DOE/PC/92160--T12

**ENGINEERING DEVELOPMENT OF ADVANCED
COAL-FIRED LOW-EMISSIONS BOILER SYSTEMS**

Project Technical Status Report

QUARTERLY REPORT

For the Period of:
January 1997 to March 1997

April 1997

Submitted by:

Babcock & Wilcox Company

Contract Research Division
1562 Beeson Street
Alliance, Ohio 44601

Prepared for:

United States Department of Energy

U.S. DOE Reference DE-AC22-92PC92160
B&W Reference: CRD 1319

Patent Cleared by Chicago OPC on 6/6/97

RECEIVED
JUL 07 1997
OSTI

MASTER

RECEIVED
USDOE/PC
97 JUN 12 AM 10:39
ACQUISITION & INFORMATION DIV.

**CLEARED BY
PATENT COUNSEL**

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

P1X

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

"This report was prepared by Babcock & Wilcox pursuant to a contract partially funded by the U. S. Department of Energy and neither Babcock & Wilcox, nor any of its subcontractors nor the U. S. Department of Energy, nor any person acting on behalf of either:

- (a) makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or**
- (b) assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method or process disclosed in this report.**

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the U. S. Department of Energy. The view and opinions of authors expressed herein do not necessarily state or reflect those of the U. S. Department of Energy."

II. NO_x Subsystem

The goal of the NO_x Subsystem is to achieve continuous operation of the Low-Emissions Boiler System (LEBS) at NO_x emissions at or below 0.20 lb/MBtu through combustion techniques only, with a further target of 0.1 lb NO_x/MBtu using supplementary advanced flue gas cleanup technologies if necessary. These goals place practical constraints that must be considered on the NO_x Subsystem design. Not only must the boiler be designed to achieve time-temperature mixing histories that minimize NO_x, but it must also be designed to operate that way throughout its working lifetime. Therefore, NO_x minimization strategies must be integrated into the control systems for every boiler component from the pulverizers to the stack. Furthermore, these goals must be met without increases in carbon loss and CO emissions from the levels achieved with current low-NO_x combustion systems. Therefore, the NO_x Subsystem requires not only sound mechanical designs of burners, furnace surface, and staging air/fuel injectors, but also sensors and software to allow control of their operation. Through engineering analysis, experimental testing, and numerical modeling in Phase II, an advanced low-NO_x control system is being developed. The progress of these activities is presented in this report.

II.1 Summary of Activities

II.1.1 Period of January 1997 to March 1997

The results from the final series of NO_x subsystem burner tests were compiled. The information obtained is also being used as a comparison to the numerical modeling predictions. The engineering design of the Proof-of-Concept (POC) Facility was revised based on the information gained through the Phase II activities. A POC Test Plan is being developed.

A technical paper entitled, "The Development of a Combustion System for B&W's Advanced Coal-Fired Low-Emission Boiler System," was presented at the 22nd International Technical Conference on Coal Utilization & Fuel Systems. Results of the DRB-4Z™ burner sparked much interest from the conference participants.

II.2 Key Accomplishments

II.2.1 Subsystem Test Unit

The 100 MBtu/hr DRB-4Z™ advanced low-NO_x burner was configured for the final round of subsystem testing based on results from previous test series. B&W's Clean Environment Development Facility was utilized for subsystem testing. The advantage of using the CEDF for subsystem scale testing was in the ability to test the near CGU-size burner in an environment which closely simulates conditions in a utility boiler.

Hardware Optimization - The best hardware configurations from previous campaigns were tested and compared during this final series to determine the optimum burner configuration. Parametric

testing was performed for each burner configuration. Tests were performed by varying the air distribution, primary air-to-coal ratio, burner stoichiometry and load. The data collected were averaged over the time frame of the test and were plotted for each configuration separately, while the optimum conditions were compared collectively.

Load variations were tested to simulate furnace turn-down. The visual stability of the flame was noted along with emission performance. The DRB-4Z™ burner did not display any problems while operating at 60% and 35% load conditions.

Staged Operation - To obtain the desired NO_x emissions target of 0.1 lb NO_x/MBtu, external staging of the burner was determined to be required. Overfire air ports are to be utilized in the commercial generating unit while firing the burners at 0.75 stoichiometry. To investigate the effect of this deep staging, experimental testing and numerical modeling studies were performed.

The effect of externally staging the DRB-4Z™ burner (designed for unstaged operation) was tested for the stability of the flame and to obtain a relative indication of NO_x reduction. The CEDF while firing in the single burner mode is not optimally configured for staged operation. However, by incorporating information obtained through pilot-scale testing and numerical modeling, a relative indication of NO_x reduction could be obtained. Various levels of staging were tested, achieving between 1.17 to 0.86 burner stoichiometry.

During this series of tests, the Illinois #6 design coal was utilized at a fineness level of 75% < 200 mesh. The flame of the DRB-4Z™ burner remained stable at all burner stoichiometries tested. Compared to unstaged operation, the DRB-4Z™ burner achieved a 35% reduction in NO_x emissions (90 ppm, 0.12 lb NO_x/MBtu) when staged to 0.86 burner stoichiometry. This level of reduction is typical of what is seen in field operation with external staging. Despite the fact that the 100 MBtu/hr DRB-4Z™ burner was not designed for staging, Figure II.2.1-1 illustrates that the burner maintains the necessary aerodynamics for minimizing NO_x emissions at all stoichiometries.

The CO emissions remained around 100 ppm, while LOI values increased to around 4%. LOI results peaked around stoichiometric operation (0.95 to 1.05) and dropped off at burner stoichiometries above 1.10 and below 0.90.

In order to get the best air flow penetration and uniform mixing in the burnout zone, the OFA ports were designed to operate in conjunction with a burner stoichiometry of 0.85. When the burner was staged above this 0.85 stoichiometry, the overfire air-to-furnace momentum flux ratio dropped below the design value. As a result, LOI and CO levels increased at low OFA flow rates. Moreover, low-NO_x unstaged burners that are operated at low air flow rates for staging may not perform as well as staged burners designed specifically for the same throughput. Staged burners are usually designed with smaller throats to maintain the proper aerodynamics and mixing patterns for minimizing NO_x and LOI levels. When reconfigured for staged operation at 0.75 burner stoichiometry, the DRB-4Z™ burner is expected to achieve the program developmental NO_x target of 0.1 lb NO_x/MBtu, as illustrated in Figure II.2.1-2.

Coal Specifications - The effect of coal properties on combustion parameters are another interest of the NO_x subsystem in the development of a NO_x control system. One concern the NO_x subsystem is addressing is that the burner is required to operate over a wide range of coals. Another concern is the integration of the advanced pulverizer with the fuel requirements of the burner. Various fuel properties were tested during the burner development program. The optimum fuel specifications were then given to the boiler subsystem for input to the Commercial Generating Unit (CGU) design.

Figure IL2.1-1. NO_x Emissions Versus Burner Stoichiometry
(100 MBtu/hr, 1.17 furnace stoichiometry, firing Illinois #6 coal)

Figure IL2.1-2. Curve Fit of NO_x Emissions versus Burner Stoichiometry
(100 MBtu/hr, 1.17 furnace stoichiometry, firing Illinois #6 coal)

Coal Rank - The purpose for testing different coal types is to show the effect of changing fuel types on the burner performance. Five different coals have previously been fired with the DRB-4Z™ burner including the Illinois #6, Mahoning 7A, Ohio/Mahoning 7, Ohio Horizon, and

Kentucky #9. These coals ranged in fixed carbon-to-volatile matter ratios (FC/VM) of 1.16 to 1.57. NO_x values were found to be similar for these firing cases, however, the LOI values were greatly different and in some cases unacceptable (>5%). Additional coals were fired during the last test series to cover a larger range of fixed carbon-to-volatile matter ratios and to include a sub-bituminous coal as required in the DOE project statement of work. All coals were fired at fineness levels of 75% < 200 mesh.

While firing the Illinois #6 coal, the average NO_x values were found to be 140-160 ppm with the DRB-4ZTM burner. NO_x values averaged 140-180 ppm while firing the Mahoning 7, Ohio #7, Kentucky #9, and Ohio Horizon coals with the DRB-4ZTM burner. Firing the Middle Kittaning coal resulted in NO_x emissions averaging 240-260 ppm. The NO_x emissions achieved with the DRB-4ZTM while firing the Montana Decker coal were found to average 110-125 ppm.

Average CO emissions while firing the Illinois #6 coal were below 100 ppm. The CO emissions while firing the Mahoning coal were greatly increased over previous experience firing this coal, as could be expected due to the significant NO_x reduction with the DRB-4ZTM. However, looking at the Ohio Horizon coal results, although the NO_x was significantly reduced with the DRB-4ZTM burner, the CO emissions were not as greatly affected, with the average remaining around 50 ppm. CO emissions for the Montana Decker, Kentucky #9 and Ohio #7 coals averaged between 50 and 100 ppm, similar to the Illinois #6 and Ohio Horizon coals. CO emissions obtained while firing the Middle Kittaning with the DRB-4ZTM burner were low, averaging 25 ppm. Again, it should be noted that the values reported on the graphs are for the optimum burner configurations for that particular test series, firing the various coals. These graphs do not necessarily represent the average values obtained over the wide variety of test configurations.

The LOI values correspond to the CO emissions. The cases where lower CO emissions were obtained, lower LOI values were also measured, except for the Middle Kittaning coal. LOI data was not collected while firing the Ohio Horizon. All fly ash samples collected were measured for loss on ignition at 1380°F. A few random samples were also measured for unburned carbon determined by an ASTM method. A comparison between the two measurements showed that the LOI measurements were on the average 7% higher than the UBC measurements.

The results show that with the DRB-4ZTM burner, NO_x values approaching the goals of the program can be achieved, however, sometimes at the expense of CO and LOI values depending on the coal being utilized. The extent of this sacrifice and the benefit of reduced NO_x emissions obtained would need to be determined for each application, and could be mitigated to some extent by coal fineness.

Coal Fineness - The effect of coal fineness on NO_x emissions and unburned carbon was further investigated during the subsystem test series. Fineness levels were evaluated from 60% to 90% < 200 mesh with the Illinois #6 coal. The purpose of testing the effect of coal fineness on the burner performance was to set the optimum conditions for the CGU. This information was used in conjunction with information obtained during pilot-scale testing and an engineering analysis study.

Testing the coal fineness levels with the DRB-4Z™ burner showed that in terms of NO_x, CO and LOI, the coal fineness setting of approximately 85% < 200 mesh proved to give the optimum performance. This information is similar to what was seen previously during pilot-scale testing. While firing at a fineness level of 60% < 200 mesh, the NO_x emissions were 150-160 ppm, while CO levels increased significantly. The emissions levels while firing with the coal fineness level at approximately 75% < 200 mesh were found to be at 140 ppm NO_x, 60-100 ppm CO and 1.8-3.5 % LOI. As the coal fineness increased, the NO_x levels tended not to be greatly affected. However, the CO emissions and LOI values did see an effect. While firing at the 85% < 200 mesh coal fineness level, the CO emissions remained around 100 ppm, however, the LOI values were only 1.7-2.3%. When the coal fineness was set at approximately 90% < 200 mesh, the average NO_x, CO and LOI values increased slightly. As a result of pilot- and subsystem testing, the optimum coal fineness level was set at approximately 85% < 200 mesh for incorporation into the burner design for the POC and CGU facilities.

Conclusions - Firing the optimized unstaged DRB-4Z™ burner with the design Illinois #6 coal at 100 MBtu/hr and 17% excess air achieved the program minimum environmental performance requirement of 0.2 lb NO_x/MBtu. Other coals with a fixed-carbon-to-volatile matter ratio of less than 1.32 also generated less than 0.2 lb NO_x/MBtu. NO_x formation increased mainly with decreasing volatile matter (increasing rank). Unburned carbon loss was higher for the lower volatile and less reactive coals. Staging the burner at 0.86 stoichiometry with all other conditions being the same reduced NO_x to 0.12 lb/MBtu, while still maintaining acceptable levels of unburned carbon in the fly ash.

For a given coal, the DRB-4Z™ burner generated 37 to 40% less NO_x than current commercial low-NO_x burners. Although the corresponding LOI levels for the DRB-4Z™ were at times higher, installation of certain swirlers or impellers in the burner along with minimal increase in the coal fineness level, can increase the carbon burnout without increasing the NO_x emissions appreciably. The DRB-4Z™ burner designed for deep staging at a burner stoichiometry of 0.75, while firing the Illinois #6 coal at 85% < 200 mesh fineness, will achieve the ultimate NO_x emission target of 0.01 lb/MBtu while maintaining acceptable unburned carbon levels.

III. SO₂/Particulate/Air Toxics/Solid By-Product Subsystem

The scope of the SO₂ subsystem comprises the control of SO₂, particulate matter, hazardous air pollutants (commonly called "air toxics"), and solid byproducts from the B&W LEBS plant. The specific minimum performance requirements for the SO₂ subsystem are:

- SO_x -- Less than 0.20 lb (SO₂ equivalent)/MBtu for coals with sulfur levels of 3 lb of sulfur per MBtu and no more than 0.067 times the sulfur content (lb/MBtu) for coals with less than 3 lb of sulfur per MBtu.
- Particulate -- Less than 0.015 lb particulate/MBtu
- Potential to comply with possible emissions control regulations for targeted air toxics.
- Produce environmentally benign solid byproduct.
- Integrate with other plant subsystems to yield optimal overall performance and cost.

In addition, the following performance targets have been established:

- SO_x -- Less than 0.10 lb (SO₂ equivalent)/MBtu for coals with sulfur levels of 3 lb of sulfur per MBtu and no more than 0.0333 times the sulfur content (lb/MBtu) for coals with less than 3 lb of sulfur per MBtu.
- Particulate -- Less than 0.01 lb particulate/MBtu (B&W plans to achieve 0.005 lb/MBtu)

On the basis of the results compiled during the concept selection process completed in Phase I, the Limestone Injection Dry Scrubbing (LIDS) process was selected for further development and evaluation in B&W's LEBS project. The LIDS process is a cost-effective integration of three commercially proven flue gas cleanup technologies: furnace limestone injection, dry scrubbing, and pulse-jet fabric filtration. As a result of Phase I testing, the initial LIDS process was enhanced by the addition of a particulate collector before the dry scrubber and the new process was named E-LIDS™. Through engineering analysis, experimental testing, and numerical modeling, an E-LIDS™ process is being developed that is capable of ultra-high SO₂ removal and superior particulate control while addressing the potential issues of air toxic emissions and solid byproduct utilization. The progress of the E-LIDS™ activities follows.

III.1 Summary of Activities

Proposal efforts to the North Dakota Lignite Research Council (NDLRC) continued. A second proposal package was prepared in an attempt to gain their funding participation in the B&W LEBS Phase IV POC Demonstration. The proposal was submitted on February 1, 1997, and received a second unfavorable vote in their mid-March meeting. The request was for 1.5 million dollars over 3 years, one-half of what was requested in the first proposal. It is believed that the NDLRC is looking for a project directed at specific pieces of the LEBS program. A new proposal directed at air toxics, fine particulate matter (PM 2.5), and solid by-product issues and requesting a lesser amount is being considered for submittal to NDLRC on June 1, 1997.

The solid by-product cognizance effort continued. B&W is aggressively pursuing ways to reduce or utilize the solid waste produced by its various clean coal and FGD processes through a variety of in-house and externally-funded development programs.

The following engineering analyses were completed (Task 7.1):

- *Air Toxics Regulations.* This activity focused on the current status of electric utilities air toxics studies and their potential impact on B&W's LEBS concept.
- *Convection Pass Fouling.* The primary objective of this activity was to address the fouling concerns associated with limestone injection into the furnace.
- *Furnace limestone injection system requirements.* This activity focused on the specifications necessary for transport and injection of the limestone into the furnace.
- *Particulate collector requirements.* A source of reactive sorbent solids for the dry scrubbing process slurry in E-LIDS™ is the particulate matter from the flue gases at the outlet of the boiler/air heater. This activity specified the particulate collector requirements and specifications.
- *Slaking System Considerations.* This study was conducted to determine the optimum slaking process for E-LIDS™.
- *Dry Scrubber Considerations.* The primary objective of this study was to evaluate various dry scrubber design considerations, and develop specific design recommendations for the POC and CGU.
- *Alternative/Competing Systems.* The purpose of the activity was to take a second look at the conclusion reached during the Phase I concept selection work in the light of all of the development work conducted on the project since that time.
- *Alternative systems comparison.* This activity investigated other current state-of-the-art systems for SO_x, particulate, and air toxics control and compares them with B&W's E-LIDS™ system.

All data reduction and analyses for the E-LIDS™ 100 MBtu/hr test series were completed. In summary the E-LIDS™ system:

- was successfully scaled-up from 5 MBtu/hr to 100 MBtu/hr,
- achieved the LEBS target of 0.10 lb SO₂/MBtu (98% SO₂ removal) with both a fine (6 micron mass mean diameter) and coarser (17 micron mass mean diameter) limestone,
- repeated greater than 90% mercury removal for the third time,
- achieved greater than 99% HCl and HF removal and greater than 90% removal for all trace metals.

All SO₂ and mercury removal data has been reported in previous quarterly reports. The acid gas and trace metals removal for the E-LIDS™ system is covered under the key accomplishment section of this quarterly report (Task 11.1 & 11.2)

III.2 Key Accomplishments

III.2.1 - E-LIDS™ Acid Gas and Trace Metal Removal at 100 MBtu/hr.

Air toxics capture is likely to be an important issue by the time a LEBS plant is commercialized. Hence, it was necessary to characterize the performance of the E-LIDS™ process with respect to the capture of air toxic species. Emissions of mercury, other trace metals (arsenic, barium, beryllium, cadmium, chromium, cobalt, manganese, nickel, lead, and selenium), and acid gases (HCl and HF) were evaluated. Mercury emissions were covered in detail in the previous quarterly report.

Trace Metals Capture - Particulate regulations, although particulate itself is not an air toxic per se, are likely to become more stringent. One reason for this is that many of the trace elements of interest condense onto the particulate as the flue gas cools through backend emissions control equipment. Therefore, particulate removal systems have the potential to remove large amounts of air toxic substances associated with the particulate matter. A pulse-jet fabric filter operating at low temperatures is an integral part of the B&W E-LIDS™ system. This gives the E-LIDS™ process two advantages in terms of air toxics removal: 1) fabric filtration has been shown to be extremely effective in removing particulate and therefore many trace metals, and 2) the E-LIDS™ dry scrubber and baghouse are operating at low temperatures creating a higher potential for trace metals to condense out of the flue gas.

Measurements were made at the cyclone exit (dry scrubber inlet) and the stack using the Ontario Hydro Method. Greater than 90% removal was achieved for all trace metals measured.

Acid Gases Capture - Acid gases have come under scrutiny primarily because of the large quantity of these substances emitted from electric power utilities. If acid gas regulations are required, coal-fired plants equipped with wet or dry FGD have been shown to achieve over 90% removal of HCl. Another form of HCl and HF control may be furnace sorbent injection. The E-LIDS™ acid gas capture efficiency was investigated at 100 MBtu/hr through the use of EPA Method 26A.

Figure III.2.1-1 presents the air toxics emissions for the E-LIDS™ 100 MBtu/hr tests. Figure III.2.1-2 and Table III.2.1-3 present the air toxics removal obtained.

Figure III.2.1-1 - Average E-LIDST™ Air Toxics Emissions

Figure III.2.1-2 - Average E-LIDST™ Air Toxics Removal

	Uncontrolled (lb/trillion Btu)	Stack (lb/trillion Btu)	E-LID Total % Removal based on Coal
Arsenic	697.5	1.208	99.8
Barium	703.9	66.17	90.6
Beryllium	9.096	0.1592	98.3
Cadmium	1.593	0.1585	90.1
Cobalt	149.3	0.6019	99.6
Chromium	343.6	3.285	99.0
Manganese	369.2	5.199	98.6
Nickel	562.0	4.737	99.2
Lead	74.74	0.7309	99.0
Mercury	12.38	0.0745	99.4
Selenium	26.61	0.3094	98.8
Chloride	113830	179.4	99.8
Fluoride	2461	14.3	99.4

Table III.2.1-3 - Average E-LIDS™ Air Toxics Removal

IV. Boiler Subsystem

At the heart of the LEBS is the boiler. Within this advanced B&W boiler, all of the low emission technologies are integrated. To meet the net plant efficiency goal of 42%, the boiler must be designed not only to achieve the proper conditions for low NO_x combustion with air staging and accommodate the in-furnace injection of the limestone for the LIDS process, but it must also efficiently capture the heat to produce high temperature steam at well above critical pressure. The steam conditions selected for the boiler are 4500 psi, 1100°F/1100°F/1100°F.

Since the steam-side pressure and main and reheat steam temperatures are higher than conventional cycles and operation of low NO_x burners creates sub-stoichiometric conditions in portions the furnace, additional challenges are presented. Higher alloy materials must be used in the outlet portions of the superheater and reheater banks to obtain acceptable surface metal temperatures. In addition, materials must be selected that will resist corrosion since the surface of these outlet tubes will operate at temperatures which will allow the coal ash to remain molten on their surfaces. Consideration must also be given to furnace wall corrosion in the combustion zone. Thus, boiler design work has been identified to address the integration of the NO_x and SO₂ subsystems while applying B&W's advanced supercritical boiler technology.

IV.1 Summary of Activities

IV.1.1 CGU Boiler Development

As indicated in the NO_x and SO₂/Particulate/Air Toxics/Solid By-Product Subsystems, the results of data analysis are nearly completed and the initial assumptions used to design the Commercial Generating Unit boiler are being confirmed or modified. Design activities continued and by the end of the Quarter, the boiler design was finalized, all information was provided for cost estimating, drawings were marked for final revisions and report writing began. Interfaces between the boiler and balance of plant subsystem were resolved permitting Raytheon to finalize plant arrangements and P&ID's as well as initiating plant cost estimating and determination of the final heat rate (net plant efficiency).

IV.2 Key Accomplishments

IV.2.1 CGU Boiler Development

Activities this quarter centered around finalization of the CGU boiler design and drawings, providing detailed component information to cost estimators and initiating writing of volume 2 of the Phase III final report describing the Commercial Generating Unit.

CGU Boiler Design - The spiral wound furnace analysis was completed. The spiral is more expensive and requires higher pressure drop than the new vertical tube design. The costs and performance impacts are being developed to assess the differences. Based on these efforts, the

new vertical wall once-up design was selected for the CGU.

A review of the boiler horizontal convection pass to improve the design was completed and some surface arrangement changes were made which reduced surface required for the same performance. Graphics and cost estimating are being updated.

The boiler arrangement incorporating limestone injection is being finalized. This will complete the boiler design effort.

Cost Estimation - All boiler header and piping thicknesses were calculated based on the final boiler performance and were supplied to cost estimators. Review of the boiler horizontal convection pass design was completed and some surface arrangement changes are being made. Graphics and cost estimating are being updated.

All cost estimating data was assembled and submitted and generation of the boiler island cost for both the conventional 2400 psi 1000°F/1000°F and LEBS designs is in progress.

All airheater quotes were received and forwarded to Raytheon for use in the airheater optimization study. The results of the study showed that in spite of higher auxiliary power (but lower capital cost), mechanical draft condensate cooling was more economical on a net present worth basis than the natural draft hyperbolic cooling tower system.

Plant Efficiency - Boiler auxiliary power requirements were provided to Raytheon and total plant auxiliary power is being reviewed.

IV.2.2 Corrosion Evaluation

The two 5000-hour laboratory tests performed at 1300°F and 1500°F were completed in February and March, respectively. Results of the 1300°F test, which simulated a 5-year exposure of different commercial coatings to the condition of lower furnace in LEBS, suggest that several coatings may be useful in protecting the furnace walls. Sample analysis for the 1500°F test, simulating a 10-year field exposure in LEBS, is still in progress. However, preliminary results indicate that few coatings could survive from such a long and aggressive exposure.

The fabrication of a test panel for the corrosion field test in Unit 2 of Allegheny Power System at the Hatfield Ferry's Station was completed and delivered to the site for installation.

V. Balance of Plant Subsystem

In order to develop an overall plant design and to evaluate plant efficiency and cost, B&W subcontracted with Raytheon Engineers and Constructors of Denver, Colorado. Together a Phase I concept was developed that achieved the initial LEBS goal of 38% net plant efficiency. That design resulted in identification of a number of potential improvements to the turbine cycle and auxiliary equipment needed to meet the Phase II goal of 42% net plant efficiency.

V.1 Summary of Activities

Interfaces between the balance of plant and other subsystems have been resolved and final plant arrangement and P&ID drawings are being completed. Balance of plant equipment costs are being developed and the economic criteria for pricing the total plant have been established with DOE. Auxiliary power requirements have been compiled and are in final review as is the net plant heat rate calculation.

V.2 Key Accomplishments

Plant Arrangement - Raytheon is revising the plant layout drawings based on final review information provided by B&W.

Cost Studies - Based on the information provided to Raytheon, the Airheater optimization study was completed (see Boiler Subsystem report). Evaluation of the use of a hyperbolic cooling tower instead of mechanical condensate cooling was completed. In spite of the lower auxiliary power required, the increased capital cost for a hyperbolic cooling tower resulted in the conclusion that the mechanical draft condensate cooling system would have the lower cost.

Plant Costs - Work began to develop balance of plant costs for the conventional and LEBS designs and prepare the cost analysis information to generate levelized costs.

Net Plant Efficiency - The steam cycle heat and mass balances and auxiliary power summary are being finalized to finalize the net plant efficiency (which exceeds 42%).

Final Reporting - Final comments on the System Description for the Balance of Plant equipment portion of volume 2 of the Phase III final report were discussed with Raytheon. Except for final editing, this, along with the final drawings and P&ID's, will complete the BOP portion of the report. The entire cost evaluation section is in progress awaiting completion and finalization of plant costs and heat rate.

VI. Controls & Sensors Subsystem

In order to maintain low stack emissions and optimum boiler performance throughout the operating range and lifetime of the LEBS, a state-of-the-art integrated control system must be developed. This control system must include new sensors as well as old sensors used in new ways. It must make sense out of the data provided while initiating or directing the operator to take appropriate action. The control system that will help assure that the LEBS will meet its stack emission, efficiency, availability, and cost of electricity goals.

The overall philosophy of the LEBS control system is to use conventional, state-of-the-art solutions to satisfy new control requirements. Existing sensors, hardware, and software are specified whenever possible and new measurements or advanced equipment are recommended for development only where necessary to assure the success of the project. The progress of the Controls & Sensors Subsystem is contained in this report.

VI.1 Summary of Activities

Activities this quarter focused on completing the design concepts for both the Commercial Generating Unit and Proof of Concept facility control systems and their estimated costs. In addition, work on draft final reports was initiated.

VI.2 Key Accomplishments

CGU Control System - A meeting was held with the NO_x Subsystem team to review preliminary results of their program as related to operational objectives and constraints which are needed to be addressed by the control system for the CGU. A similar meeting was held with the Boiler and SO₂ subsystem teams to address the specific design requirements for the CGU. As a result of these meetings a configuration and cost for the CGU control system was developed.

POC Control System - A meeting was held with the NO_x Subsystem team to review preliminary results of their program as related to operational objectives and constraints which are needed to be addressed by the control system for the POC. With the detailed design of the control system for the POC becoming available, the single loop controllers which had been used to characterize the POC dynamic model was replaced with an integrated control scheme based on the POC control design. Development of a coordinated plant for integrating the operation of all subsystems is in progress. In addition to demonstrating the performance of the subsystems, a key feature of the POC will be demonstration of operation in an integrated manner similar to a commercial power plant. Control objectives and strategy are being considered.

Final Reporting - Work began developing the text describing Controls and Sensors activities in Phases II and III for the final reports.