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Comprehensive Report to Congress Clean Coal Technology Program

Demonstration of Coal Reburning for Cyclone Boiler NO_x Control

A Project Proposed By: Babcock & Wilcox Company

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U.S. Department of Energy
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1.0 EXECUTIVE SUMMARY

In December 1987, Public Law No. 100-202, as amended by Public Law No. 100-446, provided $575 million to conduct cost-shared Innovative Clean Coal Technology (ICCT) projects to demonstrate emerging clean coal technologies that are capable of retrofitting or repowering existing facilities. To that end, a Program Opportunity Notice (PON) was issued by the Department of Energy (DOE) in February 1988, soliciting proposals to demonstrate technologies capable of being commercialized in the 1990's that are more cost effective than current technologies and capable of achieving significant reduction of sulfur dioxide (SO_2) and/or nitrogen oxides (NO_x) emissions from existing coal burning facilities, particularly those that contribute to transboundary and interstate pollution.

In response to the ICCT PON, fifty-four proposals were received by the DOE in May 1988. An additional proposal, received in another office, was also judged to be eligible for consideration in this second round of the Clean Coal Technology (CCT) program. After evaluation, sixteen projects were selected for award in September 1988. These projects involve both advanced pollution control equipment that can be "retrofitted" to existing facilities and "repowering" technologies that not only reduce air pollution but also increase generating plant capacity.

One of the proposals selected is the Babcock & Wilcox Company (B&W) project that will demonstrate an innovative technology to reduce nitrogen oxide emissions from coal-fired cyclone boilers. This technology consists of burning a portion of the coal fuel in an oxygen-deficient atmosphere in a reburning zone. To destroy the nitrogen oxides formed in the main combustion zone, the reburning is located above the combustion zone of the boiler.

Nitrogen oxides (NO_x) are formed when nitrogen in the fuel or nitrogen in the combustion air oxidizes. The coal reburning process reduces NO_x in the main furnace through the use of multiple combustion zones. The main combustion zone uses 70 to 80% of the total heat equivalent fuel input to the boiler and slightly less than normal combustion air input. The balance of the coal (20 to 30%), along with significantly less than the theoretically determined requirement of air, is fed to the boiler above the cyclones in the reburning zone to create an oxygen-deficient condition. The NO_x formed in the cyclone burners reacts with the resultant reducing flue gas to be converted into nitrogen and water in this zone. The completion of the combustion process occurs in the third zone, called the burnout zone, where the balance of the combustion air is introduced. Application of this process results in a reduction of NO_x emissions by greater than 50%.

The project will be conducted at the 100 megawatt (MWe) coal-fired Nelson Dewey Station Unit No. 2, owned by Wisconsin Power & Light Company (WP&L). The plant is located in Cassville, Wisconsin, as shown in Figure 1.

The WP&L plant is presently in commercial operation. The intent of this project is to demonstrate the technical and economic viability of retrofitting coal reburning on a cyclone boiler that is representative of those constructed before New Source Performance Standards (NSPS) became effective. Reburning pilot tests have been conducted and the results indicate that the technology is ready for a full-scale demonstration.

This demonstration project will be performed over a forty-three month period and will include design, permitting, equipment installation, testing, data analysis, and result reporting. Field testing is scheduled to begin in late 1991. Overall project completion is scheduled to occur in early 1993.

The total estimated cost of the project is $10,655,261 of which $5,072,631 will be funded by DOE and $5,582,630 will be provided by B&W and its co-funders, including Wisconsin Power & Light Company, Illinois Department of Energy and Natural Resources, the Electric Power Research Institute, and utility sponsors.

2.0 INTRODUCTION AND BACKGROUND

The domestic coal resources of the United States play an important role in meeting current and future energy needs. During the past 15 years, considerable effort has been directed to developing improved coal combustion, conversion, and utilization processes to provide efficient and economic energy options. These technology developments permit the use of coal in a cost-effective and environmentally acceptable manner.

2.1 Requirement for Report to Congress

In December 1987, Congress made funds available for the ICCT Program in Public Law No. 100-202, "An Act Making Appropriations for the Department of Interior and Related Agencies for the Fiscal Year Ending September 30, 1988, and for Other

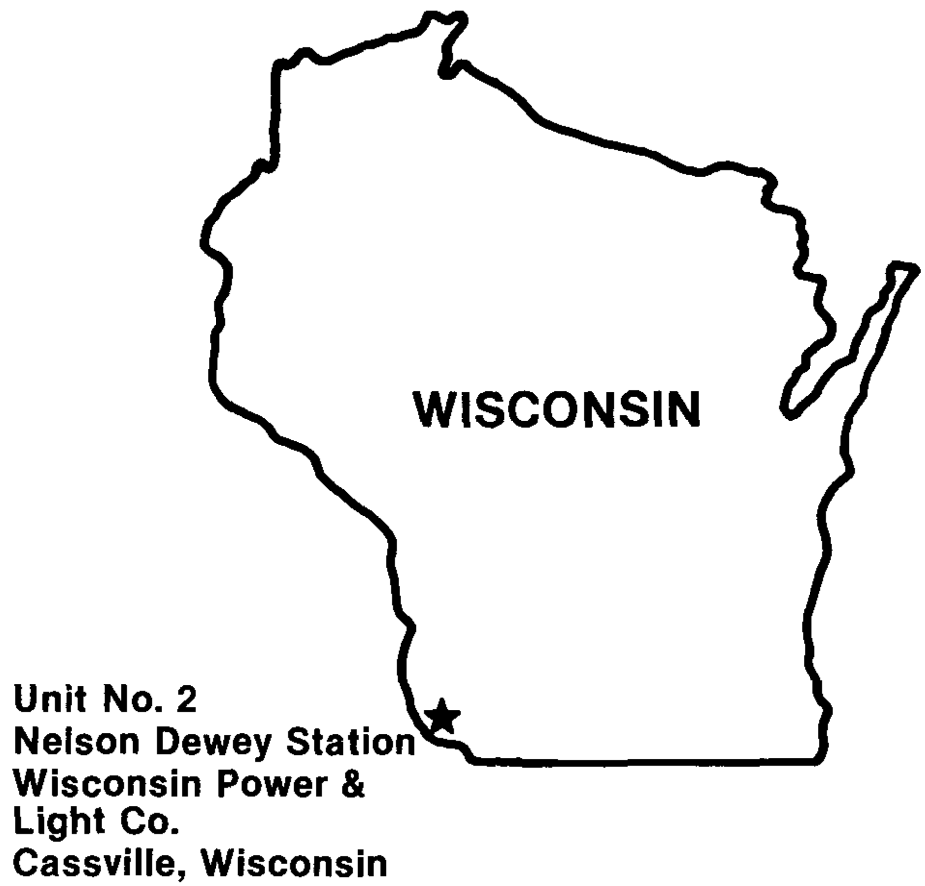

FIGURE 1. B&W CYCLONE BOILER COAL REBURNING DEMONSTRATION PROJECT SITE LOCATION.

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Purposes" (the "Act"). This Act provided funds for the purpose of conducting cost-shared clean coal technology projects to demonstrate emerging clean coal technologies that are capable of retrofitting or repowering existing facilities and authorized DOE to conduct the ICCT Program. Public Law No. 100-202, as amended by Public Law No. 100-446, provided $575 million, which will remain available until expended, and of which (1) $50,000,000 was available for the fiscal year beginning October 1, 1987; (2) an additional $190,000,000 was available for the fiscal year beginning October 1, 1988; (3) an additional $135,000,000 will be available for the fiscal year beginning October 1, 1989; and (4) $200,000,000 will be available for the fiscal year beginning October 1, 1990. Of this amount, $6,782,000 will be set aside for the Small Business and Innovative Research Program, and is unavailable to the ICCT Program.

In addition, after the projects to be funded had been selected, DOE prepared a comprehensive report on the proposals received. The report was submitted in October 1988 and was entitled "Comprehensive Report to Congress: Proposals Received in Response to the Innovative Clean Coal Technology Program Opportunity Notice" (DOE/FE-0114). Specifically, the report outlines the solicitation process implemented by DOE for receiving proposals for ICCT projects, summarizes the project proposals that were received, provides information on the technologies that are the focus of the ICCT Program, and reviews specific issues and topics related to the solicitation.

Public Law No. 100-202 directed DOE to prepare a full and comprehensive report to Congress on each project selected for award under the ICCT Program. This report is in fulfillment of this directive and contains a comprehensive description of the Demonstration of Coal Reburning for Cyclone Boiler NO_x Control project.

2.2 Evaluation and Selection Process

A PON was issued by DOE on February 22, 1988, to solicit proposals for conducting cost-shared ICCT demonstrations. Fifty-five proposals were received. All proposals were required to meet the six qualification criteria provided in the PON. Failure to satisfy one or more of these criteria resulted in rejection of the proposal. Proposals that passed Qualification Review proceeded to Preliminary Evaluation. Three preliminary evaluation requirements were identified in the PON. Proposals were evaluated to determine whether they met these requirements; those proposals that did not were rejected.

Of those proposals remaining in the competition, each offeror's Technical Proposal, Business and Management Proposal, and Cost Proposal were evaluated. The PON provided that the Technical Proposal was of somewhat greater importance than the Business and Management Proposal and that the Cost Proposal was minimal importance; however, everything else being equal, the Cost Proposal was very important.

The Technical Evaluation Criteria were divided into two major categories. The first, "Commercialization Factors", addressed the projected commercialization of the proposed technology. This was different from the proposed demonstration project itself and dealt with factors involved in the commercialization process. The criteria in this section provided for consideration of (1) the potential of the technology to reduce total national emissions of SO_2 and/or NO_x emissions and reduce transboundary and interstate air pollution with minimal adverse environmental, health, safety, and socio-economic (EHSS) impacts; and (2) the potential of the proposed technology to improve the cost-effectiveness of controlling emissions of SO_2 and NO_x when compared to commercially available technology options.

The second major category, "Demonstration Project Factors," dealt with the proposed project itself. Criteria in this category provided for the consideration of the following: the technical readiness for scale-up; the adequacy and appropriateness of the demonstration project; the EHSS and other site-related aspects; the reasonableness and adequacy of the technical approach; and the quality and completeness of the Statement of Work.

The Business and Management Proposal was evaluated to determine the business and management performance potential of the offeror, and was used as an aid in determining the offeror's understanding of the technical requirements of the PON. The Cost Proposal was reviewed and evaluated to assess the validity of the proposer's approach to completing the project in accordance with the proposed Statement of Work and the requirements of the PON.

Consideration was also given to the following program policy factors:

(1) The desirability of selecting projects for retrofitting and/or repowering existing coal-fired facilities that collectively represent a diversity of methods, technical approaches, and applications (including both industrial and utility);

(2) The desirability of selecting projects that collectively produce some near-term reduction of transboundary transport of emitted SO_2 and NO_x; and,

(3) The desirability of selecting projects that collectively represent an economic approach applicable to a combination of existing facilities that significantly contribute to transboundary and interstate transport of SO_2 and NO_x in terms of facility types and sizes, and coal types.

The PON also provided that, in the selection process, DOE would consider giving preference to projects located in states where the rate-making bodies of those states treat innovative clean coal technologies the same as pollution control projects or technologies. The inclusion of this project selection consideration was intended to encourage states to utilize their authorities to promote the adoption of innovative clean coal technology projects as a means of improving the management of air quality within their areas and across broader geographical areas.

The PON provided that this consideration would be used as a tie breaker if, after application of the evaluation criteria and the program policy factors, two projects received identical evaluation scores and remained essentially equal in value. This consideration would not be applied if, in doing so, the regional geographic distribution of the projects selected would be altered significantly.

An overall strategy for compliance with the National Environmental Policy Act (NEPA) was developed for the ICCT Program, consistent with the Council on Environmental Quality regulations for implementing NEPA and the DOE guidelines for compliance with the act. This strategy includes both programmatic- and project-specific environmental impact considerations during and after the selection process.

In light of the tight schedule imposed by Public Law No. 100-202 and the confidentiality requirements of the competitive PON process, DOE established alternative procedures to ensure that environmental factors were fully evaluated and integrated into the decision-making process to satisfy its NEPA responsibilities. Offerors were required to submit both programmatic and project-specific environmental data and analyses as a discrete part of each proposal submitted to DOE.

The DOE strategy for NEPA compliance has three major elements. The first involves preparation of a programmatic environmental impact analysis for public distribution, based on information provided by the offerors and supplemented by DOE, as necessary. This environmental analysis documents that relevant environmental consequences of the ICCT Program and reasonable programmatic alternatives are considered in the selection process. The second element involves preparation of a preselection project-specific environmental review for internal DOE use. The third element provides for preparation by DOE of publicly available site-specific NEPA documents for each project selected for financial assistance under the ICCT Program.

No funds from the ICCT Program will be provided for detailed design, construction, operation, and/or dismantlement until the third element of the NEPA process has been successfully completed. In addition, each Cooperative Agreement entered into will require an Environmental Monitoring Plan (EMP) to ensure that significant technology, project, and site-specific environmental data are collected and disseminated.

After considering the evaluation criteria, the program policy factors, and the NEPA strategy, sixteen proposals were selected for negotiation for award. The Coal Reburning for Cyclone Boiler NO_x Control proposal submitted by B&W was one of these proposals.

3.0 TECHNICAL FEATURES

3.1 Project Description

The B&W project will demonstrate the reduction of NO_x emissions by coal reburning in cyclone boilers, and will demonstrate the suitability of coal reburning for retrofit applications.

The project will be conducted at Wisconsin Power & Light (WP&L) Company's 100 MWe

Nelson Dewey Station Unit No. 2. The goal of this project is to evaluate the technical and economic feasibility of coal reburning in full-scale, cyclone boilers. If successful, it will achieve a greater than 50% reduction in NO_x emissions.

3.1.1 Project Summary

Project Title:	Demonstration of Coal Reburning for Cyclone Boiler NO_x Control
Proposer:	Babcock & Wilcox Company (B&W)
Project Location:	Wisconsin Power & Light Company (WP&L) Nelson Dewey Station Unit No. 2 Cassville, Grant County, Wisconsin
Technology:	Flue Gas Cleanup by Coal Reburning for NO_x Control
Application:	Retrofit onto Coal-Fired Utility Cyclone Boilers
Types of Coal Used:	Southern Indiana Bituminous Coal (1.67 to 1.92% sulfur)
Product:	Environmental Control Technology Greater than 50% Removal of NO_x
Project Size:	100 MWe
Project Start Date:	September 1, 1989[1]
Project End Date:	March 31, 1993

[1] In accordance with the PON provision, the participant is proceeding with the project at its own risk pending execution of the Cooperative Agreement by the Government.

3.1.2 Project Sponsorship and Cost

Project Sponsor:	Babcock & Wilcox Company	
Proposed Co-Funders:	U.S. Department of Energy Wisconsin Power & Light Company Illinois Department of Energy and Natural Resources Electric Power Research Institute Utility Sponsors	
Estimated Project Cost:	$10,655,261	
Project Proposed Cost Distribution:	Participant Share(%)	DOE Share(%)
	52.4	47.6

3.2 Coal Reburning Process

3.2.1 Overview of Process Development

The Babcock & Wilcox Company has developed the coal reburning process for application to B&W-constructed cyclone boilers. B&W has proven that the technology is applicable for cyclone-boiler NO_x control on their 6 MM Btu/hr cyclone test facility. The technology was developed as an extension of the In-Furnace NO_x Reduction (IFNR) process developed by Babcock-Hitachi K. K. (BHK) which previously had not been applied to cyclone boilers. B&W currently licenses the IFNR process from BHK. IFNR was developed during the early 1980's by BHK and Tokyo Electric Power Company (TEPCO). Early development of BHK's INFR system progressed from bench-scale flame studies to single-burner, multi-burner, and INFR system combustion tests with coal, oil, and natural gas. BHK and TEPCO then jointly applied the INFR technology in a 175-MW natural gas-fired boiler. Subsequently, BHK has applied the INFR technology to numerous wall-fired utility boilers in Japan, ranging in size from 175- to 700-MW. BHK's experience does not include cyclone boilers. B&W has concluded that their Cyclone Reburning technology does not fall within the purview of the BHK licence agreement.

BHK has also developed a pulverized coal burner, which has been refined by B&W and is now commercially available. It has been used at the 100-MW Ohio Edison EPA LIMB demonstration. Further development of the burner has led to major contracts with ENEL (Italy) for new and retrofit units. Investigators other than those at BHK and B&W have also conducted bench-scale and pilot-scale reburning tests.

Through a contract with the Electric Power Research Institute (EPRI), B&W has conducted a study to determine the feasibility of retrofitting cyclone boilers with reburning technology. The results of the study indicated that the majority of cyclone boilers can utilize coal reburning. Subsequently, B&W conducted pilot-scale cyclone combustion tests in the 6 MMBtu/hr Small Boiler Simulator (SBS) at B&W's Alliance Research Center in Ohio. The tests, jointly funded by EPRI and the Gas Research Institute, showed favorable results when firing natural gas, oil, and coal.

3.2.2 Process Description

Nitrogen oxides are formed when nitrogen contained in the fuel or in the combustion air is oxidized during the combustion process. The formation of NO_x depends on flame temperature, nitrogen content of the fuel, quantity of excess air available for combustion, and residence time at high temperature. The tendency to form NO_x is in direct proportion to any of these parameters.

Many NO_x reduction options are available for most coal-fired utility boilers, including delayed mixing and staged combustion. These combustion techniques, however, cannot be applied to cyclone boilers, because their application results in severe corrosion problems. On the other hand, post combustion NO_x reduction systems, such as selective catalytic reduction (SCR) and Thermal De-NO_x, appear viable but are very expensive. In the SCR process, ammonia (NH_3) is injected into the flue gas upstream of the air preheater, and the flue gas is passed over a catalyst where the NH_3 and NO_x react to form nitrogen and water vapor. In Thermal De-NO_x, NH_3 is injected into the superheater section of the boiler where temperatures are sufficiently high for the NH_3 and NO_x to react without a catalyst. The reburning process is a technically and economically promising process for NO_x reduction in cyclone boilers.

Natural gas, oil, or coal can be used as the reburning fuel, but pulverized coal is more advantageous than other fuels for coal-fired boilers because of its lower cost. Also, natural gas or oil is often not readily available at coal burning power plants.

The Cyclone Coal Reburning process utilizes multiple combustion zones as shown in Figure 2. The main combustion zone is operated with 70 to 80% of the fuel heat input. In this zone, the coal is burned with sufficient air for combustion. Also, sufficient residence time is provided to complete combustion before the combustion products enter the reburning zone.

The balance of the coal is injected into the reburning zone, above the cyclone burners through reburning burners. This zone is operated in an oxygen deficient condition, which will chemically reduce NO_x, formed in the main combustion zone, to molecular nitrogen. Again, sufficient residence time is provided to enable the reburning reactions to occur.

The flue gases leaving the reburning zone are oxygen deficient and still contain unburned components (carbon, H_2, and CO). In order to complete the combustion process, the balance of the combustion air is introduced into the boiler above the reburning zone through overfire air ports. This zone also requires adequate residence time for oxygen to thoroughly mix and react with the furnace combustibles before entering the convective heat transfer section of the boiler.

The net effect of this combustion technique is that it produces a greater than 50% reduction in NO_x formation without increasing the emission rates of other pollutants or increasing fuel consumption.

3.2.3 Application of Process in the Proposed Project

The two specific sites involved in this project are WP&L's Nelson Dewey Station Unit No. 2 in Cassville, Wisconsin, and B&W's Alliance Research Center in Alliance, Ohio.

Nelson Dewey Station Unit No. 2

The Nelson Dewey Station Unit No. 2 boiler, built by B&W, is a single wall-fired, drum-type radiant boiler of 700,000 lbs/hr steam capacity with three B&W cyclone burners. This unit has a Research Cottrell electrostatic precipitator installed to treat the flue gas stream after it is passed through a portion of the air heater, i.e., on the "warm side" of the air heater.

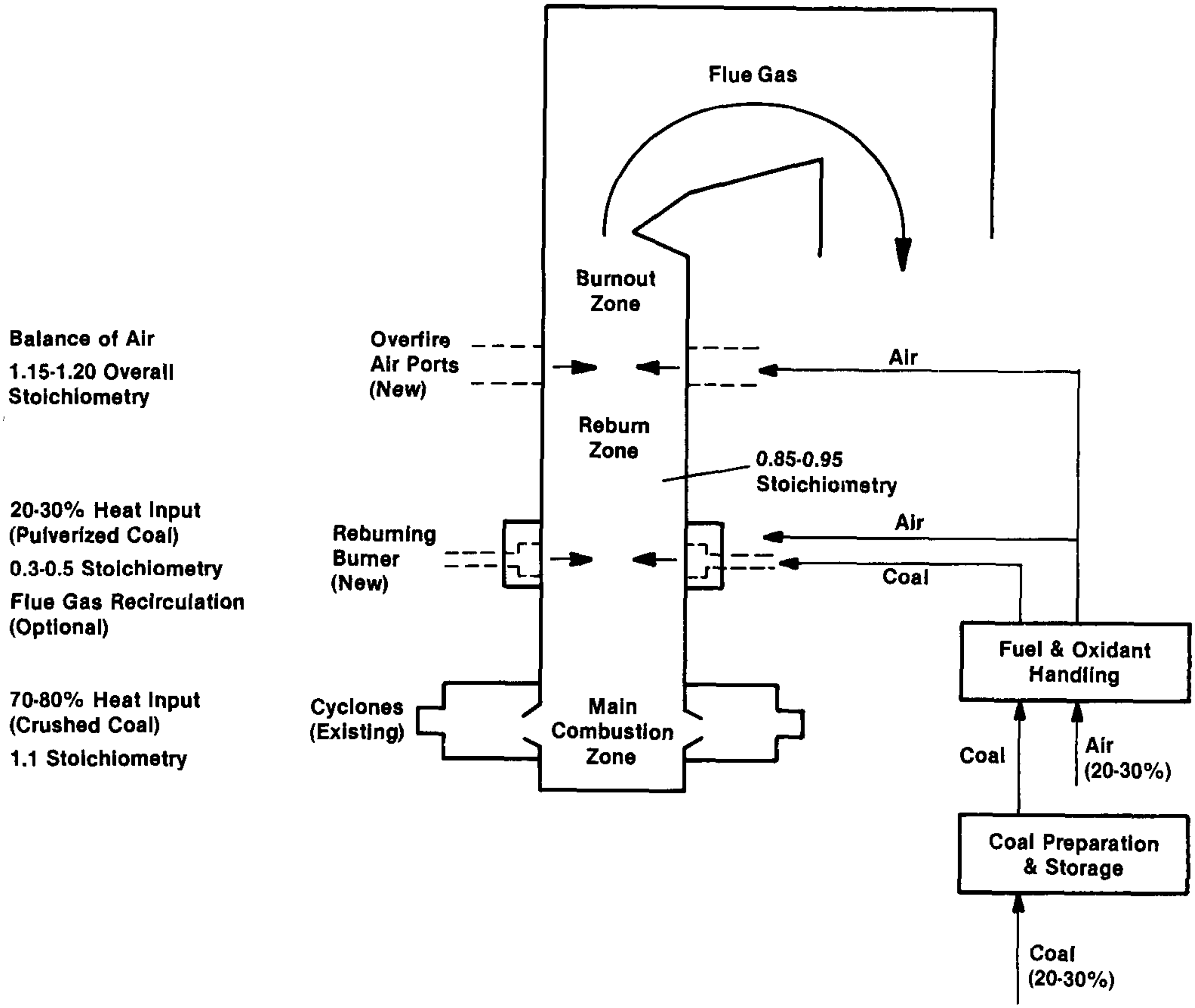

FIGURE 2. B&W COAL REBURNING PROJECT GENERIC SCHEMATIC DIAGRAM.

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The installation of a coal reburning system will require the addition of: (1) reburn burners above the cyclone burners; (2) overfire air ports above the reburn burners; (3) boiler tube panel modifications to accommodate the new burners and air ports; (4) a pulverizer with gravimetric coal feed metering system for the reburning burners; (5) control management system modifications for reburning burners and overfire air ports; (6) flue gas recirculation and overfire air port ducting; (7) dampers, piping, and air monitors; (8) boiler test probe openings in the furnace and convection pass; (9) a continuous gaseous emission monitoring system; and, (10) a B&W continuous monitoring Diagnostic System 140.

The technology to be demonstrated at Nelson Dewey Station Unit No. 2 is intended to provide greater than 50% reduction in NO_x emissions while not significantly impacting cyclone burner operation, boiler efficiency, boiler fireside performance (corrosion and soot deposition), or boiler ash removal system performance. Coal reburning technology will be utilized to achieve the specific objectives of the demonstration.

B&W Alliance Research Center

B&W Alliance Research Center has a 6 MMBtu/hr Small Boiler Simulator (SBS), which was used to perform the pilot-scale cyclone coal reburning tests. Figure 3 schematically illustrates the cyclone-equipped SBS facility. The furnace is water cooled and simulates the geometry of B&W's single-cyclone, front wall-fired cyclone boilers.

The SBS will be used to simulate the operating conditions at Nelson Dewey Unit No. 2 to examine the effectiveness of reburning and to evaluate its associated side effects, such as fireside corrosion and soot deposition in the secondary superheater tube bank.

3.3 General Features of the Project

3.3.1 Evaluation of Developmental Risk

As with any new technology, there is some risk involved with the continued development and scale-up of coal reburn technology. However, as described earlier, much development work has already been done. The data and experience gained from this earlier work accords this project a high probability of success.

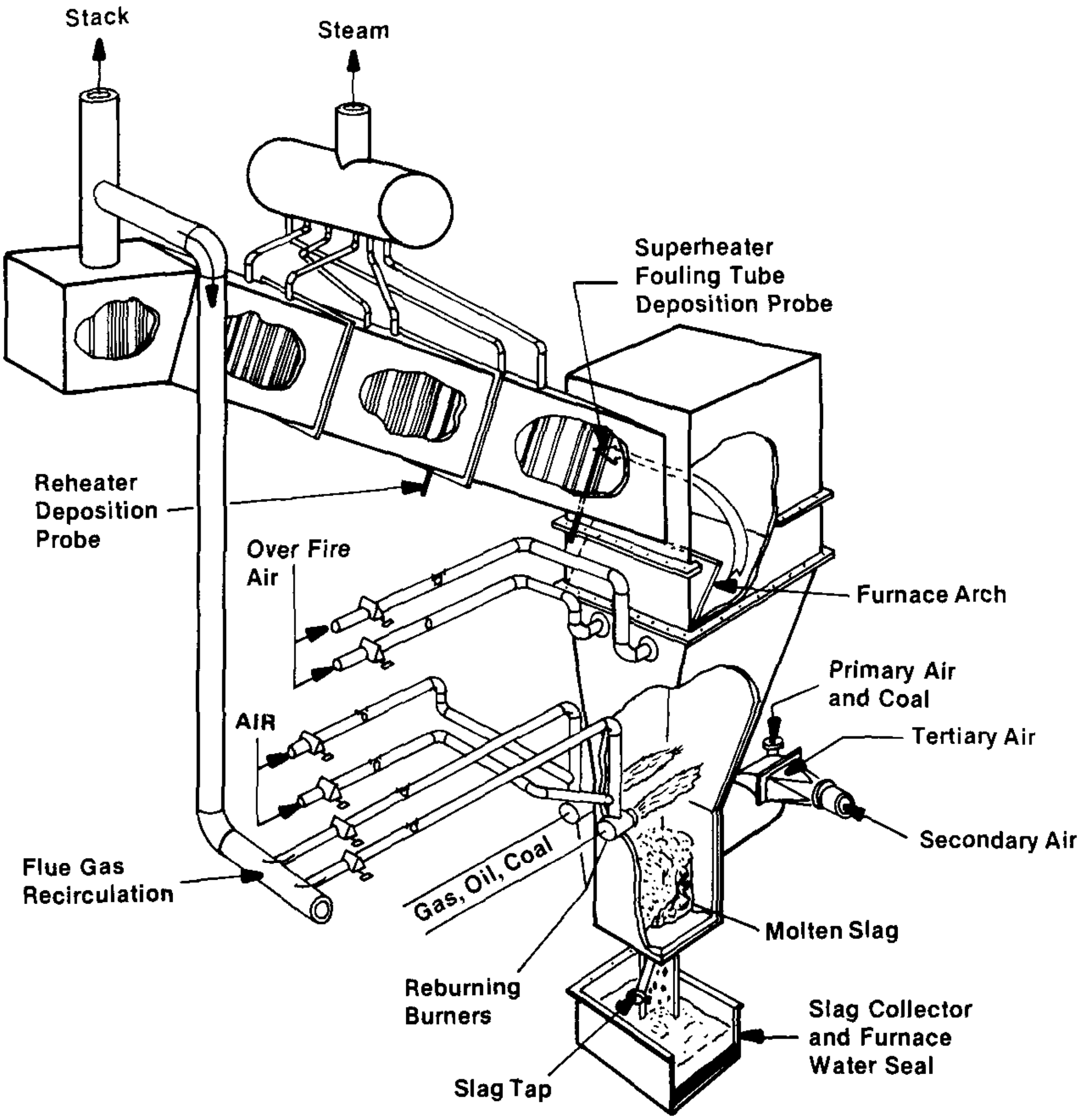

FIGURE 3. B&W SMALL BOILER SIMULATOR (SBS) FACILITY SCHEMATIC.

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Under a contract with the Electric Power Research Institute (EPRI), B&W studied the feasibility of retrofitting cyclone boilers with reburning technology. The study showed that the majority of cyclone units can apply the technology. Pilot-scale testing in B&W's cyclone-burner-equipped 6 MM Btu/hr SBS facility was then performed, confirming the results of the study. These tests demonstrated that the risks associated with this project are low.

Cyclone boilers emit substantially less fly ash than pulverized-coal-fired boilers; however, because of the relatively smaller particle size of the fly ash generated in cyclone boilers, the particulate removal equipment for cyclone boilers is typically similar in size to that of conventional pulverized-coal units. Expressed in other words, cyclone boiler particulate removal equipment is generally oversized when considering the weight of ash as the design parameter. The use of coal reburning will increase the quantity of ash loading to the particulate removal equipment. The average particle size will also increase. Nonetheless, since the particulate removal equipment is oversized relative to fly ash quantity, no significant impact on particulate emission control performance is anticipated.

The reburn process requires operation in an oxygen-deficient atmosphere within the lower furnace region. In this reducing atmosphere, the sulfur in the coal can form hydrogen sulfide (H_2S). In sufficient concentration, H_2S is corrosive to boiler tubes. For the ten operating utility reburn applications installed in Japan, H_2S has not been a problem. Corrosion will be carefully monitored as a part of the B&W coal reburn demonstration project.

3.3.1.1 Similarity of the Project to Other Demonstration/Commercial Efforts

Reburning converts NO_x to molecular nitrogen by injection of a supplemental fuel (gas, oil, or coal) above the main furnace combustion zone in an oxygen-deficient atmosphere. The Japanese have successfully utilized reburning on oil- and gas-fired units, but have only limited experience on coal-fired units. The Japanese coal experience does not include cyclone-equipped units.

3.3.1.2 Technical Feasibility

The majority of cyclone boilers were manufactured prior to 1971. These boilers have not been required to comply with NSPS. Since prospective new legislation may require NO_x emissions control for these pre-NSPS cyclone boilers, a suitable technology is required for NO_x emission control.

An investigation of existing NO_x emission control technologies, with the view to use such technologies on cyclone boilers, revealed that these technologies would not be technically and economically feasible on cyclone boilers. Consequently, B&W evaluated alternative technologies and determined that reburning offered the most promise of success.

B&W then generated a three-phase program to develop the Cyclone Coal Reburning technology. The work was financed by B&W and EPRI. The first phase involved the adaptation of the Babcock-Hitachi K. K. (BHK) patented In Furnace NO_x Reduction (IFNR) process to cyclone boilers.

In Phase 2, an engineering feasibility study was performed to determine the applicability of the reburn process to existing cyclone units. This study showed that the majority of cyclone units could utilize the reburn technology. Phase 3 involved the performance of pilot-scale tests of the reburn concept applied to a cyclone boiler. These tests were conducted on B&W's 6 MMBtu/hr SBS facility. Natural gas, oil, and coal reburn fuels were evaluated under various reburning conditions. The results of the tests indicated that attaining 50 to 80% reduction of NO_x emissions was possible.

A sound data base has been developed which demonstrates that reburning can reduce NO_x emissions from a variety of boilers, including cyclone boilers. The base reburn technology has been applied on a commercial scale in Japan and in pilot-scale tests in the United States. This experience provides the basis for the expectation that Cyclone Coal Reburning technology will achieve greater than 50% NO_x emission reductions.

3.3.1.3 Resource Availability

Adequate resources are available for this program. B&W will use present members of its staff to fill key and support positions. The boiler and other process equipment will be operated by existing Wisconsin Power & Light Company employees.

Because this project will not modify the host boiler's coal requirements, neither the quantity nor the quality of coal to be burned will change with the proposed project. This technology requires no chemicals. Incremental electrical power consumed in operating the retrofitted boiler is not substantial and is readily available.

This demonstration involves a cyclone-burner-fired pre-NSPS boiler installation which is fully operational and has the appropriate facilities and scheduling flexibility to support this project. The site selected will provide an excellent opportunity to evaluate the technology with the results being directly applicable for commercialization to the entire cyclone boiler population, estimated at over 26,000 MW of existing generating capacity.

3.3.2 Relationship Between Project Size and Projected Scale of Commercial Facility

The demonstration site was chosen based upon its representative cyclone boiler size and characteristics. The selected boiler is representative of the existing cyclone boilers with respect to available furnace residence time, which is a critical factor in the reburn process.

The combustion characteristics of all cyclone boilers are similar. The demonstration facility will burn a bituminous coal, which is the most commonly used fuel in cyclone boilers. The 100-MW size of the unit provides a lower cost demonstration, while providing data which can be scaled up easily for larger units. At most, any additional scale-up would be at a factor of less than 2, which is well within normal scale-up ranges for this kind of mechanical equipment.

3.3.3 Role of the Project in Achieving Commercial Feasibility of the Technology

The full-scale demonstration is expected to resolve many technical issues that are not possible to fully address with only pilot-scale testing. Both full-load and reduced-load operation will be evaluated. Readiness for commercialization will be determined through the comprehensive evaluation of the data gathered during the demonstration.

3.3.3.1 Applicability of the Data to be Generated

To produce accurate and reliable performance data, the demonstration will be fully instrumented and will use automated data collection. A boiler performance diagnostic system will be installed and connected to the data acquisition system.

Prior to the reburn retrofit, tests and operating records will be reviewed to determine baseline boiler characteristics.

Data concerning boiler operating conditions and emissions will be obtained. These parameters vary with changes in boiler load, excess air quantities, and reburn system operation. As a minimum, the following parametric information will be collected:

- Superheater steam temperature and pressure
- Feedwater temperature and pressure
- Air heater inlet and outlet gas and air temperatures
- Economizer inlet and outlet gas temperatures
- Gas and air differential pressures across the air heater
- Feedwater flow
- Steam flow
- Air flows
- Primary and secondary air temperatures
- Generator output
- Forced draft fan power consumption
- Coal flows
- Coal composition
- Combustion efficiency

In addition, the following data will be collected to further analyze boiler reliability and operability:

- Tube-bundle, gas-side differential pressure
- Inspection and sampling of tube surface deposits before and after testing for evidence of slagging or fouling
- Ultrasonic tube testing within the reburn zone
- Electrostatic precipitator performance
- Sootblower frequency and flow

Further, the flue gas will be monitored for concentrations of:

- o Sulfur dioxide
- o Sulfur trioxide
- o Nitrogen oxide
- o Nitrous oxide
- o Carbon dioxide
- o Carbon monoxide
- o Oxygen
- o Water
- o Unburned hydrocarbons

Also, particulate matter quantities, particle size, and resistivity will be measured at the electrostatic precipitator inlet and outlet. The quantities of bottom ash, economizer ash, and air heater ash will be measured.

Process economics will be determined based on the results of the demonstration. Since the proposed demonstration is at a commercial scale, the resulting technical and economic analyses will be directly applicable to costs for other utility plants.

3.3.3.2 Identification of Features that Increase Potential for Commercialization

The majority of the existing cyclone boilers, with generating capacities totaling more than 26,000 MWe, are expected to continue to operate for many years. This being so, it is desirable to develop efficient, economical, and reliable technologies to control the pollutants resulting from the combustion of coal in these boilers. Moreover, Congressional enactment of more stringent acid rain precursor control regulations could mandate either control of the precursor pollutants or shutting down the boilers.

Once commercially proven, the Cyclone Coal Reburning process will provide a technically acceptable and economic means to reduce NO_x emissions in cyclone boilers. The minimum retrofit requirements and competitive cost of this process make it attractive for retrofit applications.

The equipment used in this process is commercially available, and consists of burners, overfire air ports, coal feeders, pulverizers, and control systems. Some boiler modifications are required to install the reburn burners and overfire air ports.

In summary, commercialization of coal reburning for cyclone boilers will be aided by the following advantages as compared with other retrofit technologies:

- Reduction of NO_x emissions by more than 50%
- Minimal space requirements
- Relative ease of retrofit
- Minimal impact on boiler efficiency, combustor operation, or fireside performance
- Use of commercially available components

The success of this demonstration will establish that the Cyclone Coal Reburning technology is an effective, economical, and reliable approach to controlling NO_x emissions. As such, the technology is expected to significantly penetrate the large pre-NSPS cyclone-boiler market.

3.3.3.3 Comparative Merits of Project and Projection of Future Commercial Economics and Market Acceptability

Currently, there is no proven retrofit combustion technology for the reduction of NO_x emissions from cyclone boilers. Cyclone Coal Reburning technology offers a viable retrofit combustion technology at reasonable capital and operating costs.

The Cyclone Coal Reburning process is intended to provide utility companies with another technology option to reduce NO_x emissions from existing boilers. Existing NO_x reduction technology includes delayed mixing, staged combustion, selective catalytic reduction (SCR), and Thermal De-NO_x.

The need for a new technology arises because delayed mixing and staged combustion cause serious corrosion problems in cyclone boilers and because the post-combustion processes, SCR and Thermal De-NO_x are very expensive. In contrast, the Cyclone Coal Reburning technology offers a low capital and operating cost system with minimum space and retrofit equipment requirements.

An economic comparison of various Low-NO_x burners, SCR, Thermal De-NO_x, and coal reburning was made for a 500-MW plant. The Cyclone Coal Reburning technology is more expensive than standard wall or tangentially fired, low NO_x burner/retrofits but standard low-NO_x burners are not easily retrofitted to cyclone boilers because of their inherent unique design characteristics. Since a complete new lower furnace would be required to apply low-NO_x burners, this retrofit option would be extremely expensive to implement and is, therefore, not a practical alternative.

Cyclone Coal Reburning is also more expensive than the Thermal De-NO_x system from a capital cost point of view; however, the operating costs for reburning are substantially less than those for Thermal De-NO_x. On a levelized cost basis, reburning costs less than Thermal De-NO_x. Finally, reburning also offers substantially lower capital and operating costs than SCR technology.

Utility companies are expected to implement pollution control technologies that do not require large capital outlays, extensive plant modifications, or significant operational difficulties. Cyclone Coal Reburning can be incorporated into existing cyclone boiler plants and meets these criteria.

4.0 ENVIRONMENTAL CONSIDERATIONS

The overall strategy for compliance with NEPA, cited in Section 2.2, contains three major elements. The first element, the Programmatic Environmental Impact Analysis (PEIA), was issued as a public document in September 1988. In the PEIA, the Regional Emission Database and Evaluation System (REDES), a model developed by DOE at Argonne National Laboratory, was used to estimate the environmental impacts that could occur by the year 2010 if each technology were to reach full commercialization and capture 100 percent of its applicable market. The environmental impacts were compared to the no-action alternative, for which it was assumed that use of conventional coal technologies continues through 2010, with new plants using conventional flue gas desulfurization controls to meet NSPS.

In the PEIA, the expected performance characteristics and applicable market of the Cyclone Coal Reburning technology were used to estimate the environmental impacts that could result if the Cyclone Coal Reburning technology were to reach full commercialization in 2010. Results derived from the REDES computer model were used to project the impacts of the Cyclone Coal Reburning technology as compared to the no-action alternative.

Projected environmental impacts from maximum commercialization of the Cyclone Coal Reburning technology into national and regional areas in 2010 are given in Table 1. Negative percentages indicate decreases in emissions or wastes in 2010. Conversely, positive values indicate increases in emissions or wastes. These results should be regarded as approximations of actual impacts.

Table 1. Projected Environmental Impacts in 2010
(Percent Change in Emissions and Solid Wastes

Region	Sulfur Dioxide (SO_2)	Nitrogen Oxides (NO_x)	Solid Waste
National	0	-23	0
Northeast	0	-31	0
Southeast	0	-28	0
Northwest	0	- 8	0
Southwest	0	-13	0

Source: Programmatic Environmental Impact Analysis (DOE/PEIA-0002), U.S. Department of Energy, September 1988.

As shown in Table 1, significant reductions of NO_x are projected to be achievable nationally due to the capability of the Cyclone Coal Reburning process to remove 50% of NO_x emissions from coal-fired boilers and the wide potential applicability of the process. Negligible changes in effluents are anticipated because the technology produces no solid waste product. The REDES model predicts greatest environmental impacts will be felt in the Northeast because of the large amount of coal-fired capacity there that can be retrofitted with the Cyclone Coal Reburning process. The least impact occurs in the Northwest because of the minimal use of coal there. The national quadrants used in this study are shown in Figure 4.

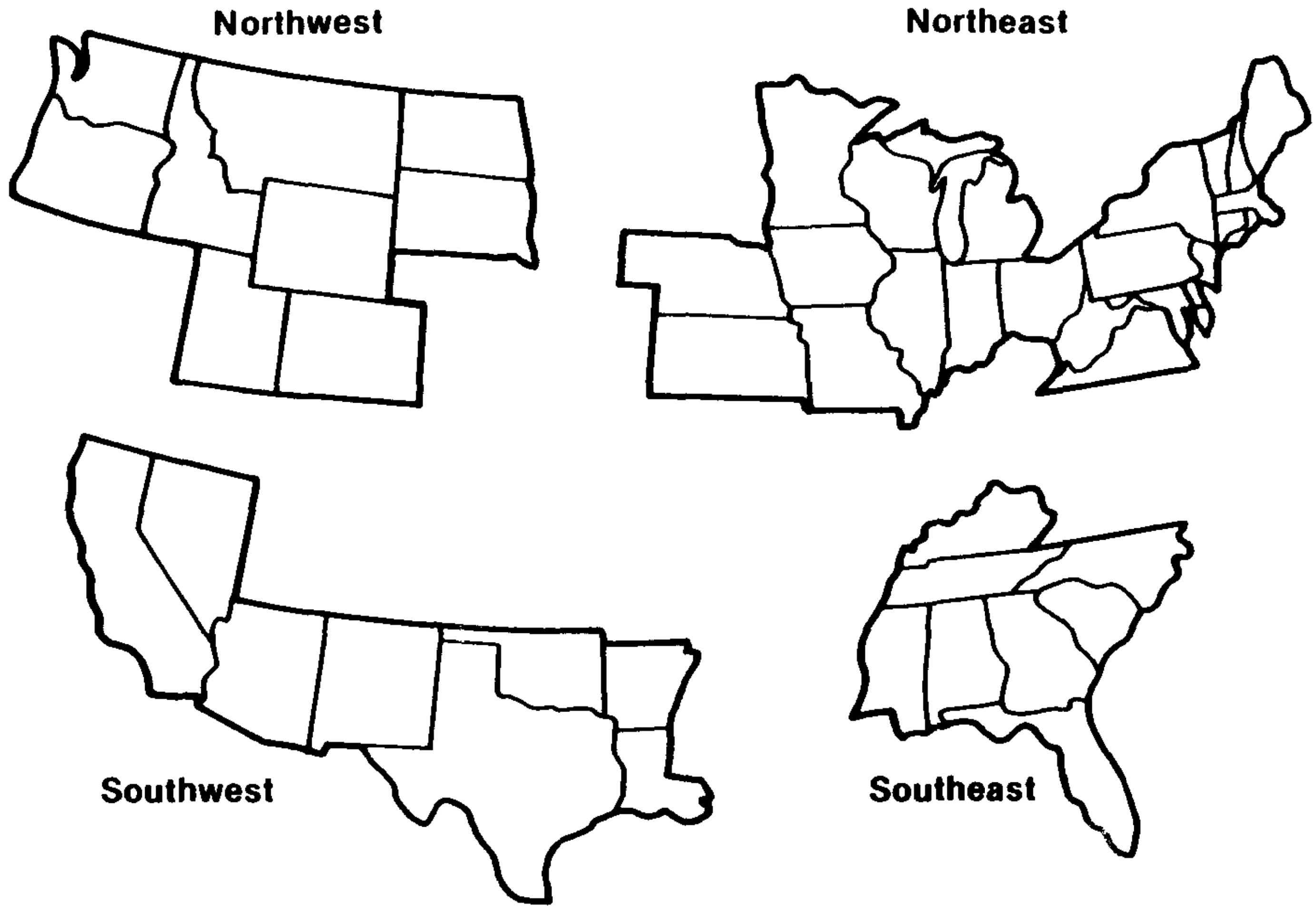

FIGURE 4. QUADRANTS FOR THE CONTIGUOUS UNITED STATES.

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The second element of DOE's NEPA strategy for the ICCT program involved preparation of a preselection environmental review based on project-specific environmental data and analyses that offerors supplied as a part of each proposal. This analysis, for internal DOE use only, contained a discussion of site-specific EHSS issues associated with each demonstration project. It included a discussion of the advantages and disadvantages of the proposed and alternative processes reasonably available to each offeror. A discussion of the impacts of each proposed demonstration on the local environment, and a list of permits that must be obtained to implement the proposal, were included. It also contained options for controlling discharges and for management of solid and liquid wastes. Finally, the risks and impacts of each proposed project were assessed. Based on this analysis, no environmental, health, or safety issues have been identified that would result in any significant adverse environmental impacts from construction and operation of the Cyclone Coal Reburning demonstration facility.

As the third element of the NEPA strategy, the Participant (B&W) will be required to submit the environmental information specified in Appendix J of the PON. This detailed site- and project-specific information will be used as the basis for the development of the site-specific NEPA documents to be prepared by DOE. These documents will be completed, approved, and publicly distributed in full conformance with the Council on Environmental Quality (CEQ) regulations for implementing NEPA (40 CFR Parts 1500-1508) and DOE guidelines for NEPA compliance (52 FR47662-47670) before federal funds are provided for detailed design, construction, and operation.

In addition to the NEPA requirements, the Participant must prepare and submit an Environmental Monitoring Plan (EMP). Guidelines for the development of the EMP are provided in Appendix N of the PON. The EMP is intended to ensure that significant technology, project, and site-specific environmental data are collected and disseminated to provide health, safety, and environmental information should the technology be used in commercial applications.

5.0 PROJECT MANAGEMENT

5.1 Overview of Management Organization

The DOE intends to enter into a Cooperative Agreement with the Participant, Babcock & Wilcox Company, to conduct this project. The DOE will monitor the project through the Contracting Officer and the Contracting Officer's Technical Representative. The Participant will manage this project through a Project Manager, who will be assisted by a team of technical and managerial personnel from several organizations.

A multiorganization team headed by B&W (Figure 5) will be involved in the management of this project. In addition to B&W, other members of the team are Wisconsin Power & Light, Illinois Department of Energy and Natural Resources, Electric Power Research Institute, and Sargent & Lundy.

5.2 Identification of Respective Roles and Responsibilities

DOE

DOE shall be responsible for monitoring all aspects of the project and for granting or denying approvals required by the Cooperative Agreement between B&W and DOE. The DOE Contracting Officer is the authorized representative of DOE for all matters related to the Cooperative Agreement.

The DOE Contracting Officer will appoint a Contracting Officer's Technical Representative (COTR) who will be the authorized representative for all technical matters and will have the authority to issue "Technical Advice" which may:

- Suggest redirection of the Cooperative Agreement effort, recommend a shifting of work emphasis between work areas or tasks, and suggest pursuit of certain lines of inquiry which assist in accomplishing the Statement of Work

- Approve the reports, plans, and technical information required to be delivered by the Participant to DOE under the Cooperative Agreement

The DOE COTR does not have the authority to issue any technical advice which:

- Constitutes an assignment of additional work outside the Statement of Work

- In any manner causes an increase or decrease in the total estimated cost, or the time required for performance of the Cooperative Agreement

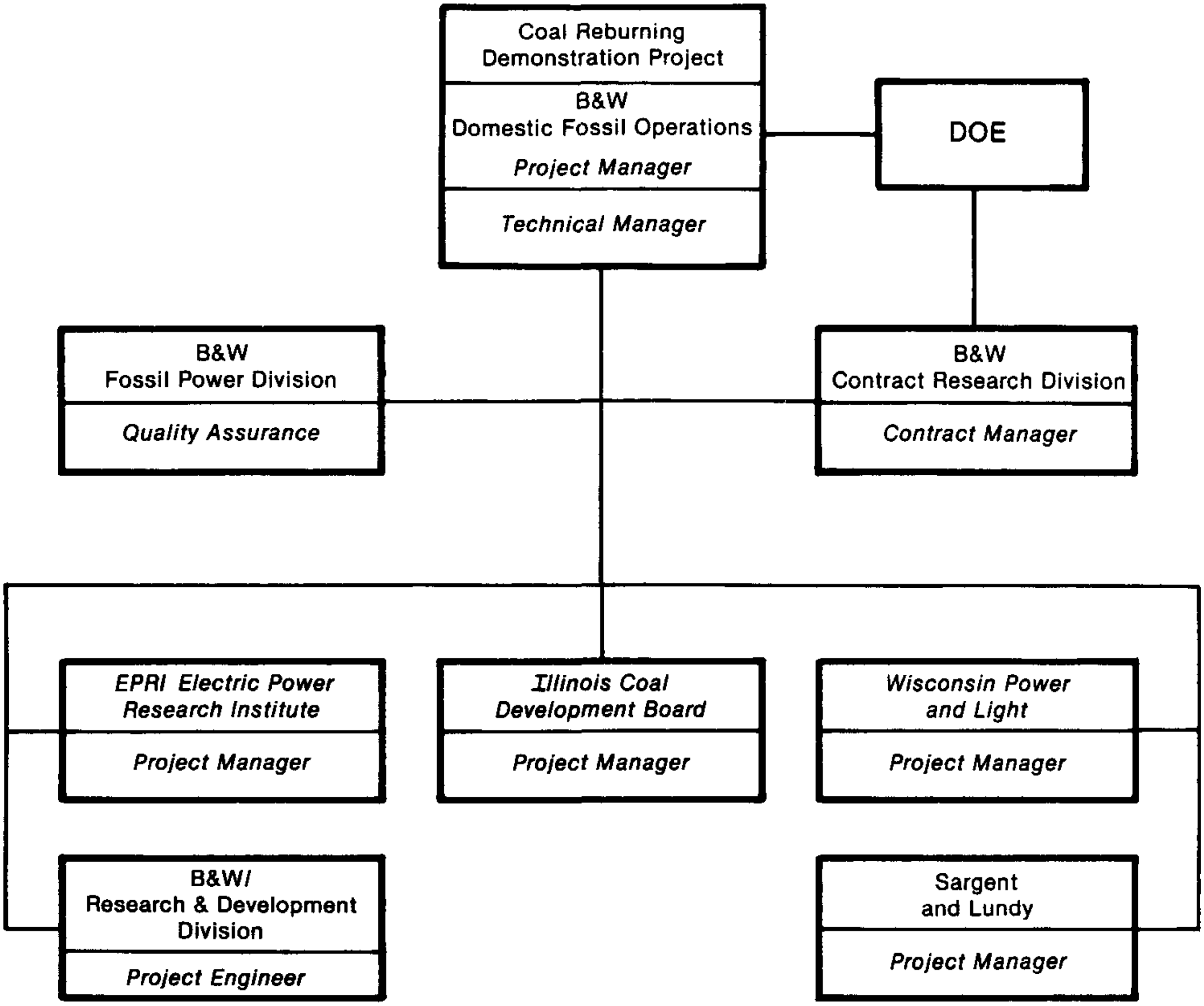

FIGURE 5. B&W PROJECT ORGANIZATION FOR COAL REBURNING FOR CYCLONE BOILER NO_x CONTROL DEMONSTRATION.

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- o Changes any of the terms, conditions, or specifications of the Cooperative Agreement
- o Interferes with the Participant's right to perform the terms and conditions of the Cooperative Agreement

All technical advice shall be issued in writing by the DOE COTR.

Participant

The Participant (B&W) will be responsible for all aspects of project performance under this Cooperative Agreement as set forth in the Statement of Work.

The Participant's Project Manager is the authorized representative for the technical and administrative performance of all work to be performed under the Cooperative Agreement. He will be the single authorized point of contact for all matters between the Participant and DOE.

B&W's responsibilities include the design, procurement, fabrication and installation of the boiler and auxiliary equipment modifications. In addition, B&W will provide guidance and participation in the test program, data analysis, and report preparation. B&W will also work to commercialize the technology.

Wisconsin Power and Light Company will provide the host site, provide permits required for the site work, operate and maintain the equipment, provide the test coal, and provide other utilities required for the demonstration project. The Illinois Department of Energy and Natural Resources will review the Phase I testing, data analysis, and reports.

The Electric Power Research Institute will participate in project reviews; provide guidance for the testing program; and review the testing, data analysis, and reporting performed by B&W and the environmental subcontractor.

B&W will subcontract performance and environmental testing. This work will include providing guidelines for preparation of the Environmental Monitoring Plan; preparing the plan for testing to be performed by the subcontractor; performing environmental monitoring for the cyclone coal reburn retrofit; and preparing a final report to evaluate the data obtained from the baseline parametric tests.

Sargent & Lundy will assist B&W in the design of some system components.

5.3 Project Implementation and Control Procedures

All work to be performed under the Cooperative Agreement for this project is divided into three phases. These phases and their durations are:

Phase I	Design and Permitting (18 months)
Phase IIA	Long Lead Procurement (7 months)
Phase IIB	Construction and Start-up (8 months)
Phase III	Operation, Data Collection, Reporting, and Disposition (17 months)

Phase IIA is concurrent with the last 7 months of Phase I. Phase III will begin upon completion of Phase II. The total project duration is forty-three months.

Three budget periods will be established to coincide with the project phases as follows: Budget Period 1 covers Phases I and IIA; Budget Period 2 covers Phase IIB; Budget Period 3 covers Phase III. Consistent with P.L. 100-202 as amended by P.L. 100-446, DOE will obligate sufficient funds to cover its share of the cost for each budget period. Throughout the course of this project, reports dealing with the technical, management, cost, and environmental monitoring aspects of the project will be prepared by B&W and provided to DOE.

5.4 Key Agreements Impacting Data Rights, Patent Waivers, and Information Reporting

B&W's incentive to develop this process is to realize retrofit business from, and produce new designs for, the utility and power boiler industry with respect to NO_x-abatement technology.

The key agreements with respect to patents and data are:

- o Standard data provisions are included, giving the Government the right to have delivered and use with unlimited rights all technical data first produced in the performance of the Agreement.

- o A patent waiver may be granted by DOE giving B&W ownership of foreground inventions, subject to the march-in rights and U.S. preference found in P.L. 96-517.

- o Rights in background patents and background data of B&W and all of its subcontractors are included to assure commercial availability of the technology.

B&W will make such data as is applicable and non-proprietary available to DOE, the U.S. EPA, the Ohio EPA, other interested agencies, and the public.

5.5 Procedures for Commercialization of Technology

The cyclone boiler coal-reburn NO_x reduction technology (or Cyclone Coal Reburning) is one component of the overall Babcock & Wilcox Company Clean Coal Technology strategy for the utility and industrial markets. The overall objective is to profitably supply low-cost, retrofit pollution control equipment to utility and industrial customers in order to reduce atmospheric emissions from fossil fuel boilers and combustors and meet regulatory requirements.

Because of the large diversity of plant designs, customer needs and local regulatory requirements, a broad line of products will be offered on a customized, site-specific basis to achieve this objective. These products will focus on reducing SO_2, NO_x, particulates, and other trace emissions from stationary sources. Cyclone Coal Reburning represents one key component of this strategy which is intended to meet the demands of a regulation-driven market.

Proposed "acid rain" and "clean coal" legislation will potentially require retrofitting of pre-NSPS boilers and power systems with control technologies to significantly limit NO_x and SO_2 emissions. Federally mandated state-wide NO_x emission limits under consideration range from 0.3 to 1.0 lbs NO_x (as NO_2) per million Btu heat input, depending upon the combustion technology used, regulatory time limits, and other factors. Regulation-driven retrofit markets tend to start slowly, grow rapidly, and then decline rapidly as the target population is retrofitted. It is therefore critical to have technology fully demonstrated before the market develops. Otherwise, even highly cost-effective emissions-control technology can be precluded from use by the constraints of time and risk.

The final phase of this development program prior to full commercialization is, therefore, verification of the operation and overall performance of Cyclone Coal

Reburning technology in a full-scale demonstration. From a business perspective, this is a key step in the rapid commercial success of this product. It will demonstrate the ability to reliably meet predicted performance on a full-scale commercial boiler and will expose any potential problem areas that must be addressed.

Parallel with, but separate from, the demonstration project, detailed marketing and manufacturing plans will be developed along with engineering standards for use in proposal preparation and future unit design. Since this product is similar to existing combustion equipment designed and manufactured by B&W, systems are already in place to address design, manufacturing, and marketing interfaces.

Full-commercialization timing of the project is contingent upon the enactment of new environmental legislation or the revision of existing clean air regulations, which will require modifications of existing utility equipment. During the intervening period, performance of the demonstration unit will be monitored and the time will be used to communicate the performance and benefits of Cyclone Coal Reburning technology to the cyclone boiler owners. This will further enhance commercial acceptance of this product by the potential ultimate users when more stringent regulations provide the impetus to install retrofit environmental control equipment.

6.0 PROJECT COST AND EVENT SCHEDULING

6.1 Project Baseline Costs

The total estimated cost for this project is $10,655,261. The Participant's contribution and the Government share in the costs of this project are as follows:

	Dollar Share ($)	Percent Share (%)
PRE-AWARD		
Government	73,207	47.6
Participant	80,568	52.4
PHASE I		
Government	1,420,926	49.9
Participant	1,424,318	50.1
PHASE IIA		
Government	790,304	50.0
Participant	790,305	50.0
PHASE IIB		
Government	1,641,831	46.1
Participant	1,916,547	53.9
PHASE III		
Government	1,146,363	45.5
Participant	1,370,892	54.5
TOTAL PROJECT		
Government	5,072,631	47.6
Participant	5,582,630	52.4
TOTAL	10,655,261	100.0

Cash Contributions will be made by the co-funders as follows:

B&W	$1,500,550
DOE	5,072,631
EPRI	1,000,000
Illinois Dept. of Energy	190,000
Wisconsin Power & Light	2,174,630
Utility Sponsors*	718,000
TOTAL	$10,655,261

*Allegheny Power System
Associate Electric
Atlantic Electric
Baltimore Gas & Electric
Iowa Electric Light & Power
Iowa Public Service
Kansas City Power & Light
Missouri Public Service
Northern Indiana Public Service
Tampa Electric

At the beginning of each budget period, DOE intends to obligate sufficient funds to pay its share of expenses for that budget period.

6.2 Milestone Schedule

As shown in Figure 6, the overall project will be completed in 43 months.

Phase I, which involves permitting, flow modeling, baseline testing, and preliminary and final design, will start immediately after award and continue for 18 months. Phase II, which consists of procurement, fabrication, and installation of equipment, will overlap Phase I by seven months and continue through the 26th month. Phase III will start upon completion of Phase II and last for 17 months.

The final months of the Phase III portion of the program will involve site restorations, if required, and completion of the final report for the overall project.

6.3 Repayment Plan

Based on DOE's recoupment policy as stated in Section 6.4 of the PON, DOE is to recover an amount up to the Government's contribution to the project. The Participant has agreed to repay the Government in accordance with the stated Recoupment/Repayment Plan to be included in the final negotiated Cooperative Agreement.

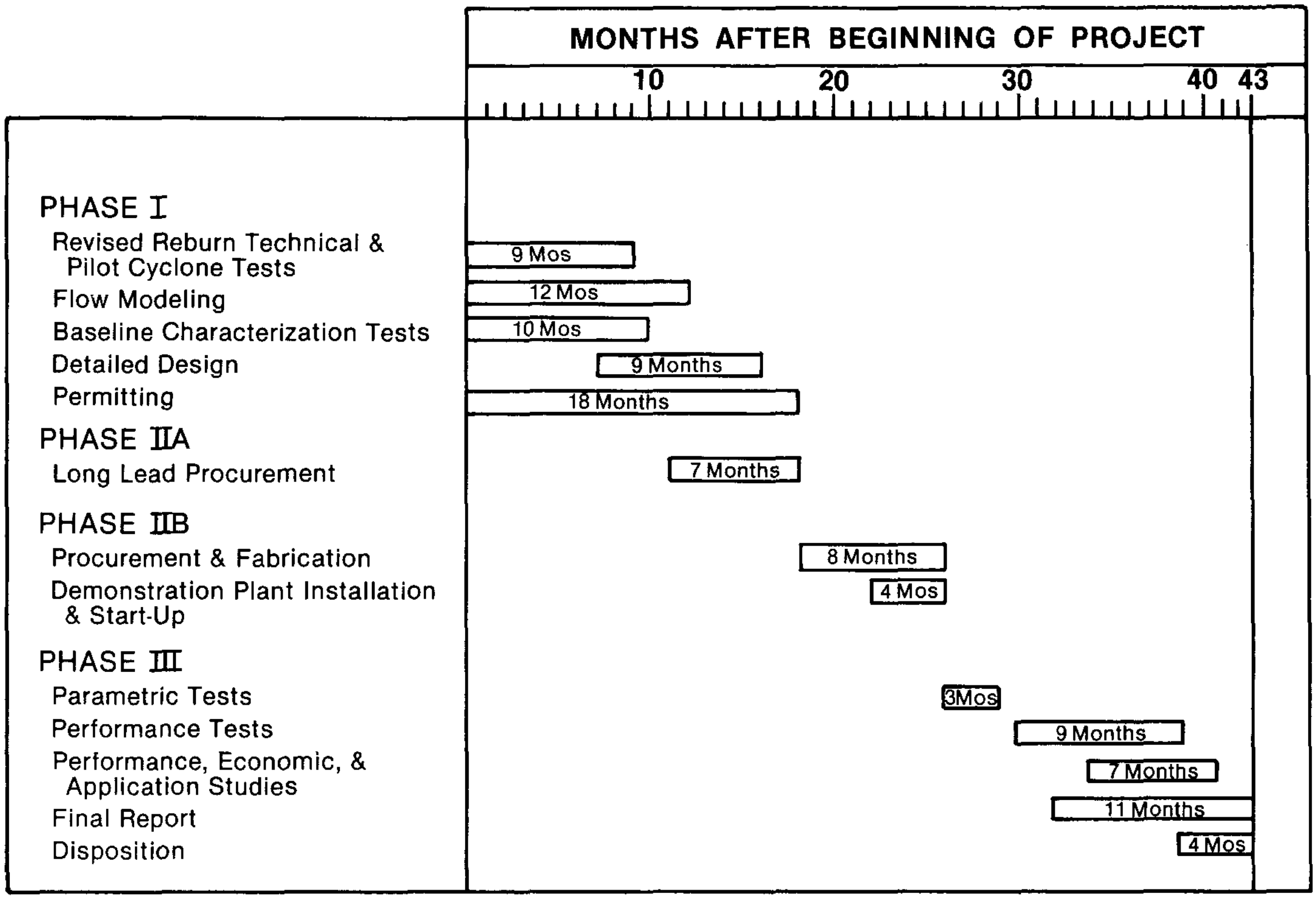

FIGURE 6. OVERALL B&W PROJECT SCHEDULE FOR NELSON DEWEY STATION CYCLONE COAL REBURNING DEMONSTRATION.

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