BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58501-0564
PHONE 701/223-0441

June 3, 1992

Lignite Research Council
State of North Dakota
Office of the Industrial Commission
State Capitol
Bismarck, ND 58505

Dear Gentlemen:

Enclosed is the application of the North Dakota Lignite Cyclone Users Group for a grant from the North Dakota Lignite Research Fund. By this application, the North Dakota Lignite Cyclone Users Group hereby commits itself to complete the project as described in the application should the Industrial Commission of North Dakota make the grant requested by the application.

The applicant certifies that it has read and understands the statutes and administrative rules governing grants from the Lignite Research Fund and agrees to all conditions and terms set forth therein. The applicant also certifies that all information contained in the application is true to the best of the applicant's knowledge and acknowledges the right of the North Dakota Industrial Commission to modify or terminate any subsequent agreements with applicant if the Commission becomes aware of any material misrepresentation contained in this application.

Sincerely,

Richard Fockler

Richard B. Fockler
Assistant General Manager
Basin Electric Power Cooperative

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2453 C

EVALUATION OF REBURNING FOR NOX CONTROL FROM LIGNITE-FIRED CYCLONE BURNERS
LRC-IX-36

PROJECT OBJECTIVES

The objective of this project is to evaluate the applicability of reburning technology to reduce NOx emissions from cyclone-equipped utility boilers which use North Dakota lignite as a primary fuel.

PROJECT FUNDING $260,000 LRF 1 Year

Attach. K-2

PROJECT TITLE

EVALUATION OF REBURNING FOR NO_x CONTROL FROM
LIGNITE-FIRED CYCLONE BURNERS

ORGANIZATION

NORTH DAKOTA LIGNITE CYCLONE USERS GROUP
COYOTE GENERATING STATION
LELAND OLDS GENERATING STATION
MILTON R. YOUNG GENERATING STATION

INVESTIGATORS

CURT MELLAND, RESULTS ENGINEER, BASIN ELECTRIC
B&W ALLIANCE RESEARCH CENTER

DATE OF APPLICATION

APRIL 1, 1992

BASIN ELECTRIC
POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58501-0564
PHONE 701/223-0441

March 31, 1992

Lignite Research Council
State of North Dakota
Office of the Industrial Commission
State Capitol
Bismarck, ND 58505

Gentlemen:

Three North Dakota lignite cyclone fired plants (**Coyote Generating Station** owned by Northern Municipal Power Agency, Montana-Dakota Utilities Co., Northwestern Public Service Co., and Otter Tail Power Co.; **Leland Olds Generating Station** owned by Basin Electric Power Cooperative; and **Milton R. Young Generating Station** owned by Minnkota Power Cooperative) have joined together to form the **North Dakota Lignite Cyclone Users Group**. The **North Dakota Lignite Cyclone Users Group** submits this proposal for determining NO_x levels produced by lignite fired cyclone boilers with reburn and over-fire air modifications.

The test program described in this proposal would be added to an existing DOE demonstration program for determining cyclone boiler NO_x levels burning bituminous and subbituminious coal. The results of the DOE project is expected to have a strong influence on the clean air regulations written for all cyclone units. Test data from lignite fueled cyclone units will be needed to produce clean air regulations that includes the unique characteristics of cyclone boilers burning lignite fuel. If regulations are promulgated disallowing lignite to be used as fuel for the reburn portion of the combustion system, North Dakota's annual lignite consumption would decrease 8-10 percent.

The **North Dakota Lignite Cyclone Users Group** will utilize B&W facilities and personnel to facilitate the test program. This proposal covers the initial testing at B&W's Alliance test site. If full scale testing is required an additional proposal will be submitted at a later date.

The **North Dakota Lignite Cyclone Users Group** is requesting the

North Dakota Industrial Commission to issue a grant for the sum of $260,000, which is 50% of the $520,000 needed to complete the project.

Curt Melland, Results Engineer, at Basin Electric's Leland Olds Station is the project coordinator and can be contacted at (701) 745-3371 if there are any questions or concerns.

Sincerely,

Rich Fockler

Richard Fockler
Assistant General Manager
Basin Electric Power Cooperative

CM/td

PROJECT TITLE

EVALUATION OF REBURNING FOR NO_x CONTROL FROM
LIGNITE-FIRED CYCLONE BURNERS

ORGANIZATION

NORTH DAKOTA LIGNITE CYCLONE USERS GROUP
COYOTE GENERATING STATION
LELAND OLDS GENERATING STATION
MILTON R. YOUNG GENERATING STATION

INVESTIGATORS

CURT MELLAND, RESULTS ENGINEER, BASIN ELECTRIC
B&W ALLIANCE RESEARCH CENTER

DATE OF APPLICATION

APRIL 1, 1992

AMOUNT OF REQUEST

$260,000

TABLE OF CONTENTS

1.0 ABSTRACT

There are currently no commercially-demonstrated combustion modification techniques for cyclone boilers which reduce NO_x emissions. The emerging reburning technology offers cyclone boiler owners a promising alternative to expensive flue gas cleanup techniques for NO_x emission reduction. Reburning involves the injection of a supplemental fuel (natural gas, oil, or coal) into the main furnace in order to produce locally reducing stoichiometric conditions which convert NO_x produced in the main combustion zone to molecular nitrogen, thereby reducing overall NO_x emissions.

After obtaining encouraging results from engineering feasibility and pilot-scale studies [1,2], Babcock & Wilcox (B&W) is presently performing a U.S. Department of Energy Clean Coal II project to demonstrate the cyclone coal reburn technology on a full-size utility boiler. [3] The host site for the demonstration is Wisconsin Power & Light's (WP&L) Nelson Dewey Station. This demonstration project utilizes a medium sulfur eastern bituminous coal from Indiana.

The potential of Lignite as reburn fuel has not been studied yet and is proposed for evaluation in B&W's cyclone-equipped Small Boiler Simulator (SBS).

2.0 PROJECT SUMMARY

Objectives

The objective of this proposed project is to evaluate the applicability of reburning technology to reduce NO_x emissions from cyclone-equipped utility boilers which use North Dakota Lignite as a primary fuel.

Introduction & Background

The Department of Energy (DOE) under its Clean Coal II solicitation is sponsoring B&W and WP&L to perform a full-scale demonstration of the reburning technology for cyclone boiler NO_x control. This full-scale evaluation is justified via a previous Electric Power Research Institute-sponsored (project RP-1402-30) engineering feasibility study and EPRI/GRI (EPRI RP-2154-11; GRI:5087-254-1471) pilot-scale evaluation of reburning for cyclone boilers performed by B&W.[1,2] The host site for the demonstration is Wisconsin Power & Light's Nelson Dewey Station.

There are presently 105 operating, cyclone-equipped utility boilers representing approximately 14% of pre-New Source Performance Standards (NSPS) coal-fired generating capacity (over 26,000 MW_e). However, these units contribute approximately 21% of the NO_x emitted since their inherently turbulent, high-temperature combustion process is conducive to NO_x formation. Although the majority of cyclone units are 20 - 30 years of age, utilities plan to operate many of these units for at least an additional 10 - 20 years. These units (located primarily in the Midwest) have been targeted for the second phase of the Federal acid rain legislation scheduled to go into effect in 1995. The cyclone boilers that use Lignite located in the Dakotas represent 2000 MW_e generating capacity.

Cyclone-equipped boilers have a unique configuration which prevents application of standard low-NO_x burner technology — that is that the combustion occurs within a water-cooled horizontal cylinder attached to the outside of the furnace. Furthermore, other conventional NO_x reduction techniques, such as two-stage combustion, cannot be applied to the full extent due to associated cyclone operational concerns (cyclone corrosion and slagging). The use of selected catalytic reduction or selected non-catalytic reduction (SCR/SNCR) technologies offers promise of controlling NO_x from these units, but at high capital and/or operating costs. Reburning involves the injection of a supplemental fuel (natural gas, oil, or coal) into the main furnace in order to produce locally reducing stoichiometric conditions which convert NO_x produced in the main combustion zone to molecular nitrogen, thereby reducing overall NO_x emissions. Reburning is, therefore, a promising alternative NO_x reduction approach for cyclone-equipped units at more reasonable capital and operating costs.

The Need For This Research

EPA will be making rules effecting cyclone boilers by 1997. At present DOE demonstration projects will supply data for cyclones with reburn, over-fire air modifications burning bituminous and subbituminous coal.

Lignite has not been evaluated as a reburn fuel at pilot or full scale and is proposed for evaluation in B&W's cyclone-equipped facility. The characteristics of North Dakota Lignite such as high moisture content, low Btu, and low Fixed Carbon/Volatile Matter (FC/VM) ratios are unique and require pilot-scale evaluation prior to full-scale reburning retrofit to cyclone boilers in North Dakota. Without the lignite data attached to the DOE demonstration project report, rules may be made which are not possible to meet with lignite cyclone-fired boilers.

Statement of Work

B&W's Small Boiler Simulator (SBS) will be utilized to evaluate the potential of the reburn technology for cyclone boilers that use Lignite as the primary fuel. A Lignite from North Dakota will be delivered to B&W by Basin Electric. The pilot-scale study consists of baseline (no reburning), and reburning tests. The NO_x reduction potential will be evaluated by comparison of baseline and reburning results. The side effects of the technology such as impact on unburned combustibles, changes on furnace exit gas temperature (FEGT), impact on superheater deposition, and potential for fireside corrosion within the reburn zone will be explored. Using the SBS is a logical approach for evaluation of Lignite in the cyclone reburn process and much less costly than a full scale test.

The same reburn tests (described as Task 2 for the Lignite) will be conducted in the SBS using a comparison coal to be fired at Wisconsin Power & Light's (WP&L) Nelson Dewey Station. The comparison coal will be evaluated as part of DOE's Clean Coal II cyclone reburn demonstration. Comparing the SBS data with the WP&L test results will provide a very good indication of the performance of a full-scale lignite cyclone boiler's application.

Value to North Dakota

To date, natural gas has been promoted as a reburn fuel in the majority of the US DOE- sponsored clean coal programs (with the exception of B&W's project at Nelson Dewey), because it was believed that natural gas would provide higher NO_x reduction and combustion efficiency than coal. Recent B&W pilot- and full-scale research with some eastern bituminous coals has shown that coal as a reburning fuel performs nearly as well as gas while maintaining acceptable boiler operating conditions.

Without further development of reburning for Lignite-fired cyclone boilers, pending stricter emission control legislation, utilities may have to either phase out cyclone-fired boilers, convert them to gas/oil firing or retrofit them with oil or natural gas reburning. Utilizing oil or natural gas as the reburn fuel would decrease lignite consumption by 8 to 10% if present generation levels were maintained. The increased fuel costs associated with an oil or natural gas reburn system would decrease the lignite unit's ability to compete in the surplus energy market and could increase consumers rates. Both of these effects tend to decrease the amount of electricity generated and lignite fuel burned further decreasing North Dakota lignite consumption.

3.0 PROJECT DESCRIPTION

3.1 INTRODUCTION & OBJECTIVES

There are presently 105 operating, cyclone-equipped utility boilers representing approximately 14% of pre-NSPS coal-fired generating capacity (over 26,000 MW_e). However, these units contribute approximately 21% of the NO_x emitted, since their inherently turbulent, high-temperature combustion process is conducive to NO_x formation. Although the majority of cyclone units are 20 - 30 years of age, utilities plan to operate many of these units for at least an additional 10 - 20 years. The potential of future acid rain control and the location of the majority of these units (Midwest) eventually will target these boilers for NO_x emission control.

Cyclone-equipped boilers have a unique configuration which prevents application of standard low-NO_x burner technology — that is that the combustion occurs within a water-cooled horizontal cylinder attached to the outside of the furnace. Furthermore, other conventional NO_x reduction techniques, such as two-stage combustion, cannot be applied to the full extent due to associated cyclone operational concerns (cyclone corrosion and slagging). The use of selected catalytic reduction or selected non-catalytic reduction (SCR/SNCR) technologies offers promise of controlling NO_x from these units, but at high capital and/or operating costs. Reburning is, therefore, a promising alternative NO_x reduction approach for cyclone-equipped units at more reasonable capital and operating costs.

Reburning technology involves injection of a second fuel into the main furnace (above the cyclone region) to produce a secondary combustion zone where a reducing atmosphere exists. These local chemical reducing conditions convert NO_x to molecular nitrogen, thus destroying a portion of the NO_x produced in the primary cyclone combustion zone. Since reburning can be applied to the cyclone while it is operating under normal oxidizing conditions, this technology merits development for ultimate commercialization.

Babcock and Wilcox Company (B&W) has been evaluating the reburn technology for NO_x control from cyclone boilers. [1,2,3] Today, the entire data base consists of medium and high sulfur eastern bituminous coals in a pilot-scale cyclone. In addition, the U.S. Department of Energy (DOE) under its Clean Coal II solicitation is currently sponsoring B&W to perform a 100-MW_e demonstration of coal reburning using a medium sulfur bituminous coal. Lignitic coal has not been evaluated and is proposed for evaluation in this proposed project.

The purpose of the pilot-scale tests is to evaluate cyclone reburn technology using Lignite and to assess the potential NO_x emission reduction capabilities of the process. This information will aid in identifying the potential commercial application of the technology for cyclones firing North Dakota Lignite. The following summarizes the specific objectives of the test program:

- Evaluate the major process parameters such as reburning/main combustion zone stoichiometries, fuel quantity, and reburning/burnout zone residence times.

- Determine effects of reburning on:

  - Slagging/fouling in the upper furnace and convection pass.

  - Combustion efficiency (based upon unburned combustibles and CO emissions).

  - Corrosion potential.

  - Changes in furnace exit gas temperature (FEGT).

- Maximize NO_x reduction while maintaining combustion conditions compatible with design and operation of cyclone-equipped boilers.

3.2 CYCLONE AND REBURNING PROCESS DESCRIPTION

The cyclone furnace consists of a cyclone burner connected to a horizontal water-cooled cylinder called the cyclone barrel (Figure 3-1). This auxiliary furnace was an attractive alternative to pulverized coal (PC) by providing the ability to burn low-grade coals, significantly reducing flyash in the flue gas, requiring less fuel preparation equipment, and allowing for a reduction in total boiler size. Crushed coal and air are introduced through the cyclone burner into the cyclone barrel. The larger coal particles are thrust out to the barrel walls where they are captured and burned in the molten slag layer which has formed, while the finer particles burn in suspension. The mineral matter melts, exits the cyclone furnace from a tap at the cyclone throat, and is dropped into a water-filled slag tank. The flue gases and remaining ash leave the cyclone and enter the main furnace.

No commercially-demonstrated combustion modifications have significantly reduced NO_x emissions without adversely affecting cyclone operation. Past tests with combustion air staging achieved 15 - 30% reductions. Cyclone tube corrosion concerns due to the resulting reducing conditions were not fully addressed because of the short duration of these tests. Further investigation of staging for cyclone NO_x control was halted due to utility corrosion concern. Additionally, since no mandatory Federal/State NO_x emission regulation was enforced, no alternative technologies were pursued.

The recent emergence of the reburning technology offers a promising alternative to conventional combustion controls and SCR systems. The reburning process employs multiple combustion zones in the furnace, as shown in Figure 3-2. The main combustion zone is operated at a reduced stoichiometry and has the majority of the fuel input (70 - 85% heat input). The majority of investigations on natural gas-/oil-/coal-fired units have shown that the main combustion zone of the furnace should be operated at a stoichiometry of less than 1.0. This operating criteria is impractical for cyclone units due to the potential for highly corrosive conditions, since most cyclones burn high-sulfur, high-iron content bituminous coals. To avoid this situation and its potentially catastrophic consequences, the cyclone main combustion zone was determined to be operated at a stoichiometry of no less than 1.1 (2% excess O_2 at the stack).

The balance of fuel is introduced above the main combustion zone (cyclones) in the reburning zone through reburning burners. To protect the tubes around the reburning burners in the reburning zone from fireside corrosion, some air is introduced through these burners. The burners are operated in a similar fashion to a standard wall-fired burner. The furnace reburning zone is operated at stoichiometries in the range of 0.85 - 0.95 in order to achieve maximum NO_x reduction based on laboratory/actual boiler application results. [4,5]

The balance of the required combustion air — totaling 15 - 20% excess air at the economizer outlet — is introduced through overfire air (OFA) ports. These ports are designed with adjustable air velocity controls to enable optimization of mixing for complete fuel burnout prior to exiting the furnace.

Pilot- and field-scale studies [4,5,6,7,8] have defined acceptable limits of residence times in the reburning zone for high volatile matter bituminous coal. A 50 - 60% reduction can be achieved at residence times greater than 0.45 second. In order to complete combustion (based on experience with staged combustion), about 0.65 second residence time is required. Thus, a total of about 1.1 seconds is required between the reburning burners and furnace exit for bituminous coal. The NO_x reduction potential and residence time to burn Lignite will be evaluated in the pilot-scale.

3.3 PROJECT METHODOLOGY

Although B&W has been evaluating coal reburning, the reburning technology has never been applied to cyclone-equipped boilers using Lignite as the cyclone and reburning fuel. Our technical approach for evaluation of Lignite is to utilize B&W's 6 million Btu/Hr Small Boiler Simulator (SBS) to fully characterize a Lignite as the primary cyclone and reburn fuel. Since the facility has shown good agreement with full-scale cyclone boilers, the experimental results of Lignite reburning in the SBS could be evaluated against other coals fired in both the SBS and full-scale boilers.

During baseline conditions loads will be varied to experimentally select conditions similar to the full-scale boiler. Anticipated full load is 5 MBtu/hr. This is to provide some additional residence time for Lignite to dry, devolatilize and burn in the cyclone. Reducing full load from 6 MBtu/hr (used for eastern Bituminous coal) to approximately 5 MBtu/hr also increases the residence time in the reburn and burnout zone. This is advantageous since Lignite-fired boilers usually are larger than boilers designed to burn eastern Bituminous coal.

Baseline tests (no reburning) will be performed as a point of reference. All other reburning results will be compared to the baseline test results. The major parameters affecting NO_x emissions will be investigated. For example, fuel split between cyclone and reburn burners will be varied. In some test conditions flue gas recirculation (FGR) will be introduced into the reburn burners to enhance the mixing between reburn fuel and flue gases from the cyclone.

Potential side effects of the technology also will be studied. Unburned combustibles and dust loading will be performed at the stack to assess the potential of higher combustible losses under reburn conditions. Furnace exit gas temperature (FEGT) will be measured in order to evaluate the potential variation in FEGT. Since the reburn zone is operated under reducing conditions, potential corrosion in this zone will be studied. By operating the cyclone under normal oxidizing conditions, the majority of the sulfur will be oxidized to SO_2. Some H_2S could be formed inside of the reburn zone. High levels of H_2S near the tubes can be conducive to corrosion. In-furnace H_2S measurements within the reburn zone will be performed to assess potential for fireside corrosion. The superheat ash deposition will be evaluated due to higher ash concentrations in the flue gas.

3.4 STATEMENT OF WORK

North Dakota lignite cyclone boiler firing conditions will be simulated in B&W's Small Boiler Simulator (SBS) using North Dakota Lignite. The pertinent parameters that must be simulated are the furnace residence time and thermal conditions. Baseline and coal reburning tests will be performed. The NO_x reduction, as well as potential side effects of the technology such as unburned combustibles, fireside corrosion and deposition, will be addressed.

Task 1 - Planning and Site Preparation

Upon receiving the contract, the first milestone will be to prepare a test plan. A trip to Basin Electric's Leland Olds station is planned to observe and discuss the operating conditions of the plant. Forty (40) tons of North Dakota Lignite will be delivered to ARC, and laboratory analysis will be performed on the coal. This laboratory analysis will consist of proximate and ultimate analysis, chemical analysis of ash, determination of T250 (the temperature at which slag viscosity is 250 poise), and Hardgrove grindability index. The coal will be dried and stored in bins. The coal drying will be monitored for removing only some of the surface water. For safety purposes, the coal will be covered by a nitrogen blanket. The range of calibration sample gases for 0_2, CO_2, CO, NO_x, SO_2, and H_2S will be identified and purchased. All other miscellaneous items, such as recorder paper, will be purchased. Prior to the tests, all equipment will be under calibration, and the SBS facility will be operating under wall-firing conditions. For these tests the SBS will be converted to cyclone-firing mode. The facility will be checked and any required maintenance will be performed. The parametric tests will then be initiated.

Task 2: Lignite Evaluations

Tasks 2 will be the evaluation of the Lignite coal and will consist of the following tests and measurements:

Parametric Tests

The baseline tests will be performed without the reburning system in operation in order to provide the benchmark data to which the subsequent reburning results will be compared. Table 3-1 shows the test matrix for the pilot scale baseline test for the North Dakota Lignite. The full load conditions will be determined experimentally. The cyclone operating conditions will be observed, and coal particle size will be adjusted on-line to achieve acceptable slag tapping and cyclone temperature. The anticipated full load is 5 MBtu/hr. Partial load will be selected as 70% or lowest cyclone stable conditions. The tests will be performed at two load conditions, full and partial, and at three excess air levels. At each test condition, boiler operating data, and stack gas analysis will be collected. FEGT, cyclone exit temperature, and unburned combustibles will be collected for selected conditions.

The reburning tests will be performed with two coal reburning burners and the two rear wall OFA ports in service. The cyclone will be operated at 10% excess air and at 70 to 80% of total heat input with crushed coal. The heat input to the boiler will be supplemented utilizing pulverized coal introduced through the two coal reburning burners at a burner zone stoichiometry of 0.3 - 0.5. OFA will be added via two OFA ports to complete combustion. Table 3-2 shows the test matrix for the pilot scale coal reburning tests.

The fuel split between the cyclone and reburning burners, load turn down and the effects of FGR are the parameters to be investigated. North Dakota Lignite will be used as the main test coal. The reburning coal will be pulverized to 90% through 200 mesh and full load tests at three different reburning zone stoichiometries will be tested. FGR (10%) will be added to the reburning burners and similar tests will be repeated. Low load tests will be performed at the optimum conditions. At each test condition, boiler operating data and stack gas analysis will be collected. FEGT, cyclone exit temperature, and unburned combustibles will be measured at selected tests.

Detailed In-Furnace Measurements

At representative baseline and optimum coal reburning conditions, detailed in-furnace probing (mostly in the reburn zone) will be performed (while firing the Lignite). Gas species (O_2, CO_2, CO, SO_2, H_2S, NO_x), and temperatures will be measured throughout the furnace.

TABLE 3-1 SBS BASELINE TESTS

	Boiler Load	O_2 %	FGR %	FEGT	Unburned Carbon	Gas Species
Task 2	Full *	4	0	X	X	X
	Full	3	0	X	X	X
	Full	2	0	X	X	X
	70% **	4	0			X
	70%	3	0	X	X	X
	70%	2	0			X

In-furnace Probing - O_2, CO, CO_2, SO_2, NO_x, H_2S, Temperatures, at the full load conditions inside the reburn zone.

Operating conditions, gas species, and opacity will be taken for all tests.

* To be determined by combustion characteristics.

** or lowest stable load

TABLE 3-2 PILOT-SCALE COAL REBURNING TESTS

Cyclone @ 10% Excess air, Reburn Burner at 0.4, Total 3% O_2 @ stack

Reburn Fuel %	Load	Reburning Coal % < 200 mesh	Reburning Burner Stoichiometry	FGR %
28	Full	90	0.9	0
22	Full	90	0.95	0
35	Full	90	0.85	0
22	Full	90	0.95	10
35	Full	90	0.85	10
28	Full	90	0.9	10
28	75%	90	0.9	0
28	75%	90	0.9	10
22	75%	90	0.95	10
35	75%	90	0.85	10

In-Furnace Probing - O_2, CO, CO_2, SO_2, NO_x, H_2S, Temperatures, at the optimum conditions.

Operating conditions, gas species and opacity will be taken for all tests. FEGT and unburned combustibles will be measured for selected tests.

Task 3: Superheater Deposition Testing

At optimum conditions, two 48-hour tests will be performed: baseline and coal reburning operation. A simulated superheater probe will be installed in front of the superheater tube bank. Commercial sootblowers are available throughout the convection pass region. Boiler operating conditions, FEGT, stack temperature, and the probe's heat flux data will be monitored. The sootblower pressure required to remove ash deposits from the probe will be measured. Sintered flyash deposits from the simulated superheater probe and flyash at the stack will be taken, and chemical analysis will be performed. The data from the baseline and Lignite reburning tests will be compared, and the potential host boiler operational changes will be evaluated. Following the tests, the SBS will be cleaned and all equipment will be stored. The SBS will remain in the cyclone firing mode.

Task 4 SBS Testing of Comparison Coal

The same reburn tests (described as Task 2 for the Lignite) will be conducted in the SBS using a comparison coal to be fired at Wisconsin Power & Light's (WP&L) Nelson Dewey Station. The comparison coal will be evaluated as part of DOE's Clean Coal II cyclone reburn demonstration.

The purpose of this test is to allow a direct comparison between the SBS results on the Lignite and on the comparison coal. By comparing the comparison coal data at full scale as well as in the SBS, a better extrapolation can then be made to indicate the expected performance of Lignite in a full-scale plant.

Task 5: Analysis and Reporting

The test results will be reduced into standard engineering terms and tabulated. Typical variables include air, fuel, and FGR rates, furnace stoichiometries, fuel split, stack NO_x and SO_2 concentrations, FEGT, and cyclone temperatures. NO_x, SO_2, and other data will be plotted and discussed. These data will also be compared to previous B&W results; therefore, the performance of Lignite coal will be compared with coals previously tested.

Quarterly progress reports will be prepared summarizing project accomplishments and expenditures. A final report will be prepared to describe the experimental apparatus and test procedure. The final report will also provide results of the work, conclusions, and recommendations for future considerations of full-scale Lignite reburnings.

3.5 ANTICIPATED RESULTS

A data base will be developed to determine the NO_x reduction and potential side effects of the reburning technology when it is applied to cyclone boilers firing Lignite as their primary fuel. This pilot-scale data is expected to provide adequate information to define the potential of Lignite as a reburning fuel.

3.6 EXPERIMENTAL FACILITY

B&W's 6-million Btu/hr small boiler simulator (SBS) will be utilized to perform the pilot-scale study (Figure 3-3). This facility is described in detail in Appendix B. A short description of the facility pertinent to this project is presented here.

The SBS is fired by a single, scaled-down version of B&W's cyclone furnace. Coarse pulverized coal (44% through 200 mesh), carried by primary air, enters tangentially into the burner. Pulverized coal has to be utilized in the SBS instead of crushed coal to obtain complete combustion in this small cyclone. Preheated combustion air at 600°F to 800°F enters tangentially into the cyclone furnace.

The water-cooled furnace simulates the geometry of B&W's single-cyclone, front-wall fired cyclone boilers. The inside surface of the furnace is insulated to yield a furnace exit gas temperature (FEGT) of 2250°F at the design heat input rate of 6-million Btu/hr. This facility simulates furnace/convective pass gas temperature profiles and residence times, NO_x levels, cyclone slagging potential, ash retention within the resulting slag, unburned carbon, and flyash particle size of typical full-scale cyclone units. A comparison of baseline conditions of these units is shown in Table 3-3.

TABLE 3-3 COMPARISON OF BASELINE CONDITIONS FOR THE SBS FACILITY AND COMMERCIAL UNITS

	SBS	TYPICAL CYCLONE-BOILERS
Cyclone Temperature	>3000°F	3000°F
Residence Time	1.4 seconds at full load	0.7 - 2 seconds
Furnace Exit Gas Temperature	2265°F	2200° - 2350°F
No_x Level	900 - 1200 ppm	600 - 1400 ppm
Ash Retention	60 - 80%	60 - 80%
Unburned Carbon	<1% in ash	1 - 20%
Ash Particle Size (MMD; Bahco)	6 - 8 microns	6 - 11 microns

Two reburning burners were installed on the SBS furnace rear wall above the cyclone furnace. Each burner consists of two zones with the outer zone housing a set of spin vanes while the inner zone contains the reburning fuel injector. Air and flue gas recirculation (FGR) can be introduced through the outer zone. Overfire air (OFA) ports are located on both the front and rear walls of the SBS at three elevations, with each elevation containing two ports.

Two air-cooled deposition probes and simulated commercial sootblowers are available in the convective section (simulating secondary superheater and reheater tubes) in order to allow fouling (deposition) studies to be performed.

3.7 THE NEED FOR THIS PROJECT

Despite five years of reburning experience in B&W's pilot- scale facility and current full-scale evaluation, the evaluation of Lignite for reburning applications has not been addressed. The characteristics of North Dakota Lignite such as high moisture content, low Btu, and low FC/VM ratios are unique and require pilot-scale evaluation prior to full-scale reburning retrofit to cyclone boilers in North Dakota . Use of B&W's Small Boiler Simulator is a logical approach for evaluation of Lignite in the cyclone reburn process and will minimize the risk in comparison to a more costly full-scale application.

3.8 ENVIRONMENT & ECONOMIC IMPACT

Reburning is a combustion modification technique and does not produce any new waste streams. The most important environmental impact is reducing NO_x emissions from cyclone boilers. Other gaseous emissions, like CO_2 and H_2O, will not change. Pilot-scale data shows that CO emissions also do not increase. The only waste stream affected was the flyash loading to the ElectroStatic Precipitator (ESP). The reburn technology produces higher ash loading. Based upon the preliminary results from testing performed at Wisconsin Power & Light on a DOE-sponsored Clean Coal II Program for reburn technology, the ESP performed well, and stack opacity did not increase with coal reburning. The collected flyash can usually be land filled or it could be converted to other materials (e.g. cement brick).

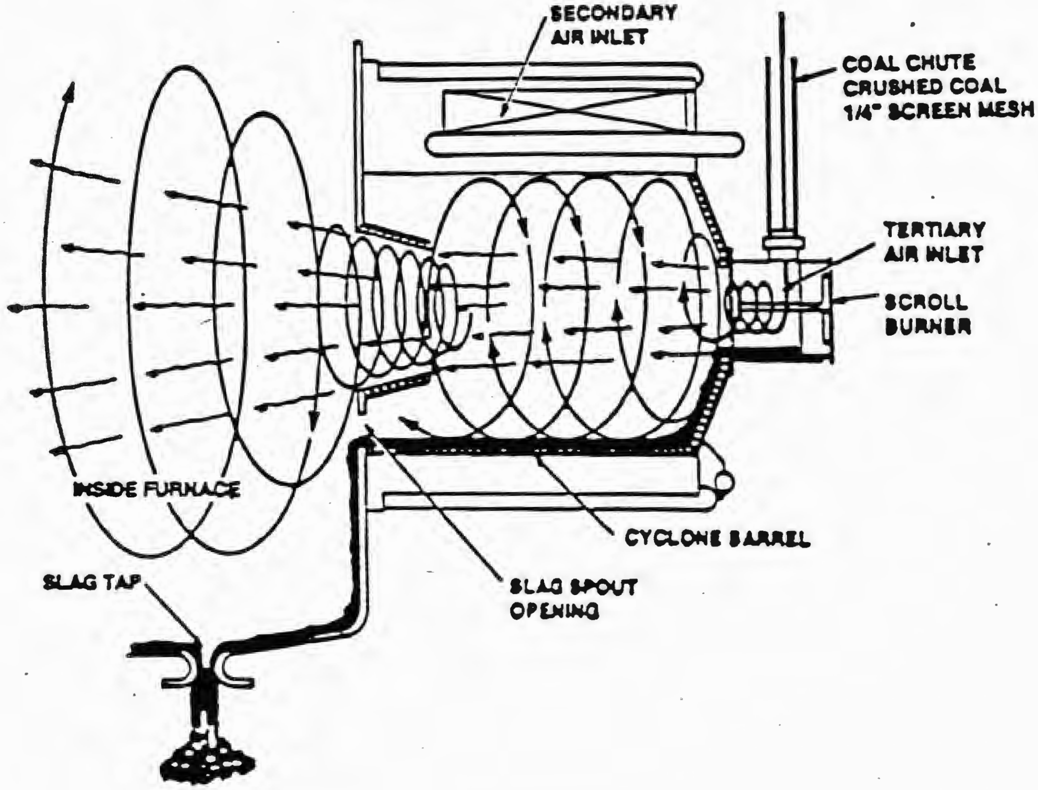

FIGURE 3-1 CYCLONE FURNACE

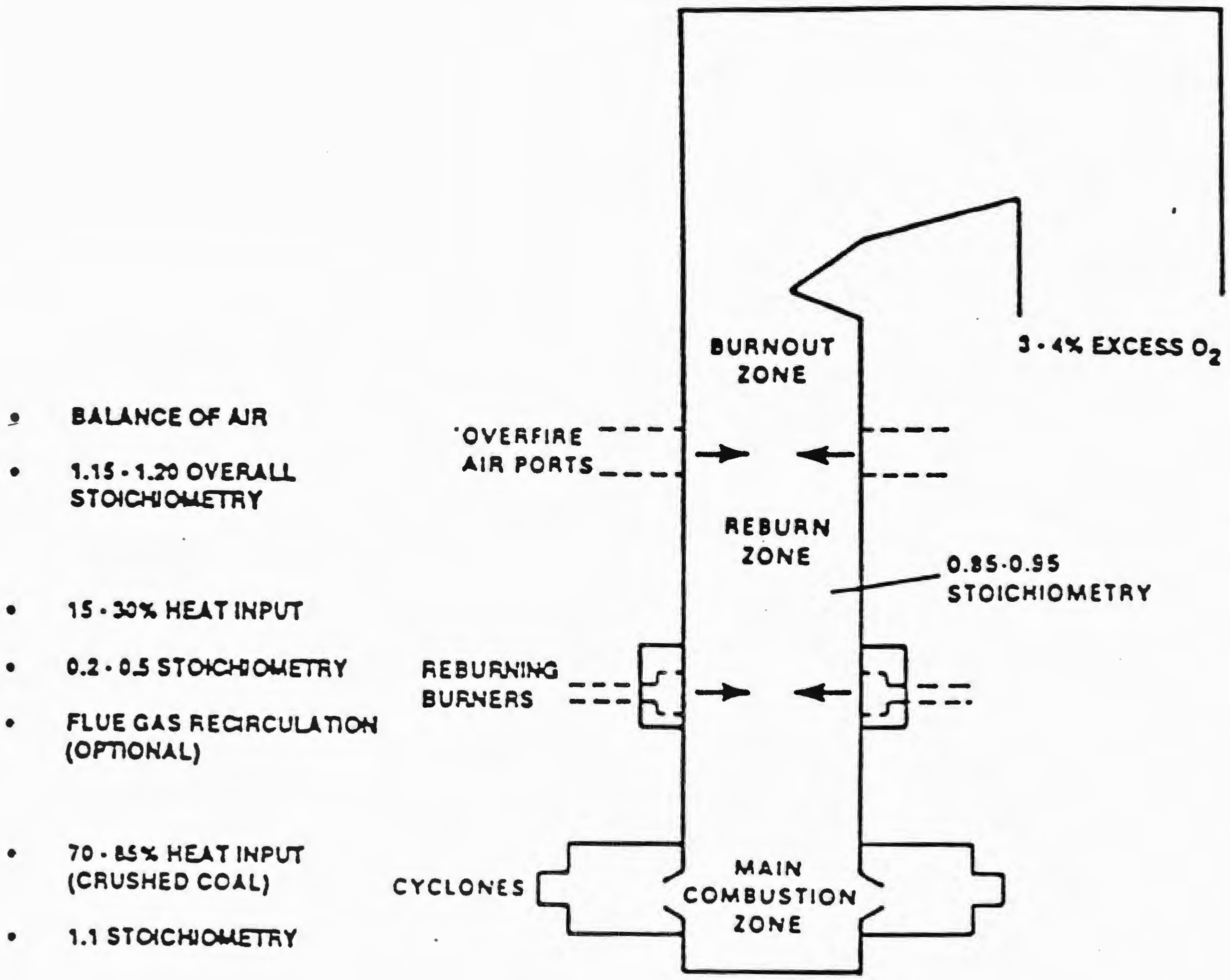

FIGURE 3-2 REBURNING TECHNOLOGY

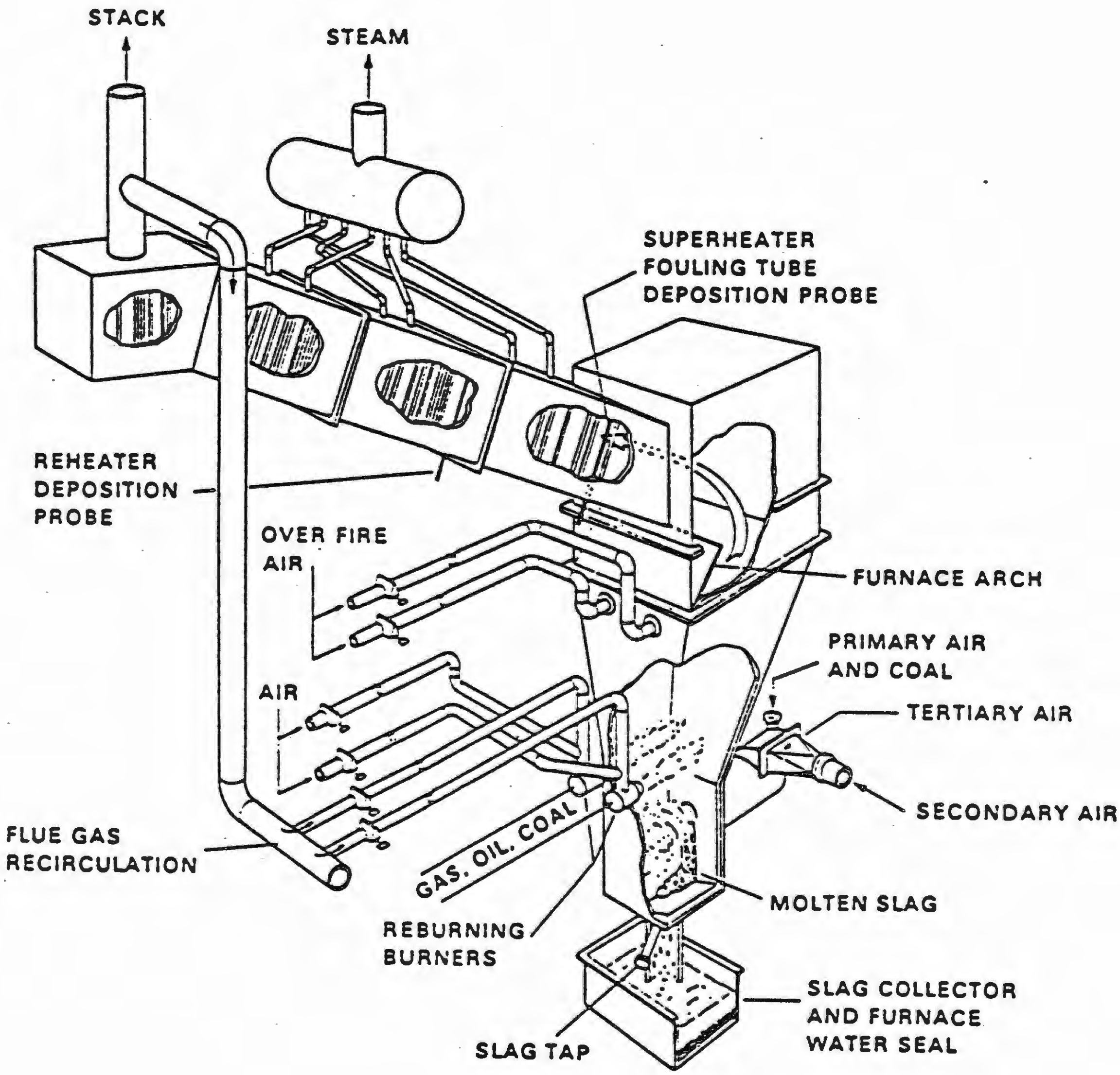

FIGURE 3-3 SMALL BOILER SIMULATOR (SBS)

4.0 STANDARDS OF SUCCESS

The performance goals of the project while burning Lignite in the cyclone and reburn zone are:

- Greater than 50 percent reduction in NO_x emissions, as referenced to uncontrolled (baseline) conditions at full load.
- No serious impact on cyclone combustor operation, boiler efficiency, or boiler fireside corrosion and deposition.

5.0 BACKGROUND

No commercially-demonstrated combustion modifications have significantly reduced NO_x emissions without adversely affecting cyclone operation. Past tests with combustion air staging achieved 15 - 30% reductions. Cyclone tube corrosion concerns due to the resulting reducing conditions were not fully addressed because of the short duration of these tests. Further investigation of staging for cyclone NO_x control was halted due to utility corrosion concern. Additionally, since no mandatory Federal/State NO_x emission regulation was enforced, no alternative technologies were pursued.

During the mid 1980's B&W started a research program to develop the reburn technology for NO_x control from cyclone boilers. B&W initiated a literature review to assess the potential of the technology. We discovered that although numerous laboratory, pilot-scale, and full-scale research on reburning had been performed, reburning had not been applied to cyclone boilers. B&W then initiated a 3-phase research program to develop coal reburning for cyclone boilers. To date, the application of coal reburning on a pilot or full- scale cyclone boiler is limited to B&W's current research program on the SBS and Wisconsin Power & Light's (WP&L) Nelson Dewey station. The other current research is the use of natural gas as the reburning in Ohio Edison's Niles station. These projects will be summarized below.

B&W and EPRI co-sponsored (Project RP-1402-30) an engineering feasibility study of reburning for cyclone boilers performed by B&W. The feasibility study revealed that the majority of cyclone-equipped boilers could successfully apply this technology in order to reduce their NO_x emission levels by approximately 50 -70%.[1] The major criteria that substantiated this potential was that sufficient furnace residence time does exist within these boilers in order to apply the technology. Economic comparison of coal reburning technology was compared to alternative technologies (see Table C-1). The economic comparison showed that coal reburn is not only a technically feasible but is also an economically viable technology in comparison to other alternatives. Thus, based upon these conclusions, the next level of confirmation, pilot-scale evaluation, was justified.

The Electric Power Research Institute (EPRI) and the Gas Research Institute (GRI) contracted with the Babcock & Wilcox Company (B&W) to perform a pilot-scale evaluation of thereburning technology for cyclone boiler NO_x emissions control. These pilot tests involved evaluating the potential of natural gas, oil, and coal as the reburning fuel in reducing NO_x emissions. All three reburning fuels showed over 50% NO_x reduction, while the side effects of the technology were minimal. [2] Figure C-1 shows that coal reburning and natural gas reburning results. The coal was Kittaning, an eastern bituminous coal from Pennsylvania. The figure also shows the results with Lammar coal, a medium bituminous coal from Indiana, that is currently being used for full-scale demonstration.

The comparison of these results with full-scale results will be discussed later.

The U.S. Department Of Energy (DOE) under its Clean Coal II solicitation is sponsoring B&W to perform a 100-MW_e demonstration of coal reburn technology for NO_x control from cyclone boilers. The host site is WP&L's Nelson Dewey station in Cassville, Wisconsin. As a part of the project B&W's six-million Btu/hr SBS facility was utilized to duplicate the operating practices of the Nelson Dewey station using the Lammar coal. During the full-scale testing, emission and performance data was collected before the coal reburn conversion to determine the NO_x reduction impact on boiler performance. Our scale-up methodology combined this combustion testing with physical and numerical modeling of the technology as applied to Nelson Dewey Unit No. 2. It provides a comprehensive test program not only for successful application of WP&L's unit, but for the cyclone population as a whole. [3,9] This scale-up methodology could be applied to Lignite firing cyclone boilers providing that pilot-scale data are available.

5.1 DOE CLEAN COAL TECHNOLOGY II CYCLONE REBURN DEMONSTRATION DESCRIPTION

The objective of the cyclone demonstration is to evaluate the applicability of the coal reburning technology for reducing NO_x emissions in full-scale cyclone-equipped boilers. The performance goals are:

1. Provide a technically and economically feasible low-NO_x alternative for cyclone boilers to achieve a greater than 50% NO_x reduction where one currently does not exist.
2. Show significant reductions in emission levels of oxides of nitrogen achieved at a low capital and very low operating cost (compared to the SCR technology).
3. Show that there is no need for a supplemental fuel. Reburn will be carried out using the present boiler fuel which is coal.
4. Provide a system that will maintain boiler reliability, operability, and steam production performance after retrofit.

To meet the above stated goals, the coal reburn project consists of three separate phases as shown in Figure 5-2. The project is currently in Phase III Optimization Testing.

A summary of the project participants follows:

5.2 DOE CLEAN COAL TECHNOLOGY II CYCLONE REBURN DEMONSTRATION ORGANIZATION

- Department of Energy - 50% funding co-sponsor
- B&W - prime contractor, project manager, and co-sponsor
- WP&L - host site utility and funding co-sponsor
- State of Illinois - funding co-sponsor
- Utility funding co-sponsors
- Acurex Corporation - testing subcontractor
- Sargent & Lundy - architect engineer subcontractor

The utility funding co-sponsors are:

1. Allegheny Power System
2. Atlantic Electric
3. Associated Electric Co-op, Inc.
4. Baltimore Gas & Electric
5. Iowa Electric Light & Power Company
6. Iowa Public Service
7. Missouri Public Service
8. Kansas City Power & Light
9. Northern Indiana Public Service Company
10. Tampa Electric Company
11. Kansas City Board of Public Utilities

Figure 5-3 shows a general overview of the reburning system and how it compares to the existing boiler arrangement. The basis of the reburning technology is the range of in-furnace operating stoichiometries along with reaction times. In order to accurately control the process, additions to the existing control system have to be made in order to control the fuel and air splits between the cyclones, reburning burners, and OFA ports.

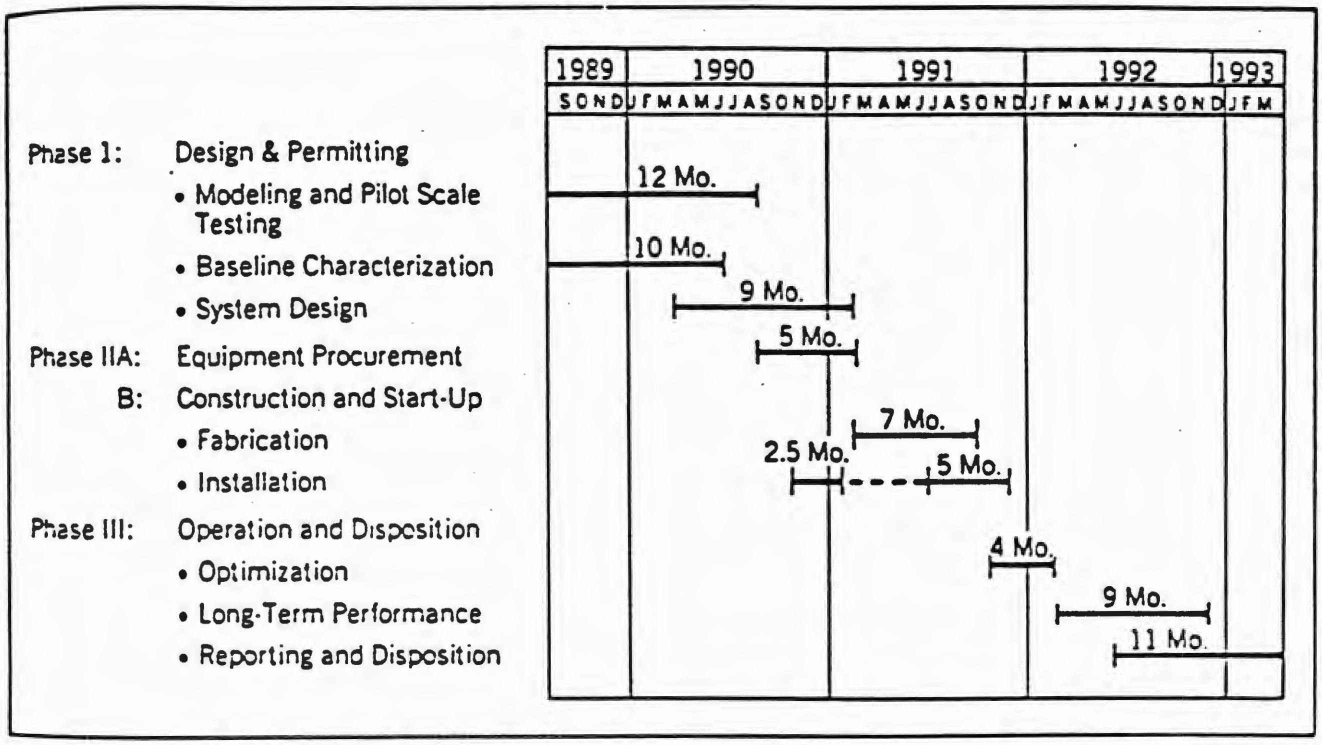

FIGURE 5-2 DOE CLEAN COAL II COAL REBURNING FOR CYCLONE BOILER NO_x CONTROL PROJECT SCHEDULE

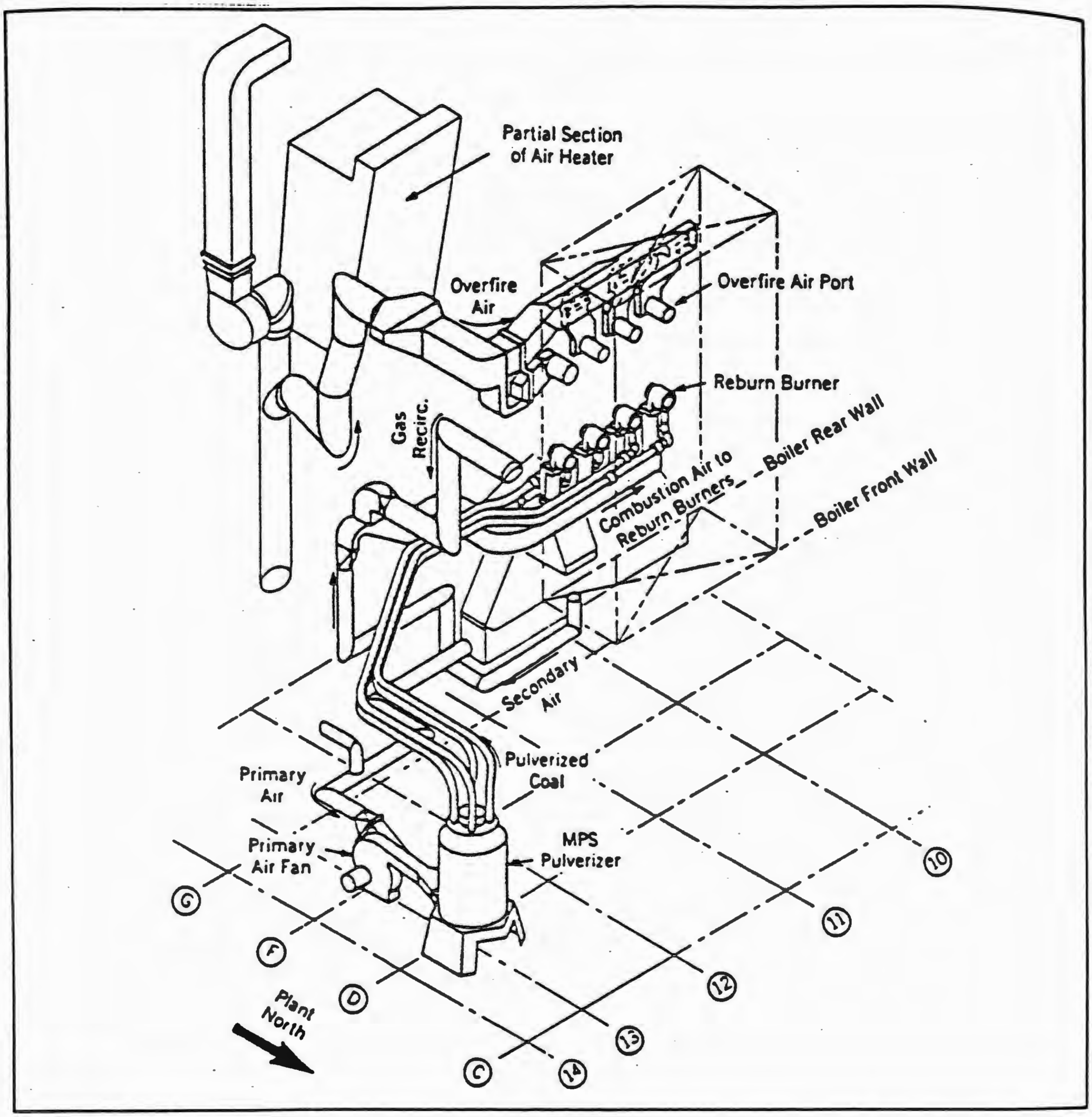

FIGURE 5-3 EQUIPMENT ARRANGEMENT FOR THE COAL REBURN PROJECT

6.0 QUALIFICATIONS

6.1 PROJECT ORGANIZATION

Mr. Curt Melland will coordinate the efforts of B&W in accordance with the wishes of the North Dakota Lignite Cyclone Users Group. Mr. Earl Backhaus will be the spokesman for the Coyote generating station, Mr. Merrill Lewis will be the spokesman for the Milton R. Young generating station, and Mr. Curt Melland will be the spokesman for the Leland Olds generating station.

The B&W team, as shown in Figure 6-1, will be directed by the Project Manager and the Contract Manager. Mr. Hamid Farzan, the Research and Development Coordinator, from the Research and Development Division, will be directly responsible for the planning, coordination, supervision and integration of research, engineering and other technical activities of the project. Mr. Farzan will be assisted on the day-to-day technical activities, by a team of experts from R&DD and B&W's operating divisions to perform the work in each task area. The total project responsibility and commensurate authority for directing and accomplishing all aspects of the project will reside with Mr. Yagiela, the Project Manager, who will be the prime contact between B&W and Basin Electric.

Mr. Roy W. Haggard, the Contract Manager from the Contract Research Division, will have the prime responsibility for all contractual matters between B&W and DOE. He will monitor adherence to the schedule, budgets, reporting requirements and contract terms.

6.2 MANAGEMENT CAPABILITIES

6.2.1 Resources and Management Capabilities

For over 125 years, B&W has been a leading designer, manufacturer, supplier and servicer of steam generation systems and auxiliary equipment, electrostatic precipitators, baghouses, wet and dry scrubbers, low-NO_x burners, selective catalytic reduction de-NO_x systems, and boiler performance measurement instrumentation. The Company has also developed and demonstrated advanced NO_x/SO_x, particulate and waste management control systems with DOE, EPA, EPRI, Ohio Coal Development Office and B&W funding. B&W is knowledgeable of the operation of all equipment in a coal-fired power plant and all gaseous, liquid and solid streams in and out and throughout the plant. Also, B&W has long established working relationships with both the Government and the utility industry. Therefore, B&W as a large organization, has all the resources necessary to successfully manage and complete the project work.

B&W's Alliance (Ohio) Research Center of the Research and Development Division (R&DD) will conduct the proposed project with support from the Fossil Power Division and Energy Services Division of the Power Generation Group in Barberton, Ohio. In addition to supporting the Operating Divisions' product/process requirements, R&DD performs contract R&D through the Contract Research Division.

B&W's Contract Research Division (CRD), with offices in Alliance, Ohio; Lynchburg, Virginia; Washington, D.C.; and Barberton, Ohio, provides marketing, proposal preparation, contracting, and contract management services for conducting research and development programs covering a wide range of interests.

Major customers include the Department of Energy, the Department of Defense, the Electric Power Research Institute, the U.S. Environmental Protection Agency, the Gas Research Institute, the Nuclear Regulatory Commission, state governments, and electric utilities. Contracts vary from multimillion-dollar demonstration programs involving multiple participants to small technical service agreements involving quick response.

Whatever the project's size or complexity, B&W's technical staff and facilities can be assembled to satisfy customer requirements. When a technical problem requires additional expertise, B&W can call upon other industry sources, create technology partnerships, obtain licenses, make contractual arrangements, work with overseas partners, or create internal development programs.

R&DD has conducted over 875 contract R&D projects through CRD without a single contract terminated for cause.

6.2.2 Related Experience

McDermott International is one of the broadest based energy services companies in the world. McDermott consists of five core businesses: marine construction, fossil power generation, commercial nuclear power, project management, and U.S. Government operations. A pioneer in offshore platform and pipeline construction, McDermott and its subsidiaries have over half a century of experience providing comprehensive services to the offshore oil and gas industry. In addition, McDermott engineers and builds processing plants for the oil, gas, petroleum, chemical, and mineral industries.

Babcock & Wilcox, McDermott's largest operating unit, has been committed to power generation since 1867. One of B&W's chief objectives is to help the Nation continue to use its abundant natural resources (coal, gas, uranium, oil and others) to produce electric power, while lessening the negative impact they have on the environment. B&W is actively developing new products and processes to address both energy needs and environmental concerns.

B&W's Power Generation Group designs, manufactures, services and markets fossil and nuclear steam generation systems, heat exchangers, and emission abatement systems for the utility industrial and marine sectors.

During the 125 year period, B&W has learned that there are large differences between coals. B&W has had to develop laboratory techniques to evaluate numerous characteristics of coals and their ash. These characteristics include:

1. The effect of ash deposits on radiant furnace heat transfer.
2. The tendency of deposits to plug convection passes of superheater.
3. The grindability, abrasiveness and erosiveness of coals.
4. The combustibility of coals.
5. The corrosiveness of ash.

B&W has also learned that good and controlled mixing of the combustion air and the fuel are necessary for high-combustion efficiency and NO_x control.

From 1953 to 1988, B&W completed delivery on 289 contracts for coal-fired boilers. Several of these contracts required delivery of more than one boiler. Of these contracts, 209 were pulverized coal-fired units, and 80 were for units equipped with cyclone furnaces which use a coarser crushed coal. Sixty-two of the pulverized coal orders and 25 of the cyclone furnace orders were for units that could operate above or below the critical pressure of water. Most, if not all of these units, are still in operation and B&W continues to supply parts and field services. One of the most important of these services is to evaluate the remaining life of older units and advise the customer about what needs to be done to extend the life.

In addition to the boilers equipped with cyclone furnaces, three additional designs of burners were included in the units. The larger units contain as many as 98 burners. The NO_x emissions from the older units do not meet the New Source Performance Standards, NSPS.

In the 1970's, B&W began to develop modifications of the non-cyclone burners to meet NO_x emission standards. More recently B&W has begun to develop modifications to cyclone-fired systems to reduce NO_x emissions to meet the standards. Over 3,000 of the pulverized-coal burners have been installed in about 70 boilers to meet NO_x emission requirements.

About 50% to 70% of the ash from the cyclone-equipped units is discharged from the bottom of the furnace as molten slag. The molten slag is quenched in a tank of water located below the bottom of the furnace. Recent environmental tests of solidified slag from the furnace of B&W's research unit have shown that it is benign. The remaining ash is discharged as dry material from hoppers in the convection passes and from the hoppers of the particulate collection equipment.

About 30% of the ash from the pulverized-coal-fired units is discharged from the bottom of the furnace. The remainder is discharged from downstream hoppers and particulate removal equipment.

All of the boilers ordered since 1953 were of the "water wall" construction, i.e., the walls are made of tubing in which water boils to produce steam.

Prior to 1950, B&W sold many "wet-bottom" or "slag tap" pulverized-coal-fired boilers. The ash from the furnaces of these boilers was tapped in the molten state. These boilers had refractory lined walls. The superheat temperature of these boilers was limited to less than 1100°F. One of the major reasons for this limitation is the corrosiveness of the products of combustion (including potential liquid phases in the ash deposits).

B&W services its boilers and those of other manufacturers.

6.2.3 Experience of Project Personnel

Earl Backhaus has worked in the lignite power generating industry for Montana Dakota Utilities for 37 years. He has served as Plant Manager of the Lewis & Clark generating station in Sidney, Montana and has been Power Production Manager since 1978.

Merrill Lewis has worked in the lignite power generating industry for 30 years. He joined Minnkota Power Cooperative in 1985 and presently serves as Director of Power Production. Mr. Lewis has a B.S. and M.S. in Mechanical Engineering from North Dakota State University.

Curt Melland is the Results Engineer at Basin Electric's Leland Olds generating station. He has worked for Basin Electric as a mechanical engineer for 15 years. Mr. Melland has a B.S. and M.S. in Mechanical Engineering from North Dakota State University.

Hamid Farzan is a Senior Research Engineer at B&W's Alliance Research Center. He has been a Project Manager for numerous R&D projects at ARC as well as various customer's plant sites. He has performed research and development work on retrofit low-NO_x technologies for utility and industrial boilers, and coordinated ARC's activities with the design and evaluation of the retrofit of Wisconsin Power & Light's 100 MW_e cyclone boiler at their Nelson Dewey Station. Hamid has a B.S. in Mechanical Engineering from Aryamehr University, an M.S. in Mechanical Engineering from Ohio State University, and is a PhD candidate at Ohio State University.

George Taylor is a Group Supervisor of the Analytical Chemistry Group at B&W's Alliance Research Center. His group performs a wide variety of chemical and physical analysis on fossil fuels, ash samples, water, metals, coal water slurries, and fire side and water side deposits from steam generating systems. George has a B.S. in Chemistry from Youngstown State University.

Aniefiok Akan-Etuk is a Research Engineer in the Combustion and Advanced Energy System Section of B&W's Alliance Research Center. He has performed combustion work for NO_x control including pilot-scale combustor conversion for burner testing. Aniefiok has a B.S. in Engineering Science from Harvard University, an M.S. in Mechanical Engineering from Stanford University, and is a PhD Candidate at Stanford University.

Larry Rodgers is a Group Supervisor of the Combustion & Advanced Energy Systems Section at B&W's Alliance Research Center. He is intimately familiar with combustion technologies developed for NO_x control including burner development and reburning. Larry has a B.S. in Mechanical Engineering from Purdue University, an M.S. in Mechanical Engineering from the University of Toledo, and a PhD from the University of Illinois.

Gerald Maringo is a Development Engineer in the Combustion Systems Section of B&W's Fossil Power Division. He has developed emission control technologies for cyclone-equipped boilers including reburning for NO_x control. Gerald has a Bachelor of Chemical Engineering from Cleveland State University.

Anthony Yagiela is a Project Manager of Utility Projects in B&W's Energy Service Division. He has overall responsibility for the management and execution of all company clean coal projects including WP&L's Nelson Dewey station cyclone boiler retrofit. Anthony has a B.S. and M.S. in Chemical Engineering from Carnegie Mellon University and an M.B.A. from the University of Pittsburgh.

Roy Haggard is a principal Contract Manager in B&W's Contract Research Division. He manages CRD contracts and has supervisory responsibilities for the contract management group. Roy has a B.S. in Mathematics from the University of Akron.

Detailed resumes of the project team are contained in Appendix A.

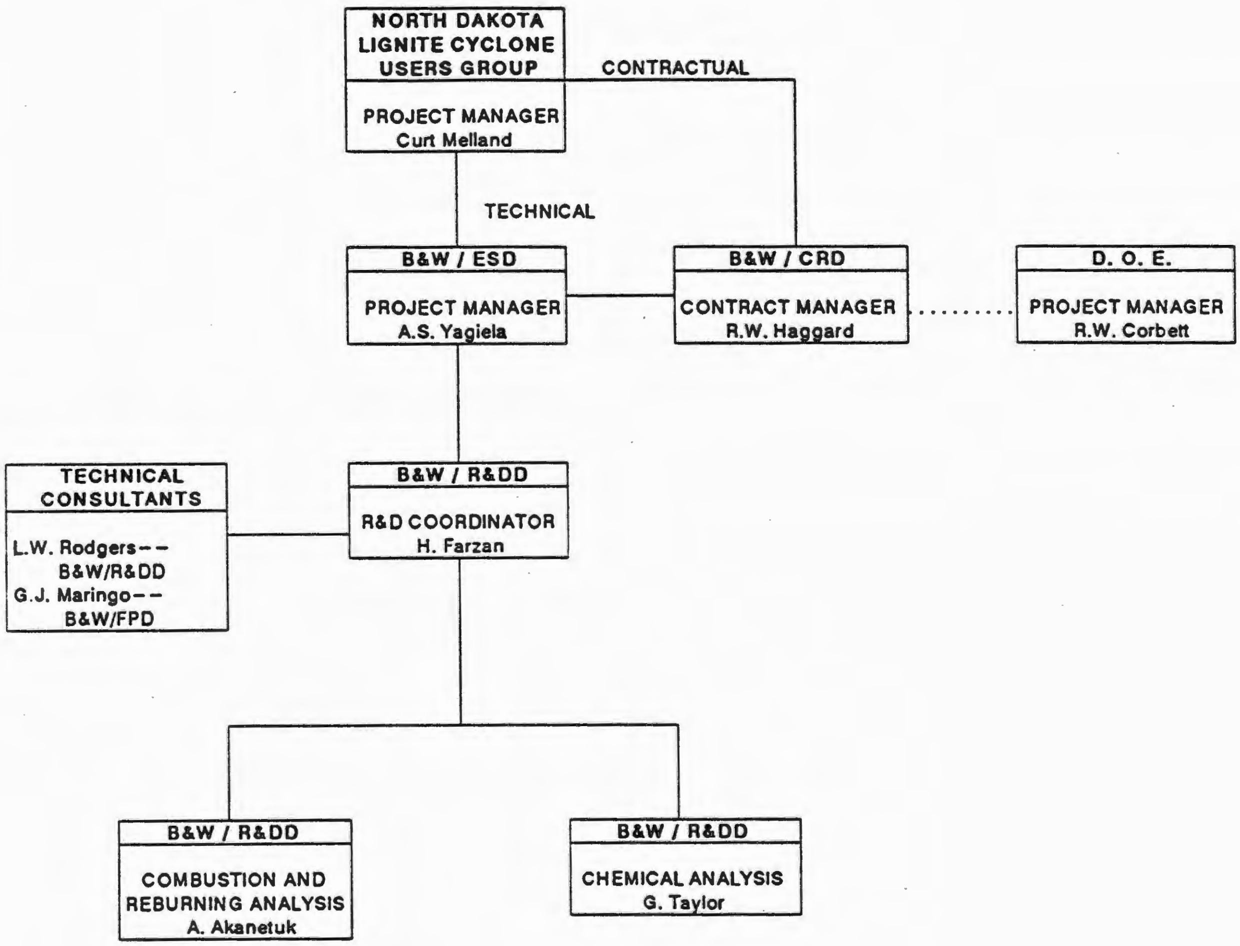

FIGURE 6-1 PROJECT ORGANIZATION

7.0 VALUE TO NORTH DAKOTA

There are currently no commercially-demonstrated combustion modification techniques for cyclone boilers which reduce NO_x emissions. To date, natural gas has been promoted as a reburn fuel in the majority of the US DOE-sponsored clean coal programs, because it was believed that natural gas would provide higher NO_x reduction and combustion efficiency than coal. Recent B&W pilot and full-scale research with some eastern bituminous coals has shown that coal as reburning fuel performs nearly as well as gas while maintaining acceptable boiler operating conditions. Lignite has not been evaluated at pilot or full scale. Thus, without further development of reburning for Lignite-fired cyclone boilers, pending stricter emission control legislation, utilities may have to either phase out cyclone-fired boilers, convert them to gas/oil firing or retrofit them with oil or natural gas reburning. This proposed technology represents a practical solution to the utilities that use Lignite in their cyclones (2,000 MW_e total capacity) in North Dakota. Following this pilot-scale study, it should be possible to use reburning for NO_x control with 100% Lignite instead of requiring up to 20% natural gas for reburn fuel. Therefore, this project will maintain the use of Lignite in cyclone boilers and preserve existing jobs associated with mining, cleaning, and firing North Dakota Lignite in cyclone boilers. If new clean air legislation disallows the use of lignite as the reburn fuel, annual lignite consumption would be reduced by 8-10 percent.

With successful application of reburning with Lignite more costly post-combustion control such as gas reburn or Selective Catalytic Reduction will not be necessary. Therefore, NO_x reduction in cyclone boilers could be achieved at a reasonable cost to the utility owners of cyclone boilers. By avoiding higher electric rates, industry in North Dakota will not be at a competitive disadvantage.

8.0 MANAGEMENT

8.1 COST AND SCHEDULE CONTROLS

Curt Melland, Project Coordinator, together with the B&W team will supervise, direct, plan, manage and analyze all the work assignments with the goal of accomplishing the technical objectives in a timely and cost-effective manner. This team will be available to commence work immediately upon award of a contract. This work will become a part of the Clean Coal II cyclone reburn demonstration, and the results will be published in the final clean coal report to DOE.

The team will perform the activities needed to effectively manage the project employing those management and planning tools and techniques normally used for controlling technical performance, schedule and budget. This includes the establishment and maintenance of management systems in accordance with the Contract Research Division (CRD) Policies and Procedures Manual for monitoring and controlling schedules, costs, technical performance, manpower, procurements and quality of work. These management systems will use the orderly application of standard Babcock & Wilcox management techniques and procedures, as appropriate, to the requirements of the contract. The techniques will be applied to this project management system based on proper planning, plan management and plan variance control.

Project planning usually is initiated with the preparation of the proposal baseline plans including project organization, work breakdown structure, resource allocation, schedule, cost plan, etc. Under execution of the resulting contract, the Contract Manager will issue documentation to the Research and Development and Operating Division for development of firm, functional baseline plans to process Work Orders. This early planning phase is necessary so that proper managing, monitoring and reporting can be performed in accordance with the final contract Terms and Conditions as opposed to the initial proposal plan. These baseline plans will be incorporated into an overall Work Plan which consists of the following major sections:

- Management Structure and Organization
- Management Processes
- Work Plan [including Contract Work Breakdown Structure (CWBS)]
- Cost/Schedule Baseline Plans
- Manpower Plan
- Quality Assurance
- Reporting

Once developed, the Work Plan will only be changed under controlled conditions and only after all elements are appropriately justified and adjusted within the overall contractual limits.

The Work Plan and baselines will be the major documents utilized by the Project Manager to monitor, control and report this project. Periodic monitoring against the baselines will be accomplished via developing appropriate information for the Project Plan and Status reports, designed to provide visibility in all areas of control, including, but not necessarily limited to:

- Technical Progress
- Milestone Status
- Start and Completion Dates
- Time to Completion
- Cost Expenditure
- Cost to Complete
- Variances and Corrective Action

Resources and work elements will be distributed to the Research and Development Division and other participating organizations, if applicable, through formal Interdivisional Work Orders (IWO's) issued by the Contract Manager. Further, more detailed distribution of funds will be provided for by cognizant division personnel, with the concurrence of the Project Manager, to the section level.

The cost limits established by the initial IWO will constitute the limits for the Research and Development and other participating organizations budgets. Project personnel will receive monthly printouts of actual vs. budget costs by category to the level of detail design into the Cost Plan. The Contract Manager will receive monthly printouts of individual divisional costs and in addition, a summary printout which accesses and displays all divisional actual vs. budget costs. This dual monitoring feature will allow for the integration of close-up, detailed evaluation of costs incurred by the Project Manager to be augmented by the evaluation of the Contract Manager from an overall perspective.

The results of this ongoing technical, cost and schedule monitoring system will be reviewed and evaluated with respect to the percent of work complete at least on a monthly basis. The monthly evaluation of progress by both the Contract Manager and Project Manager will be culminated by issuance of progress reports in accordance with project reporting requirements for both external and internal distribution. In addition, B&W participating divisions have in place, requirements for the periodic review of major projects including those projects funded by outside sources. Typical of this internal review is the Contract Research Division's monthly review of contracts for technical progress and cost/schedule control. This requirement provides for management attention/involvement from the onset and for the duration of the project.

In summary, the CRD system for the management of contract research:

- Has demonstrated the capability to meet or exceed varied sponsoring agency control and reporting requirements including DOE's Contractor Uniform Reporting System, DOD's reporting requirements, EPRI's Management Performance System, and numerous Government, utility, commercial and academic formats.
- Provides for a controlled, yet responsive environment to accommodate project changes.
- Can accommodate a broad spectrum of R&D projects, from small paper studies to those involving large-scale testing or development and fabrication and installation of hardware.
- Provides for automated accumulation of the clerical data required, yet demands team member evaluation of and judgement of the program status on a periodic (at least monthly) basis.

In particular, the cost control portion of the CRD Contract Management System:

- Has the capability to expand/compress level of cost accounting to accommodate proposal requirements and resulting contract cost plan level of detail.
- Provides automated accrual of actual costs by cost category geared to support frequency of contract report/evaluation requirements.
- Provides dual monitoring, by two automated systems, of detailed actual cost vs. budget plans for the total program.

8.2 QUALITY ASSURANCE

STANDARD PRACTICE

The Babcock & Wilcox Company has two levels of quality assurance under which the R&D Division programs are performed. They are Standard Practice and Specified Quality Assurance (SQA).

Standard Practices are those activities normally performed by the Research and Development Division (R&DD) when no specific requirements are imposed. Standard Practice is the baseline operating level designation for normal business practices of the Division. These practices are described in the STANDARD PRACTICE MANUAL[C] and are further implemented by R&DD Administrative Procedures.

When no specific conditions are customer-imposed upon the research project, Standard Practices are automatically applied, without additional cost to the customer.

The workscope is defined by way of project planning with the result being an agreement with the customer at the outset of the project. Changes to workscope are also agreed upon with the customer. Project records are maintained throughout the testing program to provide a historical account of all significant activities. The calibration of all measurement standards and measuring and test equipment used within the R&DD is controlled in order to assure that the measurements made are quantifiable and reproducible in terms of nationally recognized standards. Suppliers of instruments and calibration services are audited periodically to determine that calibration requirements are being satisfied.

The quality of work in a given project is in evidence within the final report which is prepared upon completion of the project. If there are specific customer requirements such as material certification, inspections, special test or calibration, they must be specified in the work authorizing document. The individual project leader and the R&DD management will ensure these requirements are met and appropriate documentation is on file.

Quality Assurance exercises general surveillance over projects conducted according to Standard Practice. Periodically, projects are selected randomly for audit for compliance with applicable R&DD Administrative Procedures and to criteria identified as good engineering practices.

Project records are available for customer review at the Research and Development Division. The retention of these records is in accordance with B&W policy (minimum one year) or as specified by customer requirements, applicable codes, standards, or specifications.

The Standard Practice level of quality assurance will be applied for the project outlined in this proposal.

9.0 TIMETABLE

The proposed project has been divided into four tasks, and the time to complete the entire project is estimated to be eight (8) months. B&W anticipates starting the project on May 1, 1992 and completing the project by December 31, 1992. Task 1 (planning and site preparation) is expected to be complete by August 15, 1992. Task 2 (Lignite evaluation) completion is targeted for August 31, 1992, and Task 3 (superheater deposition) is scheduled for completion by September 22, 1992. Task 4 (comparison coal) is scheduled for completion by September 15, 1992.

The overall project schedule is shown in Figure 9-1.

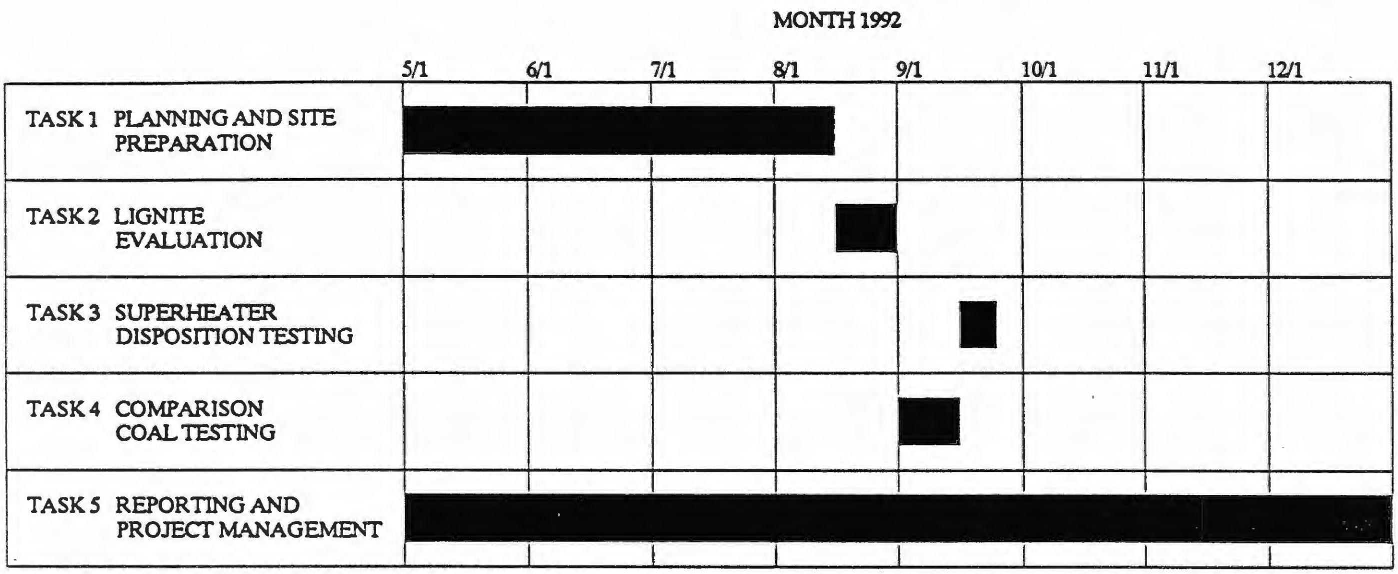

FIGURE 9–1 PROJECT SCHEDULE

10.0 BUDGET

Babcock & Wilcox performs its contract research work through its Contract Research Division headquartered at Alliance, Ohio. The Contract Research Division has the responsibility for business management and admnistration functions associated with contract research work performed within the Company.

The direct and indirect rates used for estimating are the most recently established provisional rates. However, notwithstanding any other provision, the rates in effect at the time of actual performance of the work will be charged, whether these rates are higher or lower than the rates used for estimating purposes. The direct labor and material dollars have been escalated according to when the particular tasks are to be performed. It has been assumed that work will begin on May 1, 1992 for the purpose of this cost estimate.

PROJECT COSTS

DOE Participate Fee	$108,360
B&W SBS Testing	364,103
Coal & Shipping	8,400
Project Coordination Travel & Administration	15,200
Contingency	23,937
Total	$520,000

FUNDING

North Dakota Lignite Research Council Grant	$260,000
North Dakota Lignite Cyclone Users Group	260,000
Total	$520,000