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

Project Technical Status Report

QUARTERLY REPORT

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Submitted by:

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I. Project Management

I.1 Summary of Activities

A meeting of the sensor team was held at ARC to evaluate results and work remaining to complete their activities in order to permit selection of sensors to be incorporated in control system design. A Boiler Subsystem planning meeting was also held to review remaining work toward completion of the CGU design.

Several discussions with DOE took place concerning NEPA approvals for Phase IV and an assessment of the impact of the four-month extension of the program on schedule and cost was made.

I.1.1 Technical Papers Submitted or Presented

The following technical papers were submitted or presented during the reporting period:

The International Joint Power Generation Conference, in Houston, Texas, was attended in October 1996 and a paper titled "Status of Phase II Subsystem Testing in Support of B&W's Advanced Coal-Fired Low-Emission Boiler System" was presented in the Combustion 2000 - LEBS session.

A technical paper entitled, "A Low-NO_x Burner Prototype Developed for B&W's Advanced Coal-Fired Low-Emission Boiler System," was presented at the 1996 AFRC Fall International Symposium. The audience seemed to be interested in the ability of the burner to fire a range of high-volatile Eastern bituminous coals without greatly effecting the NO_x emissions.

A technical paper entitled "Performance of Babcock & Wilcox's Limestone Injection with Dry Scrubbing (LIDS) Process" was presented at the Second North American Conference and Exhibition -- Clean Air 1996, in Orlando, Florida, November 19-22, 1996. The paper was very well received as evidenced by the many questions and discussions throughout the conference.

A technical paper abstract entitled "B&W's E-LIDS Process - Advanced SO_x, Particulate, and Air Toxics Capture for the Year 2000," was submitted for consideration for EPRI's NO_x/SO₂/Particulate controls "Mega" Symposium scheduled for August, 1997.

A technical paper "Evaluation of Microwave, Acoustic, and Hot-Film Sensors for Measuring Pulverized-Coal Flow and Air Flow in Burner Lines" was presented at Power-Gen International '96.

1.1.2 Phase IV Funding

A visit was made in October to three North Dakota Utilities and the North Dakota Lignite Research Council headquarters to promote our proposal for cosponsor funding. In addition, the NLRC meeting was attended. The Council voted not to fund the proposal at that meeting but we have received encouragement and intend to resubmit it in February.

A proposal requesting five million dollars was submitted to OCDO in October. The OCDO's Technical Advisory Committee (TAC) voted on December 12 to fund B&W's LEBS Phase IV project at \$5 million. The vote followed an excellent technical review (by independent proposal reviewers) which recommended funding by all evaluators.

A visit was made and a proposal submitted to the Illinois Office of Coal Development and Marketing and a prospectus was sent to the State of Indiana to gain their funding participation in the B&W LEBS Phase IV POC demonstration.

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

The final series of NO_x subsystem burner tests were completed in November on the CEDF. The purpose of this test series was to optimize the DRB-4Z^{TM} burner hardware configuration in addition to investigating the effect of fuel properties including various coals and fineness levels. The unstaged DRB-4Z^{TM} burner was also staged to a burner stoichiometry of 0.85 to see the effect of staged operation on flame stability. The DRB-XCL® burner was tested again to repeat the baseline condition and to obtain information to be used as a comparison for the different coals and coal fineness levels tested.

II.2 Key Accomplishments

II.2.1 Subsystem Test Unit

B&W's 100 MBtu/hr Clean Environment Development Facility (CEDF) was used for the final round of burner development for the NO_x subsystem testing. The advantage of using the CEDF for subsystem scale testing is in the ability to test a near-full size burner in an environment which closely simulates a utility boiler.

The optimum DRB-4Z^{TM} burner hardware configurations from previous subsystem testing were chosen for a final comparison. The purpose of this was to determine the optimum configuration of the DRB-4Z^{TM} burner for completion of the proof-of-concept (POC) and commercial generating unit (CGU) designs and numerical modeling cases. All hardware configurations were tested while firing the Illinois #6 design coal. Once the optimum hardware configuration was determined for the Illinois #6 coal, this configuration was then tested while firing three other coals.

The purpose for firing different coal types was to show the effect of changing fuel characteristics on burner performance. Using the Illinois #6 coal as a baseline comparison, a Mahoning 7, Middle Kittanning and Montana Decker coal were tested. The Mahoning 7 coal has a slightly higher fixed carbon-to-volatile matter ratio (FC/VM) than the Illinois #6. The Mahoning coal is a typical coal utilized at many utility boilers. A Middle Kittanning coal was chosen to fire due to its higher fixed carbon-to-volatile matter ratio. The Montana Decker coal is a sub-bituminous coal with a very high volatile matter content, therefore, a low fixed carbon-to-volatile matter ratio. All of these coals had been previously fired in the CEDF with the DRB-XCL® burner. Table II.2.1.1 gives the characteristics for the four test coals.

Table II.2.1.1: Chemical Analysis of Test Coals

	Illinois #6		Mahoning 7A		Middle Kittanning		Montana Decker	
	As Rec'd	Dry	As Rec'd	Dry	As Rec'd	Dry	As Rec'd	Dry
Proximate Analysis, %								
Moisture	13.92	—	5.70	—	3.26	—	26.36	—
Volatile Matter	33.53	38.95	37.85	40.14	22.74	23.51	31.93	43.36
Fixed Carbon	44.37	51.55	49.98	53.00	63.90	66.05	37.06	50.33
Ash	8.18	9.50	6.47	6.86	10.10	10.44	4.65	6.31
Gross Heating Value	11122	12920	13120	13913	13476	13930	9237	12543
Btu/lb (M&A Free)	—	14276	—	14938	—	15554	—	13388
FC/VM	1.32		1.32		2.81		1.16	
Ultimate Analysis, %								
Moisture	13.92	-----	5.70	-----	3.26	-----	26.36	-----
Carbon	61.96	71.98	73.63	78.08	76.61	79.19	53.64	72.84
Hydrogen	4.44	5.16	4.98	5.28	4.54	4.69	3.73	5.07
Nitrogen	1.17	1.36	1.56	1.66	1.34	1.39	0.88	1.19
Sulfur	3.02	3.51	0.93	0.99	0.81	0.84	0.51	0.69
Ash	8.18	9.50	6.47	6.86	10.10	10.44	4.65	6.31
Oxygen (by difference)	7.31	8.49	6.73	7.13	3.34	3.45	10.23	13.90

Preliminary results indicate that while firing the Illinois#6 coal, the average NO_x values were found to be 140-160 ppm, average CO emissions were below 100 ppm, while LOI values averaged <5%. NO_x values averaged 140-180 ppm while firing the Mahoning 7 coal, however, LOI values were found to average between 8 and 10%. Firing the Middle Kittanning coal with the

DRB-4Z™ burner resulted in NO_x emissions of 250 ppm. While firing the Montana Decker coal, NO_x emissions averaged 110-125 ppm, with low CO and LOI values. The NO_x, CO, and LOI values obtained during the final round of tested are illustrated along with previously obtained results in Figures II.2.1.1 through II.2.1.3 respectively.

The effect of coal fineness on the burner performance was also tested during the final round of subsystem testing in order to obtain the optimum conditions for the commercial generating unit. This information was used in conjunction with information obtained during pilot-scale testing and an engineering analysis. Four coal levels were tested; 65%, 75%, 85%, and 95% less than 200

Figure II.2.1.1 NO_x Emissions For Coals Utilized During Subsystem Testing

Figure II.2.1.2 CO Emissions For Coal Utilized During Subsystem Testing

mesh. Preliminary results indicate that the coal fineness of 85%< 200 mesh gave the optimum burner performance in terms of NO_x and CO emissions and LOI values. This result corresponded to the results obtained during pilot-scale tests. Due to these results, the coal fineness was set at

Figure II.2.1.3 LOI Values For Coals Utilized During Subsystem Testing

85%<200 mesh for incorporation into the burner design for the POC and CGU facilities.

The effect of staging the unstaged configuration of the DRB-4Z^{TM} burner 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 0.85 burner stoichiometries.

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^{TM} burner remained stable at all burner stoichiometries tested. Preliminary results show that the DRB-4Z^{TM} burner achieved a 35% reduction in NO_x emissions (90 ppm) when staged to 0.85 burner stoichiometry. This level of reduction is typical of what is seen in field operation. The CO emissions remained around 100 ppm, while LOI values increased to around 4%. The reduction seen with the DRB-4Z^{TM} burner was a gradual reduction from unstaged operation to 0.85 burner stoichiometry.

Since the single burner firing configuration of the CEDF is not typical of field operation, the NO_x reduction potential of staging the DRB-4Z^{TM} burner needed to be further investigated through pilot-scale testing and numerical modeling.

Two burner types were tested during the pilot-scale evaluation, the DRB-4Z^{TM} and the DRB-XCL® burners. Testing was performed during this series with the unstaged DRB-XCL® burner to set a relative baseline for comparison to the DRB-4Z^{TM} burner. Tests have previously been performed with the DRB-XCL® burner in both a staged and unstaged firing mode to characterize the staging ports on the SBS. Previous testing with the DRB-XCL® burner in the SBS has shown that a 35% reduction in NO_x is achieved when staging the burner to a 0.85 burner stoichiometry. Therefore, it is believed that the effect of staging is relatively accurate for the SBS in comparison to typical field operation. Since the SBS facility has previously been shown to accurately show the effect of staging in the wall-fired configuration, it was decided to use this facility to better correlate the effect of staging on NO_x emissions while firing the DRB-4Z^{TM} burner. Testing was also performed to show the effect of staging the unstaged DRB-4Z^{TM} burner configuration. This information could then be used in conjunction with the subsystem experimental testing and the numerical modeling cases.

The preliminary results indicate that the baseline NO_x emissions for the DRB-XCL® burner firing the Illinois #6 coal was found to be approximately 50 ppm higher than that obtained in the CEDF. This value was repeatable to the emissions obtained during previous test series. The unstaged DRB-4Z^{TM} burner showed a 25% reduction in NO_x emissions over the unstaged DRB-XCL® burner, similar to the reduction seen in the subsystem tests. NO_x values for the unstaged DRB-4Z^{TM} burner were also found to be approximately 50 ppm higher in the SBS furnace in comparison to the CEDF furnace. When the staged DRB-4Z^{TM} burner configuration was fired at a 0.85 burner stoichiometry, a NO_x reduction of approximately 35% was achieved. This reduction corresponds to typical field experience and to the values obtained in the CEDF. The effect of staging the unstaged DRB-4Z^{TM} burner configuration was also tested to correlate to the data obtained during subsystem testing. Preliminary results indicate that a NO_x reduction of

approximately 25% was obtained when the unstaged DRB-4Z^{TM} burner was staged to 0.85 burner stoichiometry. Relating this information to the NO_x reductions obtained in the CEDF during subsystem testing, it is expected that the DRB-4Z^{TM} burner, when designed to a 0.85 burner stoichiometry, would obtain a 35% reduction in NO_x levels over the unstaged levels

Numerical modeling continued to be used to provide insight into unstaged and staged performance of the DRB-4Z^{TM} burner, and to evaluate NO_x reduction for deeply staged burner operation. A series of burner models were begun this quarter to compare unstaged combustion characteristics of the burner with staged combustion at a burner stoichiometry of 0.85 and 0.75. These models are also being used to compare carbon monoxide concentrations and carbon burnout, both in the burner near-field and in the overfire air zone. This information is being compared with measured trends obtained during subsystem testing and providing information for the deep-staging designs for the commercial generating unit and the proof-of-concept facility in progress.

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. Through engineering analysis, experimental testing, and numerical modeling, a 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 LIDS activities follows.

III.1 Summary of Activities

Proposal efforts to the Ohio Coal Development Office (OCDO), the North Dakota Lignite Council, and the State of Illinois to gain their funding participation in the B&W LEBS Phase IV proof-of-concept demonstration continued. A proposal was completed and submitted to the OCDO on October 22, 1996. The OCDO's Technical Advisory Committee (TAC) voted on December 12 to fund B&W's LEBS Phase IV project at \$5 million. The vote followed an excellent technical review (by independent proposal reviewers) which recommended funding by all evaluators.

The following conferences were attended and technical papers prepared (Task 1):

- The International Joint Power Generation Conference, in Houston, Texas, was attended to participate in the Combustion 2000 - LEBS session.
- A technical paper entitled "Performance of Babcock & Wilcox's Limestone Injection with Dry Scrubbing (LIDS) Process" was presented at the Second North American Conference and Exhibition -- Clean Air 1996, in Orlando, Florida, November 19-22, 1996. The paper was very well received and inspired many questions and discussions throughout the conference.
- A technical paper abstract entitled "B&W's E-LIDS Process - Advanced SO_x, Particulate, and Air Toxics Capture for the Year 2000," was submitted for consideration for EPRI's NO_x/SO₂/Particulate Controls "Mega" Symposium scheduled for August, 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 Energy and Environmental Research Center (EERC - University of North Dakota) received solid by-product produced during the September 100 MBtu/hr E-LIDS test series to begin utilization tests and economic evaluations on the E-LIDS™ by-product. Two utilization methods will be evaluated and products produced. Results will be reported to B&W in January 1997. (Task 7.1)

The air toxics cognizance effort continued. B&W is conducting a wide variety of air toxics-related research projects, and is closely following the regulatory process. The effort will continue throughout the project. (Task 7.1)

The following engineering analyses were begun (Task 7.1):

- *Furnace limestone injection system requirements.* This activity is focusing 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 will specify the particulate collector requirements and specifications.
- *Alternative systems comparison.* This activity is investigating other current state-of-the-art systems for SO_x, particulate, and air toxics control and compares the with B&W's E-LIDS system.

Data reduction and analysis for the third and final round of Phase II 100 MBtu/hr E-LIDS testing (September 1996) was begun. The test series focused on repeating the ultra-high SO₂ removal achieved in the June 1996 test series, obtaining SO₂ performance curves using a coarser limestone, completing air toxic measurements, and addressing the effect of low-load operation on furnace limestone injection performance. This effort is covered under the key accomplishment section (Task 11.1 & 11.2)

III.2 Key Accomplishments

III.2.1 - E-LIDS Subsystem Test Series #3 Results

Data reduction and analysis for the third and final round of Phase II 100 MBtu/hr E-LIDS testing (September 1996) was begun. Goals of the test series included: 1) achieve 98% SO₂ removal while using a limestone with a grind between 15 and 20 microns mass mean diameter, 2) quantify the effects of low-load operation on furnace limestone injection performance, and 3) make air toxics measurements.

Coarser limestone grind. All of the 100 MBtu/hr E-LIDS test during the first and second E-LIDS test series had used a limestone with a grind of less than 10 microns mass mean diameter (MMD). In the third round of tests coarser limestone was tested to prove that ultra-high SO₂ removal (98%) should be achieved while using a limestone between 15 and 20 microns MMD. This goal is important to the process in order to improve the E-LIDS system economics and operability. A coarser limestone will do the following: 1) decrease the auxiliary power necessary to grind the limestone, hence, increase the cost-effectiveness of the E-LIDS system and 2) decrease the amount of convection pass fouling associated with limestone adhering to the tubes. **The SO₂ emissions target of 0.10 lbs SO₂/MBtu was met while using a limestone near 17 microns MMD.** Figure III.2.1.1 shows the total percent of SO₂ removed at the outlet of the furnace, dry scrubber, and baghouse. At the outlet of the furnace limestone injection system, 32% SO₂ removal was achieved. At the outlet of the dry scrubber, 62% SO₂ removal was achieved. At the outlet of the baghouse (or the E-LIDS system outlet) 99% SO₂ removal was achieved. The approximate operating conditions for this test included: 1) furnace stoichiometric ratio (Ca/S) - 1.40 mol Ca/mol S, 2) approach to saturation temperature - 10°F, 3) slurry percent solids - 30%, and 4) limestone grind > 15 microns MMD.

Figure III.2.1.1 - 100 MBtu/hr E-LIDS Total System SO₂ Removal - %
Coarser Limestone

Figure III.2.1.2 shows that for 2363 ppm SO₂ produced from the coal, SO₂ capture occurred as follows: 31.9% (854 ppm) removed in the furnace, 30.5% (699 ppm) removed in the dry scrubber, 37.2% (801 ppm) removed in the baghouse, and 0.40% (9 ppm) went up the stack.

**Figure III.2.1.2 - 100 MBtu/hr E-LIDS™ SO₂ Removal by Unit Operation - %
Coarser Limestone**

Figure III.2.1.3 shows the SO₂ removal obtained versus approach to saturation temperature (T_{as}) for the dry scrubber, baghouse and total E-LIDS systems while using a coarser limestone. Once again, the figure clearly shows that low operating temperatures enhance SO₂ capture in the dry scrubber, baghouse, and therefore, the overall E-LIDS system.

**Figure III.2.1.3 - 100 MBtu/hr E-LIDS SO₂ Removal % versus T_{as}
Coarser Limestone**

Low load-operation. The effects of low-load operation on the furnace limestone injection process were investigated. This information will be used to determine operating procedures covering the entire load range. Table III.2.1.1 shows results from the low-load tests.

Load	100%	80%	60%	40%
Furnace SO₂ Removal	36.0%	28.4%	25.1%	16.0%
Major constituents by Inductively Coupled Argon Plasma (ICAP)				
% Silicon	9.14	9.42	7.77	9.99
% Aluminum	5.49	5.71	4.67	5.87
% Iron	6.95	7.64	6.56	6.08
% Titanium	0.27	0.31	0.27	0.28
% Calcium	52.59	48.42	50.95	44.97
% Magnesium	0.98	0.83	0.82	0.74
% Total Sulfur	15.62	15.10	14.29	4.35
% Phosphorus	<0.21	<0.21	<0.22	<0.26
% Sulfate Sulfur	13.91	14.20	11.59	3.55
% Sodium	0.25	0.27	0.20	0.24
Alkali by Flame Atomic Absorption Spectroscopy (FAAS)				
% Potassium	0.37	0.35	0.29	0.38
Carbonate by carbonate train				
% Carbonate	8.93	10.99	15.27	27.96
%CaO by Quantitative X-ray Power Diffraction (QXRPD)				
% CaO	25	20	16	2.7

Table III.2.1.1 - E-LIDS Furnace Limestone Injection Product Results

Air toxics measurements. Air toxics measurements were made at the inlet to the dry scrubber and at the stack during E-LIDS operation. Measurements of total mercury, trace metals, and acid gases were collected to confirm the systems capability to achieve greater than 90% mercury removal and to further characterize the E-LIDS system's air toxics removal capabilities.

- *Mercury.* Because it seems likely that mercury emissions will be regulated in some manner in the future, measurements of mercury emissions from the E-LIDS process have been characterized throughout the LEBS project. Initial mercury characterization of the LIDS and E-LIDS processes were conducted by Frontier GeoSciences (MESA method) at 5 MBtu/hr (April

1994 and January 1995). These previous LEBS pilot-scale results showed that the E-LIDS system was capable of removing greater than 90% of the mercury entering the dry scrubber.

To confirm these previous results at larger scale and with a different method E-LIDS mercury measurements were made with the Ontario Hydro method during 100 MBtu/hr testing in the CEDF. The Ontario Hydro method applies to the determination of particulate and gaseous metals emissions from industrial, utility, and municipal sources. Measurements were made before the E-LIDS dry scrubber and at the stack. Table III.2.1.2 lists the 100 MBtu/hr E-LIDS total mercury removal results. The greater than 90% mercury removal obtained at 5 MBtu/hr with the MESA

Total Mercury Data Summary				Avg = 99.4
	<i>lb/trillion Btu Uncontrolled</i>	<i>lb/trillion Btu DS Inlet</i>	<i>lb/trillion Btu Stack</i>	<i>E-LIDS Total Removal based on Coal %</i>
OH #1	12.378	0.94777	0.09065	99.3
OH #2	12.378	2.88872	0.09006	99.3
OH #2A	12.378	4.98302	0.09006	99.3
OH #3	12.378	1.93703	0.05488	99.6
OH #3A	12.378	1.60578	0.05488	99.6
OH #4	12.378	0.76554	0.06671	99.5

Table III.2.1.2 - 100 MBtu/hr E-LIDS Mercury Removal by Ontario Hydro Method

Figure III.2.1.4 - 100 MBtu/hr E-LIDS Mercury Emissions on a Log Scale

method was confirmed at 100 MBtu/hr with the Ontario Hydro method. These results showed that the E-LIDS mercury removal is not an artifact of the facility or the measurement method. Figure III.2.1.4 presents the E-LIDS mercury emissions graphically.

- *Trace Metals and Acid Gases.* Air toxics data reduction and analysis will continue during the next quarter of the project. Results from the September 1996 air toxics E-LIDS tests will be presented in the next quarterly report.

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

Design criteria from other subsystems are being incorporated into the boiler. Design activities continued in an effort to finalize the boiler design in preparation for cost estimating. Many interfaces between the boiler and balance of plant subsystem remain open and we working to identify and close these issues.

IV.2 Key Accomplishments

IV.2.1 CGU Boiler Development

A preliminary list of boiler and LIDS system auxiliary power requirements were issued to Raytheon. This list is in the process of being updated to final numbers to be used for final heat rate and plant efficiency.

Surface setting was redesigned to reduce the main steam pressure drop. These changes were submitted to graphics and a new boiler arrangement drawing was produced.

Airheater quotes have been received from various vendors. We received quotes on a single regenerative airheater, two secondary regeneratives, a tubular primary, and a heat pipe for use as primary. The information was forwarded to Raytheon for an economic COE evaluation on which air heater arrangement to use. Once this evaluation is received our performance and arrangement

drawings will be updated to reflect the chosen airheater selection. The airheater vendors are concerned about our gas exit temperature being below the acid dew point. It is our belief that the limestone injection will capture nearly all of the SO_3 and thus eliminate the concern for acid condensation. This theory will need to be proven in the POC plant.

Preliminary data was received from the numerical modeling group on furnace absorptions, temperatures, and flow patterns. Initially it looks like the furnace absorption rates are more evenly distributed than our standard correction factors. If these trends hold true, they should help reduce the upsets in the circulation analysis.

Information from our last burner tests in the CEDF indicated NO_x reduction to be optimum at a primary air to fuel ratio of 1.8 and a fineness content of 82% thru 200 mesh. Our pulverizer calculations show a need of this ratio to 2.3 for mill operation. Discussions are ongoing with the pulverizer group on ways of reducing this air flow requirement but in all likelihood this parameter will need to be addressed in the POC plant.

Design of a spiral wound furnace was started. Although this type of furnace is more expensive and requires a higher pressure drop, preliminary indications suggest this would be a better arrangement technically.

IV.2.2 Corrosion Evaluation

The two 5000-hour laboratory tests are being continued. One test will be completed in late January, and the other in early March. The fabrication of a test panel for the corrosion field test in Unit 2 of Allegheny Power System at the Hatfield Ferry's Station is also in progress. Detailed engineering drawings for the test panel were completed, and fabrication of the subpanels was initiated. The subpanels were delivered to various coating vendors in December after being manufactured at B&W's West Point facility. It is anticipated that the final panel assembly will be completed in the last week of February 1997.

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

Work continues on closing the interfaces between the balance of plant and other subsystems. Balance of plant equipment costs are being developed as are auxiliary power requirements. The economic criteria for pricing the total plant are also being developed.

V.2 Key Accomplishments

A preliminary auxiliary power list for the complete plant was received from Raytheon. It appears we are in the ball park of where we need to be for net plant heat rate. A final revision is being compiled for calculation of the net plant heat rate.

Plant arrangement drawings are being developed after boiler island drawings were issued. Initial plant layout drawings were received for our review and comments.

Raytheon provided an estimate of DCS I/O's for the C-2000 plant.

Arrangement of limestone storage and transport have been finalized.

A preliminary evaluation of a mechanical draft versus a hyperbolic cooling tower indicates that the added capital investment of the hyperbolic tower may be economically attractive. A more thorough evaluation is on hold until plant auxiliary power requirements are tabulated.

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

A technical paper "Evaluation of Microwave, Acoustic, and Hot-Film Sensors for Measuring Pulverized-Coal Flow and Air Flow in Burner Lines" was presented at Power-Gen Intl. '96.

The SO_x/E-LIDS™ process model with delivered and integrated with the combustion NO_x dynamic process model.

A meeting of the sensor team was held at ARC to evaluate results and work remaining to complete their activities in order to permit selection of sensors to be incorporated in control system design.

A meeting was held with the SO_x Subsystem team to review preliminary results of their testing of E-LIDS™ system as related to operational objectives and constraints which are needed to be addressed by the control system. Similar meeting are scheduled with the NO_x Subsystem team and the CGU design team in early January.

The final reporting effort was kicked off in November with outlines, writing assignments and schedule distributed to team members.

Planned evaluations of Insittec's on-line particle size monitor in B&W's solids flow facility has been dropped from the plan as continued delays in Insittec's availability would not allow completion of the testing & analysis within the program schedule.

VI.2 Key Accomplishments

The SO_x/E-LIDS™ process model was run with two simple control loops simulated on the E-LIDS™ system. Parametric process simulation runs were completed to study the SO_x reduction process and its control including lime injection flow in the furnace, slurry injection in the dry scrubber and solids removal in the baghouse. For simplicity purposes, the chemical reaction of lime and flue gas were not simulated. However, to maintain the process fidelity, the effect of lime flow on sulfur reduction in the furnace was implemented with an empirical relation. Such an approach kept the process simulation modeling trends close to what might be expected for the POC E-LIDS™ process. This activity was completed to *predict control trends* necessary to setup the POC demonstration control system, not to predicted absolute test data.

The SO_x reduction model included three single-loop controllers during these parametric tests. One loop monitored stack SO_x to control slurry concentration. The second loop monitored furnace SO_x to control lime injection rate. The third loop controlled approach temperature in the dry scrubber by changing the slurry flow rate. These controllers were left in manual mode during the parametric study.

During the parametric study, the following observations were made regarding the sulfur reduction process independent of any controller effect:

1. The sulfur reduction process seemed to be very sensitive to changes in slurry solids concentration. A concentration change beyond +/- 10 % off the design value of 42 % caused the model to terminate prematurely.
2. At a set slurry flow to the dry scrubber, the reduction of lime injection flow caused a predictable trend in sulfur reduction in the furnace. It should also be noted that the heat of reaction caused the approach temperature to drop, subsequently causing sulfur capture in the dry scrubber to increase (see Fig. VI.2.1 for Percent Sulfur Reduction and Fig. VI.2.3 for PPM Sulfur at the Stack). However, at a lower slurry flow, the reduction of the lime flow caused the SO_x concentration to drop consistently across the furnace, dry scrubber and baghouse (see Fig. VI.2.2 for Percent Sulfur Reduction and Fig. VI.2.4 for PPM Sulfur at the Stack).

Figure VI.2.1 - Total Sulfur Reduction at Various Lime Injection Flows for Slurry Flow of 349.1 Lbs/Hr

Figure VI.2.2 - Total Sulfur Reduction at Various Lime Injection Flows for Slurry Flow of 314.1 Lbs/Hr

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Figure VI.2.3 - Stack SO_x at Various Lime Injection Flows for Slurry Flow of 349.1 Lbs/Hr

Figure VI.2.4 - Stack SO_x at Various Lime Injection Flows for Slurry Flow of 314.1 Lbs/Hr

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