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LIFAC NORTH AMERICA

LIFAC SORBENT INJECTION DESULFURIZATION DEMONSTRATION PROJECT

PROJECT PERFORMANCE SUMMARY
CLEAN COAL TECHNOLOGY DEMONSTRATION PROGRAM

AUGUST 2004

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ENVIRONMENTAL CONTROL DEVICES

LIFAC SORBENT INJECTION DESULFURIZATION DEMONSTRATION PROJECT

LIFAC represents a relatively low capital cost SO_2 control option for older, smaller, space-constrained plants. As such, LIFAC can supplement scrubbers applied to larger plants for overall utility compliance.

OVERVIEW

This project is part of the U.S. Department of Energy's (DOE) Clean Coal Technology Demonstration Program (CCTDP) established to address energy and environmental concerns related to coal use. The project presented here was one of 13 selected from 48 proposals submitted in response to the CCTDP's third solicitation in 1989.

LIFAC North America, a joint venture of ICF Kaiser Engineers, Inc., and Tampella Power Corporation, successfully demonstrated the LIFAC process for sulfur dioxide (SO_2) control — limestone injected into the furnace with activation of untreated calcium oxide. Richmond Power and Light Company (RP&L) hosted the project at their 60-MWe (net) Whitewater Valley Station Unit 2, located in Richmond, Indiana.

LIFAC is a dry flue gas desulfurization (FGD) process, as opposed to more capital cost intensive wet FGD "scrubbers." As do most scrubbers, LIFAC uses limestone as the raw sorbent rather than the more expensive hydrated lime (three times the cost). LIFAC activates (converts) the limestone to hydrated lime by using boiler heat and a relatively simple humidification activation chamber, while scrubbers use sophisticated slurry absorber systems. LIFAC's use of a vertical, space-saving humidification activation reactor differentiates it from other dry sorbent injection systems.

LIFAC demonstrated long-term SO_2 removal efficiency of 70% for coals averaging 2.25% sulfur content and high system availability, and produced a solid by-product readily removed in the existing electrostatic precipitator (ESP) and suitable for disposal in a landfill. Plant operating limitations precluded meeting project objectives of demonstrating successful operation of LIFAC on high-sulfur coals (over 3.0% sulfur) and demonstrating SO_2 removal efficiencies up to 85%. However, test data showed that LIFAC could be applied to high-sulfur coals and possibly achieve 85% SO_2 removal with certain plant upgrades.

Entrance to Richmond Power and Light Company's Whitewater Valley Station

THE PROJECT

Tampella Power Corporation initiated work on the LIFAC process in Finland in the 1980s as a response to increasingly stringent acid rain regulations in that country. In 1988, Tampella tested high-sulfur U.S. coals in a pilot project in Finland, demonstrating over 70% removal of SO_2 from flue gas. This DOE-sponsored commercial-scale LIFAC demonstration project was an extension of that early experimentation in Finland.

The project site for the LIFAC demonstration in Richmond, Indiana, was carefully chosen for its unique qualities. RP&L's Whitewater Valley Station Unit No. 2 was the site of a prior demonstration of another sorbent injection technology, which at that time was jointly sponsored by the Electric Power Research Institute and the U.S. Environmental Protection Agency. Sorbent injection equipment remained on site and was used to its advantage in the LIFAC demonstration. In 1980, Unit No. 2 was fitted with a low-NO_x concentric firing system for NO_x control. Whitewater Valley Station Unit No. 2 also represented a challenging candidate for a retrofit due to cramped conditions, typical of the many U.S. power plants that are potential candidates for application of LIFAC. Moreover, the tangentially fired boiler is one of the smallest, thus having a high temperature profile, requiring sorbent injection high in the boiler to avoid excessive temperatures and presenting the challenge of low sorbent residence time.

One obstacle that precluded meeting SO_2 reduction objectives was the limited capacity of the ESP. The ESP is a Lodge Cottrell unit with a relatively small specific collection area (SCA) of 198 cubic feet/1,000 actual cubic feet per minute (acfm) of flue gas.

The primary objectives of the project were to achieve a total SO_2 removal efficiency of up to 85%; demonstrate successful operation of the LIFAC process in a retrofit application in a power plant burning high-sulfur U.S. coals; and produce a dry solid waste suitable for disposal in a landfill.

Project Sponsor
LIFAC North America (a joint venture partnership between Tampella Power Corporation and ICF Kaiser Engineers, Inc.)

Additional Team Members
ICF Kaiser Engineers, Inc.– cofunder and project manager
Tampella Power Corporation – cofunder
Richmond Power and Light Company – cofunder and host utility
Electric Power Research Institute – cofunder
Black Beauty Coal Company – cofunder
State of Indiana – cofunder

Location
Richmond, Wayne County, Indiana (Richmond Power and Light Company's Whitewater Valley Station, Unit No. 2)

Technology
LIFAC's sorbent injection process with sulfur capture in a unique, patented vertical activation reactor

Plant Capacity/Production
65 MWe (gross); 60 MWe (net)

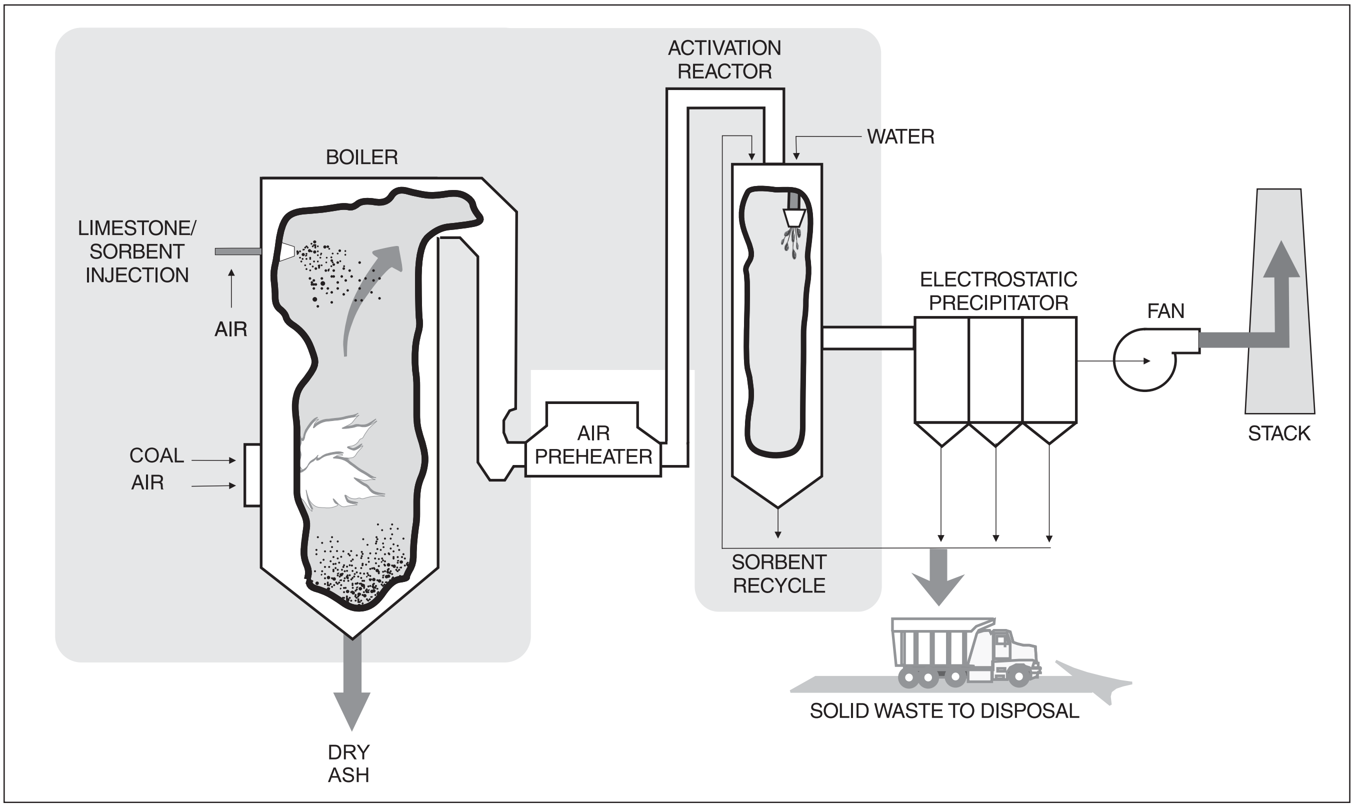
Coal
Indiana bituminous, 2.25% sulfur average (range 1.4–2.8% sulfur)

Demonstration Duration
September 1992–June 1994

Project Funding

Total Project Cost	$21,393,772	100%
DOE	$10,636,864	50%
Participant	$10,756,908	50%

THE TECHNOLOGY



Finely pulverized limestone (80% < 325 mesh) is pneumatically conveyed and injected into the upper part of the boiler where temperatures are in the range of 1,800–2,000 °F. These temperatures are moderate enough to prevent melting or fusing of the limestone, but high enough to decompose the limestone into lime (CaO) and carbon dioxide (CO_2). Provision is made for injection of the limestone through sets of six injection ports at two different boiler elevations. Each set of six ports has four ports on the wall opposite the boiler nose and one port on each adjacent wall. The amount of limestone injected is determined by the sulfur content of the coal and the calcium-to-sulfur (Ca/S) molar ratio desired for SO_2 control. Approximately 25% of the total SO_2 capture occurs as the SO_2 reacts with the CaO passing through the boiler to form calcium sulfite ($CaSO_3$), which oxidizes to calcium sulfate ($CaSO_4$).

Flue gas, unreacted CaO, and ash exit the boiler, pass through the air preheater, and enter the LIFAC activation reactor. The LIFAC activation reactor uses an array of dual fluid nozzles in a header atop a 138 foot high, 28 foot diameter, vertical chamber to humidify and cool the incoming flue gas. The dual fluid nozzles are connected to a 115 gallon/minute, 175 pounds per square inch gage (psig) water supply and a 870 acfm, 125 psig air supply. Atomizing air pressure at 38–65 psig controls droplet size, which provides complete evaporation of water in the chamber.

Humidification activates CaO to calcium hydroxide — $Ca(OH)_2$ or hydrated lime — to enhance SO_2 capture, as does cooling the flue gas stream as close to the saturation temperature as practical. The saturation temperature is the point at which water and acids in the flue gas condense and are no longer entrained in the flue gas, which would result in plugging and corrosion. The LIFAC activation reactor provides 75% of the total SO_2 capture by reacting $Ca(OH)_2$ with SO_2 to form $CaSO_3$, which oxidizes to $CaSO_4$. The temperature of the flue gas leaving the activation reactor determines the flow rate of the water to the dual fluid nozzle array.

Baffles at the bottom of the activation reactor redirect flue gas 180 degrees upward to the ESP and allow for some particulate matter to fall out. Stainless steel steam reheaters installed at the activation reactor outlet raise the flue gas temperature high enough to prevent acid precipitation in the ESP, which captures the spent sorbent and fly ash. Two of four ESP hoppers are equipped to pneumatically recycle spent sorbent/ash directly into the flue gas ductwork immediately preceding the activation reactor.

RESULTS SUMMARY

ENVIRONMENTAL PERFORMANCE

- The four parameters with the greatest influence on sulfur removal efficiency were limestone fineness, Ca/S molar ratio, approach-to-saturation temperature, and ESP ash recycle ratio (pounds of spent sorbent/ash recycled to pounds received at the ESP).
- Long-term tests under load-following conditions (near-full load average) with an average coal sulfur content of 2.25% demonstrated an SO_2 removal efficiency of 70% at a Ca/S molar ratio of 2.0, approach-to-saturation temperature of 10 °F, and limestone fineness of 80% <325 mesh.
- Both ESP ash recycle ratio and approach-to-saturation temperature were limited by the demonstration system configuration. Increasing the ash recycle ratio and sustaining a 5 °F approach-to-saturation temperature were projected to increase SO_2 removal efficiency to 85% at a Ca/S molar ratio of 2.0 and limestone fineness of 80% <325 mesh.
- Fly and bottom ash were dry and readily disposed of at a local landfill. The quantity of additional solid waste can be determined by assuming that approximately 4.3 tons of limestone are required to remove 1.0 ton of SO_2.

OPERATIONAL PERFORMANCE

- Automated programmable logic modules and simple design make the LIFAC system easy to operate in startup, shutdown, or normal duty cycles.
- The existing induced draft (ID) fan required a capacity upgrade to allow LIFAC to process high-sulfur coals, but attempts to upgrade during the demonstration failed, which limited the sulfur content of the coals tested.
- When operating with fine limestone (80% <325 mesh), the soot-blowing cycle for the superheater had to be reduced from 6.0 hours to 4.5 hours.
- During startup with low LIFAC reheat temperatures, the resulting humidity caused the ESP to release residual dust and produce opacity excursions, which required modification of the operating procedures.
- ESP collection efficiency during LIFAC operation increased slightly from a baseline 99.05% to 99.3%, but particulate emissions increased from a baseline 0.049 lb/10^6 Btu to 0.119 lb/10^6 Btu as particulate loading increased 3.5 times.

ECONOMIC PERFORMANCE

- Capital cost estimates were $66/kW for two LIFAC reactors (300 MWe); $85/kW for one 150-MWe LIFAC reactor; and $99/kW for one 65-MWe LIFAC reactor, with the differences attributable to economies of scale.
- The operating cost of a 150-MWe reactor was estimated at $325/ton of SO_2 removed, assuming 70% SO_2 capture, Ca/S molar ratio of 2.0, fine limestone (80% <325 mesh) composed of 93% $CaCO_3$ and costing $20/ton, and disposal cost of $15/ton.

LIFAC activation reactor

TABLE 1. TYPICAL COAL PROPERTIES

Proximate Analysis :		
Fixed Carbon	(wt% as received)	44.12
Volatile Matter	(wt% as received)	33.36
Moisture	(wt% as received)	11.74
Ash	(wt% as received)	10.78
	Total	**100.00**
Average Sulfur	(wt%)	2.24
Higher Heating Value	(Btu/lb)	11,345

TABLE 2. PROCESS PARAMETERS AND RANGES

Process Parameter	**Unit of Measure**	**Test Range**
Limestone Grind	Mesh	80% <200
		80% <325
Ca/S Ratio	Mol/Mol	1.0–2.8
Reactor Outlet Temp	ºF above saturation	4–11
Ash Recycle Ratio	lb recycle/lb from reactor	0.0–1.0
Boiler Load	MWe	43–60
Injection Ports*	Level, Right, Left, Middle	Ports 1–6
		Ports 7–12
		Ports 4–6 & 10–12
		Ports 1–3 & 7–9
		Ports 2–5, 10, &11

* Injection port nozzles could be tilted 15 degrees vertically, but were held horizontal.

ENVIRONMENTAL PERFORMANCE

The purpose of the LIFAC technology was to enhance the effectiveness of dry sorbent injection systems for SO$_2$ control while minimizing operating costs and maintaining the desirable aspects of low capital cost and compactness for ease of retrofit. Using limestone rather than lime reduces sorbent costs by about one-third. Recycling sorbent increases sorbent utilization, further reducing operating costs.

The coals used during the demonstration varied in sulfur content from 1.4% to 2.8%, with an average of about 2.25%. Table 1 provides an average composition of the coals burned in the demonstration project. If coal quality changed during operation, operating parameters were adjusted upon receipt of laboratory analyses.

Parametric Testing

Both parametric and long-term tests were performed. The process parameters and range of values evaluated are shown in Table 2. High-sulfur coals (>3.0% sulfur) could not be tested primarily because of ID fan limitations. The existing ID fan was operating near 100% capacity before LIFAC installation, and attempts to upgrade fan capacity during the demonstration to accommodate high LIFAC loads failed. Significant pressure drop occurs across the LIFAC process as air, water, and sorbent are added to the flue gas stream. The pressure drop increases as SO$_2$ reduction level increases.

Parametric tests showed the following:

- At a given Ca/S molar ratio, SO$_2$ removal efficiency is significantly higher for a fine limestone grind (80% <325 mesh) than for a coarse limestone grind (80% <200 mesh). The difference ranges from 10 percentage points at the lower Ca/S molar ratios to 20 percentage points at the higher Ca/S molar ratios.
- SO$_2$ removal efficiency increases linearly as Ca/S molar ratio increases, ranging from 60% at a Ca/S molar ratio of 1.5 to 80% at a Ca/S molar ratio of 2.8.

- SO_2 removal efficiency increases from an average of about 60% at 11 °F above the flue gas saturation temperature (approximately 126 °F) to an average of about 70% at 4 ºF above the flue gas saturation temperature.
- SO_2 removal efficiency increases from about 50% at a recycle ratio of 0.2 to about 70% at a recycle ratio of 1.0.
- SO_2 removal efficiency is essentially constant over a boiler load range of 43–60 MWe.
- Injection through the higher boiler elevation ports (1–6) provided the best SO_2 removal efficiency. (Temperatures at the higher elevation were approximately 100 °F cooler than at the lower elevation.)

Long-Term Testing

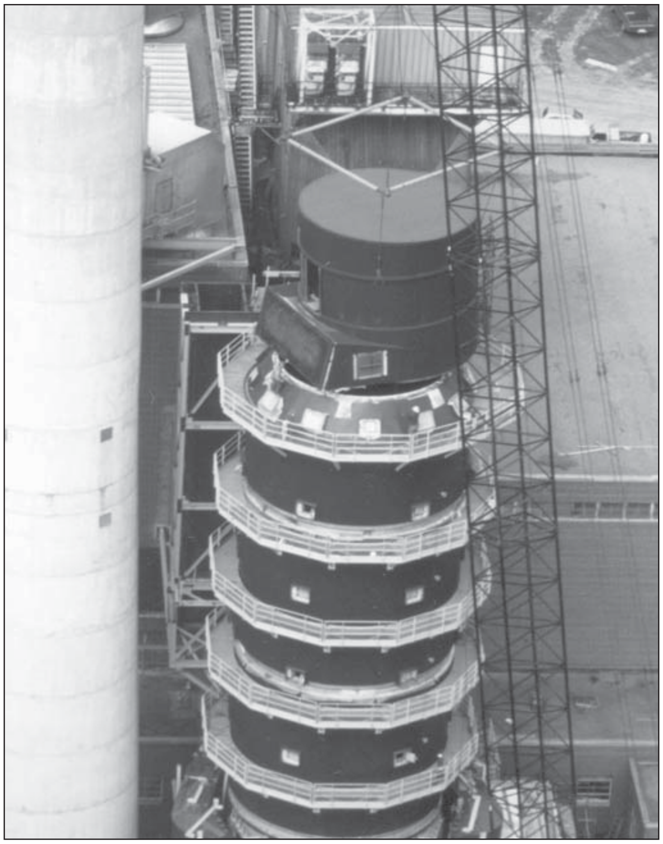
Based on the parametric tests, a set of operating parameters was selected for long-term testing to provide the best possible SO_2 capture while ensuring efficient plant operation. The parameters selected are shown in Table 3.

The finer grind limestone was selected because the extra cost to achieve the finer grind is overshadowed by the significant performance gains due to enhanced reactivity. The Ca/S molar ratio of 2.0 represents a compromise between SO_2 removal performance and negative impacts on plant performance, such as superheater fouling and ID fan limitations. An approach-to-saturation of approximately 10 °F was chosen to provide a safety cushion to prevent possible plugging of the reheat coils in the activation reactor outlet. The upper set of sorbent injection ports proved the best in parametric testing. Although the highest possible ash recycle ratio was sought, availability of ash to recycle was severely limited. Much of the ash never reached the ESP because it was captured in the LIFAC activation reactor where no provision was made for recycling, and only two of the four ESP ash collection hoppers were equipped to recycle the ash. Moreover, not all the ash from the two recycle hoppers could be recycled without compromising ESP performance. The balance of the parameters were selected based on observed performance.

In long-term testing, the boiler was operated primarily at or near full load. LIFAC controlled limestone injection to maintain a Ca/S molar ratio of 2.0 assuming a coal sulfur content of 2.25%, and controlled humidification to maintain an approach-to-saturation of about 10 °F. Under these conditions, and using a limestone fineness of 80% <325 mesh and recycle ratio of less than 0.5, LIFAC achieved an average 70% SO_2 removal efficiency.

TABLE 3. LONG-TERM OPERATION PARAMETERS

Limestone Grind	80% <325 mesh
Ca/S Molar Ratio	2.0
Reactor Bottom Temperature	135 ºF
Ash Recycle Ratio	<0.5
Injection Ports	1–6
Recycle Pressure	1.0 psig
Atomizing Air Pressure	55–60 psig
ESP Inlet Temperature	200 °F
Bypass Damper	Closed



Installation of spray header atop the LIFAC activation reactor

Projections of LIFAC performance potential were made, assuming certain modifications based on test data. Modifications included enabling recycle of nearly all ash containing spent sorbent and replacing steam reheat coils in the ductwork with hot flue gas from the boiler injected into the ductwork. Increasing the spent sorbent/ash recycle would significantly increase both SO_2 removal efficiency and sorbent utilization. Removal of the steam reheat coils would reduce pressure drop by more than 50% — alleviating the ID fan burden — and allow a closer approach-to-saturation temperature, which was limited by concern over particulate deposition on the reheat coils under moist conditions. LIFAC projected an 85% SO_2 removal efficiency by increasing the ash recycle ratio to nearly 1.0 and sustaining a 5 °F approach-to-saturation temperature at a Ca/S ratio of 2.0. Also, alleviating the pressure drop would enable processing of high-sulfur coals.

Solid Waste

The solid waste generated was, as projected, a mixture of fly ash and calcium compounds readily disposed of at a local landfill. The quantity of additional solid waste can be determined by assuming that approximately 4.3 tons of limestone are required to remove 1.0 ton of SO_2.

OPERATIONAL PERFORMANCE

The project also addressed operational considerations and issues associated with LIFAC retrofit of power plants, which are presented below. Some of the issues have already been introduced in discussing environmental performance.

Boiler

Injection of 130 lb/minute of fine limestone into the upper reaches of the boiler at full load to accommodate 950 lb/minute of relatively high sulfur content coal creates the potential for increased superheater and wall tube fouling. The finer the limestone particle size, the greater the potential for fouling. Using the 80% <325 mesh limestone grind size required an increase in superheater sootblowing frequency from every 6.0 hours to 4.5 hours. No limestone fouling occurred in the economizer, where there is no sootblowing capability, and the air preheater sootblowing frequency remained unchanged.

The steam reheat installed at the LIFAC outlet did not affect boiler performance, but as discussed, compromised LIFAC system performance. During the demonstration, a small reheat duct was installed between the economizer inlet and LIFAC outlet, drawing 5% of the total boiler gas volume. This flue gas reheat approach raised LIFAC exit gas temperatures by 30 °F without impacting boiler performance, which suggests that the flue gas reheat approach may be used in lieu of the steam reheat. The pressure drop through the LIFAC system with steam reheat was 4.5 inches of water. With hot flue gas reheat used in place of steam reheat, the pressure drop was predicted to be approximately 2.0 inches of water.

ID Fan

To deal with the pressure drop through the LIFAC system, efforts were made to increase ID fan capacity by installing a variable frequency drive (VFD). The VFD failed repeatedly during the demonstration and ceased to be used, as it caused the boiler to trip. The need for an ID fan upgrade may be obviated by using hot flue gas reheat in lieu of steam reheat.

ESP

During startup of LIFAC, the plant experienced opacity excursions. These excursions were primarily attributed to release of residual dust on the ESP collector plates. The residual dust was caused by low-temperature, high-humidity flue gas that significantly reduced residual fly ash resistivity and tensile strength. The significant drop in resistivity decreased the electrical clamping force (a function of resistivity and current density) by 2–3 orders of magnitude. Excursions were also attributed in part to poor flue gas distribution to the ESP.

Based on the above findings, RP&L adopted the following recommended solutions: (1) increase the amount of reheat during startup to decrease the relative humidity, and gradually decrease the ESP inlet temperature under steady-state conditions until design conditions are met; and (2) upgrade the ESP so that flue gas flow is uniform.

Under steady-state conditions, LIFAC had a slightly positive effect on ESP collection efficiency as long as ESP inlet temperature was in the 198–209 °F range. Baseline ESP collection efficiency was 99.05% and, under LIFAC operation, ESP collection efficiency was 99.3%. However, LIFAC increased the particulate mass loading to the ESP by a factor of 3.5, or 17.15 lb/10^6 Btu. Baseline particulate matter emissions were 0.049 lb/10^6 Btu and, under LIFAC operation, emissions rose to 0.119 lb/10^6 Btu.

As suggested in the previous discussion, LIFAC installations should include provision to recycle all of the ESP ash and the ash captured in the LIFAC activation reactor.

General

Long term testing of the LIFAC system showed that SO_2 reductions of 70% or more can be maintained under normal boiler operating conditions with no adverse effects on the boiler or subsystems. Furthermore, the system proved to be highly practical because it has few moving parts, is simple to operate, and can be easily shut down and restarted. The process is controlled by a programmable logic system that regulates process control loops, interlocks, startup, shutdown, and data collection. The entire LIFAC system was easily managed by two personal computers located in RP&L's control room.

ECONOMIC PERFORMANCE

The capital cost breakdown of the LIFAC installation at RP&L's Whitewater Station Unit No. 2 is provided in Table 4. The cost breakdown is unique because the installation was a retrofit to an existing facility and included equipment from an earlier FGD demonstration donated to LIFAC, providing a capital cost savings. However, additional capital costs accrued due to the demonstrative nature of the project. These factors provide context for the total capital cost of the Whitewater demonstration of approximately $8,101,000.

The annual operating costs for the LIFAC RP&L demonstration are shown in Table 5. An estimated fixed operating cost of $581,200 is based on two operators per shift, three shifts per day, and a seven day work week. The variable operating cost of $327.50/hour is based on actual site cost.

Taking into account the above capital and operating cost estimates, a generic cost estimate was developed for a commercial LIFAC system having a 150-MWe equivalent capacity, which was deemed the largest practical size for LIFAC. The estimated costs are shown in Table 6.

The commercial estimate assumes a feed coal containing 4.0 pounds of sulfur per million Btu, 70% SO_2 removal, and an $85/kW capital cost for a 150-MWe LIFAC retrofit unit. The levelized total cost estimate is 4.55 mills/kWhr, or $325/ton of SO_2 removed. Other capital cost estimates developed by LIFAC range from about $99/kW for a 65-MWe system down to about $66/kW for a 300-MWe system. The reduction in cost for the 300-MWe system is attributed to economies of scale. The LIFAC cost data as reported by LIFAC-North America do not express a project life, financing costs, or whether the costs represent constant or current dollars. The dollar figures used in the report are evidently actual 1993 and 1994 dollar estimates.

TABLE 4. LIFAC DEMONSTRATION CAPITAL COST AT RP&L

Equipment & Materials	Cost ($)
Limestone Handling & Storage	160,000
Activation Reactor & Ductwork	669,000
Sorbent Recycle System	67,000
Electrical/Instrumentation	272,000
ID Fan Upgrade	255,000
Total Equipment & Materials	**1,423,000**
Subcontracts	
Foundations	324,000
Reactor Fabrication & Erection	1,670,000
Structural/Mechanical/Piping	1,569,000
Electrical/Instrumentation	574,000
Insulation & Cladding	268,000
Miscellaneous Fabrication	573,000
Total Subcontracts	**4,978,000**
Engineering	1,200,000
Management & Administration	300,000
Construction Supervision	200,000
Total Capital Cost	**8,101,000**

TABLE 5. OPERATING COSTS FOR LIFAC AT RP&L

Fixed Operating Costs	Cost ($)
Operating Labor	499,200
Maintenance Labor	25,000
Maintenance Material	50,000
Administrative & Support Labor	7,000
Total Fixed Operating Costs	**581,200**
Variable Operating Costs	Cost ($/hr)
Limestone ($35/ton)	210.00
Reheat Steam ($0.003/lb)	18.50
Auxiliary Power ($0.02/kWhr)	7.20
Ash Removal ($17/ton)	91.80
Total Variable Operating Cost	**327.50**

TABLE 6. ESTIMATED COSTS FOR 150-MWE LIFAC SYSTEM FOR COMMERCIAL OPERATION

Capital Costs ($85/kW)	1.50 mills/kWhr
Limestone ($20/ton)	1.25 mills/kWhr
Disposal ($15/ton)	0.90 mills/kWhr
Other O&M	0.90 mills/kWhr
Total	**4.55 mills/kWhr**
SO_2 removed	2.8 lb/10^6 Btu
\$/ton SO_2 removed	$325

COMMERCIAL APPLICATIONS

LIFAC systems have been designed for plant capacities ranging from 25 to 300 MWe. The maximum size LIFAC reactor corresponds to a power plant capacity of about 150 MWe. Thus, a 300-MWe plant would require two LIFAC reactors. The Whitewater demonstration proved the practicality and reliability of the LIFAC process when burning typical U.S. bituminous coals. A total of nine commercial LIFAC installations are in other countries, including Canada, China, Finland, and Russia.

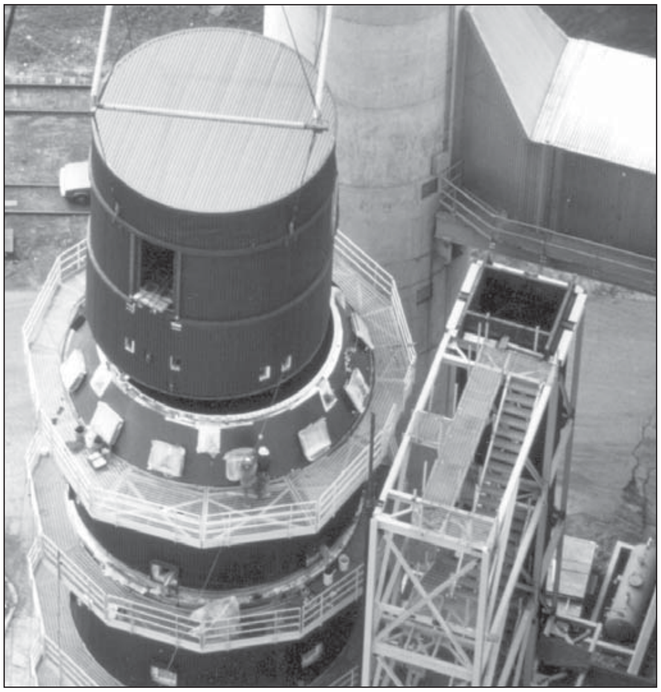
Wet scrubbers are the most prevalent FGD technology and account for about 90% of U.S. scrubber systems. Wet scrubbers apply lime or limestone in sophisticated slurry process systems to remove 90% or more of the SO_2, and produce a wet by-product that must undergo processing before being used or undergoing permanent disposal. Although the LIFAC process cannot match the high removal rates achieved by conventional wet scrubbers, the LIFAC process does offer several advantages:

- The technology can be more easily retrofit onto most power plants because the vertical activation chamber requires less space.
- The technology has lower capital costs, which makes it especially attractive to existing plants that have fewer years to amortize capital investments compared to newer power plants.
- The technology uses a widely available reagent, limestone, rather than more expensive sorbent materials, such as lime.
- The need for slurry preparation/handling equipment is eliminated.
- The waste product is dry and easy to handle and may have application in soil stabilization, mined land reclamation, and mine subsidence control.
- The technology should not typically require major upgrades of plant components.

The LIFAC system also has potential advantages over some of the other sorbent injection systems designed for retrofit of space-constrained plants, such as:

- Use of limestone as opposed to lime or other more expensive sorbent;
- Relatively high SO_2 removal efficiency;
- Improved control of wall deposits with humidification in a vertical chamber, as opposed to in-duct humidification; and
- The combination of relatively high SO_2 removal efficiency, minimum space requirements, and low retrofit costs.

The acid rain provisions of the Clean Air Act Amendments of 1990 give utilities the option of selecting the most cost effective approaches to control SO_2 emissions to required levels. On this basis, there are a number of plants in the United States suitable for application of the LIFAC system. LIFAC North America identified about 850 boilers having a capacity of 500 MWe or less that could use the process. LIFAC North America believes that it can obtain a share of this market because of its cost competitiveness in certain retrofit applications.



Close-up of sprayer and access platforms

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