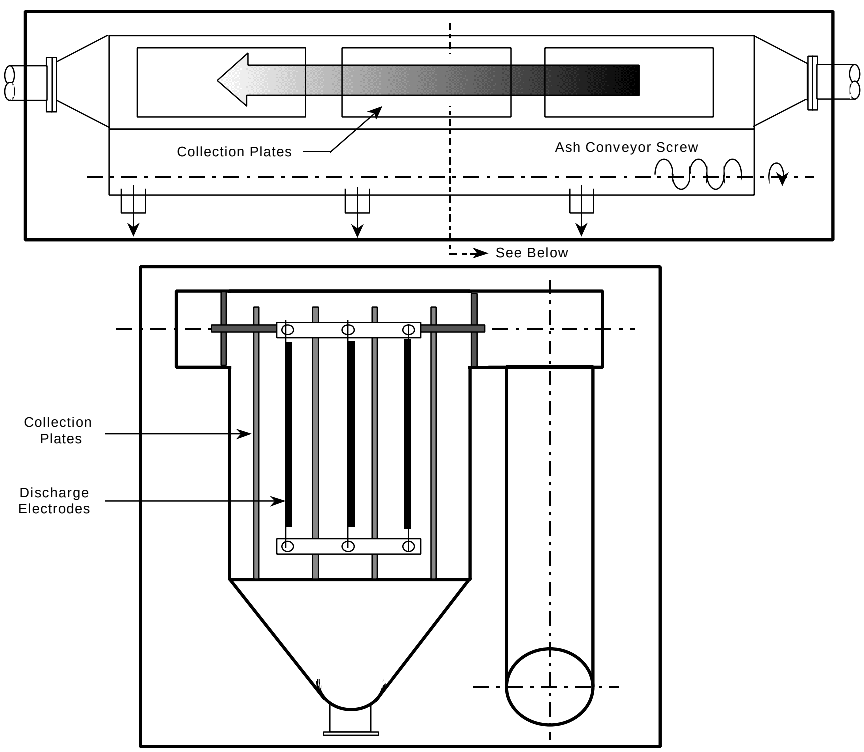

Figure 3.1-2 Schematic of Pilot ESP Internal Arrangement

Figure 3.1-3 is a photograph of the spiral wire electrode assembly utilized in the pilot ESP. The collection plates are also shown. Shown in Figure 3.1-4 are removable collection plate panel sections that were used to allow removal of collected dust layers without disturbing the dust cake. The dust cake could then be analyzed off-line for determination of physical and chemical properties at various depths in the dust-cake layer.

Each field of the pilot ESP was equipped with an advanced transformer/rectifier (T/R) set (developed by ABB) called a Switched Integrated Rectifier (SIR). The SIR allowed more flexible operation and higher voltage operation without sparkover. Instead of transforming and rectifying at normal frequency (50/60 Hz), the mains were first rectified, then chopped at 50 kHz and thereafter transformed to a high voltage. Thus, a pure DC voltage was achieved, that allowed ESP operation at a higher voltage level, and closer to the peak value, than with current T/R sets. The SIR unit also had a built-in microprocessor that was capable of intermittent energization with any desired charging frequency. For high resistivity fly ashes, the varying voltage, if correctly applied, can substantially reduce both power consumption and emissions. The ability to implement pulsing scenarios is therefore important, and the SIR provided that flexibility.

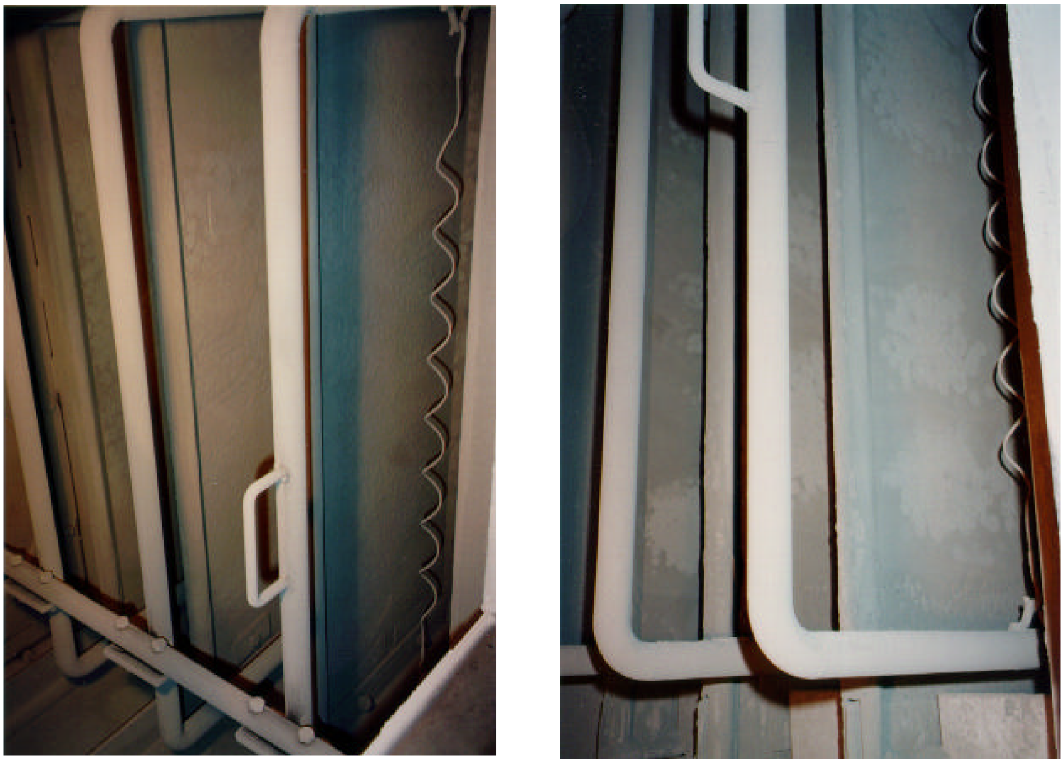

Figure 3.1-3 Pilot ESP Discharge Electrode and Collection Plate Assemblies

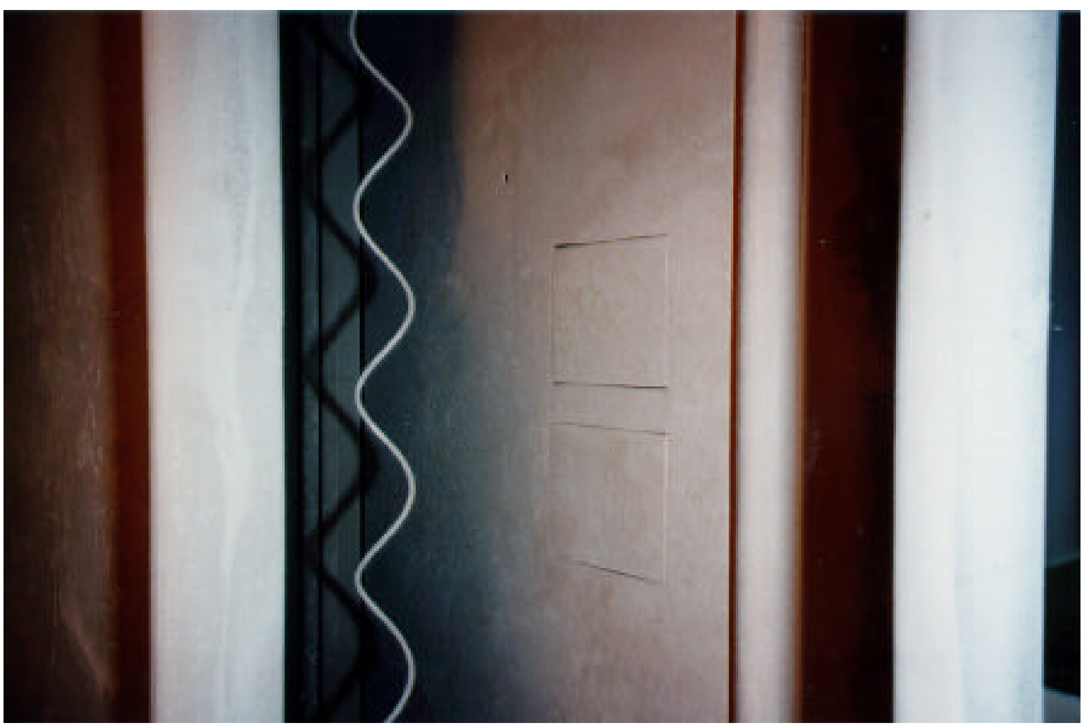

Figure 3.1-4 Pilot ESP Removable Dust Cake Sampling Panels

The moisture content of the flue-gas entering the ESP is controlled in the ABB pilot facility. In typical field spray cooling systems, moisture is added via a water spray at the ESP inlet. Evaporation of the water at this location both cools the flue-gas entering the ESP and increases its moisture content. An important objective of the Phase I program was to quantify the independent effects of flue-gas temperature and humidity on the ESP performance. Controlled amounts of water were sprayed into the high temperature flue-gas (about 2400^{o}F) to control its humidity. Gas temperature was independently controlled with a heat exchangers located near the inlet of the Pilot ESP.

3.2 Slipstream Installation

ComEd's Waukegan Station 16, Unit 8 was chosen as the host site for the pilot ESP. This is a 380-megawatt, tangentially-fired unit currently firing a variety of PRB coals. In 1995, the Unit No. 8 ESP in Waukegan, IL was substantially upgraded, allowing for a broad-range of coals to be fired while meeting all plant emission requirements.

The configuration of the field-installed advanced ESP is shown in Figures 3.2-1 and 3.2-2. In the field (slipstream) installation, the gas velocities (SCAs) were to be varied over much wider range than those encountered in the Phase I pilot work. As can be seen in Figure 3.2-1, flue-gas and suspended particulate are isokinetically drawn from the inlet of the plant's ESP using a sampling rake consisting of 20 evenly distributed sampling points. Figure 3.2-3 shows the sample rake installed in the inlet of the main ESP.

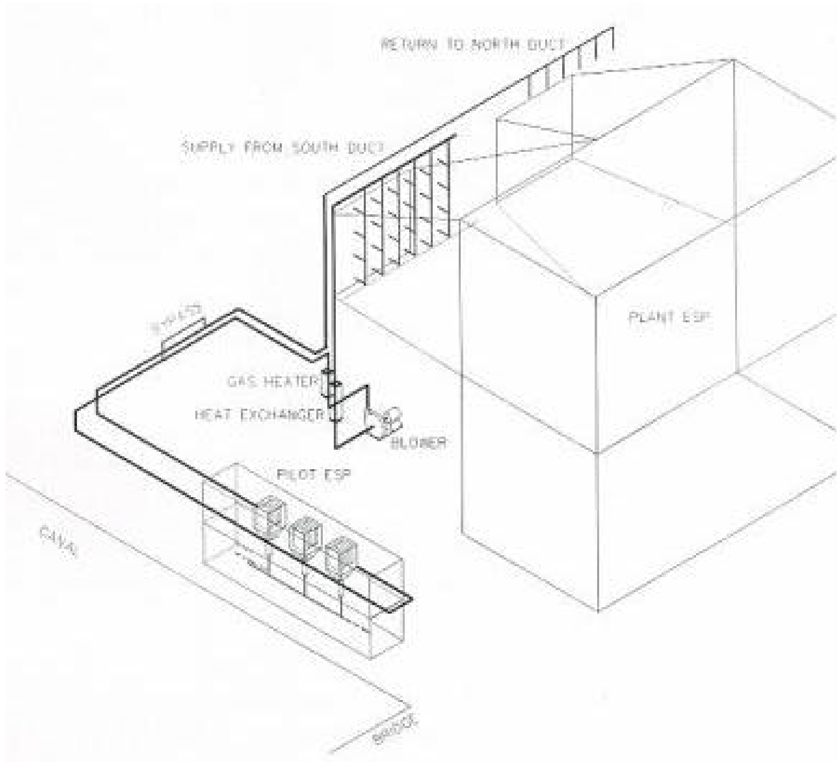

Figure 3.2-1 Slipstream Installation Schematic

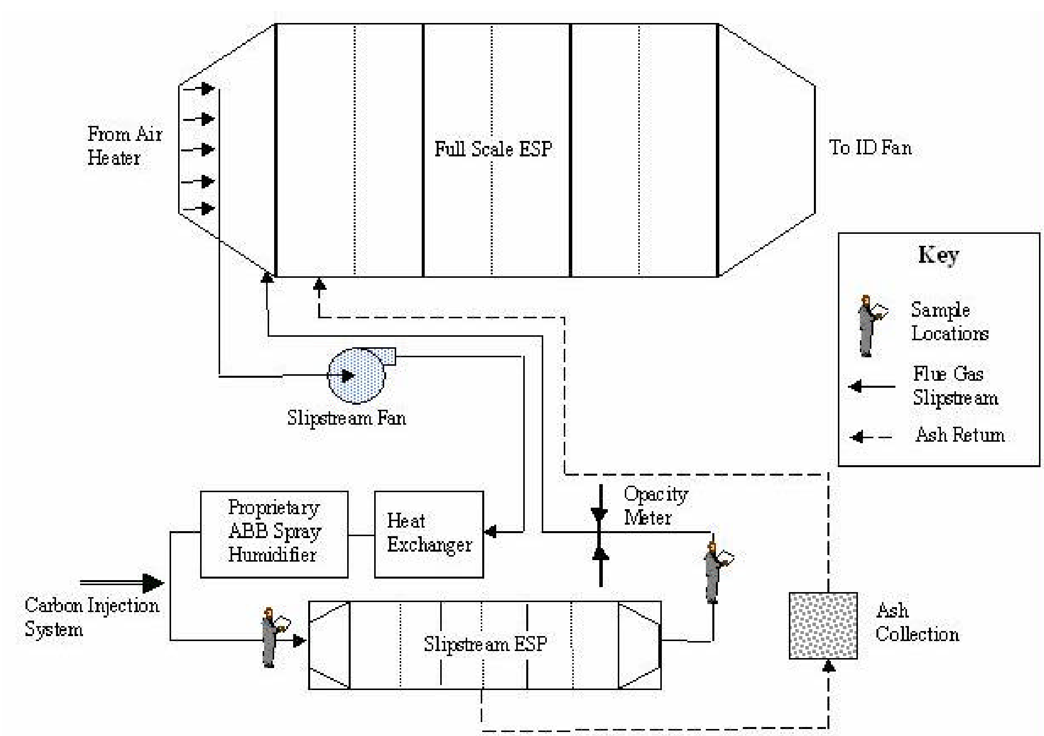

Figure 3.2-2 Pilot ESP - Slipstream General Arrangement

Figure 3.2-3 Slipstream Sample Rake Installation

Suction is achieved through the use of a fan located near the sample rake header. During Phase I, the flue-gas velocities ranged between 0.6 and 1m/s. During Phase II, the impacts of higher flue-gas velocities (up to 2 m/s) and lower SCA, typical for field units, were to have been evaluated. Once extracted, the flue-gas passed through a heat exchanger for precise temperature control and a proprietary humidification system before entering the pilot ESP. A carbon-injection system for mercury control was located in the ductwork between the humidification system and the pilot ESP inlet. Gases exiting the pilot ESP were discharged back to the inlet of the North duct of the main ESP. Ash collected within the pilot ESP was discharged into collection hoppers ultimately being returned to the main ESP for disposal.

Installation of the pilot ESP and slipstream at Waukegan Unit No. 8 are shown in Figures 3.2-4 and 3.2-5. Figure 3.2-4 is a side view showing the overall installation next to the body of the unit's main ESP. As can be seen in this photo, the pilot ESP was supported on a second shipping container that housed both the ash collection equipment as well as acted as a control center for test operations. The slipstream suction and return lines can be seen being installed between the boiler building and the main ESP casing.

Figure 3.2-4 Pilot ESP Installation at Waukegan Unit No. 8

Figure 3.2-5 presents a photo detailing the slipstream collection header. The connection points to the sample rake can be seen protruding from the top of the main ESP inlet transition.

Figure 3.2-5 Slipstream Sample Rake Header at Main ESP Inlet Transition

4.0 Phase II Results

The Phase II test program encompassed Tasks 9 through 17 of the overall Ultra High Efficiency ESP Development for Air Toxics Control Program. Tasks 1 through 8 were completed in Phase I of the overall program and have been reported separately (DOE Contract DE-AC22-95-PC95259). The original Phase II schedule is presented in Figure 4.0-1 At the time of program termination, the following project tasks had been completed; Task #9 Select Host Site, Task #10 Design Field Pilot ESP, Task #11 Modify Field Pilot ESP, and Task # 12 Develop Test Plan. In addition, Task #13, Install Pilot ESP was approximately 90% complete. Tasks 14 through 17 were not started/completed. A brief description of each Phase II task is given below.

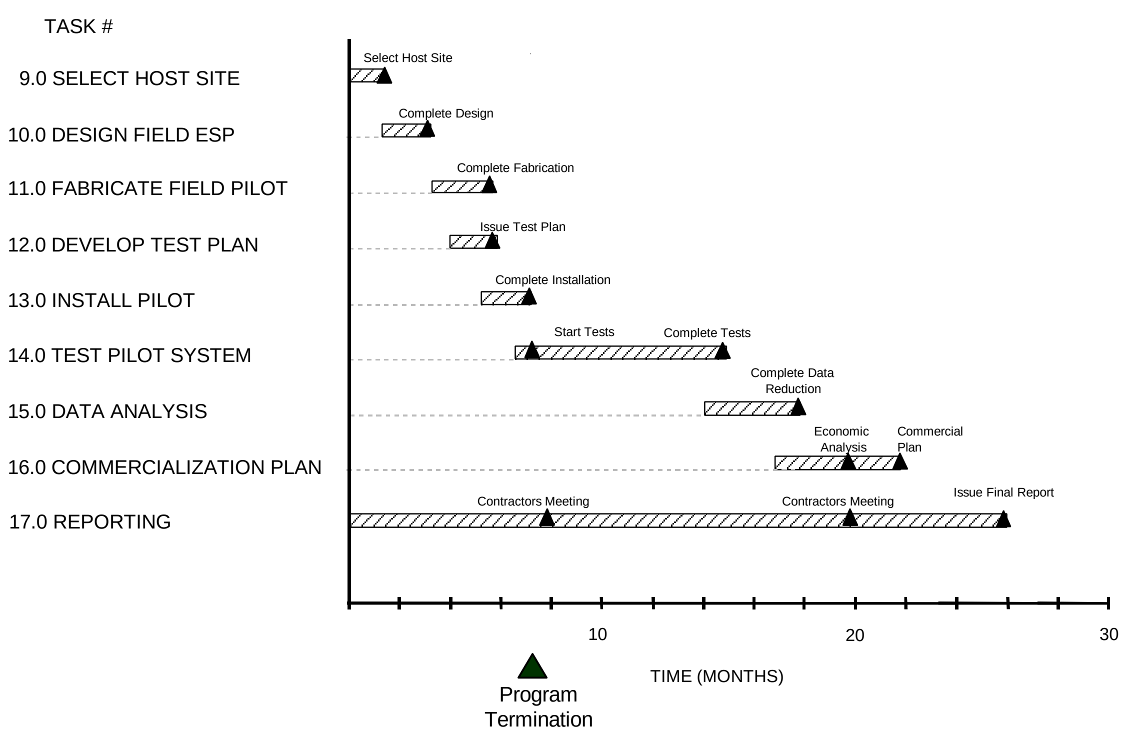

Figure 4.0-1 - Phase II Program Schedule

Task 9. Selection of Host Site

ComEd's Waukegan Station 16, Unit No.8 in Waukegan, IL was chosen as the host site for Phase II. The unit's recently upgraded ESP was found to be adequately sized to handle a variety of low-sulfur coals, and the station site plan was such that the ABB pilot ESP could be integrated with a minimum of construction effort. A host site agreement was negotiated and executed between ABB and Commonwealth Edison in November 1998. Due to program termination the slipstream ESP was decommissioned and the host site returned to its pre-program condition. The host site agreement with Commonwealth Edison was fully terminated in November of 1999.

Task 10. Design and Fabrication of Advanced ESP for Slipstream Testing

Flue-gas cooling, humidification (ABB spray cooler), pulsed energization (SIR), and sorbent injection (for mercury capture) are modules that were to be pursued under Phase II. These modules were designed, fabricated, and shipped to the host site for integration into the Pilot ESP.

Task 11. Modification of Existing Pilot-Scale ESP Systems

The ABB pilot ESP used in Phase I was configured for slipstream operation and relocated to Commonwealth Edison's Waukegan Unit No.8. A flue-gas humidification system was designed and fabricated. A flue-gas temperature control system including a heat exchanger train to provide cooling independent of humidification, and a heating system was provided. A sorbent injection system was to be installed to introduce activated carbon sorbent for a range of duct residence times. An accelerated corrosion test section was incorporated in the field-installed pilot ESP, as was a specialized heat exchanger train to be utilized for long-term fouling investigations.

Task 12. Development of Test Plan

A detailed test plan was developed describing all the tasks, sub-tasks, test parameters, and key operating data required for the successful and timely execution of Phase II. The test coals were to be selected based on performance characteristics and importance to the U.S. utility industry. Sorbents for use in mercury capture investigations were to have been selected with input from companion DOE program results.

Task 13. Installation of Advanced ESP at Host Site

Installation of the advanced pilot ESP and slipstream from the full-scale host unit was 90% completed when unanticipated cost growth led to the termination of the program. Shakedown testing of the unit was not conducted. The cost growth was due to a number of unanticipated site specific events related to the bidding/awarding of Phase II prior to the selection of a host site. These included:

- The need to redesign the slipstream for high-wind loading that required the services of an Architect-Engineer to design a foundation as well as permanent access platforms.
- Additional unanticipated costs arose from the need to locate the Pilot Plant across a canal from the control room requiring long runs of services and the leasing and use of a large construction crane to set the Pilot ESP and it's support container.
- Installation of long duct runs that, in turn, required additional flue-gas controls.

- The lack of a suitable local disposal site for the fly ash collected by the pilot necessitated the design and construction of a system to return the fly ash back to the plant ductwork upstream of the North side precipitator.

Task 14. Field Testing of the Advanced ESP System

Because of program termination, no testing was performed. The performance period was to have been approximately 6 to 12 months allowing proper time to allow for seasoning effects and attainment of steady-state operation for each subject fuel. Detailed test data was to have been collected for each of two test coals to fully characterize system performance. Computerized data collection was to be employed to document pilot ESP performance for the entire period that the test unit is in operation. The data to be collected would have included dust loading and particle size distributions at the inlet and outlet of the pilot ESP, the electrical characteristics of the ESP, flue-gas composition, opacity, coal and fly ash analyses, and boiler operating data. In addition, the effects of sorbent injection on mercury emissions were to be quantified as a function of sorbent feed rate, flue-gas temperature, and residence time.

Task 15. Data Analysis

Test data collected from field testing was to be analyzed and related to the advanced ESP and boiler operating data. Phase II data, coupled with the Phase I results, would have been used to generate a detailed database from which projections can be made regarding advanced ESP performance for a range of coals and boiler/ESP operating conditions.

Task 16. Commercialization Plan

A comparative technical and economic evaluation was to have been performed based on the experience gained from field testing and the data obtained from Task 15, the results being used to formulate a commercialization plan for the advanced ESP.

Task 17. Reporting

Details of the findings and recommendations from Phase II, along with relevant supporting data from Phase I, were to be documented in a comprehensive final report.

5.0 Concluding Remarks

In Phase I of this program, ABB investigated five technologies to improve the collection of ultra fine particulate and trace metals, including mercury, in ESPs. These included: (i) flue-gas cooling, (ii) flue-gas humidification, (iii) pulsed energization, (iv) wet ESP and precharger modules, and (v) sorbent injection for mercury control. The impacts of these different retrofit technologies on ESP performance, individually and in combination, were evaluated in-depth through advanced sampling and measurement techniques. The pilot testing clearly demonstrated several cost-effective means to accomplish the improved collection ultra fine particulate and mercury. It was clearly shown that controlling ESP inlet temperature and humidity, in combination with pulsing, increased the effectiveness of the collection of ultra-fine particulate and mercury from low-sulfur coals.

In Phase II of the program, the long term operation effects of these concepts, including fouling and corrosion, was to have been evaluated in a slipstream from a utility boiler. Commonwealth Edison's Waukegan Unit No.8 was chosen as the host site for these tests. The ESP pilot facility utilized under Phase I was modified for long term operation and incorporated into a slipstream installed at the inlet of Unit No.8's ESP.

During installation of the pilot ESP and slipstream, unanticipated cost growth was encountered and a stop work order was issued by ABB until a review of the root causes could be completed. Based on this review, it was determined that the lack of a fully identified host site and the associated lack of a detailed host site modification, construction, and installation cost estimate during the Phase II proposal/bidding process was the basis for the cost growth. Had all the site specific issues been identified during the proposal preparation process, they would have been accounted for in the proposed budget and project plan. Based on this conclusion, it is highly recommended that visits to potential host sites should be incorporated into the proposal efforts for any projects planning field or slipstream testing. It must also be recognized that this is a costly and time consuming step in the proposal process.

Based on a review of the technical and budgetary status of the project, a number of recovery scenarios were proposed to the DOE by ABB. These ranged from project termination to completion of the full test plan. However, additional funding necessary to complete the full test plan was not available and the project was terminated. The ESP pilot and slipstream were subsequently returned to ABB and the host site returned to its original condition.

While it is unfortunate that the Phase II program was terminated, the lack of focused long term operational data should in no way obviate the importance or relevance of the Phase I results. These results have significantly improved our understanding of ESP operation, particularly for ultra fine particulate control, and have direct and immediate commercial implications. Long term testing of the Phase I concepts, while an important and necessary part of an overall commercialization strategy, should be carried out under a future program.