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CCT/87 PC 79796

Comprehensive Report To Congress Clean Coal Technology Program

Enhancing the Use of Coals By Gas Reburning and Sorbent Injection

A Project Proposed By
Energy and Environmental Research Corporation

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

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

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

One of the nine projects selected was the Energy and Environmental Research (EER) Corporation proposal to demonstrate the Gas Reburning-Sorbent Injection process (GR-SI) on three different boilers representing three different combustion configurations.

The GR-SI process has been developed to interface with the existing coal combustion systems. The existing burners or combustors are retained when the GR-SI process is installed. Control of nitrogen oxides (NO_x) is achieved by burning a lesser amount of coal in the boiler at a carefully controlled air to fuel ratio. The decreased coal input to the boiler is compensated for by the use of natural gas which is injected downstream of the coal combustion zone. A portion of the NO_x formed by the coal combustion is converted to nitrogen by the reducing conditions caused by the partial combustion of natural gas. Air is then injected downstream of the natural gas injection point to complete this staged combustion process. The net effect of this procedure is to reduce NO_x emissions by approximately 60%.

Sulfur oxides, or SO_x, consist primarily of sulfur dioxide, SO_2. Emission of this pollutant is reduced in the GR-SI process by injecting a sorbent into the upper part of the boiler or into the flue gas duct downstream of the boiler. The sorbent, now contained in the fly ash, is removed from the flue gas in an existing electrostatic precipitator (ESP) or baghouse. The need for flue gas humidification, which enhances both sorbent activity for SO_2 capture and ESP performance, will be determined on a site specific basis. For this project, humidification will be used at two of the three sites and sorbent injection into the flue gas duct will be tested at the cyclone boiler site. While this technology is capable of reducing SO_2 up to 80%, one of the objectives of this study will be to achieve control at approximately the 50% level while burning a blend of coal containing a higher percentage of sulfur The GR-SI process provides an alternative technology to conventional wet Flue Gas Desulfurization (FGD) processes, while requiring less physical space.

This project will use the following as host sites:

- A tangentially fired, 80 megawatt electric (MWe) boiler owned by Illinois Power Company and located near Hennepin, Illinois. A tangentially fired boiler has burners mounted at the corners and directs the burning coal and air toward points just off the center of the boiler.

- A wall fired 117 MWe boiler owned by Central Illinois Light Company (CILCO) located near Bartonville, Illinois. A wall fired boiler has burners which direct the burning air/coal into the furnace in a direction which is perpendicular to the wall in which the burners are mounted.

- A cyclone fired 40 MWe boiler owned by City Water Light and Power Company (CWLP) located in Springfield, Illinois. A cyclone fired boiler has a combustion system which is external to the boiler and the hot combustion products enter the boiler after the combustion is complete.

The locations of these facilities are shown in Figure 1. All three units are commercial boilers that are presently operating. This project is intended to demonstrate the technical and economic viability of GR-SI on three boilers with different firing

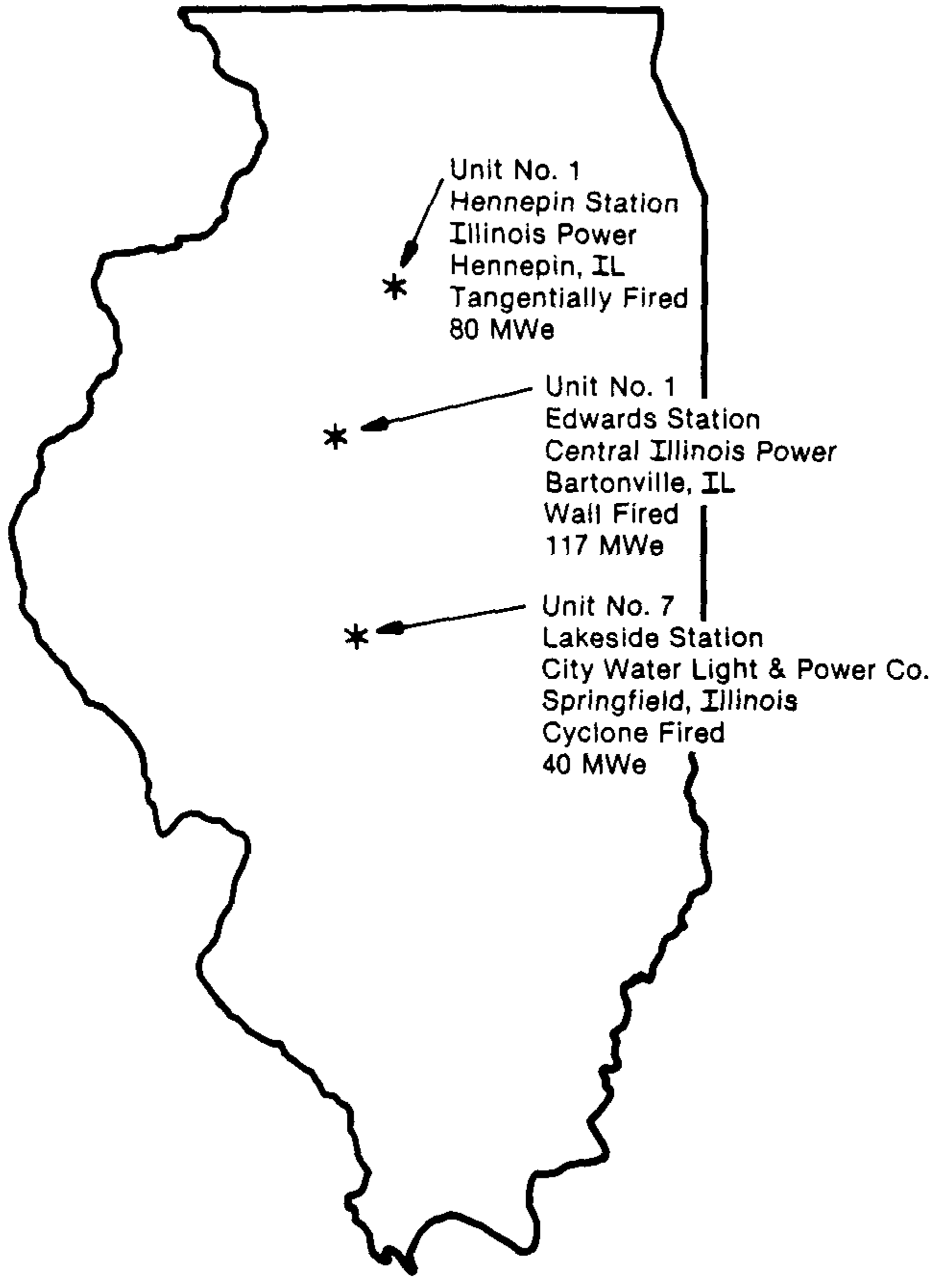

FIGURE 1. EER GAS REBURNING-SORBENT INJECTION PROJECT LOCATIONS OF DEMONSTRATION PLANTS IN ILLINOIS.

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configurations which represent the majority of all U.S. coal-fired, pre-NSPS boilers. Gas reburning and sorbent injection has been fully tested on a pilot scale. This program will demonstrate the performance of the integrated technology on full scale commercial boiler systems, which is expected to have about the same operating cost as wet FGD. However, FGD captures only SO_2 and has no effect on NO_x.

This demonstration project will be performed over a fifty-four month period at three test sites and includes the design and installation of equipment, testing, data analysis, site restoration and reporting of results. This project as originally proposed was scheduled for forty-eight months with phase overlaps or sixty months without phase overlaps. A fifty-four month project period has since been selected to accommodate plant outage periods and eliminate phase overlaps at any one test site.

The total project cost is $29,998,253. The co-funders are DOE ($14,998,253), the Gas Research Institute ($10,000,000) and the State of Illinois ($5,000,000). Testing is scheduled to begin at the CILCO site in early 1989, the Illinois Power site in mid-1989 and at the CWLP site in mid-1990. Overall project completion is scheduled to occur in late 1991.

2.0 INTRODUCTION AND BACKGROUND

The domestic coal resources of the United States play an important role in meeting current and future energy needs. During the past 15 years, considerable effort has been directed to developing improved coal combustion, conversion, and utilization processes to provide efficient and economic energy options. These technology developments permit the attainment of environmental acceptability as well as the efficient utilization of coal resources.

2.1 Requirement for Report to Congress

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

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

Public Law No. 99-190 directed DOE to prepare a full and comprehensive report to Congress on any project to receive an award under the CCT program. This report is in fulfillment of this directive and contains a comprehensive description of the Energy and Environmental Research Corporation GR-SI Demonstration Project.

2.2 Evaluation and Selection Process

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

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

The Technical Evaluation Criteria were divided into two major categories. The first, "Commercialization Factors," addressed the projected commercialization of the proposed technology. This was different from the proposed demonstration project itself and dealt with all of the other steps and factors involved in the commercialization process. The subcriteria in this section allowed for consideration of the projected environmental, health, safety, and socioeconomic impacts (EHSS); the potential marketability and economics of the technology; and the plan to commercialize the proposed technology subsequent to the demonstration project.

The second major category, "Demonstration Project Factors," recognized the fact that the proposed demonstration project represents the critical step between "pre-demonstration" scale of operation and commercial readiness, and dealt with the proposed project itself. Subcriteria in "Demonstration Project Factors" allowed for consideration of technical readiness for scale- up; adequacy and appropriateness of the demonstration project; the EHSS and other site-related aspects; and the reasonableness and adequacy of the technical approach and quality and completeness of the Statement of Work.

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

Consideration was also given to the following program policy factors:

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

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

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

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

In light of the tight schedule imposed by Public Law No. 99-190 and the confidentiality requirements of the competitive PON process, DOE established alternative procedures to ensure that environmental factors were fully evaluated and integrated into the decision-making process to satisfy its NEPA responsibilities. Offerors were required to submit both programmatic and project-specific environmental data and analyses as a discrete part of their proposal.

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

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

After considering the evaluation criteria, the program policy factors, and the NEPA strategy, the proposal submitted by Energy and Environmental Research Corporation, Irvine, California, was one of the proposals selected for award.

3.0 TECHNICAL FEATURES

3.1 Project Description

The EER project will demonstrate that Gas Reburning and Sorbent Injection (GR-SI), a control technology for the acid rain precursors, SO_x and NO_x, is suitable for retrofit applications. It will be the first commercial scale demonstration of this particular technology that is relevant to utility boilers in the United States.

The demonstration will be conducted at three different utility test sites each of which has a boiler with a different firing configuration: tangential, wall and cyclone. The boilers are all relatively small commercial units sized at 80, 117, and 40 MW, respectively. These design configurations represent most of the existing pre-NSPS coal-fired utility boilers in the U.S. and successful demonstrations on these units will make GR-SI attractive for retrofit applications.

The goal of this program is to prove the technical and economical feasibility of the GR-SI technology. If successful, it will achieve up to 60% NO_x and 50% or more SO_2 reduction at about the same cost as wet FGD processes which capture only SO_2. GR-SI will use humidification in two of the three test sites. Humidification will enhance SO_2 pick-up by the sorbent and aid in improving ESP efficiency.

A summary of the three demonstration projects is shown in Table 1.

Table 1. Summary of Demonstrations by EER

GENERAL			
Utility	Illinois Power	CILCO	CWLP
Station, Unit	Hennepin, 1	Edwards, 1	Lakeside, 7
Location: State	Illinois	Illinois	Illinois
Capacity (MWe)	80	117	40
BOILER			
Firing Configuration	Tangential	Front Wall	Cyclone
Steam Capacity (10^3 lb/hr)	585	850	320
Manufacturer	CE	Riley	B&W
PRECIPITATOR			
Location	Cold Side	Cold Side	Cold Side
Size (Sq. Ft.)	223	137	333-1000
Manufacturer	Buell	American Standard	Smidth
FUEL			
Coal Type	Illinois, BIT	Blend of Illinois,BIT Kentucky, BIT	Illinois, BIT
Sulfur (%)	3.8	1.0	3.6
Gas Availability	Yes	4 miles from plant	on site, within 1/2 mile
EMISSIONS CONTROL APPROACH			
NO_x Approach	Gas Reburning	Gas Reburning	Gas Reburning
Control (%)	up to 60	up to 60	up to 60
SO_2 Approach	Upper Furnace Injection	Upper Furnace Injection	Duct Injection
Control (%)	50 minimum	50 minimum	50 minimum
ESP Enhancement	Humidification	Humidification SO_3, Injection	None

3.1.1 Project Summary

Project Title:	Gas Reburning - Sorbent Injection
Proposer:	Energy and Environmental Research Corporation (EER)
Project Locations:	Bartonville, Illinois (Edwards Station) - Peoria County Hennepin, Illinois (Hennepin Station) - Putnam County Springfield, Illinois (Lakeside Station) - Sangamon County
Technology:	Flue Gas Cleanup by gas reburning for NO_x control and sorbent injection for SO_2 control
Application:	Retrofit of coal fired utility and industrial boilers
Types of Coal Used:	Illinois and Kentucky bituminous coals (1% to 3.8% sulfur)
Product:	Environmental Control Technology
Project Size:	80 MWe, 117 MWe, 40 MWe (three sites)
Project Start Date:	July, 1987
Project End Date:	December, 1991

3.1.2 Project Sponsorship and Cost

Project Sponsor:	Energy and Environmental Research Corporation
Proposed Co-Funders:	U.S. Department of Energy, State of Illinois, and the Gas Research Institute (GRI)
Proposed Project Cost:	$29,998,253

Proposed Cost Distribution:	Participant Share (%)	DOE Share (%)
	50	50

3.2 Gas Reburning-Sorbent Injection Process

3.2.1 Overview of Process Development

Sorbent Injection Demonstrations

Sorbent injection has been undergoing development since the mid-1970s under funding from EPA, DOE, EPRI and several commercial firms. Most of the work has focused on identifying the process parameters which optimize sulfur capture. Work has focused on the impacts of the sorbent injection process on the overall performance of a utility boiler and methods for reducing those impacts. This work has included laboratory scale reactivity tests; bench scale process design development tests that focus on time/temperature history and sorbent reactivity effects; large pilot scale tests that focus on impacts of firing system design and furnace mixing and combustion model development programs. A number of field evaluations have been completed and additional efforts are in progress. EER has participated either directly or indirectly in most of this development work.

In the last 10 years, a number of test programs for sorbent injection have been carried out on boilers ranging from 15 to 600 MW and using a variety of coals. Most of these programs were carried out in Europe and Canada and they all focused on optimizing sorbent injection alone without regard to other competing technologies. None of the programs involve gas firing or have potential for NO_x

control except by installation of low NO_x burners. This project offers the added feature of NO_x control through the use of the natural gas reburning process.

Reburning Demonstrations

Compared to sorbent injection, considerably less development and demonstration effort has been expended on gas reburning for NO_x control. The original work was done in the United States in the early 1970s with subsequent work done in Japan, including commercial scale tests where NO_x emission reductions of greater than 50 percent were achieved. During these tests coal and oil were fired simultaneously (mostly oil) and the reburning fuel was oil. Hence, the results are not representative of recent U.S. utility boiler practice.

Since 1981, EER has continued the development of reburning in the United States under support from EPA and GRI. This work has focused on defining the key process variables and included tests up to large pilot scale: 10 million Btu/hr which corresponds to about 1 MWe. These tests have demonstrated that gas is the optimum fuel for reburning. The EPA program has focused on gas reburning only; the work for GRI includes integration of gas reburning with sorbent injection. GRI and EPA have agreed to co-fund a reburning demonstration. This EPA/GRI demonstration of reburning will provide considerable data on the design and operation of full scale gas reburning systems. However, this reburning demonstration will be technology specific in that it will not include sorbent injection for SO_2 control.

3.2.2 Process Description

Gas Reburning-Sorbent Injection is a two part process in which combustion staging is used to control NO_x while sorbent injection is used to control SO_2.

Gas Reburning

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

Reducing any of these parameters will reduce NO_x formation. Unfortunately lower flame temperature, short residence time and oxygen deprivation, sufficient to greatly reduce NO_x, result in other problems such as high emissions of carbon monoxide, soot, and partially oxidized organic compounds, some of which may produce adverse health effects. In addition, these NO_x avoidance practices result in lower boiler efficiency and thereby waste a portion of the energy contained in the fuel. Therefore, the problem has been to reduce NO_x formation and emissions without these undesirable side effects. Special combustion techniques are required and one that has been developed is gas reburning (GR), part of the GR-SI process. This process is applicable to all types of combustors currently used for firing pulverized coal. In gas reburning, NO_x is reduced to molecular nitrogen (N_2).

For NO_x control, the combustion process is divided into three stages. These are the primary, or main heat release zone, the reburning zone and the burnout zone. The primary fuel is coal and the reburning fuel is natural gas. Others have used oil or coal as the reburning fuel in earlier experiments, however NO_x levels were not decreased to the extent achieved with natural gas.

Figure 2 depicts a boiler schematic which indicates the key areas pertaining to gas reburning and identifies the points A-E at which sorbent may be injected. The primary zone is the main heat release zone and accounts for approximately 80 to 85 percent of the total heat release. In this zone, coal is burned with sufficient air for its combustion. Very little excess air is used in this zone. Sufficient residence time is provided to complete the combustion reactions before the combustion products, including some NO_x, enter the next zone.

In the next zone, the reburning zone, natural gas is injected to produce an oxygen deficient condition. This converts some of the NO_x which was formed in the primary zone to nitrogen. The use of

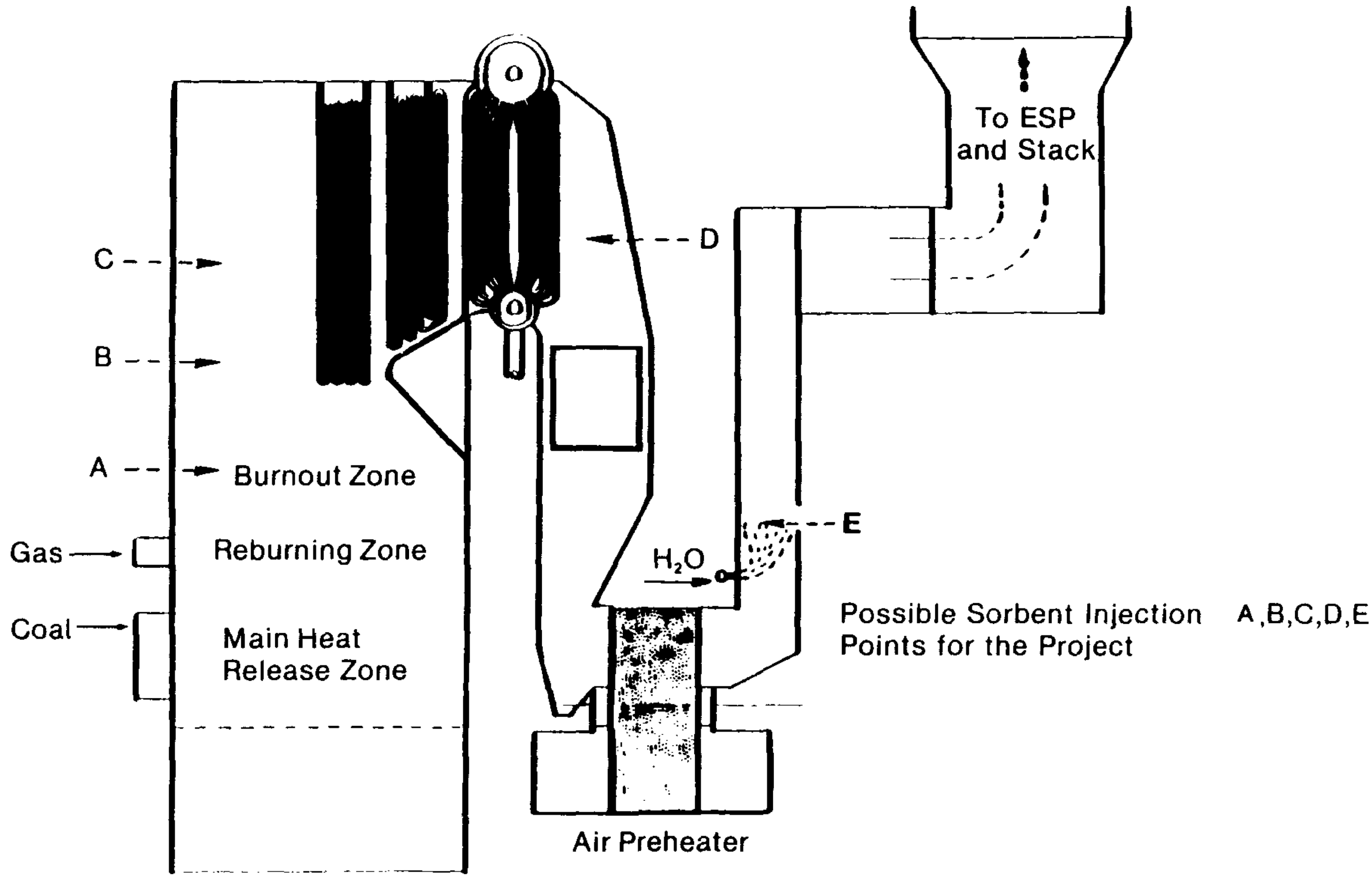

FIGURE 2. EER GAS REBURN-SORBENT INJECTION PROJECT GENERIC FLOW DIAGRAM.

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natural gas instead of a coal or oil as the reburning fuel avoids introduction of additional fuel bound nitrogen into the process. Some ammonia (NH_3) and hydrogen cyanide (HCN) are also formed in this zone as well as fragments of the fuel molecules. This mixture then enters the next zone.

In the burnout zone, additional air is injected to burn the fuel fragments and this produces water vapor and carbon dioxide. In this zone the ammonia (NH_3) and hydrogen cyanide (HCN) are also converted to molecular nitrogen and to some residual NO.

The net effect of this combustion technique is up to a 60% reduction in NO_x formation without increases in the emission of other undesirable chemical compounds or a waste of fuel. In addition, since gas contains no sulfur, there is a reduction in SO_2 emissions commensurate with the fraction of gas fired.

Sorbent Injection

Sulfur oxides, predominantly SO_2, are formed from the oxidation of sulfur compounds in the coal and its ash. The SO_2, if not controlled, is discharged to the atmosphere with the balance of the flue gas.

One method of removing the SO_2 is by dry sorbent injection as used in this and several other processes that are in approximately the same state of development as GR-SI. Locations A-E, where the sorbent can be injected, are shown in Figure 2.

In the GR-SI process, sorbent (lime) is unloaded from trucks and conveyed to a storage silo and then transported to a feed silo. From the feed silo, the sorbent is conveyed to a distribution or injection system to the point that it is injected into the flue gas. It can be injected with the burnout air, in the upper part of the boiler combustion zone (A, B, C) or in the duct downstream of the boiler (D, E). After absorbing the SO_2, the spent sorbent is removed in an ESP. If an existing ESP is considered to be inadequate for the job, it may have to be upgraded or humidification may be required to enhance its performance. Humidification, which has several benefits, is accomplished by the injection of a water spray into the duct between the boiler and the ESP. Moisture additions and humidification will be carefully controlled in these operations to meet the requirements of particulate control improvements and SO_2 capture.

For all three test sites, the nominal test design basis is for 15 percent of the heat input to be by gas firing and 85 percent by coal firing. The sorbent utilization rate is projected to be 25 percent. Due to the lower coal consumption, the quantity of bottom ash is reduced and due to sorbent injection, the amount of precipitator solid waste is increased. The net impact is an increase in solid waste.

3.2.3 Application of Processes in Proposed Project

The three specific sites involved in this project and a description of the activities planned for each site are as follows.

Hennepin Station Unit No. 1

This unit is a tangentially fired boiler which has burners mounted at the corners. The burners at each corner direct the burning coal and air toward points which are just off the center of the boiler in such a manner as to impart a swirling motion to the gas and coal particles. The installation of the GR-SI system on the boiler requires that the furnace penetrations and windbox modifications be redesigned to accommodate the tangential firing system. Figure 3 is an overall process flow diagram for a typical GR-SI installation.

The specific objectives of the demonstration at Hennepin Station are to: (1) reduce NO_x emissions by 60 percent, (2) reduce SO_2 emissions by 50 percent or more and (3) maintain or improve particulate emissions and general operability. The preliminary approach to applying GR-SI at the Hennepin station is the use of gas reburning in the upper furnace integrated with upper furnace sorbent injection and humidification to improve SO_2 removal and ESP performance.

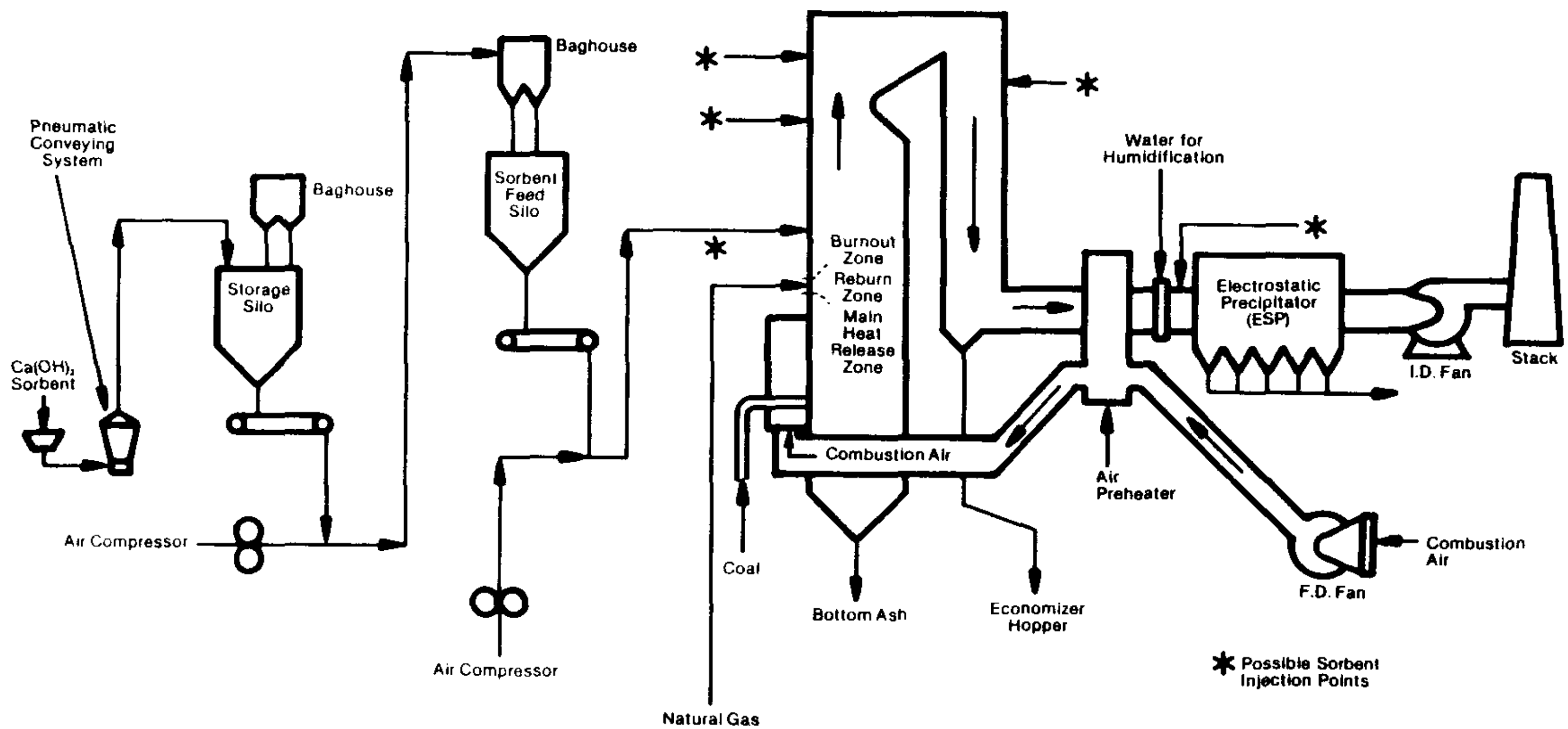

FIGURE 3. GENERAL PROCESS FLOW DIAGRAM FOR GR-SI.

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Edwards Station Unit No. 1

The Edwards unit is front wall fired. In a wall fired unit the burners direct the burning air/coal into the furnace with their direction being perpendicular to the wall in which the burners are mounted. The front wall is opposite the exit ductwork. The specific objectives of the demonstration at Edwards Station are to: (1) reduce NO_x emissions by 60 percent, (2) maintain SO_2 emission levels equivalent to those of a 1% sulfur coal while firing a coal blend with a higher sulfur level, and (3) maintain particulate emissions at current levels even though a solid sorbent is being used.

The planned approach used to apply the GR-SI process to this unit is to install the gas reburning system in the upper furnace, integrate the upper furnace sorbent injection of hydrated lime with the reburning system and improve electrostatic precipitator performance via humidification.

GR-SI will allow a significant increase in the fraction of high sulfur coal which can be fired. The fuel distribution on a heat input percent basis is as follows:

	Heat Input %	
Fuel	Present, Baseline	GR-SI
High Sulfur Coal	19	43
Low Sulfur Coal	81	42
Gas	0	15
TOTAL	100	100

Natural gas is presently not available at Edwards Station. A new line will be run approximately four miles to the station to supply this fuel. The gas will be injected into the upper furnace through multiple nozzles. A humidification system will be added downstream of the air heater. The water will be injected through an array of nozzles to improve precipitator performance. Bench scale tests suggest that this process may increase sulfur capture considerably thus reducing the sorbent requirement.

City Water Light & Power (CWLP) Lakeside Unit No. 7

This boiler uses a cyclone combustor system. In this system the combustor is external to the boiler and the hot combustion products enter the boiler after combustion is complete. The cyclone combustor is a cylinder into which coal and a small amount of air are injected from the end while the bulk of the combustion air enters tangentially at a very high velocity. This imparts an intense swirling or cyclonic motion to the coal and gases.

The specific objectives of the demonstration at Lakeside Station are the same as at Hennepin Station: (1) reduce NO_x emissions by 60 percent, (2) reduce SO_2 emissions by 50 percent or more, and (3) maintain or improve particulate emissions and general operability. However, the cyclone firing configuration at this plant requires an alternate sorbent injection approach. Convective pass erosion and corrosion are serious problems for cyclone units that may be worsened by sorbent injection into the upper furnace. Consequently, the planned approach involves sorbent injection downstream of the air heater but upstream of the precipitator. Gas reburning reduces the particulate loading and should result in a commensurate reduction of erosion and corrosion. The ESP at this station is large and no enhancements are required to maintain the existing particulate emission rates. For SO_2 control, various approaches, including the use of sorbent slurry systems and alternative sorbents, will be assessed.

Due to the design of the air supply system to the cyclone combustors, it will be most convenient to run a lateral duct from the preheated combustion air duct around the side of the unit to the space above the cyclone combustors. This plant will require the addition of a short gas supply line. Gas and overfire air injection into the upper furnace on the front wall are planned. Alternate locations on the rear wall and closer to the cyclone exit will also be considered.

3.3 General Features of the Project

3.3.1 Evaluation of Developmental Risk

As with any new technology, there is some risk. However as described earlier, much prior work has been done in the area of sorbent injection. A lesser, but still significant amount of work has also been done with the reburning technology, especially with oil as the reburning fuel. It is through the data and experience obtained from this earlier work that this project retains a high probability of success.

After reviewing the results of the developmental work at the 0.1 MW and 1.0 MW levels for the GR-SI process and information supplied by EER, a low to moderate risk has been assigned to this process. It will result in increased solids loading, affecting both the ESP and ash handling equipment. Upper furnace sorbent injection may increase the potential for slagging, fouling and erosion of boiler tubes. Duct injection of sorbent may lead to a build up of solids in the duct work and humidification may result in condensation in the ESP and/or stack. These are considered to be low or moderate risks because there will be instrumentation and controls that will identify and mitigate potential problems. Further, the regular plant operating staff will be in full charge of the boilers that will be involved in this test program.

3.3.1.1 Similarity of the Project to Other Demonstration/ Commercial Efforts

Gas reburning-sorbent injection is a combination of processes aimed at reducing emissions of undesirable acid rain precursor chemicals from combustors. To capture SO_2, a calcium based sorbent is injected into the boiler above the reburning zone or between the boiler and the ESP. This process is similar to the

Babcock & Wilcox LIMB process, where the sorbent is injected into the upper part of the combustion zone. Both processes are proceeding to near term commercial scale demonstrations. If the sorbent injection takes place downstream of the boiler then the GR-SI process is similar to two other low temperature, dry sorbent injection processes, Coolside and Hydrate Addition at Low Temperature (HALT).

The distinguishing characteristics of the Coolside process are the injection of a dry sorbent (hydrated lime) downstream of the air preheater followed by humidification for SO_2 capture. Humidification decreases flue gas volume by lowering temperature and thereby improves ESP efficiency. The Coolside process has been demonstrated at the 0.1 and 1.0 MW levels.

In the Dravo HALT process, the flue gas stream is cooled through humidification, then the hydrated lime sorbent is injected to capture SO_2. The HALT process is now undergoing demonstration at the 5 MW level.

The gas reburning aspect of the GR-SI process is a unique method of converting NO_x mainly to nitrogen. Low NO_x burner control technologies use burners that permit staged combustion without the later injection of fuel to destroy a portion of the NO_x which was formed in the burner. Work done on reburning to this point has been accomplished largely with oil as both a primary and reburning fuel.

3.3.1.2 Technical Feasibility

The concept of reburning has been recognized for over a decade. Early research demonstrated that significant flue gas NO_x reductions can be achieved based on the principle that carbon-hydrogen (CH) fragments of larger organic fuel molecules can react with NO. When this happens, NO_x is mainly converted to molecular nitrogen (N_2), and the CH fragments are oxidized to CO_2 and H_2O. This concept has recently been applied at a foreign commercial scale but it has not been demonstrated commercially in the United States. EER has conducted extensive bench and pilot scale testing to characterize the fundamental processes and develop a scale-up methodology appropriate for use in U.S. boilers burning domestic fuels.

The results of EER bench and pilot scale research programs which have been recently completed under funding from EPA and GRI are now available. These studies were undertaken to quantify the impact of fuel type and process parameters on reburning effectiveness and to provide scale-up information required for commercial applications of reburning under industrial conditions. Initial parametric screening studies were conducted in a 25 kW refractory lined tunnel furnace which allowed workers to control the time temperature profile. Premixed and diffusion burners were used to study gaseous fuels, petroleum liquids, pulverized coals, and coal water slurries as primary and reburning fuels. In subsequent tests, a 3.0 MW, downfired furnace was used to develop scaling criteria. The work at both scales focused on the importance and fate of reacting nitrogen species within the reburning zone. The experimental conditions were designed to directly simulate a practical boiler.

There is, therefore, a sound basis of data existing for the concept of reburning as a way to reduce NO_x emissions. This technology has been practiced on the commercial scale in Japan in installations capable of coal firing and in pilot scale in the United States. This background experience provides the basis for believing that a high probability of success exists for this technology achieving a 60% reduction in NO_x emissions.

The sorbent injection technology is based on an even greater amount of data and experience to enhance its chances for success. Demonstrations at the commercial scale are scheduled for similar technologies developed by the EPA, Babcock & Wilcox, and Conoco. A smaller scale (5 MW) demonstration on a similar technology is also planned by Dravo. These demonstrations are all the culmination of extensive laboratory and pilot work which enabled these companies to establish the proper conditions for successful operation. In addition, a significant number of foreign commercial applications of the sorbent injection technology have been carried out.

EER has participated in a number of field evaluations of sorbent injection and is scheduled to carry out another project for process optimization of a sorbent injection system.The experience of EER plus the wide spread interest and work on sorbent injection indicate that sorbent injection is technically viable and that this project will achieve its goal of a 50% or greater reduction in SO_2 emissions.

3.3.1.3 Resource Availability

Adequate resources are available for this program. EER will use present members of its staff to fill key positions. Additional personnel will be hired as needed.

This project will not increase the host boilers' requirements for coal. The project will use approximately 45,000 tons of sorbent which is a very minor amount compared to the total U.S. annual production of 700 million tons of limestone. The requirement for natural gas can be met from current supplies using available surpluses in the natural gas market. The availability of these major raw materials is expected to be adequate not only for the demonstration program but also to meet the demands when this technology has been commercialized.

This program involves pre-NSPS boiler installations at three separate sites, each being a fully operational electrical power generating station, with appropriate facilities and scheduling flexibility to accommodate this project. These three sites, selected for the proposed demonstration of GR-SI, will provide an excellent opportunity to evaluate the technology in essentially all of the situations that will likely be encountered in the commercialization of the technology. All appropriate resources can be made available to the site such as coal, natural gas, and sorbent. The installation, construction and restoration of GR-SI hardware will be handled by personnel available at EER and at the utilities themselves. Adequate funds have been committed by the co-funders to cover their share of the estimated project costs.

These sites are likely to be required to lower their emissions if acid rain legislation is enacted. Two of the sites are burning medium sulfur coals for which application of GR-SI will lower SO_x and NO_x emissions. The Edwards unit is burning a lower sulfur blend in order to meet compliance in a non-attainment region. At this site the use of GR-SI will be evaluated as a means whereby the sulfur content of the blend can be increased while still maintaining SO_x emissions at compliance levels and at the same time lowering NO_x emissions. The furnaces are large enough to provide a full scale test of the technology. Finally, the suitability of the process will be demonstrated for three distinct systems, tangential, wall fired, and cyclone fired units, which will prove the technology for all commonly used firing systems.

3.3.2 Relationship Between Project Size and Projected Scale of Commercial Facility

As mentioned previously, all three test boilers are operating, small commercial units ranging from 40 to 117 MWe. However, they use multiple burners and the test will require the use of multiple gas injection nozzles, air injection ports and sorbent injection nozzles. Therefore scale up to larger utility boilers only involves increasing the number of injection points and distribution points representing only the most minimal risk. The net effect is that this project will prove the applicability of the GR-SI technology for retrofit on many pre-NSPS boilers without further demonstration.

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

The combination of GR-SI has the potential to enhance the use of medium and high sulfur coals under conditions requiring compliance with environmental control. The commercialization of the GR-SI technology requires a comprehensive data base demonstrating emission control, performance enhancement and cost effectiveness applied to meet specific industry needs and means whereby the technology can be transferred directly to industry.

3.3.3.1 Applicability of the Data to be Generated

In order to produce accurate and reliable performance data, the demonstrations will be fully instrumented and use automated data collection techniques. A new computerized data acquisition system will interface with the existing plant instrumentation to gather data to monitor the following:

- o Furnace absorption/cleanliness
- o Convective surface cleanliness
- o Slag deposition rates
- o Sootblower effectiveness
- o Gas temperatures
- o Effectiveness of SO_x and NO_x reduction
- o ESP performance
- o Combustion efficiency
- o Boiler performance
- o Feed rates of coal, sorbent and gas
- o Humidification
- o Gas velocities
- o Heat rate deviations

The demonstrations will produce data to fully characterize both the boilers and the GR-SI process and for engineering of the commercial applications. The process performance data obtained can be directly applied to a large population of existing U.S. utility stations using high and medium sulfur coal. In addition, the cyclic nature of the operation of these host site units will give a good characterization of the GR-SI process under varying load conditions.

Analyses of the flue gas and coal will also be made. These analytical results will provide the basis for evaluating SO_2 and NO_x reductions, ESP efficiency and process controllability. Further, gas and solids analyses will provide data for material balance calculations on sulfur and sorbent species important for data reliability evaluation.

Based on the SO_2 removal and operability results, process economics will be determined for the GR-SI process. Since the proposed demonstration is at a commercial scale, the resulting technical and economic analyses will be directly applicable to other utility situations.

3.3.3.2 Identification of Features that Increase Potential for Commercialization

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

To achieve these environmental goals the reduction of NO_x and SO_2 emissions from fossil fuel-fired boilers has been a major objective of the DOE, the EPA and major boiler/burner manufacturers for many years. This is demonstrated by a number of concurrent efforts that have been and are being conducted to develop lower-NO_x burners and improved combustion techniques.

Once commercially proven, the GR-SI process will provide an economical means for simultaneous control of SO_2 and NO_x. The minimal space requirement and competitive cost of this process are also important features which make this technology especially applicable to the retrofit of existing boilers.

This process consists of proven, commercially available equipment such as nozzles, pumps, blowers and pneumatic transport systems. Some boiler modifications are required for installation of the reburn gas and burnout air nozzles. If sorbent is injected into the furnace it can be injected with the burnout air. Since the sorbent can also be injected into the ductwork downstream of the boiler, boiler performance need not be impaired. Due to the replacement of 10-20% of the coal with natural gas, boiler performance may be enhanced by the smaller quantities of ash passing through the tube banks when duct injection is used. Since the price of natural gas has recently been falling and is approaching the cost of coal in some areas, fuel cost differences are expected to be minor.

In summary commercialization of this technology will be aided by:

- o Simultaneously reducing NO_x emissions by up to 60% and SO_2 emissions by 50% or more
- o Lowering capital cost
- o Requiring minimal space
- o Relatively easy retrofit
- o Little or no derating of the boiler
- o Flexibility
- o Using commercially available components
- o Having been proven on three different popular boiler types.

Thus, success of this program will establish that GR-SI is an effective, economical approach to controlling the two major pollutants associated with acid rain. As such, the technology is expected to significantly penetrate the large pre-NSPS boiler market.

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

The GR-SI process, assuming successful demonstration of the technology, will be one of the most developed of the sorbent injection processes. It will also offer a viable alternative to complete burner replacement for NO_x control.

One attractive feature of this project is that the technology will be demonstrated on three different size and types of boilers, all of which operate under varying loads. This will provide a good demonstration of the process under different conditions and on different coals. It will also demonstrate sorbent injection into the boiler and in the downstream duct, thus offering a high degree of flexibility to potential customers.

Factors which contribute to minimizing the cost of this project include on-site availability of natural gas at two of the sites, adequate ESP capacity, and availability of sorbent and waste disposal areas.

The GR-SI process is intended to provide technology options for utilities which desire to reduce SO_2 emissions from existing boiler units. Existing SO_2 reduction technology includes wet flue gas desulfurization and lime spray dryer processes. The need for new technology development arises from the fact that the existing processes are high in capital cost, which makes their application particularly expensive under certain scenarios which include problems presented by regulations. Short remaining boiler life and lack of available space for retrofit installation, can increase the cost of compliance using the existing technology options. By contrast, GR-SI technology is characterized by low capital cost and minor installation space requirements.

An economic comparison of wet limestone flue gas desulfurization and GR-SI technology was made at the 200 MWe, 300 MWe and 400 MWe level. The capital cost for GR-SI is estimated at being less than half that for wet flue gas desulfurization.

The electric utility generating companies are expected to implement technology that does not require large capital outlays, extensive plant modifications or extreme operational difficulties. GR-SI can be incorporated into existing plants without displacing other equipment or requiring significant new real estate. Operation of the plant will not be significantly affected. The operating costs for the GR-SI process are estimated to be about the same as FGD, which captures only SO_x, not both NO_x and SO_x as does GR-SI.

The drive toward lower capital cost is evidenced by the rapid acceptance of spray dryer technology in the U.S. and of boiler sorbent injection in Europe. The potential for a higher level of SO_2 control, relative to other low cost technologies makes this approach particularly desirable.

4.0 ENVIRONMENTAL CONSIDERATIONS

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

5.0 PROJECT MANAGEMENT

5.1 Overview of Management Organization

The project will be managed by EER's Project Director. He will be the principal contact with DOE for matters regarding the administration of the agreement. In his absence, the EER Project Manager will have this authority. 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.

A Participants Committee will be formed and will be composed of personnel from EER, DOE, GRI and the State of Illinois Department of Energy and Natural Resources (ENR). This Committee will meet as needed to review the project, assess plans and provide advice on correcting any deficiencies.

A Senior Review Committee (SRC) will be formed and will consist of senior representatives of the same organizations whose personnel make up the Participants Committee. The Committee serves to provide a more encompassing view of the project, and hence, it is targeted to influence decision-making activities through supplying pertinent information that may not have been otherwise available.

In addition to DOE, the project co-funders are the State of Illinois and the Gas Research Institute.

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

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

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

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

- 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 (EER) 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 Director is the authorized representative for the technical and administrative performance of all work to be performed under this Cooperative Agreement. He will be the single authorized point of contact for all matters between the Participant and DOE. In his absence the Participant's Project

Manager will be authorized to represent the Participant in contacts with DOE. The Participant will interrelate between the government and all other project sponsors as shown in Figure 4, Project Management Structure.

Industry Panel

EER will establish an Industry Panel to transfer the project results to industry, to encourage commercialization and to receive comments from the panel members. This panel will be formed in Phase 1 and will meet periodically (at least annually) throughout the project. The panel will include representatives from organizations expected to be directly involved in the application or use of gas reburning-sorbent injection technology, possibly including: DOE, GRI, EPRI, EPA, electric utilities equipment vendors, fuel suppliers, sorbent suppliers, utilities and architect/engineers. The Industry Panel will review the status of the project and provide guidance to ensure that, to the maximum extent possible, the project will meet industry needs.

Participants Committee

The Participants Committee will consist of representatives from DOE, GRI, ENR, and EER. This Committee will meet as needed, but at least once each quarter, to review the project, assess future

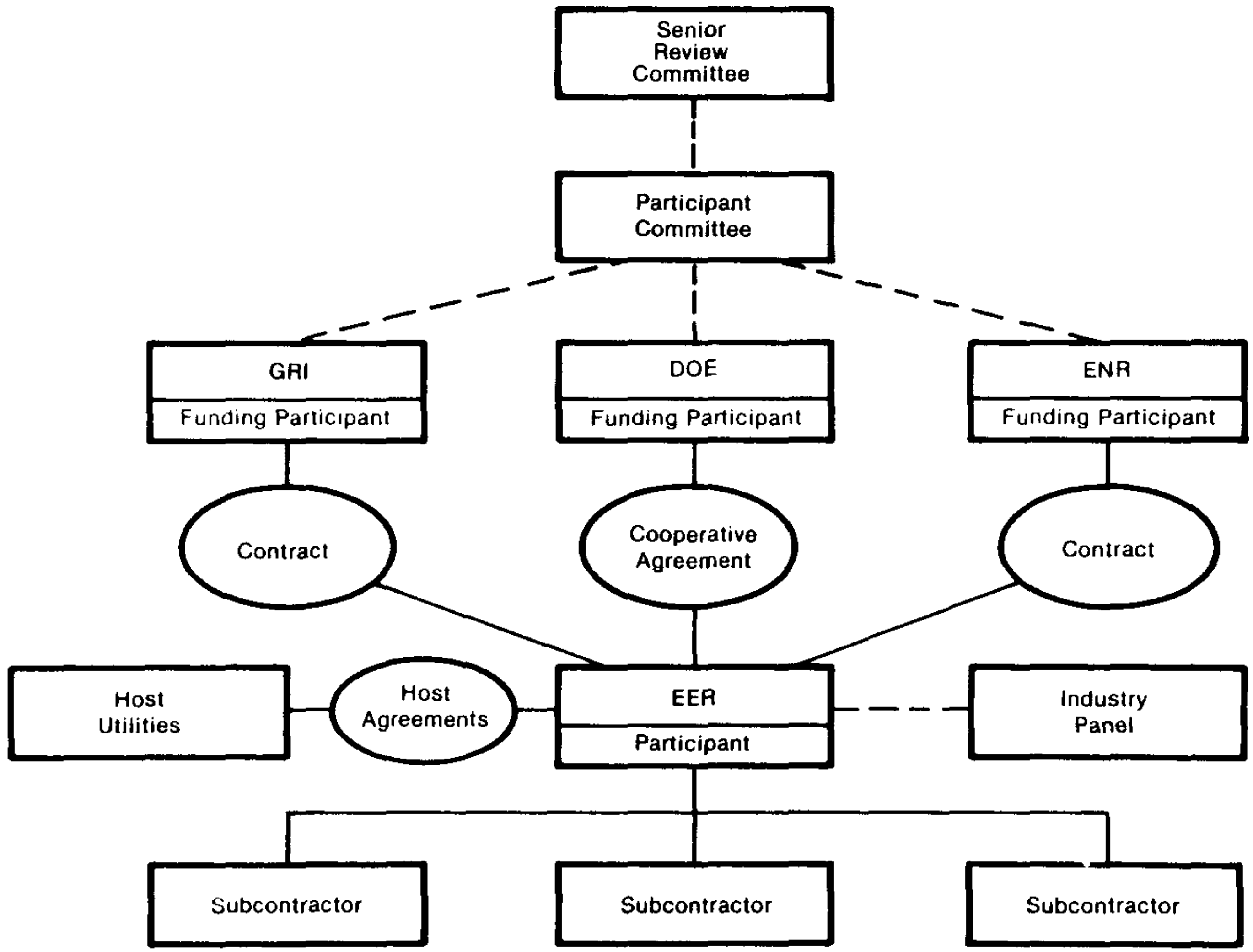

FIGURE 4. EER PROJECT MANAGEMENT STRUCTURE FOR GAS REBURNING-SORBENT INJECTION.

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plans, recommend shifts in emphasis and provide advice on correcting any deficiencies. The Participants Committee is intended to be a working group of personnel directly involved in the project and will ensure that the objectives of each participating organization will be met. The Participants Committee will not direct EER.

Senior Review Committee

The project review organization will be the Senior Review Committee (SRC) that will be responsible for the administrative overview of the project.

The SRC will be composed of executive level individuals with members representing DOE, the Participant, and the co-funding participants. Each Participant may change its representative(s) on the Committee by designating another Senior Manager. The SRC will meet at least annually, or at the request of any member of the Participant's Committee. The Committee will function as advisory in nature and has no specific management authority.

5.3 Summary of Project Implementation and Control Procedures

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

- o Phase I: Design and Permitting
- o Phase II: Construction and Start-Up
- o Phase III: Operation, Data Collection, Reporting and Disposition

As shown in Figure 5, there will be a one month pause between Phases I and II and an eight month overlap between Phases II and III. It should be noted that although there will be phase overlap in the overall project, there will be no phase overlap at any one site. This plan will also accommodate scheduled test site outages for the installation of equipment. It is for these reasons a fifty-four month project period was selected.

Budget periods will be established to coincide with the project phases. Consistent with P.L. 99-190, DOE will obligate sufficient funds to cover its share of the cost for each budget period. Throughout the course of this project, reports dealing with the technical, management, cost and environmental monitoring aspects of the project will be prepared by EER and provided to DOE.

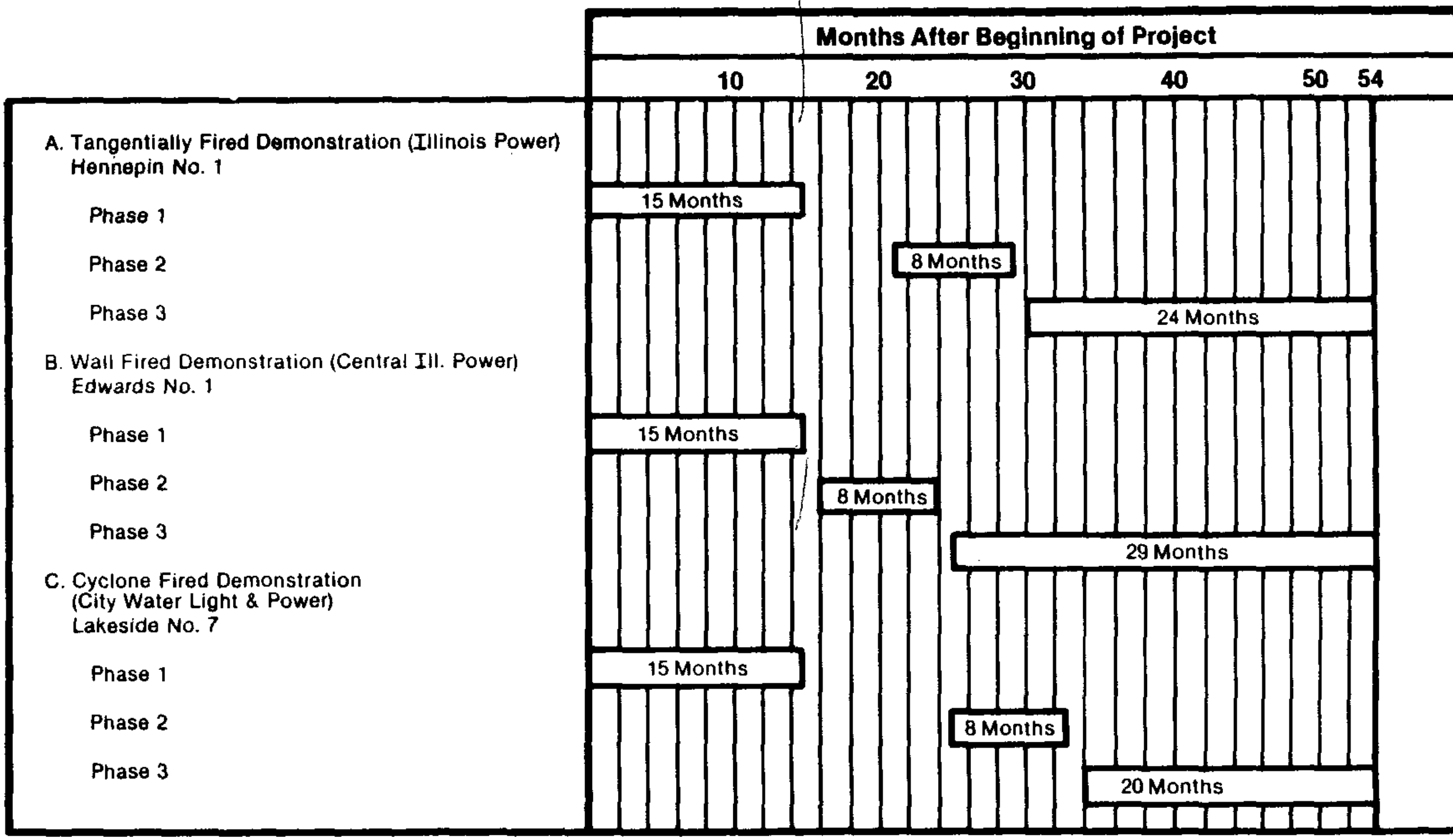

FIGURE 5. OVERALL EER PROJECT SCHEDULE FOR GAS REBURNING-SORBENT INJECTION.

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

Since EER is a small business, patent rights to discoveries made during this demonstration project will remain with EER. Standard patent and data clauses for a small business will apply. The government will have unlimited rights in technical data first produced under this Cooperative Agreement.

5.5 Procedures for Commercialization of Technology

As part of the project, EER will produce a design manual for the GR-SI technology. In the event that know how is developed or inventions are made EER will attempt to sell the know how or licenses to use the inventions to other business concerned with engineering and construction or the production of equipment used in these technologies. EER's interest in commercializing GR-SI is also in the license fees and consulting to the licensees at installations where this technology can be used. Since the technology is being developed and demonstrated by EER, their experience will also be valuable as consultants.

The market for low cost retrofit SO_2 control technology can be enhanced by regulatory changes which require reductions in SO_2 emissions from non-NSPS utility stations. Currently, about 20 million tons per year of SO_2 are emitted from electric generating stations which emit over 1.2 lbs. of SO_2 per million BTU's in the Eastern United States, representing about 175,000 MWe of coal fired electric generating capacity. Any required SO_2 emission reductions would affect the availability of a proportionate share of this capacity. The purpose of the proposed project is to demonstrate the commercial readiness of the GR-SI technology for utility application, and to allow clear definition of those site-specific situations in which these technologies will be the lowest cost compliance option.

The raw sorbent availability is sufficient to handle current and projected GR-SI requirements. Additional haulage of lime would be required, but existing rail/truck capacity is expected to be adequate. The solid waste produced will increase resulting in an increase in the tonnage of waste disposed. There currently exists in the U.S. a surplus in the available supply of natural gas. There is an even larger unused capacity in the natural gas delivery system. Therefore, feedstock availability is not expected to restrain the commercialization of this technology.

For the proposed technology, manufacturing of equipment will easily be performed due to the large overcapacity within the industry. There are no unusual fabrication requirements that would preclude the use of existing manufacturing facilities. The nature of the individual components makes the GR-SI technology very compatible with existing power plant and environmental manufacturing methods.

6.0 PROJECT COST AND EVENT SCHEDULING

6.1 Project Baseline Costs

The total estimated cost for this project is $29,998,253. The Participants' cash contribution and the Government share in the costs of this project are as follows:

	Dollar Share ($)	Percent Share (%)
PHASE I		
Government	1,764,986	50
Participants	1,764,986	50
PHASE II		
Government	6,249,623	50
Participants	6,249,623	50
PHASE III		
Government	6,983,644	50
Participants	6,985,391	50
TOTAL PROJECT		
Government	14,998,253	50
Participants	15,000,000	50

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

DOE:	$14,998,253
GRI:	10,000,000
State of Illinois:	5,000,000
TOTAL	$29,998,253

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

6.2 Milestone Schedule

The overall project will be completed in 54 months after award of the Cooperative Agreement.

Phase 1 which involves permitting, preliminary and final design, will start for all sites immediately after award and continue for fifteen months. Upon completion of Phase 1, there will be a pause of one month in the project. Upon completion of the pause, Phase 2 will start and continue through the thirty-third month. Each test site will have its own 8 month period in order to complete the installations and checkouts required for Phase 2.

Following is the anticipated Phase 3 schedule for each test site:

> Testing on the tangentially fired unit located at the Illinois Power Site is scheduled to start in the thirtieth month of the project and last for eighteen months.
>
> Testing on the wall fired unit located at the CILCO site is scheduled to start in the twenty-fifth month and be completed in eighteen months.

Testing on the cyclone fired unit located at the CWLP site is scheduled to start in the thirty-fourth month and last for eighteen months.

The final months of the program will involve site restorations and completion of the final report for the overall project.

6.3 Recoupment Plan

In response to the stated policy of the DOE to recover an amount up to the Government's contribution to the project, the Participant has agreed to repay the Government in accordance with the Recoupment/Repayment Plan included in the Cooperative Agreement.