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Comprehensive Report to Congress Clean Coal Technology Program

Demonstration of Innovative Applications of Technology for the CT - 121 FGD Process

A Project Proposed By: Southern Company Services, Inc.

February 1990

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

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY

In December 1987, Public Law No. 100-202, as amended by Public Law No. 100-446, provided $575 million to conduct cost-shared Innovative Clean Coal Technology (ICCT) projects to demonstrate emerging clean coal technologies that are capable of retrofitting or repowering existing facilities. To that end, a Program Opportunity Notice (PON) Number DE-PS01-88FE61530 was issued by the Department of Energy (DOE) in February 1988, soliciting proposals to demonstrate technologies capable of commercialization in the 1990s, that are more cost effective than current technologies and capable of achieving significant reductions in sulfur dioxide (SO_2) and/or nitrogen oxides (NO_x) emissions from existing coal burning facilities, particularly those that contribute to transboundary and interstate pollution.

In response to the PON, 55 proposals were received by the DOE in May 1988. After evaluation, 16 projects were selected for 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 the generating plant capacity.

One of the sixteen projects selected for funding is a project proposed by Southern Company Services, Inc. (SCS), entitled "Demonstration of Innovative Applications of Technology for the CT-121 FGD Process (CT-121)". The CT-121 process is a wet flue gas desulfurization (FGD) process that removes sulfur dioxide (SO_2) and particulates, produces a salable by-product gypsum and eliminates solid waste production. This process removes SO_2 and particulate matter using a unique, limestone-based scrubber called the Jet Bubbling Reactor (JBR). In this process, the flue gas enters the scrubbing solution in the JBR. The SO_2 in the flue gas is absorbed and forms calcium sulfite ($CaSO_3$). Air is bubbled into the bottom of the solution to oxidize the $CaSO_3$ to calcium sulfate ($CaSO_4$), or gypsum. The JBR is designed to allow time for the oxidation of $CaSO_3$ and to provide time to grow the gypsum crystals. The slurry, which is continuously withdrawn from the JBR, is dewatered in a gypsum stack. The stacking techniques involves filling a dyked area with gypsum slurry. Gypsum solids settle in the dyked area, and clear water overflows to a retention pond. The clear water from the pond is returned to the process.

The CT-121 process is in commercial use in Japan and in the United States. At the University of Illinois, a 45 MWe unit began operations in 1988 on a stoker boiler, which is not a typical utility boiler. In Japan, commercial CT-121 units are used to treat the flue gas from boilers which burn oil or low-sulfur, low-ash coal without prior particulate removal. The purpose of this ICCT project is to demonstrate the process on high-ash and high-sulfur, U.S. coal using several design modifications that will reduce the estimated cost of the present CT-121 process applications by 23% for power plant retrofit applications and 50% for new power plant installations. This will be accomplished while maintaining 90% SO_2 removal and 99+% particulate removal from the flue gas and simultaneously producing a commercial-grade gypsum.

The major cost-reducing design changes to be demonstrated are:

- o Using less expensive materials of construction
- o Eliminating a spare scrubber module
- o Eliminating flue gas reheat
- o Combining SO_2 and particulate removal in a single vessel

Utility scale units with the CT-121 process currently use JBRs and associated outlet ductwork constructed of stainless steel, which is relatively expensive. For this demonstration project, the JBR and outlet duct will be constructed of fiberglass-reinforced plastic (FRP).

The federal and state regulations normally require that spare scrubbers be installed on utility flue gas desulfurization (FGD) systems. This project is intended to demonstrate that the CT-121 process using a fiberglass-reinforced plastic JBR is reliable and effective enough to eliminate the need for a spare scrubber.

Another cost-saving modification to be demonstrated in this project is the elimination of flue gas reheat downstream of the scrubber. The flue gas leaving any scrubber is at its dew point. Without reheating, subsequent cooling in the ductwork and stack causes moisture to condense into small droplets that absorb traces of SO_2 and form acid droplets that cause severe corrosion problems in ducts and stacks. In addition, these droplets tend to fall near the base of the stack, causing damage to structures and vehicles. To prevent these problems, this project will use operating techniques and mist eliminators that will eliminate the need for costly reheating of the flue gas.

The final cost-saving modification is the simultaneous removal of SO_2 and particulates in the JBR. Typically, an electrostatic precipitator or baghouse is used upstream of the scrubber to remove particulates. In the CT-121 process, 90% of the SO_2 and 99^{+}% of the particulates from the incoming flue gas are removed in the same JBR. When used with new power plants, the elimination of the ESP or baghouse will result in substantial cost reductions including lower electrical power usage. Thus, the CT-121 process provides a cost effective alternative to conventional wet FGD systems.

This project will be performed at the Georgia Power Company's Plant Yates, Unit Number 1. This plant is located in west central Georgia, about 40 miles southwest of Atlanta near Newnan and Carrollton as shown in Figure 1. The plant is presently in commercial operation. The CT-121 process to be installed for this demonstration project will treat the whole flue gas stream generated by the 100 megawatt electric (MWe) Unit Number 1 boiler, which will use a 2.5% sulfur content blend of Illinois No. 5 and 6 coals. This boiler size was selected because it is a full-scale operating commercial unit that is sufficiently small to minimize project costs.

The demonstration project will be conducted over an 81-month period and the project activities include environmental monitoring, permitting, design, construction, operation, gypsum by-product evaluation, and dismantling of the demonstration equipment. The total estimated project costs are $35,843,678. The co-funders are SCS ($11,297,032), DOE ($17,546,646), and the Electric Power Research Institute (EPRI) ($7,000,000). The project is expected to start in early 1990 and be completed in late 1996.

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

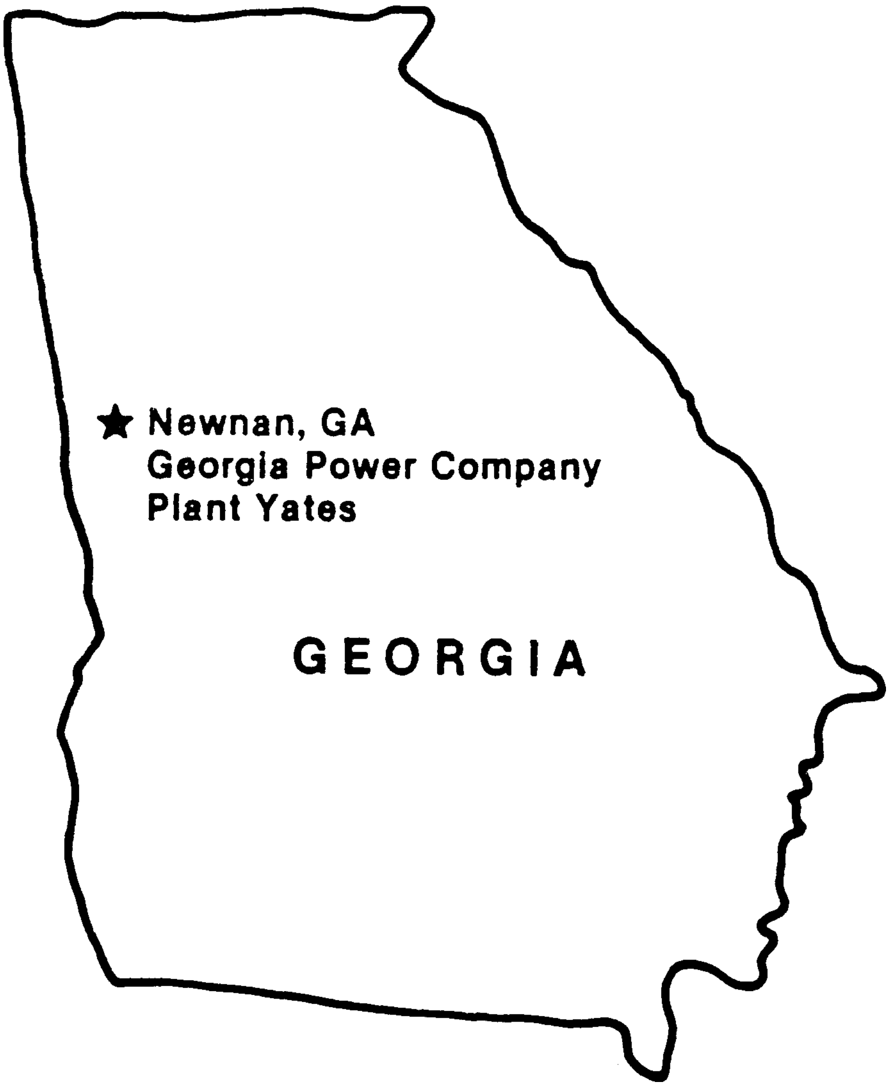

FIGURE 1. SCS CT-121 DEMONSTRATION PROJECT LOCATION.

Purposes" (the "Act"). This Act provided funds for the purpose of conducting cost-shared clean coal technology projects to demonstrate emerging clean coal technologies that are capable of retrofitting or repowering existing facilities and authorized DOE to conduct the ICCT Program. Public Law No. 100-202, as amended by Public Law No. 100-446, provided $575 million, which will remain available until expended, and of which (1) $50,000,000 was available for the fiscal year beginning October 1, 1987; (2) an additional $190,000,000 was available for the fiscal year beginning October 1, 1988; (3) an additional $135,000,000 will be available for the fiscal year beginning October 1, 1989; and (4) $200,000,000 will be available for the fiscal year beginning October 1, 1990. Of this amount, $6,782,000 will be set aside for the Small Business and Innovative Research Program, and is unavailable to the ICCT Program.

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

Public Law No. 100-202 directed DOE to prepare a full and comprehensive report to Congress on each project to receive an award under the ICCT Program. This report is in fulfillment of this directive and contains a comprehensive description of the CT-121 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 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 and award. The CT-121 proposal submitted by SCS was one of these proposals.

3.0 TECHNICAL FEATURES

3.1 Project Description

In a typical FGD-equipped utility boiler system, the flue gas leaving the particulate removal equipment flows to the FGD system. The flue gas is contacted with a lime or limestone slurry in a countercurrent spray tower and the clean flue gas exits the top of the spray tower after passing through a demister. The clean flue gas, saturated with water vapor, is then reheated to avoid condensation in the downstream duct work and stack. The clean flue gas is then discharged to the atmosphere through the stack.

The SO_2 in the flue gas reacts with the calcium-based sorbent to form calcium sulfite in the absorber. In some installations, the calcium sulfite is oxidized in a separate vessel to form calcium sulfate, which is more amenable to landfill disposal. In these FGD systems, steel and other alloys are the materials of construction. Due to corrosion, erosion, and operation problems, regulations require that spare scrubber modules be installed. The standard CT-121 process uses a Jet Bubbling Reactor (JBR) (constructed of stainless steel) for the absorber and carries out the oxidation of the calcium sulfite in the absorber.

The Southern Company Services project will demonstrate several design innovations to the basic CT-121 process. These innovations, if successful, will result in substantial cost reductions for CT-121 process applications in both existing and new power plants. These cost reductions are estimated at 23% for retrofit plants and 50% for new plants.

The design modifications to the CT-121 process that will be demonstrated during this project are:

- o Using fiberglass reinforced plastic FRP for the JBR, outlet duct, and chimney.

- o Eliminating the need for flue gas reheat.

- o Eliminating the need for a spare JBR.

- o Combining particulate and SO_2 removal in one vessel.

The CT-121 system incorporating these changes will be installed to treat the flue gas from Unit No. 1 of the Georgia Power Company's Plant Yates. This 100 MWe unit is currently used as an intermediate load unit. Particulate control is currently accomplished by an electrostatic precipitator.

During this demonstration project, SCS will also install a limestone storage and processing area, a gypsum storage/disposal area, and a new, dedicated 250-foot-tall stack to vent the flue gas from the CT-121 process.

Following completion of the installation, a 23-month operating period is proposed to demonstrate the effectiveness of the design innovations used in this demonstration project. At the end of the demonstration project, the facility will be dismantled.

During this timeframe, Unit No. 1 at Plant Yates will burn a blend of Illinois No. 5 and Illinois No. 6 coals. These coals will be supplied by an Arch of Illinois Co. mine located in Perry County and an Old Ben Coal Company mine located in Franklin County. The target blend (75% Arch of Illinois coal, 25%

Old Ben Company coal) will have a sulfur content of 2.5%.

This project, if successful, will demonstrate that the design changes identified above result in the expected cost benefits and that the high reliability of the process can be maintained when used on boilers that burn high-sulfur, high-ash U.S. coals. Additionally, this project will show that the process can remove 90% of the SO_2 and 99+% of the particulates. This project will also demonstrate the ability of the CT-121 process to produce a commercial grade of gypsum. If this material can be marketed successfully, it will reduce or eliminate the need for waste disposal. If marketing is not successful, the waste material produced by this process will be disposed of more easily than waste from conventional FGD systems, because its larger particles are more readily dewatered.

3.1.1 Project Summary

Project Title:	Demonstration of Innovative Applications of Technology for the CT-121 FGD Process
Proposer:	Southern Company Services, Inc.
Project Location:	Georgia Power Company, Plant Yates Newnan, Georgia -- Coweta and Carroll Counties
Technology:	Flue Gas Desulfurization
Application:	Coal-Fired Utility Boilers; New or Retrofit
Types of Coal Used:	Illinois No. 5 and No. 6; 2.5% Sulfur
Product:	Environmental Control Technology
Project Size:	(360,000 scfm capacity)
Project Start Date:	November 1, 1989[1]
Project End Date:	December 1, 1996

[1] In accordance with the PON provision, the participant is proceeding with the project at its own risk pending execution of the Cooperative Agreement by the Government.

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 Southern Company Services, Inc.
Estimated Project Cost:	$35,843,678

Project Cost Distribution:

Participant Share(%)	DOE Share(%)
51.05	48.95

3.2 CT-121 Process

3.2.1 Overview of Process Development

Chiyoda Corporation began its FGD development work in the early 1970s with the CT-101, process. This process, sold commercially in Japan, produced a dilute sulfuric acid that was neutralized with limestone to produce gypsum. Although the CT-101 process worked well, Chiyoda developed the CT-121 process to provide a more cost-effective FGD process. The CT-121 process combines SO_2 removal, limestone dissolution, gypsum crystal growth, and particulate removal in a single vessel.

Pilot work in Japan led to the installation of a prototype of the CT-121 process at Gulf Power Company's Plant Scholz, which operated on the flue gas of a coal fired boiler and was rated at 23 MWe. This pilot plant started up in late 1978 and operated successfully until May of 1979. This test program in the U.S. was followed in 1982 by the installation of a small (85 MWe) commercial unit in Japan that treated the flue gas produced by combustion of a heavy oil. Since then, an additional six plants were built in Japan to treat the flue gas from heavy oil, asphalt or coal combustion at sizes ranging from 75 to 250 MWe. These plants were all built without a spare JBR. They are all constructed of 316 stainless steel, which is an expensive material of construction.

The first commercial CT-121 plant to be built in the United States started up in 1988 at the University of Illinois. This 45-MWe equivalent plant uses a JBR constructed of FRP, has a coal-fired, stoker type of boiler and is equipped with both an electrostatic precipitator (ESP) and a prescrubber. Currently, no utility boilers operate with scrubbers constructed of FRP. However, vessels of the size required for this demonstration have been used successfully in the chemical industry. This demonstration project will show that FRP is suitable as the construction material for a scrubber and selected ductwork on a fully commercial coal-fired utility boiler.

The CT-121 process has operated at three installations without upstream particulate removal. However, these boilers were fired with only low-ash fuels. The largest coal-fired operating unit, without a prescrubber or ESP, is a 1 MWe CT-121 pilot plant in Japan. The SCS project will demonstrate full-scale operation on a pulverized coal-fired boiler without upstream particulate removal.

As described above, the basic CT-121 process has been commercially proven in Japan. These Japanese installations generally use low-sulfur coals. However, particulate removal is not combined with SO_2 removal when high-ash coals are used in these Japanese installations. Certain features of this demonstration project, such as combining SO_2 and particulate removal when burning high-sulfur, high-ash fuels, have been proven only at the pilot-plant scale. FRP has been used to build the JBR only on a small, non-utility boiler and the process has not been combined with a "wet" stack. This demonstration project will be the first demonstration which integrates all these features at commercial scale on high-ash, high-sulfur U.S. coals.

3.2.2 Process Description

CT-121 is a second-generation FGD process that employs a unique absorber design called a Jet Bubbling Reactor (JBR) to combine conventional limestone FGD chemistry, forced oxidation, and gypsum crystallization in one reaction vessel. The process is designed to operate in a medium acid solution, where limestone is completely soluble and where the sulfite resulting from SO_2 absorption can be oxidized completely to sulfate. Attrition of gypsum crystals caused by large centrifugal recycle pumps is eliminated. As a result of these improvements, problems such as poor sludge quality and chemical scaling, which frequently occur in conventional limestone FGD processes, are eliminated.

Process Concept

In conventional wet FGD systems, the flue gas is passed through a spray tower where it is countercurrently contacted with a limestone slurry. This produces a waste sludge consisting of $CaSO_3$ and $CaSO_4$, with $CaSO_3$ as the main product. The sludge produced contains very small particles that are very difficult to dewater. This material has no potential market value and is disposed of in large settling ponds. Some systems include a forced oxidation step, carried out in a vessel separate from the absorber, to produce $CaSO_4$. These systems typically use large centrifugal pumps to recirculate the slurry, leading to crystal attrition.

Generally, the small gypsum crystals produced are not successfully marketed and are disposed of at landfills. The basic components of SO_2 dissolution, reaction with a calcium-based sorbent and solids disposal, are common to virtually all commercial wet-FGD systems. The CT-121 process performs these operations, but does so in a manner that is more cost effective and under conditions that eliminate some of the problems (e.g., scaling) associated with some of the existing processes.

As shown in Figure 2, flue gas leaving the ESP is introduced directly into the precooler where it is cooled and saturated with water, and then introduced into the JBR through a gas inlet chamber (lower deck). From the lower deck, the gas contacts the absorbing slurry through vertical sparger pipes. Absorbed SO_2 is completely oxidized by the addition of air at the bottom of the JBR. Cleaned gas flows through vertical risers to the outlet gas chamber (upper deck), through mist eliminators (not shown), and then exits through the stack.

Limestone slurry is pumped directly into the JBR to neutralize the absorbing slurry and to precipitate the sulfate ions as gypsum. (The flow diagram shows the addition of ground limestone, but a wet grinding circuit would be included in most installations in the U.S.) Nearly stoichiometric amounts of limestone to SO_2 are added to maintain the pH between 3 and 5. Under these conditions, the limestone utilization will be greater than 99%.

The gypsum solids concentration in the JBR underflow is maintained between 10 and 30% by weight, by withdrawing a slip stream to remove gypsum and recycling the clear liquid to the JBR. Depending on its end use, the gypsum crystals may be dewatered by gravity, filtration, or centrifugation. Gypsum stacking, a type of gravity separation, is the preferred method of handling and disposal. The

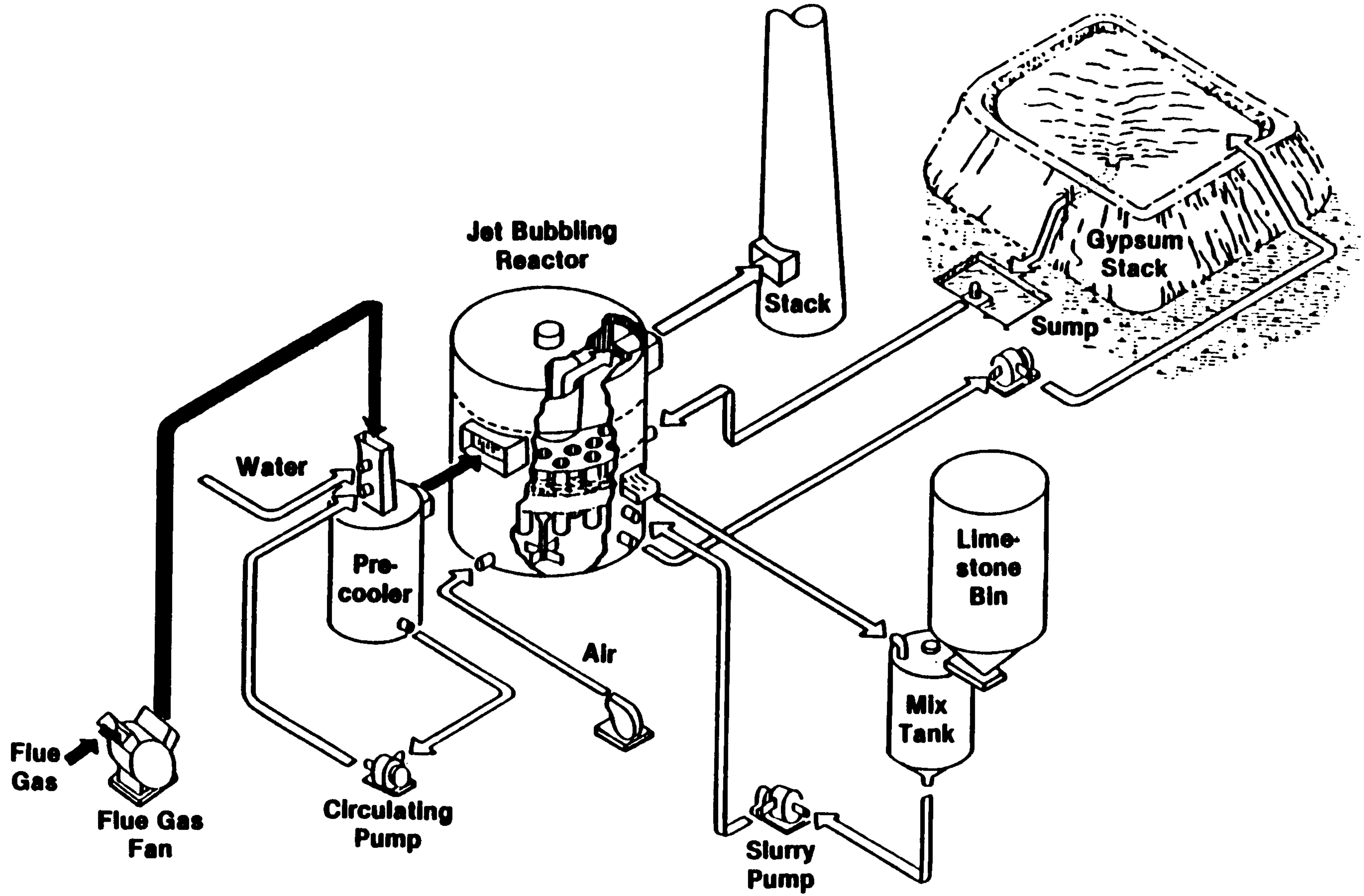

FIGURE 2. PROCESS FLOW DIAGRAM OF COMMERCIAL CT-121 PROCESS.

JBR underflow stream is pumped to a settling basin on top of the gypsum stack where the solid settles to form a product that is more than 75% solids. The decanted liquid is collected in a perimeter ditch and then returned to the process.

Jet Bubbling Reactor (JBR)

The JBR is the central feature of the CT-121 process. A detailed view of this vessel is shown in Figure 3. The untreated flue gas enters an enclosed plenum chamber formed by an upper deck plate and a lower deck plate. Sparger pipe openings in the lower deck plate force the gas into the slurry contained in the jet bubbling (froth) zone of the JBR vessel. After bubbling through the slurry, the gas flows upward through gas risers, which pass through both lower and upper deck plates. Entrained liquid in the gas disengages in a second plenum above the upper deck plate, and the cleaned gas passes out of the JBR through a mist eliminator to the stack. The flue gas velocity in the JBR above the slurry and in the disengaging chamber is very low, so minimum slurry is entrained with the cleaned flue gas that passes through the mist eliminator.

Figure 3 shows that the slurry in the JBR is actually divided into two "zones": (1) the absorption zone, also called the jet bubbling or froth zone, and (2) the reaction zone. This concept is an important design feature, because four processes are occurring simultaneously within the two zones of the JBR vessel:

- Absorption of SO_2
- Oxidation of sulfite to sulfate (both acidic species)
- Neutralization
- Growth of gypsum crystals

The Absorption Zone

The absorption or jet bubbling zone is a continuous layer of froth composed of continually forming and collapsing bubbles of slurry. This froth layer is formed when the untreated flue gas enters the JBR at normal duct velocity and is accelerated as it passes through the multiple sparger pipes in the lower deck and bubbles beneath the surface of the slurry. This action is responsible for many of the advantages offered by the CT-121 FGD process.

The froth layer provides the gas-liquid interfacial contact area where SO_2 in the flue gas dissolves in the liquid film on the surfaces of the bubbles. Fly ash

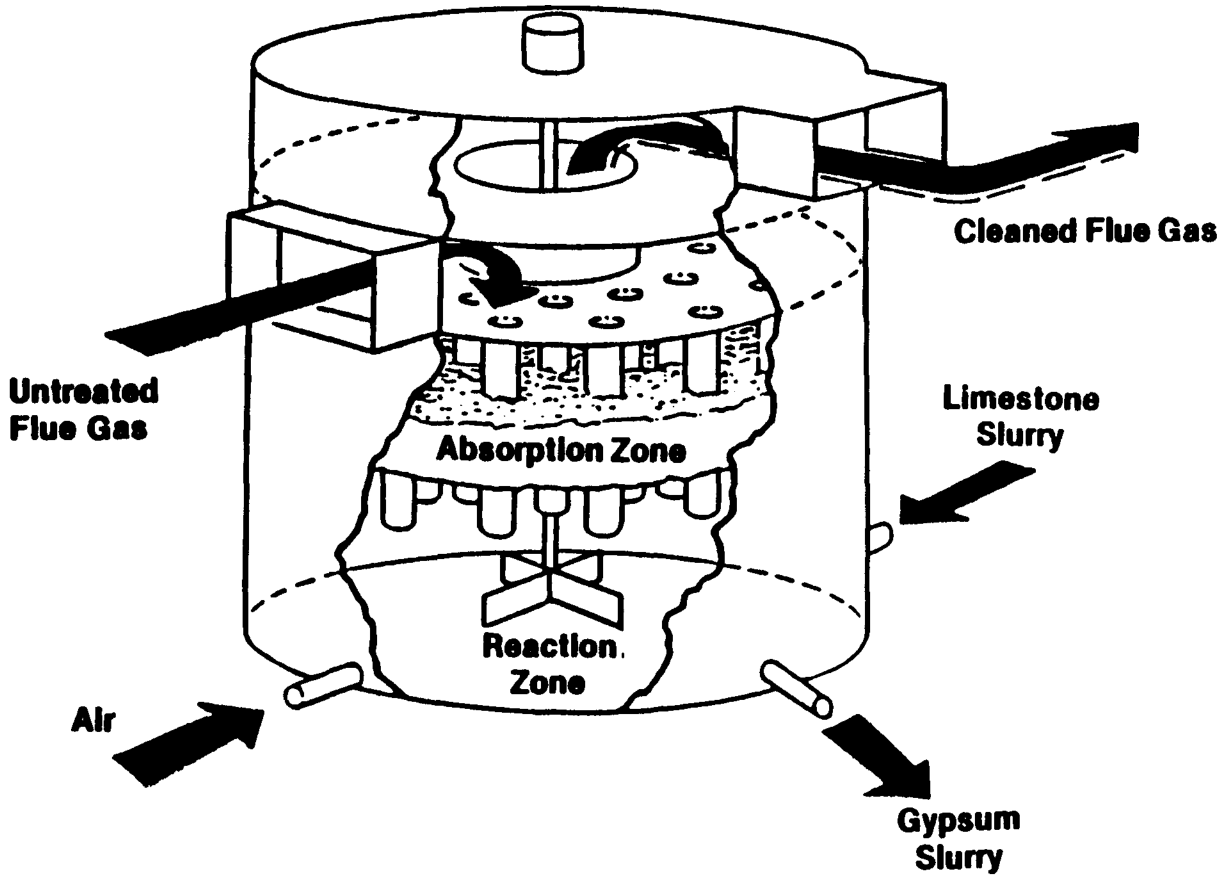

FIGURE 3. SCHEMATIC OF JET BUBBLING REACTOR.

in the gas likewise contacts the liquid film and is removed. The bubbles provide a greatly extended interfacial area and make the JBR an extremely efficient contactor.

SO_2 removal efficiency is a function of the depth of submergence of the spargers and the pH of the slurry in the JBR. The submergence depth can be varied between 4-16 inches, and, for normal pH set points, depths in excess of 8 inches result in SO_2 removal efficiency greater than 90%. All four of the processes occurring simultaneously in the JBR are initiated in the jet bubbling zone and are completed in the reaction zone below the froth zone.

The Reaction Zone

The bulk of the slurry in the JBR resides in the reaction zone. The JBR is designed to provide a liquid residence time of between 10 and 30 hours in the reaction zone which allows time to complete the reactions initiated in the jet bubbling zone. This design allows sufficient time for (1) dissolution of the oxygen from the oxidizing air sparged into the slurry at the bottom of the reaction zone, (2) oxidation of dissolved sulfite to sulfate, (3) limestone dissolution, and (4) gypsum crystal growth. While some of these reactions such as oxygen dissolution proceed rapidly, others such as crystal growth and sulfite oxidation are relatively slow.

Internal Liquid Circulation

Conventional wet FGD processes depend on large recirculation pumps, piping and separate reaction vessels to contact the gas with slurry and to provide the residence time required for the chemical reactions. In the JBR, the slurry circulation required to transport reagent and products between the jet bubbling zone and the reaction zone is supplied by a large-diameter, low-speed turbine agitator and by supplemental mixing from the flue-gas spargers and oxidation-air spargers. No external slurry circulation is required. This slurry circulation technique reduces the attrition of the gypsum crystals.

3.2.3 Application of the Process in the Proposed Project

This project is intended to demonstrate the technical and economic viability of the CT-121 process improvements, which are projected to significantly reduce costs while maintaining the effectiveness and reliability of the process when applied to high-sulfur coals. The basic CT-121 process has been successfully proven in a number of commercial-scale applications.

For this demonstration project, a 100 MWe CT-121 process unit will be designed and constructed utilizing several cost-saving modifications. In particular, the JBR, which is the heart of the CT-121 process, will be constructed of FRP to reduce cost. Because FRP has superior resistance to corrosion and erosion, the use of FRP will permit desulfurization of the flue gas without prior hydrogen chloride (HCl) and particulate removal since chlorides cause corrosion in many alloys and fly ash solids are quite erosive. These problems should be eliminated with an FRP scrubber. Current environmental regulations require a spare scrubber for all wet FGD processes due to corrosion, erosion, and operational problems commonly encountered in wet FGD processes.

The use of a wet stack, one where the flue gas contains droplets of condensed liquid, is also part of the cost-cutting modifications to the design of the CT-121 process that will be used in this demonstration project. Generally, the combined changes to the CT-121 process will, if successful, reduce costs of the flue gas scrubber by an estimated 23% for retrofit applications and 50% for new applications while maintaining a sulfur removal efficiency of 90% or greater. Thus, the CT-121 technology will reduce costs while meeting New Source Performance Standards (NSPS) requirements.

3.3 General Features of the Project

3.3.1 Evaluation of Developmental Risk

As with any new or redesigned technology, there is an element of risk associated with its continued development. However, as described earlier, the basic CT-121 process has been well-proven by its commercial use in Japan using oil and low-ash, low-sulfur coal. In addition, the idea for replacing the stainless steel JBR with one constructed of FRP is based upon the use of similar large vessels in the chemical industry. The use of the JBR without upstream particulate removal has been demonstrated in Japan at the commercial scale with low-ash fuel and at the pilot scale with higher-ash fuels. However, these pilot-scale tests with higher particulate loading carried out last year in Japan were short-term tests. The small scale and short term of these tests introduce the risk of relying on limited data taken from the operation of a unit only one-hundredth the size of the demonstration plant. The data on high-sulfur fuels is also limited.

In addition, there are risks associated with the use of FRP and simultaneous sulfur dioxide/particulate removal. The success of FRP in this application is dependent upon obtaining a proper FRP design and high-quality fabrication and construction. The lack of utility experience for FRP scrubbers introduces an element of risk. The use of an experienced company to design, fabricate, and install the FRP JBR decreases this risk. Full-ash loading (i.e. no prior particulate removal) to the JBR also introduces another element of risk. The effect of ash dropout at the JBR inlet and the possible sparger tube erosion and plugging is also a potential problem when flue gas with high-particulate loading is introduced to a full-sized JBR.

When reheat is eliminated, the successful operation of a wet fan operating downstream of the absorber poses some risk as do problems with acid fallout near the stack. Several existing conventional FGD installations operate successfully with wet fans and stacks. These units have experienced fan problems due to particulate carryover from the conventional FGD absorber vessel. A system based on the CT-121 process should avoid these problems due to more efficient particulate removal in the absorber and a more efficient mist eliminator design.

If SO_2 and particulate removal are successfully combined, the quality of the gypsum may be degraded making its sale more difficult. This would, however, have no impact on performance but would constitute an economic risk.

Since the changes to the CT-121 process are based on commercial experience, pilot-plant tests, and the experience of the chemical industry, a low to moderate risk has been assigned to this project. It is believed that any technical risks associated with this project can be resolved with appropriate design and operating procedures.

3.3.1.1 Similarity of the Project to Other Demonstration/Commercial Efforts

Commercially available FGD processes for use with high-sulfur coals include, among others, conventional wet limestone, forced oxidation limestone, Wellman-Lord, Saarberg-Holter, dual alkali, and wet lime. These systems are generally comparable in sulfur removal performance; the major differences are in the areas of costs, sludge characteristics, system reliability, chemical utilization, etc. The conventional wet limestone system is often selected as a reference system when comparing FGD processes, and it is selected here for comparison with the CT-121 process.

In the conventional wet limestone process, a limestone slurry solution is used in a spray tower to absorb SO_2, forming a calcium sulfite/sulfate sludge. The advantages of this system are its demonstrated performance in a wide range of applications and in its use of an abundant and low-cost absorbent. The system can generally meet the SO_2 reduction requirement for all types of coals, but if not operated properly, it is subject to equipment scaling, plugging, corrosion, and erosion.

Another second-generation, wet FGD system was selected from the proposals received for the ICCT Program. This system, proposed by Pure Air and developed by Mitsubishi Heavy Industries, uses a co-current spray tower instead of a JBR. In the system proposed by Pure Air, the oxidation of the $CaSO_3$ takes place in the enlarged base of the spray tower.

The Pure Air Project and many commercial wet FGD systems are somewhat similar to the CT-121 process. However, the JBR-FRP construction and combined SO_2 and particulate removal system make the CT-121 unique.

3.3.1.2 Technical Feasibility

As mentioned previously, the CT-121 process is operating commercially in a number of Japanese power plants. These installations use reaction vessels (JBRs) constructed of stainless steel and either treat a flue gas produced by a low-ash fuel or are operated downstream of particulate removal equipment. The process has, however, operated successfully for short duration at the pilot scale to treat flue gas produced by a high-ash fuel. None of the Japanese installations uses a spare JBR.

The use of FRP to construct a JBR of the size required for this project has not been demonstrated in the utility industry. FRP has been used successfully to construct similar sized vessels in the chemical industry. However, the JBR at the University of Illinois is designed and constructed of FRP and is sized to handle flue gas approximately equal to that of a 45 MWe boiler. Since the horizontal cross-sectional area will be held proportional to flow, the demonstration-project JBR will have a diameter approximately one and one half times that of the unit in Illinois.

Future designs could require the installation of units that reach or exceed 1000 MWe, and it is expected that the diameter of the JBRs will be increased to maintain approximately the same gas flow per cross-sectional area until a practical limit, as indicated by chemical plant experience, is reached. At that point, parallel absorber modules will have to be used. This project will provide needed data for design of JBR's constructed of FRP. A second major factor to be demonstrated by this project is that the JBR constructed of FRP is sufficiently reliable and effective, while operating without other particulate removal equipment, to negate the need for a spare JBR.

The experience in Japan indicates that the process is highly reliable without a spare JBR and that the process effectively removes particulates. The pilot-scale data indicates that the process can retain its efficiency and reliability when operating with a high-ash fuel. The experience in the chemical industry with large FRP vessels strongly supports the technical feasibility of using FRP in the utility industry. This combination of experience indicates that using an FRP JBR without a spare will result in a less expensive, but still effective and reliable process.

In addition to eliminating the spare scrubber, combining particulate and SO_2 removal, and using FRP in lieu of stainless steel, this project will further demonstrate the feasibility of eliminating flue-gas reheat. This has been demonstrated successfully at several U.S. power plants. The Participant will draw upon the expertise of those involved in the design of the flue-gas system at prior demonstrations to assist in the design of the ducts and equipment downstream of the JBR for this demonstration project. Therefore, it is expected that this additional cost-reducing modification will also operate successfully.

In summary, this project is believed to be technically feasible because of its proven basic process and the strong evidence to support proposed changes to that basic process.

3.3.1.3 Resource Availability

Resource needs include appropriately skilled personnel, water, coal, limestone, and electrical power. All required resources are available at the site or can be obtained and transported to the site.

Increased coal shipments will not be necessary because an existing 100 MWe unit will be used in the project. The project will use a blend of fully washed Springfield No. 5 and Herrin No. 6 coals from two Illinois vendors. Both of these coals are delivered by barge to Georgia Power Company's Pride Transloader located on the Tennessee River in northern Alabama. The target blend will have a proximate analysis of 11,200 Btu/lb, 9.7% ash, 2.5% sulfur, and 11.8% moisture.

Small additional water withdrawals from the Chattahoochee River will be required for limestone slurry makeup. This water is available and can be withdrawn under a modification to the existing water withdrawal permit.

An abundant supply of crushed limestone near Plant Yates is available to satisfy project needs at competitive prices in Georgia and Alabama. Limestone with the proper chemical analysis can also be supplied by quarries in Alabama and Georgia.

The demonstration plant will be constructed over a period of approximately 18 months. A maximum of about 120 construction workers will be needed at the peak of the construction activity. Some of these workers may come from the Plant Yates labor staff, while others may be drawn from local communities in Coweta County, such as Newnan, Carrollton, Roscoe, and Sargent.

Operation of the demonstration plant with the CT-121 process over the two-year test period will require approximately two to four persons in addition to the existing Plant Yates staff. These additional people may be temporarily assigned from other Georgia Power Company and/or Southern Company Services locations.

In summary, the resources required for this project are now used at the demonstration site or can be obtained in the vicinity of the plant in sufficient quantities for this project.

3.3.2 Relationship Between Project Size and Projected Scale of Commercial Facility

This demonstration project involves the installation of a CT-121 process, incorporating cost-saving design changes, on a 100 MWe utility boiler. This boiler is a fully commercial scale unit that is currently in operation. This size was chosen to demonstrate the cost-saving innovations at a full commercial-scale that would lead to acceptance by the utility industry.

The size of utility boilers in use covers a wide range. Some smaller boilers are rated at less than 20 MWe and a few substantially larger ones are rated up to 1300 MWe. Overall, the average utility boiler is rated at approximately 350 MWe. For the lower end of the size range, this demonstration project will not require any scaleup since designs exist for these sizes. The JBRs will be scaled up until the limits (technical or economic) are reached. At that point, smaller parallel units will be required.

Since JBR units near the 250 MWe range are already operating in Japan, it is expected that units up to 250 MWe can readily be built and that parallel modules of this size may be used for the large utility boilers. Scaleup of the FRP unit by a factor of 2.5 to 1 would be required. This degree of scaleup is commercially acceptable and should present no difficulties.

3.3.3 Role of Project in Achieving Commercial Feasibility of the Technology

This project represents the opportunity to demonstrate a technology which will reduce SO_2 emissions from coal-fired boilers burning high-sulfur U.S. coals by 90% at substantially less cost than conventional wet FGD systems. The CT-121 technology is already fully commercial for low-sulfur, low-ash fuels. This project, if successful, will provide data that demonstrates innovative, cost-saving features of a modified CT-121 process treating flue gas produced by burning high-ash high-sulfur U.S. coal. This process also uses slightly less sorbent and electric power. The modified process is equally suitable for new and retrofit applications and permits the elimination of particulate removal equipment resulting in additional capital and operating cost advantages for a new power plant.

3.3.3.1 Applicability of the Data to be Generated

Issues to be addressed and data to be collected and evaluated during the demonstration project include:

- Process evaluation
  - Process chemistry in different operating periods
  - SO_2 removal as a function of operating mode, operating parameters, and pH
  - Particulate removal as a function of unit load, operating mode, and operating parameters
  - Component reliability (JBR, ducts, fans, pumps, etc.)
  - Corrosion, particularly in the precooler, JBR inlet duct, and around the wet fan

- Fiberglass performance
- Wet chimney performance

- Gypsum stack and by-product evaluation in different operating periods

- Groundwater monitoring

- Environmental data management and reporting

- Economic evaluation

- Data obtained on Disposition

During the demonstration program, the SO_2 continuous emissions-monitoring (CEM) system, which has passed EPA certification protocol to ensure data quality, will be used to collect emissions data. The data will be logged into a microcomputer that can be downloaded directly to SCS offices for rapid data analysis by SCS engineers. Operating data, such as pH in the JBR and important differential pressures, will also be collected and stored on data disks for use with a microcomputer and included in the routine data evaluation activities. The operating data can also be transmitted electronically to subcontractor personnel located at sites remote to Yates. SCS will have two engineers and a chemistry technician at Yates to coordinate evaluation activities and perform initial data reduction functions.

The environmental data management and reporting will be handled by Radian Corporation, which has performed this function on other DOE projects. Radian will perform the groundwater monitoring analyses and will enter the data into the environmental data base. Radian will also be responsible for developing quality control procedures for both groundwater and process sampling and analysis. CEM data will be sent to Radian to be included in the data base, as will the selected process data. The specific environmental data to be collected will be determined from the post-selection NEPA and Environmental Monitoring Plan Outline (EMPO) activities.

3.3.3.2 Identification of Features that Increase Potential for Commercialization

There are several features of the CT-121 technology which should prove attractive to the utility industry if this project is successful. As described previously, this project will demonstrate innovative changes to the CT-121 process that could result in cost reductions of 23% for retrofit applications and 50% when used in a new power plant. The project combines the removal of particulate matter and SO_2 in a single vessel and removes both pollutants with sufficient effectiveness to meet NSPS. The calcium sulfate (gypsum) produced is in the form of crystals larger than either the calcium sulfite or gypsum crystals produced in conventional wet FGD systems. Production of larger gypsum crystals increases the chances of either finding a market for this by-product or making disposal easier if no market is available.

The CT-121 process consumes less electrical power than conventional wet FGD processes and uses limestone more efficiently. In addition, the CT-121 process can be used for all types and sizes of boilers.

This combination of cost, performance, and versatility factors is expected to lead this technology to widespread acceptance and use by the utility industry should more stringent environmental regulations become effective or as new boilers are built.

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

The site selected for this demonstration project has several advantages. The 100 MWe Unit No. 1 at Plant Yates is large enough to demonstrate the applicability of the CT-121 process to the utility industry but not so large as to make this project excessively expensive. Adequate space exists for the project adjacent to Unit 1, which is already permitted to burn coal with sulfur content up to 3%. This will avoid delays that could result from additional permitting. Land is also available for the gypsum stack.

This project, if successful, will demonstrate the effectiveness, reliability and economics of the modified CT-121 design. Economic projections indicate that the process is substantially less expensive than conventional wet FGD and is at least as effective in removing SO_2. In addition, the solids produced by the CT-121 process have a higher probability of finding a market than do the solids produced by wet FGD processes with or without forced oxidation. If a market is not found, the CT-121 solids are more amenable to disposal since the large particle size results in a material with a higher load-bearing strength that allows for disposal in a solid landfill instead of a sludge pond.

If more stringent environmental regulations are enacted or new boilers are built, this process will provide an efficient, reliable and economic alternative to conventional FGD processes. Therefore, with a successful demonstration program it is expected that this technology will be accepted by the utility industry.

4.0 ENVIRONMENTAL CONSIDERATIONS

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

In the PEIA, the expected performance characteristics and applicable market of the CT-121 technology were used to estimate the environmental impacts that could result if the CT-121 technology were to reach full commercialization in 2010. The REDES computer model was used to project the impacts of the CT-121 technology as compared to the no-action alternative.

Projected environmental impacts from maximum commercialization of the CT-121 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 results should be regarded as approximations of actual impacts.

Table 1. Projected Environmental Impacts in 2010
(Percent Change in Emissions and Solid Wastes)

Region	Sulfur Dioxide (SO_2)	Nitrogen Oxides (NO_x)	Solid Waste
National	-45	0	+6
Northeast	-65	0	+8
Southeast	-54	0	+8
Northwest	-10	0	+4
Southwest	-15	0	+1

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

As shown in Table 1, a significant reduction of SO_2 are projected to be achievable nationally, due to the 90 to 95 percent SO_2 removal capability and the wide potential applicability of the CT-121 process. The process offers the potential to reduce or eliminate solid waste production. However, that potential is dependent upon local market conditions relating to the saleable gypsum by-product. Accordingly, the REDES model assumed a worst-case scenario in which all of the gypsum would to be treated as waste. While this represents an increased solid waste level, the waste is readily disposable. The REDES model predicts that greatest environmental impacts will be felt in the Northeast because of the large amount of coal-fired capacity that can be retrofitted with the CT-121 process. The least impact occurs in the Northwest due to the minimal use of coal in this region. 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 part of each proposal. This analysis, for internal DOE use only, contained a discussion of site-specific EHSS issues associated with each demonstration project. It included a discussion of the advantages and disadvantages of the proposed and alternative processes reasonably available to each offeror. A discussion of the impacts of each proposed demonstration on the local environment and a list of permits that must be obtained to implement the proposal were included. It also contained options for controlling discharges and for management of solid and liquid wastes. Finally, the risks and impacts of each proposed project were assessed. Based

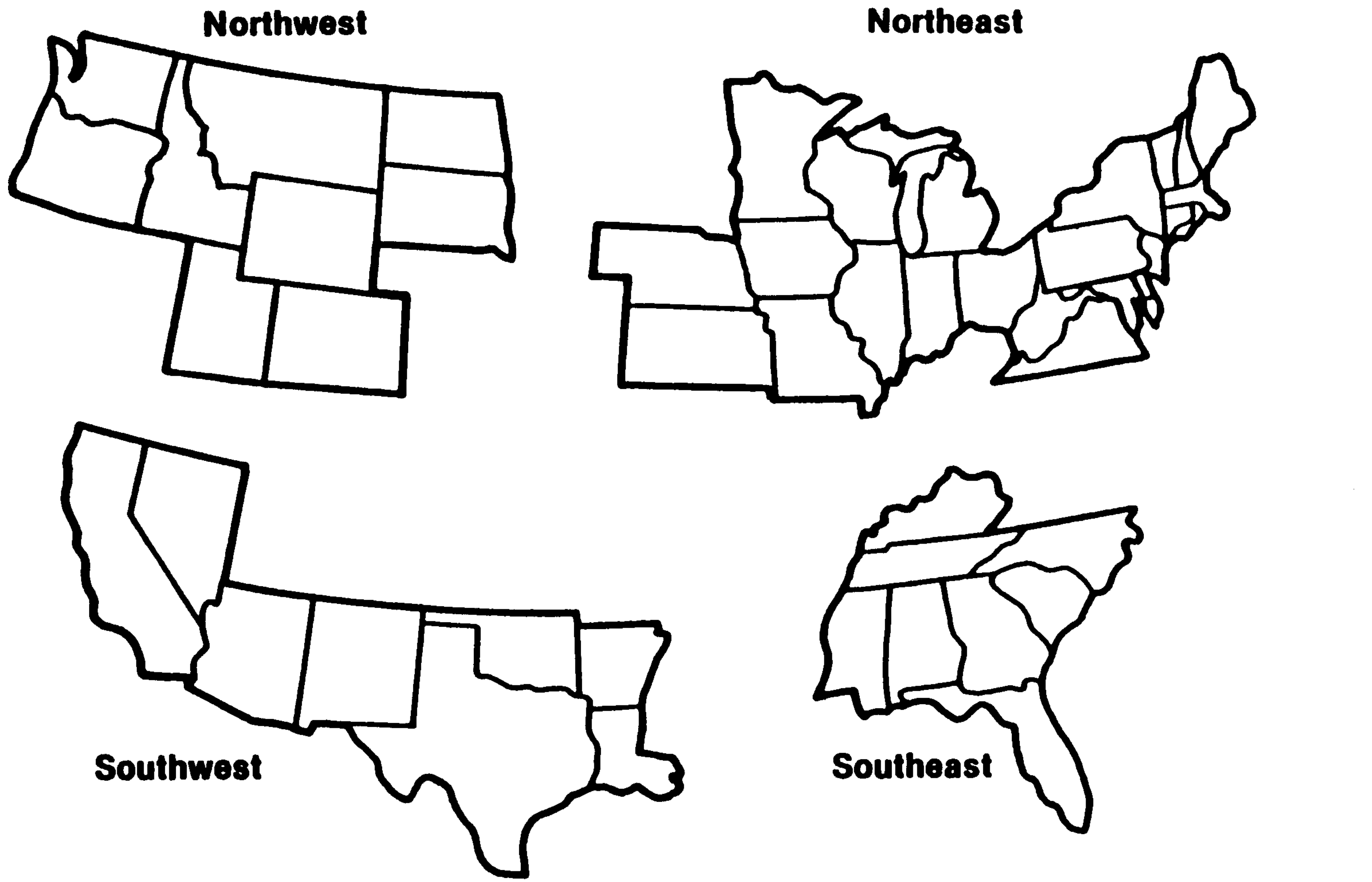

FIGURE 4. QUADRANTS FOR THE CONTIGUOUS UNITED STATES.

on this analysis, no environmental, health, or safety issues have been identified that would result in any significant adverse environmental impacts from construction and operation of the CT-121 demonstration facility.

As the third element of the NEPA strategy, the Participant (SCS) will be required to submit the environmental information specified in Appendix J of the PON. This detailed site and project-specific information will be used as the basis for the development of the site-specific NEPA documents to be prepared by DOE. These documents will be completed and approved in full conformance with the Council on Environmental Quality's requirements for implementing NEPA (40 CFR Parts 1500-1508) and DOE guidelines for NEPA compliance (52 FR 47662-47670) before federal funds are provided for detailed design, construction, and operation.

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

5.0 PROJECT MANAGEMENT

5.1 Overview of Management Organization

The Department of Energy will monitor the project through the Contracting Officer and the Contract Officer's Technical Representative (COTR). The Participant will manage this project through a Project Manager, who will be assisted by a team of technical and managerial personnel from several organizations. An advisory committee will be established in an oversight role.

A multi-organizational team headed by SCS will be involved in this project. In addition to Southern Company Services, other members of the team are Georgia Power Company, and Electric Power Research Institute (EPRI). Major subcontractors are Ershigs Inc., Dynatech, Radian Corporation, Roberson-Pitts, and the University of Georgia. Chiyoda will provide the process design package and design review outside the Cooperative Agreement.

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:

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

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

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

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

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

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

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

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

Participant

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

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

SCS's responsibilities include the design, procurement, fabrication and installation of the demonstration equipment. In addition, SCS will provide guidance and participation in the test program, environmental permitting, data analysis and final report preparation.

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

EPRI will work with SCS to ensure that the results of this demonstration are disseminated to the utility industry. EPRI will also provide technical consultation and guidance.

Ershigs, Inc., has been selected by SCS to construct the fiberglass JBR, outlet duct, and chimney liner. Ershigs will construct a manufacturing facility at Plant Yates to build the JBR while the other FRP components will be constructed off site. Ershigs will interface with SCS during the design phase and will be responsible for all quality assurance/quality control activities during JBR construction and erection.

Chiyoda provides process design support for CT-121 installation for SCS as part of their license agreement with SCS.

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

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

Several other subcontractors will carry out specific tasks during this demonstration project. The University of Georgia will evaluate the gypsum by-product as an agricultural supplement. The performance of the gypsum stack will be evaluated by Ardaman. Dynatech will perform fluid flow modeling and evaluate the performance of the wet duct and stack.

The Participant will interrelate between the government and all other project sponsors as shown in Figure 5, Project Organization.

5.3 Summary of Project Implementation and Control Procedures

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

- Phase I: Environmental Permitting, and Preliminary Engineering
- Phase II: Design, Construction, and Start-up
- Phase III: Operations, Testing, and Disposition

The total project encompasses an 81-month period. Phase I has a duration of eight months and Phase II has a duration of 27 months with a six month overlap with Phase I. Phase III operations will have a duration of 23 months. Phase III by-product evaluation will begin with operations and will last until the end of the project. Overall, Phase III will last 52 months.

Two budget periods have been established. Consistent with P.L. 100-202, as amended by P.L. 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.

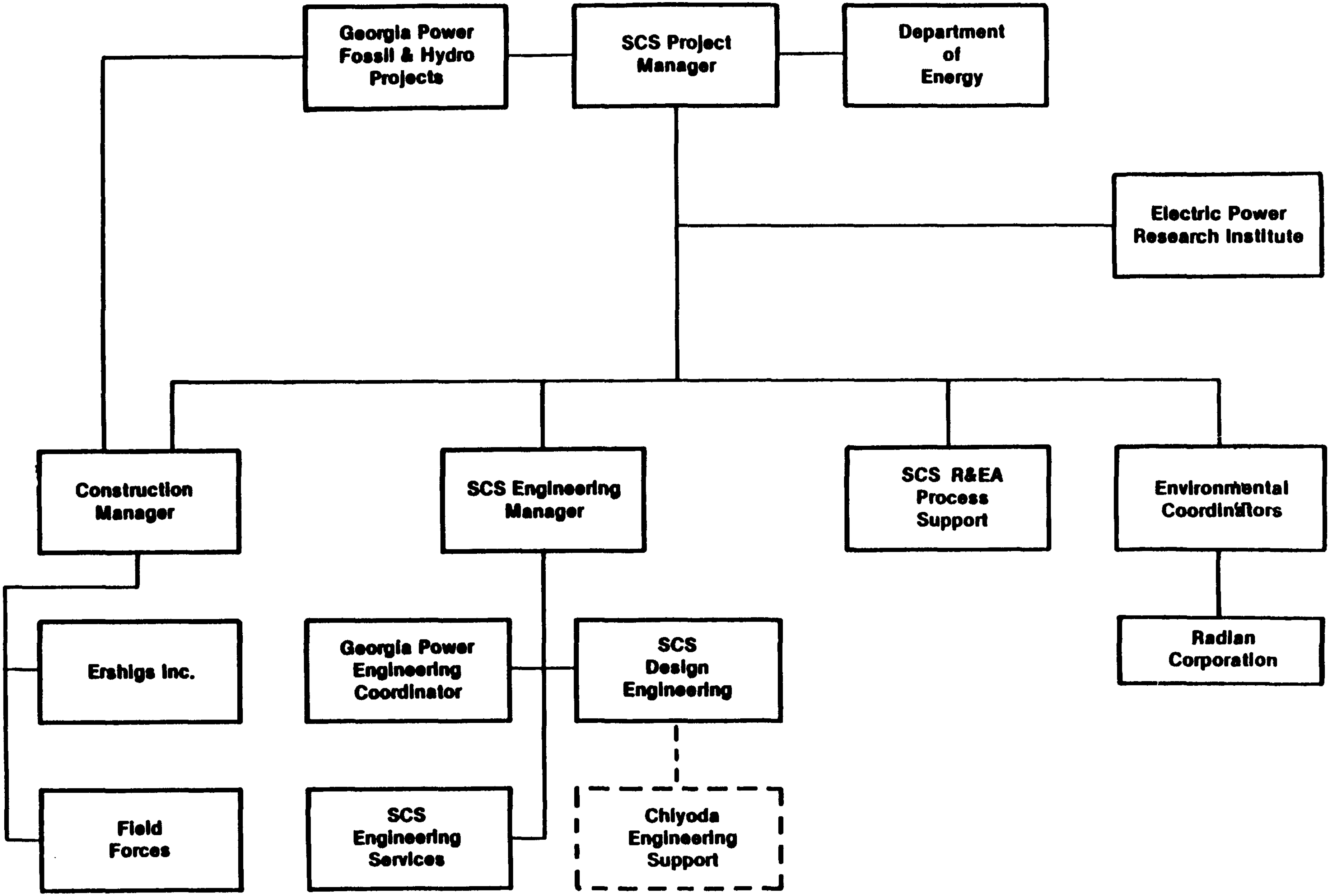

FIGURE 5. SCS CT-121 DEMONSTRATION PROJECT ORGANIZATION CHART.

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

The key agreements with respect to patents and data are:

- o Standard data provisions are included, giving the Government the right to have delivered, and use, with unlimited rights, all technical data first produced in the performance of the agreement. Proprietary data, may be required to be delivered to the Government,under appropriate provisions for confidentiality.

- o A patent waiver has been requested by SCS which, if granted, would give to SCS ownership of foreground inventions, subject to the march-in-rights and U.S. preference founded in P.L. 96-517. SCS has indicated it will assign any waived subject inventions to Chiyoda, who will also be subject to the above provisions Chiyoda, pursuant to a pre-existing agreement, has licenced the technology to Bechtel,Inc. in the U.S..

- o Rights in background patents and background data of SCS and all of its subcontractors are included to assure commercialization of the technology. Chiyoda, while not a contractor, has also agreed to provisions with regard to its background technology subject to the pre-existing license with Bechtel.

5.5 Procedures for Commercialization of the Technology

The involvement of SCS in the Yates project derives from a concern that SO_2 emission control retrofits may be required soon in the electric utility industry. It is in the best interest of the Southern electric system, through Southern Company Services, to take an active role in the project. Successful demonstration of cost-saving design changes to the CT-121 process at Plant Yates will allow confident extrapolation of the results to the remainder of the coal-fired capacity in the Southern electric system. Moreover, SCS involvement in a successful demonstration will increase the confidence of large, high-sulfur coal boiler users in the efficiency of design changes that will be demonstrated in this project. The Participant estimates that the proposed demonstration will be applicable to over 370,000 MWe of new and existing boiler capacity by the year 2010. At 90% reduction, the retrofit portion of this capacity represents the potential to reduce SO_2 emissions by over 10,500,000 tons of SO_2 annually.

A key factor in the commercialization of FGD technology is that the market for FGD is driven by the rate of growth in the electric power industry and by the regulatory environment. CT-121 in its current embodiment is a highly cost-competitive FGD process. Should the cost savings sought to be demonstrated through this proposal be successful, and legislation is passed requiring installation of scrubbers on existing facilities, the CT-121 process should capture a significant share of this future FGD market.

Subsequent to the work at Scholz, SCS signed a license agreement with Chiyoda that allows the Southern electric system to design and construct the CT-121 process within its service area. If legislation is enacted or regulations are promulgated that require substantial reductions in SO_2 emissions, and if low-sulfur coal is not a cost-effective compliance option, SCS currently expects the CT-121 FGD process to be its primary method of compliance. As many as 14,000 MWe of retrofit FGD capacity could be required in the Southern electric system's operating companies.

Bechtel Corporation of San Francisco possesses the CT-121 process license for the remainder of the U.S If this project is successful, interested utilities could obtain the technology from this large, experienced Architect/Engineering firm.

Bechtel is not part of the project team offered to DOE in this proposal since the Southern electric system prefers to execute the Yates project with its own engineering resources. However, Chiyoda is supporting SCS by providing, outside of the Cooperative Agreement, the basic process design and detailed design and construction review for Yates. Bechtel will receive all essential project information through Chiyoda. Bechtel is fully capable of responding to increased market demands should reductions in emissions from existing power plants be required.

6.0 PROJECT COST AND EVENT SCHEDULING

6.1 Project Baseline Costs

The total estimated cost for this project is $35,843,678. The Participant contribution and the Government share in the costs of this project are as follows:

	Dollar Share ($)	Percent Share (%)
PRE-AWARD		
Government	267,989	48.95
Participant	279,485	51.05
PHASE I		
Government	430,315	48.95
Participant	448,776	51.05
PHASE II		
Government	11,236,377	48.95
Participant	11,716,047	51.05
PHASE III		
Government	5,611,965	48.95
Participant	5,852,724	51.05
TOTAL PROJECT		
Government	17,546,646	48.95
Participant	18,297,032	51.05
TOTAL	35,843,678	100.00

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

DOE:	$17,546,646
SCS:	11,297,032
EPRI:	$ 7,000,000
TOTAL	$35,843,678

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

6.2 Milestone Schedule

As shown in Figure 6, the overall project will be completed in 81 months after award of the Cooperative Agreement.

Phase I, which involves permitting, preparation of an Environmental Monitoring Plan Outline, an Environmental Monitoring Plan and preliminary engineering, will start immediately after award and continue for eight months. Phase II design, construction, and start-up will start two months following the beginning of Phase I and continue for 27 months. There will be a six month overlap between Phases I and II. Phase III operation, testing and disposition, will last 52 months while the actual operation will cover 23 months starting immediately after completion of Phase II.

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.

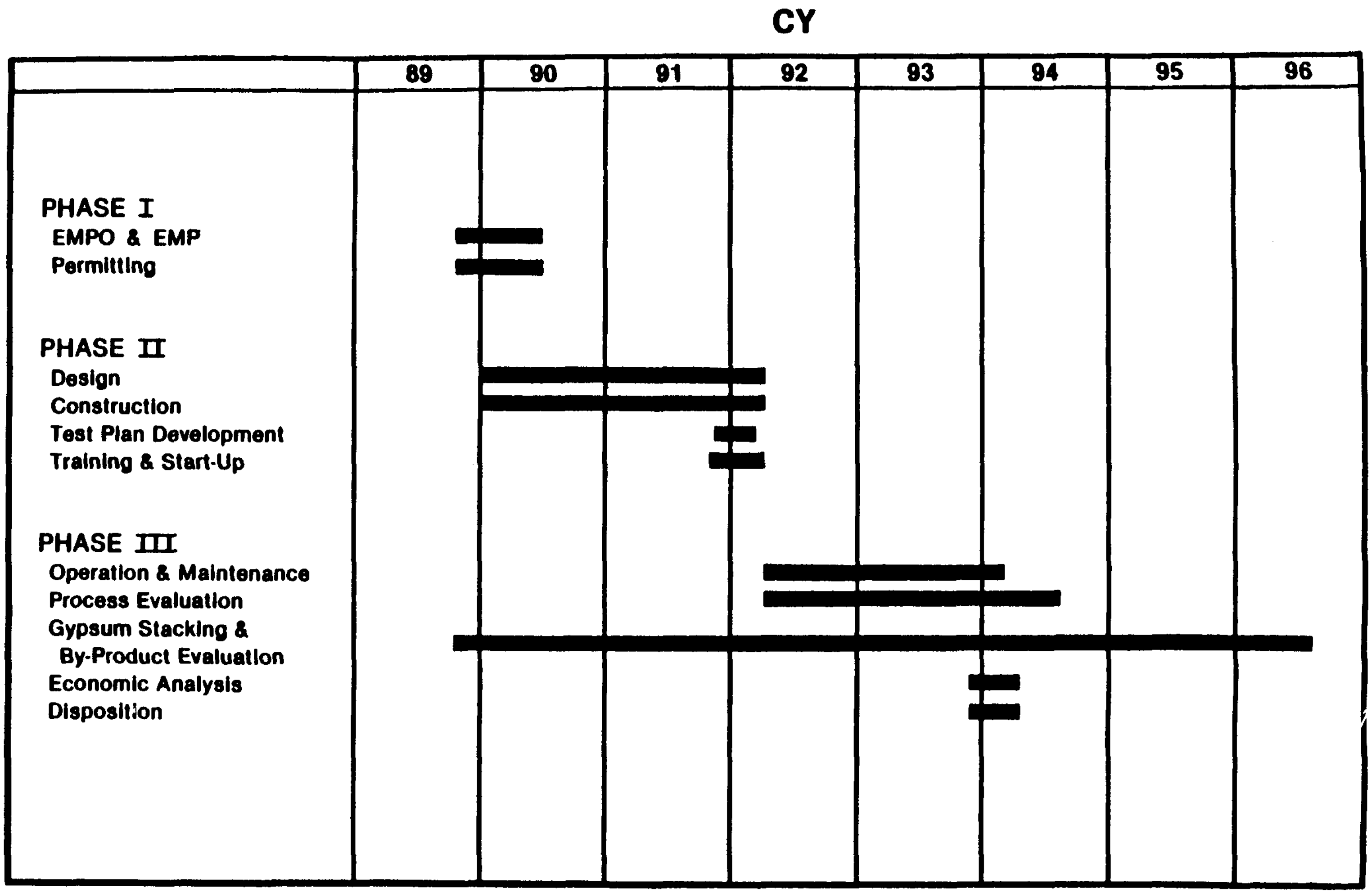

FIGURE 6. CT-121 PROCESS DEMONSTRATION SCHEDULE.