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Comprehensive Report to Congress Clean Coal Technology Program

180 MWe Demonstration of Advanced Tangentially-Fired Combustion Techniques for the Reduction of Nitrogen Oxide (NO_x) Emissions from Coal-Fired Boilers

A Project Proposed By: Southern Company Services, Inc.

July 1990

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

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1.0 EXECUTIVE SUMMARY

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

In response to the PON fifty-five proposals were received by the DOE in May 1988. After evaluation, sixteen 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.

One of the selected proposals is the Southern Company Services, Inc's (SCS) proposal to demonstrate advanced tangentially-fired combustion techniques in a 180 MWe power plant. It will demonstrate the reduction of NO_x emissions from pulverized coal-fired boilers by the use of three combustion control techniques; the Low NO_x Concentric Firing System (LNCFS), Advanced Overfire Air (AOFA), and the Combustion Engineering (CE) Concentric Clustered Tangential Firing System (CCTFS).

AOFA involves improving the mixing of overfire air with the furnace gases to achieve complete combustion, and the depletion of air from the burner zone to minimize NO_x formation. This technique is estimated to reduce NO_x in tangentially-fired boilers by about 30%.

The LNCFS technology separates the fuel and the air streams by directing the coal and the secondary air tangentially into the furnace at different angles. This technique causes the combustion of the fuel to occur in an oxygen deficient zone prior to mixing with the secondary air. In addition, the LNCFS minimizes furnace wall slagging by passing air over the furnace wall tubes. LNCFS also incorporates close-coupled, low-pressure overfire air ports. NO_x reductions of up to 40 percent are expected using this technology.

CE's CCTFS is an enhancement of the LNCFS, whereby some of the LNCFS nozzles are relocated next to existing LNCFS nozzles to create very rich fuel zones. In addition, close-coupled overfire air ports and the AOFA ports, located above the main windbox, are used for gradual overfire air staging. As with LNCFS, offset air nozzles are provided in the main windbox to protect the waterwall tubes from slagging and corrosion. This technology is expected to reduce NO_x by as much as 50 percent compared to standard tangential burners.

The project will be conducted at the 180 megawatt electric (MWe) pulverized coal-fired Plant Smith Unit No. 2, owned by Gulf Power Company, part of the Southern Company System. The plant is located in Lynn Haven, Florida as shown in Figure 1.

The plant is presently in commercial operating use and is representative of a large class of tangentially-fired boilers. The retrofit of the low NO_x combustion control techniques to the Plant Smith boiler will be similar to other boilers of this type. An important feature of this project, however, is that NO_x reduction levels and boiler performance will be demonstrated on an operating utility boiler using long-term data. The long-term data obtained for each technology will be compared to pre-retrofit baseline data and statistically analyzed. These analyses will provide data that allows calculation of the achievable emissions limit of each technology.

The demonstration will be performed over a 36 month period, after award of the Cooperative Agreement, and includes site preparation, flow modeling, baseline characterization testing, design, installation and testing of the concepts, data analysis and reporting of results. SCS will perform the following project tasks:

- Setup and Pre-Retrofit (Baseline Characterization)
- AOFA and LNCFS Retrofit and Testing
- Concentric Clustered Tangential Firing System Retrofit and Testing
- Final Reporting and Disposition

The total project cost is $8,555,303. The co-funders are DOE ($4,150,055), SCS ($3,405,248) and EPRI ($1,000,000). Testing using AOFA and the LNCFS is scheduled to begin in 1991. Testing using the Concentric Clustered Tangential Firing System is scheduled to begin in late 1992. Overall project completion is scheduled to occur by mid 1993.

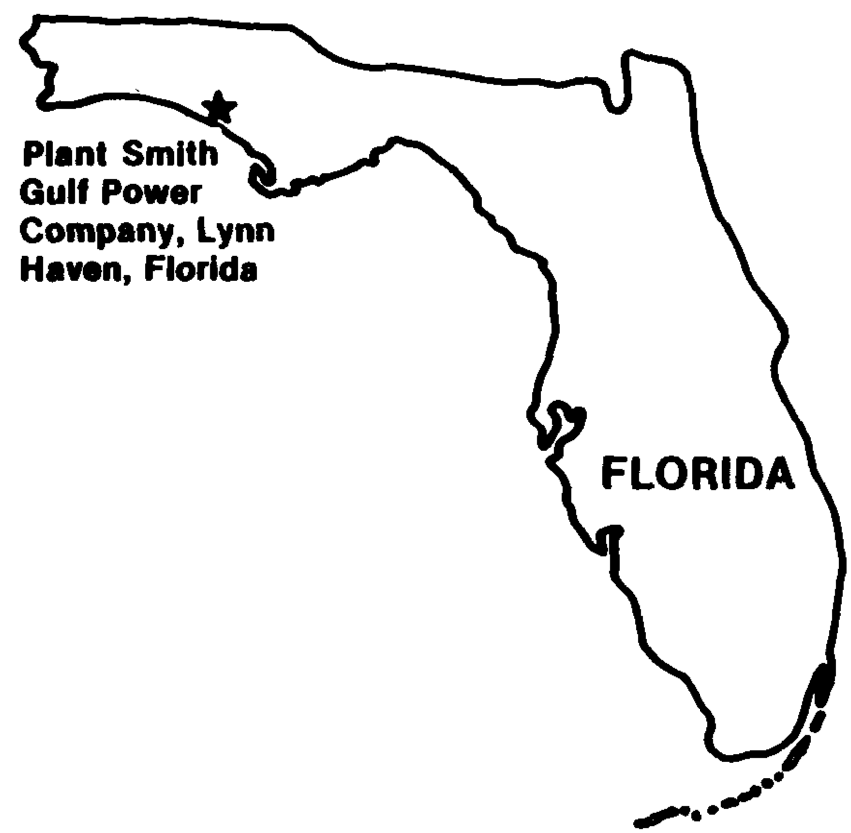

FIGURE 1. SCS, INC. ADVANCED TANGENTIALLY-FIRED COMBUSTION TECHNIQUE'S DEMONSTRATION PROJECT LOCATION.

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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 Innovative Clean Coal Technology (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 each project selected for 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 Tangentially-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 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 their proposal.

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 requirements, sixteen proposals were selected for negotiations and award. The "Demonstration of Advanced Combustion Techniques for a Tangentially-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 that three NO_x control technologies; Low NO_x Concentric Firing System (LNCFS), Advanced Overfire Air (AOFA), and Concentric Clustered Tangential Firing System (CCTFS) are suitable for retrofit applications.

The demonstration will be conducted at Gulf Power Company's Plant Smith Unit No. 2. The boiler is a nominal 180 megawatt pulverized coal, tangentially-fired unit, which is representative of most of the existing tangentially-fired utility boilers in the United States that were installed before the New Source Performance Standards (NSPS) became effective.

The objectives of this project are as follows:

- Demonstrate in logical, stepwise fashion the short-term NO_x reduction capabilities of the following advanced low-NO_x combustion technologies:
  - LNCFS
  - AOFA
  - CCTFS
- Determine the dynamic long-term NO_x emission characteristics of each of the NO_x reduction methods listed above using sophisticated statistical techniques.
- Evaluate the progressive cost-effectiveness (i.e. dollars per ton NO_x removed) of the combustion technologies tested.

- Determine the effects on other combustion parameters (e.g. CO production, carbon carryover, particulate characteristics) of applying the NO_x reduction methods listed above.

The acquisition and analyses of long term test data from a utility plant operating normally under load dispatch control are the most important elements of this demonstration. The long term data, which will be compared with long term pre-retrofit baseline data and statistically analyzed, should provide results that can be applied to other tangential fired boilers.

If successful, NO_x reductions of up to 50% will be achieved during this demonstration project and the utility industry's confidence in the technologies will be advanced.

3.1.1 Project Summary

Project Title:	180 MW Demonstration of Advanced Tangentially-Fired Combustion Techniques for the Reduction of Nitrogen Oxide (NO_x) Emissions from Coal-Fired Boilers
Proposer:	Southern Company Services, Inc. (SCS)
Project Location:	Lynn Haven, Florida (Smith Plant) Bay County
Technology:	Advanced combustion techniques for nitrogen oxide control
Application:	New and retrofit utility and industrial coal- and oil-fired boilers
Types of Coal Used:	Illinois, West Virginia, Alabama, and Kentucky coals (2.6 to 3.1% sulfur)
Product:	Environmental Control Technology
Project Size:	180 MWe
Project Start Date:	July 1990
Project End Date:	June 1993

3.1.2 Project Sponsorship and Cost

Project Sponsor: Southern Company Services, Inc.

Proposed Co-Funders: U.S. Department of Energy
Electric Power Research Institute

Proposed Project Cost: $8,555,303

Proposed Cost Distribution:

Participant Share(%)	DOE Share(%)
51.49	48.51

3.2 Advanced Tangentially-Fired Combustion Techniques

3.2.1 Overview of Process Development

Advanced Overfire Air (AOFA)

The use of overfire air to reduce nitrogen oxides was developed in the late 1950's by Babcock and Wilcox Company (B&W) and subsequently patented. Initial uses included gas and oil-fired boilers where reduction levels of 30 to 50 percent were achieved.

In the late 1960's, overfire air was considered for use on coal-fired units, primarily as a result of the Clean Air Act and subsequently the promulgation of the 1971 NSPS. Nitrogen oxide reductions of 30 to 40 percent were achieved; however, the use of overfire air caused operational problems such as slagging, steaming and carbon carryover. As a result of these problems, low NO_x burners were developed, which eliminated the use of overfire air and met more stringent NO_x requirements.

The potential for new, more stringent acid rain legislation has renewed interest in the use of overfire air. The present concept, called AOFA, is designed to eliminate the operational problems encountered in the past. The Electric Power Research Institute (EPRI) 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 greater flow are the basis for AOFA. This concept has been tested in Japan, but has not been demonstrated at full scale in the United States.

Low NO_x Concentric Firing System (LNCFS)

In 1978, the U.S. Environmental Protection Agency (EPA) awarded a contract to Acurex Corporation for pilot-scale development of low NO_x systems for tangentially-fired boilers. The 293 Kw pilot-scale system achieved low NO_x emissions by directing the fuel and a small portion of the secondary combustion air into the center of the furnace. The remaining portion of the secondary combustion air was directed toward the furnace walls to minimize slagging and fireside corrosion.

Concurrently, CE conducted field tests of a similar LNCFS at the Richmond Indiana Power and Light Company's 61 MWe Whitewater Valley Unit No. 2. NO_x reductions of up to 40 percent were achieved at full load.

In 1980, EPA awarded a contract to CE for the design, fabrication and installation of a low NO_x firing system at the 400 MWe Hunter Unit No. 2, owned by Utah Power and Light Company. Recently, CE's licensee in Great Britain, NEI International Combustion, Ltd., has completed a demonstration of a LNCFS at the Fiddlers Ferry No. 1 Power Station, owned by the Central Electric Generating Board. The results of both demonstrations indicate a short-term NO_x reduction of 60% from baseline conditions.

Concentric Clustered Tangential Firing System (CCTFS)

The Concentric Clustered Tangential Firing System (CCTFS) concept evolved as a result of the effectiveness of the LNCFS concept and the knowledge that fuel staging and fuel rich conditions are essential for in-furnace NO_x reduction.

The development of this concept has taken place at the CE coal-fired combustion test facility in Windsor, Connecticut. The goal of the test facility development program was to determine the best means to build a deeply staged tangential firing system within the confines of an existing tangential windbox. Extensive demonstrations and increased understanding of the concept by CE has resulted in a planned 1990 commercial installation of the technology in a 160 MW unit in Italy.

3.2.2 Process Description

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

The primary techniques used to reduce furnace NO_x levels include low excess air, burners out of service, overfire air ports, flue gas recirculation, reduced air preheat and low NO_x burners. In many boilers, low excess air is being implemented, but is limited due to its impact on boiler efficiency. Taking burners out of service causes slagging and corrosion within the furnace, complicates coal feed system operation and may limit unit output. Flue gas recirculation and reduced air preheat have been used on gas and oil fired boilers, but have been unsuccessful on coal-fired units. Low NO_x burners have been successful on coal-fired units, however, the potential for more stringent NO_x limitations has resulted in the further development of low NO_x burners and renewed interest in the use of overfire air.

The following sections describe the technologies proposed in this demonstration. The program consists of three combustion control approaches to reduce NO_x; the AOFA, LNCFS, and the CCTFS.

Advanced Overfire Air (AOFA)

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

To improve the mixing of overfire air (OFA) 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 to low overfire air injection in a tangentially-fired boiler.

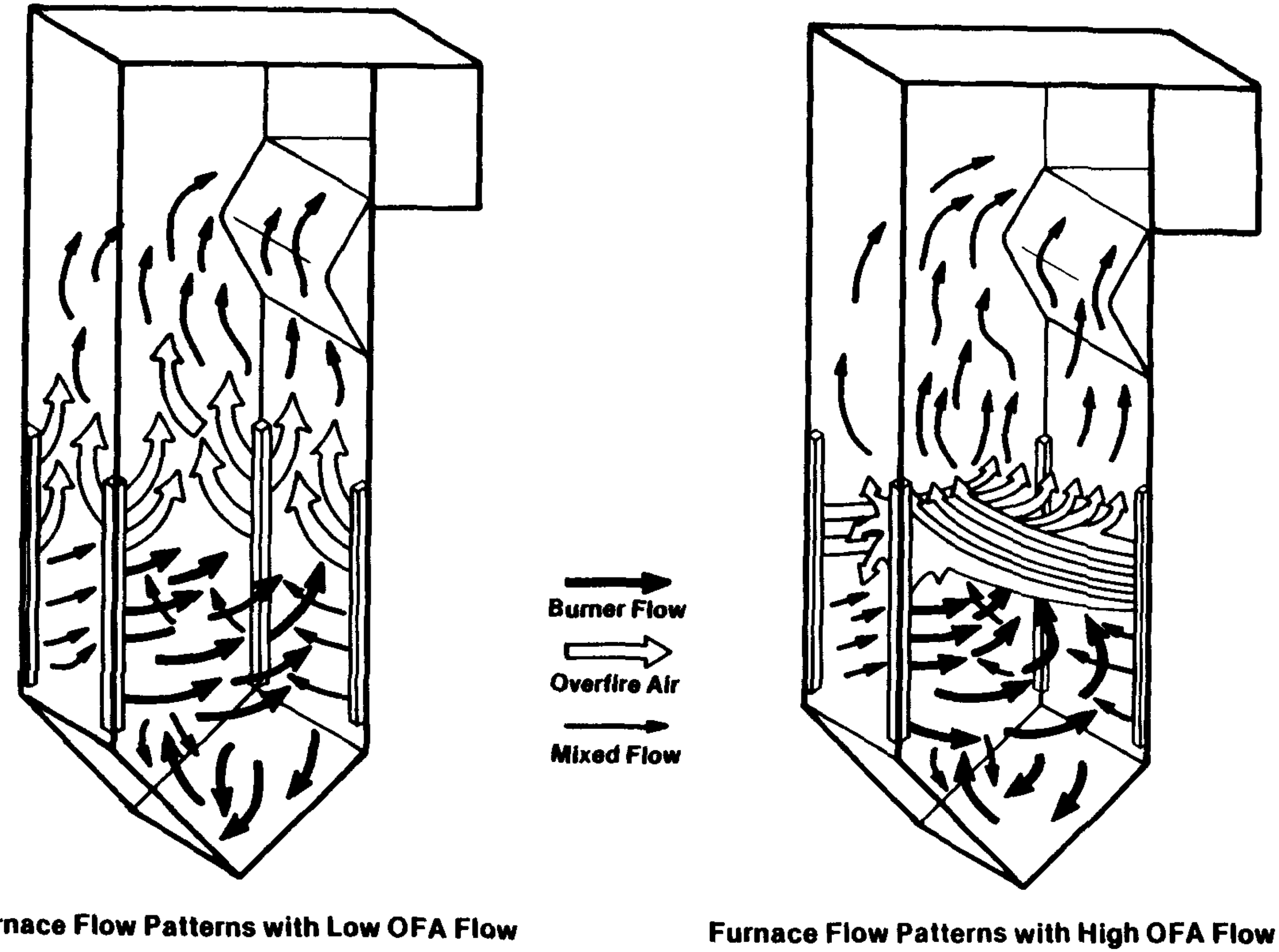

FIGURE 2. EFFECT OF OFA INJECTION VELOCITY.

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Deep 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 produces substantial reductions in NO_x production, however, it can cause slagging and furnace corrosion. To alleviate this condition, some of the air to the burners is passed over furnace wall surfaces, thereby, providing a boundary of air which maintains an oxidizing atmosphere close to the tube walls. In tangentially-fired boilers using the LNCFS, the boundary air is provided as a natural by-product of the injection of fuel into a central core swirl in the furnace, and the air into an outer concentric swirl which sweeps the wall surfaces.

The net result of the three techniques described above is that less excess air can be supplied to the primary combustion zone without causing slagging, corrosion and unburned combustible 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.

Low NO_x Concentric Firing System (LNCFS)

Conventional tangential firing systems use vertical stacks of burners at each corner of the furnace. Alternating levels of coal and air nozzles direct the air and fuel inward toward the middle of the furnace. Figure 4 shows a conventional burner/air nozzle arrangement and cross-section of the windbox. Coal is supplied to each nozzle through separate conduits. The coal and the air nozzles are angled slightly off the furnace center point toward a tangential-firing circle, which imparts a counter-clockwise swirl to the combustion gases. This promotes a stable combustion pattern and an even heat distribution to the furnace walls. In addition, the air and coal nozzles can be tilted vertically for temperature control.

The LNCFS limits NO_x emissions by controlling the mixing of the fuel and the combustion air. Control is accomplished by directing the secondary air in a circle that has a larger radius than the circle of the fuel and primary air. This configuration produces a stable flame front and a fuel rich atmosphere where fuel nitrogen can be evolved as N_2. In addition, furnace wall slagging is decreased, because some of the secondary air is passed over the furnace wall tubes.

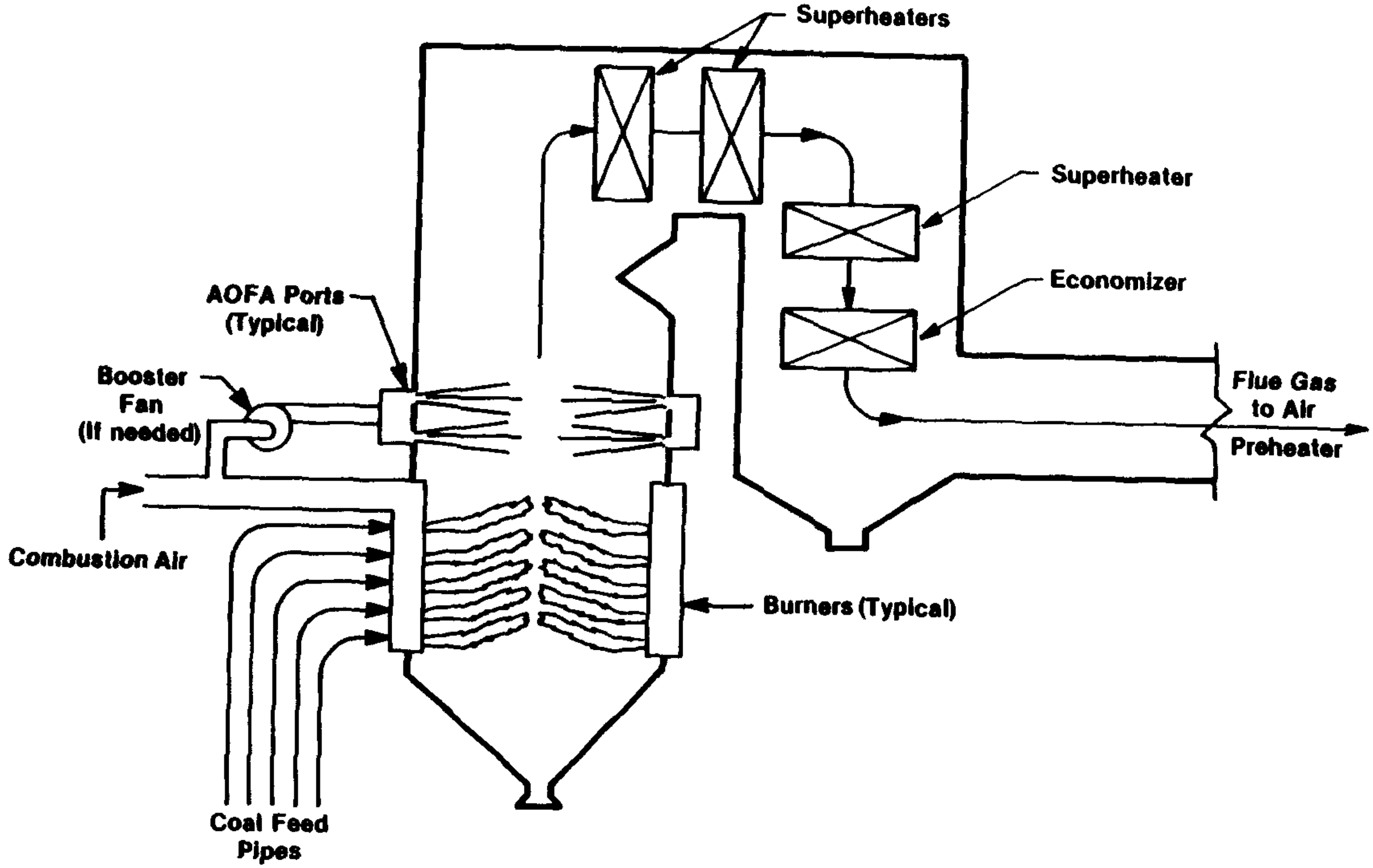

FIGURE 3. AOFA CONCEPT SCHEMATIC.

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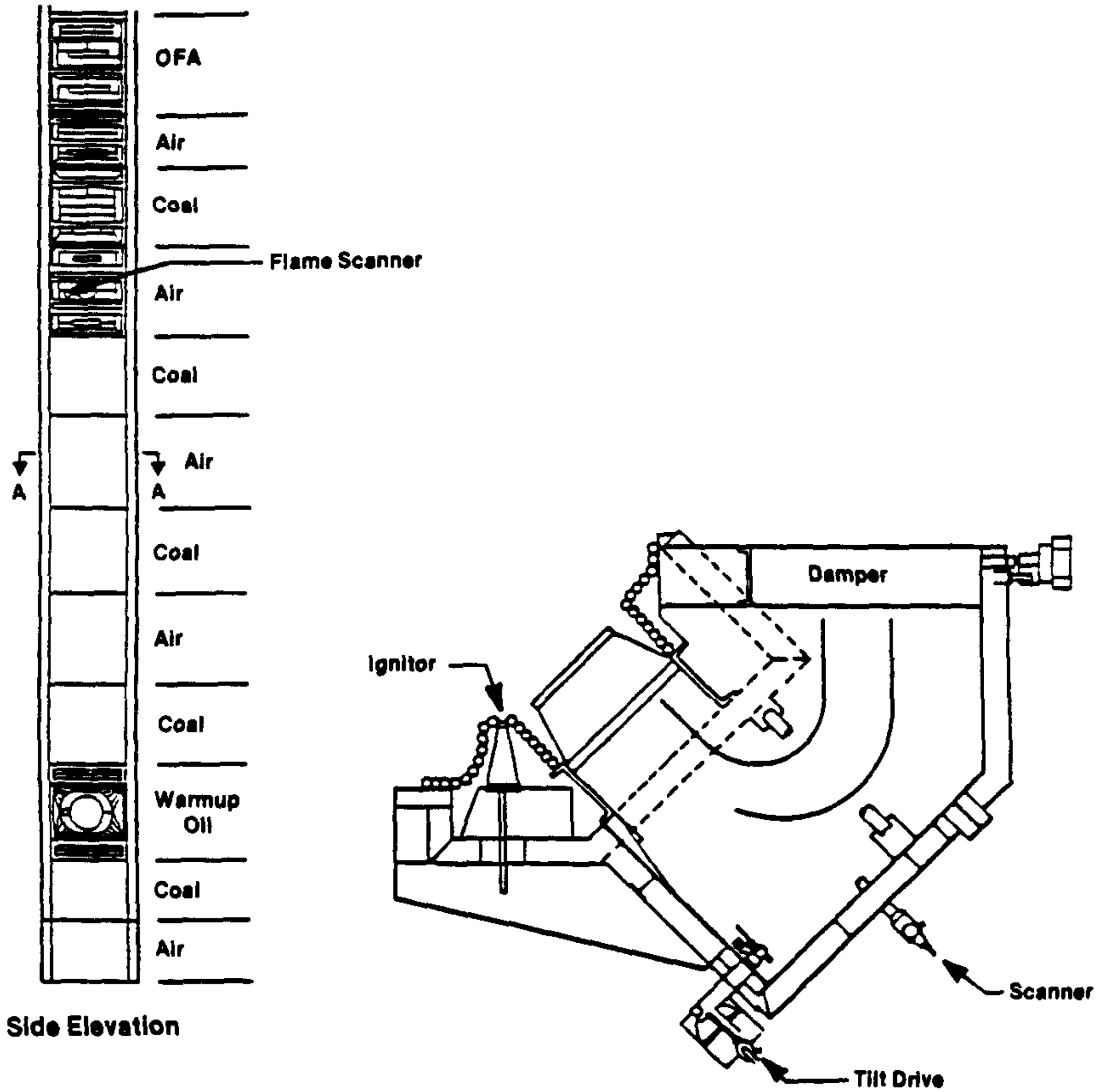

Side Elevation

Plan View (A - A) of Aux. Air Compart.

FIGURE 4. CONVENTIONAL WINDBOX/BURNER ARRANGEMENT.

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The LNCFS retrofit, shown in Figure 5, includes; (1) the addition of adjustable turning vanes to the secondary (auxiliary) air compartments so that the air can be directed at the desired angles; (2) the addition of horizontally adjustable offset air nozzle tips to the main auxiliary compartments and end auxiliary compartments; (3) the reduction of the free area available in the coal compartments through which the fuel-air mixture can pass and; (4) the addition of divergent coal nozzle tips. The free area reduction forces more air through the offset auxiliary compartments and the unmodified auxiliary compartments, thus enhancing recirculation of the fuel rich primary airstream and creating a stable flame front. The divergent coal nozzle tips provide a long sub-stoichiometric flame path between the initial ignition point and the final bulk combustion fireball. This prolonged combustion produces low NO_x.

Concentric Clustered Tangential-Firing System (CCTFS)

The CCTFS incorporates new concepts and enhancements of existing concepts, such as, AOFA and the LNCFS, to reduce the formation of NO_x. The CCTFS, shown in Figure 6, differs from a conventional tangential firing system (Figure 4) and the LNCFS (Figure 5) in that the coal nozzles are repositioned into clusters of two or three, the air nozzle compartments are larger and are designed for offset auxiliary air and secondary ignition and warm-up fuels, and two separate overfire air systems are provided instead of one or none.

The grouping of the coal nozzles creates very fuel rich zones, which provides better NO_x control over the load range. The offset auxiliary air nozzles protect the furnace waterwalls from slagging and corrosion and reduce furnace outlet gas temperature which tends to be raised by large quantities of overfire air. The close-coupled overfire air is the same as that incorporated into LNCFS. CCTFS also includes high-pressure separated overfire air, or AOFA, located above the main windbox. The use of separate overfire air systems allows gradual staging which is more effective in reducing NO_x than a single overfire air system. The combination of these components provides a low NO_x firing system that can be retrofitted without replacing the original windbox.

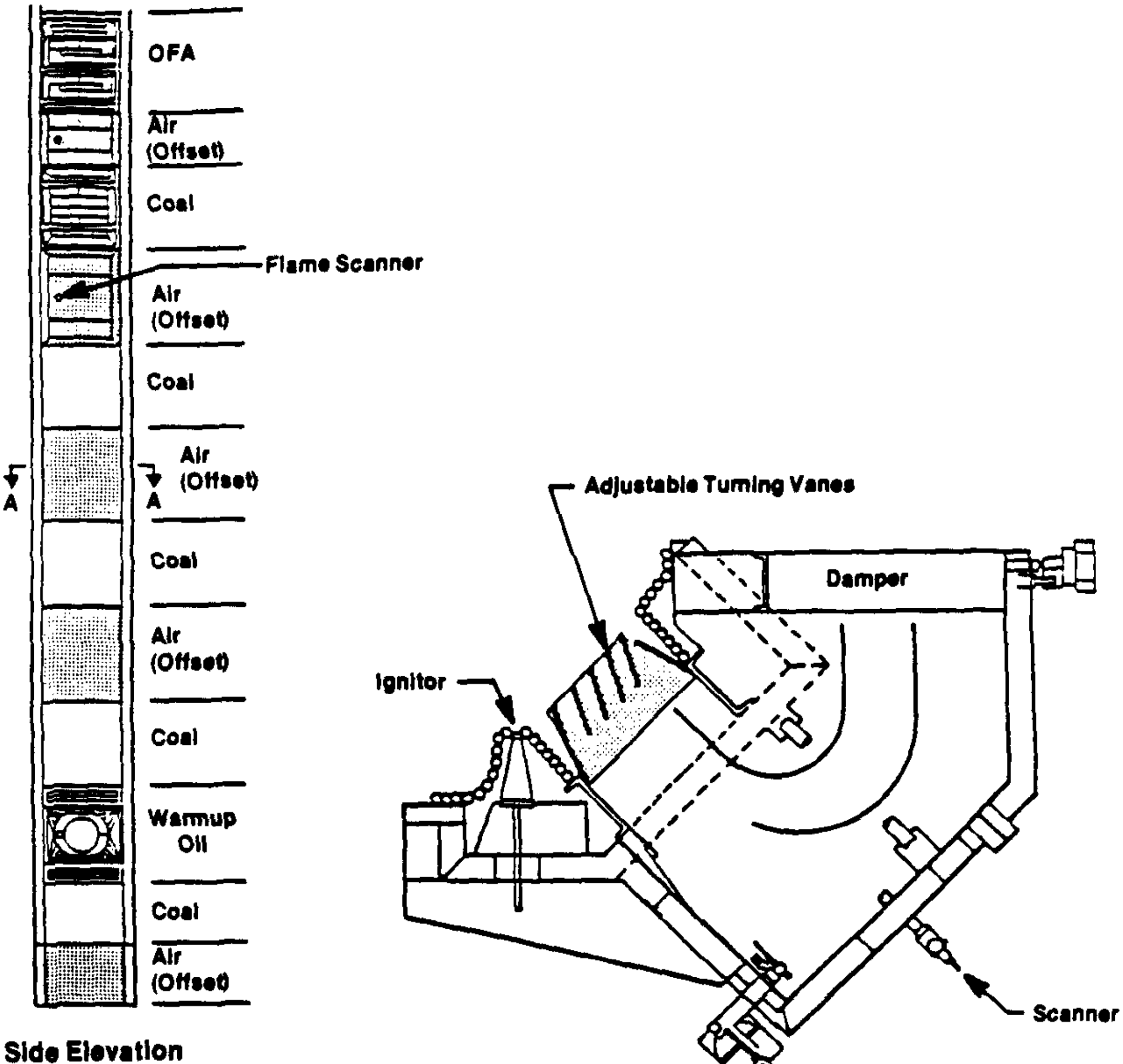

FIGURE 5. LOW-NOx CONCENTRIC FIRING SYSTEM (LNCFS) WINDBOX/BURNER ARRANGEMENT.

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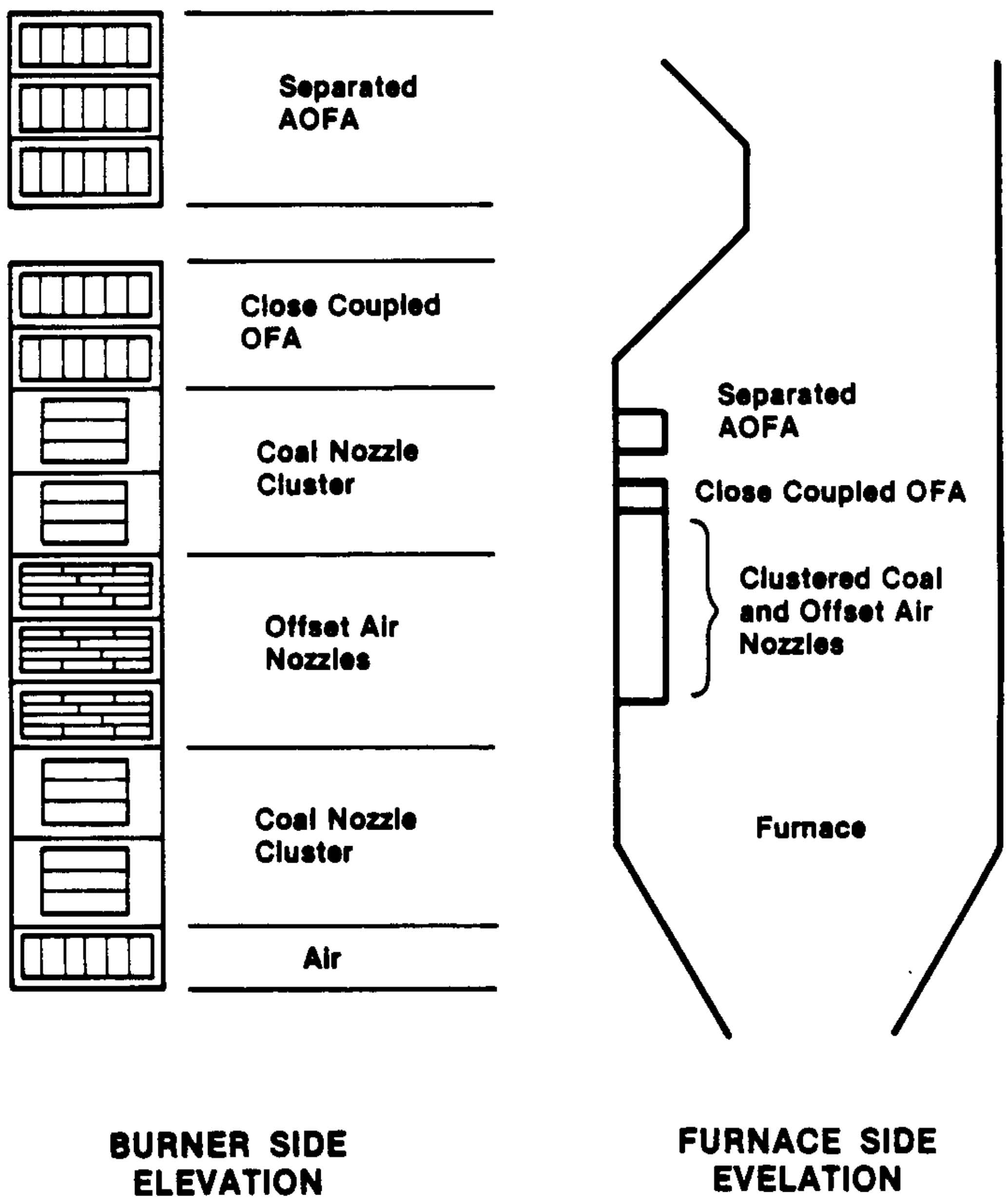

FIGURE 6. CONCENTRIC CLUSTERED TANGENTIAL FIRING SYSTEM ARRANGEMENT.

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3.2.3 Application of Processes in Proposed Project

The unit is a nominal 180 MW Combustion Engineering pulverized coal, tangentially-fired boiler, which has five coal nozzles per furnace corner. The installation of the AOFA system will require a separate air supply system, including ductwork, flow control dampers, windbox, removal of waterwall tubes to accommodate the AOFA ports, and alterations to the combustion control and flame safety systems.

LNCFS installation requires minimal boiler modifications, because the burner system is designed to fit within existing burner openings and windboxes. As stated previously, the auxiliary air compartments will require the addition of adjustable turning vanes, the three main auxiliary air compartments and end auxiliary compartments will require modification to accept horizontally adjustable offset air nozzle tips and the coal compartments will require new nozzle tips and the addition of blocking plates. Other than for the close-coupled OFA system, no pressure part changes or changes to the air or fuel supply ducts are required.

The installation of the CCTFS requires relocation of the coal nozzles, air compartments and ignition and warm-up fuel nozzles within the existing windbox, the addition of offset air nozzle tips, changes to the coal pipe locations and installation of high-pressure overfire air fans, ductwork, dampers and overfire air compartments. In some installations such as Plant Smith where the unit has been converted from pressurized to balanced draft operation, sufficient pressure may be available from existing fans to preclude the need for separate overfire air booster fans.

3.3 General Features of the Project

3.3.1 Evaluation of Developmental Risk

As with any new technology there is some risk, however, the AOFA, LNCFS and CCTFS 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 undesirable operating conditions, then the amount of overfire air can be regulated, at the expense of NO_x reduction effectiveness, until acceptable operating conditions exist. Similarly, the LNCFS and CCTFS and their respective overfire air systems can be adjusted to achieve the desired flame shape at the expense of NO_x reduction effectiveness.

Based on the above, a low risk 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 can be difficult to capture in electrostatic precipitators and 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 decreases, then the efficiency of the electrostatic precipitator, scrubber or baghouse may decrease resulting in increased stack emissions. Further, if the average resistivity of the fly ash is increased or decreased, then the collection efficiency of an electrostatic precipitator may increase or decrease. These are considered to be low risks, because previous demonstrations of the proposed technologies have shown no significant increase in carbon content.

3.3.1.1 Similarity of the Project to Other Demonstration/Commercial Efforts

Besides the proposed technologies, there are only two other concepts for retrofit combustion NO_x control for tangentially-fired coal boilers. They are the Mitsubishi PM low NO_x burner and reburning.

The PM low NO_x burner was developed by Mitsubishi Heavy Industries of Japan primarily for use in new installations. SCS states that retrofit of this burner to conventional tangential-fired boilers requires the replacement of the entire windbox from the furnace side. This necessitates cutting a large access opening in the furnace tubing, which must be repaired after burner installation. SCS states that this burner is capable of reducing NO_x by up to 50% at an installed cost between $15 to $25 per kw. An EPRI sponsored demonstration program using the PM burner is in progress at the Lawrence Energy Center of Kansas Power and Light.

Reburning was developed by several companies in Japan and is in use in a number of Japanese boilers. The technology consists of 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 slightly air rich, thereby producing high NO_x 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_x is converted to molecular nitrogen. Overfire air is then injected to complete combustion. An ongoing DOE sponsored reburning demonstration on a tangentially-fired boiler is being performed at the Hennepin Station of Illinois Power Company.

The LNCFS, AOFA and CCTFS technologies that are being demonstrated in this project are directly applicable only to tangentially-fired boilers. Low-NO_x combustion techniques for other types of coal-fired boilers will be demonstrated in the Clean Coal Technology Program. As a result of the first solicitation, two slagging combustor projects were selected to demonstrate new designs for cyclone-type combustors that reduce NO_x emissions. These projects were proposed by Coal Tech and TRW, Inc.

SCS is also demonstrating low-NO_x combustion techniques for wall-fired boilers as part of the DOE ICCT solicitation. In ICCT, TransAlta Resources Investment Corporation is demonstrating a low NO_x/SO_x burner system.

In the third round of the Clean Coal Technology Program, B&W is demonstrating a low-NO_x cell burner which is intended to replace conventional cell burners. Public Service Company of Colorado is scheduled to demonstrate low-NO_x combustion techniques for a down-fired boiler (one in which the burners are positioned on top of the boiler and the flame is directed downward).

Thus, the demonstration of LNCFS, AOFA, and CCTFS for tangentially-fired boilers, in conjunction with the other CCT projects, will provide a proven low-NO_x combustion technology for every common type of coal-fired utility boiler.

3.3.1.2 Technical Feasibility

The use of overfire air and low NO_x burners to reduce NO_x emissions has been recognized for many years. Early research by B&W demonstrated that the use of overfire air in wall-fired units can reduce NO_x levels by 30 to 50 percent. The use of overfire air technology, however, resulted in boiler slagging problems and carbon carryover and as a result the low NO_x burner was developed. Low NO_x burners are available from CE, the manufacturer of tangentially-fired boilers.

As a result of the potential for new acid rain legislation, a renewed interest in the use of the OFA system has developed. AOFA, an enhancement of the standard OFA system, incorporates improved mixing, deep staging and boundary air. The Japanese have tested variations to the AOFA system and will implement its use on a full scale unit. In addition, the EPRI has funded a flow model study to investigate ways to improve the mixing of overfire air in the furnace. The first generation LNCFS has been evaluated by EPA at Utah Power and Light Company's Hunter Unit No. 2 and by CE's licensee in Great Britain, NEI International Combustion, Ltd., at the Central Electric Generating Board's Fiddlers Ferry No. 1 Power Station. The results of both demonstrations indicate a 60% reduction in NO_x from baseline conditions.

The Mitsubishi PM burner is currently being evaluated at Kansas Power and Light's Lawrence Energy Center. The Concentric Clustered Tangential Firing System is a modification to the LNCFS. It is designed to provide the same NO_x reduction, but is less complex.

Since the basic concepts of AOFA, LNCFS and the CCTFS have been tested on full scale utility boilers, the advanced concepts are expected to operate in a similar manner, but with further improvement in emissions reductions.

3.3.1.3 Resource Availability

Adequate resources are available for this program. SCS 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 materials required for construction and operation of the demonstration are anticipated to be minimal.

The local labor needs for construction are expected to be minimal and no additional operating personnel are required. The labor force will be provided primarily from nearby Panama City, Florida.

This program involves a fully operational electric power generating station with appropriate facilities and scheduling flexibility to accommodate this project. Plant Smith Unit No. 2 is representative of typical tangentially-fired boilers, and it will provide an excellent opportunity to evaluate all of the proposed technologies.

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, Gulf Power Company, and CE. 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 180 MW commercial unit, which is considered a small to medium size unit. Scale-up to larger units will require an increase of overfire air, changeout of more burners and/or changeout of larger burners. These are considered to be minimal risks. The net effect is that this project will prove the applicability of the AOFA, LNCFS, and CCTFS technologies for retrofit on many pre-NSPS tangentially-fired boilers without further demonstration.

It is anticipated, however, that the proposed technologies will not be cost effective in retrofit applications below 100 MW.

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

SCS states that utilities have had difficulty meeting regulatory requirements with existing technology on new boilers. Consequently, they will be more likely to accept new advanced techniques on retrofits to existing boilers when they have the confidence that the new technology(s) will be economical and significantly reduce NO_x with minimal impact on boiler performance.

The proposed demonstration will provide the needed long-term performance data typical of utility boiler operation. In addition, meaningful comparisons of the proposed technologies will be possible, because each technology will be evaluated 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 plant operation under current conditions. Any 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. To establish baseline conditions for 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 eleven 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 new computerized data acquisition system will be installed that will interface with existing and new plant instrumentation. In addition, a gas analysis system, heat flux monitors, flame observation system, flame scanners, acoustic pyrometer and continuous emissions monitor will be installed.

The data acquisition system will be capable of gathering data from 150 different sources throughout the plant and the gas analysis system. Typical operating data that can be continuously recorded includes:

- Gross/Auxiliary load
- Coal feed flow
- Mills in service
- Burner tilt angle
- OFA flowrate and pressure
- Combustion air flows
- 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, the levels of nitric oxide, carbon monoxide, hydrocarbons, sulfur dioxide, and excess oxygen. Other data which will be obtained or computed includes fly ash particle size, fly ash resistivity, particulate emissions, SO_3 emissions, 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 commercial 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 commercially proven, the LNCFS, AOFA, and CCTFS processes will provide an economic and technically acceptable means of controlling NO_x from tangentially-fired boilers. The minimal retrofit requirements and competitive cost of these technologies make them especially applicable to the retrofit of existing boilers.

The concepts consist of commercially available equipment such as burners,nozzles and dampers.

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

- Reducing NO_x emissions by up to 50%
- Acquisition and analyses of long term test data
- Competitive capital and operating costs
- Knowledge of the effects of the technologies on other combustion parameters
- Relatively easy retrofit
- No derating of the boiler
- Using commercially available components

The success of this program will establish that LNCFS, AOFA, and the CCTFS are effective economical approaches to controlling NO_x. As such, the technologies are expected to significantly penetrate the large tangentially-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 were sufficient to demonstrate compliance with regulatory requirements. New regulatory requirements, however, require continuous compliance and more stringent NO_x standards. As a result of this demonstration, utilities will be more likely to accept Low-NO_x combustion techniques for retrofit applications.

Southern Company Services performed economic comparisons of the AOFA, LNCFS, and CCTFS concepts for a 100 MW, 500 MW and an 800 MW plant. The capital costs for the AOFA retrofit ranged from $7.8/KW for the 800 MW plant to $17.5/KW for the 100 MW plant. Capital costs associated with the LNCFS retrofit ranged from $1.9/KW to $4.7/KW. For the CCTFS retrofit, the capital costs ranged from $17.1/KW to $32.5/KW. These costs are substantially less than the cost of 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 80-90% compared to 50 or 60 percent reductions using low NO_x combustion techniques.

The technologies discussed herein can be incorporated into existing plants without displacing other equipment, requiring additional site space or significantly affecting plant operation. In addition, the operating costs of the technologies discussed herein are much less than those estimated for the SCR technology.

4.0 ENVIRONMENTAL CONSIDERATIONS

The overall strategy for compliance with NEPA, cited in Section 2.2, contains three major elements. The first element, the Programmatic Environmental Impact Analysis (PEIA), was issued as a public document in September 1988 (DOE/PEIA-0002). In the PEIA, the Regional Emission Database and Evaluation System (REDES), a model developed by DOE at Argonne National Laboratory, was used to estimate the environmental impacts that could occur by the year 2010 if each technology were to reach full commercialization and capture 100 percent of its applicable market. The environmental impacts were compared to the no-action alternative, for which it was assumed that use of conventional coal technologies continues through 2010 with new plants using conventional flue gas desulfurization controls to meet New Source Performance Standards.

In the PEIA, the expected performance characteristics and applicable market of the Advanced Combustion Techniques for Tangentially-Fired Boilers technology were used to estimate the environmental impacts that might result if the Advanced Combustion Techniques for Tangentially-Fired Boilers technology were to reach full commercialization in 2010. Results derived from the REDES computer model were used to project the impacts of the Advanced Combustion Techniques for Tangentially-Fired Boilers technology as compared to the no-action alternative.

Projected environmental impacts from maximum commercialization of the Advanced Combustion Techniques for Tangentially-Fired Boilers technology into national and regional areas in 2010 are given in Table 1. Negative percentages indicate decreases in emissions or wastes in 2010. Conversely, positive values indicate increases in emissions or wastes. The information presented in Table 1 represents an estimate of the environmental impacts of the technology in 2010. These computer-derived results should be regarded as approximations of actual impacts.

TABLE 1.
PROJECTED ENVIRONMENTAL IMPACTS IN 2010
(PERCENT CHANGE IN NATIONAL SO_2 AND NO_x EMISSIONS AND SOLID WASTES)

Region	Sulfur Dioxide (SO_2)	Nitrogen Oxides (NO_x)	Solid Waste
National	0	-21	0
Northeast	0	-27	0
Southeast	0	-28	0
Northwest	0	-7	0
Southwest	0	-14	0

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

As shown in Table 1, significant reductions of NO_x are projected to be achievable nationally, due to the 60 percent removal capability forecasted and the wide applicability of the process. Negligible changes in liquid effluents are anticipated and the technology produces no dry solid waste product. The REDES model predicts greatest environmental benefits will be achieved in the Northeast and Southeast because of the large amount of coal-fired capacity in this region that can be retrofitted with the Advanced Combustion Techniques for Tangentially-Fired Boilers process. The least change would occur in the Northwest because of the minimal use of coal there. The national quadrants used in this study are shown in Figure 7.

The second element of DOE's NEPA strategy for the ICCT program involved preparation of a preselection environmental review based on project-specific environmental data and analyses that offerors supplied as a part of each proposal. This analysis, for internal DOE use only, contained a discussion of site-specific environmental, health, safety and socioeconomic factors associated

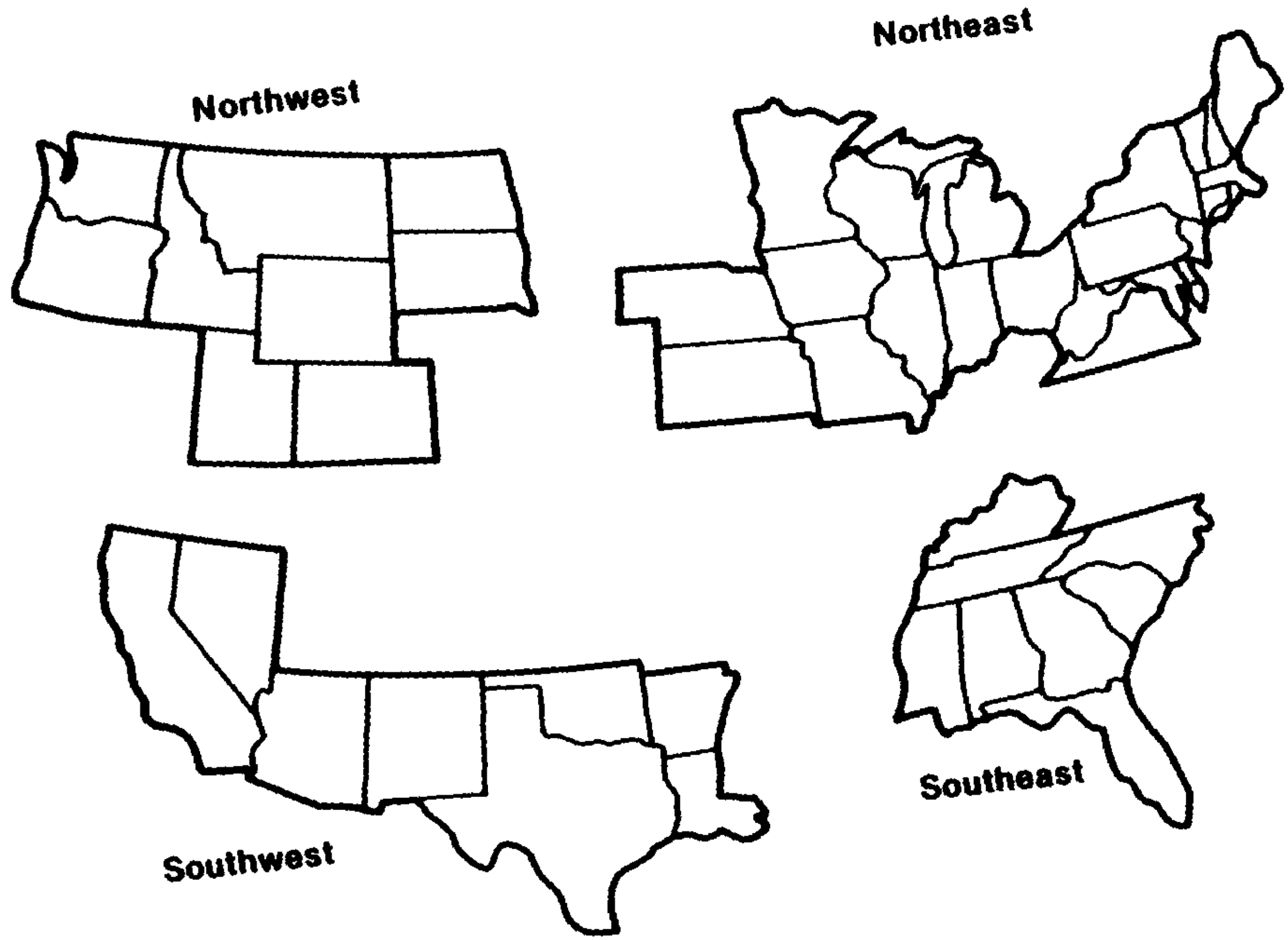

FIGURE 7. QUADRANTS FOR THE CONTIGUOUS UNITED STATES.

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with each demonstration project. It included a discussion of the advantages and disadvantages of the proposed and alternative sites and processes reasonably available to each offeror. A discussion of the impacts of each proposed demonstration on the local environment, and a list of permits that must be obtained to implement the proposal were included. It also contained options for controlling discharges, and for management of solid and liquid wastes. Finally, the risks and impacts of each proposed project were assessed. Based on this analysis, no environmental, health, safety or socioeconomic issues have been identified that would result in any significant adverse environmental impacts from construction and operation of the AOFA/LNCFS demonstration facility.

As the third element of the NEPA strategy, a detailed site- and project-specific NEPA document is prepared by DOE. This document must be completed and approved in conformance with the requirements of the Council on Environmental Quality regulations for implementing the National Environmental Policy Act (NEPA) (40 CFR Parts 1500-1508) and DOE guidelines for compliance with NEPA (52 FR 47662, December 15, 1987) before federal funds are provided for detailed design, construction, and operation. A Memorandum-to-File was signed by the DOE Assistant Secretary for Fossil Energy on July 17, 1989, thereby completing the NEPA requirements for this project.

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

5.0 PROJECT MANAGEMENT

5.1 Overview of Management Organization

The project will be managed by SCS's Project Manager. He will be the principal contact with DOE for matters regarding the administration of the Cooperative Agreement between SCS and DOE. All other participating organizations will report to the SCS Project Manager. The Project Manager will report to the SCS ICCT Program Manager.

The DOE Contracting Officer is responsible for all contract matters and the DOE Contracting Officers Technical Representative (COTR) is responsible for technical liaison and monitoring of the project.

In addition to DOE, the project will be co-funded by EPRI. The host site is Southern Company's/Gulf Power's Plant Smith. Other organizations involved in the project include Combustion Engineering, Energy Technology Consultants, Inc., Flame Refractories, Radian Corporation, Roberson-Pitts, Inc., Southern Research Institute, and Spectrum Systems.

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

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

- Approve 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:

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

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

- 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 advice shall be issued in writing by the DOE COTR.

Participant

The Participant (SCS) 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 and will be the single authorized point of contact for all matters between the Participant and DOE. The Project Manager will report to the SCS ICCT Program Manager. The Program Manager will provide the link to the executives of the Southern Electric System and will have final responsibility to the executive management of SCS for execution of the project.

SCS 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.

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

The Electric Power Research Institute (EPRI) will work with SCS to ensure that the technical direction of the project is consistent with the intent of the ICCT Program. EPRI will also provide technical consultation and guidance.

Combustion Engineering will be responsible for the design, flow modeling, fabrication, shipment, installation and start-up of the advanced low NO_x combustion hardware.

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

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

Roberson-Pitts, Inc. will serve as data analysts for the test phases of the project. Their work will consist of 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 will serve as the boiler performance subcontractor and will be responsible for diagnostic testing of the as-found boiler, evaluation of pulverizer performance, determination of air fuel ratio, flyash sampling, certification of the on-line loss-on-ignition monitor, performance of flow measurements and determination of air flow distribution characteristics.

Southern Research Institute will serve as the emissions subcontractor and will be responsible for the characterization of the gaseous and particulate emissions and certification of gas analysis and continuous emissions monitoring equipment.

Spectrum Systems will provide full-time site instrumentation maintenance and operation.

The Participant will interrelate between the government and all other project sponsors as shown in Figure 8, Project Organization.

5.3 Summary of Project Implementation and Control Procedures

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

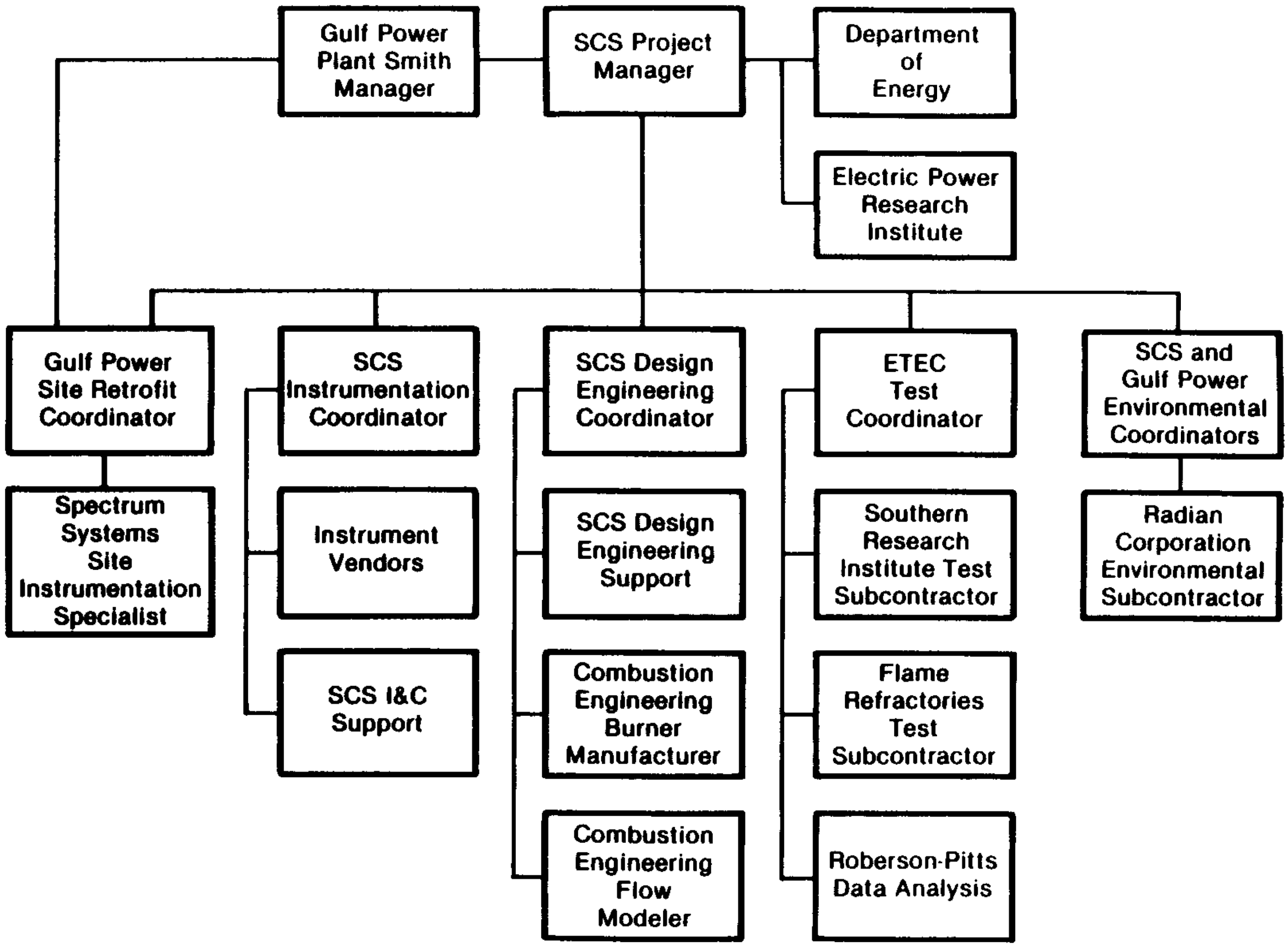

FIGURE 8. SCS, INC. PROJECT ORGANIZATION FOR ADVANCED TANGENTIALLY-FIRED COMBUSTION TECHNIQUES.

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Phase I: Site Preparation and Pre-Retrofit Testing (9 months)
Phase II:, LNCFS and AOFA Retrofit and
Post-Retrofit Testing (6 months)
Phase III: Concentric Clustered Tangential Firing System
Retrofit and Post-Retrofit Testing (10 months)
Phase IV: Final Reporting and Disposition (11 months)

As shown in Figure 9, each phase will start upon completion of the previous phase. There are no pauses or overlaps between phases that are anticipated.

Two budget periods will be established for the project. The first budget period will include Phase I and part of Phase II and the second budget period will include the remainder of Phase II and Phases III and IV. budget period I is scheduled to end in June 1991. Budget period II is scheduled to begin in July 1991 and end at the end of Phase IV. Consistent with P.L. 100-202, as amended by P.L. 100-446, DOE will obligate funds sufficient to cover its share of the cost for each budget period. Throughout the course of this project, reports dealing with the technical, management, cost, and environmental monitoring aspects of the project will be prepared by SCS or its subcontractors and provided to DOE.

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

The key agreements with respect to patents and data are as follows:

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

- o An advance patent waiver is expected to be requested by Southern Companies Services, Inc., which, if granted, will give SCS the right to elect title for its inventions under the Cooperative Agreement, subject to a government license and standard march-in and preference for U.S. industry provisions.

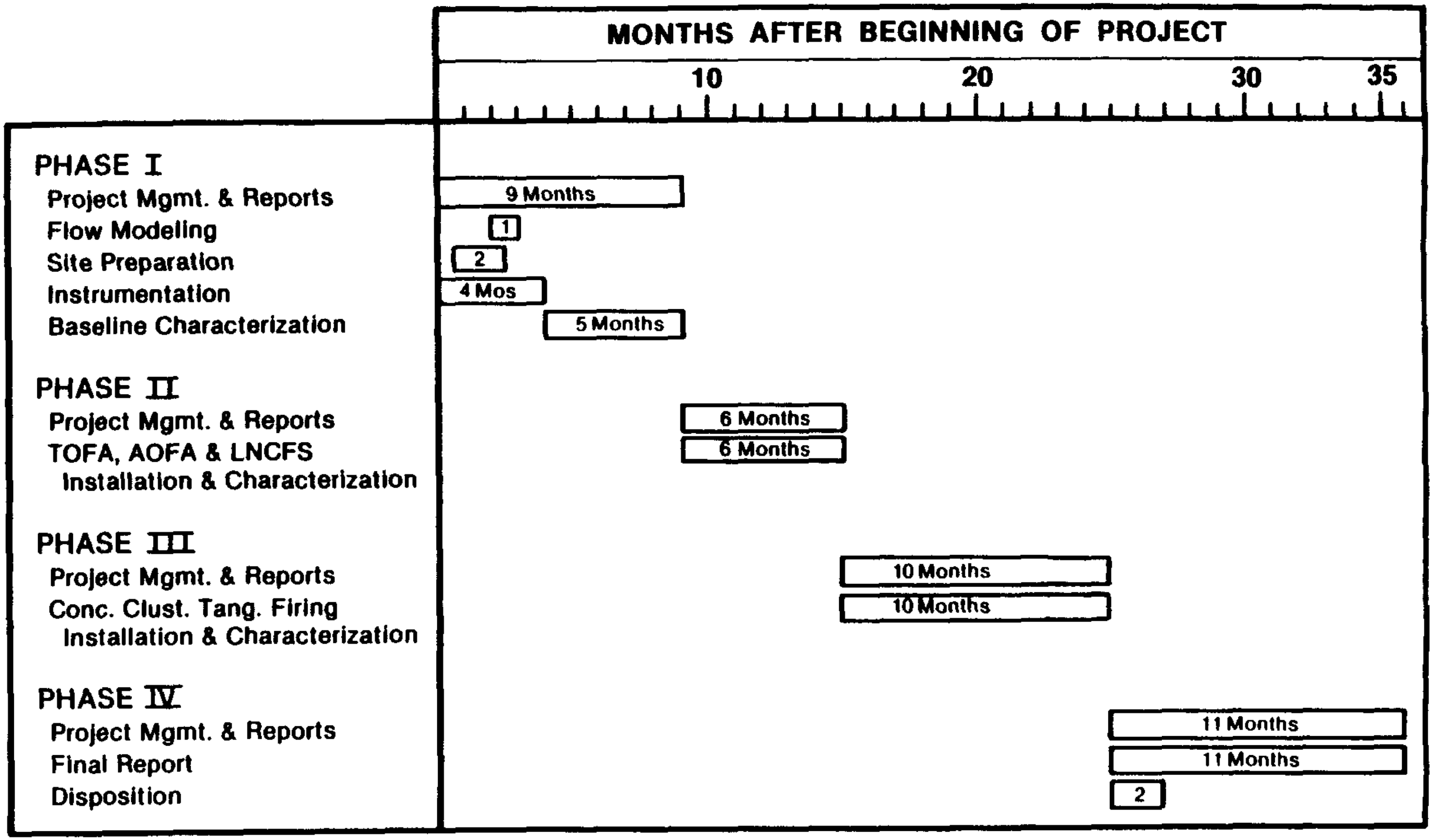

FIGURE 9. OVERALL SCS, INC. PROJECT SCHEDULE FOR ADVANCED TANGENTIALLY-FIRED COMBUSTION TECHNIQUES.

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5.5 _Procedures for Commercialization of the Technology_

SCS states that a key factor in the commercialization of low NO_x combustion technology is that its use is driven by regulatory requirements and not the business sector. If more restrictive NO_x regulations are imposed, the utilities are likely to implement the least expensive technology, which is the low NO_x combustion technology. Commercially available low NO_x burners may be unable to achieve compliance with any new regulations and therefore, there is a need for improved burner designs which the United States boiler manufacturers are continuing to develop.

The market that will benefit from the proposed demonstration is limited to tangentially-fired boilers placed in service after 1960. Pre-1960 boilers are equipped with cast windboxes, which would require replacement with the LNCFS or the CCTFS burner retrofits and therefore, substantially reduce the cost effectiveness of utilizing these technologies.

As of the end of 1985 there were approximately 1041 coal-fired utility boilers (296,000 MW) in active service. Considering the aforementioned market limitation, the potential total utility retrofit market that would benefit from the proposed demonstration is 87,493 MW or 179 boilers.

The successful completion of the proposed Plant Smith demonstration and dissemination of the program data 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 additional regulatory requirements. Adequate design and manufacturing capacity is available from CE to satisfy market requirements.

6.0 PROJECT COST AND EVENT SCHEDULING

6.1 Project Baseline Costs

The total estimated cost for this project is $8,555,303. The Participants' cash contribution and the Government share in the costs of this project are as follows:

	Dollar Share ($)	Percent Share (%)
Phase 0 (Pre-award)		
Government	131,708	48.51
Participants	139,799	51.49
Phase 1		
Government	860,059	48.51
Participants	912,893	51.49
Phase 2		
Government	2,065,846	48.51
Participants	2,193,005	51.49
Phase 3		
Government	905,237	48.51
Participants	960,846	51.49
Phase 4		
Government	187,205	48.51
Participants	198,705	51.49

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

DOE:	$4,150,055
SCS:	3,405,248
EPRI:	1,000,000
TOTAL	$8,555,303

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

6.2 Milestone Schedule

The overall project will be completed in 36 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 nine months. Upon completion of Phase I, Phase II, LNCFS and AOFA retrofit and post retrofit testing, will start and continue for six months. Phase III, CCTFS retrofit and post retrofit testing, will start upon completion of Phase II and continue for 10 months. The final phase, which involves preparation of the final report and site restoration, will start upon completion of Phase III and continue for 11 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.