LIFAC SORBENT INJECTION DESULFURIZATION DEMONSTRATION PROJECT

QUARTERLY REPORT NO. 17

OCTOBER - DECEMBER 1994

Submitted to:

U.S. DEPARTMENT OF ENERGY (DOE)

By

LIFAC NORTH AMERICA

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I. INTRODUCTION

In December 1989, 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 seventeenth Technical Progress Report covering the period October 1, 1994 through the end of December 1994. 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.

II. BACKGROUND

A. Project Team

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

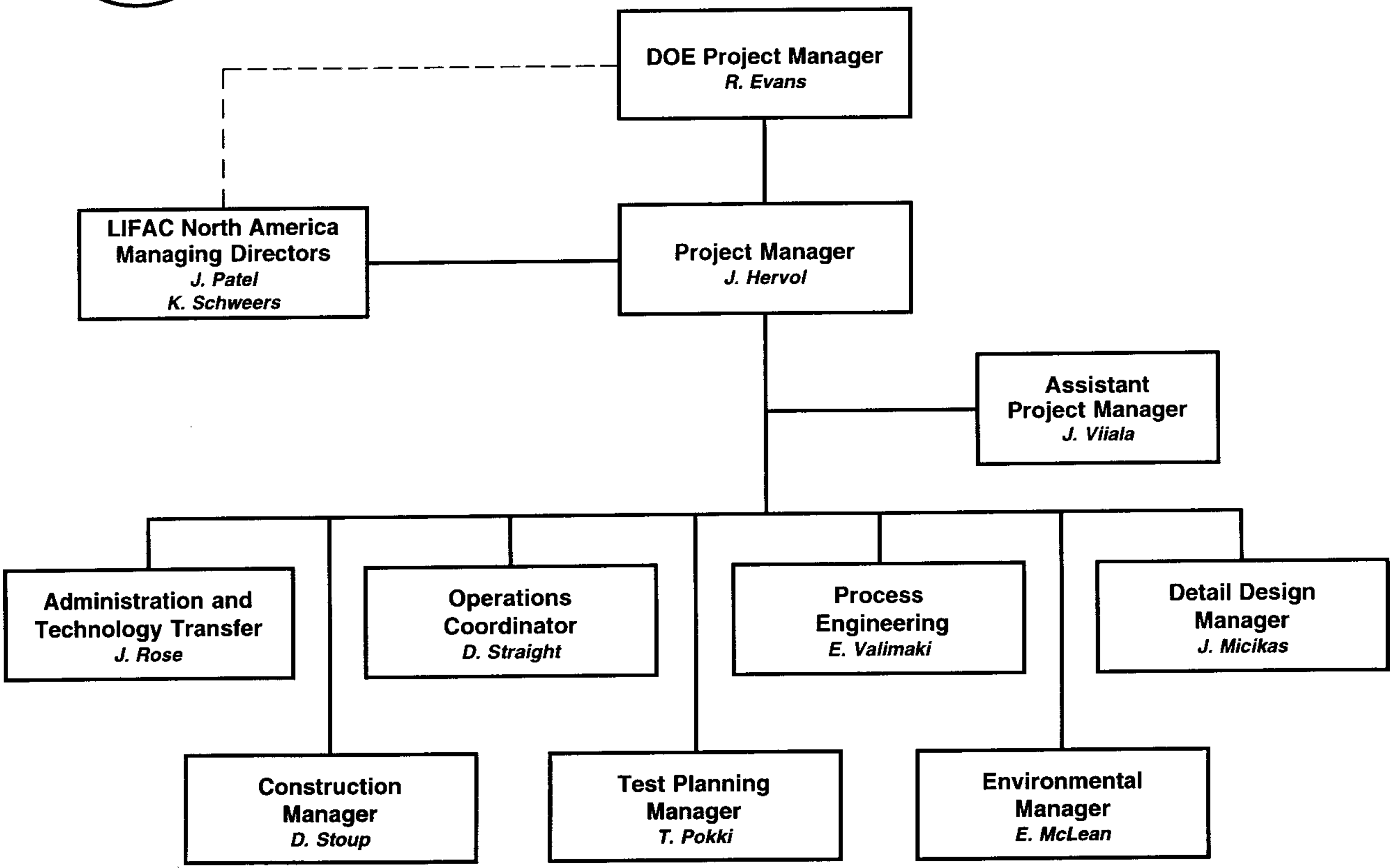
- ICF Kaiser Engineers - A U.S. company based in Oakland, California, and a subsidiary of ICF Kaiser International, Inc. (ICF) based in Fairfax, Virginia.

- 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 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.

Project Organization
(Revised July 1991)



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B. 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 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 is being 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.

C. 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.

D. 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.

III. 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 651×10^6 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 30 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.

IV. PROJECT SCHEDULEE

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 an August 8, 1990 start date and a planned outage of Whitewater Valley 2 during March 1991.

It was 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. During the initial parametric tests conducted during the first quarter of 1993, problems were encountered with increased opacity levels. These problems (see quarterly report No. 10) forced an extension in the parametric test schedule. Due to these delays, an adjustment was made during the second quarter of 1993 (report No. 11) to the testing schedule. Due to the various delays encountered in the testing schedule, a five (5) month, no-cost time extension was requested and granted to allow more time for data analysis and reporting efforts. Another no-cost time extension was requested and granted this Quarter to complete reporting efforts. The total project duration is now 58 months (see Figure 3), and is scheduled for completion by May 31, 1995.

Figure 1-2

LIFAC Demonstration

Original Project Schedule

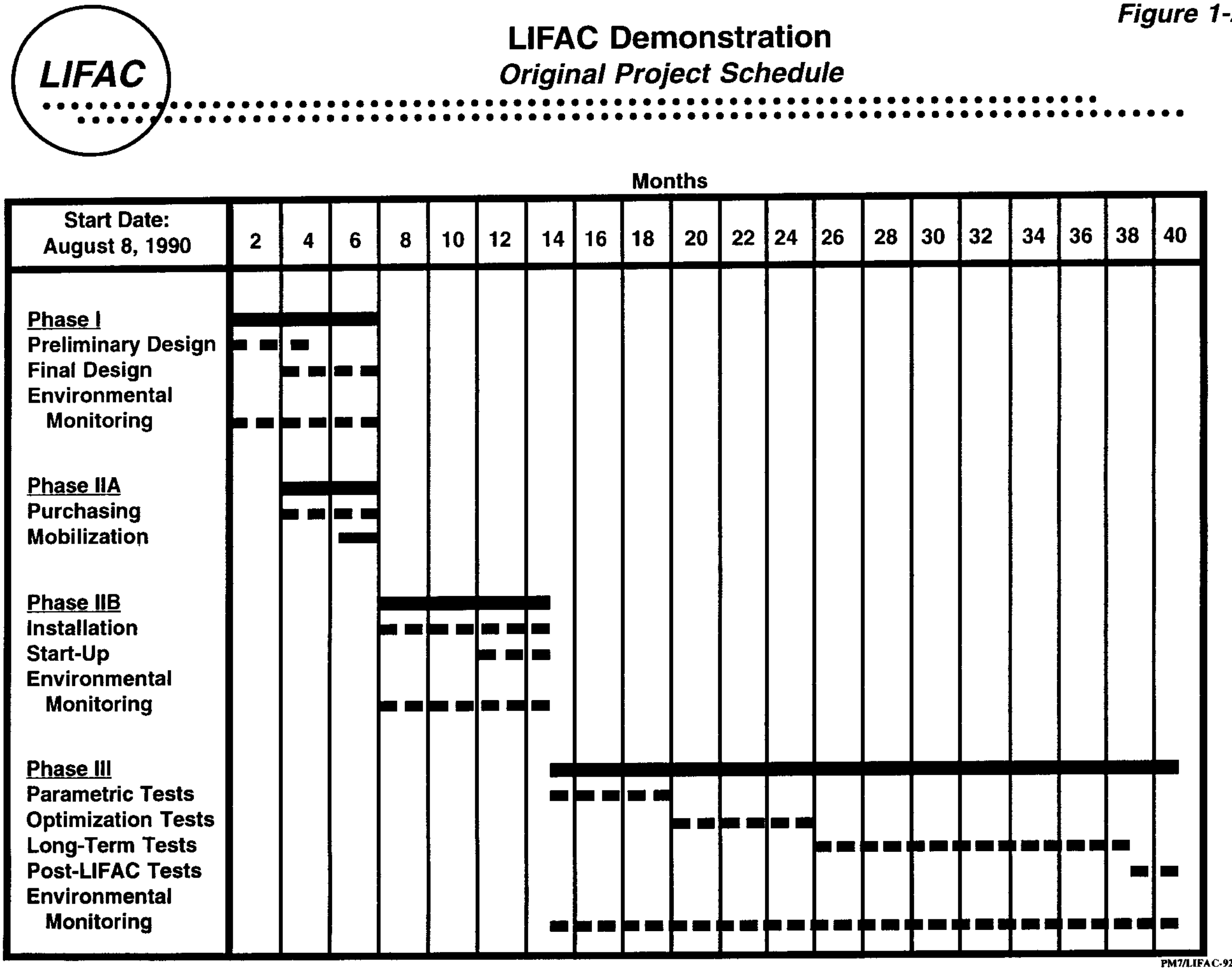
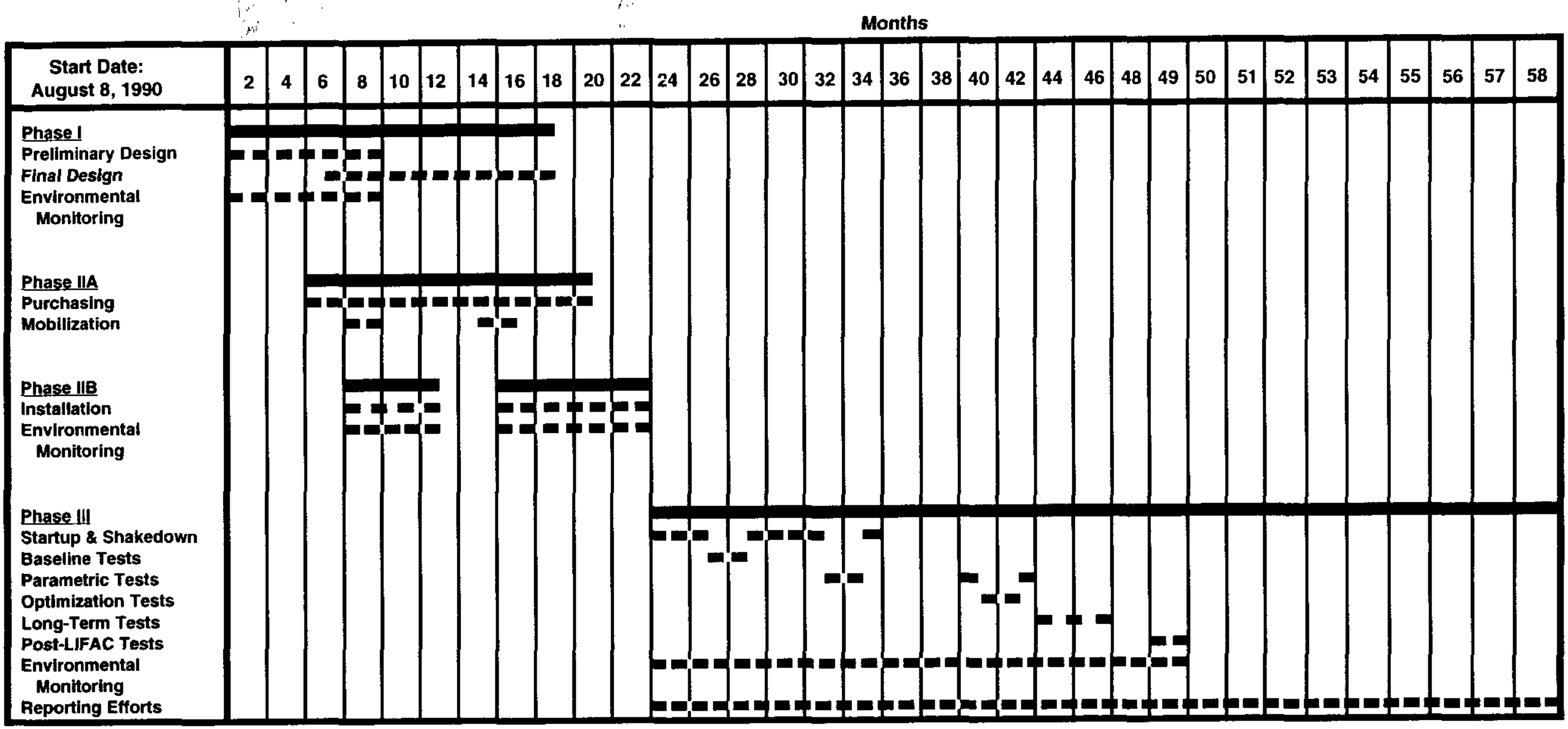


Figure 1-3

LIFAC Demonstration
Current Project Schedule
(Revised July 1994)



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V. TECHNICAL PROGRESS

Reporting efforts and data analysis were the main focus of the project team during this reporting period (October - December). The LIFAC system has been purged and preserved and the process was not operated during the Quarter. However, results from earlier testing were received and are contained in this report.

A. Testing and Data Analysis (WBS 1.3.2)

1. Reporting Efforts

Reporting efforts for the demonstration will continue through May 31, 1995. A five (5) month no-cost time extension was approved by DOE in order to complete reporting requirements. The project is now scheduled to be completed by May 31, 1995.

Data handling for the preparation of the Public Design Report, Volumes I and II, consumed most of this quarter. A draft of each volume will be submitted to DOE for review prior to issuing these reports. Volume I will provide design criteria and cost information of the LIFAC desulfurization process at the completion of construction and startup. Volume II of the Public Design Report will detail the performance and economics of LIFAC operations.

The results of the EPRI/SRI ESP evaluation was issued to LIFAC personnel during this Quarter. The summary and conclusions of the EST Evaluation are included in this report.

2. EPRI/SRI ESP Evaluation Summary

Comprehensive tests were conducted of the effects of the LIFAC SO_2 control process on the performance of the Whitewater Valley Unit 2 ESP. The following summary statements and conclusions can be drawn from the data collected.

- The LIFAC system operated reliably throughout the test program and provided consistent ESP conditions for the performance evaluation. Although the coal sulfur content did vary from 2.1% to 1.6%, since the LIFAC system operation was consistent, ESP performance should not have been biased by the sulfur variation.

- The LIFAC process produced a particle mass loading entering the ESP of 17.15 lb/10^6 Btu. This loading is a factor of 3.5 higher than expected for fly ash alone, and is in reasonable agreement with the EPRI guidelines.

- The sorbent particles contributed to the ESP inlet gas stream were generally larger than 0.8 μm in diameter. The LIFAC distribution contained fewer sub-micron particles than were produced by hydrated lime injection into the Edgewater furnace, but more than for a typical spray dryer. There were insufficient submicron particles to cause corona quenching problems, but the particles in the 0.5 - 2.0 μm range will contribute to opacity independently of mass emissions.

- ESP temperature was in the range of 198-209°F during the tests, which is 20-40°F higher than typical of low-temperature SO_2 control processes. The higher temperatures were thought necessary to reduce re-entrainment of particles from the ESP to acceptable levels. Although reduction in temperature from 209°F to 198°F did not measurably increase emissions, it was generally believed that further temperature decreases would degrade ESP performance. This hypothesis was not tested because of concerns over opacity limit violations.

- ESP performance with LIFAC was quite good with particle collection efficiency of 99.3% and a particle emission rate of 0.119 lb/10^6 Btu. This is quite impressive performance for an ESP with a modest SCA below 200 ft^2/100 acfm. Despite the improved collection efficiency with LIFAC, the increased inlet mass resulted in incased outlet emissions.

- Fractional efficiency data did not indicate a distinct dip in efficiency in the size region that is typical of particle re-entrainment. However, decrepidation of the low-tensile-strength particle agglomerates could prevent the effect of re-entrainment from being detected by this technique.

- Dust resistivity data were scattered and confusing as we have come to expect for these processes. The results of the V-I method of the in-situ measurement are probably the most appropriate values and generally indicated low resistivity. The ascending-temperature lab measurement also predicted low resistivity at the higher temperature of the ESP outlet. At the EST outlet temperature, the descending-temperature lab measurement predicted high resistivity that was not consistent with ESP electrical operation.

- ESP electrical operation was good, consistent with low resistivity values. There were no indications of high resistivity limitations or of corona quenching from excessive space charge or excessive discharge electrode deposits. Although current densities were lower than typical for the outlet fields, this is attributed to the relatively low current limit of Lodge-Cottrell ESP's.

- Calibration of the ESP power supply voltage meters indicated that the readings were low in three of the four fields by up to 6.9 kV. The low indicated values are consistent with our inability to model the performance of the ESP under baseline conditions in 1993. The control readouts were calibrated during the 1994 test.

- With corrected voltage values, the ESP model predicted a range of baseline performance that bracketed the 1993 baseline measurements. This indicates that the ESP is operating as expected for its hardware and operating conditions and that no anomalous conditions or hidden problems exist.

- Because of the increased re-entrainment with low-temperature SO_2 control processes, higher values of the non-ideal parameters in the ESP model are generally required to accurately simulate ESP performance. However, under the conditions tested at Whitewater Valley, the measured ESP performance fell between the predictions for fly ash only and then made with the poorer non-ideal conditions typical of low-temperature operation. This suggests that some increased re-entrainment was occurring, but that it was not as severe as expected. The improved performance with LIFAC is attributed to an ESP operating temperature that was 20-40°F higher than typical of low-temperature SO_2 control processes. The higher temperature was used at Whitewater Valley specifically to limit the degradation from re-entrainment and to maintain compliance with opacity limits. The recommendation made in the EPRI guidelines to design for high levels of re-entrainment in ESP's installed on low-temperature processes is still valid for operation at temperatures of 180°F and below.

3. **DOE Comments and Responses to Comments on Quarterly Report**

a. DOE: "In Table 1 on page 20, what does 'REPORT' mean under the column titled, 'LIMITS'? This should be defined in the footnotes of the table.

LIFAC NA: "Report" indicated under the column titled "Limits" in Table 1 means that RP&L are required to measure this parameter and report it to IDEM as part of their monthly monitoring, under their NPDES Discharge Permit, but no limit has been assigned.

b. DOE: "In Table 1, it is unclear why testing was not conducted for SO_2, NO_x, CO_2, and CO. Additionally, the NPDES data appears to be above the limit for Total Resid. Oxidants and Lead. An explanation would be in order."

LIFAC NA: As indicated in Table 1, SO_2, NOx, CO_2, and CO tests were not conducted. This was due to a miscommunication with Mostardi-Platt the company subcontracted to conduct the emissions testing. These tests were run on previous sampling events, note, however, they are not required for compliance with the emission variance from IDEM. As for the NPDES data in Table 1, ICF Kaiser utilized the NPDES permitting limits for comparison only with the results for the boiler bottom ash disposal water. RP&L are not required to meet these limits until all the wastewater filters through the pond system and then outfalls. These limits are met at the permitted outfall. (Note the minimal detection limit for Total Residual Oxidants is <0.05 and that based on the analytical methods specified the limit of 0.02 cannot be detected).

c. DOE: "On page 22 it is indicated that incoming feedwater was sampled 'since its incoming quality is believed to be impacting compliance with effluent criteria...'. Since Table 2 has NPDES Limits and Monitoring Results, what conclusion can be drawn from the data?"

LIFAC NA: Based on the analytical results for the incoming feedwater, we have determined that the quality of the incoming water does not appear to impact compliance with the effluent criteria.

d. DOE: "In Table 1 on page 16, the frequency of sootblowing is given. What is the duration of the sootblowing when the sootblowers are in operation? What type of and how many sootblowers are used, and where are they located?

LIFAC NA: Richmond Power & Light's Unit No. 2 is equipped with six (6) retractable sootblowers to reduce fouling of the superheated steam tubes. These steam emitting sootblowers slowly extend, in series, into the nose level of the furnace, then retract back to their initial positions. Each retract sootblowing cycle lasts approximately eight (8) minutes, for a total duration of 48 minutes. Air preheater sootblowing, which did not effect the LIFAC process or opacity, lasts nearly 20 minutes. Stationary sootblowing units located on the boiler walls ("wall blowers") were not a concern during the demonstration.

e. DOE: "In Table 1, NO_x and CO_2 Parameters are shown with two (2) units of measure, while Monitoring Results have only one (1). Additionally, the NPDES data appears to be above the Limit for Total Resid. Oxidants and Lead. An explanation would be in order.

LIFAC NA: The second unit of measure on Table 1 for NOx and CO_2 was to provide consistency with the Environmental Monitoring Plan (EMP) only. As for the NPDES data, please see the response to your Comment 4 on the LIFAC Quarterly Report No. 15 above.

4. **System Status**

LIFAC is not scheduled to be operated this year. In 1994, preservation activities were performed on all process equipment to ensure an easy start-up in the future.

VI. FUTURE PLANS

- Continue normal administrative and financial reporting to DOE.
- Submit Final Report - Volume 1 : Public Design.
- Submit Final Report - Volume 2 : Project Performance and Economics.
- Complete negotiations with Richmond Power & Light on transferring the LIFAC process to them for future, commercial operation.
- Continue to host all interested parties at the site and market the technology.
- Prepare Annual Environment Monitoring Report - 1994.