DOE/FE-0085
CCT/87 PC 79798

Comprehensive Report To Congress Clean Coal Technology Program

LIMB Demonstration Project Extension

A Project Proposed By
Babcock and Wilcox Company

April 1987

U.S. Department of Energy
Office of Fossil Energy
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1.0 EXECUTIVE SUMMARY

The FY86 Appropriations Act, P.L. 99-190, included approximately $400 million to support the construction and operation of demonstration facilities using Clean Coal Technologies. The Clean Coal projects cover a broad spectrum of technologies having the following things in common: (1) all are intended to increase the use of coal in an environmentally acceptable manner; and (2) all are ready to be proven at the demonstration level.

In response to the resulting Program Opportunity Notice (PON), fifty-one proposals were received in April 1986. After evaluation, nine projects, representing seven different technologies, were selected in July 1986 for funding under the Clean Coal Technology (CCT) Program.

One of the nine projects selected was the Babcock & Wilcox (B&W) proposal to extend an EPA funded demonstration of the Limestone Injection Multistage Burner (LIMB) process using three additional coals and four additional sorbents. This project also includes a demonstration of the Coolside process, in which sorbent and water are injected downstream of the boiler.

The LIMB process claims to achieve a 50% to 60% SO_x reduction by injecting dry sorbent into the boiler at a point above the burners. The sorbent then travels through the boiler and is removed along with fly ash in the existing particulate removal equipment, either an electrostatic precipitator (ESP) or a baghouse.

In the Coolside process, dry sorbent is injected into the flue gas after the boiler and before the ESP. The gas is also humidified in this process, to enhance both ESP performance and SO_x absorption. Also, a chemical additive will be dissolved in the humidification water to further improve SO_x absorption. Because of these benefits, it is expected that humidification equipment will be part of most, if not all, commercial Coolside applications. The spent sorbent is also collected with the fly ash as in the LIMB Process. Reduction of SO_x in the 50% to 80% range is expected.

Both demonstrations will utilize the same low NO_x (nitrogen oxide) burners for control of NO_x. These burners, which can replace conventional burners, control NO_x by injecting the coal and part of the combustion air together so that the first of the combustion reactions takes place in an oxygen deficient environment. The balance of the combustion air is introduced in a second stage to fully complete the combustion process. This staged combustion process has been found to reduce NO_x emissions by 50% to 60%.

The LIMB and Coolside processes both provide an alternative to conventional wet Flue Gas Desulfurization (FGD) processes. Both are expected to be substantially less expensive than wet FGD, and their space requirements are also substantially less. These factors are very important in retrofit applications.

This demonstration project will be conducted at the Ohio Edison Edgewater Plant in Lorain, Ohio (See Figures 1 and 2) on a 105 megawatt electric (MWe) boiler, which is a commercial unit. The present EPA sponsored project will test only one coal and sorbent combination for the LIMB process. The DOE project will demonstrate the LIMB process with multiple coal and sorbent combinations to show the general applicability of the process using medium and high sulfur coal. The DOE project will also demonstrate the Coolside process using high sulfur coal on a commercial scale. Until now, the Coolside process has been demonstrated only at the 0.1 MW and 1 MW scale.

This project will be performed over a forty-three month period and will use LIMB equipment installed during the EPA sponsored project. A new Coolside sorbent injection system with humidification will be added as a part of this DOE project. The total DOE project cost is $19,404,940. The co-funders are DOE ($7,597,026), the State of Ohio ($7,227,914), B&W ($3,355,000), and the Consolidation Coal Company (Consol) ($1,225,000). Ohio Edison will provide the use of its Edgewater facility as the host site.

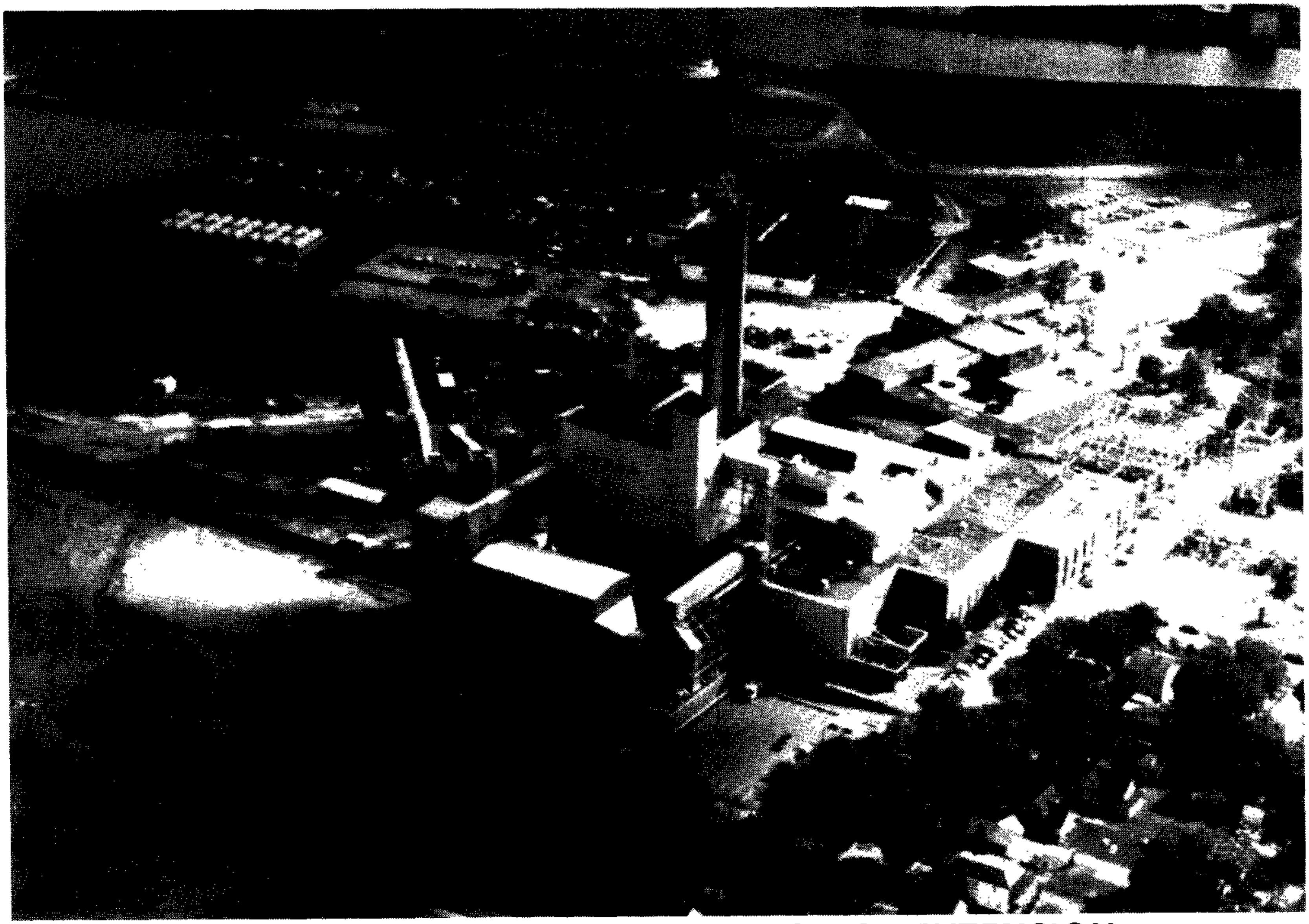

FIGURE 1. LIMB DEMONSTRATION PROJECT EXTENSION OHIO EDISON EDGEWATER PLANT, LORAIN, OHIO

FIGURE 2. SITE LOCATION
LIMB DEMONSTRATION PROJECT EXTENSION

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The ongoing EPA project and the DOE project are intertwined in both schedule and equipment, and each is dependent upon the other. The EPA project will be providing design and installation of all the LIMB equipment and much of the Coolside design. The DOE project will be providing most of the Coolside equipment. Design, procurement, and installation of the equipment required for the DOE project will be accomplished to allow testing to commence shortly after the EPA tests. Coolside testing is scheduled to start in October 1988 and will take four months. DOE LIMB testing is anticipated to start in February 1989 and last fourteen months. Completion of the project is scheduled for December 1990.

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 attainment of environmental acceptability as well as the efficient utilization of coal resources.

2.1 Requirement for Report to Congress

In December 1985, Congress made funds available for a Clean Coal Technology (CCT) Program in Public Law No. 99-190, An Act Making Appropriations for the Department of Interior and Related Agencies for the Fiscal Year Ending September 30, 1986, and for Other Purposes. This Act provided funds "...for the purpose of conducting cost-shared Clean Coal Technology projects for the construction and operation of facilities to demonstrate the feasibility for future commercial applications of such technology..." and authorized DOE to conduct the CCT program. Public Law No. 99-190 provided $400 million "... to remain available until expended, of which $100,000,000 shall be immediately available; (2) an additional $150,000,000 shall be available beginning October 1, 1986; and (3) an additional $150,000,000 shall be available beginning October 1, 1987." However, Section 325 of the Act reduced each amount of budget authority by 0.6 percent so that these amounts became $99.4 million, $149.1 million, and $149.1 million, respectively, for a total of $397.6 million.

In addition, in the conference report accompanying Public Law No. 99-190, the conferees directed DOE to prepare a comprehensive report on the proposals received, after the projects to be funded had been selected. The report was submitted in August 1986 and was titled "Comprehensive Report to Congress on Proposals Received in Response to the Clean Coal Technology Program Opportunity Notice," DOE/FE-0070. Specifically, the report outlines the solicitation process implemented by DOE for receiving proposals for CCT projects, summarizes the project proposals that were received, provides information on the technologies that were the focus of the CCT program, and reviews specific issues and topics related to the solicitation.

Public Law No. 99-190 directed DOE to prepare a full and comprehensive report to Congress on any project to receive an award under the CCT program. This report is in fulfillment of this directive and contains a comprehensive description of the Babcock & Wilcox LIMB Demonstration Project Extension.

2.2 Evaluation and Selection Process

DOE issued a Program Opportunity Notice (PON) on February 17, 1986, to solicit proposals for conducting cost-shared CCT demonstrations. Fifty-one proposals were received. All proposals were required to meet preliminary evaluation requirements identified in the PON. An evaluation was made to determine if each proposal met those preliminary evaluation requirements and those proposals that did not were rejected.

Of those proposals remaining in the competition, separate evaluations were made for each offeror's Technical Proposal, Business and Management Proposal, and Cost Proposal. The PON provided that the Technical Proposal was of significantly greater importance than the Business and Management Proposal and that the Cost Proposal was minimal; 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 all of the other steps and factors involved in the commercialization process. The subcriteria in this section allowed for consideration of the projected environmental, health, safety, and socioeconomic impacts (EHSS); the potential marketability and economics of the technology; and the plan to commercialize the proposed technology subsequent to the demonstration project.

The second major category, "Demonstration Project Factors," recognized the fact that the proposed demonstration project represents the critical step between "pre-demonstration" scale of operation and commercial readiness, and dealt with the proposed project itself. Subcriteria in "Demonstration Project Factors" allowed for consideration of technical readiness for scale- up; adequacy and appropriateness of the demonstration project; the EHSS and other site-related aspects; and the reasonableness and adequacy of the technical approach and 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 evaluated to assess whether the proposed cost was appropriate and reasonable, and to determine the probable cost of the proposed project to the Government. The Cost Proposal was also used 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:

a) The desirability of selecting for support a group of projects that represent a diversity of methods, technical approaches, or applications;

b) The desirability of selecting for support a group of projects that would ensure that a broad cross section of the U.S. coal resource base is utilized, both now and in the future; and

c) The desirability of selecting for support a group of projects that represent a balance between the goals of expanding the use of coal and minimizing environmental impacts.

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

In light of the tight schedule imposed by Public Law No. 99-190 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 their proposal.

This strategy has three major elements. The first involves preparation of a comparative programmatic environmental impact analysis, based on information provided by the offerors and supplemented by DOE, as necessary. This environmental analysis ensures that relevant environmental consequences of the CCT Program and reasonable programmatic alternatives are evaluated in the selection process. The second element involves preparation of a preselection project-specific environmental review. The third element provides for preparation by DOE of site-specific documents for each project selected for financial assistance under the PON.

No funds from the CCT 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 to ensure that significant site- and technology-specific environmental data are collected and disseminated.

After considering the evaluation criteria, the program policy factors, and the NEPA strategy, the proposal submitted by Babcock and Wilcox, Alliance, Ohio, was one of the proposals selected for award.

3.0 TECHNICAL FEATURES

3.1 Project Description

The Babcock & Wilcox project will develop acid rain precursor control technologies for retrofit applications. The first part of the DOE project is an extension of an ongoing Limestone Injection Multi-stage Burner program. Babcock & Wilcox is currently conducting a full-scale demonstration of the LIMB technology on a 105 MWe wall-fired utility boiler in a project co-sponsored by the U.S. Environmental Protection Agency (EPA) and the State of Ohio. The objectives of this project are to demonstrate NO_x and SO_2 emissions reductions on the order of 50% to 60% at a capital cost of at least $100 per kilowatt (kW) less than wet SO_2 scrubbers. Depending on unit size and site characteristics, wet scrubbers generally cost about $200 to $300 per kW. The EPA sponsored testing will be conducted using one sorbent and one coal. The B&W project planned for the CCT program will broaden the applicability of the LIMB technology through additional testing using different types of coal and sorbents.

The second part of the Babcock & Wilcox project is to evaluate the Consol "Coolside" process for SO_2 control. This process involves dry sorbent injection and humidification technology downstream of the boiler. The proposed demonstration will provide a side-by-side comparison with LIMB technology. The near term application of LIMB is for low-cost retrofit to existing boilers. The "Coolside" process is largely boiler independent, since the sorbent is injected downstream of the boiler. This may be particularly beneficial for high-sulfur coals, for which the necessary amount of in-furnace sorbent injection could cause some degradation of boiler performance. Overall, the process requires a minimum of hardware and has a low capital cost. An SO_2 reduction in the 50% to 80% range is anticipated using this technology with 3% sulfur coal, when compared to conventional uncontrolled coal-fired boilers. The potential commercialization of these retrofit technologies is enhanced by their low capital cost in comparison with competing technologies.

3.1.1 Project Summary

Project Title:	LIMB Demonstration Project Extension
Proposer:	Babcock & Wilcox
Project Location:	Ohio Edison's Edgewater Plant Lorain, Ohio - Lorain County
Technology:	Flue Gas Cleanup - LIMB and Coolside Duct Injection
Application:	Utility Boilers; New or Retrofit; Coal Fired
Types of Coal Used:	Medium to High Sulfur Bituminous
Product:	Steam or Electricity
Project Size:	105 MWe
Project Start Date:	May 1987
Project End Date:	December 1990

3.1.2 Project Sponsorship and Cost

Project Sponsor:	Babcock & Wilcox	
Proposed Co-Funders:	U. S. Department of Energy State of Ohio Babcock & Wilcox Consolidation Coal Company	
Proposed Project Cost:	$19,404,940	
Proposed Cost Distribution:	Participant Share (%)	DOE Share (%)
	60.9	39.1

3.2 LIMB and Coolside Processes

3.2.1 Overview of Process Development

LIMB is an EPA developed process, and B&W's work on this furnace sorbent injection process started at their Alliance Research Center in the late 1960's. This program, consisting of over 400 tests, culminated in a commercial scale installation at the TVA Shawnee Station in Paducah, Kentucky. Results were not completely satisfactory.

Because of the concern over SO_2 emissions and the need for relatively inexpensive SO_2 removal systems that could be retrofitted to many existing units, B&W continued studying dry sorbent injection. A recent pilot scale test program produced a data base that provided a better understanding of the conditions and parameters that would produce satisfactory results from dry sorbent injection.

Another part of LIMB, the low NO_x burner, is the result of a separate development program carried out by B&W in conjunction with Southern California Edison Company. Initial work was done with gas and oil fired burners and led to excellent results for NO_x control. When coal was burned, NO_x control required additional development because of some special flame quality requirements. These efforts were ultimately successful and resulted in a low NO_x, coal fired burner.

These two components of LIMB, now ready for commercial demonstration, have been combined in an EPA-sponsored test program to be completed by July 1988. The DOE project will extend those tests to include multiple coal and sorbent combinations, and will include tests of the Coolside process.

Work on the Coolside process was started in the laboratory in 1983 and has been developed from the laboratory scale through 1 MW field tests. Consol's Coolside test program included evaluation of various sorbents and additives to enhance sorbent efficiency, and also development of improved sorbents. Laboratory and field test programs have enabled the Coolside process to capture up to 80% of the SO_2 formed by combustion of sulfur bearing fuels.

Since flue gas humidification enhances both SO_2 removal and ESP performance, humidification will be part of the Coolside installation. Extensive work was done to determine the optimum degree of humidification. Field tests of humidification were conducted on a 3000 to 4000 actual cubic feet per minute flue gas slipstream from a coal fired industrial boiler at DuPont's Martinsville, W.Va., plant. These tests showed that humidification using commercially available nozzles is feasible on a commercial scale.

3.2.2 Process Description

LIMB is a low capital cost technology for retrofit to existing boilers that will provide 50% to 60% SO_2 removal. It combines the injection of dry sorbents into the boiler for direct capture of SO_2 from the combustion gases with the use of low NO_x burners in which staged combustion is utilized for NO_x control. Sorbent injection requires the pulverization, transportation, injection, and distribution of a suitable reagent into the combustion gases at the proper location, and then the collection of the reacted solids downstream. From a hardware perspective, sorbent injection is simpler than either a wet scrubber or a spray dryer FGD system. In the Coolside process, dry sorbent is injected into the duct after the flue gas leaves the boiler. The flue gas is then humidified with a water spray to enhance SO_2 absorption and ESP performance.

The demonstration testing of the LIMB process has been designed for installation and operation in Ohio Edison's Edgewater Unit No. 4, Boiler No. 13. This design is applicable to many other utility boilers being considered for SO_x/NO_x abatement retrofit technology. The LIMB injection system consists of three subsystems installed upstream of the boiler to provide sorbent injection, as shown in Figure 3. These are: (1) the sorbent handling, preparation and storage system, (2) the transport and feed system, and (3) the distribution and injection system.

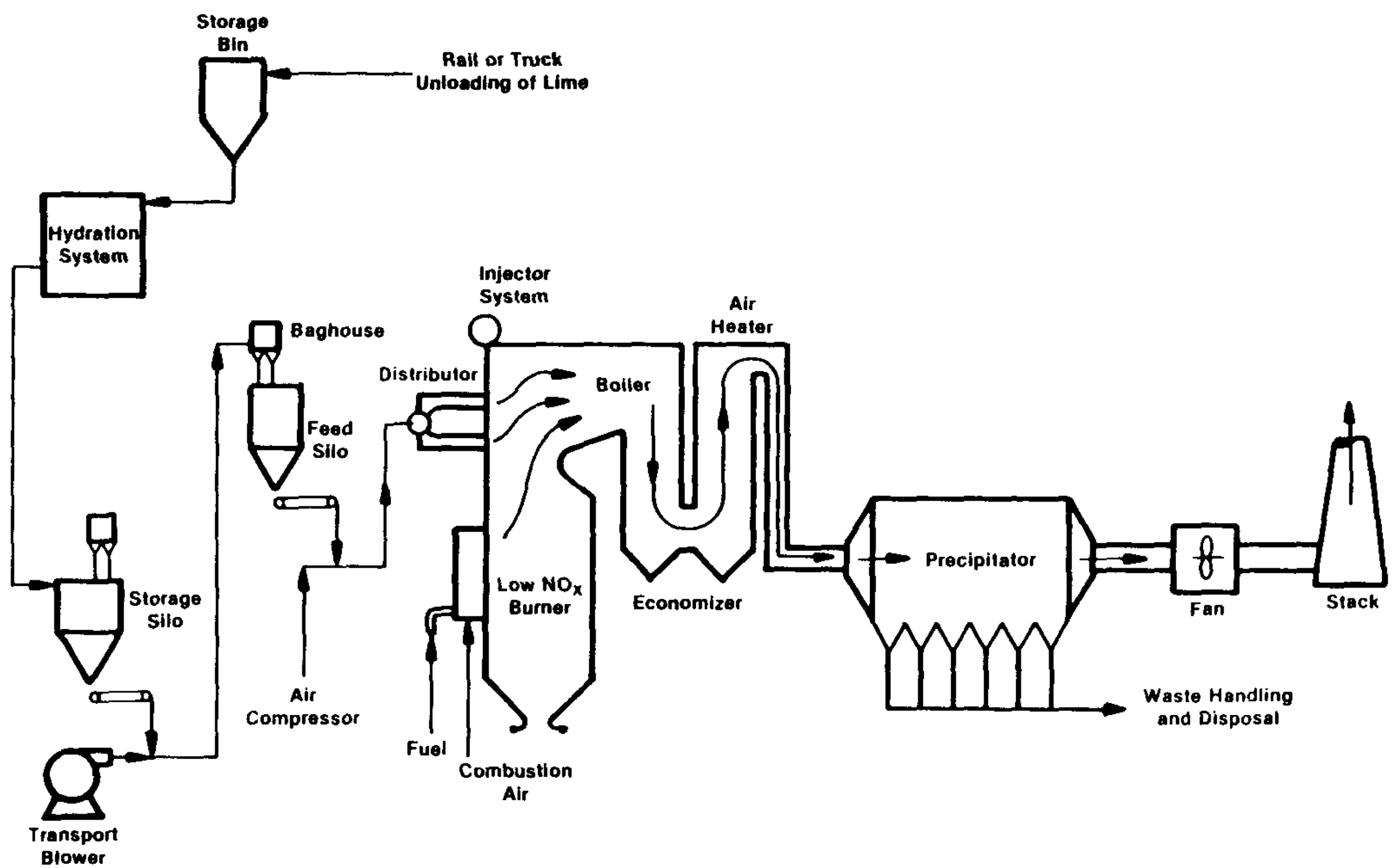

FIGURE 3. LIMB INJECTION SYSTEM INSTALLED AT THE OHIO EDISON EDGEWATER PLANT

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The sorbent handling, preparation, and storage system will prepare, store, and supply sorbent for the process. Sorbent can be delivered in bulk and, depending on the sorbent used, delivered as coarse material or in a dry pulverized state suitable for pneumatic conveying. In a commercial plant retrofit, hydrated lime , which is lime reacted with water, would be delivered and mechanically conveyed to storage. This sorbent would then be stored in a bin, from which it would be fed to the sorbent delivery system and pneumatically injected into the boiler.

The objective of the sorbent transport and feed system is to provide a controlled feed rate of sorbent to the injection ports in the boiler. This system is duplicated for each injection location, as determined on a site- specific basis. The Ohio Edison test boiler has already been modified with sorbent injection ports installed under the present EPA contract. Material will be conveyed in a dense phase from the bottom of the feed silo to a vertical pickup station, from which it will be conveyed in dilute phase to distributors. Each distributor will convey the solids and air mixture into the injection lines. Air used in transport of the sorbent will be supplied by a compressor and dried in an air dryer.

At the boiler, the distribution and injection system will give the desired penetration and dispersion of sorbent into the boiler. A booster air fan will provide the air necessary for the desired penetration and dispersion. Alternatively, lances that have higher air velocity could be used in larger units to minimize the air required for injection of the sorbent.

Additional sootblowers will probably be required in a commercial boiler to deal with the effects of higher solids concentrations in the furnace gases as a result of sorbent injection. The type and number of additional sootblowers will be dependent on the particular boiler being retrofitted and on the slagging and fouling characteristics of the coal being burned.

To meet the NO_x emissions reduction goal of 50% to 60% in the LIMB process, low NO_x pulverized-coal burners are required for a commercial boiler retrofit. Babcock & Wilcox developed low NO_x burners that are generally compatible with utility boilers and should be easily retrofitted to a number of currently operating units. B&W low NO_x burners have been selected and installed in the test boiler at the Edgewater Plant under the present EPA contract.

As shown in Figure 4, the Coolside process as conceived for a commercial application involves hydrated lime injection, flue gas humidification, and an additive to the humidification water for injection into the ductwork downstream of the boiler at a point where the flue gas is relatively cool (about 300°F). The additive is injected to enhance the sulfur removal effectiveness of the sorbent. In a commercial plant, lime would be delivered and mechanically conveyed to a storage bin. From there it would be transported to a feed bin that supplies a hydrator system. The hydrated lime product from the hydrator system is stored in a bin before pneumatic injection into the flue gas duct.

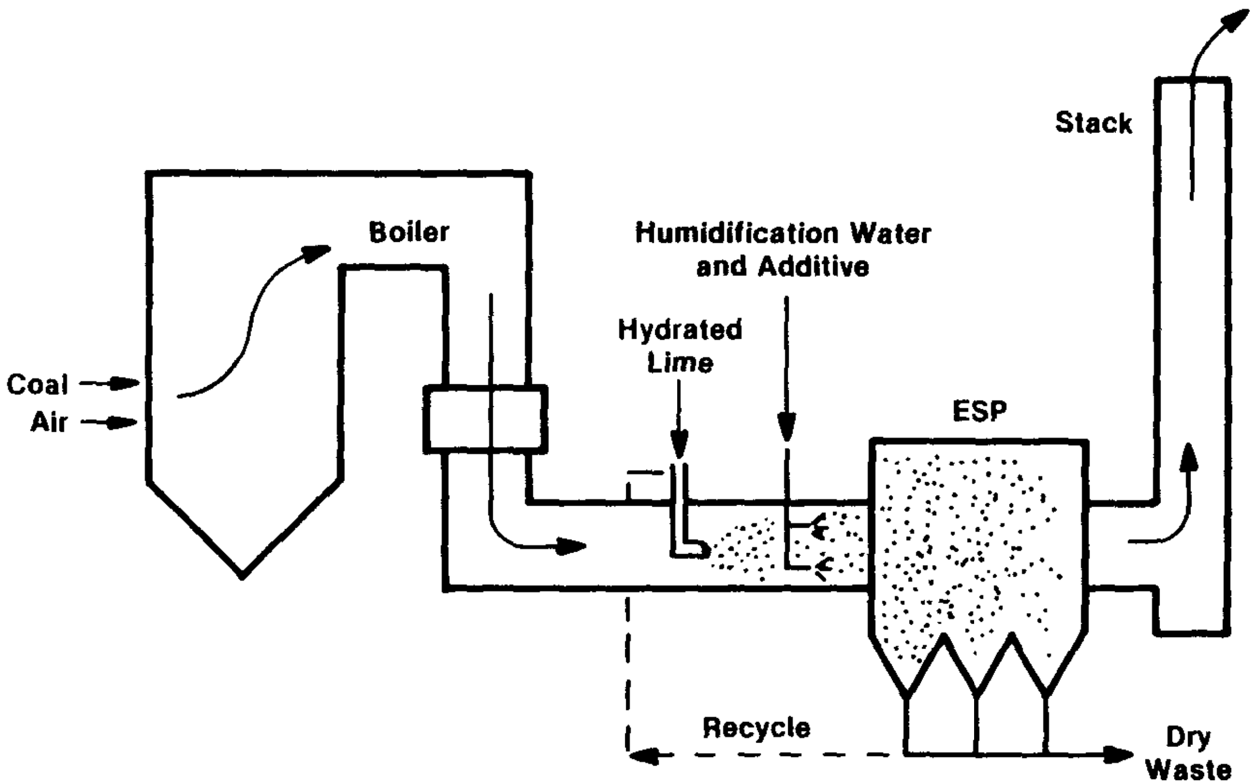

FIGURE 4. COOLSIDE PROCESS

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An additive such as soda ash or sodium hydroxide is used to enhance SO_2 absorption. It would be delivered and pneumatically conveyed to a wet storage system. Flue gas humidification water and the additive solution will be combined before injection, and mixed with an in-line mixer. This stream would then be injected into the flue gas duct (humidifier) downstream of the hydrated lime injection point. In this project, the humidifier design will include not only the equipment necessary for humidification, such as the water pump, air compressors, humidifier lances, and nozzles, but also the duct modifications. The duct modifications include removal of an unused ESP and installation of a new bypass duct. The humidification and Coolside sorbent injection equipment will be installed in the bypass duct. This duct can be isolated from the main boiler duct by valves to allow the boiler to operate normally while work is being done on the test equipment.

3.3 General Features of the Project

3.3.1 Evaluation of Developmental Risk

As with any new or emerging technology, there is an element of risk involved with its continued development and scale-up. However, the LIMB process has already been demonstrated for one case on a commercial scale, and the Coolside process has been demonstrated at the 1 MW size. Both processes are the results of development programs that started with initial bench scale research and proceeded through pilot plant work and small scale demonstrations. This project will provide:

- o the final technical demonstration needed for the processes
- o needed data on the processes' effect on the boiler and ancilliary equipment
- o applicable economic, technical, and environmental data necessary to support commercialization decisions

After reviewing the results of the development programs for both LIMB and Coolside and the information supplied by both EPA and B&W, an acceptable risk factor has been assigned to both processes. Both processes will result in increased solids loading, affecting the ESP and ash handling equipment. The LIMB system may be subject to boiler fouling and boiler tube erosion; however, this is considered to be a low risk. Coolside may be subject to duct wall solids buildup and condensation in the ESP and/or stack; this is considered to be a moderate risk.

3.3.1.1 Similarity of Project to Other Demonstration and Commercial Efforts

The LIMB and Coolside processes are better developed and ready for demonstration as compared to the other dry sorbent injection processes. LIMB and Coolside are relatively inexpensive technologies, are easily retrofittable to many existing boilers, and are ready for commercial demonstration.

The present technologies similar to Coolside are the Dravo Hydrate Addition at Low Temperature (HALT) Process, the Bechtel Confined Zone Dispersion (CZD) Process, the General Electric In-Duct-Spray Drying (IDS) Process, and the EPA E-SOX Process. These processes, if utilized in conjunction with low NO_x burners, can provide both SO_2 and NO_x reductions. All are in various stages of development.

The HALT process is most like Coolside in that dry sorbent injection and humidification take place between the boiler and ESP. Both the CZD and IDS process inject a sorbent slurry into the duct downstream of the boiler. The difference between CZD and IDS is in the specific technique used to atomize the slurry. The E-SOx process sprays slurry into the ESP and, in effect, uses a portion of the ESP as a reactor.

The distinguishing characteristics of the Coolside process are the use of flue gas humidification by water spraying and the injection of a dry sorbent (hydrated lime) downstream of the air preheater before the humidification. The EPA sponsored LIMB humidification project will also use flue gas humidification but only with in-furnace sorbent injection. The major mechanism for SO_2 removal by LIMB is sorbent calcination and sulfation in the boiler. The Coolside technology achieves the same sulfation through different engineering specifics, therefore the potential applicability of the Coolside technology is significantly different.

The DOE Coolside and LIMB testing is a natural extension of the EPA LIMB and humidification project. Because the LIMB and humidification systems will be in place at the Edgewater plant, it will be very cost-effective to combine the Coolside and LIMB extension testing into one program. The Coolside technology can be easily demonstrated by installing sorbent injection ports directly upstream of the humidification system. The DOE LIMB extension testing is an expansion rather than a duplication of the EPA LIMB program because a wide variation in coal and sorbent properties will be studied.

3.3.1.2 Technical Feasibility

The LIMB process utilizes low NO_x burners and furnace sorbent injection. Work on the low NO_x burners started thirty years ago, and these burners are now considered to be fully commercial technology.

Work on sorbent injection started approximately twenty years ago. Early work involved over four hundred pilot scale tests using over 100 sorbents to evaluate SO_x absorption under various operating conditions. The effects of the sorbents and additives on ash deposition and ash properties were also studied. This work was followed by tests on a commercial scale using a limestone sorbent. These were run at the TVA Shawnee Station and were followed by additional pilot scale tests to evaluate various arrangements for sorbent injection.

This EPA sponsored LIMB project was expanded to demonstrate flue gas humidification, which enhances ESP performance. The extensive experience with the various components of the LIMB process indicates that this process is technically feasible and the risk is low.

The Coolside process was developed by the Coal Research Division of Consol starting with laboratory work that was done in 1983. This process has also been tested extensively at the 1 MW scale. Like the LIMB process, various sorbents and operating conditions have been evaluated. Much progress has also been made on flue gas humidification for the Coolside process, both to enhance SO_2 removal and to enhance ESP performance. Commercial scale humidification tests are now being carried out by B&W as part of the EPA sponsored LIMB tests at the proposed site for this project.

This background of laboratory and small scale field tests, coupled with the on-going LIMB humidification tests, is sufficient to indicate that the Coolside process is also technically feasible. However, a moderate technical risk exists, particularly in the area of duct wall solids buildup and condensation.

3.3.1.3 Resource Availability

B&W and the other co-funders have committed adequate funds, as discussed in Section 6.1, to cover the Participants share of the proposed project cost. They have also dedicated sufficient personnel to conduct the demonstration program. Ohio-Edison personnel will continue to operate the boiler, since it is a boiler that they normally have in operation. Additional personnel will be needed only to collect data and to operate and maintain the humidification and sorbent handling equipment. Coal feed and solid wastes will continue to be handled by regular plant personnel.

Key factors in the use of the Edgewater site for the demonstration plant were:

- The Edgewater facility is a currently operating electric power generation plant. This helps to keep project costs down since the costs of operating a boiler, refurbishing an old boiler, or building a new one are not incurred.

- The Edgewater facility is currently undergoing retrofit to demonstrate the basic LIMB technology under the EPA contract. Only a minimum of additional modification is necessary for the DOE LIMB extension demonstration. The bulk of additional construction in the DOE project will be for the Coolside demonstration.

- Required materials, resources, and utilities (e.g., coal, lime and other sorbents, and cooling water) are readily available.

- The site already has waste product handling capabilities, including a holding pond for waste water and a disposal system for solid waste.

- The electrostatic precipitator is conservatively designed, giving extra particulate collection capability to ensure that emission levels will not be exceeded during testing.

- The site of the proposed facility does not border on or contain within its boundaries any sensitive aquatic or terrestrial habitats. Because the site of the proposed facility is an existing industrial complex, no environmentally sensitive resources are present. Therefore, environmentally safe operation of the proposed facility is expected.

- The facility is in an economically depressed area where labor availability is high. Some economic stimulus may be provided by the project, and the risk of project construction delays should be minimized.

3.3.2 Relationship Between Project Size and Projected Scale of Commercial Facility

The 105 MWe Edgewater plant is considered to be commercial scale. Further scale-up of the system from 100 MWe to 600 MWe may be needed. However, this would more likely require an increase in number of sorbent distribution systems rather than a significant change in system component size. No further demonstration work will be required to apply this technology to larger boilers. Since the demonstration will be conducted at the commercial scale, it will not be necessary to collect data for scale-up. Remaining data needs include characterization of system operation and performance.

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

3.3.3.1 Applicability of the Data to Be Generated

To produce accurate and reliable performance data, the demonstration will use a full range of instrumentation and data collection techniques. All instrumentation and data acquisition equipment will be in place from the EPA LIMB program. A B&W Boiler Performance Diagnostic System 140™ was installed earlier under the EPA project and will be used to gather the following information:

- o Furnace absorption and cleanliness
- o Convective surface cleanliness
- o Slag deposition rates
- o Sootblower effectiveness
- o Gas temperatures
- o Gas velocities
- o Heat rate deviations

The demonstration will produce data on process operability, including load following capability, ESP performance, and desulfurization performance. These results can be readily used to engineer other commercial applications of the LIMB and Coolside processes. The process performance data obtained can be directly applied to a large population of existing high sulfur coal utility stations because the demonstration design and host site characteristics represent typical furnace, boiler, and coolside conditions available in many stations.

Radian Corporation is a subcontractor to B&W on this project and will be used on-site to monitor flue gas composition and collect solid and liquid samples for analysis. Radian will set up a Continuous Emissions Monitoring (CEM) System to measure CO, CO_2, O_2, SO_2, NO_x, hydrocarbons, etc. They will also perform manual gas analysis and particulate sampling. This information, along with data from the System 140™ and routine operating data, will be sufficient to characterize the operation and performance of the boiler and LIMB system on each coal and sorbent combination tested.

The analytical results will provide the basis for evaluating SO_2 removal performance, ESP efficiency, and process controllability. The EPA analysis methods and continuous gas analyses will produce independent data on SO_2 removal performance. This confirmation by two different analytical techniques will enhance the accuracy and reliability of the demonstration data. Furthermore, gas and solids analyses will allow material balance calculations on sulfur and sorbent species important for data reliability evaluations.

Based on the SO_2 removal and operability results, process economics will be determined for the Coolside and LIMB processes. Since the proposed demonstration is of commercial scale, the resulting economic analysis will be directly applicable to other utility situations.

3.3.3.2 Identification of Features That Increase Potential for Commercialization

The current energy policy of the United States includes the expanded use of coal in utility and industrial applications. However, the increased use of coal must not conflict with environmental goals and thus requires development of cost-effective technology to control the pollutants resulting from coal combustion. Of major concern is the problem of acid rain in the Northeastern United States and portions of Canada.

The reduction of NO_x and SO_2 emissions from fossil fuel fired boilers has been a major objective of the DOE, the EPA, and all of the major boiler and burner manufacturers for many years. This is demonstrated by a number of concurrent efforts that have been and are being conducted to develop lower NO_x burners. Research has been sponsored to evaluate the potential for combined NO_x and SO_2 control by the injection of calcium-based sorbents through low NO_x burners. More recently, efforts have concentrated on upper furnace sorbent injection, where the thermal environment is generally regarded as more conducive to effective SO_2 control.

Sorbent injection into the furnace was the subject of extensive study during the mid-1960's as part of the overall effort to develop SO_2 control technologies capable of achieving a goal of 90% removal. In comparison to the efficiencies obtained with many of the wet flue gas desulfurization (FGD) processes, the relatively low performance of the dry injection techniques, coupled with some boiler operational difficulties, led to almost complete cessation of work in this technology area for a number of years. In the mid-1970's, interest was rekindled commensurate with advances in NO_x control technology coupled with an emerging potential for lower cost SO_2 emission control.

LIMB encompasses the potential simultaneous NO_x and SO_2 control using limestone injection with a low NO_x burner. It was originally thought that the conditions under which NO_x emissions were reduced might also enhance the capture of sulfur species with calcium-based sorbents. As a result, developmental work using dry sorbents for SO_2 control was again undertaken, and the technology has advanced to the point that it is now ready for demonstration at a commercial scale.

Unlike LIMB, the Coolside equipment is installed in the ductwork downstream of the boiler. Therefore, adverse impact on the boiler performance is avoided. However, for both LIMB and Coolside, the plant's particulate removal and ash handling equipment may have to be expanded or upgraded to handle the increased solids loading.

Both LIMB and Coolside systems consist of commercially available equipment, such as blowers, pumps, nozzles, and pneumatic transport systems, all of which are well proven, reliable equipment items that can be readily installed. Some modification to the boiler is required for the LIMB injection system. The Coolside equipment is installed in the ductwork that channels the flue gas from the boiler to the ESP.

Therefore, neither technology requires extensive modification to the power plant and will be aided in commercialization, if demonstrations are successful, by offering:

- o Significant reductions in emission levels of sulfur oxides achieved at a capital cost of at least $100/kW less than conventional full scale wet scrubbing systems.

- A system that will maintain boiler reliability, operability, and steam production performance after retrofit.

It is the objective of this project to fully establish that the LIMB and Coolside clean coal technologies offer cost-effective alternatives to the electric utilities for overall sulfur dioxide control.

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

The LIMB process and Coolside process, once this project is completed, will be the most developed of the sorbent injection processes and will be fully commercial.

An additional attractive feature of this project is the unique opportunity presented because much of the equipment for both processes is already in place; therefore, testing can be efficiently and economically carried out. In addition, the ESP, ash handling equipment, and water systems associated with the boiler can handle the increased demand without modification.

The Coolside and LIMB technologies are intended to provide technology options for utilities that want to reduce SO_2 emissions from existing (pre - New Source Performance Standards (NSPS)) boiler units. Existing technology includes wet flue gas desulfurization and lime spray dryer processes. The need for new technology development arises because the existing processes are high in capital cost, which makes their application particularly expensive under certain scenarios that new regulations could present. Retrofit, using the new LIMB and Coolside technologies, is expected to result in the same level of SO_2 reduction as the existing technologies, however at a significantly reduced cost. This is true because these new technologies are characterized by low equipment costs and minimal space requirements.

An economic comparison of wet flue gas desulfurization with the LIMB and Coolside technologies was made at the 105 MWe and 300 MWe level. For both sizes, the capital costs for LIMB and Coolside are approximately 50% less than wet flue gas desulfurization. Annual costs of LIMB with humidification, and Coolside, are expected to be about 29% and 32% lower, respectively, than wet flue gas desulfurization at the 105 MWe level.

The marketplace (the electric utility companies) is expected to implement technology that does not require large capital outlays, extensive plant modifications or extreme operational difficulties. LIMB technology can be incorporated into the existing plant without displacing other equipment or requiring new real estate. Operation of the plant will not be significantly affected.

The Coolside process concept has been well received because of its flexibility, simplicity, and economic advantages. The significant technology demonstration issue is the operability of the humidification unit, which is the key to the process and its economic advantages, especially in capital cost. Based on discussions with utilities, design engineers, and process vendors, the utility and industrial coal users are expected to adopt the Coolside process if the demonstration program achieves its goals.

The drive toward lower capital cost is evidenced by the rapid acceptance of spray dryer technology in the United States and of boiler sorbent injection in Europe. The potential for a higher level of SO_2 control, relative to other low capital cost technologies, and the boiler independence of the Coolside process, make this technology particularly desirable.

4.0 ENVIRONMENTAL CONSIDERATIONS

The PON requires that, upon award of financial assistance, the Participant 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 site-specific NEPA documents to be prepared by DOE for the selected project. Such NEPA documents shall be prepared, considered, and published in full compliance with the requirements of 40 CFR 1500-1508 and in advance of a go/no-go decision to proceed beyond preliminary design. Federal funds from the CCT Program will not be provided for detailed design, construction, operation and/or dismantlement until the NEPA process has been successfully completed.

5.0 PROJECT MANAGEMENT

5.1 Overview of Management Organization

The DOE will monitor the project through the Contracting Officer and the Contracting Officer's Technical Representative (COTR). 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. An advisory committee will be established in an overview role.

A multi-organization team headed by B&W will be involved in this project. In addition to Babcock and Wilcox, other members of the team are Consol and the Ohio Edison Company. Major sub-contractors are Stone and Webster Engineers, Radian Corporation, and the Coal Research Division of Consol.

5.2 Identification of Respective Roles and Responsibilities

DOE

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

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

- o 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.

- o Approve those technical reports and technical information required to be delivered by the Participant to the DOE under this Cooperative Agreement.

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

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

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

- o Changes any of the terms, conditions, or specifications of the Cooperative Agreement.

- Interferes with the Participant's right to perform the terms and conditions of the Cooperative Agreement.

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

Participant

As shown in Figure 5, three divisions of Babcock & Wilcox will participate in the LIMB Demonstration Project Extension:

- Contract Research Division (CRD)
- Domestic Fossil Operations (DFO)
- Research and Development Division (R&DD)

B&W's R&DD and their other operating divisions perform contract research under the sponsorship of CRD, which is responsible for all contractual matters. DFO will have prime responsibility for technical performance of the proposed project.

The CRD Contract Manager is responsible for all contractual matters related to this Agreement and is the prime contact between B&W and the DOE Contracting Officer.

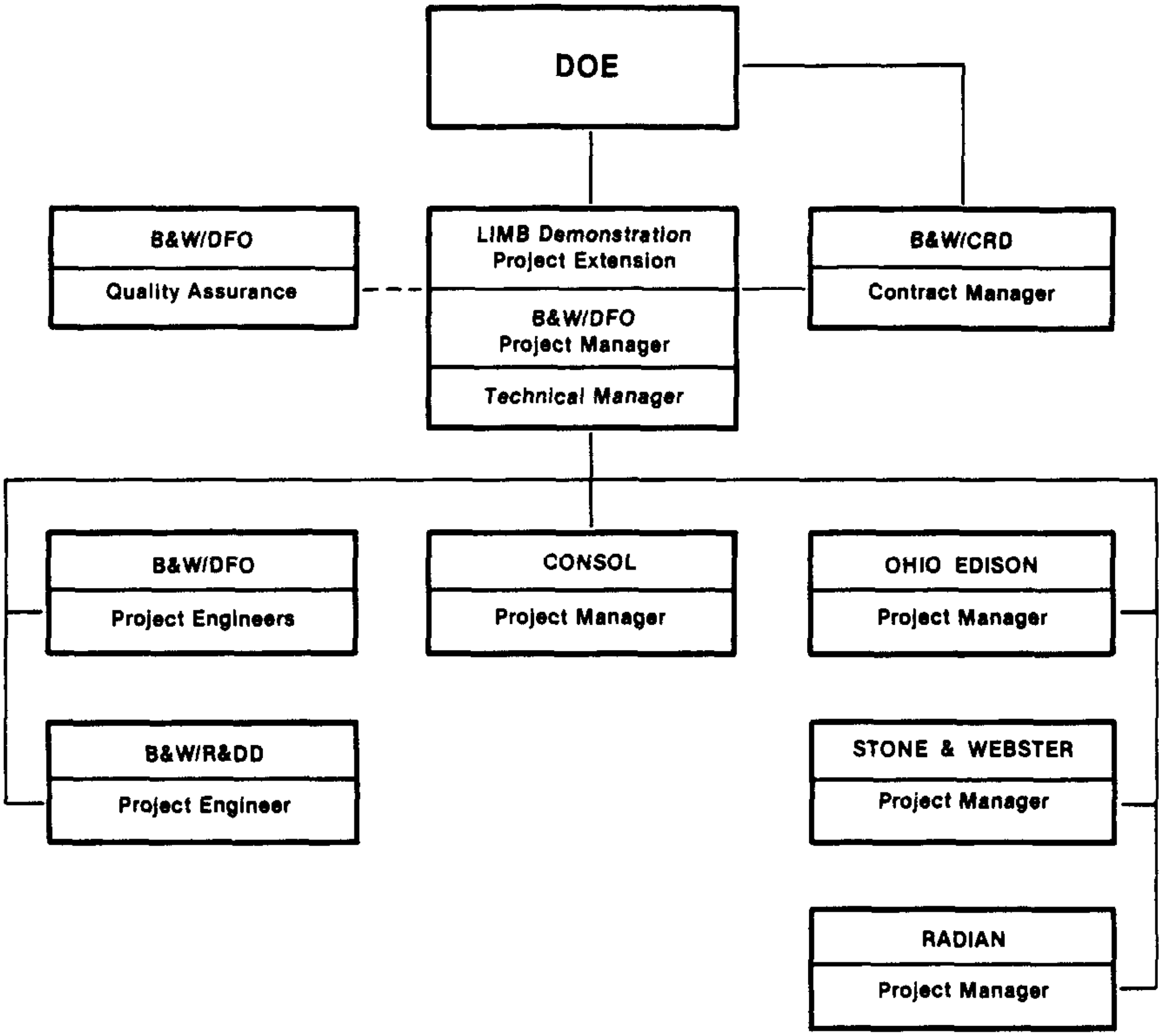

FIGURE 5. PROJECT ORGANIZATION

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The B&W Project Manager (from DFO) is the responsible decision maker in all matters dealing with the project, including proposal preparation, finances, administration, engineering, procurement, manufacturing, quality control, installation, start-up, field testing, and reporting to DOE. In addition to assuring that B&W meets its technical performance obligations in a timely manner through the interaction of a matrix organization, the Project Manager is the central point of contact between B&W and the DOE Project Office on all technical matters dealing with the project and will be assisted by the B&W Technical Manager on all day-to-day technical activities.

The CRD Contract Manager acts as a direct extension of the Project Manager. His primary responsibility is to coordinate on a day-to-day basis the transmittal of project information in accordance with the agreed upon project schedule. He will act as the normal B&W contact for liaison with the DOE Contracting Officer on most matters related to the project.

The Contract Manager will handle the majority of the contract commercial matters that arise that do not require Project Manager authorization. Technical issues will be disseminated to the project team through the project engineers.

Project review meetings will be held regularly throughout the life of the project. These meetings will provide senior level management with input to the concepts of the project and will provide background information concerning matters requiring their and cost-effective manner, bringing to the table the demonstrated expertise to engineer and construct these retrofit technologies.

The raw sorbent availability is sufficient to handle current and projected Coolside requirements. Additional haulage of lime would be required, but existing rail and truck capacity should be adequate. The solid waste produced will increase, resulting in an increase in the tonnage of waste to be disposed of.

For the proposed technologies, manufacturing of equipment can be accommodated because of the large overcapacity that currently exists within the industry. There are no unusual fabrication requirements that would preclude the use of existing manufacturing facilities. The nature of the individual components makes LIMB and Coolside technologies very compatible with existing power plant and environmental equipment manufacturing methods.

A demonstrated success in commercializing these new technologies is expected to support the belief that a new broad market will open up for U.S. manufacturers. The American public will benefit through favorable electricity costs; the American mining industry will benefit through a broader market for high-sulfur coal and lime; and the electric utilities will benefit by having access to a lower cost, simplified operations technology option.

6.0 PROJECT COST AND EVENT SCHEDULING

6.1 Project Baseline Costs

The total estimated cost for this project is $19,404,940. For budget purposes, Phase II has been divided into Phases IIA and IIB. The Participant cash contribution and the Government share in the costs of this project are as follows:

	Dollar Share ($)	Percent Share (%)
PHASE I		
Government	332,917	24.5
Participant	1,023,394	75.5
PHASE IIA		
Government	1,403,661	50.0
Participant	1,403,800	50.0
PHASE IIB		
Government	1,932,339	50.0
Participant	1,932,715	50.0
PHASE III		
Government	3,928,109	34.5
Participant	7,448,005	65.5
TOTAL PROJECT		
Government	7,597,026	39.1
Participant	11,807,914	60.9

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

DOE:	$ 7,597,026
State of Ohio:	7,227,914
B&W:	3,355,000
Consol:	1,225,000
TOTAL	$ 19,404,940

At the beginning of each Phase, DOE will obligate sufficient funds to pay its share of the expenses for that phase. Payments to the Participant will be made on a monthly basis to cover actual costs incurred and invoiced. Project schedule requirements dictate a need to fund Phases I and IIa concurrently.

6.2 Milestone Schedule

Coolside testing, including process optimization and the long term test program, will begin in the nineteenth month of the project and last for four months. The LIMB test program will start immediately upon completion of the Coolside tests. LIMB tests will last for fourteen months. The final Coolside test report will be prepared at the end of the twenty-fourth month, and the final LIMB test report is due at the end of the forty-third month.

In addition, other required reporting has been fully described and scheduled in the Cooperative Agreement. The critical project tasks are identified and scheduled as shown in Figure 6.

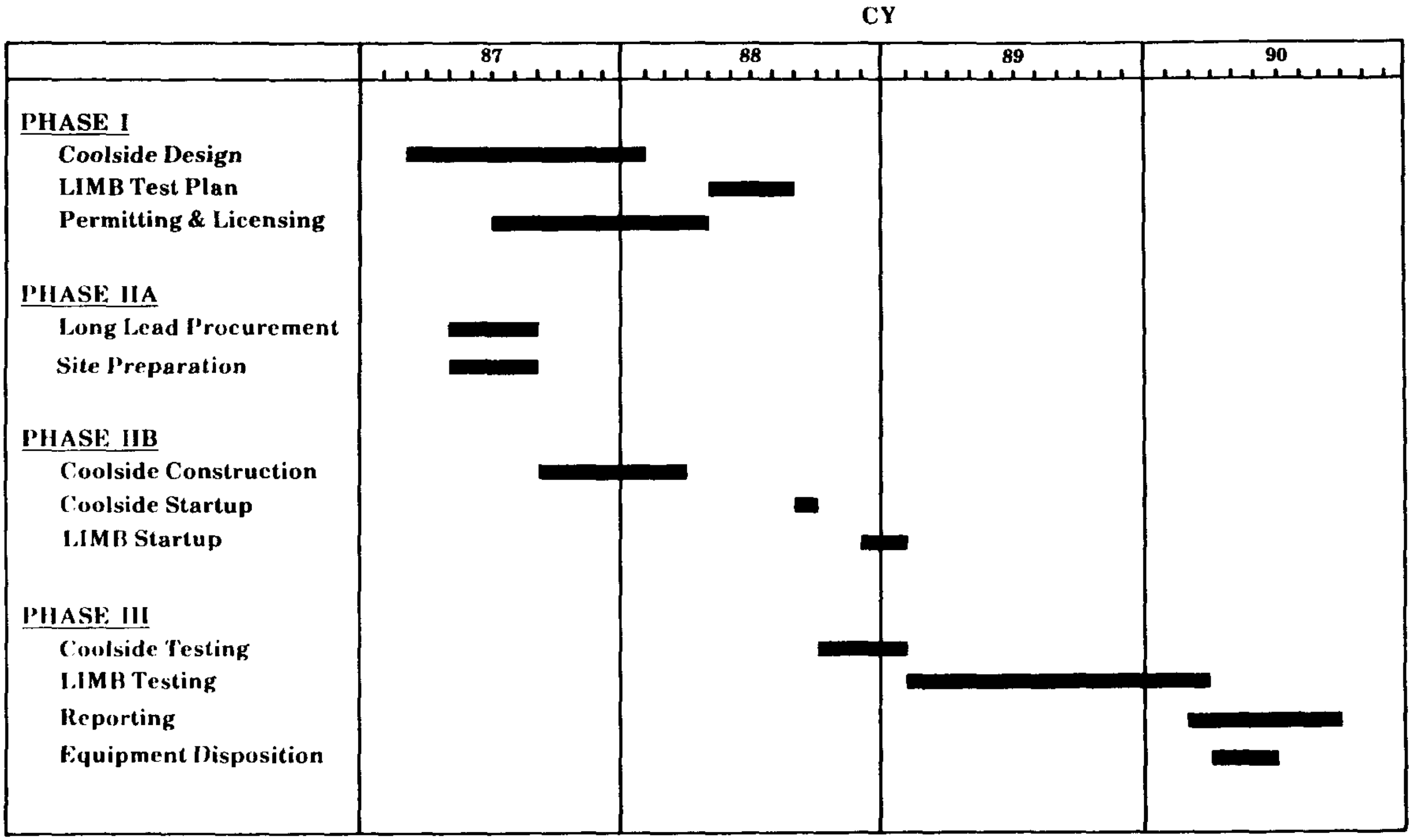

FIGURE 6. LIMB DEMONSTRATION PROJECT EXTENSION SCHEDULE.

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6.3 Recoupment Plan

In response to the stated policy of the DOE 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 Recoupment/Repayment Plan included in the Cooperative Agreement.