DOE/FE--0207P

DE91 001077

Comprehensive Report to Congress Clean Coal Technology Program

LIFAC Sorbent Injection Desulfurization Demonstration Project

A Project Proposed By:
LIFAC North America, Inc.

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

October 1990

TABLE OF CONTENTS

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY

In September 1988, Congress provided $575 million to conduct cost-shared Clean Coal Technology (CCT) projects to demonstrate technologies that are capable of retrofitting or repowering existing facilities. To that end, a Program Opportunity Notice (PON) was issued by the Department of Energy (DOE) in May 1989, soliciting proposals to demonstrate innovative energy efficient technologies that were capable of being commercialized in the 1990s, and were capable of (1) achieving significant reductions in the emissions of sulfur dioxide and/or the oxides of nitrogen from existing facilities to minimize environmental impacts such as transboundary and interstate pollution and/or (2) providing for future energy needs in an environmentally acceptable manner.

In response to the PON, 48 proposals were received in August 1989. After evaluation, 13 projects were selected in December 1989 as best furthering the goals and objectives of the PON. The projects were located in 10 different states and represented a variety of technologies.

One of the projects selected for funding is a project proposed by LIFAC North America, Inc. (LIFAC NA), titled "LIFAC Sorbent Injection Desulfurization Demonstration Project." The host site will be a coal-fired powerplant of Richmond Power & Light in Indiana. LIFAC technology uses upper-furnace limestone injection with patented humidification of the flue gas to remove 75-80% of the sulfur dioxide (SO_2) in the flue gas.

In the LIFAC process, limestone is injected into the upper part of the furnace where the temperatures are sufficiently high to calcine the calcium carbonate ($CaCO_3$) to lime (CaO), which reacts with the SO_2 in the flue gas to form calcium sulfite ($CaSO_3$), some of which oxidizes to form calcium sulfate ($CaSO_4$). The flue gas leaving the boiler then enters LIFAC's unique humidification chamber which increases the water content of the flue gas and activates the lime to enhance SO_2 removal. Reduction of SO_2 emissions are approximately 75-80%. Spent sorbent is then removed, along with the fly ash by an existing electrostatic precipitator (ESP) or baghouse.

Richmond Power and Light's (RP&L) Whitewater Valley generating plant located in Richmond, Wayne County, Indiana, will host the demonstration as shown in Figure 1. The LIFAC process will be retrofit to the plant's Unit No. 2. This unit burns high-sulfur bituminous coals mined in western Indiana, which has a sulfur content between 2.4 and 2.9%. Unit No. 2 is a tangentially-fired, dry-bottom boiler that was commissioned in 1971. The generating capacity of this unit is 60 megawatts electric (MWe).

The project duration is scheduled for 39 months. Design, permitting, procurement and construction will require 13 months and the demonstration tests will last 26 months including data acquisition, analysis, and reporting.

The total project cost is $17,018,982. LIFAC NA, Inc., the Participant, is a joint venture company formed by subsidiaries ofICF Kaiser Engineers, Inc., and Tampella, Ltd., of Finland. LIFAC NA will contribute $3,924,645 to the project. Richmond Power & Light ($3,484,846), and the Electric Power Research Institute (EPRI) ($500,000) will co-fund the project. Other team members are Black Beauty Coal Company, and Peabody Coal Company.

2.0 <u>INTRODUCTION AND BACKGROUND</u>

2.1 <u>Requirement for a Report to Congress</u>

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

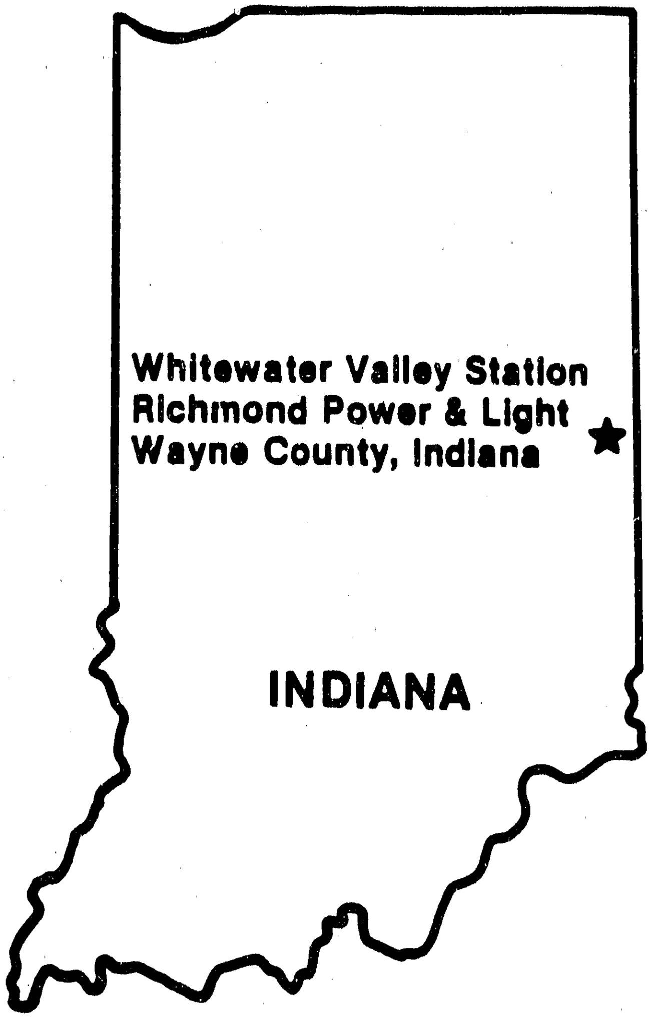

FIGURE 1. LIFAC PROCESS DEMONSTRATION PROJECT SITE LOCATION.

NOJ18.787

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

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

2.2 Evaluation and Selection Process

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

2.2.1 PON Objective

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

2.2.2 Qualification Review

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

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

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

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

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

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

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

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

2.2.3 Preliminary Evaluation

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

2.2.4 Comprehensive Evaluation

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

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

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

2.2.5 Program Policy Factors

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

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

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

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

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

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

2.2.6 Other Considerations

The PON provided that in making selections, DOE would consider giving preference to projects located in states for which the rate-making bodies of those states treat the Clean Coal Technologies the same as pollution control projects or technologies. This consideration could be used as a tie breaker if, after application of the evaluation criteria and the program policy factors, two projects receive identical evaluation scores and remain essentially equal in value. This consideration would not be applied if, in doing so, the regional geographic distribution of the projects selected would be altered significantly.

2.2.7 National Environmental Policy Act (NEPA) Compliance

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

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

2.2.8 Selection

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

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

3.0 TECHNICAL FEATURES

3.1 Project Description

This project will demonstrate LIFAC sorbent injection technology developed in Finland by Tampella, to control sulfur dioxide emissions from powerplants and represents the first demonstration of this technology in the United States. The LIFAC technology has similarities to other sorbent injection technologies using humidification, but employs a unique patented vertical reaction chamber attached to the down-stream sections of the boiler to facilitate and control the sulfur capture and other chemical reactions. This chamber improves the overall reaction efficiency enough to allow the use of pulverized limestone rather than more expensive reagents such as lime which are often used to increase the efficiency of other sorbent injection processes.

Sorbent injection is a potentially important alternative to conventional wet lime and limestone scrubbing, and this project is another effort to test alternative sorbent injection approaches. In comparison to wet systems, LIFAC will remove less sulfur dioxide - 75 to 80% relative to 90% or greater for conventional scrubbers - and require more reagent material. However, if the demonstration is successful, LIFAC will offer these important advantages over wet scrubbing systems:

- LIFAC is relatively easy to retrofit to an existing boiler and requires less area than conventional wet FGD systems.

- LIFAC is less expensive to install than conventional wet FGD processes.

- LIFAC's overall costs measured on a dollar-per-ton SO_2 removed basis are less, an important advantage in a regulatory regime with trading of emission allocations.

- LIFAC produces a dry, readily disposable waste by-product versus a wet product.

- LIFAC is relatively simple to operate.

The LIFAC demonstration project at Whitewater Valley Unit 2 powerplant site is suited for the testing and demonstration necessary to assist in commercializing this technology for the U.S. utility industry. LIFAC has not been demonstrated on a full-scale powerplant consuming high-sulfur U.S. coal. Richmond Power & Light's Whitewater Valley Unit 2, is a full-scale utility boiler (60 MWe) using high-sulfur bituminous coal produced in western Indiana. While LIFAC has been tested in Finland, LIFAC has not been demonstrated with U.S. mined coals in the U.S. The plant was commissioned in 1971 and is operated as a base-load unit with capacity factors typically ranging from 70-77%.

This boiler is also a challenging retrofit site for LIFAC and other flue gas desulfurization systems; hence, successful tests at this site will further demonstrate the wide applicability of the technology. The boiler was built in an unusually compact manner with high heat release rates which can reduce reagent residence times in the boiler and increase the sintering and deadburning of the reagent.

The principal system component to be installed is the activation reactor. Additional system components that are normally part of a LIFAC system probably will not have to be installed. These include; limestone handling and injection equipment and some humidification equipment, because this equipment is already on site, remaining from an earlier separate sorbent injection test program conducted jointly by EPA and EPRI. No major modifications of the boiler, ESP, and induced draft fans are expected to be required.

3.1.1 Project Summary

Project Title:	Demonstrate LIFAC at Whitewater Valley 2
Proposer:	LIFAC North America, Inc.
Project Location:	Whitewater Valley Unit No. 2 Richmond Power & Light Richmond, Wayne County, Indiana
Technology:	LIFAC Process
Application:	Retrofit to boilers
Types of Coal Used:	Indiana High-Sulfur Bituminous (2.4-2.9% Sulfur)
Product:	Environmental Control Technology
Project Size:	60 MWe
Project Start Date:	July 1, 1990
Project End Date:	June 30, 1993

3.1.2 Project Sponsorship and Cost

Project Sponsor:	LIFAC North America, Inc.
Co-Funders	Richmond Power & Light Electric Power Research Institute
Estimated Project Cost:	$17,018,982

Project Cost Distribution:

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

3.2 LIFAC Process

3.2.1 Overview of Process Development

In 1983, Finland enacted acid rain legislation which applied limits on SO_2 emissions sufficient to require that flue gas desulfurization systems have the capability to remove about eighty percent (80%) of the sulfur dioxide in the flue gas. This level could be met by conventional scrubbers, but could not be met by then available sorbent injection technology. Therefore, Tampella began developing an alternative system which resulted in the LIFAC process.

Initially, development included laboratory scale and pilot plant tests. Full-scale limestone injection tests were conducted at Tampella's Inkeroinen facility, a 160 MWe coal-fired boiler using high-ash, low-sulfur Polish coal. At Ca:S ratios of 3:1, sulfur removal was less than 50%. Better results could have been attained using lime, but was rejected because the cost of lime is much higher than that of limestone.

In-house investigations by Tampella led to an alternative approach involving humidification in a separate vertical chamber which became known as the LIFAC Process. In cooperation with Pohjolan Voima Oy, a Finnish utility, Tampella installed a full-scale limestone injection facility on a 220 MWe coal-fired boiler located at Kristiinankaupunki. At this facility, a slipstream (5000 SCFM) containing the calcined limestone was used to test a small-scale activation reactor (2.5 MW) in which the gas was humidified. Reactor residence times of 3 to 12 seconds resulted in SO_2 removal rates of 84%. Additional LIFAC pilot-scale tests were conducted at the 8 MWe (thermal) level at the Neste Kulloo combustion laboratory to develop the relationships between the important operating and design parameters. Polish low-sulfur coal was burned to achieve 84% SO_2 removal.

In 1986, full-scale testing of LIFAC was conducted at Imatran Voima's Inkoo powerplant on a 250 MWe utility boiler. An activation chamber was built to treat a flue gas stream representing about 70 MWe. Even though the boiler was 250 MWe, the 70 MWe stream represented about one-half of the flue gas feeding one of the plant's two ESPs (i.e., each ESP receives a 125 MWe gas stream). This boiler used a 1.5% sulfur coal and sulfur removal was initially 61%. By late 1987, SO_2 removal rates had improved to 76%. In 1988, a LIFAC activation reactor was added to treat an additional 125 MWe--i.e., an entire flue gas/ESP stream--worth of flue gas from this same boiler. This newer activation reactor is achieving 75-80% SO_2 removal with Ca:S ratios between 2.0:1 and 2.5:1. In 1988, the first tests using high-sulfur U.S. coals were run at the pilot scale at the Neste Kulloo Research Center, using a Pittsburgh No. 8 coal containing 3% sulfur. SO_2 removal rates of 77% were achieved at a Ca:S ratio of 2:1.

This LIFAC demonstration project will be conducted on a 60 MWe boiler burning high-sulfur U.S. coals to demonstrate the commercial application of the LIFAC process to U.S. utilities.

3.2.2 Process Description

LIFAC combines upper-furnace limestone injection followed by post-furnace humidification in an activation reactor located between the air preheater and the ESP (see Figure 2). The process produces a dry and stable waste product that is partially removed from the bottom of the activation chamber and partially removed at the ESP.

Finely pulverized limestone is pneumatically conveyed and injected into the upper part of the boiler. Since the temperatures at the point of injection are in the range of 1800-2000 °F, the limestone ($CaCO_3$) decomposes to form lime (CaO) which is more reactive. As the lime passes through the furnace the first set of desulfurization reactions take place. A portion of the SO_2 reacts with the CaO to form calcium sulfite ($CaSO_3$), part of which then oxidizes to form calcium sulfate ($CaSO_4$). Essentially all of the sulfur trioxide (SO_3) reacts with the CaO to form $CaSO_4$.

The flue gas and unreacted lime exit the boiler and pass through the air preheater. On leaving the air preheater, the gas/lime mixture enters the patented LIFAC activation reactor. In this reactor, the second set of sulfur dioxide capture reactions occurs after the flue gas is humidified with a water spray. Humidification converts lime CaO to hydrated lime, $Ca(OH)_2$, which enhances further SO_2 removal. The activation reactor is designed to allow time for effective humidification of the flue gas, activation of the lime, and reaction of the SO_2 with the sorbent. The net effect is that at a Ca:S ratio in the range of 2:1 to 2.5:1, 75-80% of the SO_2 is removed from the flue gas. The activation reactor is also designed specifically to minimize the potential for solids build-up on the walls of the chamber.

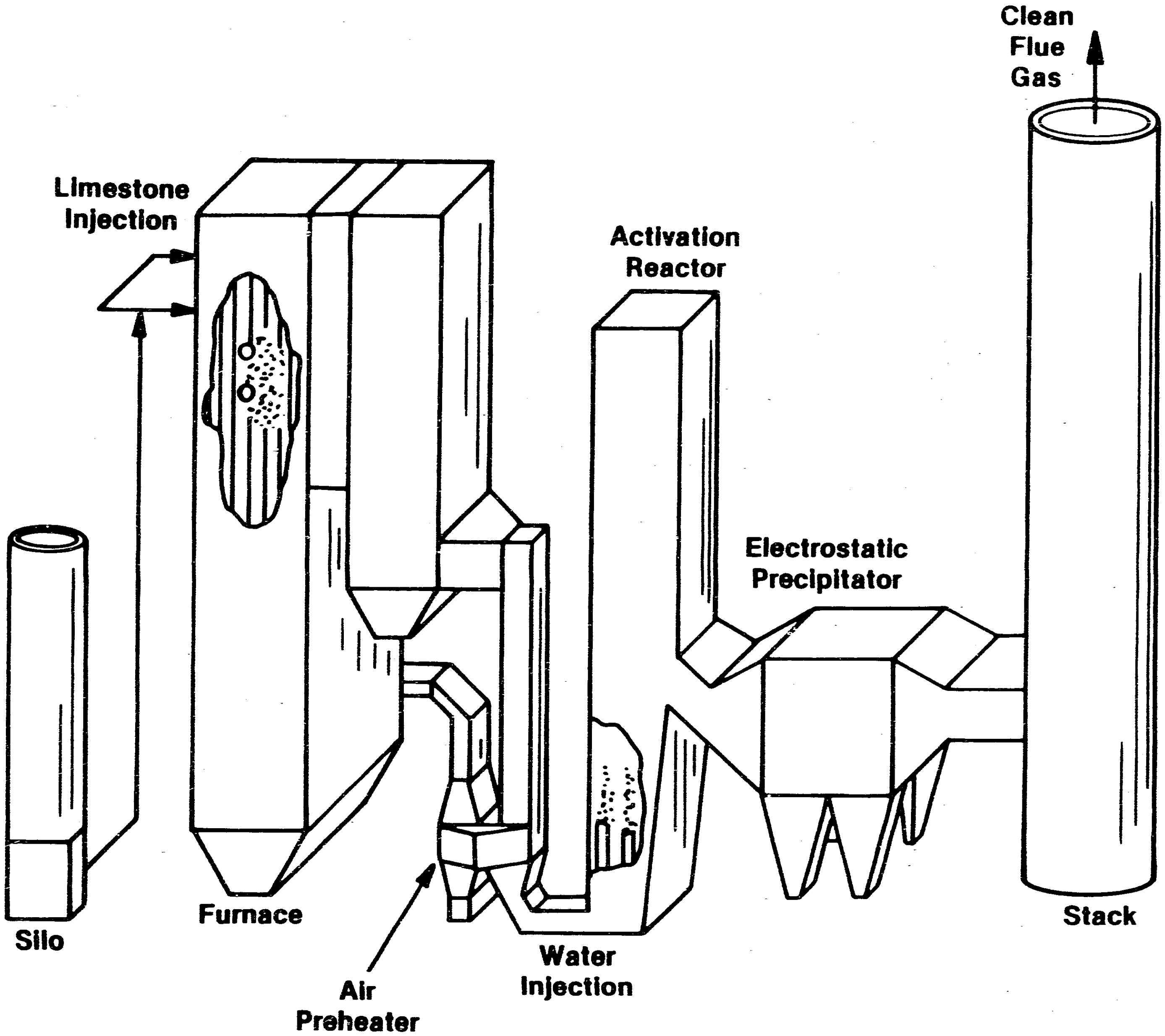

FIGURE 2. LIFAC PROCESS SCHEMATIC.

NOJ19,607

The flue gas leaving the activation reactor then enters the existing ESP where the spent sorbent and fly ash are removed from the flue gas and sent to the disposal facilities. ESP effectiveness is also enhanced by the humidification of the flue gas. The solids collected by the ESP consist of fly ash, $CaCO_3$, $CA(OH)_2$, CaO, $CaSO_4$, and $CaSO_3$.

3.2.3 Application of Process in Proposed Project

The site for the LIFAC demonstration is Richmond Power & Light's Whitewater Valley 2 pulverized coal-fired power station (60 MWe), located in Richmond Indiana. Whitewater Valley 2 began service in 1971, is a Combustion Engineering tangentially-fired boiler which uses high-sulfur bituminous coal from Western Indiana. Whitewater Valley 2 has several important qualities as a LIFAC demonstration site. One of these is that Whitewater Valley 2 was the site of a prior joint EPA/EPRI demonstration of LIMB sorbent injection technology. The sorbent injection equipment remains on site and will be used in the LIFAC demonstration, if possible. Another advantage of the site is that Whitewater Valley is a challenging candidate for a retrofit due to the cramped conditions at the site (Figure 3). The plant is thus typical of many U.S. powerplants which are potential sites for application of LIFAC. In addition, Whitewater Valley No. 2 boiler is small relative to its capacity; hence, it has high-temperature profiles relative to other boilers. This situation will require sorbent injection at higher points in the furnace in order to prevent deadburning of the reagent and may decrease residence times needed for sulfur removal. Whitewater Valley 2 will show LIFAC's performance under operational conditions most typical of U.S. powerplants. The project will demonstrate LIFAC on high-sulfur U.S. coals and is a logical extension of the Finnish demonstration work and important for LIFAC's commercial success in the U.S.

3.3 General Features of the Project

3.3.1 Evaluation of Developmental Risk

A low to moderate risk has been assigned to the LIFAC process based on a review of the developmental history of the LIFAC process and related sorbent injection technology. As described earlier, LIFAC has undergone extensive developmental work at the 2.5 MWe test facility, at the Kristiinankaupunki and the Inkoo plants, both at the pilot and commercial levels. Also, significant work has been

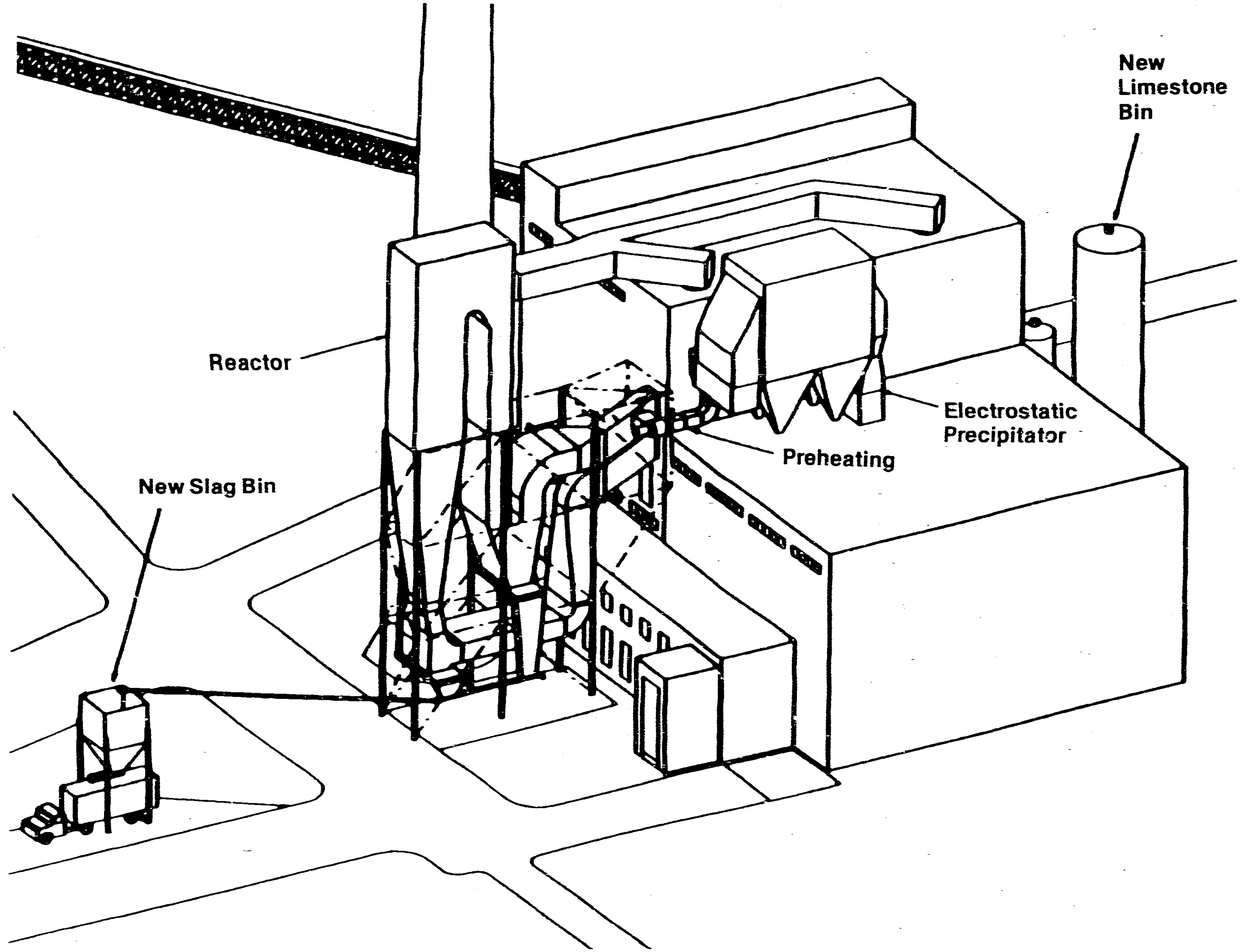

FIGURE 3. LIFAC INSTALLATION AT WHITEWATER VALLEY.

NO./19,980

done in the area of sorbent injection, and in the area of combining sorbent injection with humidification. Several risks associated with the LIFAC process are:

- <u>ESP Performance:</u> - More reagent material will be required for this demonstration project than for any previous full-scale LIFAC demonstration, increasing the ESP particulate loadings of the flue gases. However, the humidification of the flue gases has been shown to greatly improve the performance of the ESP, and as a result, there is unlikely to be a degradation of ESP performance at Whitewater Valley 2. This is because increasing the humidity of the flue gas and lowering its temperature increases the conductivity of the flyash, decreases the flue gas volume, and raises the SCA (Specific Collection Area).

- <u>Increased Furnace Material:</u> - Injection of sorbent into the upper portions of the boiler may lead to a buildup of solids on the boiler tubes and in the duct work or reactor and humidification may result in condensation in the ESP and/or stack. These are considered to be low or moderate risks because included with the installation of the LIFAC process there will be instrumentation and controls to identify and mitigate potential problems.

3.3.1.1 Similarity of the Project to Other Demonstration/Commercial Efforts

There are several on-going demonstration projects that are being funded under the Clean Coal Technology program that are similar to the LIFAC process. One of these is the LIMB (Limestone Injection Multistage Burner) project being carried out at the 105-MWe scale. This process uses low-NO_x burners to control NO_x and upper-furnace sorbent injection (with or without humidification) to control SO_2.

The SOX-NOX-ROX Box (SNRB) process uses duct injection of a calcium-based sorbent to control SO_2. NO_x is controlled by injecting ammonia into the flue gas to catalytically react with the NO_x. Particulates are removed with a baghouse, in which the bags are impregnated with the catalyst that promotes the NH_3-NO_x reaction.

Another project that uses upper-furnace injection of sorbent to control SO_2 was proposed by the Public Service Company of Colorado. This project, which has also been selected for funding under the third round of the CCT program, uses upper-furnace injection of sorbent followed by in-duct humidification for SO_2 removal. In addition, this project will also test sorbent injection in the duct downstream of the air heater. Both calcium- and sodium-based sorbents will be used for duct injection.

The Energy and Environmental Research Corporation (EER) CCT I project uses upper-furnace sorbent injection followed by humidification is being carried out at two Illinois sites. The EER project a calcium-based sorbent is injected into the upper furnace, followed by humidification, for SO_2 control. Gas reburning is used for NO_x control.

All the above projects, with the exception of the SNRB project, are treating the full flue gas stream from full-scale, commercially operating boilers. The SNRB process will treat a 5 MWe slipstream from a commercially operating boiler.

In addition, demonstration of sorbent injection downstream of the air heater has been or is being carried out by AirPol (Gas Suspension Absorption), Dravo (HALT process), Bechtel (Confined Zone Dispersion), and a number of other companies. In some cases, the sorbent is injected as a dry solid and in others, slurry injection is used. Typically, slurry injection results in about 60% SO_2 removal and dry sorbent injection results in about 50% SO_2 removal.

The activation reactor used by LIFAC results in a 75-80% removal rate without recycle is unique.

3.3.1.2 Technical Feasibility

The majority of the equipment required in the LIFAC process is similar to that required by many other processes. Therefore, much of the equipment is commercially available.

The heart of the LIFAC process is the activation reactor in which the lime-laden flue gas is humidified and the lime is made more reactive with respect to SO_2. This process has been developed starting at the bench- and pilot-scales followed by a full-scale (150 MWe) test to study sorbent injection. Additional work on sorbent injection was done at a 220 MWe boiler. Tampella initially tested humidification using a slipstream of flue gas from this boiler. This was followed by 8 MWe tests and by 70 and 125 MWe LIFAC installations in Finland. LIFAC tests were also run on a high-sulfur U.S. coal at the 8 MWe level. The successful, 8 MWe scale tests with high-sulfur U.S. coal provide further evidence that the LIFAC process is technically feasible when burning U.S. high-sulfur coal. This extensive development work, followed by two successful commercial installations, indicates that the LIFAC process is feasible.

3.3.1.3 Resource Availability

A number of resources are required to ensure success of the project. Resource availability, however, is not expected to constrain the LIFAC demonstration for the following reasons:

- Richmond Power and Light's Whitewater Valley Unit 2 will receive operational support from Tampella and ICF Kaiser personnel. Construction personnel requirements can be readily met from the Richmond area.

- The project will consume approximately six tons of limestone per hour which is minimal consumption compared with available supplies of limestone. Annual U.S. production of limestone is measured in hundreds of millions of tons.

- Electrical power consumption will increase by approximately 0.6 MWe, which is less than 1% of the total plant output. This quantity is available from the Whitewater Valley station.

- Water consumption will increase by less than 20 gallons per minute. Again, this represents an inconsequential amount. Very small quantities of steam are also available for use in the project.

- Waste disposal requirements will increase due to the use of sorbent. However, this material is readily disposed of in a landfill. The waste products will be disposed of in the current fly ash landfill or sent to a municipal landfill.

3.3.2 Relationship Between Project Size and Projected Scale of Commercial Facility

The primary target market for LIFAC includes powerplants of up to 500 MWe and is expected to be less competitive at larger sites. This is because the LIFAC process must be installed in modular fashion at larger sizes, whereas conventional scrubbers continue to benefit from economies of scale. Thus, the maximum scaleup from the Whitewater plant to a 500 MWe plant would be a factor of four. The scaleup factor is four rather than eight or more because flue gas streams are typically divided and then processed by dual or multiple ESPs so that a 500 MWe stream would be split into two flue gas streams of 250 MWe each. A four-to-one scaleup--60 MWe gas stream at Whitewater Valley versus a 250 MWe stream--is well within common industry practice. Systems and equipment (e.g., for lime handling) are currently commercially available at the size required for a 500 MWe plant.

3.3.3 Role of Project in Achieving Commercial Feasibility of the Technology

The LIFAC process has the potential to enhance the use of low-, medium-, or high-sulfur coals under conditions requiring compliance with environmental regulations. Currently, full-scale tests have been limited to two plants in Finland. An independent review of the LIFAC technology under U.S. conditions is necessary to facilitate marketing of the technology domestically.

The commercialization of the LIFAC technology requires a comprehensive data base that demonstrates the SO_2 removal effectiveness, reliability, and cost effectiveness of the technology. Commercialization of the technology also requires transfer of relevant data to the electric power industry and other interested market participants and observers. A number of important industry and trade groups are participating in the LIFAC demonstration and will assist in the preparation and dissemination of such information. Participants include: the Electric Power Research Institute (EPRI), Peabody Coal Company, Black Beauty Coal Company, and LaFarge (the largest U.S. producer of limestone).

3.3.3.1 Applicability of Data to be Generated

The objective of the testing program will be to provide a comprehensive evaluation of the LIFAC process and its impacts on boiler performance and emissions when the LIFAC process is used with high-sulfur U.S. coal. The test program will determine how the LIFAC process will be affected by changing:

- coal quality, including sulfur content
- limestone quality
- Ca/S molar ratio
- temperature approach to adiabatic saturation
- boiler load
- limestone injection location

In addition, the test program will demonstrate the effect that the LIFAC process will have on various aspects of the power plant operation. Specifically, the LIFAC test program will study the following key ares:

- reductions of SO_2 emissions
- effects on boiler performance and operability
- effects on particulate emissions and particulate control equipment performance
- effects on solid waste characteristics

The test program will be coordinated with an environmental monitoring program. The environmental monitoring program will focus on such issues as characterization of the waste product, disposal alternatives, and environmental impacts of the waste.

Tests will be performed under both baseline (i.e., without LIFAC) and LIFAC operation to provide a direct assessment of the effects on performance and emissions. A wide range of parameter values, samples, and measurements will be obtained during the test program using standard procedures. Quality assurance will be conducted as an integral part of the test program and specific quality assurance and quality control procedures will be described for each test run including replicate tests to determine data precision. Mass and thermal balances will be used to assess the overall accuracy of the data. Adequate data will be obtained to completely characterize the LIFAC process with respect to SO_2 removal performance, cost, impacts on boiler efficiency, and process reliability.

3.3.3.2 Identification of Features that Increase Potential for Commercialization

Wet scrubbers are by far the most prevalent scrubber technology and account for approximately 90% of U.S. scrubber systems. Wet FGD systems that use lime or limestone remove about 90% of the SO_2 and usually produce a sulfite/sulfate sludge waste product. The LIFAC process offers several advantages although LIFAC cannot match the high removal rates (90%) achieved by conventional wet scrubbers. Advantages of the LIFAC process include:

- The need for slurry preparation/handling equipment is eliminated.
- The technology can be more easily retrofit onto most powerplants because the vertical activation chamber requires less space.
- The technology has lower capital costs which is especially attractive to existing plants that have fewer years to amortize capital investments as compared to new long-lived powerplants.
- The technology uses a widely available reagent material, limestone, rather than more expensive materials such as lime.
- The waste product is dry and easy to handle. In comparison, conventional wet limestone scrubbers produce a wet sludge which requires special handling and treatment.
- The technology is typically compatible with other plant systems such as ESPs and ID fans, thereby minimizing costly retrofit plant modifications in order to employ the technology.

The LIFAC system also has potential advantages over less conventional sorbent injection systems now being tested. These include:

- Use of limestone as opposed to lime or other more expensive sorbents.
- Removal rates of 75-80% which exceed the removal rates of many dry sorbent injection systems.
- Improved control of slagging and fouling associated with humidification in a vertical chamber as opposed to in-duct humidification.

The participant estimates that LIFAC technology's potential for commercialization is increased by its ability to remove 75-80% of the SO_2, its low space requirement, and its low retrofit costs.

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

The LIFAC process offers many advantages compared with other FGD systems. These technical and economic advantages are expected to gain industry acceptance of LIFAC as a viable SO_2 removal alternative. LIFAC's favorable attributes include:

- The LIFAC process has lower initial capital requirements and is less expensive to operate than other FGD systems, in particular, wet scrubbers.

- The system is suitable for retrofit applications since it requires less space than other FGD systems.

- The system is capable of removing more sulfur (75-80%) than other technologies competing with wet scrubbers. This level of removal makes LIFAC suitable for use with high-sulfur coal, unlike other dry sorbent injection processes and spray dryers.

- The LIFAC Process uses limestone, which is relatively inexpensive, as the reagent.

- The selection of the RP&L Whitewater Valley Unit 2 is particularly appropriate for demonstrating the LIFAC process. The host boiler has been designed to be very compact, making retrofit particularly difficult. This boiler burns high-sulfur coal and has a high utilization rate which will demonstrate the effectiveness and reliability of the process under U.S. operating conditions.

- The site also offers several advantages not related to the technical merits of the LIFAC process. The site was used previously to demonstrate another upper-furnace sorbent injection technology and the equipment for sorbent handling and injection is available to the LIFAC demonstration, thus holding down project costs. The site is also located close to the nation's leading high-sulfur coal areas and has good transportation access to those areas.

4.0 ENVIRONMENTAL CONSIDERATIONS

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

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

As the final element of the NEPA strategy, the Participant (LIFAC North America) submitted the environmental information specified in the PON. This detail site- and project-specific information formed the basis for the NEPA documents prepared by DOE. These documents, prepared in compliance with 40 CFR 1500-1508, must be approved before federal funds can be provided for construction and operation activities.

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

The expected performance characteristics and applicable market for the LIFAC technology was used to estimate the environmental impacts that might result if this technology were to reach full commercialization in 2010. The REDES model was used to compare LIFAC technology impacts to the no-action alternative.

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

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

Region	Sulfur Dioxides	Nitrogen Oxides	Solid Wastes
National	-45	0	+19
Northeast	-65	0	+22
Southeast	-52	0	+26
Northwest	-10	0	+11
Southwest	-15	0	+11

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

As shown in Table 1, significant reductions of SO_2 are projected to be achievable nationally due to the capability of the LIFAC process to remove between 75% and 80% of SO_2 emissions from coal-fired boilers and the wide potential applicability of the process. The REDES model predicts greatest SO_2 reductions will be realized in the Northeast because of the large amount of coal-fired capacity there that can be retrofitted with the LIFAC process. The least impact occurs in the Northwest because of the minimal use of coal there. The REDES model predicts that solid waste would increase as much as 19% nationally. The solids consist of gypsum, flyash, and unreacted lime, and this material is readily disposable. The national quadrants used in this study are depicted in Figure 4.

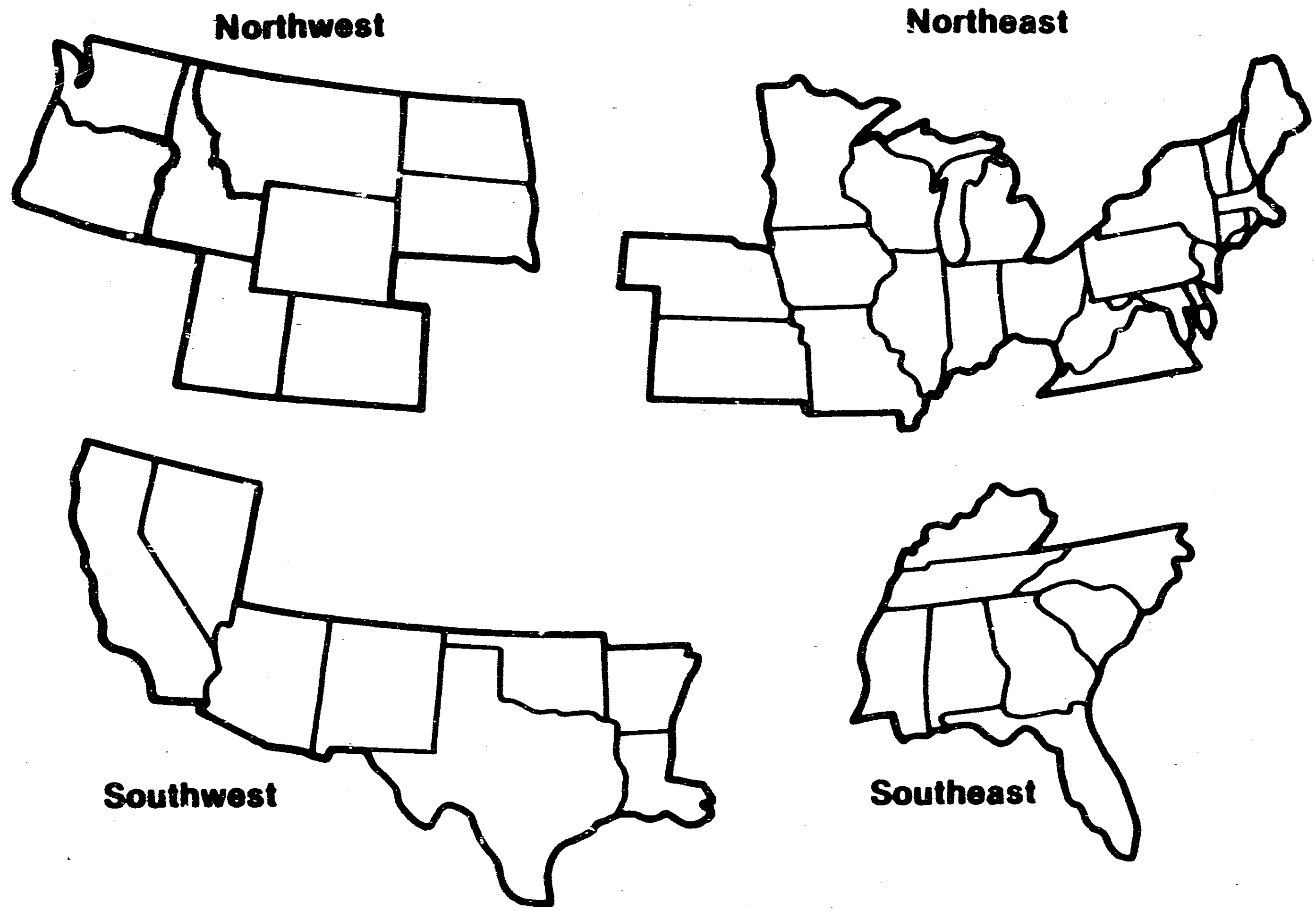

FIGURE 4. QUADRANTS FOR THE CONTIGUOUS UNITED STATES.

NOJ18,677

5.0 PROJECT MANAGEMENT

5.1 Overview of Management Organization

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

The co-funding of the project will be provided by LIFAC North America, Inc. (a joint venture between Tampella, Ltd., of Finland and ICF Kaiser Engineers of the United States), RP&L, EPRI, and others. The Project Director will have overall responsibility for execution of the Cooperative Agreement. The Project Manager will be responsible for timely completion of the required tasks and will serve as the focal point in coordinating activities of the various team members.

An Executive Coordinating Committee will be organized and will comprise management representatives from ICF Kaiser, Tampella, RP&L, and EPRI. A Technical Advisory Committee will be formed and will consist of technical personnel from ICF Kaiser Engineers, Tampella, Black Beauty Coal Company, Peabody Coal Company, EPRI, and DOE.

5.2 Identification of Respective Roles and Responsibilities

DOE

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

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

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

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

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

- Constitutes an assignment of additional work outside the Statement of Work.
- In any manner causes an increase or decrease in the total estimated cost or the time required for performance of the Cooperative Agreement.
- Changes any of the terms, conditions, or specifications of the Cooperative Agreement.
- Interferes with the Participant's right to perform the terms and conditions of the Cooperative Agreement.

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

Participant

LIFAC NA will take the lead in the effort required for the successful execution of this project and act as the center of communication and the major coordinator to all the parties participating in the project. LIFAC NA will also be responsible for fulfilling all the DOE reporting requirements as stipulated in the Cooperative Agreement.

The Program Manager will be in charge of the overall project, and the prime decision maker in all phases of the project. He will be the principal representative of LIFAC NA to DOE and provide supervision and guidance to all project management team members. The Program Manager will report to the management of LIFAC NA, ensuring top-level attention to the project.

The Project Manager will be responsible for the timely completion of all tasks required for the project and will act as the focal point in steering the progress of the project, and in coordinating with DOE, ICF Kaiser, Tampella, RP&L, EPRI, and all other project team members. The Project Manager will maintain overall cost and schedule control of the project.

He will also provide supervision and guidance to the project design team and construction management group assigned to the project. The Project Manager will coordinate with the contract specialist(s) on all procurement tasks and will interface with the environmental specialist(s) on all environmental matters. The Project Manager will report regularly to the Program Manager on the progress and performance of the project.

Tampella, one of LIFAC NA's parent companies and the inventor of the LIFAC process, will act as technical consultant on the design, operation, and testing of the demonstration system.

As the demonstration site host, RP&L will participate in the Phase III operation and testing activities. RP&L will also be responsible for the management of all resources required for plant operation such as manpower, fuel, plant utilities, and reagent. RP&L will also be responsible for the management of by-product disposal.

The team members will interface with each other and with DOE as shown in Figure 5.

5.3 Summary of Project Implementation and Control Procedures

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

- Phase I: Design (6 months)
- Phase II: Purchasing, Construction, & Startup (11 months)
- Phase III: Operation (26 months)

As shown in Figure 6, there will be a four-month overlap between Phases I and II. The project will be completed 39 months after award of the Cooperative Agreement.

Two budget periods will be established--the first covering Phases I and II and the second covering Phase III. Consistent with P.L. 100-446, DOE will obligate funds sufficient to cover its share of the cost of each budget period. Throughout the course of this project, reports dealing with the technical, management, cost, and environmental monitoring aspects of the project will be prepared by LIFAC NA and will be provided to DOE.

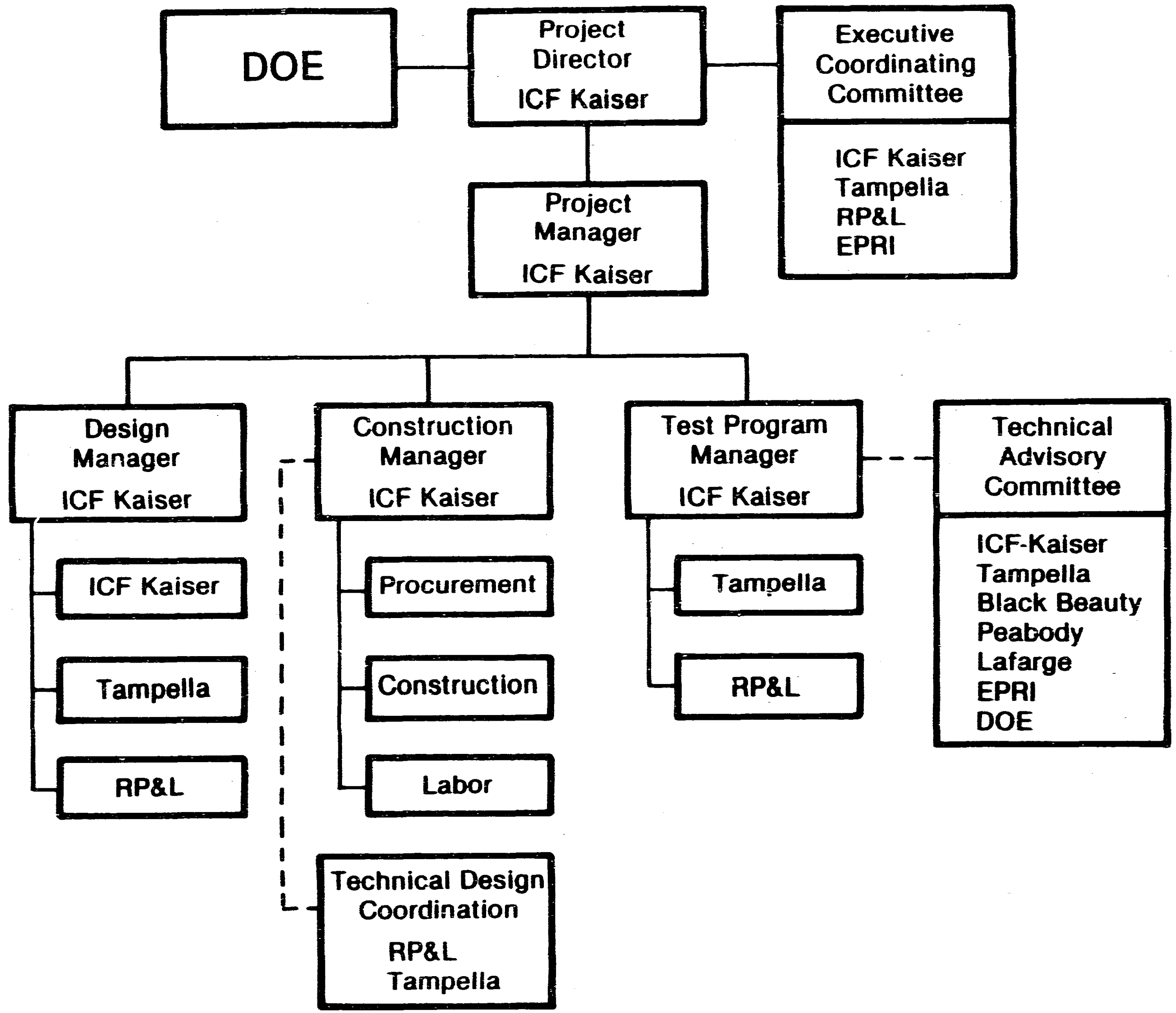

FIGURE 5. ORGANIZATION FOR LIFAC DEMONSTRATION PROJECT.

NO/19,666

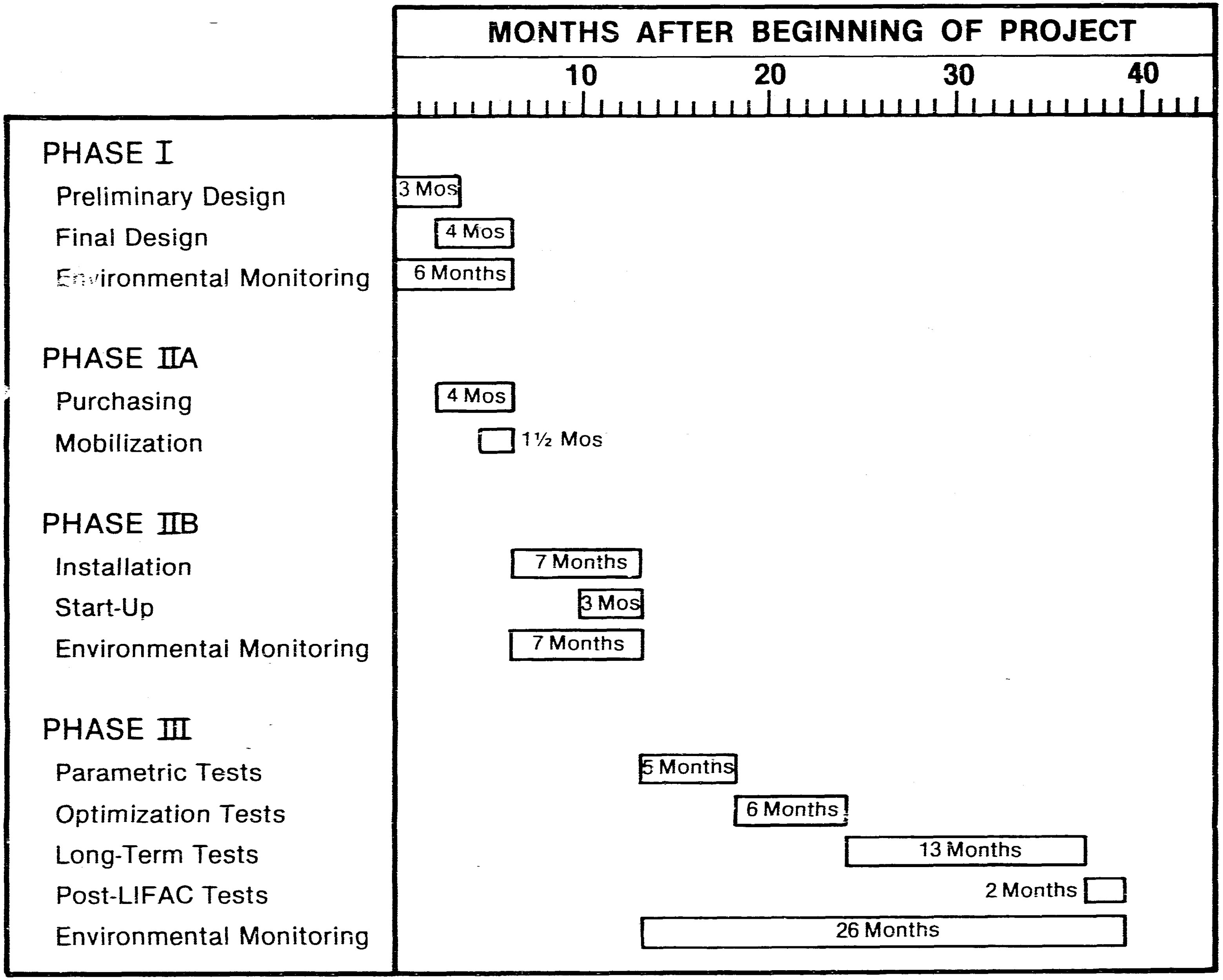

FIGURE 6. LIFAC DEMONSTRATION PROJECT SCHEDULE.

NO/19,979

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

LIFAC's incentive to develop this process is to realize retrofit business from, and produce new designs for, the utility and power boiler industry with respect to SO_2 abatement technology.

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 the Agreement.

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

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

- o Rights in background patents and background data of LIFAC NA and all of its subcontractors are included to assure commercialization of the technology.

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

5.5 Procedures for Commercialization of Technology

Tampella and LIFAC NA will work together to commercialize LIFAC technology with LIFAC NA focusing primarily on the demonstration project and technology transfer activities coordinated with other project participants. ICF Kaiser Engineers will also directly assist Tampella in its broader efforts to commercialize the LIFAC process in the U.S.

ICF Kaiser Engineers will provide its capabilities in engineering design and construction management. ICF Kaiser Engineers will also provide its market capabilities which are based on a knowledge of the utility industry, the air pollution control market, and regulatory environment. ICF Kaiser's capabilities in sales and engineering will be enhanced, with respect to LIFAC process commercialization, by the experience gained during the demonstration at Whitewater Valley.

Tampella will market LIFAC as part of its nationwide efforts to market boiler and other energy and pollution control technologies. Tampella will support the commercialization effort by granting an exclusive license to LIFAC NA, Inc., for the use of the patented LIFAC technology in the demonstration project. Tampella will continue to provide process engineering and design support, and expects to continue research on the LIFAC process and will make the results available to LIFAC NA.

Tampella and LIFAC NA are currently marketing the LIFAC technology in anticipation of having LIFAC available as a commercially demonstrated technology. Advertisements for LIFAC have been placed in key industry publications. Papers and other conference appearances have been and will continue to be important vehicles to build name identification and present information about the potential advantages of LIFAC. Most importantly, LIFAC NA has developed the proposed Whitewater Valley 2 demonstration program arranging for a site at a leading municipal utility and for participation of EPRI, the electric utility industry R&D organization, and several coal and cement companies. EPRI is well suited to transfer the results of the demonstration to the utility industry.

Tampella is also marketing LIFAC internationally. Tampella is pursuing sales in Finland, and has concluded a sale to the Vantaa coal-fired district heating plant, and is in negotiations for other sales. These sales are for future installations and while indicative of Tampella's commitment to commercialization does not eliminate the need for a full-scale demonstration of LIFAC under conditions relevant to the U.S. power plant market.

6.0 PROJECT COST AND EVENT SCHEDULING

6.1 Project Baseline Costs

The total estimated cost for this project is $17,018,982. The Participant's cash contribution and the Government share in the costs of this project are as follows:

	Dollar Share ($)	Percent Share (%)
PRE-AWARD		
Government	375,000	50
Participants	375,000	50
PHASE I		
Government	725,121	50
Participants	725,121	50
PHASE II		
Government	3,349,469	50
Participants	3,349,469	50
PHASE III		
Government	4,059,901	50
Participants	4,059,901	50
TOTAL PROJECT		
Government	8,509,491	50
Participants	8,509,491	50
	$17,018,982	

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

DOE:	$8,509,491
LIFAC NA:	$3,924,645
EPRI:	$ 500,000

Additional funding will be provided by Richmond Power & Light, Peabody Coal Company, Black Beauty Coal Company, and LaFarge. At the beginning of each budget period, DOE will obligate funds sufficient to pay its share of the expenses for that phase.

6.2 Milestone Schedule

The overall project will be completed in 39 months after award of the Cooperative Agreement.

Phase I, which includes design and permitting, will last six (6) months. Phase II will start four months before the completion of Phase I and has an overall duration of eleven months. Within Phase II, purchasing and mobilization (Phase IIA) will last four months and construction (Phase IIB), which will start after mobilization, will last for five months. Start-up and shakedown will start toward the end of construction and last for three months. Phase III will start immediately upon completion of Phase II with 26 months of experimental testing. All reports and analyses will be completed by the end of phase III.

6.3 Recoupment Plan

Based on DOE's recoupment policy as stated in Section 7.4 of the PON, DOE is to recover an amount up to the Government's contribution to the project. The Participant has agreed to repay the Government in accordance with a negotiated Repayment Agreement to be executed at the time of award of the Cooperative Agreement.

END

DATE FILMED

11 / 20 / 90