DOE/FE-0146
Distribution Category UC-101

Comprehensive Report to Congress
Clean Coal Technology Program

Demonstration of Advanced Combustion Techniques for a Wall-Fired Boiler

A Project Proposed By
Southern Company Services, Inc.

November 1989

U.S. Department of Energy
Assistant Secretary for Fossil Energy
Office of Clean Coal Technology
Washington, DC 20585

TABLE OF CONTENTS

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 that are (1) capable of being commercialized in the 1990s, (2) more cost effective than current technologies, and (3) capable of achieving significant reductions in 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 PON, 55 proposals were received by the DOE in May 1988. After evaluation, 16 projects were selected for funding. These projects involve both advanced pollution control technologies that can be "retrofitted" to existing facilities and "repowering" technologies that not only reduce air pollution but also increase generating plant capacity and extend the operating life of the facility.

One of the proposals selected is the Southern Company Services, Inc. (SCS, Inc.) (a subsidiary of Southern Electric System), 500 MWe demonstration of advanced wall-fired combustion techniques. During this project, the removal of NO_x from pulverized coal-fired boilers by the use of several combustion control techniques, Advanced Overfire Air (AOFA), Low NO_x Burners (LNB), and combined AOFA and LNB will be demonstrated.

AOFA involves three techniques consisting of (1) improving the mixing of overfire air with the furnace gases to achieve complete combustion, (2) depleting the air from the burner zone to minimize NO_x formation, and (3) supplying air over furnace wall tube surfaces to prevent slagging and furnace corrosion. This technique is expected to reduce NO_x emissions by about 35%.

Low NO_x burners utilize the technique of controlled fuel/air mixing to preclude the formation of NO_x. This is accomplished by regulating the initial fuel/air mixture, velocities, and turbulence to create a fuel-rich flame core and by controlling the rate at which additional air required to complete combustion is mixed with the flame solids and gases so as to maintain a deficiency of oxygen.

As shown by typical results for utilities, LNB technology is capable of reducing NO_x emissions by about 45%.

Based on earlier experience, the use of AOFA in conjunction with LNB can reduce NO_x emissions by as much as 60% compared with conventional burners.

The project will be conducted at the 500 MWe pulverized coal-fired Hammond Plant Unit No. 4, owned by Georgia Power Company. The plant is located in Coosa, Georgia, as shown in Figure 1.

Unit No. 4 began commercial operation in 1970 and is representative of most of the existing wall-fired utility boilers built in the United States prior to promulgation of Federal New Source Performance Standards (NSPS). Relative to past low NO_x combustion retrofits, an important feature of this project is that NO_x reduction levels and boiler performance associated with three low NO_x combustion technologies will be demonstrated in a step-wise fashion on a large operating utility boiler over a long term. The long-term data obtained for each technology will be statistically analyzed and compared with pre-retrofit baseline data. Analysis of the long-term data will determine the achievable emissions limit and more completely characterize the NO_x reduction capability of the technology.

The demonstration project will be performed over a 35-month period, following execution of the Cooperative Agreement, and includes site preparation, flow modeling, baseline characterization testing, AOFA and LNB design, installation and testing, data analysis, and reporting of results.

SCS, Inc., took exception to the design, construction, and operation phase structure set forth in the PON, because it would not provide an efficient, effective framework for the conduct of the project proposed. Instead, SCS, Inc., has proposed the following phase structure that follows the natural chronology of the project tasks:

- Pre-award activities
- Set-up and pre-retrofit (baseline characterization)
- AOFA retrofit and testing
- LNB retrofit and testing
- Combined AOFA and LNB testing
- Disposition and final reporting

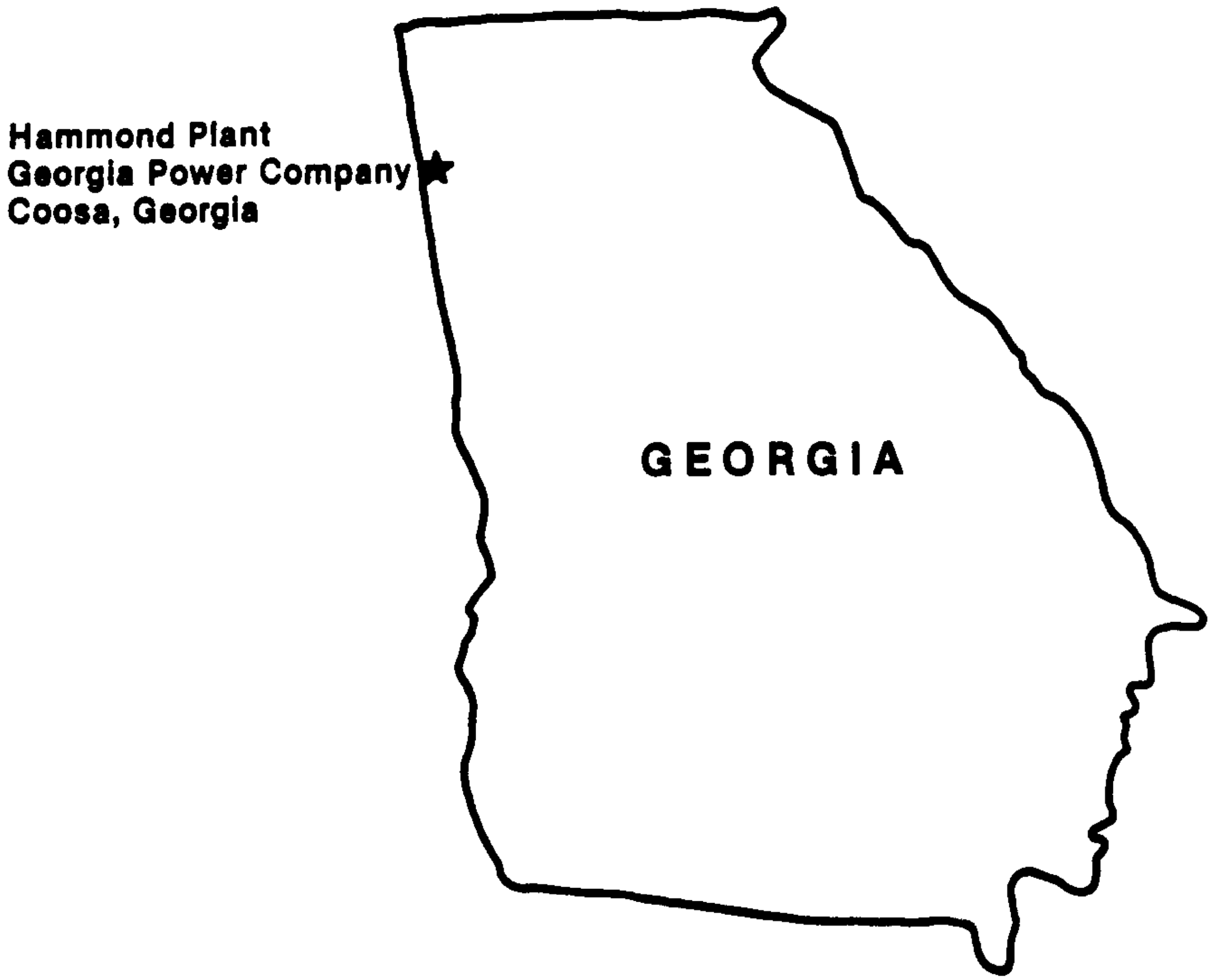


FIGURE 1. SCS, INC. ADVANCED WALL-FIRED COMBUSTION DEMONSTRATION PROJECT LOCATION.

NOJ18.377

The total project cost is $11,711,229. The co-funders are DOE ($5,242,917), SCS, Inc. ($5,468,312), and EPRI ($1,000,000). AOFA testing is scheduled to begin in the Spring of 1990 and LNB system testing is scheduled to begin in early 1991. Overall project completion is scheduled to occur in mid-1992.

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 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 any project to receive an award under the ICCT Program. This report is in fulfillment of this directive and contains a comprehensive description of the Southern Company Services, Inc., Advanced Wall-Fired Combustion Techniques Demonstration 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 of 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 socioeconomic (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 with commercially available technology options.

The second major category, "Demonstration Project Factors," recognized the fact that the proposed demonstration project represents the critical step between "predemonstration" scale of operation and commercial readiness, and 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 NEPA regulations and the DOE guidelines for compliance with NEPA. 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 and award. The "Demonstration of Advanced Combustion Techniques for a Wall-Fired Boiler" proposal submitted by Southern Company Services, Inc., was one of these proposals.

3.0 TECHNICAL FEATURES

3.1 Project Description

The Southern Company Services, Inc., project will demonstrate in a step-wise fashion that three NO_x control techniques, AOFA, LNB, and LNB combined with AOFA, are suitable for retrofit applications.

The demonstration will be conducted at the Georgia Power Company Hammond Plant Unit No. 4. The boiler is a nominal 500 MWe pulverized coal, wall-fired unit, which is representative of most of the existing pre-NSPS wall-fired utility boilers in the United States.

Previous demonstrations of low NO_x burners have been based on short-term test data, which does not properly characterize utility boiler operation. The goal of this program is to prove the technical and economic feasibility of the three techniques, using high-sulfur content U.S. coal and long-term test data. The acquisition of long-term data from a large utility plant operating normally under load dispatch control is one of the most important elements of this demonstration. The long-term data collected from operation with each technology will be statistically analyzed and compared with long-term, pre-retrofit baseline data. These analyses will provide data that can be applied to other wall-fired units.

If successful, short-term NO_x emissions reductions of up to 60% may be achieved during this demonstration project and the utility industry's confidence in the techniques will be greatly enhanced.

3.1.1 Project Summary

Project Title:	500 MWe Demonstration of Advanced Wall-Fired Combustion Techniques for the Reduction of Nitrogen Oxide Emissions from Coal-Fired Boilers
Proposer:	Southern Company Services, Inc. (SCS, Inc.)
Project Location:	Coosa, Georgia (Hammond Plant) Floyd County
Technology:	AOFA and LNB combustion techniques for nitrogen oxide emissions control
Application:	New and retrofit utility and industrial coal-fired boilers
Types of Coal Used:	Kentucky, Tennessee, Virginia, and West Virginia (1.5 to 2.5% sulfur)
Product:	Environmental Control Technology
Project Size:	500 MWe
Project Start Date:	July 31, 1989
Project End Date:	June 30, 1992

3.1.2 Project Sponsorship and Cost

Project Sponsor:	*Southern Company Services, Inc.*	
Proposed Co-Funders:	U.S. Department of Energy and Electric Power Research Institute	
Proposed Project Cost:	$11,711,229	
Proposed Cost Distribution:	Participant Share(%)	DOE Share(%)
	55.2	44.8

3.2 Advanced Combustion Techniques for Wall-Fired Boilers

3.2.1 Overview of Process Development

Advanced Overfire Air

The use of overfire air to reduce nitrogen oxides was developed in the late 1950s by Babcock & Wilcox (B&W) and subsequently patented. Initially, the technique was used with gas- and oil-fired boilers, and short-term NO_x reduction levels of 30 to 50% were achieved.

In the late 1960s, overfire air was considered for use on coal-fired units, primarily as a result of the Clean Air Act and the subsequent promulgation of the 1971 New Source Performance Standards. Short-term nitrogen oxide reductions of 30 to 40% were achieved; however, the use of overfire air caused operational problems such as slagging and carbon carryover. Because of these problems, low NO_x burners were developed and used instead of overfire air.

As a result of the possibility of new, more stringent acid rain legislation, interest has resurfaced for the use of overfire air. The present concept, called AOFA, is designed to improve deep staging (staged combustion) and overfire air mixing and to eliminate the operational problems encountered in the past. The Electric Power Research Institute has funded a flow model study to investigate the modifications necessary to improve overfire air mixing in the furnace. The Japanese have conducted test-scale studies incorporating additional booster fan capacity to the overfire air ports. The two concepts of improved mixing and deep staging are the basis for AOFA. This concept has been tested in Japan, but has not been demonstrated in the United States.

Low NO_x Burner System

As stated previously, low NO_x burners were developed because of the problems associated with the use of overfire air. B&W was the first to develop a low NO_x burner. Development proceeded from test furnace evaluation to a full-scale demonstration at Alabama Power Company's Plant Gaston. This burner, known as the Dual Register Burner (DRB) configuration, was further refined and used on all new B&W boilers to meet the 1971 and 1978 NSPS for NO_x emissions. Under license from B&W, Hitachi modified the DRB burner to achieve more than 50% reductions in NO_x emissions. Hitachi's NR burner was subsequently modified and tested by B&W.

This modified NR burner, known as the XCL, has been installed in the DOE-sponsored LIMB demonstration program at Ohio Edison's Edgewater Plant. The DOE-sponsored tests are expected to start in late 1989. Up to mid-1989, the tests at Edgewater were part of an EPA-sponsored program. Results of the EPA-sponsored tests have not been published. However, short-term NO_x reductions are believed to be in the vicinity of 50%, but carbon carryover problems have persisted.

Following B&W's development of the XCL burner, Foster Wheeler Corporation developed a Controlled Flow Burner, which was used with overfire air. This burner was unsuccessful in substantially reducing NO_x and, subsequently, Foster Wheeler developed the Controlled Flow Split Flame Burner which does not use overfire air. The prototype of this burner was successfully tested at Public Service of New Mexico's San Juan Unit No. 1 and reportedly reduced NO_x emissions by approximately 50%.

Riley Stoker Corporation implemented a prototype LNB, the Controlled Combustion Venturi Burner, on a 360 MWe boiler at Carolina Power System's Roxboro Station. This first test was a successful retrofit to a unit that previously could not meet 1971 NSPS NO_x limitations. This type of burner was then retrofitted to a 400 MWe unit. Both retrofits achieved short-term NO_x reductions of up to 55%.

3.2.2 Process Description

SCS, Inc. proposes to demonstrate two techniques and a combination of these techniques by which NO_x emissions from wall-fired, coal-burning boilers can be reduced. The following describes these three combustion control approaches: AOFA, LNB, and LNB plus AOFA.

Advanced Overfire Air (AOFA)

AOFA technology involves the combination of three techniques, improved overfire air mixing, air staging, and boundary air.

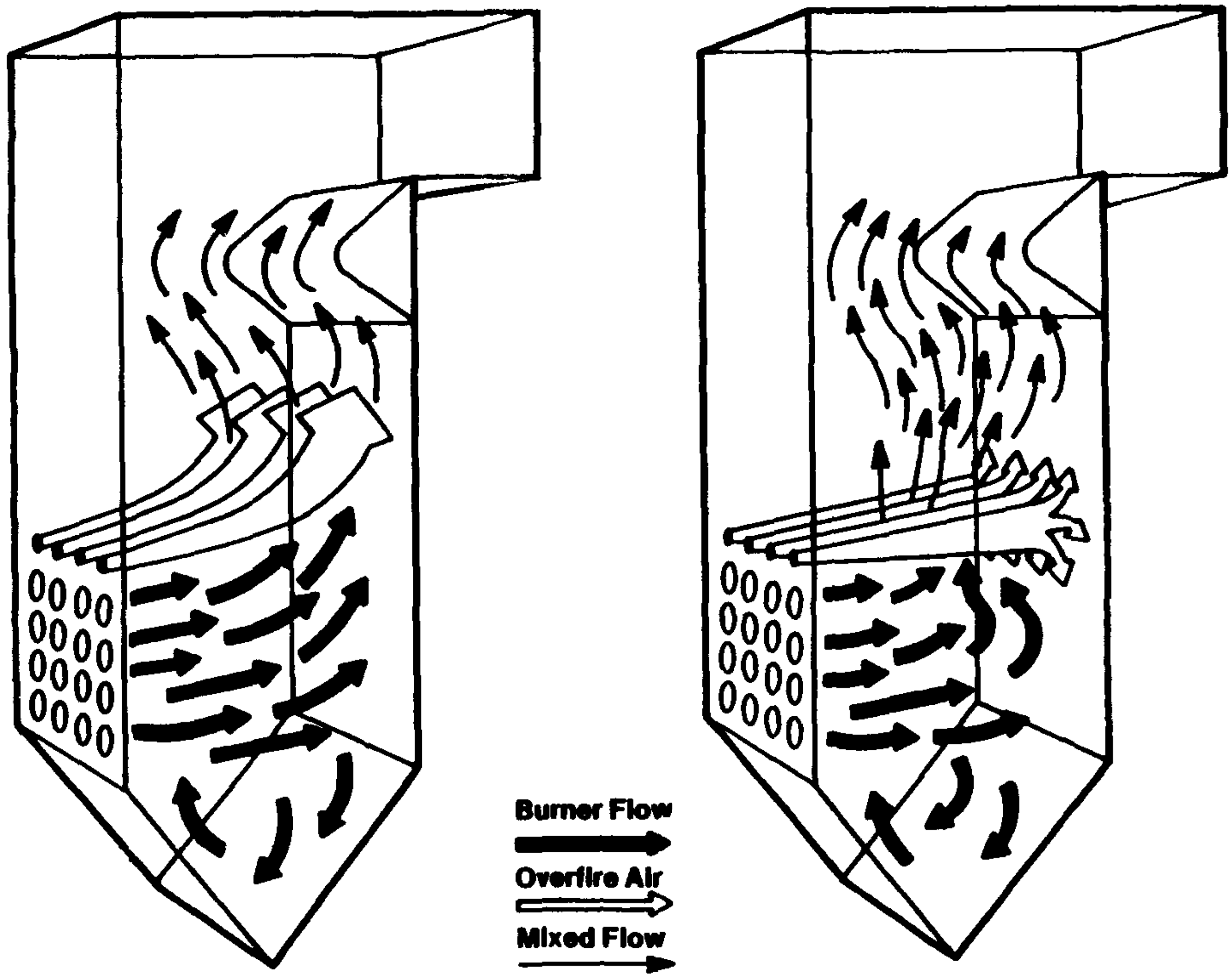
To improve the mixing of overfire air with the furnace gases, the velocity of overfire air injection relative to upward furnace gases is increased. The higher injection velocities can be achieved by increasing the air pressure above normal windbox levels and by improved overfire air port designs. Figure 2 illustrates the concept of high velocity overfire air mixing compared with normal overfire air injection.

Air staging consists of the depletion of air from the burner zone such that the air quantity provided is less than theoretically required to complete combustion. This technique results in substantial reductions in NO_x production, but it can cause slagging, furnace corrosion, and excess carbon carryover.

To alleviate this condition, some of the air to the burners is passed over furnace wall surfaces, thereby providing a boundary of air that maintains an oxidizing atmosphere close to the tube walls. In wall-fired boilers this boundary air is provided by tertiary air ports located in the lower burner zone and close to the side walls.

The net result of the three techniques described above is that the excess air supply can be decreased without causing slagging, corrosion, and unburned carbon losses; the overfire air ports can be placed higher in the furnace to increase residence time; and NO_x levels can be effectively reduced.

The AOFA concept is depicted in Figure 3. Excess forced-draft fan capacity exists at many facilities that have converted the boiler to balance draft operation. This excess capacity can be used to provide the boost for the AOFA system. Plant Hammond Unit 4 is such a unit and will not require a booster fan.



Furnace Flow Patterns with Low OFA Flow

Furnace Flow Patterns with High OFA Flow

FIGURE 2. EFFECT OF OFA INJECTION VELOCITY.

NOJ18,371

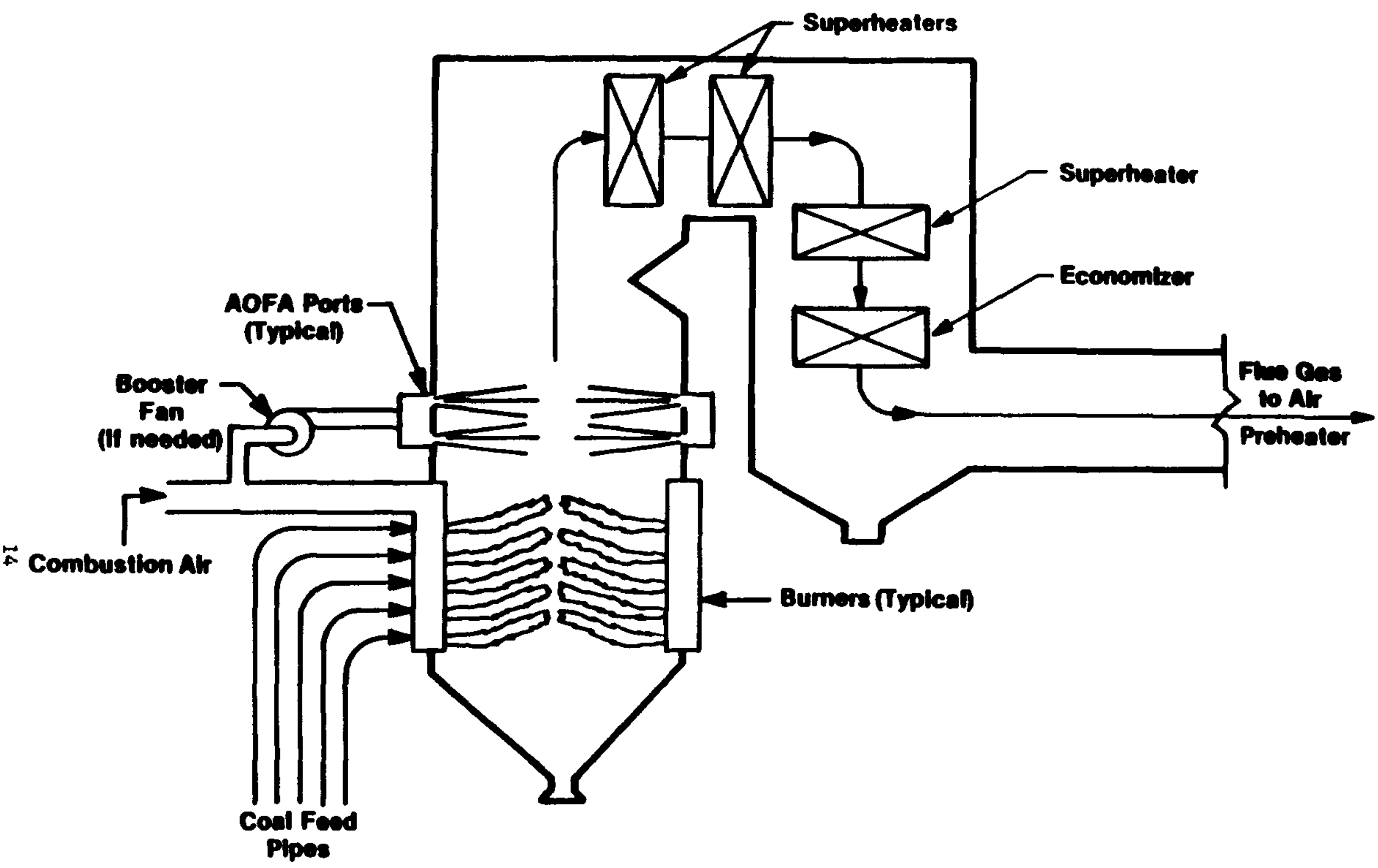


FIGURE 3. AOFA CONCEPT SCHEMATIC.

Low NO_x Burner System (LNB)

Low NO_x burners were developed as an alternative to overfire air use. These burners are designed to regulate the initial fuel/air mixture, velocities, and turbulence to create a fuel-rich flame core, with sufficient air to sustain combustion at very low excess-air levels. These burners also control the rate at which additional air, necessary to complete combustion, is mixed with the flame solids and gases so as to maintain a deficiency of oxygen until the remaining combustibles fall below the peak NO_x-producing temperature (around 2800°F). The final excess air is then mixed with the unburned products so that combustion is completed at a low temperature. Figure 4 illustrates the controlled mixing concept. The fuel-rich flame gas (Zone A in the figure) provides a sustained oxygen-deficient region in which the volatile fuel-bound nitrogen can be evolved and reduced to molecular nitrogen, rather than NO. The remaining char nitrogen evolves in the extended flame zone (C) where oxygen becomes available at a controlled mixing rate so as to minimize conversion of char nitrogen to NO. NO_x formed through the thermal fixation of atmospheric nitrogen in the combustion air is also minimized as the controlled air mixing extends into the cooler regions downstream of the flame.

3.2.3 Application of Processes in Proposed Project

The unit is a nominal 500 MWe Foster Wheeler pulverized-coal, wall-fired boiler, which has burners mounted on the front and rear walls of the furnace. The installation of the AOFA system will require a separate air supply system, including ductwork, flow control dampers, windbox and AOFA ports, removal of waterwall tubes to accommodate the AOFA ports, installation of bent tubes around the AOFA ports, and alterations to the combustion control and flame safety systems.

LNB installation requires minimal boiler modifications, because the burners are designed to fit within existing burner openings in the windbox and to fit existing bolt patterns. No changes to the air or fuel supply systems are required.

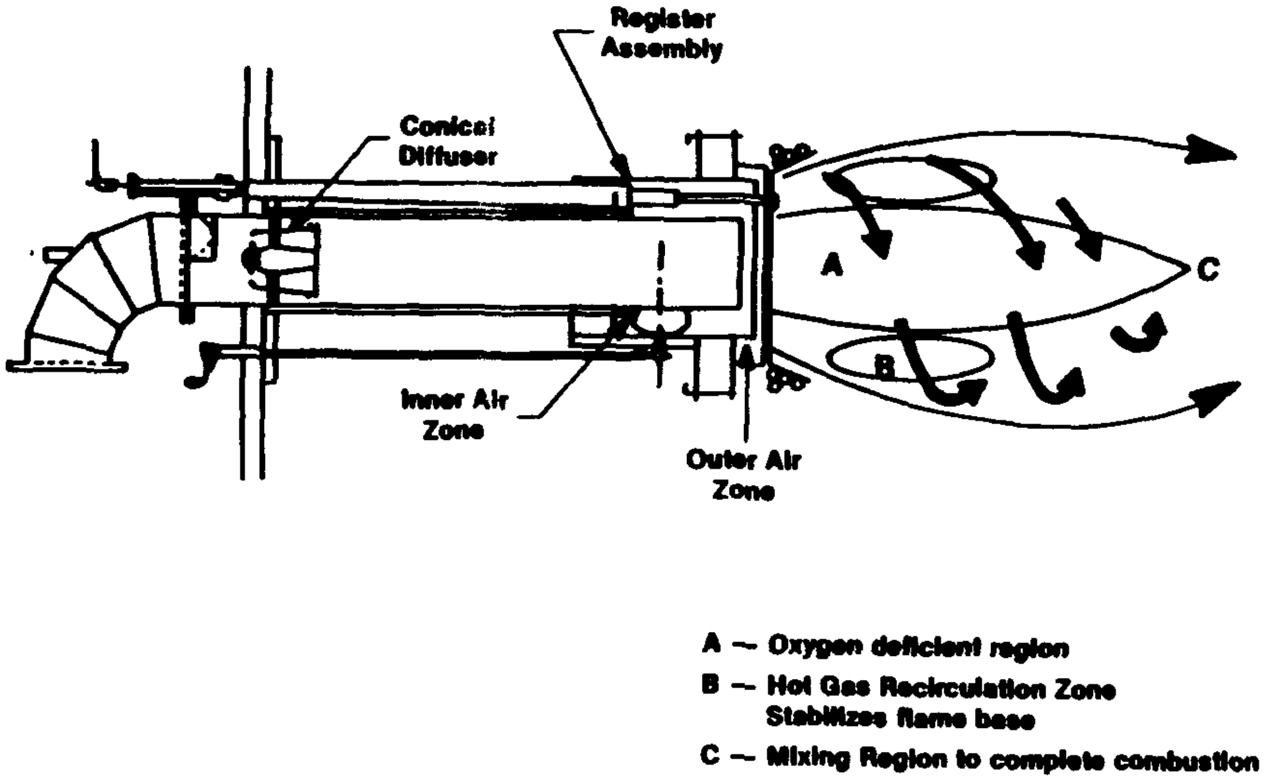


FIGURE 4. LNB CONTROLLED MIXING CONCEPT.

The specific objectives of the demonstration at the Hammond Plant are to: (1) demonstrate the performance of various advanced low NO_x combustion technologies, (2) determine long-term NO_x emission characteristics using sophisticated statistical techniques, and (3) evaluate the effect of low NO_x combustion on utility plant economics.

3.3 General Features of the Project

3.3.1 Evaluation of Developmental Risk

As with any new technology there is some developmental risk. However, the AOFA and LNB systems are unique in that they can be adjusted to achieve a balance between NO_x reduction and acceptable boiler operation. With the AOFA retrofit, the system can be operated with maximum overfire air, resulting in maximum NO_x reduction effectiveness. If, however, this creates other operational problems, the amount of overfire air can be regulated at the expense of NO_x reduction effectiveness, until acceptable operating conditions exist. Similarly, the LNB can be adjusted to achieve the desired flame at the expense of NO_x reduction effectiveness.

Based on the above, a low risk level has been assigned to these technologies. There is some risk that incomplete combustion may occur, resulting in an increase in the carbon content of the fly ash. Carbon particles are more difficult to capture in electrostatic precipitators than are ash particles; therefore, an increase in the carbon content of the fly ash may add to stack emissions. Also, if the particle size of the fly ash emissions decreases, the efficiency of the electrostatic precipitator, scrubber, or baghouse may decrease, resulting in increased stack emissions. Further, if the resistivity of the fly ash leaving the boiler is increased or decreased, the collection efficiency of an electrostatic precipitator may increase or decrease. However, these are considered to be low risks, because previous demonstrations of the proposed technologies have shown no significant increase in stack emissions.

3.3.1.1 Similarity of the Project to Other Demonstration/ Commercial Efforts

In addition to the different LNB designs, there are three alternative technologies for retrofit control of NO_x in wall-fired boilers. These are reburning, slagging combustors, and selective catalytic reduction (SCR).

Reburning was developed by several companies in Japan and is used in a number of Japanese boilers. The technology involves the addition of auxiliary burners above the main coal burners and the addition of overfire air ports above the auxiliary burners. The main coal burners are operated under slightly air rich conditions, thereby producing high NO levels. The auxiliary burners, firing natural gas, oil, or coal, are operated with significantly less than stoichiometric air, thus producing an oxygen deficient atmosphere where NO is converted to molecular nitrogen. Next, overfire air is injected to complete the combustion process. An ongoing reburning demonstration on a wall-fired boiler is being performed at the Edwards Station of Central Illinois Light Company.

Conventional slagging combustors are designed primarily for control of fly ash from coal firing and, therefore, are not considered to be as effective in reducing NO_x emissions as are LNB's. Two earlier Clean Coal Technology program demonstration projects involving slagging combustors are now in progress. One project is using TRW's Slagging Combustor at Orange and Rockland's Lovett Station in New York, and the other is demonstrating Coal Tech's Cyclone Slagging Combustor at Keeler/Dorr Oliver's Williamsport, Pennsylvania facility.

SCR involves the injection of ammonia into the upper furnace or into the flue gas downstream of the boiler to catalytically reduce NO_x to nitrogen. SCR has been successfully demonstrated in Europe and Japan. In response to the ICCT PON, SCS, Inc., has proposed an SCR demonstration at Gulf Power Company's Plant Crist, near Pensacola, Florida.

3.3.1.2 Technical Feasibility

The independent use of overfire air and LNB to reduce NO_x emissions has been recognized for many years. Early research by B&W demonstrated that the use of overfire air can reduce NO_x levels in coal-fired boilers by 30 to 50%. The use of overfire air technology, however, resulted in boiler slagging problems and carbon carryover. The LNB was developed to solve these problems. Presently, low NO_x burner technology is available from all United States boiler manufacturers and are reported to be capable of short-term NO_x reductions of 50%.

As a result of the potential for new, more stringent acid rain legislation, a renewed interest in the use of overfire air has developed. AOFA is an enhancement of the standard OFA system, which incorporates improved mixing, air staging and boundary air. The Japanese have tested variations to the AOFA system and plan to implement its use on a full-scale unit. In addition, the Electric

Power Research Institute has funded a flow model study to investigate ways to improve the mixing of overfire air in the furnace.

Advanced LNB technology is being developed by the three largest United States wall-fired utility boiler manufacturers for retrofit to single and opposed wall-fired units. The LNB selected by a competitive bid process for this project is manufactured by Foster Wheeler Energy Corporation.

Since the basic concepts of AOFA and LNB have been tested separately on full-scale utility boilers, the advanced concepts are expected to operate in a similar manner, but with considerable improvement in emissions reductions boiler operation, and safety. Further, the combined AOFA and LNB system is expected to be more cost effective than other technologies, such as reburning and SCR.

3.3.1.3 Resource Availability

Adequate resources are available for this program. SCS, Inc., will use present members of its staff to fill key positions.

This project will not increase the host boiler's requirements for major resources such as coal and water and will not generate any additional waste products, such as wastewater and ash. Plant electrical requirements will be minimal. Lumber, steel, and other raw material requirements for construction and operation of the demonstration are anticipated to be minimal.

The local labor needs for construction and operation of the demonstration are also expected to be minimal and will be provided primarily from nearby Rome, Georgia.

This program involves a fully operational electric power generating station with appropriate facilities and scheduling flexibility to accommodate this project. Plant Hammond Unit No. 4 is representative of typical wall-fired boilers and its use will provide an excellent opportunity to evaluate all of the proposed technologies on a single boiler.

All appropriate resources can be made available to the site. The installation, operation, and restoration of the hardware (if required) will be handled by personnel available at SCS, Inc., and Georgia Power Company. In addition, adequate funds have been committed by the co-funders to cover their share of the estimated project costs.

3.3.2 Relationship Between Project Size and Projected Scale of Commercial Facility

As mentioned previously, the host boiler is a 500 MWe commercial unit, which is considered large by utility industry standards. Scale up to even larger units will require an increase of overfire air while maintaining the same percentage of total air, and replacement of more burners and/or use of larger burners, both of which constitute minimal risks. The net effect is that this project will prove the applicability of the AOFA, LNB, and combined AOFA/LNB combustion techniques for retrofit on many pre-NSPS wall-fired boilers without further demonstration.

It is anticipated, however, that the proposed combustion techniques would be less cost effective in retrofit applications below 100 MWe due to the relatively high labor costs involved in boiler modifications.

3.3.3 Role of Project in Achieving Commercial Feasibility of the Technology

A major shortcoming of previous demonstrations of these NO_x control techniques has been that, generally, only short-term data has been used to quantify their performance. When regulatory requirements mandated that utilities demonstrate compliance based only upon short-term data, this type of information was adequate. When government agencies realized that short-term compliance was not preserving or improving air quality, they required continuous compliance and more stringent NO_x controls. To assure compliance in some instances, industry was forced to use unproven technology. This resulted in operation at less than optimal conditions. Utilities will be more likely to accept new advanced techniques on retrofits to existing boilers if they are confident that the new technology(s) will be economical for their customers and will significantly reduce NO_x with minimal impact on boiler performance.

The proposed demonstration will provide the needed long-term performance data typical of large utility boiler operation. In addition, meaningful comparisons of the proposed technologies will be possible, because each technology will be evaluated separately and compared with baseline data using the same boiler. This will provide the utilities, regulatory agencies, and others with a clearer understanding of the benefits of each technology.

3.3.3.1 Applicability of the Data to be Generated

The demonstration will thoroughly document the performance and operating characteristics before and after each retrofit.

The test program will start with a review and documentation of the "as found" operation. Degradation or malfunction of equipment will be repaired and operational errors will be corrected. The boiler will then be tested over a normal range of operating parameters to establish baseline operating conditions, emissions, and performance. Each control technology will then be installed and tested in a stepwise fashion. For the baseline conditions of each technology, short-term tests will be conducted to characterize the effects of various operational parameters on performance and emissions. Following short-term tests, long-term testing will be performed over an 11-week period while the boiler is operating normally under load dispatch control. At the end of each long-term test, further short-term tests will be performed to document any changes.

A dedicated computerized data acquisition system will be installed which will interface with the existing and new plant instrumentation. In addition, a gas analysis system, on-line unburned combustible monitor, heat flux monitors, flame observation system, flame scanners and continuous emissions monitor will be installed.

The data acquisition system will be capable of gathering data from more than 100 different sources throughout the plant and from the gas analysis system. Typical operating data to be continuously recorded include:

- Gross/Auxiliary load
- Overfire air flow rate and pressure
- Combustion air flows
- Coal feed flow
- Mills in service
- Superheater/reheater temperatures
- Air heater air and gas inlet and outlet temperatures
- Tube metal temperatures
- Heat flux meter output

The gas analysis system will be used to collect emissions data such as oxides of nitrogen, carbon monoxide, total hydrocarbons, sulfur dioxide and excess oxygen. Other data that will be obtained or computed includes fly ash particle size, fly ash resistivity, particulates, SO_3, carbon loss, flue gas temperatures, and boiler efficiency.

Based on the data collected, process economics and technical comparisons will be made for each technology. Since the proposed demonstration is at a utility scale, the resulting economic and technical analyses will be directly applicable to other utility situations.

3.3.3.2 Identification of Features that Increase Potential for Commercialization

Once fully proven, the AOFA and LNB processes will provide an economic and technically acceptable means of controlling NO_x from wall-fired boilers. This demonstration program is intended to confirm that LNB alone can reduce NO_x emissions by 50% and that by combining LNB with AOFA, NO_x reductions can exceed 60%. The minimal retrofit requirements and more competitive cost of these technologies, relative to post-combustion NO_x control, make them especially applicable to the retrofit of existing boilers.

The LNB and AOFA technologies consist of installing burners, ducting, dampers, fans, nozzles, controls, and instrumentation. These items, when integrated into the complete system, offer several advantages. The controls and dampers permit optimization of the burner-to-burner air balance. The balancing of air flows improves carbon burnout. Overfire air flow velocities can be adjusted to provide the turbulence necessary for complete combustion. Further, overfire air ports are provided with a windbox separate from that of the burners so that proper balance can be maintained. Separate air ports provide air to the walls to minimize slagging fouling and corrosion. All the components of these technologies are commercially available.

In summary, commercialization of this technology will be aided by:

- Reducing short-term NO_x emissions by up to 60%
- Competitive capital and operating costs
- Relatively easy retrofit
- Little or no derating of the boiler
- Use of commercially available components
- Operating and maintenance experience gained in the program
- Analyses of long-term test data

The success of this program will establish that AOFA and LNB are effective economical approaches to controlling NO_x. The acquisition and analysis of long-term test data from a large operating utility unit will enable reasonable extrapolations to be made on the effectiveness of the technologies on other similar units. This will provide the confidence in the technologies necessary to accelerate commercialization. As such, the technology is expected to significantly penetrate the large wall-fired utility boiler market.

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

The proposed demonstration is a far more complete evaluation of combustion techniques for NO_x control than has ever been performed. Past demonstrations of these concepts have involved short-term data to quantify their performance. In the past, short-term data was sufficient to demonstrate compliance with regulatory requirements. New regulatory requirements, however, require continuous compliance and more stringent NO_x standards. Because of the lack of long-term data, the utilities have been forced to use unproven technology to comply with changing regulatory requirements. This has, in many instances, resulted in operation at less than desirable conditions. As a result of this experience with new boilers, the utilities are less likely to accept unproven techniques for retrofit applications.

The acid rain legislation proposed in Congress during the last four sessions indicates that lower NO_x emission levels may be applied to existing and new coal-fired boilers. If these new regulations are imposed, the utilities will likely implement low NO_x combustion technology, because it is less expensive than post combustion technologies and requires minimal plant modifications.

An economic comparison of the AOFA, LNB, and LNB plus AOFA concepts was made for a 100 MWe, 500 MWe and an 800 MWe plant. The estimated capital costs for the AOFA retrofit ranged from \$3/kw for the 800 MWe plant to \$10.5/kw for the 100 MWe plant. Capital costs associated with the LNB retrofit ranged from \$13.6/kw to \$28.5/kw. For the LNB plus AOFA retrofit, the capital costs ranged from \$16.7/kw to \$39/kw. These costs are substantially less than post combustion NO_x reduction systems, such as selective catalytic reduction (SCR) which has a capital cost of about \$100/kw.

Although SCR is more expensive than low NO_x combustion modifications, it is capable of reducing NO_x emissions by up to 80% compared with up to 60% reductions the project include Energy Technology Consultants, Inc.; Radian Corporation; Roberson-Pitts, Inc.; and Foster Wheeler Energy Corporation.

5.2 Identification of Respective Roles and Responsibilities

DOE

The DOE shall be responsible for monitoring the project and for granting or denying approvals required by this Cooperative 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 COTR who is the authorized representative for all technical matters and will have the authority to issue "Technical Advice" 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 reports, plans, 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 advice 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.

- 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 (SCS, Inc.) 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 this Cooperative Agreement. He will be the single authorized point of contact for all matters between the Participant and DOE. The Project Manager will report to the SCS, Inc., ICCT Program Manager. The Program Manager will provide the link to the executives of the Southern Electric System and has final responsibility for execution of the project.

SCS, Inc., will provide overall project management, guide the technical direction of the program, administer contract matters, control budgets and schedules, and participate in the test program, environmental permitting, data analysis, and final report preparation.

Georgia Power Company will provide the host site, produce data required to obtain necessary permits, coordinate the activities of the erection subcontractor, operate and maintain the equipment, and provide the test coal and other utilities required for the demonstration project.

The Electric Power Research Institute (EPRI) will provide project co-funding and will also provide technical consultation and guidance.

Energy Technology Consultants, Inc., will serve as the test coordinator and will prepare test plans, direct on-site testing, analyze and interpret the data, prepare the interim and final reports, review the flow modeling effort, and direct the boiler performance subcontractor, emissions subcontractor, and data analysts.

Foster Wheeler Energy Corporation (FWEC) will be responsible for the design, fabrication, shipment, installation and start-up of the low NO_x combustion equipment. FWEC will report to the SCS Design Engineering Coordinator and also interface with Energy Technology Consultants, Inc., during equipment testing.

FWEC will also provide scale modeling of the AOFA and LNB concepts to insure that the ducts and injection nozzles are aerodynamically efficient.

Radian Corporation will provide environmental consulting services including EHSS data collection, preparation and implementation of an Environmental Monitoring Plan, and permitting assistance.

Roberson-Pitts, Inc. will serve as data analysts for the test phases of the project. Their work involves reduction and statistical analysis of long-term emissions data, review of the experimental design of parametric test programs, and quality assurance of the continuous emissions monitor and gas analysis system data.

Flame Refractories, Inc. will be responsible for performance-related testing such as diagnostic testing of the boiler prior to installation of the proposed technology, evaluation of pulverizer performance, determination of air-fuel ratio, air-flow measurements, and determination of air-flow distribution characteristics.

Southern Research Institute will be responsible for the characterization of the particulate emissions. Spectrum Systems, Inc. will be responsible for instrumentation operation and maintenance, and determination of the gas analysis and continuous emissions monitoring equipment.

The Participant will interrelate between the DOE and all other project sponsors as shown in Figure 6, Project Organization.

5.3 Summary of Project Implementation and Control Procedures

All work to be performed under the Cooperative Agreement is divided into four phases. These phases are:

Phase I: Site Preparation and Pre-Retrofit Testing (8 months)
Phase II: AOFA Retrofit and Post-Retrofit Testing (11 months)
Phase III: LNB Retrofit and Post-Retrofit Testing with and without AOFA (10 months)
Phase IV: Final Reporting and Disposition (6 months)

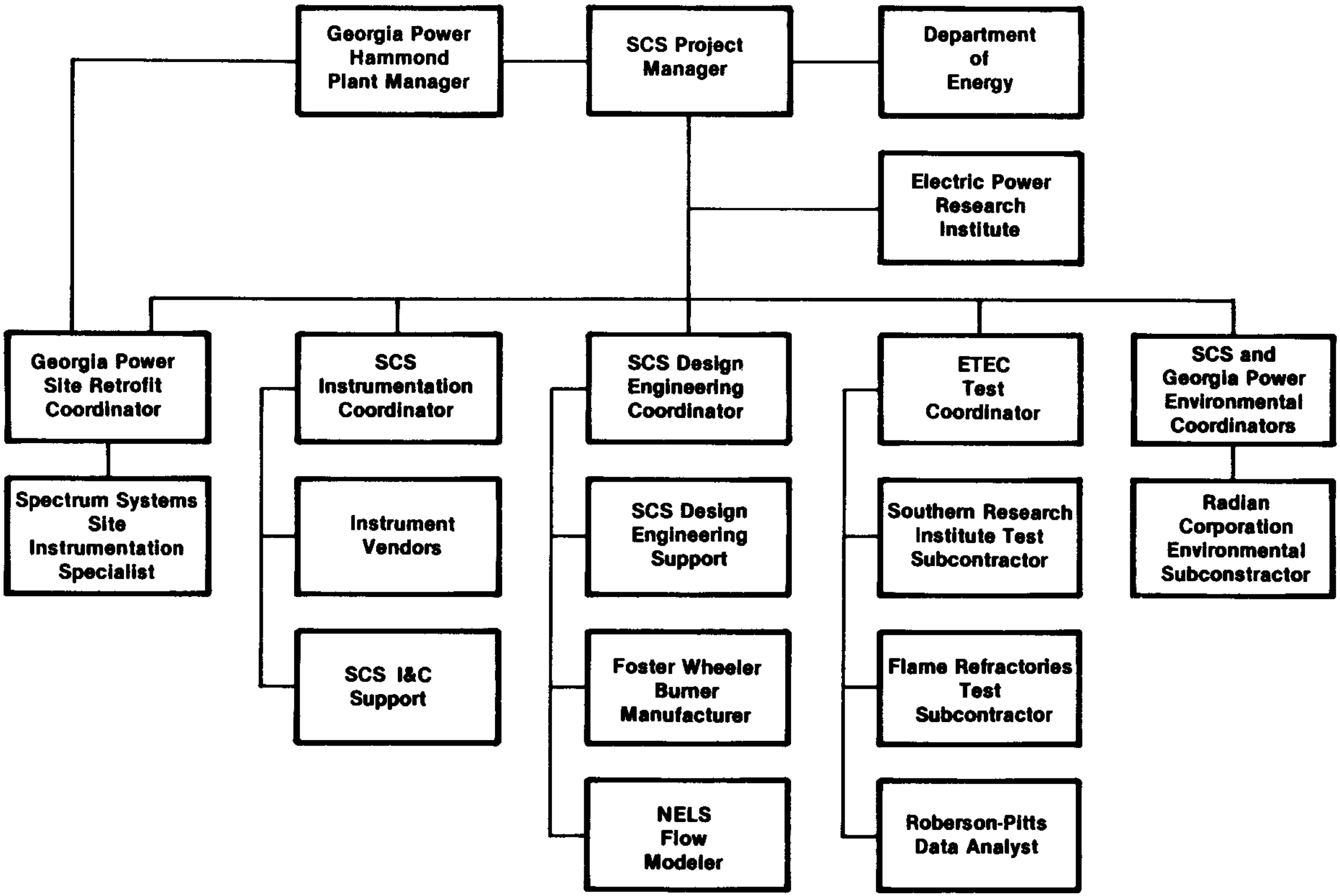


FIGURE 6. SCS, INC. PROJECT ORGANIZATION FOR ADVANCED WALL-FIRED COMBUSTION TECHNIQUES.

NOJ19,362

If these more restrictive NO_x regulations are imposed, utilities will likely implement the least expensive technology. Although it is among the least expensive low NO_x combustion technologies commercially available, in many instances low NO_x burners are not likely to achieve compliance with the new regulations. Therefore, boiler manufacturers in our Nation are continuing to develop improved burner designs and overfire air systems.

The market targeted to benefit from the proposed demonstration comprises dry bottom, wall-fired boilers. Cell burner units are not expected to benefit from this technology because they contain burners that are separated by only a fraction of a burner's diameter, which makes the LNB retrofit less effective for these boilers. Wet-bottom boilers are also not expected to benefit from this demonstration, since low NO_x combustion techniques applied to wet-bottom boilers are much different than those for dry-bottom boilers.

As of the end of 1985 there were approximately 465 wall-fired, dry-bottom boilers that fire subbituminous and bituminous coals. Of this population, 88 boilers are equipped with earlier versions of LNB or AOFA, or are equipped with or being equipped with atmospheric fluidized-bed combustion units. Therefore, the potential total utility retrofit market that would benefit from the proposed demonstration is 377 boilers. In addition, many of the remaining 88 boilers will implement more advanced NO_x reduction systems to meet new emissions standards.

Projections by the Department of Energy indicate that by the year 2010 there will be a need for an additional 186,200 MWe of coal-fired capacity. Of this total, 37,352 MWe is already committed. Based on historical data, 50% of the planned units will be tangentially fired and 50% will be wall-fired. Therefore, the total potential firm market segment of new capacity that would benefit from the proposed demonstration is estimated to be 18,676 MWe or 32 boilers and the potential planned market segment is estimated to be 74,400 MWe or approximately 150 boilers.

The successful completion of the proposed Hammond Plant demonstration and dissemination of the program data to industry is the first step in the commercialization process because it will improve the electric utility industry's confidence in the technologies. Commercialization will then proceed as dictated by existing market conditions and as fueled by additional regulatory requirements. Adequate burner design and manufacturing capacity is available to satisfy market requirements.

6.0 PROJECT COST AND EVENT SCHEDULING

6.1 Project Baseline Costs

The total estimated cost for this project is $11,711,229. The Participants' cash contribution and the Government share in the costs of this project are as follows:

	Dollar Share ($)	Percent Share (%)
Phase 0		
Government	122,311	44.8
Participants	150,898	55.2
Phase 1		
Government	873,444	44.8
Participants	1,077,589	55.2
Phase 2		
Government	1,942,802	44.8
Participants	2,396,882	55.2
Phase 3		
Government	1,863,620	44.8
Participants	2,299,192	55.2
Phase 4		
Government	440,740	44.8
Participants	543,751	55.2

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

DOE:	$ 5,242,917
SCS, Inc.:	5,468,312
EPRI:	1,000,000
TOTAL	$11,711,229

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

6.2 Milestone Schedule

The overall project will be completed in 35 months after award of the Cooperative Agreement.

Phase I, which involves site preparation, flow modeling, and baseline characterization, will start immediately after award and continue for eight months. Upon completion of Phase I, Phase II (AOFA retrofit and post retrofit testing) will start and continue for 11 months. Phase III, low NO_x burner retrofit and post retrofit testing with and without AOFA, will start upon completion of Phase II and continue for 10 months. The final phase, which involves preparation of the final report and disposition of results, will start upon completion of Phase III and continue for six months.

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.