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Comprehensive Report to Congress Clean Coal Technology Program

Demonstration of Selective Catalytic Reduction (SCR) Technology for the Control of Nitrogen Oxide (NO_x) Emissions from High-Sulfur-Coal-Fired Boilers

A Project Proposed By: Southern Company Services, Inc.

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Washington, DC 20585

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1.0 EXECUTIVE SUMMARY

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

In response to the PON, fifty-five proposals were received by the DOE in May 1988. After evaluation, sixteen projects were selected in September 1988 for award. These projects involve both advanced pollution control equipment that can be "retrofitted" to existing facilities and "repowering" technologies that not only reduce air pollution but also increase generating plant capacity and extend the operating life of the facility.

One of the proposals selected for funding is the project proposed by Southern Company Services (SCS) to demonstrate the Selective Catalytic Reduction (SCR) Process that will remove nitrogen oxides (NO_x) from the flue gas of boilers that burn U.S. high-sulfur coal. This technology consists of injecting ammonia (NH_3) into the flue gas and passing it through a catalyst bed where the NO_x and NH_3 react to form nitrogen and water vapor.

Nitrogen oxides are formed when nitrogen in the fuel or nitrogen in the combustion air oxidizes. The SCR process that is to be demonstrated in this ICCT project is capable of very high NO_x removal levels. This process is normally installed between the combustion facility's economizer and air preheater where the gas is at the proper temperature for the SCR reaction. In some cases, where space is limited or ash loading/chemistry in the flue gas is a problem, it can be installed downstream of particulate removal equipment, but extensive flue gas reheat is required.

In a full-scale commercial installation, sufficient NH_3 to react with about 80% of the NO_x is added to the flue gas. The flue gas then enters the catalytic reactor where the NO_x and NH_3 react. After exiting the reactor, the flue gas then flows to the existing air preheater. If more NH_3 is added or as catalyst activity declines, some NH_3 will pass through the catalyst bed without reacting. This is referred to as NH_3 slip. The NH_3 can then react with the small quantities of sulfur trioxide (SO_3) present in the reactor exit gas to form ammonium bisulfate (NH_4HSO_4) which can corrode down stream equipment. This is a greater problem with high-sulfur coals. The more NH_3 slip that can be tolerated, the more NH_3 can be added to the flue gas stream and consequently up to 90% of the NO_x can be removed. However, worldwide experience suggests that NH_3 slip is the limiting factor for NO_x removal, therefore, for high sulfur coals, 80% NO_x removal may be more likely.

This process is widely used in boilers firing low-sulfur coal in Europe and Japan. Thus, the process is well understood when applied to low-sulfur coal. The only questions concerning the use of SCR with higher sulfur American coals involve the process chemistry which impacts catalyst life and therefore can significantly impact cost. The application of the process to boilers burning high-sulfur U.S. coals still requires demonstration to resolve the questions on chemistry, catalyst life, and costs. Since small scale tests can resolve these questions, this project will treat a small portion of the total flue gas stream (slip-stream) from one of two commercial coal-fired utility boilers. The demonstration plant will consist of nine parallel reactor trains; three to treat slip-streams equivalent to the flue gas emanating from a 2.5 MWe (about 5000 standard cubic feet per minute (SCFM)) boiler facility and six to treat streams equivalent to about 0.20 MWe (400 SCFM). Specifying slip stream size as MWe is intended to facilitate comparison with the sizes of larger facilities and assumes that these small units have the same amount of flue gas per MWe as do larger utility boilers. This arrangement will allow simultaneous tests on multiple catalysts. Short term tests can continue while longer term tests are run on promising catalysts.

The project will be conducted at Units 5 and 6 of Gulf Power Company's Plant Crist located in Pensacola, Florida. Unit 5 is a 75 MWe unit and Unit 6 is rated at 320 MWe. The location of Plant Crist is shown in Figure 1.

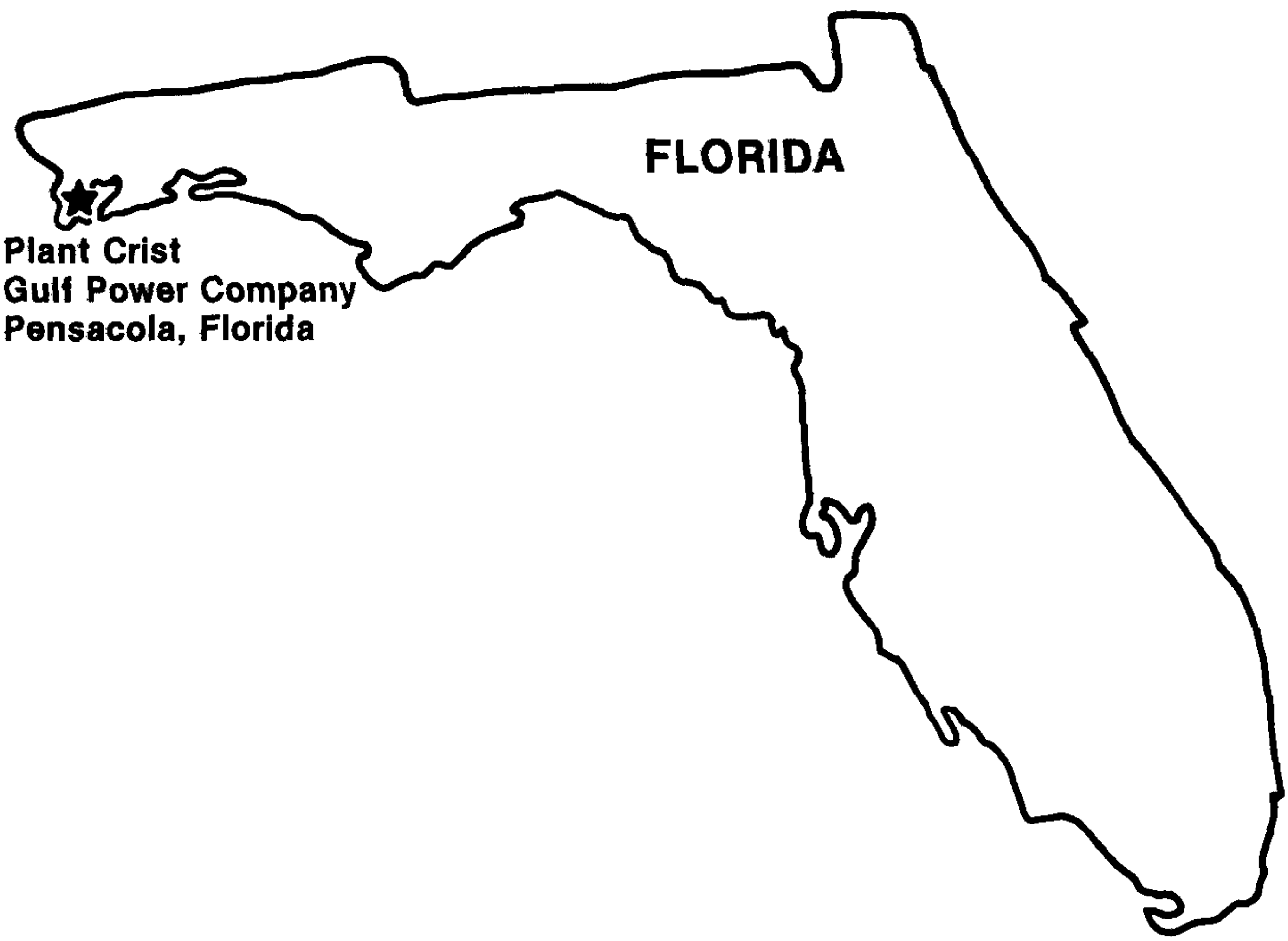

FIGURE 1. SCS SELECTIVE CATALYTIC REDUCTION DEMONSTRATION PROJECT SITE LOCATION.

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Plant Crist is currently in commercial operation. The intent of this project is to demonstrate commercial catalyst performance, proper operating conditions, and catalyst life for the SCR process on boilers using U.S. high- sulfur coals. This project will also demonstrate the technical and economic viability of SCR while reducing NO_x emissions by at least 80%. At the end of this project, if it is successful, the SCR process should be ready for commercial application on U.S. high-sulfur coals.

The total estimated cost of this project is $15,574,355 of which $7,525,338 will be funded by DOE, $6,049,017 will be provided by SCS and $2,000,000 will be provided by the Electric Power Research Institute.

2.0 INTRODUCTION AND BACKGROUND

The domestic coal resources of the United States play an important role in meeting current and future energy needs. During the past 15 years, considerable effort has been directed to developing improved coal combustion, conversion, and utilization processes to provide efficient and economic energy options. These technology developments permit the use of coal in a cost-effective and environmentally acceptable manner.

2.1 Requirement for Report to Congress

In December 1987, Congress made funds available for the ICCT Program in Public Law No. 100-202, "An Act Making Appropriations for the Department of Interior and Related Agencies for the Fiscal Year Ending September 30, 1988, and for Other Purposes" (the "Act"). This Act provided funds for the purpose of conducting cost-shared clean coal technology projects to demonstrate emerging clean coal technologies that are capable of retrofitting or repowering existing facilities and authorized DOE to conduct the ICCT Program. Public Law No. 100-202, as amended by Public Law No. 100-446, provided $575 million, which will remain available until expended, and of which (1) $50,000,000 was available for the fiscal year beginning October 1, 1987; (2) an additional $190,000,000 was available for the fiscal year beginning October 1, 1988; (3) an additional $135,000,000 will be available for the fiscal year beginning October 1, 1989;

October 1, 1989; and (4) $200,000,000 will be available for the fiscal year beginning October 1, 1990. Of this amount, $6,782,000 will be set aside for the Small Business and Innovative Research Program, and is unavailable to the ICCT Program.

In addition, after the projects to be funded had been selected, DOE prepared a comprehensive report on the proposals received. The report was submitted in October 1988 and was entitled "Comprehensive Report to Congress: Proposals Received in Response to the Innovative Clean Coal Technology Program Opportunity Notice" (DOE/FE-0114). Specifically, the report outlines the solicitation process implemented by DOE for receiving proposals for ICCT projects, summarizes the project proposals that were received, provides information on the technologies that are the focus of the ICCT Program, and reviews specific issues and topics related to the solicitation.

Public Law No. 100-202 directed DOE to prepare a full and comprehensive report to Congress on any project to receive an award under the ICCT Program. This report is in fulfillment of this directive and contains a comprehensive description of the Selective Catalytic Reduction Demonstration Project.

2.2 Evaluation and Selection Process

A PON was issued on February 22, 1988, to solicit proposals for conducting cost-shared ICCT demonstrations. Fifty-five proposals were received. All proposals were required to meet the six qualification criteria provided in the PON. Failure to satisfy one or more of these criteria resulted in rejection of the proposal. Proposals that passed Qualification Review proceeded to Preliminary Evaluation. Three preliminary evaluation requirements were identified in the PON. Proposals were evaluated to determine whether they met these requirements; those proposals that did not were rejected.

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

The Technical Evaluation Criteria were divided into two major categories. The first, "Commercialization Factors", addressed the projected commercialization of the proposed technology. This was different from the proposed demonstration project itself and dealt with factors involved in the commercialization process. The criteria in this section provided for consideration of (1) the potential of the technology to reduce total national emissions of SO_2 and/or NO_x emissions and reduce transboundary and interstate air pollution with minimal adverse environmental, health, safety, and socioeconomic (EHSS) impacts; and (2) the potential of the proposed technology to improve the cost-effectiveness of controlling emissions of SO_2 and NO_x when compared to commercially available technology options.

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

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

Consideration was also given to the following program policy factors:

(1) The desirability of selecting projects for retrofitting and/or repowering existing coal-fired facilities that collectively represent a diversity of methods, technical approaches, and applications (including both industrial and utility);

(2) The desirability of selecting projects that collectively produce some near-term reduction of transboundary transport of emitted SO_2 and NO_x; and

(3) The desirability of selecting projects that collectively represent an economic approach applicable to a combination of existing facilities that significantly contribute to transboundary and interstate transport of SO_2 and NO_x in terms of facility types and sizes, and coal types.

The PON also provided that, in the selection process, DOE would consider giving preference to projects located in states where the rate-making bodies of those states treat innovative clean coal technologies the same as pollution control projects or technologies. The inclusion of this project selection consideration was intended to encourage states to utilize their authorities to promote the adoption of innovative clean coal technology projects as a means of improving the management of air quality within their areas and across broader geographical areas.

The PON provided that this consideration would be used as a tie breaker if, after application of the evaluation criteria and the program policy factors, two projects received identical evaluation scores and remained essentially equal in value. This consideration would not be applied if, in doing so, the regional geographic distribution of the projects selected would be altered significantly.

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

In light of the tight schedule imposed by Public Law No. 100-202 and the confidentiality requirements of the competitive PON process, DOE established alternative procedures to ensure that environmental factors were fully evaluated and integrated into the decision-making process to satisfy its NEPA responsibilities. Offerors were required to submit both programmatic- and project-specific environmental data and analyses as a discrete part of each proposal submitted to DOE.

The DOE strategy for NEPA compliance has three major elements. The first involves preparation of a programmatic environmental impact analysis for public distribution, based on information provided by the offerors and supplemented by DOE, as necessary. This environmental analysis documents that relevant environmental consequences of the ICCT Program and reasonable programmatic alternatives are considered in the selection process. The second element involves preparation of a preselection project-specific environmental review for internal DOE use. The third element provides for preparation by DOE of publicly available site-specific NEPA documents for each project selected for financial assistance under the ICCT program.

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

After considering the evaluation criteria, the program policy factors, and the NEPA strategy, sixteen proposals were selected for negotiation for award. The SCR proposal submitted by Southern Company Services, Inc., was one of these proposals.

3.0 TECHNICAL FEATURES

3.1 Project Description

This project will demonstrate the application of Selective Catalytic Reduction technology to U.S. high-sulfur coal-fired utility boilers and consists of the following:

- o Three 2.5 MWe (equivalent) SCR reactors (supplied by separate 5000 SCFM flue gas slip-streams) coupled with small-scale rotary and heat pipe air preheaters.

- Six 0.20 MWe (equivalent) SCR reactors (400 SCFM).

- Associated equipment for operations, maintenance and testing.

While these reactors are small, the Participant has determined that they are sufficiently large to produce design data that will allow the SCR process to go directly to commercial- scale units. This project equipment is scheduled for erection between Units 5 and 6 at Plant Crist of Gulf Power Company located in Pensacola, Florida. Plant Crist consists of seven fossil-fuel generating units that utilize a variety of fuels. Units 1 - 3 are natural gas- and oil-fired units and consequently do not have a high utilization factor. The remaining four units (Units 4 - 7) are coal-fired. The prototype SCR facility will be built in and around the ductwork on Unit 5 and Unit 6, and will have the ability to utilize the flue gas from both units.

SCS has selected appropriate catalysts that will provide an evaluation of process chemistry effects and the economics of operation when applying SCR technology to flue gas, with high- and low-dust loading, derived from the combustion of high-sulfur U.S. coal. The large (2.5 MWe) SCR reactors will contain current SCR catalysts as offered by SCR catalyst suppliers to the Japanese and European markets. These reactors will be coupled with small-scale air preheaters to evaluate the long-term effects of SCR reaction chemistry on air preheater deposit formation and the deposits' effects on heat transfer performance and metallurgy in the air preheater. The small reactors are intended to provide a means to test additional catalysts with respect to NO_x removal and catalyst life.

A successful demonstration program would allow the technical and economic performance of a wide range of SCR catalysts to be evaluated on the flue gas produced by burning U.S. high-sulfur coal. The coal used in this demonstration project will be a blend of Illinois No. 5, Illinois No. 6, and Pittsburgh No. 8 coals with a sulfur content near 3.0%. The SCR prototype facility to be constructed will allow both parametric and long-term durability evaluation of SCR catalyst systems. Operation of this facility should yield a comprehensive database for future SCR applications by providing unbiased No_x removal (de-NO_x) performance and process chemistry data for SCR systems that are operating in both on-design and off-design points as well as the economic evaluation of each catalyst system.

3.1.1 Project Summary

Project Title:	Demonstration of Selective Catalytic Reduction (SCR) Technology for the Control of Nitrogen Oxides (NO_x) Emissions from High-Sulfur, Coal-Fired Boilers
Proposer:	Southern Company Services, Inc.
Project Location:	Gulf Power Company's Plant Crist Pensacola, Florida-Escambia County
Technology:	Selective Catalytic Reduction for Nitrogen Oxide Control
Application:	Utility Boilers; New or Retrofit; Coal-Fired
Types of Coal Used:	Illinois Nos. 5 and 6 and Pittsburgh No. 8; 2.6 to 3.1% Sulfur
Product:	Environmental Control Technology
Project Size:	8.7 MWe (equivalent-17,400 SCFM)
Project Start Date:	April 1990
Project End Date:	June 1994

3.1.2 Project Sponsorship and Cost

Project Sponsor:	Southern Company Services, Inc.
Proposed Co-Funders:	U.S. Department of Energy Electric Power Research Institute
Estimated Project Cost:	$15,574,355

Project Cost Distribution:

Participant Share(%)	DOE Share(%)
51.68	48.32

3.2 Selective Catalytic Reduction Process

3.2.1 Overview of Process Development

The selective catalytic reduction of NO_x using NH_3 as the reducing gas was first discovered and patented by Englehard Corporation in 1957. The original catalyst consisted of platinum or platinum group metals. The catalytic activity of these initial catalysts was high requiring low operating temperatures which were near the temperature range at which explosive ammonium nitrate forms. Other base metal catalysts (Fe, Co, and Ni) were evaluated in the 1960s, but rejected due to their low activity. Building upon this work and responding to severe environmental regulations imposed by the government in their country, the Japanese discovered the vanadium/titanium combination as an effective NO_x reduction catalyst. This combination forms the basis of current SCR catalysts. Several primary U.S. patents control this basic vanadium pentoxide/titanium oxide (V_2O_5/TiO_2) catalyst technology. One was issued to Mitsubishi Petrochemical Corporation and another was issued to Sumitomo Chemical Company. An additional patent assigned to NGK Insulators of Japan claims the use of the honeycomb shape for vanadium/titanium SCR catalyst for use in flue gas processing. Mitsubishi Heavy Industries has been granted an exclusive license to the NGK patent. By the late '70s, vanadium/titanium-based SCR catalysts were being applied commercially in Japan to natural-gas and low-sulfur oil-fired industrial boilers.

Also, in the late 1970s and early 1980s, three pilot-scale SCR tests (two on coal, one on natural gas) were carried out in the U.S. The first utility applications of SCR catalyst technology started in Japan in 1977 for oil- and gas-fired boilers and subsequently in 1979 for coal-fired boilers. As of 1986, ninety utility boilers in Japan had been equipped with SCR catalyst technology including twenty-two coal-fired boilers. These coal-fired boilers represent a combined capacity in excess of 6500 MWe and are typically fired with a low-ash, low-sulfur coal.

In addition to Japanese experience, several countries in western Europe (most notably West Germany and Austria) have passed stringent NO_x emission regulations that have all but mandated the installation of SCR. Prior to commercial SCR installations in West Germany, utility companies demonstrated several types of SCR facilities in prototype demonstration programs similar to this ICCT project. Over 50 SCR pilot plants were built and operated in western Europe. These pilot plants ranged from 19 to 6200 SCFM and provided the data base that led to commercialization of the SCR technology in western Europe.

3.2.2 Process Description

The basic process flow and equipment are shown in Figure 2. The SCR technology involves the catalytic reaction of NH_3 which is injected into the flue gas to react with NO_x contained in the flue gas to produce molecular nitrogen (N_2) and water vapor. These reactions take place in the SCR unit.

Specifically, hot flue gas leaving the economizer section of the boiler is ducted to the SCR reactor. Prior to entering the reactor, NH_3 is injected into the flue gas at a sufficient distance upstream of the reactor to provide for complete mixing of the NH_3 and flue gas. The quantity of NH_3 can be adjusted and it reacts with the NO_x in the presence of the catalyst to remove NO_x from the flue gas. The flue gas leaving the catalytic reactor enters the air preheater where it transfers heat to the incoming combustion air. Provisions are made for ash removal from the bottom of the reactor since some fallout of fly ash is expected. Duct work is also provided to bypass some flue gas around the economizer during periods when the boiler is operating at reduced load. This is done to maintain the temperature of the flue gas entering the catalytic reactor at the proper reaction temperature of about 700°F. The flue gas leaving the air preheater goes

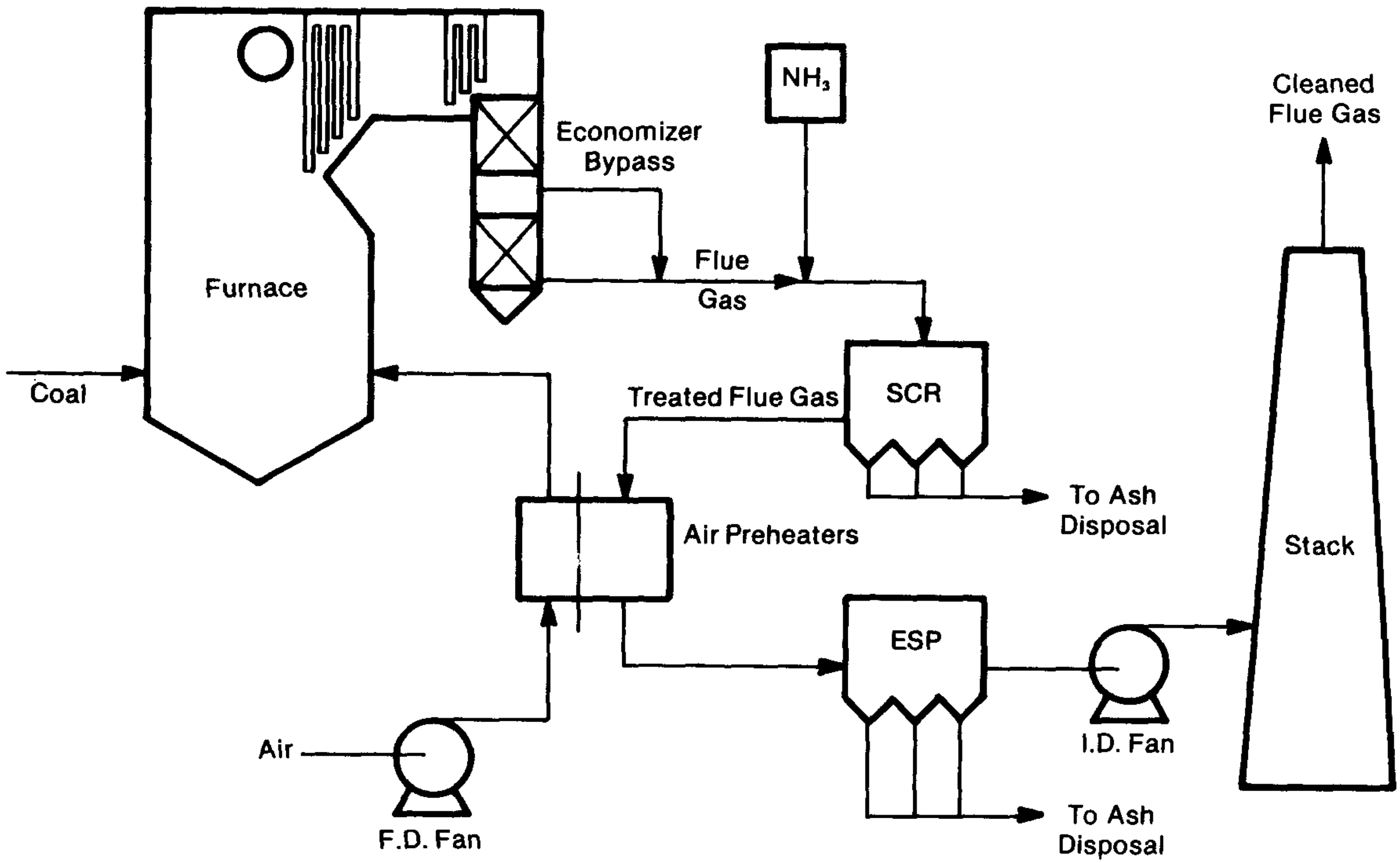

FIGURE 2. BLOCK FLOW DIAGRAM OF SCR INSTALLATION.

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to the Electrostatic precipitator (ESP) where fly ash is removed. The ESP is part of the existing plant and is generally unaffected by the SCR system except as higher SO_3 content affects the electrical resistivity of the fly ash or if NH_4HSO_4 co-precipitates with the fly ash.

Current formulations of SCR catalyst are based upon patented discoveries by the Japanese and are typically comprised of V_2O_5 as the active material deposited on or incorporated with a substrate. The V_2O_5 composition typically ranges between one and five weight percent depending upon the flue gas SO_2 content. Tungsten trioxide (WO_3) is often added as a co-catalyst/promoter in cases where additional catalyst activity is needed. But, the V_2O_5 concentration does not typically exceed 2% when using high-sulfur fuel due to concerns about SO_2 oxidation to SO_3. The catalyst substrate is typically composed of pure TiO_2, although some manufacturers use modifications to this standard material. The catalyst is offered commercially in Europe and Japan in two basic geometric shapes: honeycomb grid and plate.

Theoretically, the NO_x and NH_3 react in the presence of these catalysts according to the following equations:

$$4NH_3 + 4NO + O_2 = 4N_2 + 6H_2O \quad (1)$$

$$8NH_3 + 6NO_2 = 7N_2 + 12H_2O \quad (2)$$

$$\text{or} \quad 4NH_3 + 2NO_2 + O_2 = 3N_2 + 6H_2O \quad (2a)$$

However side reactions, which produce undesirable by-products, can occur between NH_3 and SO_3 in the flue gas. These reactions are:

$$2NH_3 + SO_3 + H_2O = (NH_4)_2\ SO_4 \quad (3)$$

$$NH_3 + SO_3 + H_2O = NH_4HSO_4 \quad (4)$$

These side reactions have the negative effects of consuming ammonia and producing by products which can create problems for downstream equipment.

Since the NO_x contained in flue gas derived from coal-fired boilers is typically composed of 90 to 95% NO; reaction (1) dominates. Inspection of these reactions reveals several points:

- o Oxygen must be present in the flue gas for the reactions to proceed.
- o The de-NO_x capability is linearly related to the NH_3 to NO_x ratio.
- o H_2O partial pressure (high concentration) in the flue gas can inhibit the forward reaction.

Under typical operating conditions of utility boilers, lack of oxygen should not occur since utility boilers are never operated below approximately 2% excess oxygen. When using standard SCR design and operating conditions, de-NO_x efficiency is directly proportional to the ratio of NH_3 to NO_x up to de-NO_x levels of approximately 80%. Above this value, some unreacted NH_3 can pass through the SCR reactor (referred to as NH_3 slippage) due to the low concentration of the reactants and to the inhibiting effect of water vapor. Minimization of NH_3 slippage is a major operational and design concern as discussed below. As a practical matter, some de-NO_x inhibition by H_2O is unavoidable since the combustion reaction will result in approximately 8 to 10 percent H_2O in the flue gas. However, above approximately 10 percent, H_2O has little additional effect on de-NO_x efficiency.

Slip NH_3 is a concern in the application of SCR to coal-fired boilers due to the formation of ammonium bisulfate (NH_4HSO_4), according to reaction (4), and its subsequent condensation on downstream equipment. The condensation of NH_4HSO_4 on equipment surfaces can lead to the plugging of equipment. In addition, NH_4HSO_4 is a sticky, corrosive material that can cause corrosion problems unless more costly, corrosion resistant materials of construction are used.

Factors that contribute to NH_4HSO_4 formation are temperature, catalyst composition and the concentrations of NH_3 and SO_3 in the flue gas. The influence of temperature and catalyst composition are interdependent. The quantity of NH_3 available can be controlled by the plant operator. The amount of SO_3 present is due to two factors: the amount formed in the boiler itself and the amount that is formed by the catalytic oxidation of SO_2 to SO_3 in the SCR unit. The combustion of low-sulfur coal typically results in very little SO_3 formation in the boiler. In addition, the SO_2 concentration in the flue gas is also very low which results in less SO_2 to SO_3 conversion. Thus, NH_3 slip is of less concern when burning low-sulfur coals. However, U.S. high-sulfur coal may form much more SO_3 in the boiler. Moreover, the higher flue gas SO_2 content will likely cause more SO_2 to be converted to SO_3 in the SCR reactor, thereby aggravating the NH_4HSO_4 formation problems.

Complete resolution of these questions regarding NO_x destruction and NH_3 slip cannot be made until actual operating experience with SCR on U.S. high-sulfur coal is obtained. However, certain design and operating changes can be made to minimize any problems.

The SCR process which will be designed, installed and operated for this demonstration project will determine the levels to which NO_x can be reduced while minimizing the production of NH_4HSO_4 and problems associated with NH_4HSO_4.

3.2.3 Application of Process in Proposed Project

The SCR process to be used in this demonstration will be designed to treat a slip-stream of flue gas and will feature multiple reactors installed in parallel. With all reactors in operation, the maximum amount of combustion flue gas that can be treated is 17,400 standard cubic feet per minute (scfm) which is roughly equivalent to 8.7 MWe.

The Participant has determined that it is not necessary to build a "full-scale" SCR demonstration facility since the major issues to be addressed are questions of chemistry, which can be adequately investigated using a slip-stream facility. Therefore, construction of a "full-scale" facility, relative to the proposed slip-stream prototype plant, would add little additional technical information and be unnecessarily expensive.

The proposed SCS facility is a slip-stream SCR test facility consisting of three 2.5 MWe (5000 SCFM) SCR reactors and six 0.20 MWe (400 SCFM) reactors that will operate in parallel for side-by-side comparisons of commercially available SCR catalyst technologies obtained from worldwide vendors. Figure 3 presents a

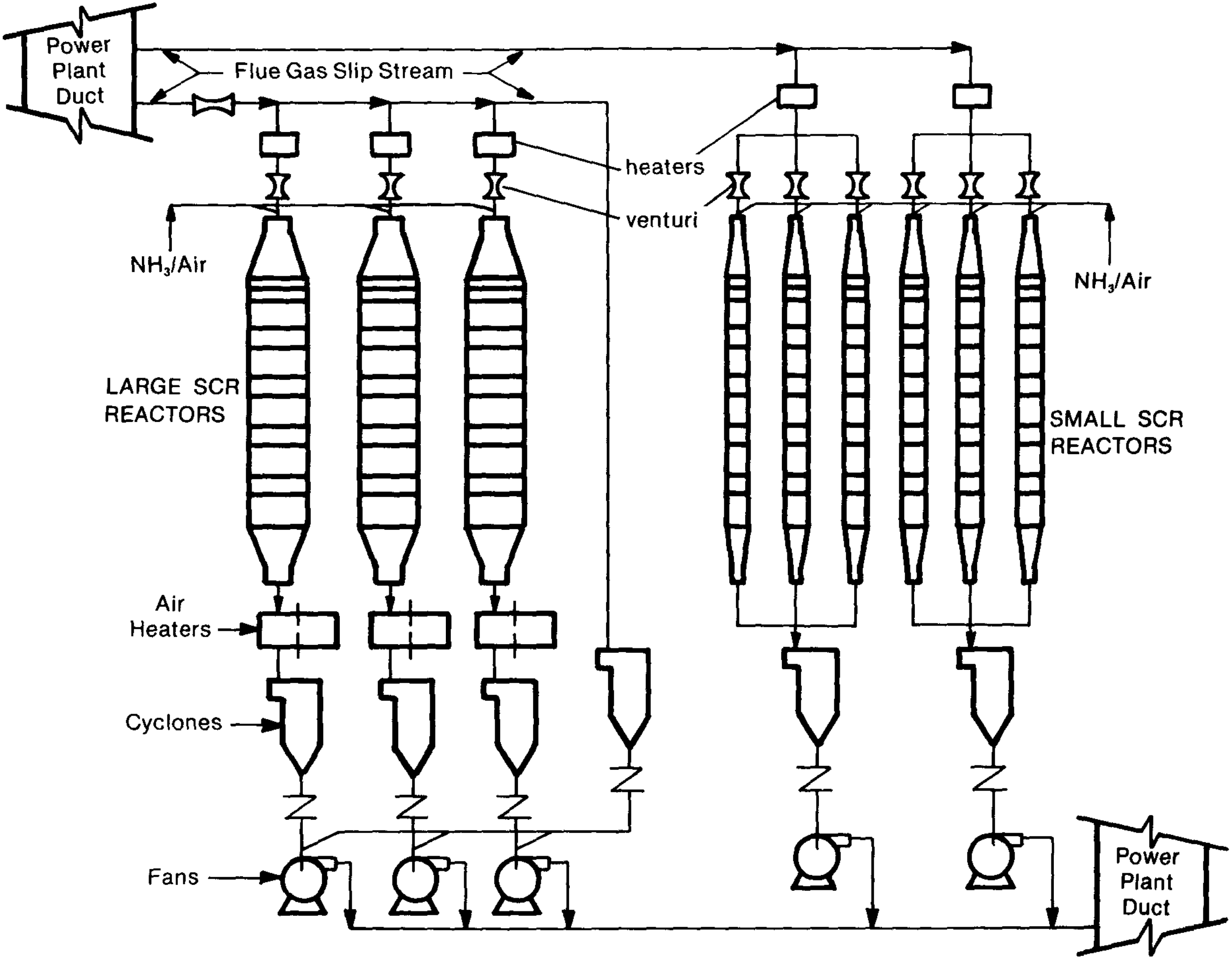

FIGURE 3. PROTOTYPE SCR DEMONSTRATION FACILITY-PROCESS FLOW DIAGRAM.

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simplified process flow diagram for the proposed facility. The large (2.5 MWe) SCR reactors will contain commercially available SCR catalysts as offered by SCR catalyst suppliers. These reactors will be coupled with small-scale air preheaters to evaluate the long-term effects of SCR reaction chemistry on air preheater deposit formation and the deposits' effects on air preheater. The small reactors will be used to test additional commercially available catalysts. This demonstration facility size will be adequate to develop performance data to evaluate SCR capabilities and costs that are applicable to boilers using high-sulfur U.S. coals.

3.3 General Features of the Project

3.3.1 Evaluation of Developmental Risk

Any new or developing technology presents some element of risk. However, the SCR process is widely used in both Europe and Japan with approximately 200 commercial-scale installations. These SCR units are used to treat the flue gas produced from a variety of coals as well as flue gas produced by burning gas or oil. These commercial installations use designs based on extensive development and pilot-scale work.

One recognized risk for this technology is that complete mixing of the NH_3 and flue gas is essential. Design for proper mixing is site-specific since each utility boiler and associated duct work is different and individually designed. Therefore, the designs to achieve good mixing are different for each plant. Sophisticated flow modeling techniques are used to achieve designs that allow effective mixing. As shown by the large number of successful commercial installations, this risk is slight.

Another area of risk lies in the SCR process chemistry. When the SCR process is used to treat flue gas derived from high-sulfur coals, it is expected that higher SO_2 and SO_3 levels will be present than is the case for flue gas from lower-sulfur coals burned in Europe or Japan. In addition, some of the SCR catalyst's components oxidize SO_2 to SO_3. Typically, if NH_3 sufficient to convert more than 80% of the NO_x is added to the flue gas, some will pass through the bed without reacting. NH_3 slippage, in the absence of SO_3, is not a major problem. However, in the presence of SO_3, NH_3 reacts to form NH_4HSO_4. This material is a sticky solid which will deposit on equipment downstream of the SCR reactor. Since NH_4HSO_4 is a sticky substance, it can trap fly ash to cause deposits which impair equipment performance. The air preheater is particularly susceptible since deposits reduce heat transfer and increase pressure drop on the flue gas side. In addition, NH_4HSO_4 can cause corrosion problems.

While the risks associated with NH_4HSO_4 formation are considered to be moderate, the factors which lead to its formation are well understood. The formation of NH_4HSO_4 can be controlled or eliminated by using a catalyst limiting the components promoting SO_3 formation and by carefully controlling the amount of NH_3 injected into the flue gas.

The SCR process has been primarily used to treat flue gas with relatively low ash loading in Japan with higher ash coals used in Europe. The ash chemistry of U.S. coals differs significantly from that of Japanese and European coals. High ash loading to the SCR reactor may shorten catalyst life if the ash chemistry is unfavorable. If this effect is severe, particulate removal may be needed before the gas enters the SCR reactor. Prior particulate removal will require that the gas be cooled for particulate removal and then reheated to SCR operating temperature. Since heating and cooling flue gas is routine, there is no technical risk and only some economic risk is involved.

While these potential problems exist, they are manageable by using sound design techniques, including materials selection, and good operating and monitoring practices. This project will enable designers and utilities to select the best catalysts and operating conditions for each installation involving U.S. coals.

3.3.1.1 Similarity of Project to Other Demonstration/Commercial Efforts

The Participant conducted a technical and preliminary economic analysis of a number of processes designed to remove or destroy NO_x. Based upon that review, SCS selected SCR as the most appropriate technology to consider for future installations within its service area if high levels of NO_x reduction are required. Consequently, SCR was selected for proposal to the DOE under the ICCT solicitation. SCR is a mature process having been used widely worldwide on gas, oil and low-sulfur, coal-fired utility power plants. It has been applied at process scales of up to 1000 MWe.

Other U.S. work with the SCR process consists of three projects which were carried out in the late 1970s and early 1980s. One of these was carried out on a natural gas fired boiler by Southern California Edison. Another project consisted of a pilot test conducted for the EPA at Georgia Power's Plant Mitchell. This pilot plant treated a 1000 SCFM (0.5 MWe) slip stream of flue gas resulting from the combustion of low- to medium-sulfur coal. A third pilot-scale project, carried out at the Public Service Company of Colorado's Arapaho Station treated a 5000 SCFM (2.5 MWe) slip stream of flue gas resulting from the combustion of U.S. low-sulfur coal.

There are several available processes that use the catalytic reduction of NO_x by ammonia. One is the patented Haldor Topsoe process which cools the flue gas as it exits the boiler by the use of an air to air heat exchanger utilizing combustion air as a process cooling medium. The particulates are then removed from the cooled flue gas in a baghouse using gortex bags. Next the flue gas is reheated and mixed with ammonia prior to entering the SCR reactor where the NO_x is converted to nitrogen and water. After NO_x removal, the SO_2 is oxidized in an SO_2 reactor to form SO_3. The SO_3 then passes through a cooling/condensing tower, thus allowing the SO_3 to cool and form commerical quality concentrated sulfuric acid.

The SOX-NOX-ROX BOX process, developed by Babcock & Wilcox, removes SO_2 by injecting a dry sorbent into the upper boiler and subsequently removing the sorbent in a baghouse. Ammonia is injected into the upper furnace to destroy NO_x. Some reaction between the NH_3 and NO_x takes place in the upper furnace and ductwork and the balance of the reaction takes place in the baghouse which contains a catalyst. This process has operated at the pilot scale. A full-scale demonstration is being funded through the CCT Program.

Another process that simultaneously removes SO_2 and NO_x is the NOXSO process, developed by the NOXSO Corporation. In this process flue gas is passed through a fluid bed of sorbent which simultaneously removes both NO_x and SO_2. The sorbent is taken from the adsorber and heated with hot combustion products to remove NO_x. The NO_x-rich stream is fed to the boiler's combustion zone. The injection of this recovered NO_x does not increase NO_x levels in the flue gas leaving the boiler since the boiler's burners operate at near-equilibrium NO_x

levels. After NO_x removal, the sorbent is regenerated in two stages: first with a hot reducing gas to liberate sulfur as SO_2 then with steam which liberates the balance of the sulfur as H_2S. The SO_2 and H_2S streams are combined and can be treated in a Claus plant to produce elemental sulfur or used to produce sulfuric acid. The regenerated sorbent is cooled and returned to the adsorber. This process was selected for demonstration under the CCT-III program.

3.3.1.2 Technical Feasibility

While questions exist with regard to the chemistry of SCR when it is applied to boilers fired with U.S. coals, there is evidence that this process is adaptable for use in this country. It is a mature process that is used in nearly two hundred foreign coal, oil, and gas commercial utility plants and has also been proven in numerous bench-scale tests and pilot plants including pilot plant tests conducted by EPRI and SCS in the U.S. These units are used to reduce NO_x levels by as much as 90% in flue gas produced by the combustion of a variety of fuels including a number of different coals.

As discussed previously, the major uncertainties in applying SCR to U.S. boilers deal with process chemistry. This demonstration project is intended to deal with the issues involving process chemistry and to demonstrate that, when operating on U.S. coals, the process can hold ammonia slippage to acceptable levels while destroying at least 80% of the NO_x. This project will demonstrate that some commercially available catalysts provide the required NO_x destruction capability, have sufficient resistance to deactivation and do not cause excessive NH_4HSO_4 formation.

Although several potential problems exist, the solutions to these problems also exist. The fact that the SCR process is operating successfully at many European and Japanese facilities using a variety of fuels is evidence that the SCR process can successfully be used in the United States.

3.3.1.3 Resource Availability

The demonstration project will require small amounts of power, steam, and water. These utilities will be provided using the current plant infrastructure. There will be no changes in coal supplied to the plant and other plant raw material supplies will remain the same. The SCR demonstration unit will require anhydrous NH_3, which is not currently used by the plant. Anhydrous NH_3 is used extensively by many industries and as a fertilizer and will be provided by a Gulf Coast chemical supplier. The quantities to be used for this demonstration project are minor and will not impact supplies.

The other major resources needed for the demonstration project are the SCR catalysts. SCS has contacted a large number of potential SCR process/catalyst suppliers and has selected several of them to participate in this program. For the demonstration project, the quantities of catalyst are small and can be readily supplied by the catalyst manufacturers. All spent SCR catalyst will be returned to the suppliers. Therefore, no disposal of catalyst used in this project will be required.

It is anticipated that an average of 30 to 35 construction personnel will be required during the 12-month construction period, with a peak workforce of 70 persons. Most of the construction work force will come from local construction contractors that are familiar with Plant Crist. Additionally, professionals familiar with the SCR technology will be at the plant during construction and start-up and will be in the Pensacola area for short periods of time.

Since this project is small, based on the quantity of flue gas treated relative to the total plant flue gas stream, impacts on supplies of reagents, catalysts, utilities and labor will be minor.

3.3.2 Relationship Between Project Size and Projected Scale of Commercial Facility

Scale-up of parameters involving chemical reactions from this project to commercial scale is simplified since catalyst manufacturers produce catalyst in modules which correspond to the catalyst quantity and configuration required for the 2.5 MWe reactor. Therefore, simply combining multiple modules, in such a manner as to maintain the duration of contact between the gas and catalyst, will effectively and reliably scale the pilot plant to any commercial size. This has been done successfully up to the 1,000 MWe size in foreign applications of the SCR process. Based on the above discussion, scale-up by a factor as much as 300 from the demonstration size of 2.5 MWe should present no major problems.

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

The purpose of this demonstration project is to demonstrate that SCR is a technically and economically viable technology to reduce NO_x emissions from coal-fired boilers that utilize U.S. high-sulfur coal. To that end, this project will use nine parallel reactors to simultaneously test SCR catalysts that might be suitable for use in the U.S. Three of the reactors will be equipped with air heaters to study the process's impact on downstream equipment.

Several companies will supply various catalysts to the project. These catalysts will include a number of different chemical compositions in the two standard geometric shapes (Honeycomb and plate). The catalysts to be tested will cover the range of compositions of commonly used SCR catalysts. Some tests will be carried out with high dust loading and others with low dust loading.

All pertinent information will be collected, analyzed and organized into a comprehensive data base. This data base will allow those boiler owners who are interested in using the SCR technology to determine the applicability of the technology to meeting their needs.

Thus, the role of this project in the commercialization of SCR in the U.S. is to provide the information to establish a data base that will allow utilities to evaluate and use the technology.

3.3.3.1 Applicability of the Data to be Generated

The proposed SCR demonstration project is not a full-scale version of SCR, but rather represents a "scale-down" of commercial SCR designs. However, the catalyst modules and elements to be used in the reactors are full-scale, commercial versions of the catalyst that is used in commercial installations in Europe and Japan. Design efforts will be made to assure that the flue gas slipstreams extracted from the main power plant duct are fully representative samples in terms of all gaseous and solids species and that the catalyst modules or elements in the SCR reactors will be exposed to flue gas conditions identical to those experienced in full-scale installations. The coal to be used in this project is typical of eastern high-sulfur coals used by many utilities in the United States and the results can be extrapolated to a wide range of high-sulfur U.S. coals.

Each SCR reactor will also be equipped with a full-flow venturi similar to equipment used successfully for over six years at another test facility operated by SCS for EPRI at Gulf Power's Plant Scholz. Gas flow to each reactor will be carefully measured and manipulated to provide control over reactor operating parameters. In addition, each large reactor inlet and each bank of three small reactors will be equipped with electric duct heaters to provide precise control over inlet flue gas temperatures. Consequently, the catalyst in each reactor will experience NO_x, SO_2 and particulate concentrations and flue gas flow rate and temperature conditions that will be identical to a full-scale, commercial unit.

The proposed SCR prototype facility is fully adequate for demonstrating the effectiveness of SCR catalysts on high-sulfur coal. The individual and final SCR reactor designs will be determined in consultation with each of the catalyst vendors that have been selected.

The operational data obtained from the unit will allow the Participant:

- To evaluate the performance of SCR catalysts when applied to operating conditions found in U.S. pulverized coal utility boilers firing U.S. high-sulfur coal.

- To identify and quantify operational changes that will be required for both boilers and SCR processes when SCR is retrofit to an existing boiler.

- To demonstrate the NO_x removal performance of SCR catalysts under various operating conditions (with an objective of achieving as much as 80% NO_x removal under certain operating conditions) consistent with acceptable levels of NH_3 slip.

- To document the potential of various SCR catalysts to cause NH_4HSO_4 to form when exposed to high levels of SO_2 and SO_3 and to determine the process operating conditions under which this formation occurs.

- To evaluate the ability of modifications to conventional utility air preheaters and a new air preheater design to accommodate NH_4HSO_4 condensation.

- To assess the potential impact of an SCR retrofit on the balance of utility plant equipment.

- To document the deactivation rates of SCR catalysts when exposed to flue gas from high sulfur U.S. coal in order to determine accurate process economics.

- To provide information for public consumption which will serve to document the SCR process capabilities and cost.

Each of the above areas involve uncertainties associated with the application of SCR technology to U.S. high-sulfur coals for NO_x emissions reduction. However, operation of the SCS prototype SCR facility will provide the U.S. utility industry with a database of the side-by-side comparison of major worldwide, commercially available SCR catalysts.

3.3.3.2 Identification of Features that Increase Potential for Commercialization

The SCR process has been developed to effectively control NO_x emissions from fossil-fuel-fired boilers. It is highly effective in removing NO_x from flue gas and can be expected to achieve at least 80% reduction of NO_x from flue gas streams. Other technologies at a similar or more advanced stage in their development (e.g. reburning or low-NO_x burners) typically result in 50 to 60% reductions in NO_x formation. If more stringent regulations are enacted that require more than 50-60% NO_x reduction, the standard NO_x emission reduction technologies, such as low-NO_x burners, will be inadequate. Other post-combustion control technologies, which are comparable to SCR in terms of NO_x reduction, are not fully demonstrated. The performance capability and maturity of the SCR process enhance its potential for commercialization once fully demonstrated on U.S. high-sulfur coals.

The SCR process may be combined with low-NO_x burners or reburning to achieve greater than 90% NO_x control. This combination may prove to be more economical than SCR alone since the size and cost of the SCR unit can be reduced, and less anhydrous ammonia and catalyst are consumed.

Another positive feature of the SCR process is that it is applicable to all types of dry-bottom boilers, provided space is available, since it is installed downstream of the boiler. Additionally, only minor work on the boiler itself is required which aids in holding down the cost and minimizes the downtime required for installation.

Another feature of the technology which enhances its potential for commercialization is that it produces no solid wastes, except for the spent catalyst, assuming no NH_4SO_4 is formed. Since the catalyst is expected to last several years the daily average rate of generation of this waste is very small. There is also the possibility of returning the spent catalyst to the manufacturer for reprocessing. If the catalyst is returned, no solid waste will be generated by the utility with the possible exception of small quantities of NH_4HSO_4.

In summary, the commercialization of the SCR technology for U.S. high-sulfur coals should be aided by its ability to achieve high removal rates of NO_x, its relatively advanced state of development and its applicability to virtually all types of boilers. Additionally, little waste is produced and only a minimal boiler outage is required to install the SCR technology.

3.3.3.3 Comparative Merits of the Project and Projection of Future Commercialization and Market Acceptability

The SCR process is commercially available in Europe and Japan where relatively low sulfur coals, compared to U. S. coals, are used. Once this project is complete, a valuable data base will be available for the U.S. utilities for the conversion of NO_x in flue gas to environmentally acceptable nitrogen. For a 200 MWe plant, the Participant estimates that the capital cost for installing and SCR is estimated at $134/kilowatt (KWe) and total operating costs (fixed and variable) are estimated at 1.7 mills/KWe. For a 1000 MWe plant these costs are $108/KWe and 1.54 mills/KWe.

As previously discussed, unanswered questions pertaining to the application of SCR to boilers utilizing U.S. coals are associated with process chemistry. One attractive feature of this project is that parallel reactors will be used (three at 2.5 MWe and six at 0.20 MWe). This will allow side-by-side comparison of a number of different catalysts. In addition, the larger reactors are equipped with air preheaters to evaluate the impact of SCR on downstream equipment. The use of parallel reactors allows several catalysts to be tested simultaneously thus removing temporal variations from the interpretation of process data.

The reactors are sized to use full-scale catalyst elements or modules. This feature makes the data obtained more readily applicable to evaluation of the catalyst and to future commercial deployment since the test catalysts will have the same configuration and chemical makeup as the catalysts used in a commercial plant.

If stringent controls are required, the use of an advanced NO_x control technology, possibly in conjunction with combustion controls, will be required. Currently, SCR is the most developed of the advanced NO_x control technologies capable of achieving high levels of NO_x control and the Participant's economic analyses indicate that combustion modifications coupled with SCR, are a viable means to achieve NO_x reductions.

If this project is successful, it is anticipated that SCR will be widely utilized by the utility industry, assuming that the legislative impetus for increased NO_x control becomes reality and assuming that the technology sources make the technology available at a reasonable price. This assumption is based on the fact that, following successful small-scale tests, SCR became widely accepted in Europe and Japan after environmental regulations required significant NO_x reduction levels.

4.0 ENVIRONMENTAL CONSIDERATIONS

The overall strategy for compliance with the National Environmental Policy Act of 1989 (NEPA), cited in Section 2.2, contains three major elements. The first element, the Programmatic Environmental Impact Analysis (PEIA), was issued as a public document in September 1988 (DOE/PEIA-002). For the PEIA, the Regional Emission Database and Evaluation System (REDES), a model developed at Argonne National Laboratory, was used to estimate the environmental impacts that could occur by the year 2010 if each technology were to reach full commercialization and captured the full extent of its applicable market. The environmental impacts were compared to the no-action alternative where it was assumed that use of conventional coal technologies continues through 2010 with new plants using conventional flue gas desulfurization controls to meet New Source Performance Standards (NSPS).

The expected performance characteristics and applicable market of the SCR technology were used to estimate the environmental impacts that might result if the SCR technology were to reach full commercialization in 2010. The results derived from the REDES computer model were used to compare the impacts of the SCR technology to the no-action alternative.

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

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

Region	Sulfur Dioxide (SO_2)	Nitrogen Oxides (NO_x)	Solid Waste
National	0	-22	0
Northeast	0	-29	0
Southeast	0	-37	0
Northwest	0	-10	0
Southwest	0	- 8	0

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

As shown in Table 1, significant reductions of NO_x are projected to be achievable nationally, due to the 80 percent removal capability forecasted and the wide applicability of the process. No changes in liquid effluents are anticipated. If the spent catalyst is returned to the vendor, there will also be no additional solid waste. The REDES model predicts greatest environmental benefits will be achieved in the Northeast and Southeast because of the large amount of coal-fired capacity in this region that can be retrofitted with the SCR process. The least change would occur in the Northwest because of the minimal use of coal there. The national quadrants used in this study are shown in Figure 4.

The second element of DOE's NEPA strategy for the ICCT program involved preparation of a preselection environmental review based on project-specific environmental data and analyses that offerors supplied as a part of each proposal. This analysis, for internal DOE use only, contained a discussion of site-specific environmental, health, safety and socioeconomic factors associated with each demonstration project. It included a discussion of the advantages and disadvantages of the proposed and alternative processes and sites reasonably available to each offeror. A discussion of the impacts of each proposed demonstration on the local environment, and a list of permits that must be obtained to implement the proposal were included. It also contained options for controlling discharges, and for management of solid and liquid wastes. Finally, the risks and impacts of each proposed project were assessed. Based on this analysis, no environmental, health, safety or socioeconomic issues have been identified that would result in any significant adverse environmental impacts from construction and operation of the SCR demonstration facility.

As the third element of the NEPA strategy, a detailed site- and project-specific NEPA document is prepared by DOE. This document must be completed and approved in conformance with the requirements of the Council on Environmental Quality regulations for implementing the National Environmental Policy Act (NEPA) (40 CFR Parts 1500-1508) and DOE guidelines for compliance with NEPA (52 FR 47662, December 15, 1987) before federal funds are provided for detailed design, construction, and operation. A Memorandum-to-File was signed by the DOE Assistant Secretary for Fossil Energy on August 7, 1989, thereby completing the NEPA requirements for this project.

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

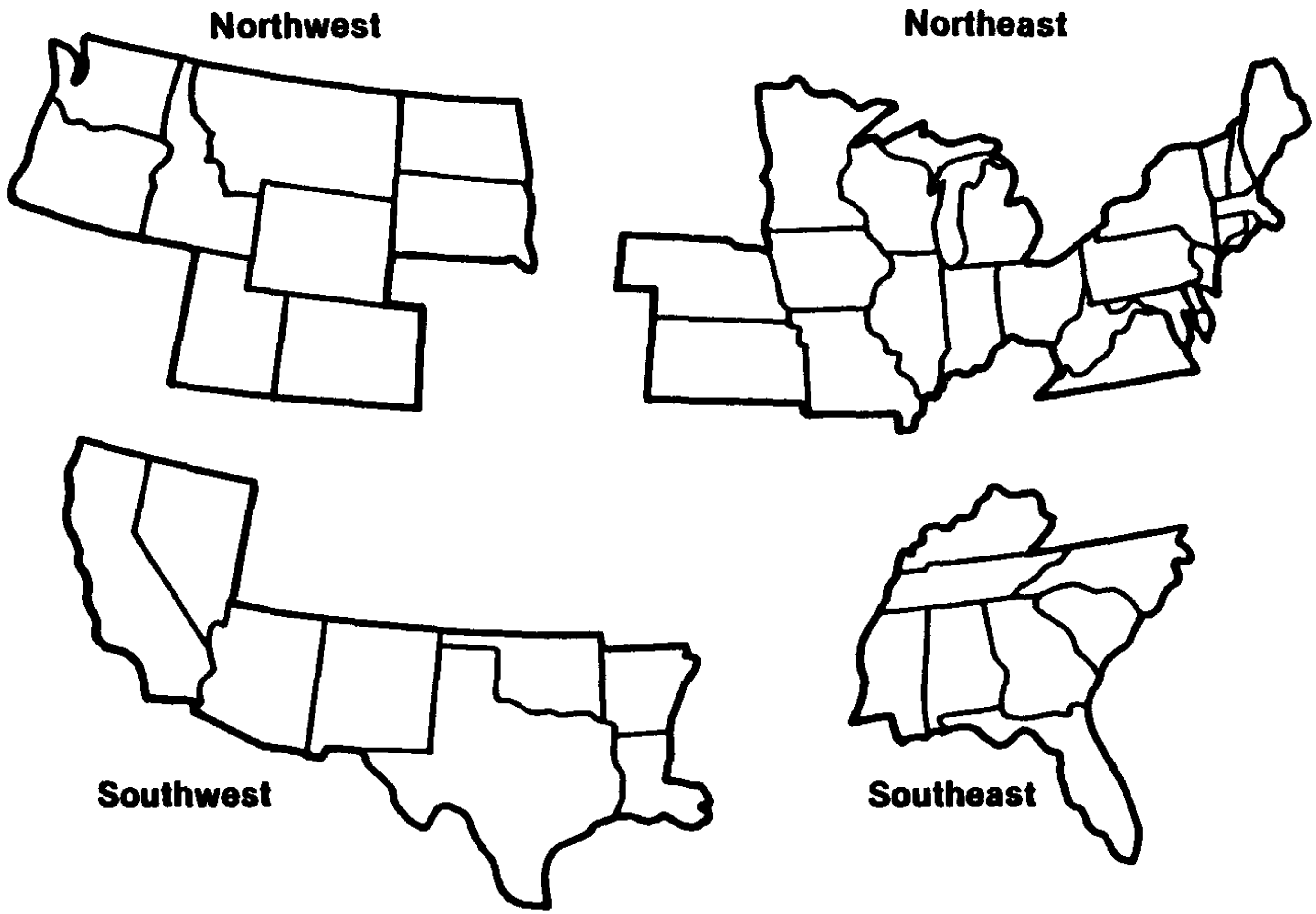

FIGURE 4. QUADRANTS FOR THE CONTIGUOUS UNITED STATES.

NOJ18,677

5.0 **PROJECT MANAGEMENT**

5.1 Overview of Management Organization

The project will be managed by SCS, Inc. A Project Manager is assigned to this project and will be the principal contact with DOE for matters regarding the administration of the Cooperative Agreement between SCS and DOE. All other participating subcontractor's organization will report to the SCS Project Manager. The Project Manager will report to the SCS ICCT Program Manager.

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

In addition to the DOE, the project will be co-funded by EPRI. The host site is Gulf Power Company's Plant Crist. Other organizations involved in this project include Radian Corporation, Dynagen, Roberson-Pitts, Southern Research Institute, Inc., and the catalyst suppliers.

A technical project review team consisting of personnel from SCS, Inc., Gulf Power, DOE, the Electric Power Research Institute (EPRI), and subcontractors will be assembled to provide timely input to and guidance for this ICCT project.

5.2 Identification of Respective Roles and Responsibilities

DOE

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

The DOE Contracting Officer will appoint a COTR who will be the authorized representative for all technical matters and will have the authority to issue "Technical Advice" which may:

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

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

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

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

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

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

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

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

Participant

The participant (SCS) will be responsible for all aspects of project performance under this Cooperative Agreement set forth in the Statement of Work.

The Participant's Project Manager is the authorized representative for the technical and administrative performance of all work to be performed under this Cooperative Agreement. He will be the single authorized point of contact for all matters between the Participant and the DOE. The Project Manager will report to the SCS ICCT Program Manager. The Program Manager will provide the link for this project to the executives of the Southern Electric System and will have final SCS executive management responsibility for execution of this project.

SCS's responsibilities for this project include the design, procurement, fabrication and installation of the demonstration equipment. SCS will develop the test program and participate in carrying it out, acquiring environmental permits, analyzing and evaluating data and preparing the final report.
Gulf Power Company will provide the host site, provide and produce data required to obtain necessary permits, coordinate the activities of the erection subcontractor, operate and maintain the equipment, and provide the test coal and other utilities required for the demonstration project.

The Electric Power Research Institute (EPRI) will provide co-funding and work with SCS to provide technical consultation and guidance based on experience gained at a 2.5 MWe SCR facility at the Arapahoe Station of Public Service of Colorado.

Dynagen will be responsible for flow modeling and will conduct a design review of the SCR facility ducts and reactors.

Roberson-Pitts will provide statistical analysis support for the project including test plan development and evaluation.

The Southern Research Institute will obtain the baseline flue gas composition, velocity and particulate measurements in support of the detailed design effort.

Radian Corporation will provide environmental consulting services, including EHSS data collection, preparation and implementation of an Environmental Monitoring Plan, and assist in acquiring permits for this project.

The catalyst suppliers will contribute to the project by providing technical information on the design of the reaction system needed to assure proper conditions for catalyst evaluation. This information will include the reactor design bases as well as host plant conditions such as available pressure drop and required inlet temperature. They will also supply the catalysts and perform analytical tests on their catalysts.

The maintenance subcontractor will provide full time personnel to maintain, calibrate and repair instrumentation and to provide expertise for the automated data acquisition system. The maintenance subcontractor will also supply personnel to maintain the mechanical and electrical equipment.

The testing subcontractor will provide the staff to document existing flue gas conditions at the demonstration site and the performance of the SCR plants. During operation of the demonstration plants the testing subcontractor will provide personnel to measure ammonia and sulfur trioxide in the flue gas as well as to periodically measure other materials, such as nitrous oxide, hydrogen chloride and particulate matter in the flue gas.

The interrelationship between the Participant, the government, and all other project sponsors are shown in Figure 5 and 6.

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 and their expected durations are:

Phase I Permitting and Preliminary Design (4 months)
Phase II Detailed Design and Construction (20 months)
Phase III Plant Operation, Evaluation, Reporting and Dismantling (28 months)

As shown in Figure 7, Phase I will start upon execution of the Cooperative Agreement. Phase II will start on completion of the Phase I and Phase III will start upon completion of Phase II. No pauses or overlaps are planned between phases.

Budget periods will be established. Budget period 1 includes the pre-award period and Phase I and II. Budget period 2 coincides with Phase III. Consistent with Public Law 100-202 as amended by Public Law 100-446, 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 SCS or its subcontractors and provided to DOE.

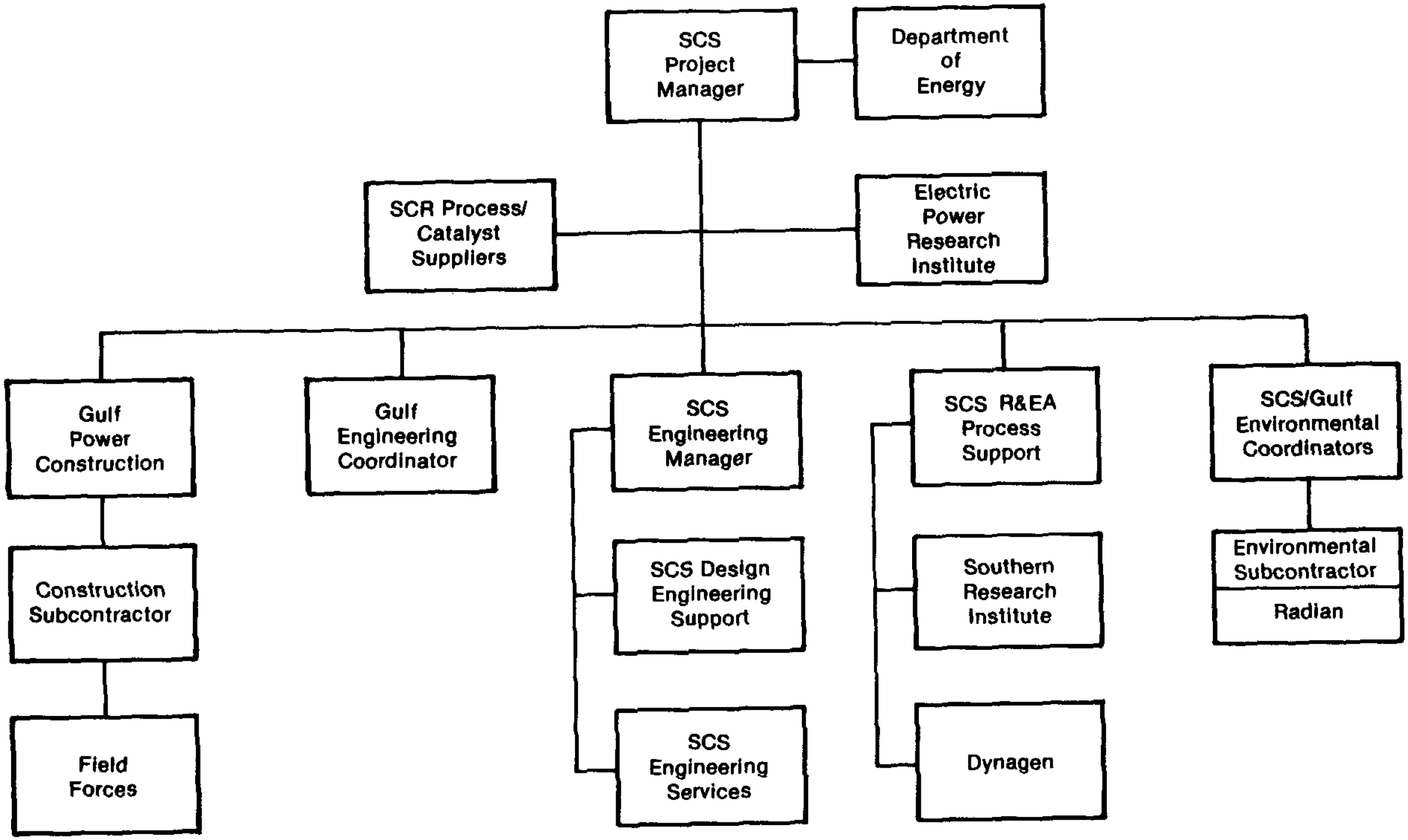

FIGURE 5. SCR DEMONSTRATION PROJECT ORGANIZATION DESIGN AND CONSTRUCTION.

NO/19,387

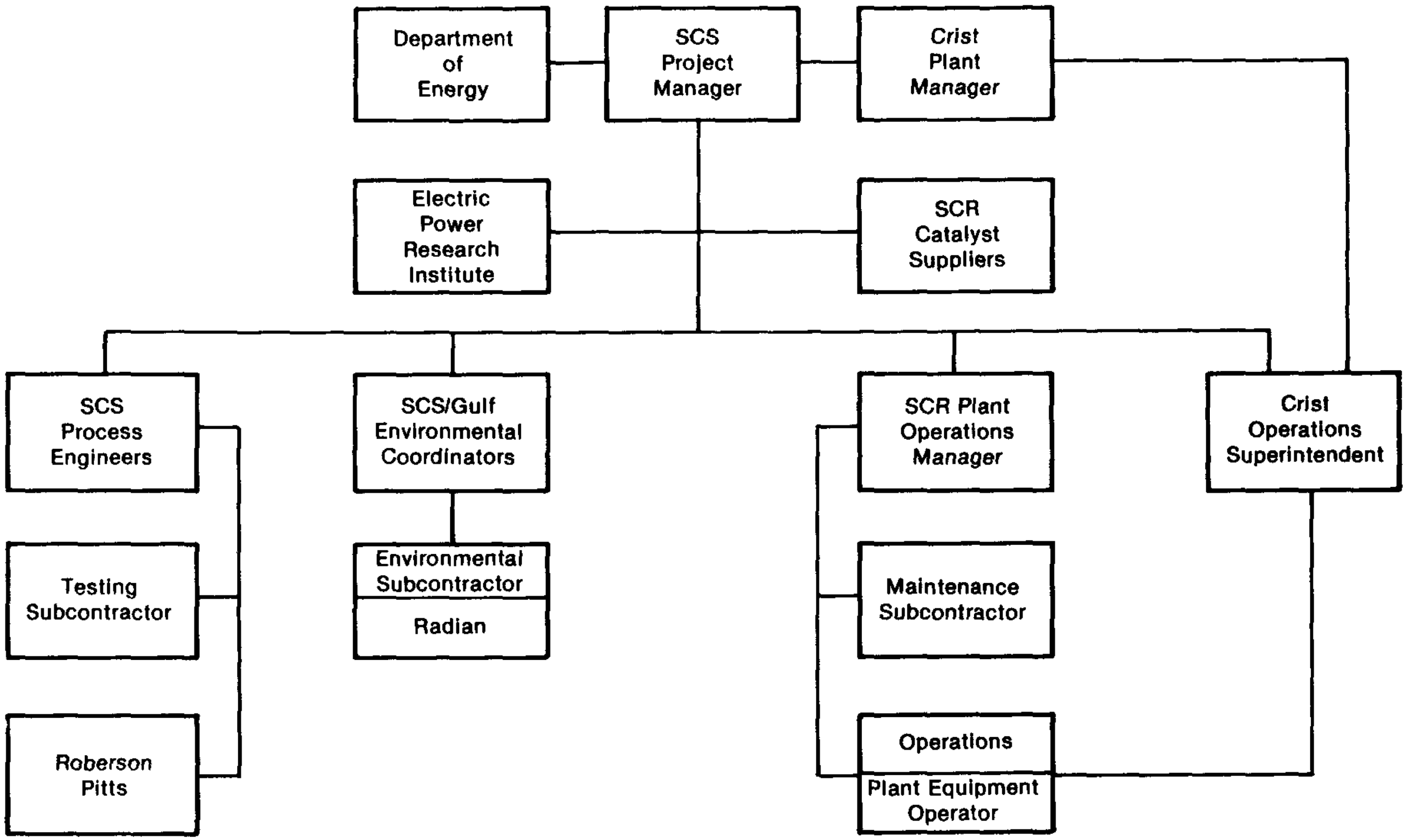

FIGURE 6. SCR DEMONSTRATION PROJECT ORGANIZATION OPERATION, MAINTENANCE AND TESTING.

NO./19,386

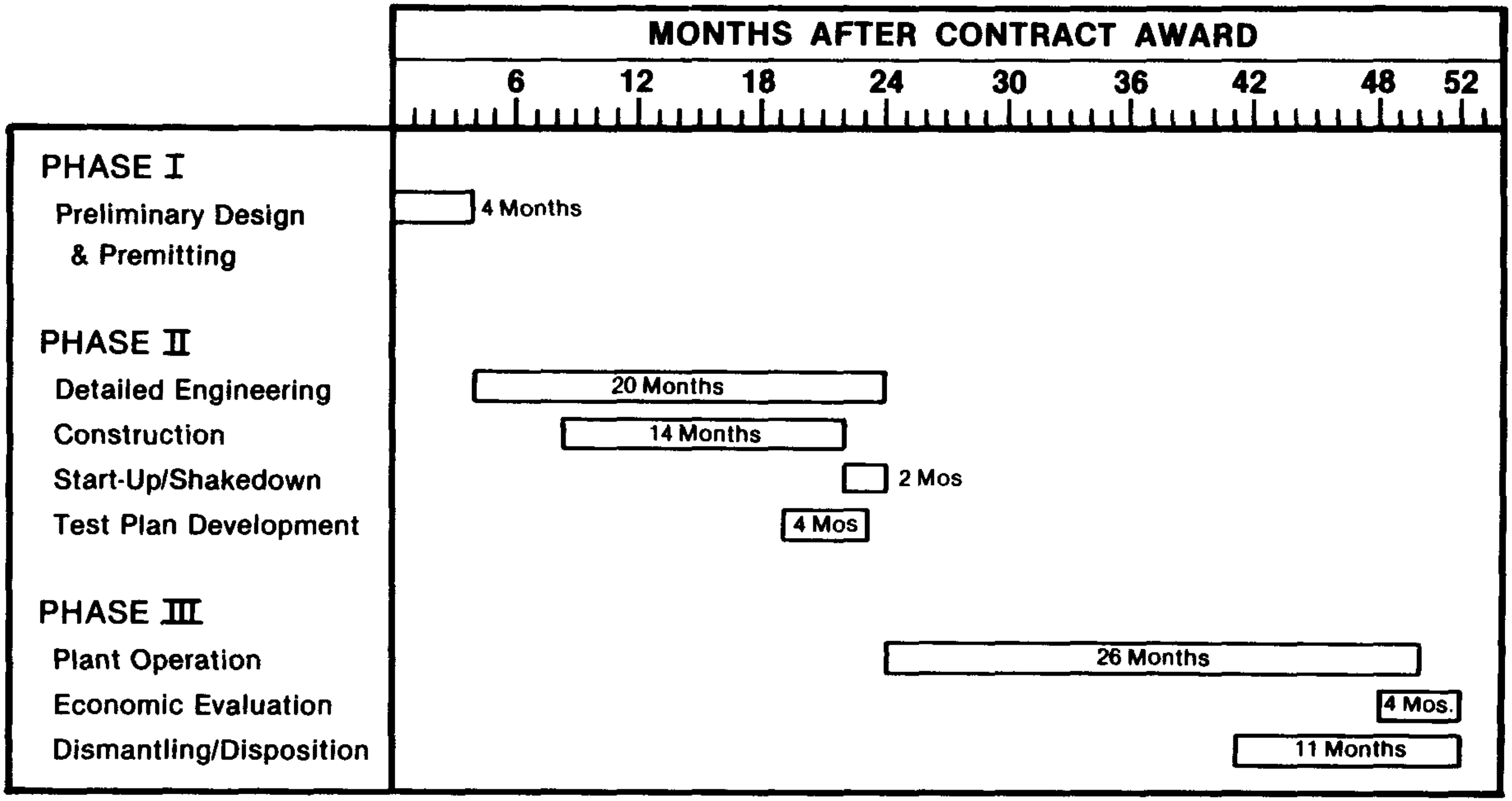

FIGURE 7. OVERALL SCHEDULE FOR SCR DEMONSTRATION PROJECT.

NO/19,385

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

The key agreements in 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 this Agreement.

- o Proprietary data, with certain exclusions, may be required to be delivered to the Government, with appropriate protective markings.

- o A patent waiver is expected to be granted by DOE giving SCS ownership of foreground inventions, subject to the march-in rights and U.S. preference found in P.L. 96-517.

- o The government has assumed any patent infringement liability that may arise from testing of catalyst under this project.

5.5 Procedures for Commercialization of the Technology

This demonstration project will result in an extensive data base on the SCR process as applied to U.S. high-sulfur coals. During the course of the project, data will be collected on a number of catalyst formulations in both standard honey comb and plate geometric shapes. This data will include catalyst effectiveness as well as its tendency to promote the formation of NH_4HSO_4. Information on catalyst life, which is a major economic consideration, will be obtained as well as information on the effects of NH_4HSO_4 on downstream equipment. In short, the data base will allow prospective users to evaluate the SCR technology's cost and efficiency for their boilers.

The successful completion of the proposed Plant Crist demonstration and dissemination of the program data to the affected industry is the first step in the commercialization process. By acquiring this data, industry's confidence in the technology will improve. Subsequent commercialization is expected to proceed as dictated by existing market conditions and as required by additional regulatory requirements. It is expected that catalyst suppliers and their licensees (e.g. engineering firms) will promote the actual commercialization of the technology outside the Southern Company's service area. Adequate design and manufacturing capacity is available from the catalyst manufacturers to satisfy market requirements.

6.0 PROJECT COST AND EVENT SCHEDULING

6.1 Project Baseline Costs

The total estimated cost for this project is $15,574,355. The Participants' contribution and the Government share in the costs of this project are as follows:

	Dollar Share ($)	Percent Share (%)
PRE-AWARD		
Government	171,097	48.32
Participant	182,995	51.68
PHASE I		
Government	328,530	48.32
Participant	350,750	51.68
PHASE II		
Government	4,207,361	47.76
Participant	4,602,112	52.24
PHASE III		
Government	2,818,350	49.17
Participant	2,913,510	50.83
TOTAL PROJECT		
Government	7,525,338	48.32
Participant	8,049,017	51.68
TOTAL	15,574,355	100.00

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

DOE	$ 7,525,338
SCS	6,049,017
EPRI	2,000,000
TOTAL	$15,574,355

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 fifty-two months after award of the Cooperative Agreement. Conceptual design and gathering environmental data for the NEPA process will be accomplished by the Participant prior to the Cooperative Agreement.

Phase I which involves permitting and development of an Environmental Monitoring Plan will take four months. Phase II will start at the end of Phase I and will last twenty months overall. Detailed engineering will take twenty months. Construction will start four months after detailed design and will last for fourteen months. Start-up/shakedown will commence in the twenty-second month, immediately following completion of construction activities and last for two months. Immediately upon completion of Phase II operation of the facility will begin and last for twenty-six months. Dismantling/Disposition will start after forty-one months and will take eleven months. The final report will be completed at the end of the fifty-two month project.

6.3 Repayment Plan

Based on DOE's recoupment policy as stated in Section 6.4 of the PON, DOE is to recover an amount up to the Government's contribution to the project. The Participant has agreed to repay the Government in accordance with the stated Recoupment/Repayment Plan to be included in the final negotiated Cooperative Agreement.