DOE/FE-0204P

Comprehensive Report to Congress Clean Coal Technology Program

Evaluation of Gas Reburning and Low-NOx Burners on a Wall-Fired Boiler

A Project Proposed By:
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U.S. Department of Energy
Assistant Secretary for Fossil Energy
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Washington, DC 20585

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1.0 EXECUTIVE SUMMARY

In September 1988, Public Law No. 100-446, provided $575 million to conduct cost-shared Clean Coal Technology (CCT) projects to demonstrate 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 May 1989, soliciting proposals to demonstrate innovative energy efficient technologies that were capable of being commercialized in the 1990s. These technologies were to be capable of (1) achieving significant reductions in the emissions of sulfur dioxide and/or nitrogen oxides from existing facilities to minimize environmental impacts such as transboundary and interstate pollution and/or (2) providing for future energy needs in an environmentally acceptable manner.

In response to the PON, 48 proposals were received by DOE in August 1989. After evaluation, 13 projects were selected for award. 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 13 projects selected for funding is a project proposed by Energy and Environmental Research Corporation (EER), "Evaluation of Gas Reburning and Low-NO_x Burners on a Wall-Fired Boiler," to demonstrate the Gas Reburning and Low-NO_x Burners technology. This process combines two NO_x control technologies to achieve a greater reduction in NO_x emissions than either technology is capable of achieving when used alone.

Low-NO_x burners, use one or more design features to reduce the amount of NO_x that forms during the combustion process. These features include staged injection of the coal and/or air, slower mixing of the coal and air or increasing the flame volume, which results in a combustion process that is less conducive to NO_x formation.

Gas reburning is used downstream of the combustion of the coal. Eighty to 85% of the total fuel value is burned with a slight excess of air. Natural gas, which provides the balance of the heat input, is injected downstream of the coal burners to produce a reducing zone which destroys the NO_x produced by the combustion of coal. Air is then injected downstream of the reducing zone to complete the combustion process.

Low-NO_x burners typically reduce NO_x formation by 30-50% and gas reburning can reduce NO_x emissions by about 50%. The combination of the two technologies will reduce NO_x emissions by more than 70%. By virtue of replacing some of the coal with natural gas, SO_2 and particulate will be reduced by 15-20%. Natural gas has a higher ratio of hydrogen to carbon than coal, therefore, carbon dioxide emissions will also be reduced by approximately 6-8%.

The project will be carried out at the Public Service Company of Colorado's (PSCo) Cherokee Station, unit No. 3. The Cherokee Station is located near Denver, Colorado as shown in Figure 1. Unit No.3 is a commercially operating, 172 MWe wall-fired boiler that uses pulverized, Colorado bituminous coal. This demonstration project will complement EER CCT-1 project which is demonstrating Gas Reburning-Sorbent Injection on cyclone- and tangentially-fired boilers.

The project will be performed over a 43 month period and will include design, permitting, installation of equipment, testing, data collection and analysis, site restoration, reporting of results, and the preparation of design guidelines.

The total estimated project cost is $14,472,117. DOE will contribute $7,236,058 to the project and EER will contribute $7,236,059 to the project. The Public Service Company of Colorado, the Electric Power Research Institute, the Gas Research Institute, and the Colorado Interstate Gas Company will assist EER in funding the project. The project is expected to begin in September of 1990 and is scheduled for completion in April of 1994.

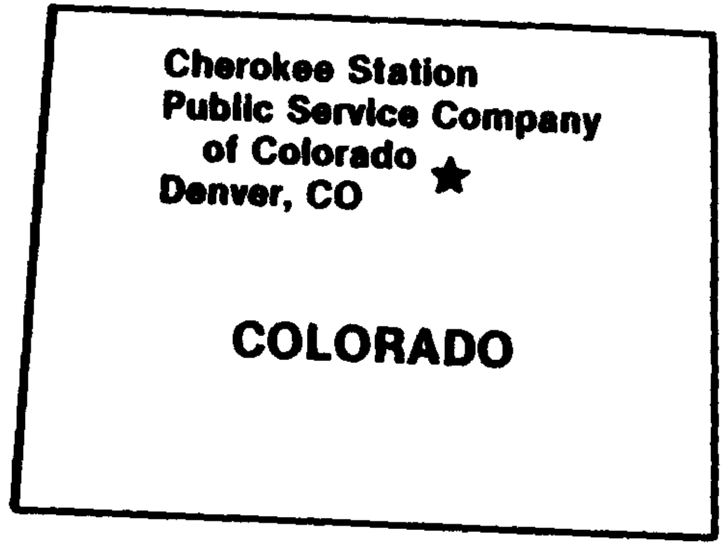

FIGURE 1. EER GAS REBURNING AND LOW-NO_x BURNERS DEMONSTRATION PROJECT LOCATION.

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2.0 INTRODUCTION AND BACKGROUND

2.1 Requirement for a Report to Congress

On September 27, 1988, Congress made available funds for the third clean coal demonstration program (CCT-III) in Public Law 100-446, "An Act Making Appropriations for the Department of the Interior and Related Agencies for the Fiscal Year Ending September 30, 1989, and for Other Purposes" (the "Act"). Among other things, this Act appropriates funds for the design, construction, and operation of cost-shared, clean coal projects to demonstrate the feasibility of future commercial applications of such "... technologies capable of retrofitting or repowering existing facilities ...." On June 30, 1989, Public Law 101-45 was signed into law, requiring that CCT-III projects be selected no later than January 1, 1990.

Public Law 100-446 appropriates a total of $575 million for executing CCT-III. Of this total, $6.906 million are required to be reprogrammed for the Small Business and Innovative Research Program (SBIR) and $22.548 million are designated for Program Direction Funds for costs incurred by DOE in implementing the CCT-III program. The remaining, $545.546 million was available for award under the PON.

The purpose of this Comprehensive Report is to comply with Public Law 100-446, which directs the Department to prepare a full and comprehensive report to Congress on each project selected for award under the CCT-III Program.

2.2 Evaluation and Selection Process

DOE issued a draft PON for public comment on March 15, 1989, receiving a total of 26 responses from the public. The final PON was issued on May 1, 1989, and took into consideration the public comments on the draft PON. Notification of its availability was published by DOE in the Federal Register and the Commerce Business Daily on March 8, 1989. DOE received 48 proposals in response to the CCT-III solicitation by the deadline, August 29, 1989.

2.2.1 PON Objective

As stated in PON Section 1.2, the objective of the CCT-III solicitation was to obtain "proposals to conduct cost shared Clean Coal Technology projects to demonstrate innovative, energy efficient technologies that are capable of being commercialized in the 1990s. These technologies must be capable of (1) achieving significant reductions in the emissions of sulfur dioxide and/or the oxides of nitrogen from existing facilities to minimize environmental impacts such as transboundary and interstate pollution and/or (2) providing for future energy needs in an environmentally acceptable manner."

2.2.2 Qualification Review

The PON established seven Qualification Criteria and provided that, "In order to be considered in the Preliminary Evaluation Phase, a proposal must successfully pass Qualification." The Qualification Criteria were as follows:

(a) The proposed demonstration project or facility must be located in the United States.

(b) The proposed demonstration project must be designed for and operated with coal(s) from mines located in the United States.

(c) The proposer must agree to provide a cost share of at least 50 percent of total allowable project cost, with at least 50 percent in each of the three project phases.

(d) The proposer must have access to, and use of, the proposed site and any proposed alternate site(s) for the duration of the project.

(e) The proposed project team must be identified and firmly committed to fulfilling its proposed role in the project.

(f) The proposer agrees that, if selected, it will submit a "Repayment Plan" consistent with PON Section 7.4.

(g) The proposal must be signed by a responsible official of the proposing organization authorized to contractually bind the organization to the performance of the Cooperative Agreement in its entirety.

2.2.3 Preliminary Evaluation

The PON provided that a Preliminary Evaluation would be performed on all proposals that successfully passed the Qualification Review. In order to be considered in the Comprehensive Evaluation phase, a proposal must be consistent with the stated objective of the PON, and must contain sufficient business and management, technical, cost, and other information to permit the Comprehensive Evaluation described in the solicitation to be performed.

2.2.4 Comprehensive Evaluation

The Technical Evaluation Criteria were divided into two major categories: (1) the Demonstration Project Factors were used to assess the technical feasibility and likelihood of success of the project, and (2) the Commercialization Factors were used to assess the potential of the proposed technology to reduce emissions from existing facilities, as well as to meet future energy needs through the environmentally acceptable use of coal, and the cost effectiveness of the proposed technology in comparison to existing technologies.

The Business and Management criteria required a Funding Plan and an indication of Financial Commitment. These were used to determine the business performance potential and commitment of the proposer.

The PON provided that the Cost Estimate would be evaluated to determine the reasonableness of the proposed cost. Proposers were advised that this determination "will be of minimal importance to the selection," and that a detailed cost estimate would be requested after selection. Proposers were cautioned that if the total project cost estimated after selection is greater than the amount specified in the proposal, DOE would be under no obligation to provide more funding than had been requested in the proposer's Cost Sharing Plan.

2.2.5 Program Policy Factors

The PON advised proposers that the following program policy factors could be used by the Source Selection Official to select a range of projects that would best serve program objectives:

(a) The desirability of selecting projects that collectively represent a diversity of methods, technical approaches, and applications.

(b) The desirability of selecting projects in this solicitation that contribute to near term reductions in transboundary transport of pollutants by producing an aggregate net reduction in emissions of sulfur dioxide and/or the oxides of nitrogen.

(c) The desirability of selecting projects that collectively utilize a broad range of U.S. coals and are in locations which represent a diversity of EHSS, regulatory, and climatic conditions.

(d) The desirability of selecting projects in this solicitation that achieve a balance between (1) reducing emissions and transboundary pollution and (2) providing for future energy needs by the environmentally acceptable use of coal or coal-based fuels.

The word "collectively" as used in the foregoing program policy factors, was defined to include projects selected in this solicitation and prior clean coal solicitations, as well as other ongoing demonstrations in the United States.

2.2.6 Other Considerations

The PON provided that in making selections, DOE would consider giving preference to projects located in states for which the rate-making bodies of those states treat the Clean Coal Technologies the same as pollution control projects or technologies. This consideration could be used as a tie breaker if, after application of the evaluation criteria and the program policy factors, two projects receive identical evaluation scores and remain 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.

2.2.7 National Environmental Policy Act (NEPA) Compliance

As part of the evaluation and selection process, the Clean Coal Technology Program developed a procedure for compliance with the National Environmental Policy Act of 1969 (NEPA), the Council on Environmental Quality NEPA regulations (40 CFR 1500-1508) and the DOE guidelines for compliance with NEPA (52 FR 47662, December 15, 1987).

This procedure included the publication and consideration of a publicly available Final Programmatic Environmental Impact Statement (DOE/EIS-0146) issued in November 1989, and the preparation of confidential preselection project-specific environmental reviews for internal DOE use. DOE also prepares publicly available site-specific documents for each selected demonstration project as appropriate under NEPA.

2.2.8 Selection

After considering the evaluation criteria, the program policy factors, and the NEPA strategy as stated in the PON, the Source Selection Official selected 13 projects as best furthering the objectives of the CCT-III PON.

Secretary of Energy, Admiral James D. Watkins, U.S. Navy (Retired), announced the selection of 13 projects on December 21, 1989. In his press briefing, the Secretary stated he had recently signed a DOE directive setting a 12 month deadline for the negotiation and approval of the 13 cooperative agreements to be awarded under the CCT-III solicitation.

3.0 TECHNICAL FEATURES

3.1 Project Description

EER will demonstrate the reduction of NO_x emissions by Gas Reburning and Low-NO_x Burners in a wall-fired boiler. This project will be the first commercial-scale demonstration of this technology and will complement EER's CCT-1 project which is demonstrating Gas Reburning - Sorbent Injection technology on cyclone - and tangentially-fired boilers.

The project will be conducted at the Public Service Company of Colorado's 172 MWe Unit No. 3 at their Cherokee Station. The goal of this project is to evaluate the technical and economic feasibility of Gas Reburning and Low-NO_x Burners in a full-scale, wall-fired boiler. If successful, this project will achieve a reduction of greater than 70% in NO_x emissions, as well as some reduction in SO_2, particulate, and CO_2 emissions. It will further demonstrate that this technology is technically and economically viable in a retrofit application. It will provide cost and performance data from a commercial- scale application to demonstrate the viability of the process for new boilers.

The Public Service Company of Colorado intends to install a sorbent injection system for SO_2 control, separate from this demonstration project. The sorbent injection system operation is scheduled to coincide with Phase III of this project.

3.1.1 Project Summary

Project Title:	Evaluation of Gas Reburning and Low-NO_x Burners on a Wall-Fired Boiler
Proposer:	*Energy and Environmental Research* Corporation
Project Location:	Public Service Company of Colorado Cherokee Station Unit No. 3 Denver, Adams County, Colorado
Technology:	Flue Gas Clean-up by Gas Reburning and Low-NO_x Burners for NO_x Control
Application:	Retrofit to Wall-Fired Utility Boilers
Type of Coal Used:	Colorado Bituminous Coal (0.4% Sulfur)
Product:	Environmental Control Technology, 70% NO_x Removal
Project Size:	172 MWe
Project Start Date:	September 1990
Project End Date:	April 1994

3.1.2. Project Sponsorship and Cost

Project Sponsor:	Energy and Environmental Research Corporation
Co-Funders:	Public Service Company of Colorado The Gas Research Institute Colorado Interstate Gas Company The Electric Power Research Institute Energy and Environmental Research Corporation
Proposed Project Cost:	$14,472,117

Proposed Cost Distribution:

Participant Share (%)	DOE Share (%)
50	50

3.2 Gas Reburning and-Low NO_x Burners Process

3.2.1 Overview of Process Development

EER will demonstrate the combination of two different technologies - Gas Reburning and Low-NO_x Burners. These technologies have been developed separately and are currently at different stages of development.

Low-NO_x burners development started over 30 years ago and they are commercially available from several manufacturers. Four U.S. manufacturers dominate the U.S. market for utility boilers and all four offer a low-NO_x burner. In addition, low-NO_x burners are offered by other burner manufacturers.

Gas reburning technology is less developed than low-NO_x burners. Reburning reduces NO_x by reactions involving hydrocarbon fuel fragments under oxygen deficient conditions. John Zinc Company developed and built a flue gas NO_x incinerator using natural gas as the reburning fuel. The term "reburning" was first used in conjunction with work at Shell Development where the NO_x concentration in a laboratory-scale flame was reduced by the injection of methane. Further developmental work took place in Japan where the concept of reburning was first applied to a full-scale boiler by Mitsubishi. It was claimed that reburning could reduce NO_x by at least 50% regardless of the reburning fuel used. These developments interested EER and contract to DOE, EPA, and GRI, EER conducted extensive bench- and pilot-scale tests to characterize the fundamental process and to develop a scaling methodology suitable for use on U.S. utility boilers. Other U.S. studies have been directed toward reburning with coal or have applied reburning to combustion equipment other than utility boilers.

Gas reburning is currently being applied to two utility boilers under a project selected in Round 1 of the Clean Coal Technology Program. One boiler is tangentially fired and the other is equipped with cyclone burners. In both cases, gas reburning is combined with sorbent injection for combined NO_x and SO_2 control.

This Gas Reburning and Low-NO_x Burners demonstration project is the first time that gas reburning will be combined with low-NO_x burners to achieve greater NO_x reductions than can be achieved by either technology alone and thus extends the development of gas reburning technology.

3.2.2 Process Description

The Gas Reburning and Low-NO_x Burners technology is a low-cost technology that can be applied in both retrofit and new applications. This demonstration will be conducted on a utility boiler; however, the technology is applicable to industrial boilers and other combustion systems. Although this technology is primarily a NO_x reduction technology, some reductions in other emissions will take place. Since 15-20% of the coal is replaced with natural gas, SO_2 and particulate emissions are reduced commensurately. Also the lower carbon-to-hydrogen ratio of natural gas compared to coal reduces CO_2 emissions.

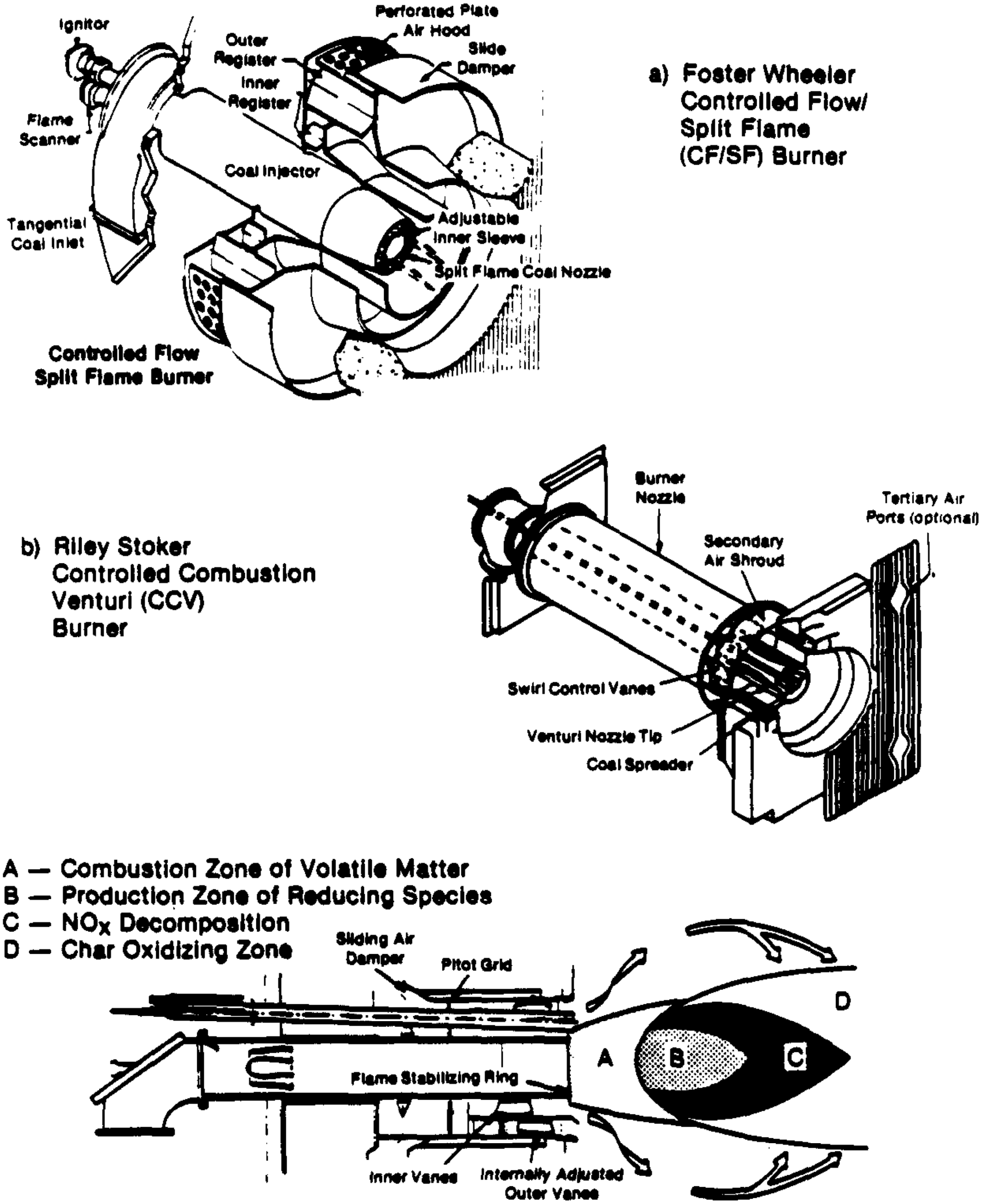
The formation of NO_x is controlled by several factors: (1) the amount of nitrogen that is chemically bound in the fuel; (2) the flame temperature; (3) the residence time that combustion products remain at very high temperatures; and (4) the amount of excess oxygen available, especially at the hottest parts of the flame. Decreasing any of these parameters, tends to reduce NO_x formation. Unfortunately, low flame temperatures, short flame residence times and severely limiting oxygen to the combustion zone all cause undesirable effects such as high emissions of carbon monoxide and hydrocarbons as well as a lower thermal efficiency.

Low-NO_x burners inject only part of the combustion air with the coal. The balance of the air is injected separately near the outlet of the burner and the burner is designed to delay mixing of the secondary combustion air with the primary combustion air and coal. This is known as air staging. Air staging allows part of the combustion reaction to take place in oxygen-deficient conditions. Furthermore, some heat is lost from the flame during the combustion process which results in temperatures that are somewhat lower than normal in that portion of the flame where there is a surplus of oxygen. The net result of this combustion technique is a 30-50% reduction in NO_x formation. Fuel staging can also be used to achieve lower NO_x emissions. Typical low-NO_x burners are shown in Figure 2.

Gas reburning, which operates independently of the burner, destroys up to 60% of the NO_x that was formed during the coal combustion process. Combustion at the burner is carried out with a slight amount of excess air. Downstream of the flame, natural gas is added into the hot combustion products. This creates a reducing zone in which hydrocarbon molecular fragments react with NO_x to produce N_2. Additional air is then injected downstream of the natural gas injection point where the combustion reactions are completed at temperatures less conducive to NO_x formation. When these techniques are combined, NO_x reductions of more than 70% are possible. A Gas Reburning and Low-NO_x Burner system is shown in Figure 3.

3.2.3 Application of Process in Proposed Project

The participant will conduct this demonstration of Gas Reburning and Low-NO_x Burners on a front-wall-fired western utility boiler with characteristics typical of wall-fired units. The site is the PSCo Cherokee Power Station Unit 3, located in Denver, Colorado. The first of the plant's four units was placed in service in September 1957, the second in 1959. The No. 3 unit, which is the host boiler, was added in 1962. It has a capacity of 172 MWe, and can be fired with either gas or coal. The fourth and largest unit went into operation in 1968. The station comprises four coal-fired steam electric generating units with a total gross generating capacity of 775.5 MWe and a single 5.5 MWe diesel-driven generator. A complete system including new low-NO_x burners, gas and air injectors, and all auxiliary equipment will be installed on the host boiler.



c) Babcock & Wilcox XCL Burner

FIGURE 2. COMMERCIALLY AVAILABLE LOW-NO_x BURNERS.

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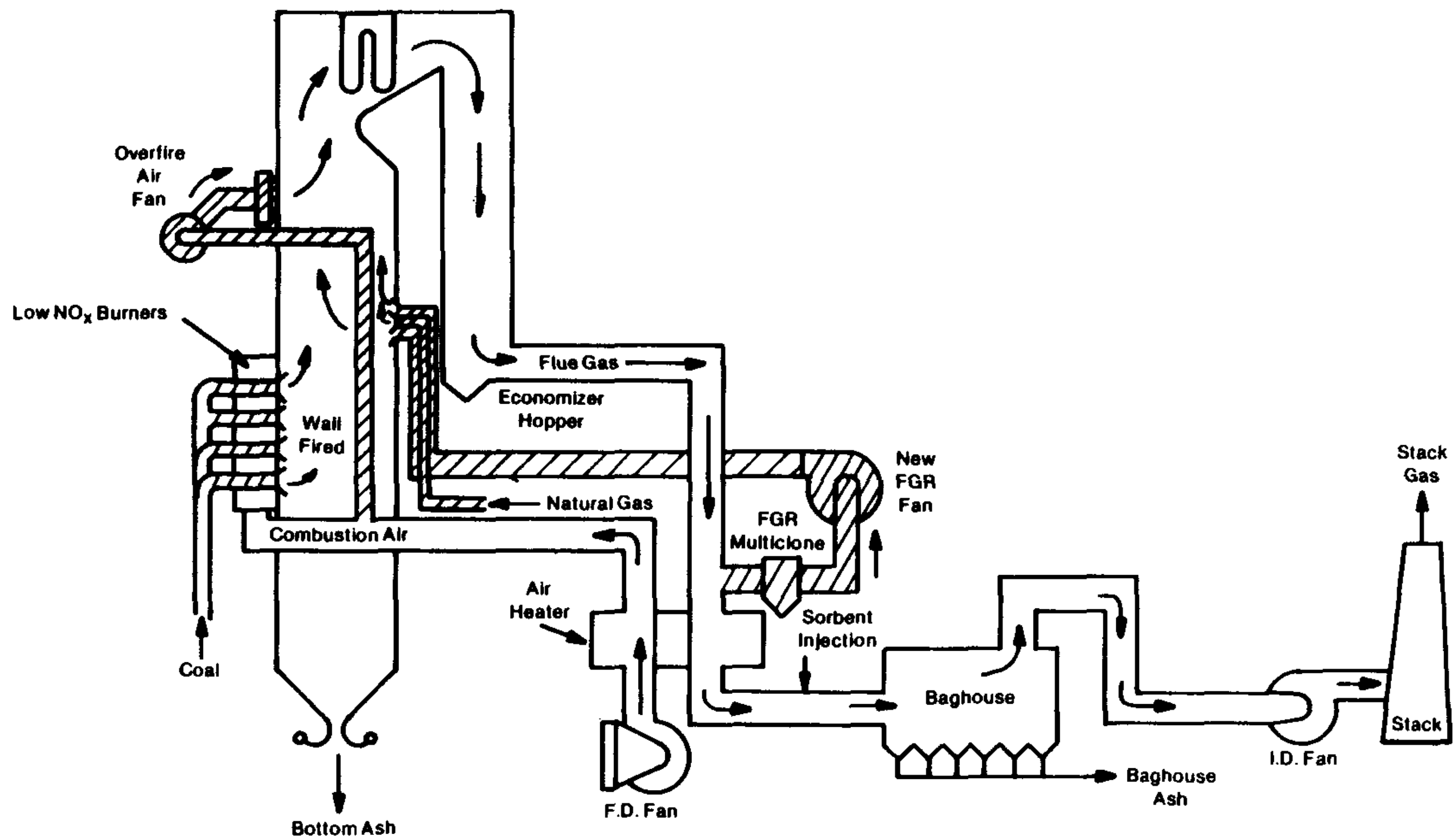

Note: Gas Reburn and Low NO_x Burners Technology Equipment is Crosshatched

FIGURE 3. GAS REBURNING AND LOW-NO_x BURNERS INSTALLED ON A TYPICAL BOILER.

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3.3 General Features of the Project

3.3.1 Evaluation of Developmental Risk

There is some risk associated with this project. However, a substantial data base for gas reburning which indicates that the technology is workable. Furthermore, low-NO_x burners are commercially available from a number of manufacturers. Since the two technologies operate sequentially rather than simultaneously, it can be expected that they will have little or no impact on each other. Specific risks for the Gas Reburning and Low-NO_x Burners project include:

- NO_x control effectiveness
- Changes in steam temperature and boiler thermal performance
- Furnace Slagging
- Furnace puffs (or explosions)

A review of the development program for this technology, indicates that a low risk can be assigned to the development of the Gas Reburning and Low-NO_x Burners technology. A substantial data base exists that supports the expectation that NO_x removal efficiency can be met. EER has developed and field validated a sophisticated, three-dimensional computer model which will enable it to design the Gas Reburning and Low-NO_x Burners system to minimize changes in boiler performance and to keep the boiler operating within its design range.

Slagging, which is the deposition of ash solids in the furnace, is influenced by a number of factors including ash chemistry, ash fusion temperature, conditions (reducing or oxidizing) under which the ash is formed, and furnace wall temperature. The Gas Reburning and Low-NO_x Burners technology will alter several factors that could possibly affect slagging, some in a manner that will decrease and some in a manner that will increase the tendency for slagging. Careful design and inspections during operation, as well as increased frequency of soot blowing, will minimize the chances of adverse operational impacts due to slagging.

Furnace puffs or explosions can occur if unburned fuel accumulates in the furnace under oxidizing conditions and then ignites. This risk is also minimal since the control system will meet NFPA codes and the control system will permit gas to flow into the reburn zone only if it can react immediately.

While the above risks do exist, preventive and/or mitigating measures are being taken to minimize these risks. In addition, pilot-scale work indicates that these risks are minimal.

3.3.1.1 Similarity of Project to Other Demonstration/ Commercial Efforts

There are several on-going projects similar to this demonstration. These either involve reburning or low-NO_x burners with gas reburning.

Babcock and Wilcox (B&W) is currently operating a demonstration facility for their Limestone Injection-Multistage Burner (LIMB) process under Round 1 of the Clean Coal Technology Program. In the LIMB process sorbent injection into the upper furnace is combined with one type of low-NO_x burner, B&W's multistage burner. This demonstration is being carried out at Ohio Edison's Edgewater facility where the LIMB process has been installed on a 105 MWe, wall-fired boiler.

EER is also conducting a project as part of the Round 1 of the CCT program. This project is demonstrating EER's Gas Reburning-Sorbent Injection process on two coal-fired boilers. In this process, gas reburning is carried out in the same way as it is for EER's Gas Reburning and Low-NO_x Burners technology. In the CCT-1 project, sorbent is injected into the furnace to remove SO_2. One boiler is a 71 MWe, tangentially-fired boiler located at the Illinois Power Company's Hennepin Station and the other is a 33 MWe cyclone-fired boiler located at City Water, Light and Power's Lakeside Station.

In the second round of the CCT program, B&W is demonstrating coal reburning on a 100 MWe, cyclone-fired boiler at the Nelson Dewey Station of Wisconsin Power and Light. Coal reburning is very similar in concept to gas reburning except that finely ground coal is used as the reburning fuel. Since no natural gas is used, SO_2, particulate matter, and CO_2 emissions remain unchanged.

In another project selected in the second round of the CCT program, Southern Company Services, Inc., is demonstrating several combustion techniques to reduce NO_x emissions from a 500 MWe boiler at Georgia Power's Plant Yates. These techniques include the use of low-NO_x burners and the use of overfire air. When these techniques are used together, up to 60% reductions in NO_x emissions are possible.

TransAlta, Inc. will test its LNS Burner during another Round 2 project. The LNS burner is a slagging combustor that uses low-NO_x combustion techniques and sorbent (plus additive) injection to control NO_x and SO_2 respectively. This project will be carried out at the Southern Illinois Power Cooperative plant located in Marion, Illinois. The LNS Burner will be retrofit to a 33 MWe boiler.

Another project selected for this third round of the CCT program is B&W's demonstration of a low-NO_x cell burner in a retrofit application. This project will demonstrate a low-NO_x burner specifically designed to economically replace standard cell burners. This project will be conducted at Dayton Power and Light Company's Stuart Station on a 605 MWe cell burner-fired boiler.

In addition to these demonstrations there is also an unknown number of commercial applications of low-NO_x burners. It should be noted that the purpose of this project is not to demonstrate low-NO_x burner technology, but to demonstrate the first-time, full-scale demonstration of low-NO_x burner technology combined with gas reburning.

3.3.1.2 Technical Feasibility

Low-NO_x burners are fully commercial and are available from several manufacturers. The other part of the technology to be demonstrated, gas reburning, has been under development for more than 20 years. Started at the pilot scale in the United States, reburning was first applied to a full-scale boiler by the Japanese in 1981. In the U.S. there is in an extensive amount of bench- and pilot-scale work demonstration gas reburning as well as coal and oil reburning. This work included studies directed toward reburning in utility boilers, package boilers, process heaters, and cement kilns.

In summary, the Gas Reburning and Low-NO_x Burners technology is technically feasible. Since low-NO_x burners are commercial equipment, gas reburning has been tested extensively at both bench and pilot scales, and their combined operation requires minimal integration.

3.3.1.3 Resource Availability

All resources required are readily available to the project. The host boiler is equipped to burn either coal or natural gas and all gas supply lines are in place. There will be a net reduction in coal consumption during the project. Due to decreased coal demand, there will also be a reduction in electrical power demand for the pulverizers and coal handling equipment which results in a net decrease in power consumption during the project. Since the system is mounted on the boiler, no additional land area is required.

The project will consume 4833 standard cubic feet per minute (SCFM) of natural gas. There is currently a surplus delivery capability of 6,500,000 SCFM in the United States. This project will consume only about 0.07% of the excess capacity and the Colorado Interstate Gas Company has agreed to transport the gas for the project.

Operational manpower will remain at current levels during the demonstration project. The additional personnel required for construction of the plant are available locally since, with the exception of some large cities, Adams County is officially a "Labor Surplus Area."

The participant and co-funders have committed monetary resources sufficient to pay their share of the costs. Therefore, all resources required to complete this demonstration are available to the project.

3.3.2 Relationship Between Project Size and Projected Scale of Commercial Plant

The host boiler is a 172 MWe wall-fired utility boiler. Utility boilers range in size from less than 50 MWe to approximately 1300 MWe, with the average size falling between 250 and 300 MWe. Thus, this boiler is somewhat smaller than average but is a representative utility boiler. However, the equipment (burners, gas nozzles, air nozzles) to be demonstrated are standard size and retrofit to larger or smaller boilers will simply use more or fewer burners and nozzles, respectively. The only alterations for the design of different size or type of boilers is in the arrangement of injection nozzles and operating parameters of the equipment to ensure proper mixing of the injected gas and air. This is part of normal design required for each boiler and is not a result of boiler size.

Therefore, the data obtained during this demonstration project will be applicable directly to the general population of pre-NSPS boilers.

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

The proposed demonstration will provide the needed long-term performance data typical of large utility boiler operation. This will provide the users, the utilities, the regulatory agencies and others with a clearer understanding of the benefits of the technology. The economics and commercial feasibility of this process will be established in a full-sized plant under actual working conditions.

3.3.3.1 Applicability of the Data to be Generated

This project will provide a comprehensive data base on the performance of Gas Reburning and Low-NO_x Burners and will validate EER's design methodology. The data generated will be directly applicable to a large number of boilers since the host boiler is a mid-sized, wall-fired boiler and wall-fired boilers are the single most common type of coal-fired utility boiler.

The Gas Reburning and Low-NO_x Burners project will provide data on the operation (thermal and environmental) of the host boiler both before and after installation of Gas Reburning and Low-NO_x Burners. The information will be obtained by conducting tests prior to installation of the Gas Reburning and Low-NO_x Burners to fully characterize boiler operation with respect to thermal and environmental performance. Data that fully characterize the operation (coal consumption and steam rate and properties) and data that characterize the environmental performance (emission rates of NO_x, CO_2, CO, SO_2 and particulate) will be collected.

After installation of Gas Reburning and Low-NO_x Burners, the operation of gas reburning and operation of the low-NO_x burners will be optimized separately. The integrated Gas Reburning and Low-NO_x Burners technology will then be optimized and the longer term tests will begin. These tests will be conducted with and without the sorbent injection system that PSCo intends to install outside the scope of the Gas Reburning and Low-NO_x Burners demonstration project.

EER will collect all data necessary to characterize fully the performance and economics of the Gas Reburning and Low-NO_x Burners technology. Records of capital costs, operating labor requirements and utility consumption will enable both the Participant and the utility industry to accurately estimate costs for future installations. Measurements of NO_x, CO, SO_2, CO_2, and particulate emissions will fully describe the environmental effectiveness of the Gas Reburning and Low-NO_x Burners process. All of this data will be applicable directly to many utility boilers since the host boiler is a typical full-scale utility boiler. The participation of EPRI in this project will assure that all pertinent, non-proprietary data is made available to the utility industry as well as other interested parties.

3.3.3.2 Identification of Features that Increase Potential for Commercialization

This project will demonstrate the commercial readiness and the technical and economic advantages of Gas Reburning and Low-NO_x Burners. If the demonstration is successful, the utility industry and other boiler operators will be provided with a proven technology for the economic control of NO_x.

Specific features of the Gas Reburning and Low-NO_x Burners technology that increase its potential for commercialization are:

- It can be retrofitted readily to existing units
- It can reduce NO_x emissions by more than 70%
- It is suitable for use with a wide range of coals
- It reduces the emission rates of SO_2, CO_2, and particulate
- It has the potential to improve boiler operability
- It is a technology that has had extensive development in the U.S.
- It has the potential to reduce the costs of electricity
- It consists of commercially available components
- It requires minimal space

If successful of this demonstration will establish that the Gas Reburning and Low-NO_x Burners process is a technically and economically viable approach to the control of NO_x that also reduces emissions of SO_2, CO_2, and particulate from both utility and industrial boilers in both retrofit and new installations. Accordingly, this technology has the potential to significantly penetrate the pre-NSPS and new boiler markets to a significant extent.

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

The Gas Reburning and Low-NO_x Burners process is a viable alternative to other NO_x control technologies. NO_x control technologies have been extensively developed. However, except for SCR, they are generally limited to 50-60% reductions in NO_x emissions. The SCR process requires catalytic reactors that consume ammonia as well as investments in new equipment.

The Gas Reburning and Low-NO_x Burners process is applicable to most coal-fired boilers, as well as other combustion systems. In coal-fired boilers, it can reduce NO_x emissions substantially and also reduces SO_2, CO_2 and particulate emissions to some extent. The system consists of low-NO_x burners, piping and injection nozzles for air and natural gas, and instrumentation and controls. With no special vessels and material-handling equipment requirements for the process, space requirements are minor.

This demonstration project is that it will be carried out on a full-scale, commercially-operating boiler, which burns pulverized coal and is a wall-fired unit that is characteristic of many pre-NSPS boilers. Scale-up problems are minimal since larger or smaller units will only require more or fewer nozzles and burners, respectively. During the operational phase of the project, the boiler and Gas Reburning and Low-NO_x Burners system will be operated by the host utilities own personnel.

The host utility is expected to equipped the boiler with a sorbent injection system for SO_2 control. This sorbent injection system is being installed outside the scope of this project, but it will provide the opportunity to demonstrate the operation of the Gas Reburning and Low-NO_x Burners system in conjunction with sorbent injection.

The Participant has estimated the capital cost of the Gas Reburning and Low-NO_x Burners technology to be $28 per kilowatt. This cost is an economically attractive cost for a technology that reduces NO_x by more than 70% while also reducing the emissions of SO_2, CO_2, and particulate. The cost and NO_x reduction capability indicate that the Gas Reburning and Low-NO_x Burners technology has the potential to penetrate the retrofit market significantly when controls are required for pre-NSPS boilers and that it is an attractive option for new boilers.

4.0 ENVIRONMENTAL CONSIDERATIONS

The NEPA compliance procedure, cited in Section 2.2, contains three major elements: a Programmatic Environmental Impact Statement (PEIS); a pre-selection, project-specific environmental review; and a post-selection, site-specific environmental analysis. DOE issued the final PEIS to the public in November 1989 (DOE/EIS-0146). In the PEIS, results derived from the Regional Emissions Database and Evaluation System (REDES) were used to estimate the environmental impacts expected to occur in 2010 if each technology were to reach full commercialization, capturing 100 percent of its applicable market. These impacts were compared to the no-action alternative, which assumed continued use of conventional coal technologies through 2010 with new plants using conventional flue gas desulfurization to meet New Source Performance Standards.

The preselection, project-specific environmental review, focusing on environmental issues pertinent to decision-making, was completed for internal DOE use. The review summarized the strengths and weaknesses of each proposal in comparison with the environmental evaluation criteria in the PON. It included, to the extent possible, a discussion of alternative sites and processes reasonably available to the offeror, practical mitigating measures, and a list of required permits. This analysis was provided for consideration of the Source Selection Official in the selection of proposals.

As the final element of the NEPA strategy, the Participant (EER Corporation) submitted to DOE the environmental information volume specified in the PON. This detailed site- and project-specific information formed the basis for the NEPA documents prepared by DOE. This document, prepared in full compliance with the Council on Environmental Quality regulations for implementation of NEPA (40 CFR 1500-1508) and DOE guidelines for NEPA compliance (52 FR 47662), must be approved before federal funds can be provided for any activity that would limit the choice of reasonable alternatives to the proposed action.

In addition to the NEPA requirements outlined above, the Participant must prepare and submit an Environmental Monitoring Plan (EMP) for the project. The purpose of the EMP is to ensure that sufficient technology, project, and site environmental data are collected to provide health, safety, and environmental information for use in subsequent commercial applications of the technology.

The expected performance characteristics and applicable market for the Gas Reburning and Low-NO_x Burners technology were used to estimate the environmental impacts in 2010 which would result from full commercialization of Low-NO_x Burners. The REDES model was used to compare Gas Reburning and Low-NO_x Burners technology impacts to the no-action alternative.

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

Table 1
Projected Environmental Impacts in 2010,
Gas Reburning and Low-NO_x Burners
(Percent Change in Emissions and Solid Wastes)

Region	Sulfur Dioxides	Nitrogen Oxides	Solid Wastes
National	-10	-13	-2
Northeast	-15	-19	-3
Southeast	-11	-17	-2
Northwest	- 2	- 5	<1
Southwest	- 4	- 6	-3

Source: Programmatic Environmental Impact Statement (DOE/EIS-0146) November, 1989.

As shown in Table 1, significant reductions of NO_x are projected to be achievable nationally due to the capability of the Gas Reburning and Low-NO_x Burners process to remove 75% of NO_x emissions from coal-fired boilers and the wide potential applicability of the process. Negligible changes in effluents are anticipated because the technology produces no solid waste product. The REDES model predicts greatest environmental impacts will be felt in the Northeast because of the large amount of coal-fired capacity there that can be retrofitted with the Gas

Reburning and Low-NO_x Burners process. The least impact occurs in the Northwest because of the minimal use of coal there. The national quadrants used in this study are depicted in Figure 4.

5.0 PROJECT MANAGEMENT

5.1 Overview of Management Organization

The project will be managed by EER's Program Manager. He will be the principal contact with DOE for matters regarding the administration of the Cooperative Agreement. The DOE Contracting Officer is responsible for all contract matters and the DOE Contracting Officer's Technical Representative (COTR) is responsible for technical liaison and monitoring of the project.

An Advisory Committee, consisting of representatives of EER, the DOE, the Public Service Company of Colorado, the Gas Research Institute, the Colorado Interstate Gas Company, and the Electric Power Research Institute, will be formed to coordinate the interests of all parties.

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 the Cooperative Agreement. The DOE Contracting Officer is DOE's authorized representative for all matters related to the Cooperative Agreement.

The DOE Contracting Officer will appoint a Contracting Officer's Technical Representative (COTR) who is the authorized representative for all technical matters and has the authority to issue "Technical 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 items of technical information required to be delivered by the Participant to DOE under the Cooperative Agreement.

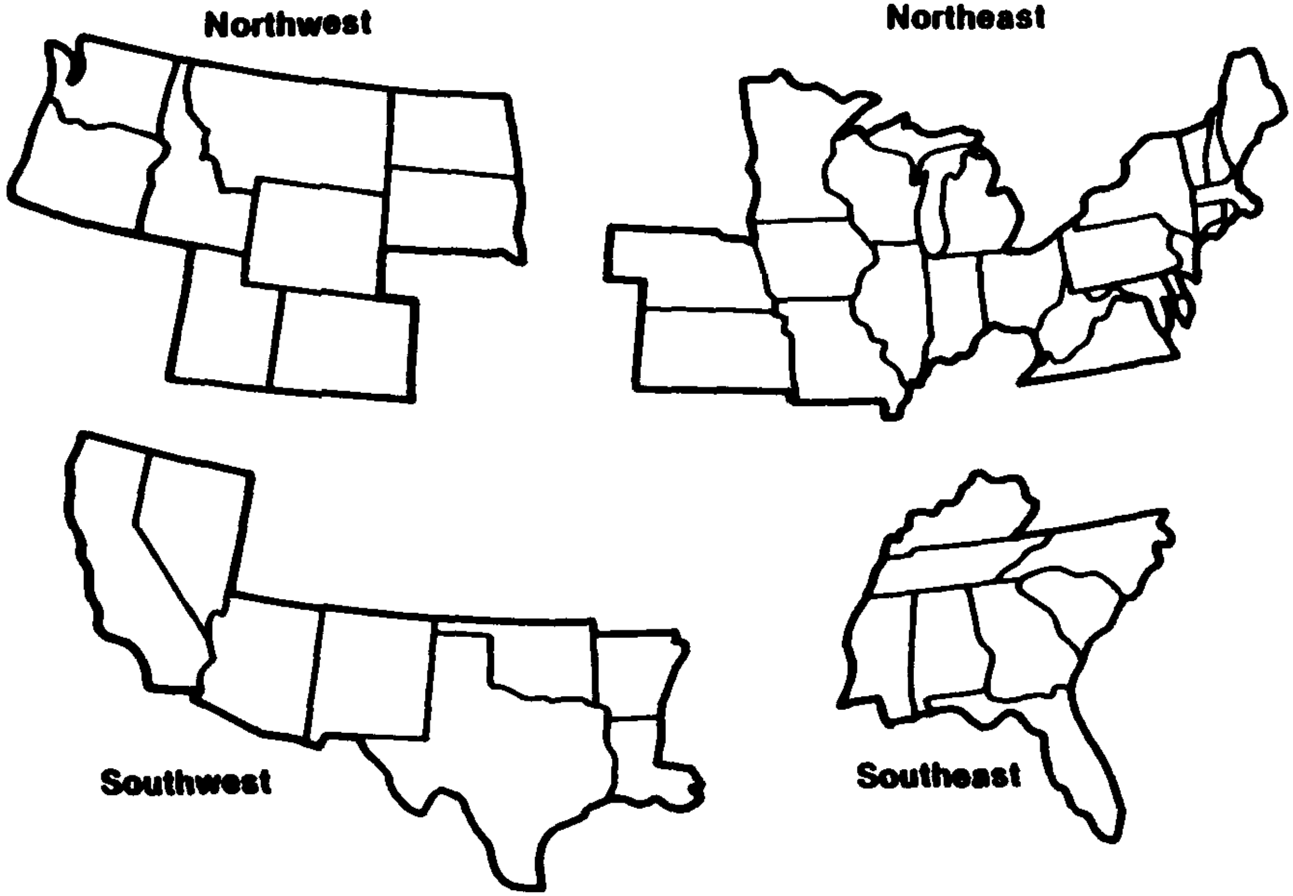

FIGURE 4. QUADRANTS FOR THE CONTIGUOUS UNITED STATES.

NOJ18,677

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's Program Manager will be responsible for all aspects of project performance under the Cooperative Agreement as set forth in the Statement of Work.

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

EER's responsibilities include overall project management, as well as the design, procurement, fabrication, and installation of the gas reburning equipment, boiler performance testing, data analysis, reporting of results, and commercialization of the technology. In addition, EER will conduct the project reviews, serve on the Advisory Committee, and contribute to funding.

The Advisory Committee will review all aspects of the testing program; attend project reviews; review the testing, data analysis, and reporting performed by EER; and, through the members' organizations, contribute to funding.

The Public Service Company of Colorado will be responsible for the selection, purchase, and installation of the low NO_x burners. The Public Service Company of Colorado will also provide the host site; provide site access, load dispatch, and operation and maintenance personnel; provide the test coal and utilities; attend project reviews; serve on the Participants' Committee; participate in the testing activities; review the testing, data analysis, and reporting performed by EER, and contribute to funding. The Participant will coordinate project acivities between the government and all other project participants as shown in Figure 5, Project Organization.

5.3 Summary of Project Implementation and Control Procedures

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

- o Phase I: Design (9 months)
- o Phase II: Construction (14 months)
- o Phase III: Operation (20 months)

As shown in Figure 6, there will be no pauses or overlaps between phases.

Budget periods will be established to coincide with the project phases. Consistent with P.L. 100-446, DOE will obligate funds sufficient to cover its share of the cost of 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 EER and will be provided to DOE.

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

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

The key agreements with respect to patents and data are:

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

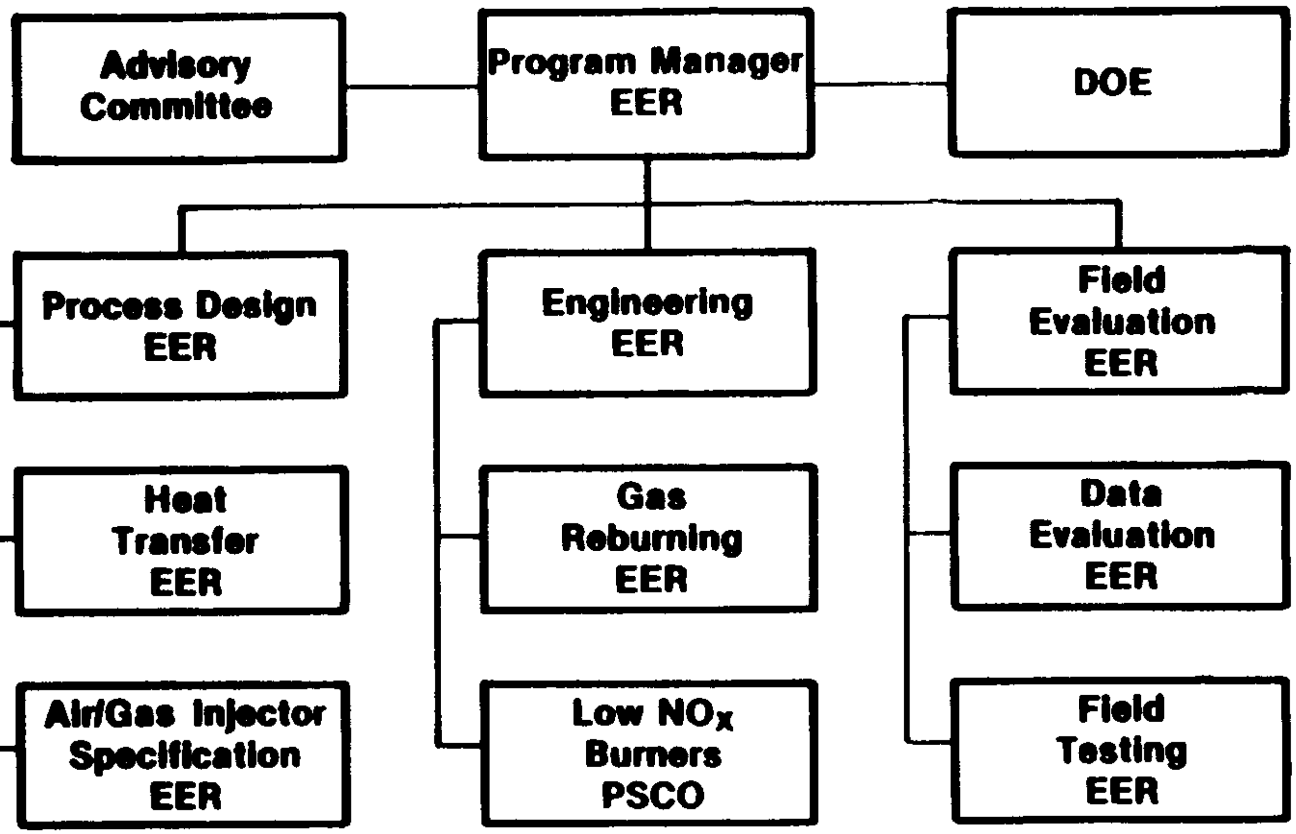

FIGURE 5. GAS REBURNING AND LOW-NO_x BURNERS DEMONSTRATION PROJECT ORGANIZATION.

NO/19,429

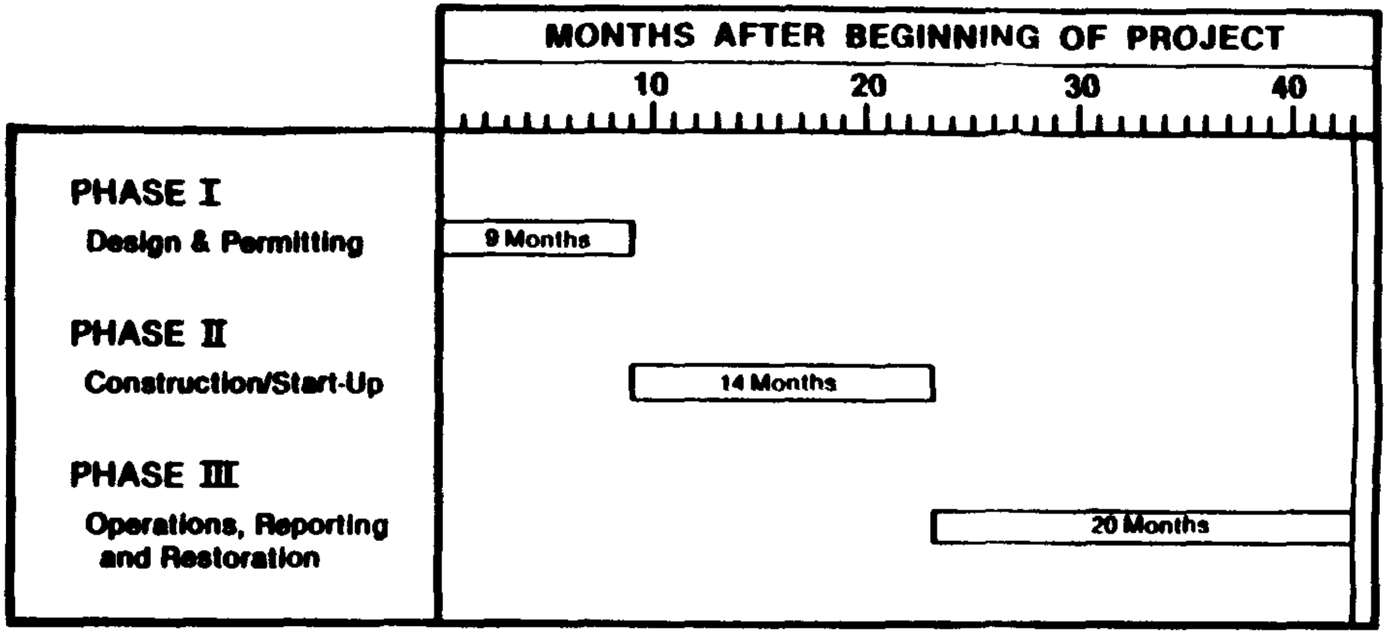

FIGURE 6. OVERALL SCHEDULE FOR GAS REBURNING AND LOW-NO_x BURNERS DEMONSTRATION.

NO/19,428

- Proprietary data, with certain exclusions, may be required to be delivered to the Government. The Government has obtained rights to proprietary data and non-proprietary data sufficient to allow the Government to complete the project if the Participant withdraws.

- EER is a small business and, therefore, it retains title to inventions developed under the project.

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

5.5 Procedures for Commercialization of Technology

EER is a relatively small company engaged in providing combustion and pollution control services. NO_x control from stationary combustion sources has been one of the major activities of the company from its inception. EER has a battery of NO_x control technologies that are applicable not only to coal-fired boilers but also to boilers and incinerators burning municipal, medical, and hazardous waste. Gas reburning plays an integral part in all these applications. It is necessary for the application of the technology to coal-fired boilers that one of the demonstrations is carried out on a wall-fired boiler. Thus, a demonstration of integrated control schemes is an essential part of EER's commercialization strategy.

The technology that is to be demonstrated is the integration of Gas Reburning and Low NO_x Burners. However, EER's commercialization plans are much broader than this and include all uses of reburning for NO_x emission control. Gas Reburning is not a patented process; the hardware associated with its application is standard. The proprietary "know how" is associated with the process design and the ability to predict reburning performance for various applications. The reburning system design is site specific even though the basic process, the use of hydrocarbon to reduce NO_x, is similar for each application.

The proposed demonstration project represents the final step in the development process of the technology. It will verify the operation and overall performance of the technology in a full-scale demonstration. From a business perspective, this is a key step to ensure the rapid commercial success of this technology. The project will demonstrate the ability to meet predicted performance with reliability on a full-scale commercial boiler and will expose any potential problem areas which must be addressed.

EER intends to develop detailed marketing plans, and design guidelines and engineering standards to market the technology. Full commercialization of the process is contingent upon the enactment of new environmental legislation or the revision of existing clean air regulations, which will require modifications of existing utility equipment. Performance of the demonstration unit will be monitored and the results of the demonstration of the performance and benefits of the Gas Reburning and Low-NO_x Burners will be disseminated to the pre-NSPS boiler owners. The dissemination of data will further enhance commercial acceptance of this technology.

6.0 **PROJECT COST AND EVENT SCHEDULING**

6.1 Project Baseline Costs

The total estimated cost for this project is $14,472,117. The Participant's cash contribution and the Government share in the costs of this project are as follows:

	Dollar Share ($)	Percent Share (%)
PRE-AWARD		
Government	111,228	50
Participants	111,228	50
PHASE I		
Government	602,798	50
Participants	602,798	50
PHASE II		
Government	4,423,480	50
Participants	4,423,480	50
PHASE III		
Government	2,098,552	50
Participants	2,098,553	50
TOTAL PROJECT		
Government	7,236,058	50
Participants	7,236,059	50
	$14,472,117	

Cash contributions will be made by:

DOE:	$ 7,236,058
EER:	205,440
EPRI:	200,000
PSCo:	3,000,000
Colorado Interstate Gas Company:	300,000
Gas Research Institute:	3,530,619
	$14,472,117

The contributions of EPRI, PSCo, Colorado Interstate Gas Company, and the Gas Research Institute are part of the Participant's contribution to the project.

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 43 months after award of the Cooperative Agreement.

Phase I, which involves pre-retrofit testing, engineering, planning, burner selection and permitting will start immediately after award and continue for nine months. After the completion of Phase I, the subsequent Phase II, Construction, will start immediately and continue for 14 months. Phase III, Operation and Evaluation, will start immediately after completion of Phase II and continue for 20 months. Actual long-term tests will last for 12 months.

6.3 Repayment Plan

Based upon DOE's recoupment policy as stated in Section 7.4 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 a negotiated Repayment Agreement to be executed at the time of award of the Cooperative Agreement.