# PROJECT TITLE

ENGINEERING FEASIBILITY STUDY OF COAL REBURN APPLICATION
TO THE CYCLONE FURNACES IN NORTH DAKOTA LIGNITE
CYCLONE USERS GROUP

# 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

OCTOBER 1, 1993

# AMOUNT OF REQUEST

$170,985

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

September 24, 1993

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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# 1.0 ABSTRACT

There is an emerging reburning technology offering 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.

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 the configuration and cost from a reburn retrofit at each of the Users Groups' facilities. A previous grant showed that coal reburning with lignite coal is technically feasible producing $NO_x$ level comparable with other coals. This study will help determine the cost effectiveness of a lignite coal reburn retrofit. The reburn portion of these combustion systems would affect 8-10 percent of North Dakota's annual lignite consumption.

The North Dakota Lignite Cyclone Users Group will contract B&W to conduct the studies. In addition, studies will be conducted to ascertain the effect a reburn modification would have on key boiler performance parameters for each unit. The project will cost $341,970 and last nine months after the contract is signed with B&W. The North Dakota Lignite Cyclone Users Group is requesting the North Dakota Industrial Commission to issue a grant for the sum of $170,985 which is 50 percent of the funds needed to complete the project.

# 2.0 PROJECT SUMMARY

## Objectives

The objective of this study is to show that a reburn system retrofit on a North Dakota Lignite Cyclone Users Group boiler is feasible physically, is feasible economically and is feasible from a boiler performance standpoint.

## Introduction & Background

There are presently 105 operating, cyclone-equipped utility boilers representing approximately 14 percent of pre-New Source Performance Standards (NSPS) coal-fired generating capacity (over 26,000 MW). However, these units contribute approximately 21 percent 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 2,000 MW generating capacity.

Cyclone equipped boilers have a unique configuration which prevents application of standard low-$NO_x$ burner technology. 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 North Dakota Lignite Cyclone Users Group in conjunction with the State of North Dakota recently completed a pilot study at the B&W Alliance Research Facility. The study showed that the reburn methodology offered a technically feasible alternative for reducing lignite cyclone boiler $NO_x$ emissions.

## The Need For This Feasibility Study

The EPA will be making rules effecting cyclone boilers by 1997. The North Dakota Lignite Cyclone Users Group will need to find a cost-effective method for meeting the requirements of the new emission limits. This study will ascertain the physical, operational, and economical viability of a full scale retrofit for North Dakota Lignite Cyclone Boilers.

## Statement of Work

The feasibility study consists of five tasks.

- Task 1 answers the question "Can a reburn system be installed at each of the candidate sites?"
- Task 2 uses B&W's numerical modeling techniques to determine the optimum reburn burners and over fire air locations.
- Task 3 provides a budgetary cost estimate for a reburn system installation.
- Task 4 determines the effect of the reburn retrofit on boiler performance.
- Task 5 is a final report summarizing the results of the study.

The project is expected to take nine months after the finalization of the contract with B&W.

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 bituminous, sub-bituminous, and lignite 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 percent 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

The North Dakota Lignite Cyclone Users Group and Babcock and Wilcox Company (B&W) recently completed a pilot-scale evaluation of the reburning technology for $NO_x$ control from lignite-fired cyclone boilers. The purpose of this pilot-scale evaluation was to explore the potential of North Dakota lignite for $NO_x$ reduction and potential side effects of the technology such as unburned combustibles, boiler temperature profiles, fireside corrosion, and fireside deposition.

Also, B&W has been evaluating the reburn technology for $NO_x$ control from cyclone boilers at full-scale. B&W recently completed a 110-$MW_e$ demonstration of the reburn technology under the U.S. Department of Energy (DOE) Clean Coal II program. The demonstration host-site is the Wisconsin Power and Light's Nelson Dewey Station.

B&W's six-million Btu/hr facility, the Small Boiler Simulator (SBS), was used for pilot-scale evaluation of lignite for the reburning application. Two coals were used; Decker, a Western sub-bituminous coal (presently being fired at the Nelson Dewey station), and a representative lignite from North Dakota. The SBS $NO_x$ reduction levels with the North Dakota lignite was very encouraging; a nominal 45 to 58 percent $NO_x$ reduction was achieved depending upon the reburn zone stoichiometry. If gas recirculation was added into the reburn burners $NO_x$ reduction increased to 60 to 71 percent depending upon the reburn zone stoichiometry. The experimental results with western sub-bituminous coal from the SBS were compared to the full-scale results. Although the baseline $NO_x$ levels in the SBS were substantially higher than those observed at Nelson Dewey (770 versus 560 ppm), the resultant percent $NO_x$ reduction in the SBS was only 8-10 percent higher than the Nelson Dewey station. In contrast, the baseline SBS $NO_x$ emissions were very close to the data from the Leland Olds Station Unit 2. In order to determine if the SBS $NO_x$ reduction levels can be duplicated at the full-scale cyclone boilers utilizing North Dakota lignite,

we need to determine that the SBS mixing characteristics can be duplicated at full-scale cyclone boilers using North Dakota lignite. Therefore, The North Dakota Lignite Cyclone Users Group is proposing an engineering feasibility study to further develop the reburn technology for lignite-fired cyclone boilers in North Dakota.

## 3.2 OBJECTIVES

The objective of this study is to develop and evaluate reburn system conceptual designs for Basin Electric's Leland Olds Unit 2, Minnkota Power Cooperative's Milton R. Young Station, Unit 2, and Montana-Dakota Utilities Coyote Station, Unit 1. Specific objectives are as follows:

- to develop conceptual designs for the three aforementioned units
- to perform mixing analysis on one of the units to determine if mixing characteristics will be satisfactory
- to develop budgetary cost information for these reburn retrofits
- an optional objective is to evaluate performance of these boilers under the reburning conditions

## 3.3 PROJECT METHODOLOGY

The coal reburning technology has been characterized by B&W in the Small Boiler Simulator (SBS) for a number of coals including lignite. The SBS results have been numerically modeled to help understand the effects of mixing in the reburn zone. Under the Clean Coal Technology Program, Round II, the U.S. DOE co-funded a reburn demonstration at Wisconsin Power & Light Co.'s Nelson Dewey Generating Station Unit 2 in Cassville, WI. This was a 110 MW scale demonstration which correlates both the numerical modeling and actual test results at the 110 MW scale with SBS modeling and test results. Having tested the lignite coal in the SBS and having actual results both at full scale and in the SBS with other coals, prediction of $NO_x$ reduction performance in a full scale lignite demonstration is possible. In addition, the numerical modeling is a tool to help design the system to

maximize mixing and therefore $NO_x$ reduction. Using numerical modeling, the question of whether adequate mixing can be achieved in a 400 MW lignite-fired boiler will be answered.

Based on the results of SBS pilot-scale testing at the Alliance Research Center, lignite fired reburn technology may be applicable to Basin Electric's Leland Olds Unit 2, Minnkota Power Cooperative's Milton R. Young Station, Unit 2, and Montana-Dakota Utilities' Coyote Station, Unit 1 to reduce the $NO_x$ emissions. Reburn technology appears to be the lowest cost per KW technology available but never the less bears a considerable cost. Therefore, it is deemed prudent to evaluate the impact of a reburn system by having an Engineering Study performed. The Engineering Study is designed to provide justification to Basin Electric, Minnkota Power Cooperative, and Montana-Dakota Utilities management that a reburn system is feasible both physically and from a boiler performance standpoint.

In general, the Engineering Study will evaluate the application of reburn technology, identify the necessary boiler modifications as well as related boiler island modifications, and provide a preliminary design concept as well as budget prices for the boiler related components and equipment. Installation estimates will be provided for the boiler equipment changes recommended. The reburn fuel is lignite coal, the analysis of which will be provided by the utilities.

Finally, once the mixing question and the feasibility of locating reburn equipment is verified in each of the three plants, boiler performance should be studied.

## 3.4 STATEMENT OF WORK (SOW)

In order to achieve the stated objectives discussed in the Technical Approach, a statement of work consisting of 5 tasks is proposed.

**Task 1: Conceptual Design**

The objective of this task is to answer the question, "Can a reburn system be installed at each of the candidate sites?" To address this issue, the following activities will occur:

- Preliminary Equipment Layout - A B&W process engineer will approximate the number and sizes of various reburn system components as well as locate the equipment within the plant for each of the three units. System flow rates will be calculated to allow equipment sizing as well as ductwork and piping sizing. Balance of plant drawings will be provided by the respective utilities.

- Site Visits - All three sites will be visited and walked down with the preliminary information in hand. The process engineer as well as a graphics representative will participate in the unit walkdowns. The objective will be to verify whether the preliminary layout is feasible and what modifications are necessary to allow the reburn system to be installed at each plant.

- Finalize the Conceptual Layout - Based on the site visit to each of the three units, layout drawings will be developed showing equipment location on the boiler and within the boiler house. Suitable locations for the terminal points on the boiler based on assumed sizes of the reburn equipment will be detailed. Final reburn equipment sizing will not be developed in this study. This activity is part of a material contract scope.

**Task 2: Numerical Modeling**

The purpose of this task is to determine the baseline flow patterns in order to identify optimum reburn burners and overfire air (OFA) locations. Since these three boilers are similar, one of the boilers will be selected for numerical analysis. As a first task, boiler operational data will be gathered. The majority of this data has

already been gathered during the pilot-scale evaluation. The rest of the data will be compiled in order to numerically simulate the boiler flow patterns. B&W's FORCE model will be utilized to determine the baseline flow patterns and velocity profiles. These baseline boiler flow patters and velocity profiles provide an input into Task 1 for definition of conceptual design of the reburn system. Boiler space availability for the reburn burner/OFA locations is another input for determination of the conceptual design as described in Task 1. After completion of this conceptual reburn system, B&W will analyze it using the FORCE model to determine if adequate mixing can be achieved with the conceptual design. Full load conditions will be utilized in this study. The output variables of the modeling are as follows:

- boiler flow patterns (baseline, and reburn)
- % flow < stoichiometry of one versus boiler evaluation for the reburn system
- stoichiometric distribution for the reburn system

These results then will be compared with the existing mixing performance from the Nelson Dewey and SBS reburn systems. B&W proposes a scale-up methodology using pilot-scale evaluation and numerical modeling techniques. Appendix B shows B&W's scale-up technique that is proposed to be utilized in determination of mixing performance at the full-scale boiler.

**Task 3: Budgetary Cost For a Reburning Retrofit**

For each of the three plants, a budgetary price will be developed for the reburn system scope normally performed by B&W. This includes material and installation costs for the following items:

1. Reburn burners/burner management system/ignitors
2. Overfire air ports
3. Primary/secondary air systems

4. Coal pipes
5. Flues, ducts and expansion joints
6. Coal pulverizer
7. Boiler pressure part modifications
8. Air monitors/control dampers
9. Gas recirculation system modifications

Balance of plant items, the material and installation costs, and budgetary estimates will be provided by B&W using historial cost data. These include the following:

1. Coal handling modifications
2.. Storage silo for the reburn system pulverizer
3. Foundations
4. Additional buildings
5. Structural steel modifications inside the boiler house
6. Power distribution
7. Distributed control system upgrade to handle reburn

**Task 4: Boiler Performance (Optional)**

Once it is determined whether installation of a reburn system is feasible, boiler performance input will be addressed.

The expected boiler performance with the reburn system in service will be calculated using B&W design models. The study will confirm whether the units will maintain current output and if improvements can be expected. Unit performance will be calculated and tabulated into a performance summary sheet. Existing

components of the boilers proper will be evaluated for application with the new reburn operating conditions. Inadequate components will be listed with recommended upgrades. Comments on impact to FEGT, slagging and fouling will be addressed. The performance studies will be based on lignite fuel. The coal analysis will be provided by the utilities. A series of two loads (MCR and Control) will be modeled at each of the three units. Either or all of the two loads specified may be revised by the utilities at their discretion.

**Task 5: Reporting**

A final report will be submitted to summarize the results of this study.

## 3.5 ANTICIPATED RESULTS

The completion of this study will dictate the number, size, and location of reburn burns and overfire air ducts required to achieve optimum $NO_x$ reductionin a full size boiler. In addition, the effect of these modifications on boiler performance i.e. (steam temperature, furnace exit gas temperature, air heater exit gas temperature and steam attemperation requirements) will be quantified. If undersirable performance characteristics are uncovered, additional boiler modifications may be required. Finally, the capital cost of the reburn retrofit will be determined to allow comparison with other $NO_x$ reduction techniques that are in development.

## 3.6 THE NEED FOR THIS PROJECT

The EPA will be making rules effecting cyclone boilers by 1997. The North Dakota Lignite Cyclone Users Group will need to find a cost-effective method of meeting the requirements of the new emission limits. This study will ascertain the physical, operational, and economic viability of a full scale retrofit from North Dakota Lignite Cyclone Boilers.

## 3.7 ENVIRONMENT & ECONOMIC IMPACT

This project has no environmental impact while it is underway. While the economic impact of a full scale reburn retrofit may be significant in the future, this project would have a minimal effect.

# 4.0 STANDARDS OF SUCCESS

- Determine configuration and equipment general arrangements of a reburn system retrofit.

- Determine costs of full scale reburn retrofit in North Dakota Lignite Cyclone Boilers.

- Determine boiler performance effect of full scale reburn retrofit on North Dakota Lignite Cyclone Boiler.

# 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 percent 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-1980s 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 percent. 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. The economic comparison showed that coal reburn is not only a technically feasible but may be 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 the reburning 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 percent $NO_x$ reduction, while the side effects of the technology were minimal.

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. B&W's scale-up methodology combined this combustion testing with physical and numerical modeling of the technology as applied to Nelson Dewey Unit 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. This scale-up methodology would be applied to Lignite firing cyclone boilers.

# 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. Gerald Gress 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 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, by a team of expert 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.

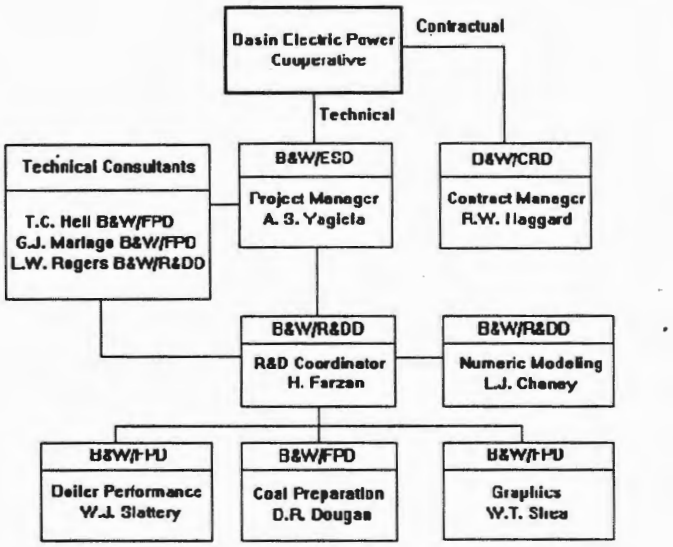


**Figure 1**

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 Basin Electric. 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 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 Division's 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 percent to 70 percent 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 percent 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 the 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

Gerald L. (Gary) Gress has worked in the electric utility industry for 22 years. He has been Plant Manager and Director of Power Production for Southern Indiana Gas and Electric Company. He joined Montana-Dakota Utilities in August, 1993 and presently serves as Power Production Manager. Mr. Gress has a B.S. degree in Electrical Engineering Technology from Purdue University and a M.B.A. from the University of Evansville in Indiana.

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, and M.S. in Mechanical Engineering from Ohio State University, and is a PhD candidate at Ohio State University.

Larry Chaney is a Research Engineer in the Heat Transfer & Fluid Mechanics Section of B&W's Alliance Research Center. He has conducted three-dimensional, numerical flow and combustion analysis of cyclone boiler reburning systems. Larry has a B.S. in Mechanical Engineering from Saginaw Valley State University and a M.S.

in Mechanical Engineering from the University of Michigan.

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.

Thomas Heil is a Technical Consultant in the Engineering Technology Section of B&W's Fossil Power Division. He is responsible for heat transfer calculations, on-line boiler diagnostics, boiler performance tests, and analysis of field data. Thomas has a B.S. in Mechanical Engineering from the University of South Carolina.

William Slattery is the Manager of Utility Performance Engineering in B&W's Fossil Operations Division. He is responsible for the application engineering functions for utility boiler performance and has designed utility boilers to meet functional requirements. Bill has a BME in Mechanical Engineering from Ohio State University.

Donald Dougan is a Product Design Specialist in B&W's Fossil Operations Division. He is responsible for pulverizer research, fuel technology, design standards, liaison with other departments for mill performance.

Donald has a B.S. in Mechanical Engineering from Purdue University.

William Shea is a Supervisor of Utility Energy Service Graphics in B&W's Fossil Power Division. He is responsible for the graphics and design layouts for all utility projects assigned to his section.

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 proposed project team are contained in Appendix A.

# 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 U.S. 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, western sub-bituminous, and North Dakota lignite has shown that coal as 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. 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. With full development of the technology with North Dakota lignite, it should be possible to use reburning for $NO_x$ control with 100 percent Lignite instead of requiring up to 20 percent 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.

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 reveive 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 autmented 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 wtih 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 reiew is the Contract Reserach Division's monthly review of contracts for technical progress and cost/schedule control. This requirements 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 numeous 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 documentaion 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 period of performance is nine months. A schedule reflecting the individual spans for each of the tasks is shown below:

**MONTHS**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Task 1 Conceptual Design | | | | | | | | | |
| Task 2 Numerical Modeling | | | | | | | | | |
| Task 3 Budget Cost/Retrofit | | | | | | | | | |
| Task 4 Boiler Perf. (Optional) | | | | | | | | | |
| Task 5 Reporting | | | | | | | | | |

# 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 administration 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 December 1, 1993, for the purpose of this cost estimate.

## PROJECT COSTS

| | |
|---|---|
| Task 1 - Conceptual Design | $112,094 |
| Task 2 - Numerical Modeling | 118,755 |
| Task 3 - (included in pricing ofTask 1) | No Charge |
| Task 4 - Boiler Performance | 107,121 |
| Task 5 - Report (included in pricing of other tasks) | No Charge |
| Project Coordination | 4,000 |
| Total | $341,970 |

## FUNDING

| | |
|---|---|
| North Dakota Lignite Research Council Grant | $170,985 |
| North Dakota Lignite Cyclone Users Group | 170,985 |
| Total | $341,970 |