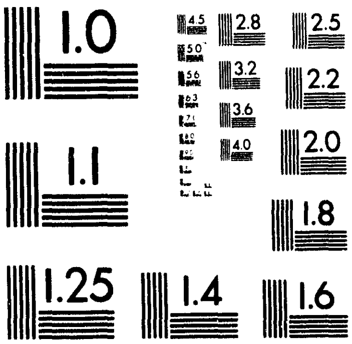
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Contract No. DE-FC22-90PC90548

Quarterly Report

No.10

LIFAC Sorbent Injection Desulfurization Demonstration Project

Presented By

LIFAC NORTH AMERICA, INC.

A Joint Venture Between

ICF KAISER ENGINEERS

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Pittsburgh, Pennsylvania 15222

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Presented To

U.S. Department of Energy

Pittsburgh Energy Technology Center
Pittsburgh, Pennsylvania 15236

MASTER

January - March 1993

LIFAC SORBENT INJECTION DESULFURIZATION DEMONSTRATION PROJECT

QUARTERLY REPORT NO. 10
JANUARY - MARCH 1993

Submitted to

U. S. DEPARTMENT OF ENERGY

by

LIFAC NORTH AMERICA

LIFAC Sorbent Injection Desulfurization Demonstration Project

QUARTERLY REPORT NO. 10

OCTOBER - DECEMBER 1992

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INTRODUCTION

In December 1990, the U.S. Department of Energy selected 13 projects for funding under the Federal Clean Coal Technology Program (Round III). One of the projects selected was the project sponsored by LIFAC North America, (LIFAC NA), titled "LIFAC Sorbent Injection Desulfurization Demonstration Project." The host site for this $22 million, three-phase project is Richmond Power and Light's Whitewater Valley Unit No. 2 in Richmond, Indiana. The LIFAC technology uses upper-furnace limestone injection with patented humidification of the flue gas to remove 75-85% of the sulfur dioxide (SO_2) in the flue gas.

In November 1990, after a ten (10) month negotiation period, LIFAC NA and the U.S. DOE entered into a Cooperative Agreement for the design, construction, and demonstration of the LIFAC system. This report is the tenth Technical Progress Report covering the period January 1, 1993 through the end of March 1993. Due to the power plant's planned outage in March 1991, and the time needed for engineering, design and procurement of critical equipment, DOE and LIFAC NA agreed to execute the Design Phase of the project in August 1990, with DOE funding contingent upon final signing of the Cooperative Agreement.

BACKGROUND

Project Team

The LIFAC demonstration at Whitewater Valley Unit No. 2 is being conducted by LIFAC North America, a joint venture partnership between:

- ICF Kaiser Engineers - A U.S. company based in Oakland, California, and a subsidiary of ICF International (ICF) based in Fairfax, Virginia.

- Tampella Power Corp. - A U.S. subsidiary of a large diversified international company, Tampella Corp., based in Tampere, Finland and the original developer of the LIFAC technology.

LIFAC NA is responsible for the overall administration of the project and for providing the 50 percent matching funds. Except for project administration, however, most of the actual work is being performed by the two parent firms under service agreements with LIFAC NA. Both parent firms work closely with Richmond Power and Light and the other project team members, including ICF Resources, the Electric Power Research Institute (EPRI), Indiana Corporation for Science and Technology (ICS&T), and Black Beauty Coal Company. LIFAC NA is having ICF Kaiser Engineers manage the demonstration project out of its Pittsburgh office, which provides excellent access to the DOE representatives of the Pittsburgh Energy Technology Center. Figure 1 shows the management structure being used throughout the three phases of the project.

LIFAC NA administers the project through a Management Committee that decides the overall policies, budgets, and schedules. All funding sources, invoicing, and information flows to LIFAC NA where the managing partners ensure that the project, funding and expenditures are consistent and in-line with the established policies, budgets, schedules and procedures.

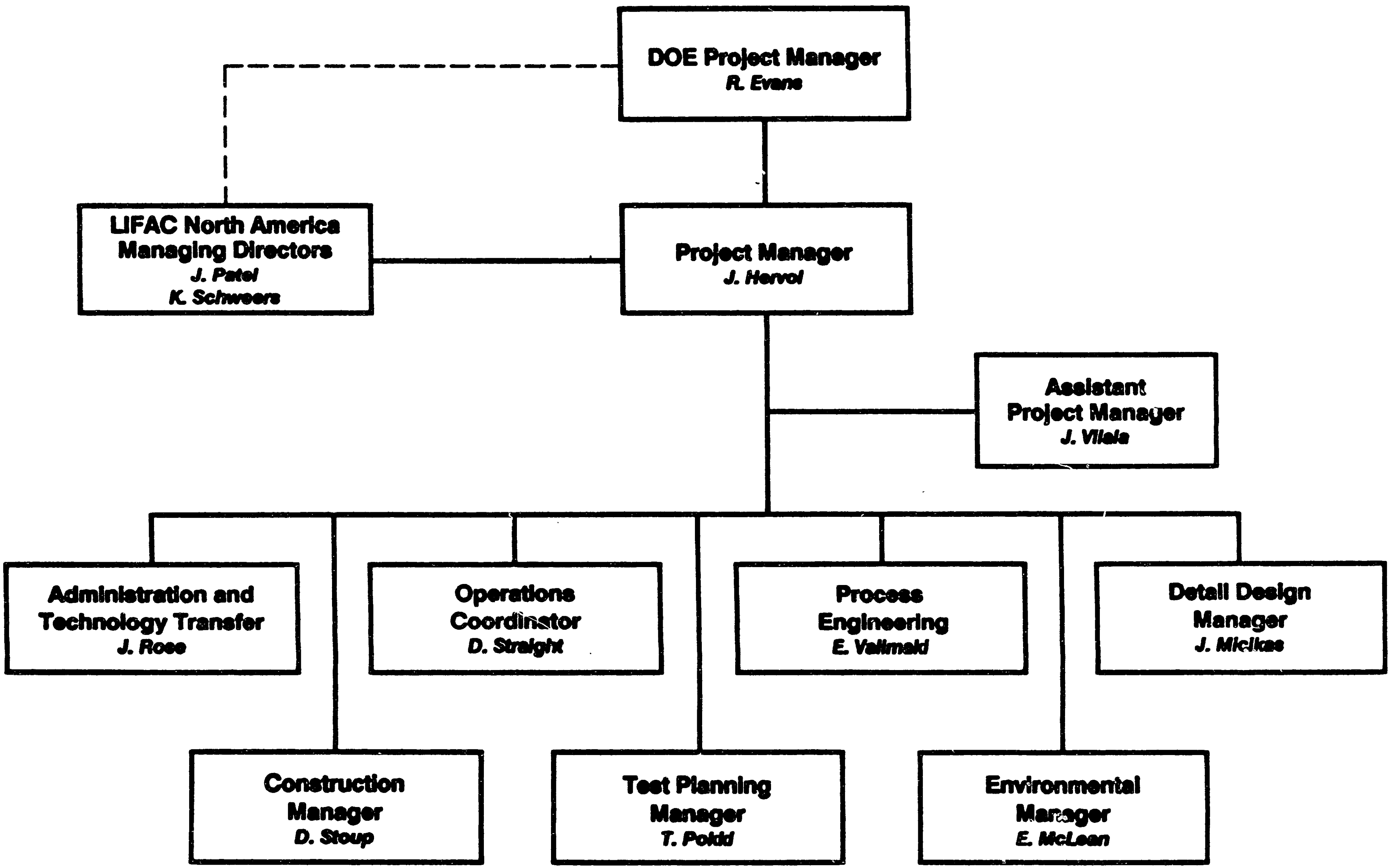
Process Development

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 MW 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

Project Organization



a 220 MW 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 up to 84%. Additional LIFAC pilot-scale tests were conducted at the 8 MW (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 power plant on a 250 MW utility boiler. An activation chamber was built to treat a flue gas stream representing about 70 MW. Even though the boiler was 250 MW, the 70 MW stream represented about one-half of the flue gas feeding one of the plant's two ESP's (i.e., each ESP receives a 125 MW 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 MW -- 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 2:1 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 MW boiler burning high-sulfur U.S. coals to demonstrate the commercial application of the LIFAC process to U.S. utilities.

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. The process produces a dry and stable waste product that is partially removed from the bottom of the activation reactor 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). As the lime passes through the furnace, initial 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 is directed to the patented LIFAC activation reactor. In the reactor, additional sulfur dioxide capture 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. All the water droplets evaporate before the flue gas leaves the activation reactor. The activation reactor is also designed specifically to minimize the potential for solids build-up on the walls of the chamber. The net effect is that at a Ca:S ratio in the range of 2:1 to 2.5:1, 70-80% of the SO_2 is removed from the flue gas.

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 $CaSO_3$. To improve utilization of the calcium, and increase SO_2 reduction to between 75 and 85%, a portion of the spent sorbent collected in the bottom of the activation reactor and/or in the ESP hoppers is recycled back into the ductwork just ahead of the activation reactor.

Process Advantages

The LIFAC technology has similarities to other sorbent injection technologies using humidification, but employs a unique patented vertical reaction chamber located down-stream 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, with recirculation of the sorbent, removes less sulfur dioxide - 75-85% relative to 90% or greater for conventional scrubbers - and requires 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.

HOST SITE DESCRIPTION

The site for the LIFAC demonstration is Richmond Power and Light's Whitewater Valley 2 pulverized coal-fired power station (60 MW), located in Richmond, Indiana. Whitewater Valley 2, which began service in 1971, is a Combustion Engineering tangentially-fired boiler which uses high-sulfur bituminous coal from Western Indiana. Actual power generation produced by the unit approaches 65 megawatts. As such, it is one of the smallest existing, tangentially-fired units in the United States. The furnace is 26-feet, 11-inches deep and 24-feet, 8-inches wide. It has a primary and secondary superheater. Tube sizes and spacings are designed to achieve the highest possible heat-transfer rates with the least potential for gas-side fouling. The unit also has an inherent low draft-loss characteristic because of the lack of gas turns. At full load 540,000 lbs/hr. of steam are generated. The heat input at rated capacity is 651 x 10^6 Btu per hour. The design superheater outlet pressure and temperature are 1320 psi at 955°F. The unit has a horizontal shaft basket-type air preheater. The temperature leaving the economizer is about 645°F, while the stack gas temperature is about 316°F. The balanced-draft unit has 12 burners.

In 1980 the unit was fitted and fully optimized with a state-of-the-art Low-NO_x Concentric Firing System (LNCFS). The LNCFS represents a very cost effective means of reducing NO_x emissions in comparison with other retrofit possibilities. The system works on the principal of directing secondary air along the sides of the furnace and creating a fuel rich zone in the center of the furnace. With the LNCFS, the excess air can be maintained below 20 percent. Additionally, the installation reduces ash accumulation on the furnace walls increasing heat absorption and reducing attemperation requirements. With the LNCFS, each corner of the furnace has a tangential windbox consisting of three coal compartments and four auxiliary air compartments. At full load with all three 593 RB pulverizers operating, primary transport air from the pulverizers amounts to 23 percent of the total combustion air. Pulverizer capacity is 26,400 lbs/hr. with 52 grind coal and 70 percent minus 200 mesh.

Whitewater Valley 2 has a Lodge Cottrell cold side precipitator which was erected with the boiler. The precipitator treats 227,000 actual cubic feet per minute of 316°F flue gas with 45,000 square feet of collection area. The unit has two mechanical fields and four electrical fields and achieves 99 percent removal efficiency (from 3.9 gr/ft^3 to 0.04 gr/ft^3). The ESP performance was optimized by Lodge Cottrell when Richmond Power and Light purchased new controllers in 1985.

Whitewater Valley Unit 2's overall efficiency of 87.47 percent at full load has shown little variation over the years. The unit's average heat rate is 10,280 Btu/Kwh. At 60 percent of full load, the unit's efficiency increases to 88.17 percent. The unit uses approximately 0.935 pounds of coal per Kwh and generates 8.51 pounds of steam per Kwh.

The primary emissions monitored at the station are SO_2 and opacity. SO_2 emissions are calculated based on the coal analysis and are limited to 6 lbs/Mbtu. Opacity is monitored using an in-situ meter at the stack and is currently limited to 40 percent. Current SO_2 emissions for the unit are approximately 4 lbs/Mbtu, while opacity at full load ranges from 15 to 20 percent. Opacity at low load (40MW) ranges from 3 to 5 percent. Limited testing was conducted in November of 1986 for NO_x emissions. Results from the test work indicated that NO_x emissions averaged 0.65 lbs/MBtu.

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. Much of the sorbent injection equipment remains on site and is being used in the LIFAC demonstration. Another advantage of the site is that Whitewater Valley 2 was a challenging candidate for a retrofit due to the cramped conditions at the site. The plant is thus typical of many U.S. power plants which are potential sites for application of LIFAC. In addition, the Whitewater Valley 2 boiler is small relative to its capacity; hence, it has high-temperature profiles relative to other boilers. This situation requires sorbent injection at higher points in the furnace to minimize deadburning of the reagent, but it decreases residence times needed for sulfur removal. Whitewater Valley 2 will show LIFAC's performance under operational conditions most typical of U.S. power plants. 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.

PROJECT SCHEDULE

To demonstrate the technical viability of the LIFAC process to economically reduce sulfur emissions from the Whitewater Valley Unit No. 2, LIFAC NA is conducting a three-phase project.

Phase I: **Design**

Phase IIA: **Long Lead Procurement**

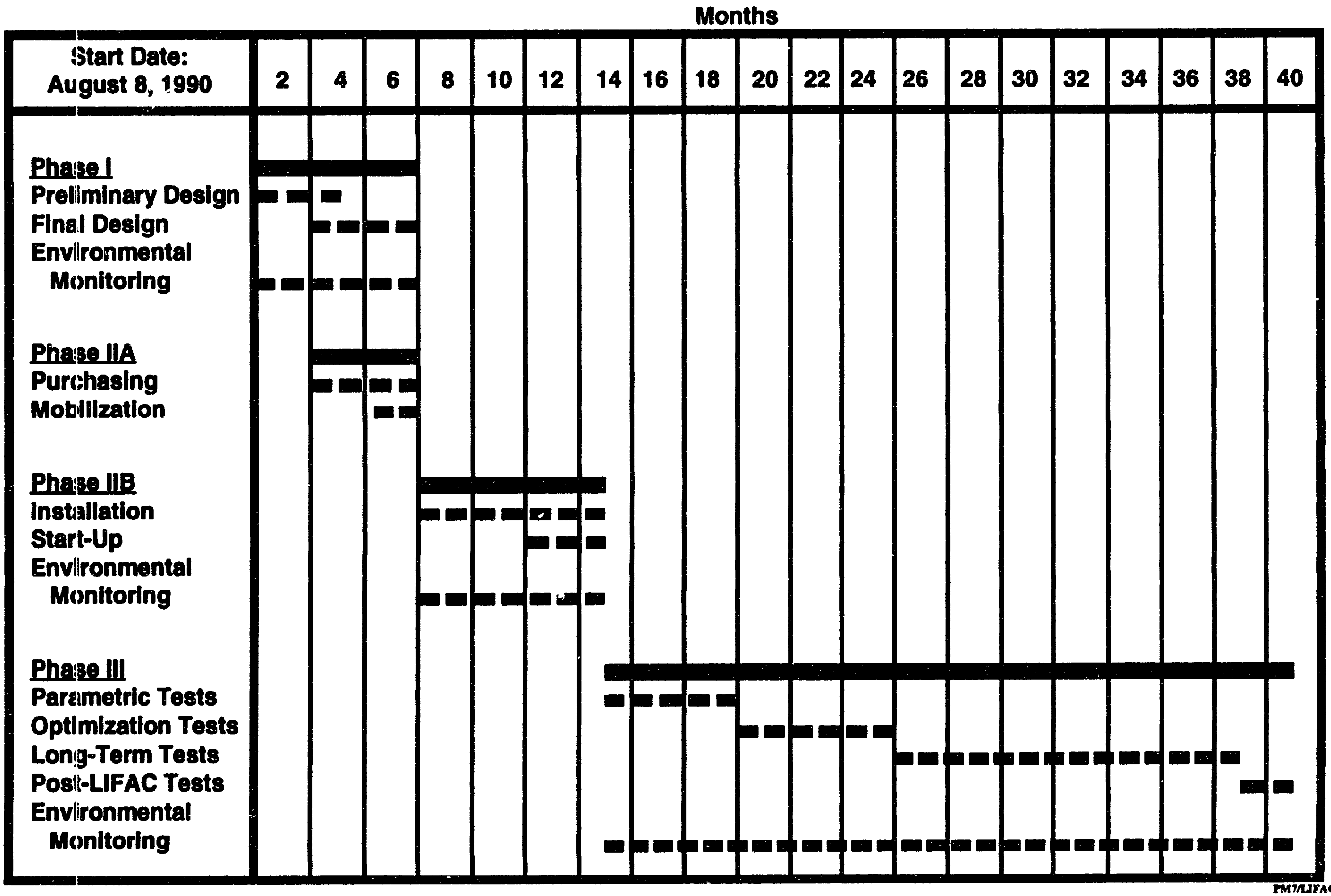
Phase IIB: **Construction**

Phase III: **Operations**

Except Phase IIA, each phase is comprised of three (3) tasks, a management and administration task, a technical task and an environmental task. The design phase began on August 8, 1990 and was scheduled to last six (6) months. Phase IIA, long lead procurement, overlaps the design phase and was expected to require about four (4) months to complete. The construction phase was then to continue for another seven (7) months, while the operations phase was scheduled to last about twenty-six (26) months. Figure 2 shows the original estimated project schedule which is based on a August 8, 1990 start date and a planned outage of Whitewater Valley 2 during March 1991.

It is during this outage that all the tie-ins and modifications to existing Unit No. 2 equipment were made. This required that the construction phase begin in early February, 1991 -- construction was to be completed by the end of August 1991. Operations and testing were to begin in September 1991 and continue for 26 months. However, during previous reporting periods, the project encountered delays in receiving its construction permit. These delays, along with some design changes, and an approved expansion in project scope required that the Design Phase be extended by about eleven months. Therefore, construction was not completed until early June 1992. This represents a nine-month extension in the overall schedule. During the last half of 1992, problems were encountered during startup and commissioning of some of the LIFAC components and systems. These problems required the parametric tests to be delayed until the first quarter 1993 which subsequently required adjustments in the entire testing schedule. These delays, however, will not impact the overall duration of the Operations Phase. Figure 3 shows the revised project schedule including the adjustments made in the testing schedule. During the initial parametric tests conducted this period, problems were encountered with increased opacity levels. These problems (see later discussion) forced an extension in the parametric test

LIFAC Demonstration
Original Project Schedule



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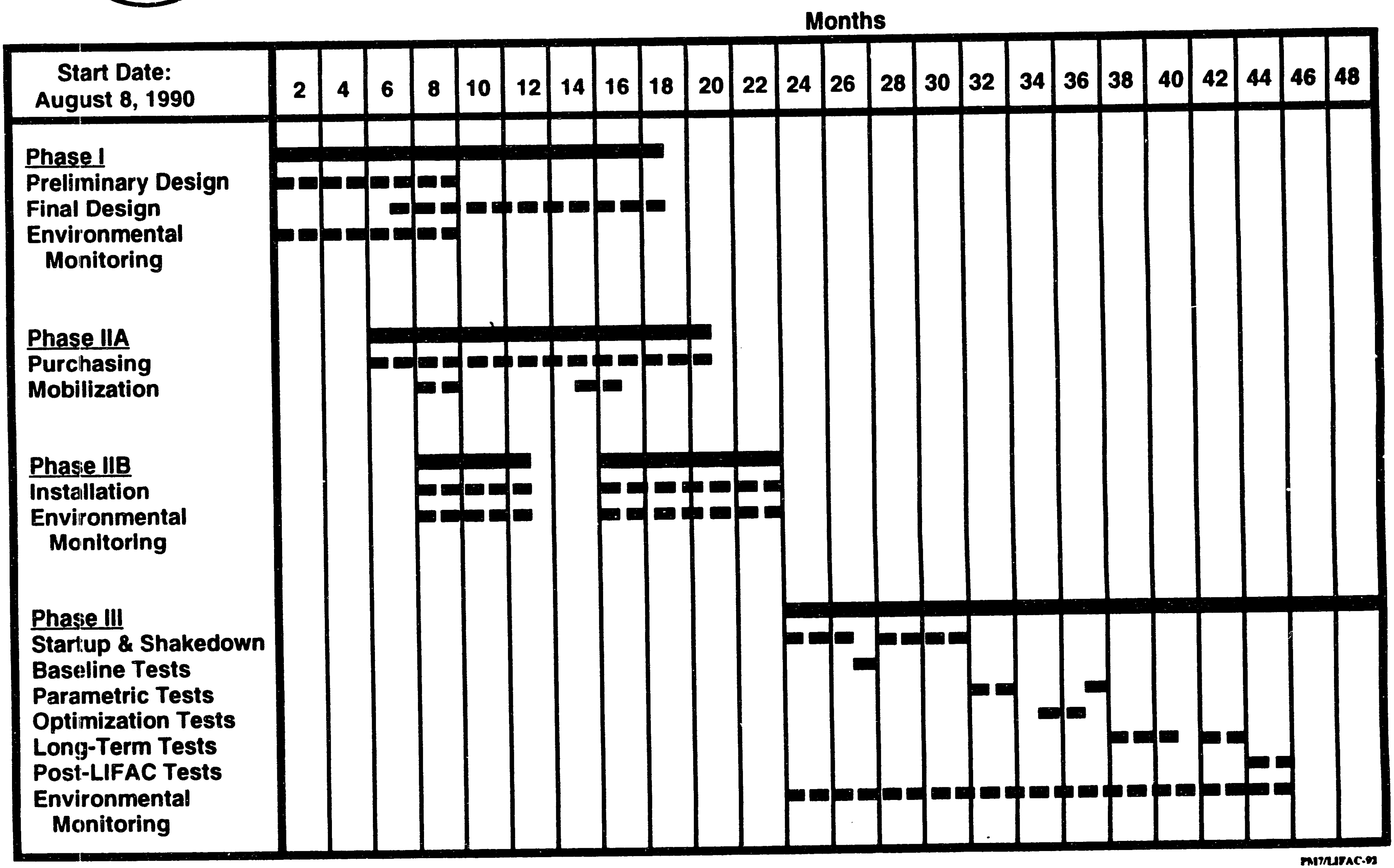
LIFAC Demonstration

Current Project Schedule

(Revised December 1992)



schedule. An adjustment will be made to the testing schedule next period. Total project duration will remain at 48 months.

TECHNICAL PROGRESS

The work performed during this period (January - March 1993) was consistent with the revised Statement of Work (Scope Increase) and the approved schedule change contained in the Cooperative Agreement. During this period, all startup and commissioning problems were resolved, baseline testing completed, and parametric testing initiated. Work was conducted under the three tasks comprising the Operations Phase. Following is a summary of the work performed under these tasks.

Project Management (WBS 1.3.1)

During January through March 1993, management efforts and achievements included:

- **LIFAC Management Committee Meetings -** During this quarter, the Committee held two conference-call meetings (January 12 and February 4) to discuss project status, problems, and potential solutions. Discussion topics included:

  - Schedule status for the operations phase and cause of the delays. Parametric testing was delayed in prior periods due to mechanical startup problems. Opacity problems encountered this period has caused additional delays. An approach to study the problem was reviewed and approved by the Committee.

  - Budget status was reviewed to determine the effect the delayed schedule was having on total project cost. Although there has been delays, expenditures are also behind schedule.

  - Subcontractor invoices were reviewed and payments approved.

  - Project staffing levels were reviewed to ensure adequate personnel are available for operations, testing, data analysis, and reporting.

- **Joint LIFAC NA - DOE Cooperation** - During this period, LIFAC NA continued to implement the Cooperative Agreement's management and administrative and technical provisions including DOE reporting and administrative requirements.

  - LIFAC NA sent invoices to DOE during the period consistent with DOE requirements that the project report invoiced and committed costs on a phase-and-task basis.

  - LIFAC NA management reviewed progress on the numerous periodic reports such as the Cost Management Report, the Financial Assistance Management Summary Report, Monthly Progress Report, Quarterly Reports, Milestone Status Reports, etc.

- **Regulatory** - LIFAC NA continues to monitor the negotiations between RP&L, IDEM, and EPA Region V. RP&L has requested a formal rule change in the SIP limits for TSP. The new proposed limits reflect actual day-to-day experience with the Whitewater Valley units. This process does not impact the demonstration project since LIFAC is operating under a variance from the state.

- **Funding Agreements** - LIFAC NA continued negotiations with the Electric Power Research Institute for its share of co-funding. EPRI has agreed to contribute up to $250,000. Most of the EPRI funds will be directed towards the study of the effects of LIFAC on ESP performance.

- **Technology Transfer** - During this period, LIFAC NA committed to three technical presentations for the following conferences:

  - 1993 SO_2 Control Symposium, August 24-27, 1993
  - Second Annual Clean Coal Technology Conference, September 7-9, 1993
  - SO_2 Capture Seminar - "Sorbent Options and Considerations, September 19-21, 1993

Testing and Data Analysis (WBS 1.3.2)

- **Baseline Test Report** - During this period, A draft of the Baseline Test Report was formulated and data analysis completed.

Startup and commissioning activities were completed in the three main areas.

Limestone Handling and Storage Area - During this quarter, all mechanical equipment has functioned properly and several minor modifications made:

- The 5" rubber conveying line that feeds the primary splitter was hard-piped from the West Plant wall up to the splitter.
- The 2" existing rubber conveying hoses from the secondary splitters to the injection nozzles were replaced.
- The Acrison weight feeder was re-calibrated.
- Approximately 100 tons of limestone was pneumatically conveyed to both the upper and lower injection nozzles.
- The three existing air compressors have not yet been modified to enhance their performance, however, their operation seems to be more stable.
- The MCC room heating and ventilating system had a faulty transformer replaced.

- **Boilerhouse and ESP area** - The preceding period's problems have been resolved, however, one minor bug continues to hinder operations as follows:

  - The flue gas analyzers continue erratic operating/calibrating characteristics. The field service rep has been on site to make repairs and the units are currently working satisfactorily.

- The VFD induction cubicle (D. C. Link) was replaced, rewired, and tested. The unit will be put back on line during the scheduled spring outage.

- The two new rotary valves for the ESP ash recycle system were installed and adjusted. The recycle system is ready for operation.

- **Reactor Area -** All mechanical systems are operating in this area including:

  - The steam and water control valves have been repaired, installed and re-calibrated. They are both currently responding to command signals.

  - The liqui-mover had a higher voltage solenoid installed and is now working flawlessly.

- **LIFAC Operations -** The LIFAC process was operated on a limited basis due to several problems during this period, one being that the VFD was out of service, which restricts operation to lower boiler loads. On several occasions, inoperative equipment caused testing to be halted. However, the single most prohibitive factor has been the high opacity readings. As a result, EPRI was contacted to discuss specific tests and study the impact of LIFAC on ESP. It was decided to conduct flue gas and fly ash condition and emission tests to determine the impact LIFAC operations has on ESP opacity and particulate emissions.

  Mostardi-Platt was contracted to test opacity changes and particulate/sulfur compound emissions during baseline and LIFAC operation. During these tests, the existing stack opacity probe calibration was verified, particulate emissions at high opacity levels were measured and SO_3/SO_2 emissions were measured in the stack.

Stack RTD's were installed permanently in the stack verifying temperatures during opacity excursions.

A certified stack emissions visual reader was also contracted to compare results.

During the quarter, EPRI and their contractor, Southern Research Institute, began extensive ESP performance and emissions testing.

Initial results indicate that during the process start-up, increased opacity results from reduced ESP performance. However, opacity goes down shortly afterward when the ESP stabilizes and efficiency increases.

Parametric Testing - Some parametric tests have been performed with limestone injection and humidification. These parameters have had little effect with SO_2 capture and process operation. Because of the increased opacity levels, limestone flow and humidification water flow rate have been low. Therefore, reactor temperatures have been too high for successful SO_2 capture. Ash recycle, an important contributor to SO_2 capture, has not yet been tested.

Environmental Monitoring (WBS 1.3.3)

Due to startup problems encountered last reporting period, and opacity problems encountered during initial parametric testing this period, no formal environmental monitoring activities occurred in the field this period. However, a draft report was prepared of the Compliance and Supplemental Monitoring that occurred during baseline testing. The report will be reviewed internally and submitted to DOE next reporting period. Environmental monitoring will be re-initiated once parametric testing has been resumed.

FUTURE PLANS

- Upcoming spring outage will enable the VFD to be put back in service.
- Complete EPRI and SRI testing and analyze results.
- Review requirements that will reduce opacity emissions.
- Revise test schedule to reflect current test delays.
- Continue parametric testing and operate process for longer, continuous periods.
- Test recycle system.
- Prepare conference presentations.
- Resume environmental monitoring.
- Continue to submit the technical and the financial reports to the Department of Energy.

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