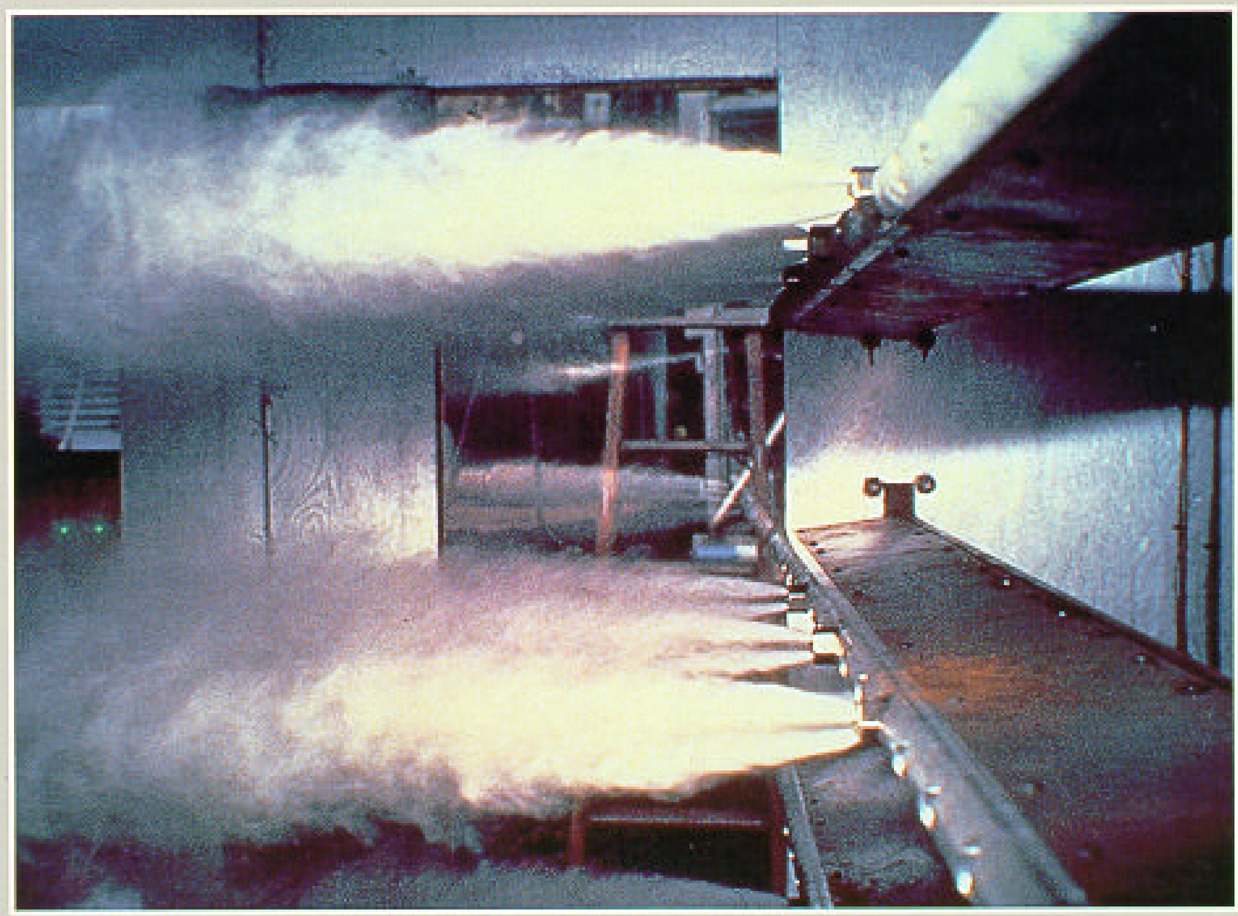
TOPICAL REPORT NUMBER 2

SEPTEMBER 1990

CLEAN COAL TECHNOLOGY



Coolside and LIMB: Sorbent Injection Demonstrations Nearing Completion

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A report on a project conducted jointly
under a cooperative agreement between:

The U.S. Department of Energy

The Babcock & Wilcox Company

Coolside and LIMB: Sorbent Injection Demonstrations Nearing Completion

Contents

Cover photo:
Coolside and LIMB are sorbent injection technologies. In Coolside, the sorbent is injected into the flue gas duct, while in LIMB, sorbent is injected into the upper portion of the boiler. Both clean coal technologies rely on humidification—mist sprayed into the flue gas (as shown in the photo)—which helps to maximize sulfur capture by the sorbent.

Coolside and LIMB: Sorbent Injection Demonstration Nearing Competion

Project Participants

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Ohio Coal Development Office
U.S. Department of Energy

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The first full-scale, commercial demonstration of two emerging *sorbent injection technologies* for controlling sulfur dioxide (SO_2) emissions from existing coal-fired power plants is under way. These two clean coal technologies— Coolside and Limestone Injection Multistage Burner, or LIMB—offer low capital-cost alternatives to relatively expensive, conventional flue gas desulfurization (FGD).

These sorbent injection technologies work by spraying a sulfur-absorbing compound (lime) into the gases given off by burning coal. SO_2 removal is enhanced by carefully controlling the humidity of the flue gas and the spray pattern of the sorbent, and by using chemical additives. The reaction produces dry particles that are collected downstream.

When used with coal-fired burners designed to reduce the formation of nitrogen oxides (referred to as low-NO burners), both processes can simultaneously control SO_2 and NO emissions.

The LIMB Demonstration Project Extension builds on a U.S. Environmental Protection Agency (EPA) project, which is referred to as the "EPA base LIMB project." Through the Clean Coal Technology Demonstration Program, the U.S. Department of Energy (DOE) is funding jointly with industry a $19.4-million expansion of the project. Under the extended effort, the LIMB process is being tested with additional coal and sorbent combinations, and the Coolside process is being demonstrated.

The Babcock & Wilcox Company (B&W), prime contractor for the project, is funding $3.4 million. The Consolidation Coal Company (Consol) is adding $1.2 million. Ohio's Coal Development Office is committing $7.2 million in support of industry's efforts to accelerate the availability of clean coal technologies. The Ohio Edison Company is providing the host site—a 104-MWe coal-fired, electric generating unit at its Edgewater Plant in Lorain, Ohio.

Ohio Edison's Edgewater Plant is the demonstration site for LIMB and Coo side, two flue gas cleanup processes. This coalfired power plant is located on the southern shore of Lake Erie, west of the mouth of the Black River in Lorain, Ohio.

The EPA project, completed in 1989, and the DOE project extension are intertwined. The EPA project has provided the design and installation of all LIMB equipment and much of the Coolside design. The DOE project has provided most of the Coolside equipment. The EPA project tested one combination of coal and sorbent in LIMB; the DOE project will test several other coalsorbent combinations.

Significant progress has been made in the project extension. Successful testing of the Coolside process was completed in February 1990. During these tests, SO_2, emissions were reduced by up to 70%. Performance data from the tests are scheduled to be available in late 1990. Preliminary results are highlighted in this topical report.

The LIMB demonstration was resumed in April 1990, and over the next year, the general applicability of LIMB technology will be tested. Results are scheduled to be available in late 1991.

The Processes

Both Coolside and LIMB are sorbent injection technologies that can be retrofitted to existing coal-fired plants. Both can be used with low-NO burners to control SO_2 and NO emissions.

The processes differ with respect to the location where the sorbent is injected into the system. In LIMB, sorbent is injected into the boiler. In Coolside, sorbent is injected into the flue gas duct downstream of the boiler and air heater.

Coo/side

The sorbent (hydrated lime) is injected as the flue gas enters the humidification chamber. Here, a fine mist is sprayed into the sorbent and flue gas. The mist contains water and a dilute solution of sodium hydroxide (NaOH) or sodium carbonate (Na_2CO_3). The spray cools the flue gas from approximately

300 ^{0}F to about 140 to 145 ^{T}F. In the presence of the sodium-based compounds in the mist, the sorbent reacts with SO_2 in the flue gas. Humidification of the flue gas to a 20 to 25 ^{0}F approach to saturation is essential to obtain maximum sulfur capture with the Coolside process.

Further downstream, a baghouse or an electrostatic precipitator (ESP) removes spent sorbent and fly ash from the flue gas. Material collected contains unreac-ted sorbent and sodium compounds that are still highly reactive with SO,. These can be recycled and reinjected with fresh hydrated lime to reduce requirements for fresh sorbent and additive.

Because the Coolside process is downstream of the air heater, this SO_2, control technology is generally independent of the boiler's configuration. This allows the process to be retrofitted to a broad range of boiler types and sizes.

LIMB

In the LIMB process, a calcium-based sorbent is injected into the boiler where it calcines to active calcium oxide, and then reacts with SO_2 and oxygen in the flue gas to form a solid that is removed with fly ash in the ESP. LIMB is designed to capture SO_2 in flue gases ranging in temperature from about 1,600 to 2,300 ^{0}F. Sorbent injectors are located where the temperature in the boiler is at the upper end of this range.

This process, however, changes the physical properties of particulates, making the ash more difficult to collect in an ESP. Humidification has been demonstrated as a means of overcoming this problem.

As in Coolside, flue gas enters a humidification chamber downstream of the boiler and air heater. A fine water mist is sprayed into the duct, which enables more of the free lime to react with SO_2. In addition, the water lowers the flue gas temperature and flyash resistivity, which restores the operability of the ESP.

Conventional Scrubbers

A flue gas scrubber, whether "wet" or "dry," is actually a complex chemical plant. A scrubber is a separate gas processing facility installed at the back end of the power plant to remove SOP. The process is flue gas desulfurization, or FGD.

In a wet scrubber, flue gases from burning coal are sprayed with a mixture of water and an alkaline reagent, usually lime-stone. The SO_2 in the flue gas reacts chemically with the reagent to form calcium sulfite and calcium sulfate as a wet sludge. Over its life, a 500-MWe coal-fired power plant will produce enough sludge to fill a 500-acre disposal pond 40 feet deep, often creating a waste disposal problem.

Although wet scrubbers can remove 90% or more of the SO2, they are expensive to install, costing $300 or more per kW of capacity (or about $150 million for a 500-MWe plant). They consume 5% to 8% of the power plant's thermal energy to run pumps, fans, and a flue gas reheat system, thereby reducing electricity output by roughly 2% (a significant reduction for a utility). Scrubbers occupy a large space and use large amounts of water, typically 500 to 2,500 gallons per minute for a 500-MWe unit.

In a dry scrubber (or spray dryer), the reagent mixture (usually lime) is injected as a finely atomized mist. The droplets evaporate in the hot gas, leaving only dry particles for collection as waste. Although simpler in concept than the wet scrubber, the dry scrubber has not been as successful on high-sulfur coals due to the increased amounts of expensive reagents required to reduce SO_2 emissions by 90%.

Benefits of LIMB and Coolside

More than 900 utility boilers currently in operation in the U.S. are not equipped with 502 removal systems. Most of these boilers have many years of operating life remaining. The New Source

Performance Standards (NSPS) currently do not apply to most of these existing, older installations; however, other emissions standards, such as the National Ambient Air Quality Standard (NAAQS), still must be met.

For many of these boilers, LIMB and Coolside may be economically attractive options for reducing SO_2 emissions.

In the LIMB process, 55% to 63% of the sulfur is captured in the boiler with an additional 7% to 9% captured in the humidifier when humidifying to a 20 °F approach to saturation at a calcium-to-sulfur (Ca/S) ratio of 2.0. The Coolside process can capture up to 70% of the sulfur, depending on the amount of sorbent and additive used.

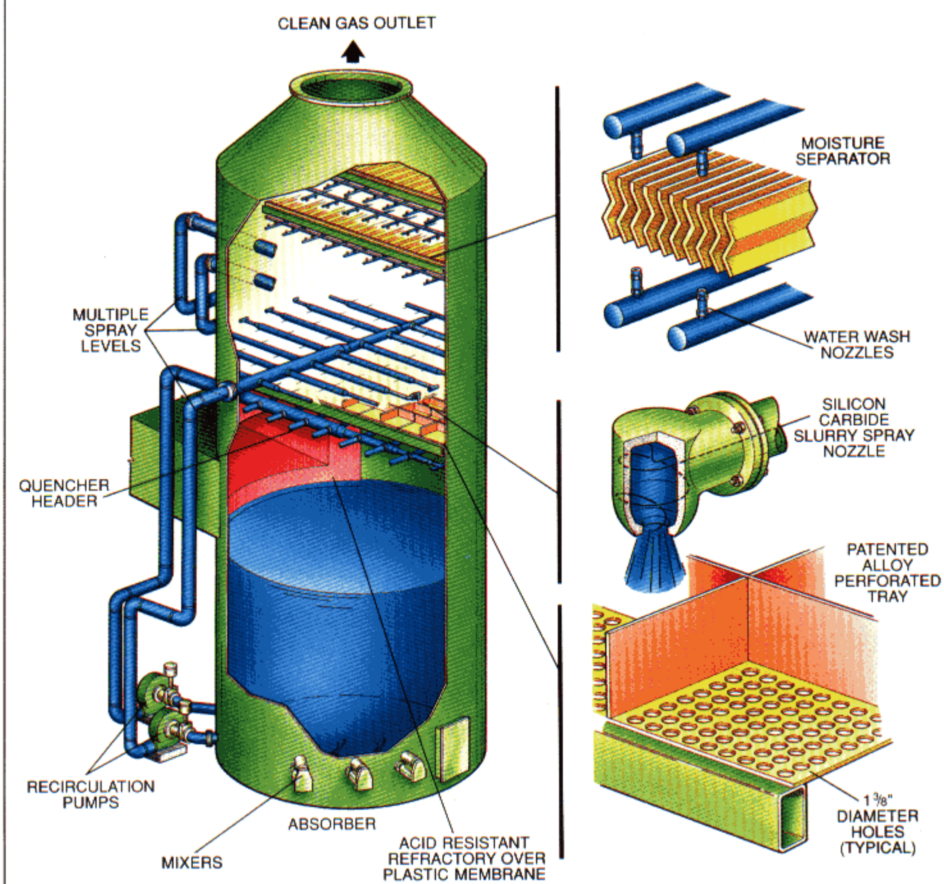
Low-NO_x burners can be used with either LIMB or Coolside to reduce the formation of NO_x in the boiler. These burners have demonstrated reductions in NO_x emissions of up to 50% of the levels produced when conventional circular register burners are used.

The LIMB and Coolside processes are expected to reduce SO_2 emissions at significantly less cost than wet scrubbers. Annual costs for LIMB with humidification and Coolside are projected to be significantly lower than scrubbers. (In general, a wet scrubber adds about 10 mills per kWh to the cost of power.)

Capital costs for LIMB and Coolside are expected to be approximately 50% less than the costs of wet FGD, which translates into a comparative savings of $100 per kW. Lower capital costs result in part because neither LIMB nor Coolside requires extensive modification of the plant being retrofitted.

In addition, LIMB and Coolside require only minimal space for installation and can be constructed within relatively short time frames. This is advantageous to smaller and older plants that are tighlty spaced or have relatively short remaining operating lives.

Wet FGD System



After being retrofitted, boilers are expected to maintain their reliability, operability, and steam production. Also, both processes can be used with an ESP or a baghouse to control particulates.

The waste byproduct from a utility boiler using either LIMB or Coolside is a dry solid that is less costly and easier to handle than the sludge produced by wet scrubbers. The byproduct may be usable as a neutralizing agent for acid wastes or a synthetic aggregate for roadbeds.

Depicted is B&W's Quencher/Absorber Spray Tower, a conventional wet FGD system that can remove as much as 90% of the sulfur in flue gases. However, scrubbers are relatively costly to build and require large sites. LIMB and Coolside are promising as low capital-cost options for small, tightly spaced, and aging power plants.

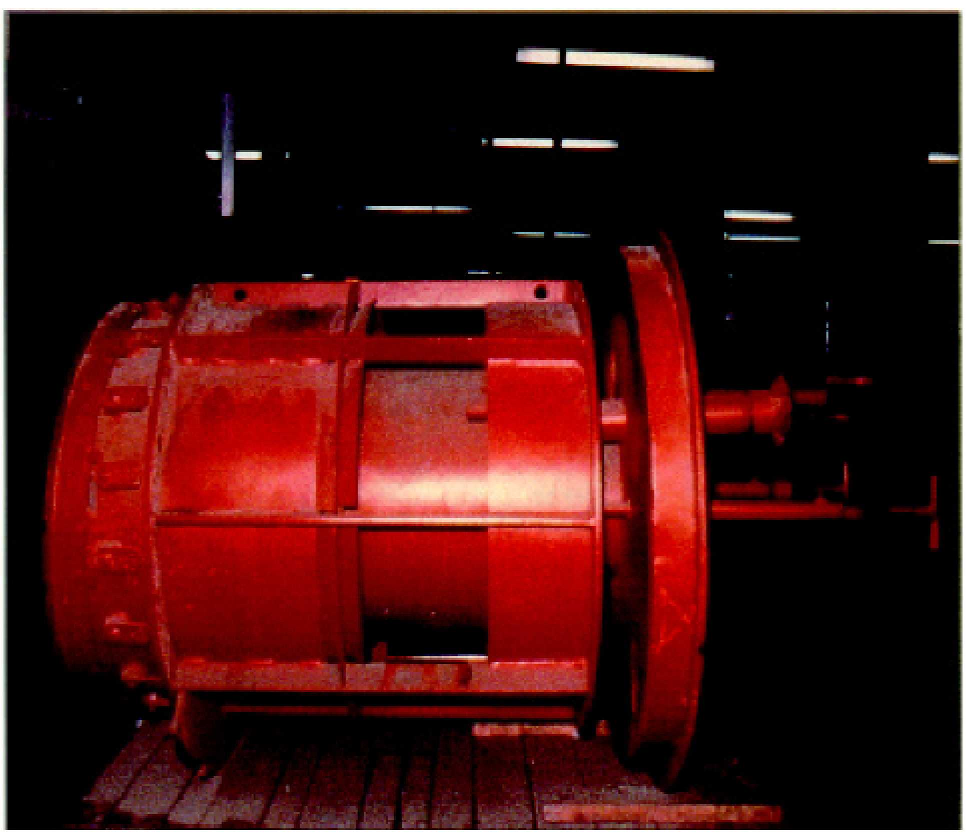
Need for the Demonstration

Prior to being tested at Edgewater, neither the LIMB nor Coolside process had been used continuously in a commercially operating power plant. Previous research and development efforts had been conducted in the laboratory and at pilot plants. These smaller-scale tests indicated that both the LIMB and Coolside processes potentially could reduce SO_2 emissions by at least 50%, with reductions of 70% for Coolside. Emissions of NO,, could be reduced by approximately 50% using special low-NO, burners. Experience with the various components also had indicated that potential technical problems were likely to be relatively few.

The next logical step in the road to commercialization was to apply the experience gained from the small-scale applications to a commercial, operating plant. The technologies needed to be proven as technically successful and economically competitive under “real world” operating conditions.

The Edgewater demonstration is providing the opportunity to prove commercial readiness of the two new processes. Test programs for Coolside and LIMB have been designed to characterize system operation and performance. Data from LIMB tests also can be used directly to design LIMB systems for retrofitting units.

The demonstration is being conducted at what is considered to be commercial scale. A unit larger than Edgewater typically would have parallel ducts and ESPs downstream of the air heater. The Coolside process can be applied to each individual duct-and-ESP train. The scale of this individual train would be comparable to the scale being used in the demonstration at the Edgewater plant.



The Edgewater boiler was retrofitted with 12 XCL coal-fired burners capable of cutting NOR emissions to 50% of the level produced by the original burners.

Commercialization

The LIMB and Coolside processes are expected to control SO_2 emissions at less total cost than conventional wet FGD processes, and with much lower capital costs. LIMB and Coolside are most applicable to older coal-fired plants that have not yet installed FGD or other SO_2 control systems. The processes are expected to be especially economical in plants with intermediate sized boilers and load factors of between 45% and 65%.

The practicality of LIMB as a retrofit technology for a specific plant will depend on its compatibility with the layout of the existing plant. Major factors affecting compatibility include the design of the boiler, convection system, and ash removal system. Coolside, being independent of the boiler, may be an alternative process for many of these plants. However, Coolside requires sufficient residence time in the flue gas duct for humidification water to evaporate (about 2 seconds).

The potential retrofit market for LIMB or Coolside technologies in the U.S. is estimated to be about 400 units, representing about 109 gigawatts of electric generating capacity nationwide. These units share characteristics such as the following:

- Operational coal-fired boiler
- Less than 40 years old
- At least 50 MWe in size
- Not currently subject to NSPS
- Without an FGD system.

Because a decision to retrofit a plant must be based on site-specific characteristics, the demonstration project has also been designed to produce the information required for identifying those sites and situations in which LIMB and Coolside are likely to be attractive, cost-competitive options for emissions control.

Following successful demonstration of the processes at Edgewater, the necessary technical information will be made available to enable utilities to evaluate the applicability of these two clean coal technologies for specific installations.

Progress

Testing of the Coolside process has been successfully completed. The technical report on the demonstration and the evaluation of the Coolside process is expected to be available in late 1990.

LIMB testing has resumed and will run for about a year. Extended testing of sorbent and coal combinations is scheduled for completion in spring 1991.

Tubes in the boiler's nose are shown in this photo taken inside the boiler cavity during the repair of a tube failure. Water flowing through these tubes is heated and converted to steam, which drives turbines that generate electricity.

Commercialization Plans

In support of commercialization efforts, B&W plans to engineer and construct LIMB and Coolside units in much the same way that the company now offers other technologies for achieving environmental compliance. Although the company holds no proprietary position with respect to LIMB technology, B&W plans to pursue business in retrofitting power plants with SO_2 abatement technologies and to market the company's low-NO burners.

Consol, a large coal company and developer of the Coolside process, does not plan to maintain a proprietary position in Coolside. Rather, the company plans to continue to assist in the development and commercialization of Coolside technology. Commercial availability of clean coal technologies is central to Consol's business goals. Clean coal technologies will enable customers buying Consol's medium- and high-sulfur coals to remain in compliance with SO_2 emission requirements.

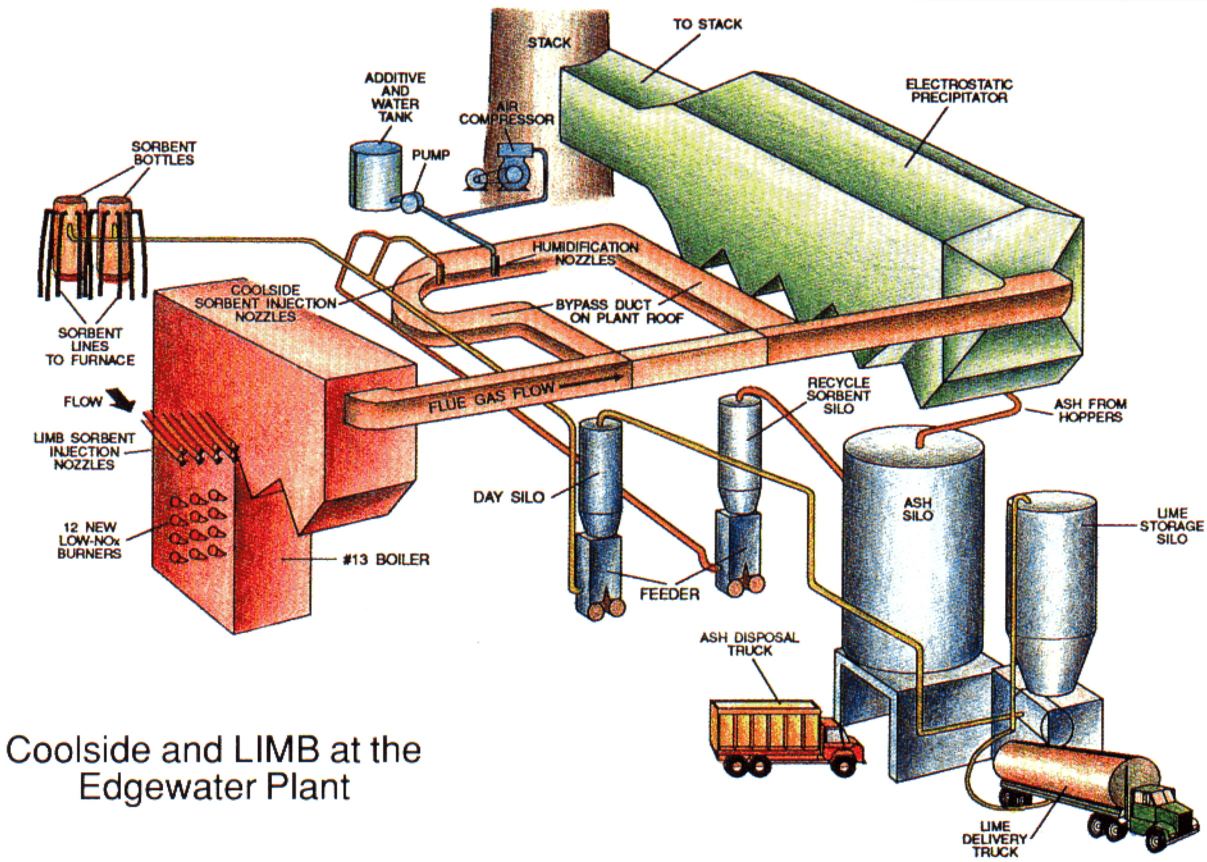
B&W intends to offer utilities a "package" consisting of retrofit technologies capable of reducing both SO_2 and NO,, emissions in a cost-effective and timely manner.

Because of the relative simplicity of both the LIMB and Coolside processes, and since process components are already commercially available, most major process vendors are capable of engineering and constructing the equipment. This work can be performed in a manner similar to that now offered for other environmental compliance systems. In addition to B&W, several other manufacturers have expressed interest in marketing LIMB or Coolside once commercial viability is demonstrated.

Material and equipment availability appears to be more than adequate for both of these two technologies. Raw sorbent is sufficiently available to meet both current and projected requirements. And equipment manufacturing for LIMB and Coolside is not expected to present any unusual fabrication requirements that would preclude the use of existing manufacturing facilities. Moreover, the technologies required by both processes are compatible with existing methods for manufacturing power plant and environmental equipment.

LIMB and Coolside Timetable

1950s	Low-NO, burner development begins.
1960s	EPA sets stringent new air quality regulations.
	B&W begins LIMB R&D.
Mid-1970s	Interest is renewed in sorbent injection for SO_2 emission control.
1981	EPA initiates LIMB R&D.
1983	Consol begins work on Coolside
1984	Humidification field tests are conducted on the flue gas stream from a coal-fired industrial boiler.
	Demonstration of EPA base LIMB project begins.
1987	EPA tests of LIMB process are conducted.
	DOE and B&W sign a cooperative agreement to extend LIMB tests to to 4 sorbents and 3 coals and to test Coolside.
1988	Humidifier is installed.
1989	EPA LIMB testing is completed.
	DOE Coolside tests begin.
1990	Coolside is successfully demonstrated.
	DOE LIMB tests begin.
1991	Completion of DOE LIMB testing is scheduled.



Coolside and LIMB at the Edgewater Plant

LIMB Demonstration Project Extension

Description:

The boiler at Edgewater's Unit 4 was retrofitted with low-NO_x burners and two alternative SO_2 control systems—LIMB and Coolside. In LIMB, the furnace is retrofitted with a sorbent injection system, and a humidification chamber is installed in the flue gas duct. In Coolside, an in-duct sorbent injection system is placed between the boiler and the ESP; sorbent can be recycled. Both processes use flue gas humidification to improve sulfur capture and ESP performance. The DOE project is testing Coolside and extending the EPA LIMB tests to 3 coals and 4 sorbents.

Capacity: 104 MWe
Boiler: Carolina, wall-fired, radiant
Burners: 12 XCL, multistage, low-NO_x (replaced 12 circular register burners)
Steam conditions: 770,000 lb/hr at 1,000 °F and 1,495 psia

Coolside test results:

SO_2 emissions were reduced by 40% to 70%, with higher levels achieved by increasing the rate of sorbent and NaOH injection. Sorbent utilization rates of 30% to 35% were achieved during once-through tests; recycling showed the potential to cut requirements for fresh lime and NaOH by up to 30%. Tests were run with Ohio bituminous coal (3.0% sulfur) and two commercially available hydrated limes.

Funding for project extension:

DOE	$7,597,026
Industry	$11,807,914
Total	$19,404,940

Participants:
- The Babcock & Wilcox Company
- Ohio Edison Company
- Consolidation Coal Company
- Ohio Coal Development Office
- U.S. Department of Energy

SO_2 abatement potential:

LIMB	55-72%
Coolside	40-70%

NO_x abatement potential: 50%

Milestone	Completion
Phase I — Design & permitting	12/88
Phase II — Construction, start-up, and shakedown	
Coolside shakedown	8/89
LIMB extension shakedown	4/90
Phase III — Operation, data collection, reporting, and disposition	
Coolside test program	2/90
Coolside evaluation and preliminary report	10/90
LIMB extension test program	3/91
Final technical report	10/91

Coolside Successfully Demonstrated

The ability of the Coolside process to reduce SO_2 emissions by 40% to 70% has been successfully demonstrated at recently completed tests at the Edgewater Plant.

Commercial-scale testing of the Coolside process was conducted between October 1989 and February 1990. In total, the system operated for more than 1,300 hours, including 265 hours of continuous, uninterrupted operation.

Preliminary analysis of the Coolside test data showed the following:

- The Coolside process was operated successfully for continuous periods of up to 11 days (24 hours daily).

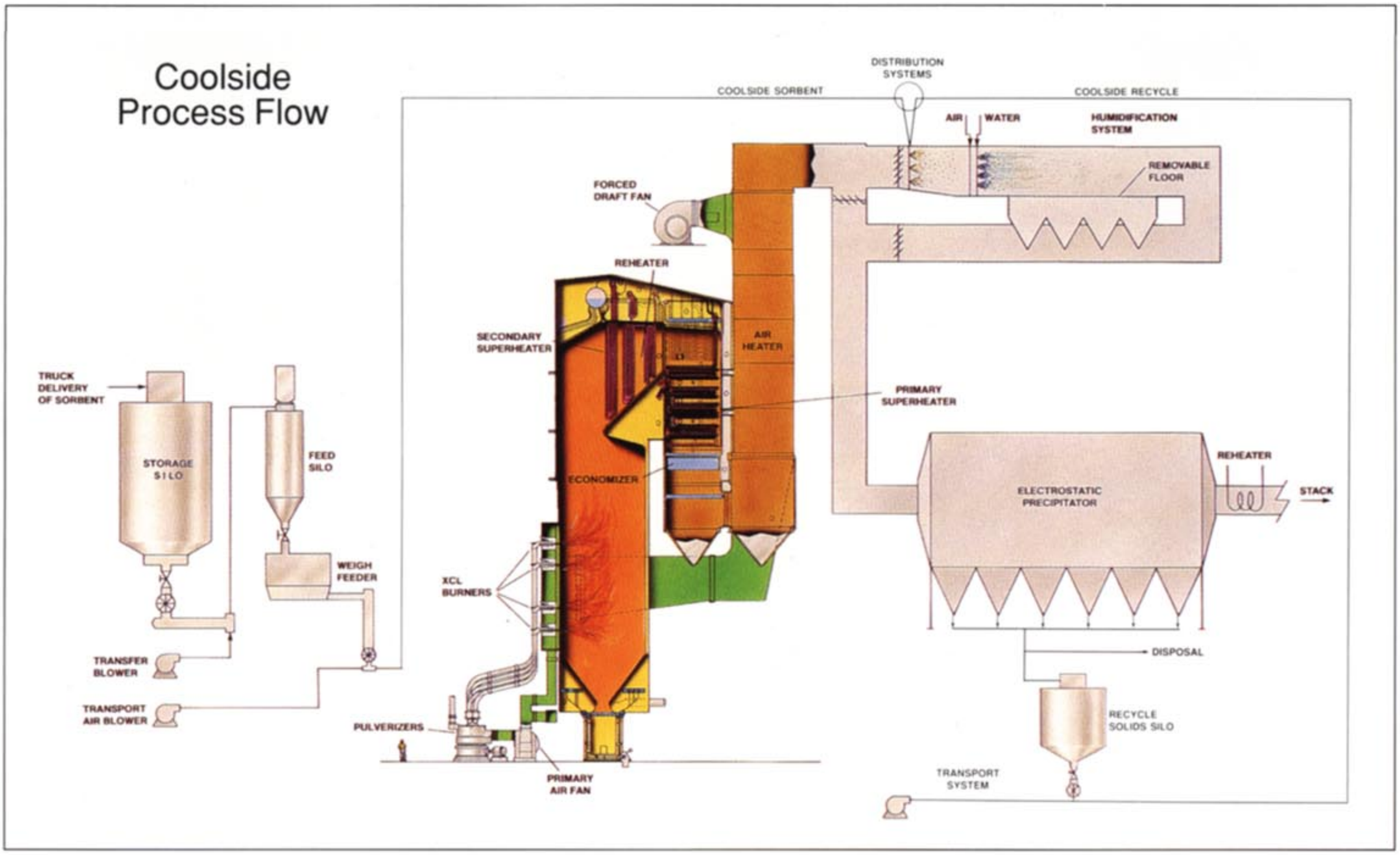
- Sulfur emissions were reduced by 40% to 70%, with higher levels achieved by increasing the rate of sorbent injection and by adding NaOH to the water mist.

- The level of sulfur capture varied depending on the sorbent used.

- Sorbent utilization rates of 30% to 35% were routinely achieved in once-through tests. When the sorbent was recycled, tests indicated that requirements for fresh lime and NaOH could be reduced by up to 30%.

- Results were consistent with those from pilot-scale tests, indicating that the earlier test data can be used to predict performance.

Tests were run under the following sets of conditions: with and without sorbent recycle, two commercially available hydrated limes, Ca/S molar ratios of 1.0 to 2.0, Na/Ca molar ratio of 0.2, 20 to 25 ^{T}F approach to saturation, and Ohio bituminous coal (3.0% sulfur).



The two sorbents were selected from among 12 commercially available sorbents studied in pilot-scale tests. One was highly active, but more expensive, while the other was moderately active but had a lower delivered cost.

The Coolside test program consisted of three phases. In the first phase, the operability of the humidification system and ESP were established and optimized under process conditions approaching adiabatic saturation. In the second and third phases, process performance was tested with each of the two sorbents chosen for the demonstration.

Coolside performance testing included operation of the hydrate injection systems under two modes—once-through and sorbent recycle. Parameters measured in once-through testing included SO_2 removal, ESP efficiency, and sorbent use with NaOH. In recycle testing, partially spent sorbent collected in the ESP was reinjected. Sorbent usage was monitored over a range of ratios of recycle solids to fresh hydrate.

Tests simulated different particulate mass loadings at the ESP inlet. The large size of the Edgewater ESP allowed performance to be tested over a range of effective ESP sizes.

The test program for the Coolside demonstration was designed to provide information about the sulfur removal potential of Coolside under various conditions as well as the operating reliability of the boiler and other related equipment. The demonstration also was structured to generate data that could be used to determine costs and design features for retrofitting other commercial units with the Coolside process.

The Coolside tests were monitored with a full range of measurements and

The Coolside process is a post-combustion, sorbent injection technology capable of reducing SO_2 emissions by 40% to 70%. Sorbent is injected downstream of the boiler and air heater. This clean coal technology has been successfully demonstrated at Ohio Edison's Edgewater Plant, a commercially operating power plant.

Coolside's sorbent inlection nozzles and the humidification chamber are located in a flue gas duct on the roof of the Edgewater Plant.

Coolside Process

Coolside is a post-combustion process that can be retrofitted to an existing coal-fired power plant to control SO_2 emissions. Sulfur is captured by a dry sorbent (calcitic, hydrated lime) which is injected into the flue gas between the boiler and the ESP (injection ports are located downstream of the air heater). After sorbent is injected into the duct, the flue gas is nearly saturated with a spray of finely atomized water mixed with a water-soluble sodium additive to enhance SO~ removal.

An ESP captures the dry, used sorbent along with the fly ash. A portion of the used sorbent can be recycled. Reinjecting the still highly reactive sorbent cuts requirements for fresh sorbent, lowering costs and reducing the volume of solid waste produced.

With the Coolside process, large, costly, add-on scrubbers are not needed. This is an especially important advantage for smaller or older plants that are tightly spaced or have relatively short remaining operating lives. And, because the process operates downstream of the boiler and air heater, Coolside does not affect boiler performance and has broad applicability to a range of boiler types and sizes.

analytical instruments. Measurements were taken of flue gas temperature and humidity, SO_2 concentrations at the outlets of the air heater and ESP, dust loadings at the ESP inlet and outlet, ESP current and voltage characteristics, ESP solids levels, calcium and sulfur content of ESP solids, in-situ resistivity of the ash, and stack opacity.

Data on process operability were obtained through detailed logging of operation, repair, and modification of the key process systems during the entire period. Monitored most closely were the lime feeding system, nozzle array and atomization system, humidification control system, and ESP. At the conclusion of the demonstration tests, the ESP and humidification system were inspected for signs of corrosion, erosion, deposition, and wall wetting.

Coolside Systems

In the Coolside process, a dry sorbent is injected into the flue gas in the duct between the air heater and the ESP. After the sorbent is injected, the flue gas is nearly saturated with a fine spray of water mixed with a water-soluble, sodium-based chemical additive, such as caustic soda (another name for NaOH), to enhance sulfur removal.

Equipment to inject sorbent and water into the flue gas has been installed in a bypass duct on the plant's roof. Dampers are used to divert the flue gas from the main flue into the bypass duct which was installed primarily to handle potential problems during the demonstration.

The bypass flue allows various operating conditions at close approaches to saturation to be tried without having to shut down the boiler if wall deposition or other problems occur.

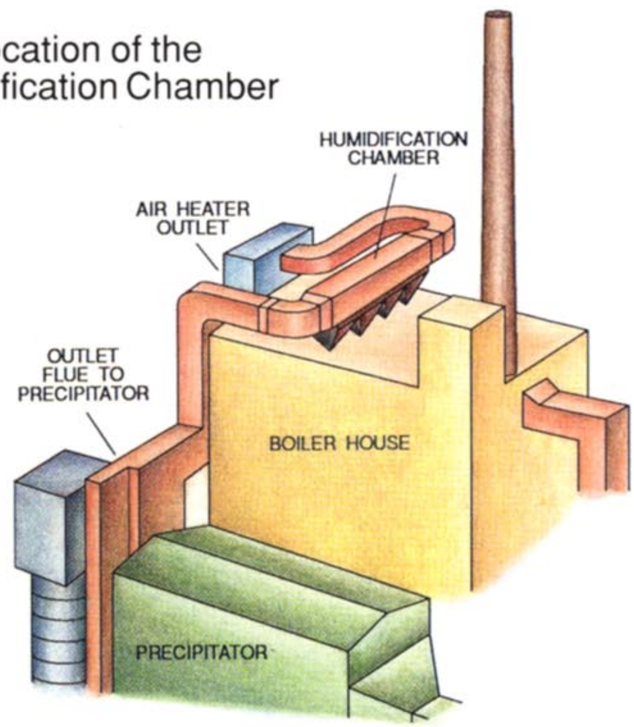
Sorbent Feed System

A significant portion of the sorbent feed system previously installed for the base LIMB demonstration was also used in the Coolside process. These elements included the sorbent storage silo and the pneumatic conveying system that brings sorbent to the feed silo. Modifications to Edgewater relating specifically to Coolside included new piping installed from the end of the present pneumatic conveying system to the sorbent injection point upstream of the atomizers. A separate distributor bottle was installed to assure good distribution of the sorbent injected into the duct.

Dry lime is delivered to Edgewater by tank trucks that are pneumatically unloaded into a 3-day storage silo. (For the demonstration, hydrated lime was delivered to the test site instead of being prepared onsite.) A baghouse mounted on the silo controls dust while venting the delivery air.

The humidification chamber is located in the flue gas duct. For the demonstration tests, a bypass duct is used so that various operating conditions at close approaches to adiabatic saturation can be tried without having to shut down the boiler if plugging or other problems occur.

Location of the Humidification Chamber



After sorbent is injected in the Coolside process, the flue gases are saturated with a fine spray of water mixed with a water-soluble, sodium-based chemical to enhance sulfur removal. Nozzles on two rows of humidification lances are shown close up. when the photo was taken, the top lance had been newly installed to replace one of an older design. The bottom lance had been placed into the chamber earlier to test the upgraded design.

An air system promotes material flow from the storage silo by fluidizing the sorbent along the cone walls. A rotary valve and vibrator at the feed silo's discharge port help to move the lime to a gravimetric weigh feeder which controls the feed rate of the hydrated lime based on the boiler steam production rate, percent sulfur in the feed coal, and Ca/S molar ratio.

From the weigh feeder, the hydrated lime is fed to the pneumatic injection line through a rotary air lock. An injection blower supplies the air for the pneumatic transfer of the hydrate into the duct upstream of the humidification section. Deflection plates in the duct can be used to distribute the sorbent into the flue gas, if necessary.

Atomizer Array

Downstream of the sorbent injection ports is the humidification chamber. At the chamber's entry is an array of atomizers that spray a fine mist of air and water into the flue gas. The array consists of 110 atomizers supported in 22 lances which enter the chamber from each side and meet at the center. This configuration comprises 11 rows of 10 atomizers each.

A shield air system designed into each lance provides each nozzle with an envelope of clean air to prevent solids buildup on the nozzle. The shield air is drawn from the enclosure around the humidifier. The air is drawn into each lance by natural draft since the humidifier operates at negative pressure.

A three-stage compressor rated at about 4,600 cfm provides the compressed air required for humidification. The compressed air is piped to the air receiver tank. Next, the air is filtered and transported to the atomizer through stainless steel pipe to prevent scale from entering the atomizer and having a detrimental effect on atomization.

The compressed air provides the energy necessary to atomize the humidification water. An air-to-water weight ratio of up to 0.45 is required to form the fine droplets in the spray pattern.

Water Supply System

Existing service water pumps deliver strained water from Lake Erie to a spray water storage tank. The water strainers have been upgraded, and a backflush system was added to provide the additional water capacity needed.

Humidification water is filtered through three strainers before reaching the atomizer nozzles. Spray nozzles as well as the piping and fittings after the final strainer are stainless steel.

Additive Feed System

A sodium-based additive is mixed into the humidification water to enhance the reaction between the sorbent and the

SO_2. For the Edgewater test program, NaOH, delivered in tank trucks, is pumped into a storage tank with a 5-day capacity. From the storage tank, the NaOH is pumped into the humidification water line with a metering pump. The humidification water and the NaOH are combined and blended with an in-line mixer. The mixture is injected into the flue gas duct downstream of the point at which the sorbent is injected.

Sorbent Recycle System

In sorbent recycle, some of the ESP solids are reinjected. ESP solids contain unreacted sorbent and additive particles that are still highly reactive. The recycle system reduces the need for fresh sorbent and additive.

Solids from the ESP are stored in an existing ash silo with two discharge ports. When the sorbent recycle system is in use, one port disposes of the waste material and the second port directs the solids into the recycle system.

A blower transfers the recycle solids from the existing ash silo to the recycle-solids silo for short-term storage. A volumetric feeder controls the feed rate of the recycle solids into the pneumatic transport system. A transfer line ties into the sorbent injection line just before the duct injection location. A process controller adjusts the recycle feed rate and fresh sorbent feed rate to maintain desired SO_2 removal levels.

Predicting Coolside Performance

Results of full-scale tests, completed in early 1990, were consistent with those from the pilot-plant tests conducted in the late 1980s. The full-scale test results indicated that pilot-scale data can be used to predict Coolside performance in a utility application.

At the pilot plant, 12 commercially available hydrated limes were evaluated and the Coolside process was tested in two *modes—once-through* and *recycle.*

Sorbent selection was shown to be an important factor in determining how well the process removes sulfur. Two sorbents were chosen for further testing. (These were the same sorbents used at Edgewater.) Both sorbents were tested in the once-through mode under widely varying conditions which encompassed those at Edgewater.

Statistical correlations were developed for SO_2 removal as a function of key process variables. Sorbent recycle tests showed a significant enhancement of process sorbent utilization.

Humidification

Flue gas humidification is the controlled addition of water to flue gas. Humidification changes the characteristics of the gas so that emissions control and particulate collection are more effective. Basically, humidification increases sulfur capture by improving the reactivity of sorbent particles. Although the mechanism by which this occurs is not completely understood, it appears that SO_2 absorption becomes more efficient as the flue gas approaches adiabatic saturation.

The Edgewater humidifier has been designed to bring the flue gas to within 20 ^{0}F of saturation. The final approach temperature is a trade-off. In other words, at a given temperature, sulfur removal is best achieved when the moisture content of the flue gas is high (the gas is nearly saturated); however, fewer problems that would disrupt the plant's operation tend to occur when the flue gas is relatively dry.

The temperature of the flue gas entering the humidification chamber is about 300 ^{0}F prior to humidification. At this temperature, the reaction of the injected lime with the SO_2 would be inadequate without the presence of liquid water. After the sorbent is injected into the flue gas, water mixed with a sodium-rich additive is sprayed into the chamber to nearly saturate the flue gas.

Coolside Pilot Plant

Consol's 0.l-MWe Coolside pilot plant was designed to simulate the interaction between water droplets and sorbent particles, a key aspect of the Coolside process. An 8.3-inch in-duct, vertical downflow humidifier provided a 20-foot humidification zone downstream of the two-fluid nozzle used to spray water. Residence time in the humidifier was about 2 seconds (same as Edgewater). A baghouse removed particulates.

Measurements of SO_2 were taken continuously at the inlet and outlet of the humidifier and at the stack.

Pilot Sorbent Evaluation Tests

Sorbents were tested and evaluated to determine the effect of sorbent variation on process performance. The 12 sorbents tested included 10 hydrated calcitic limes and 2 pressure-hydrated dolomitic limes.

Desulfurization performance varied widely among the different sorbents. Removing the same amount of SO, required about 35% more of the worst performing sorbent than of the best sorbent. Also, calcitic hydrated limes were generally superior to dolomitic hydrates. (Comparisons were based on per unit sorbent weight.)

For hydrated calcitic limes, SO., capture improved somewhat with increasing surface area and porosity, but the impact of these variables was reduced significantly when NaOH was added to the humidification water.

Two hydrated calcitic limes were selected for further testing. One, hydrated lime A, was a highly active but relatively expensive sorbent. The other, hydrated lime B, was a moderately active but very economical sorbent.

Pilot Once-Through Tests

Once-through simulation tests were made with the two sorbents to develop process performance data over a wide range of conditions (including those at Edgewater). NaOH additive was mixed with the humidification water.

The tests with the more economical sorbent, referred to as hydrated lime B, were based on a Box-Behnken statistical experimental design. The design employed the following five variables: approaches to adiabatic saturation of 45 to 25 ^oF, Ca/S molar ratios of 0.75 to 2.25, Na/Ca molar ratios of 0 to 0.2, inlet SO_2 content ranging from 500 to 2,500 parts per million (ppm) on a wet basis, and inlet flue gas temperatures of 270 to 330 ^oF.

Tests using the more reactive sorbent, referred to as hydrated lime A, were made with Ca/S and Na/Ca as variables at a constant 25 ^0F approach to saturation, an inlet temperature of 300 ^0F, and an inlet SO_2 content of 1,500 ppm wet (or 1,620 ppm on a dry basis).

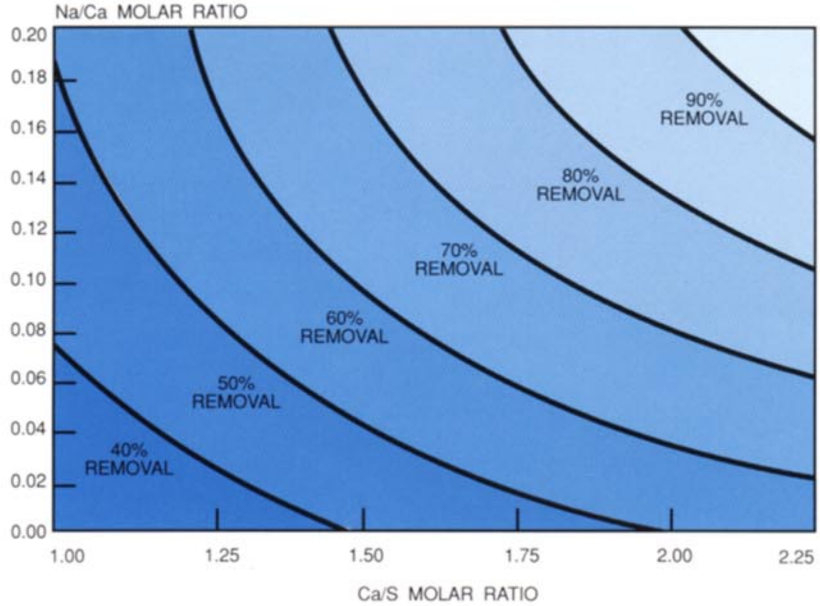
Test results showed that SO_2 removal increased strongly with a closer approach to saturation and with increasing Ca/S and Na/Ca molar ratios. Flue gas inlet temperature and SO_2 content had secondary effects. Statistical correlations indicated that SO_2 removal roughly doubled as the saturation approach was changed from 45 to 25^oF.

For hydrated lime B, the attainable SO_2 removal level without NaOH injection was calculated to be less than 50% at Ca/S molar ratios up to 2.25. But injecting NaOH at Na/Ca molar ratios of up to 0.2 expanded the attainable range of SO., removal to over 70%.

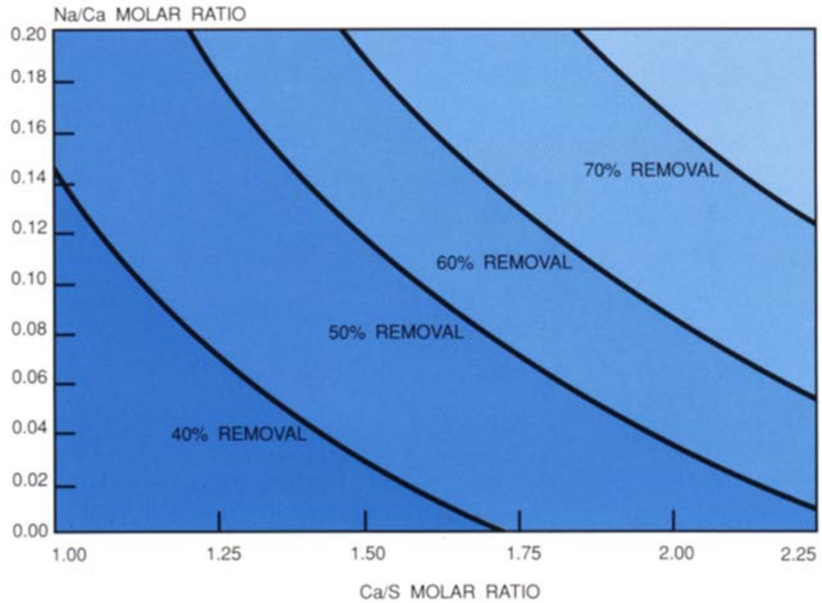
With the more reactive sorbent (hydrated lime A), significantly less sorbent and NaOH additive are required to remove the same level of SO_2. For example, to remove 60% of the SO_2 at a Na/Ca molar ratio of 0.1, requirements for fresh sorbent and additive would be about 20% less with hydrated lime A than with hydrated lime B.

Predictions of SO_2 Removal by Coolside Process

Hydrated Lime A
(More Active, More Costly)



Hydrated Lime B
(Less Active, Less Costly)



Common conditions for once-through tests were as follows: 25 °F approach to saturation, 300 °F inlet temperature, and 1,620 ppm (dry) inlet SO_2.

Pilot Sorbent Recycle Tests

Recycle simulation tests indicated that sorbent utilization can be enhanced significantly. By recycling the sorbent, fresh sorbent and additive usage was reduced by up to 30%.

In all recycle tests, hydrated lime B was fed at a fresh Ca/S molar ratio of 1.0. The recycle tests were made with and without the additive. For the tests with NaOH, the injection rate was fixed at a Na/Ca molar ratio of 0.2 (based on the hydrated lime feed) and the approach to saturation was 25 ^{0}F. Recycle sorbent was injected simultaneously with the fresh hydrated lime at recycle ratios of 0.5, 1.0, and 1.8 (the ratio was defined as pound of recycle material per pound of fresh lime and fly ash). Steady-state continuous recycle was simulated by making successive sets of runs with batchwise recycle fixed at the same recycle ratio.

SO_2 removal increased significantly in the sorbent recycle mode. Without recycling, 41% of the SO_2 (system-wide) was removed. When the recycle ratio was set at 1.8, over 60% of the SO_2 was removed, indicating also that the recycled sorbent was highly reactive.

In successive pilot runs with batchwise recycle, the conditions for steady-state recycle were approached but not quite attained. (In truly steady-state continuous recycle, sorbent utilization levels would be somewhat higher and SO_2 removal levels somewhat lower than those measured.)

It was assumed that the single-pass conversion of available sorbent and additive (i.e., calcium and sodium not tied up with sulfur) was constant at each recycle ratio and equal to the value observed in the pilot runs.

These simulated steady-state tests also indicated that recycling can substantially reduce requirements for sorbent and NaOH additive. To remove 64% of the 502 *without* recycle, a Ca/S molar ratio of 1.4 and a Na/Ca molar ratio of 0.2 would be required, based on correlations for hydrated lime B from once-through tests. *With* the recycle ratio fixed at 1.8 (same Na/Ca molar ratio of 0.2), the Ca/S molar ratio would need to be only 1.0 to remove the same 64% of the SO_2.

These results indicate that at a recycle ratio of 1.8 (which is also Edgewater's estimated maximum recycle ratio) sorbent recycling has the potential to reduce requirements for fresh sorbent and additive by about 30%.

Coolside Technology Development

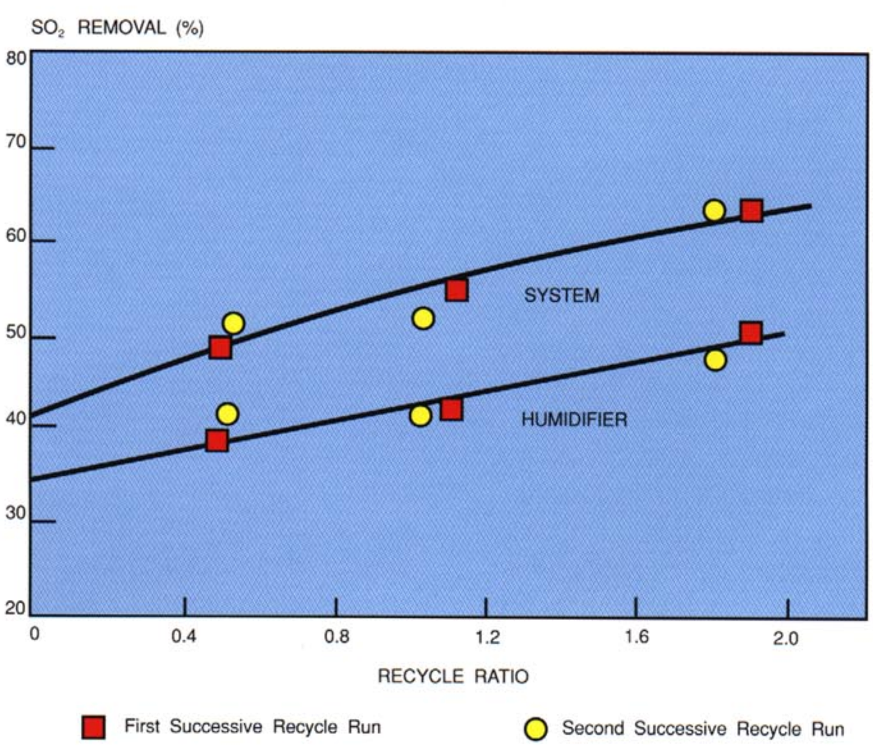
The Coolside process was developed by Consol through laboratory studies, pilot-plant studies, and field tests. Development work focused on process optimization for maximum SO_2 removal and sorbent utilization and on developing criteria for the design and operation of the humidification system.

Development work included scaling up Consol's 0.1-MWe pilot humidifier to 5 MWe for design validation tests at DOE's proof-of-concept duct injection facility in Ohio Edison's Toronto plant.

These tests showed that the single-nozzle pilot-plant design could be readily scaled up to a multiple nozzle array for use in a rectangular horizontal duct.

The laboratory and pilot-plant work led to a better understanding of process fundamentals, such as the SO_2 capture mechanism, the role and effect of SO_2 capture promoters, the role of the humidifier water droplets in SO_2 removal, the benefits of sorbent recycle, and the relationship between sorbent characteristics and process performance.

Increased SO_2 Removal with Sorbent Recycle



Estimated Steady-State SO_2 Removal and Sorbent Utilization

Recycle Ratio	SO_2 Removal (System)	Overall Sorbent Utilization (System)
0	41%	37%
0.5	48%	43%
1.0	50%	46%
1.8	64%	49%

Recycle tests were conducted using the less active hydrated lime B under the following conditions: 25 °F approach to saturation, fresh Ca/S ratio of 1.0, and fresh Na/Ca molar ratio of 0.2.

Extended LIMB Demonstration Begins

Extended testing of LIMB is under way to demonstrate its ability to control SO., emissions while also reducing NO,,. Testing began in April 1990 following successful demonstration of Coolside. Tests now in progress are part of the DOE LIMB project extension —a continuation of the EPA base LIMB project initiated in 1984.

The overall effort is demonstrating the LIMB process in a full-scale application representative of Carolina-type wall-fired utility boilers. The project is expected to provide an understanding of controlling factors in the process and to demonstrate the following:

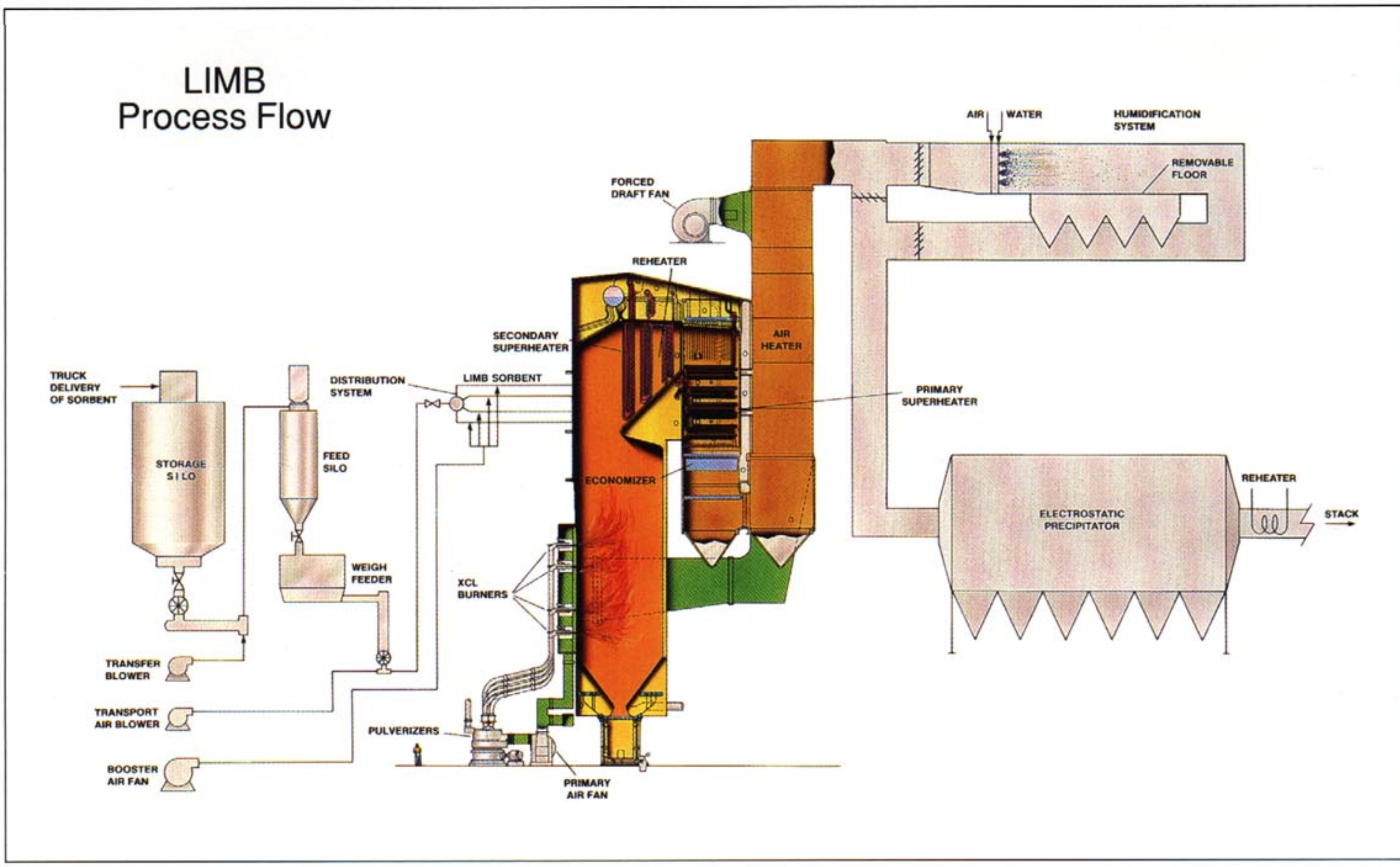
- Reductions of 50% or more in SO., emissions can be achieved at a fraction of the cost of add-on FGD systems. Reductions of NO emissions also can be achieved by using low-NO, burners.

- Boiler reliability, operability, and steam production can be maintained at levels existing prior to retrofitting the plant with LIMB.

- Technical difficulties attributable to LIMB operation can be resolved in a cost-effective manner.

The LIMB demonstration is also using flue gas humidification as a means of enhancing process performance and overcoming difficulties encountered with ESP operation during the EPA base LIMB demonstration project.

In the earlier EPA demonstration, there was some degradation in ESP performance during LIMB operation due to a combination of three factors. First, dust loading to the ESP more than doubled. Second, the size of injected sorbent particles were finer and harder to capture than normal fly ash. Third, the



LIMB Process Flow

sorbent exhibited a chemical affinity for SO_3; this resulted in a lower acid dew point and higher resistivity of the ash.

Humidification has provided a low-cost option for restoring ESP performance in a system where the boiler has been retrofitted with LIMB technology. Humidification also has increased SO_2 capture by rendering sorbent particles more reactive.

However, the extent of SO_2 removal is highly dependent on how much the flue gas temperature is reduced. The risk of scaling, plugging, and other operating problems also tends to increase sharply as the gas cools and the temperature approaches adiabatic saturation. Yet these risks must be balanced against the advantages of humidifying to as close an approach to saturation as possible. One advantage is that particulate emissions from a plant with a small ESP potentially can be kept in compliance without the high cost of additional particulate collection area. Furthermore, SO_2 removal potentially can be increased by taking advantage of unspent sorbent from the boiler.

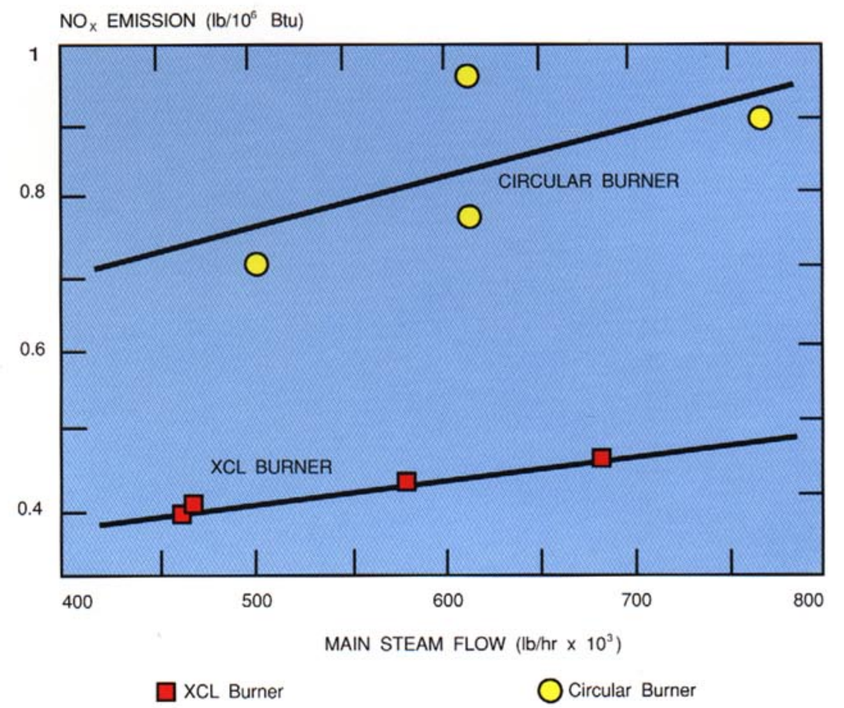
Because of the risk of scaling and plugging, the demonstration of humidification is being carried out in a bypass duct, which allows various operating conditions at close approaches to saturation to be tried without having to shut down the boiler if wall deposition occurs or the humidifier becomes plugged.

LIMB Systems

In the LIMB process, sorbent is injected into the upper part of the boiler.

LIMB is a sorbent injection technology involving combustion and post-combustion modifications. In LIMB, sorbent is injected into the upper portion of the boiler. This clean coal technology is being demonstrated at the commercially operating Edgewater power plant. Reductions of 50% or more in SO_2 and NO_x emissions can be achieved when LIMB is used with low-NO_x burners.

NO_x Performance of XCL and Circular Burners



Low-NO_x Burners

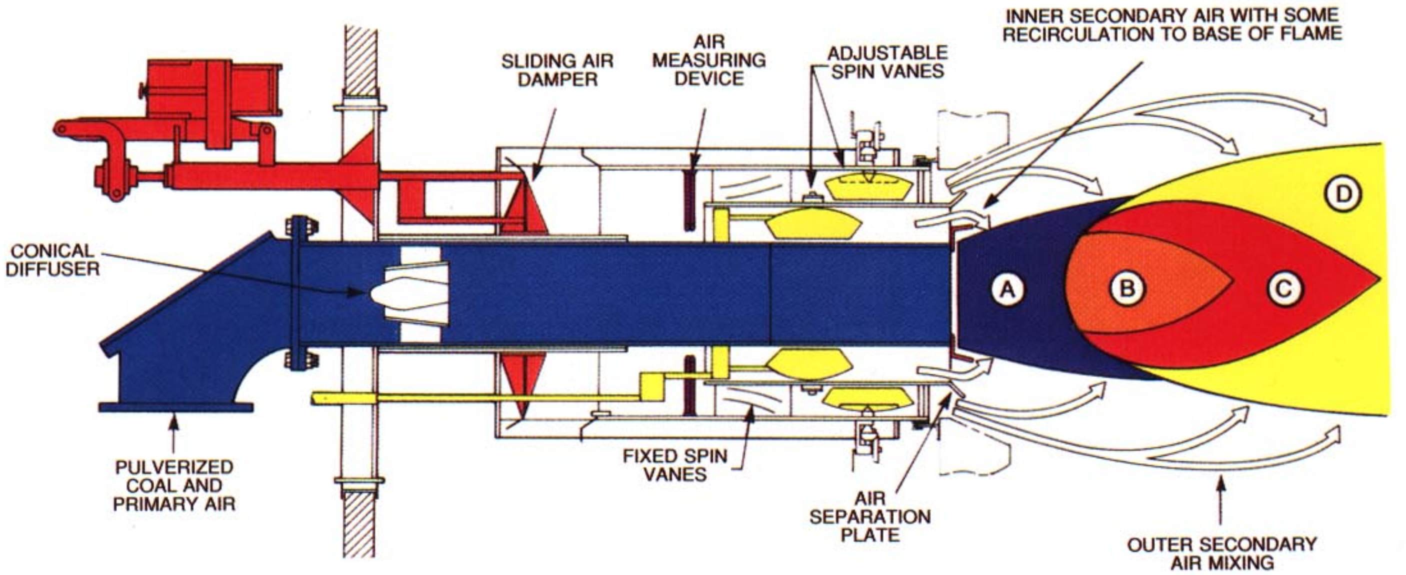
The original 12 B&W circular register burners in the Unit 4 boiler were replaced in 1986 with B&W's dual-register-type XCL burners. These retrofitted coal-fired burners form less NO_x by carefully controlling coal/air mixing in the combustion process.

A short series of tests were conducted with the low-NO_x burners prior to sorbent injection. Results were compared with data obtained from the circular register burners before the retrofit.

Under the test conditions, NO_x emissions from the XCL burners did not exceed 0.5 pound per million Btu over the full operating range of the boiler. (For the purposes of the project, the maximum continuous rating of the boiler's main steam flow is 700,000 lb/hr, with a peak load of 770,000 lb/hr.) The original burners produced NO_x emissions ranging from about 0.7 to over 0.9 pound per million Btu.

The performance of the XCL low-NO_x burners represents roughly a 50% reduction in NO_x emissions compared to the original burners.

XCL-Type Burner



The diagram depicts the current design of the XCL burner. A prototype was installed in the Edgewater boiler for the demonstration. The diagram identifies four key zones in the flame: (A) a high-temperature, fuel-rich devolatilization zone; (B) an area where reducing species are produced; (C) the NO_x-decomposition zone; and (D) the char-oxidizing zone.

After leaving the boiler and air heater, the flue gas is humidified. A fine mist of water is sprayed into the flue gas to promote SO_2 capture and enhance particulate collection.

Low-NO_x Burners

The original 12 circular register burners were replaced with low-NO_x burners. B&W's dual-register-type XCL burner was selected for use in this application to accommodate constraints of the existing unit while avoiding changes to the boiler pressure parts. Tests have indicated that these burners form only about half of the NO_x produced by the original burners.

The XCL burner controls the mixing of air and fuel in the near-flame region. Primary air mixed with pulverized coal is fed through a burner elbow to the nozzle. Immediately past the elbow is a conical diffuser that produces a fuel pattern of higher density near the nozzle walls.

The nozzle is axisymmetric to the burner and is surrounded by two secondary air zones—an inner zone and an outer zone. A fraction of the secondary air enters an inner zone where it passes through spin vanes. Upon leaving the vanes, the swirling inner air comes into contact with the jet of fuel and air feeding from the burner's nozzle. The mixture of fuel and air ignites in the burner throat.

Most of the secondary air enters through the outer zone with swirl imparted by spin vanes. This air surrounds the ignited fuel mixture and eventually enters into the combustion process as the jet expands downstream.

Sootblowers

Four additional sootblowers were installed at Edgewater to deal with the increase in solids in the furnace gases as a result of sorbent injection and to lessen the possibility of plugging during operation. Two sootblowers were installed in the cavity before the entrance to the first downflow convection tube bank, and two in the third cavity of the downflow convection pass. A plant using LIMB technology may require additional sootblowers to handle the higher level of solids and to avoid impaction of sorbent on the boiler tubes. Sootblower specifications depend on the configuration of the boiler being retrofitted and the coal's slagging and fouling characteristics.

Sorbent Injection System

LIMB's sorbent injection system consists of three subsystems installed upstream of the boiler—sorbent storage and handling, sorbent transport and feed, and sorbent distribution and injection.

The storage and handling system supplies and prepares sorbent for the LIMB process. For the tests, commercially hydrated sorbents are being delivered to the plant, rather than being hydrated onsite. Self-unloading trucks pneumatically fill a storage silo through two loading stations at grade level.

From the storage silo, the sorbent is conveyed on demand to a feed silo with a 4-hour capacity. Low-pressure, dry air transfers sorbent at a rate of 50 tons per hour. At the feed silo, an inlet alleviator separates the sorbent from conveying air.

The transport and feed system delivers sorbent at a controlled feed rate to the injection ports in the boiler. A vibrator promotes sorbent flow from the bottom of the feed silo to the conveying line. The vibrator and a pneumatic slide gate operate upon demand from a signal indicating a low sorbent level. Each feeder delivers 2.1 to 8.6 tons per hour of hydrated lime, or 5.0 to 10.2 tons per hour of limestone.

From the feeder, the mixture of sorbent and air is conveyed to distributors. One distributor feeds 8 injection lines which transport the mixture to the boiler, while the other has 12 lines.

Sorbent is fed into the boiler at the desired penetration and dispersion rates. There are three rows of injector nozzles at different elevations on the front wall of the boiler—181, 187, and 191 feet. Sorbent can be fed into any two of the three elevations at one time.

A booster air fan provides the air necessary for injection. Alternatively, lances that have higher air velocity could be used in larger units.

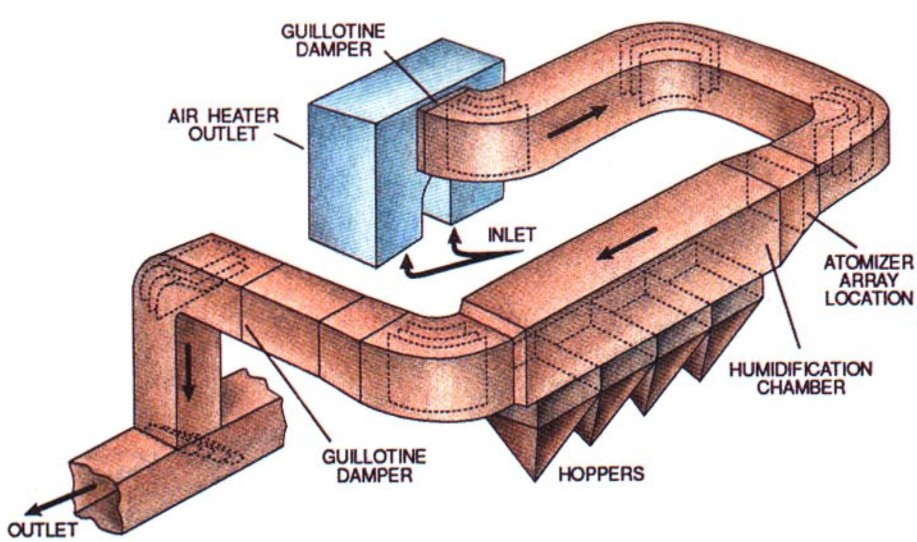
Research has shown that maximum sorbent reactivity and sulfur capture are obtained in the temperature range of 1,600 to 2,300 °F. The sorbent injectors are located where the temperature in the boiler is at the upper end of this range.

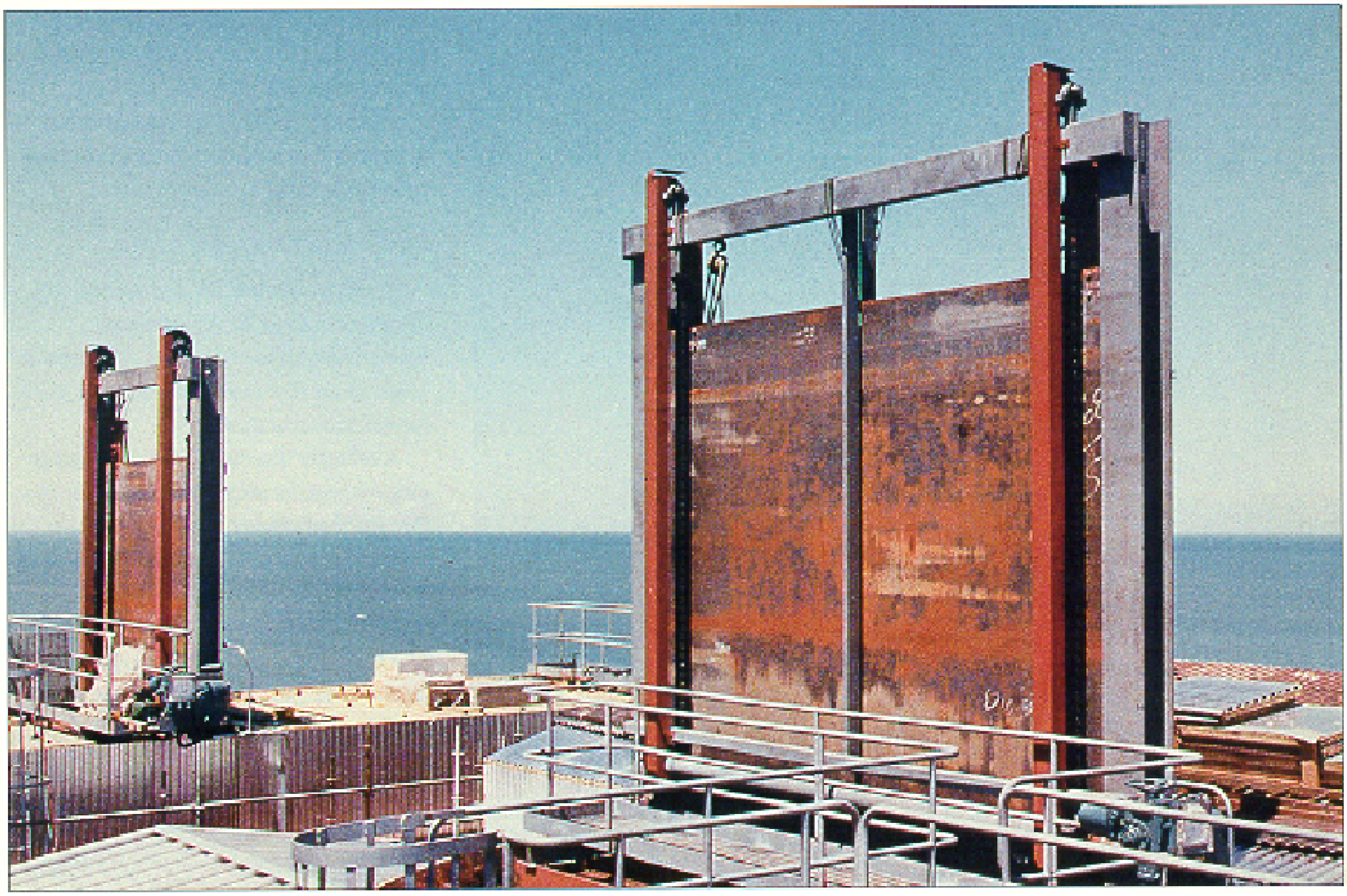
Humidification Chamber

Duct modifications were made at Edgewater to enable the humidification chamber to be installed in a bypass duct. The humidification system includes equipment such as water pumps, air compressors, and an atomizer array. The humidifier is 14 feet 7 inches square by 56 feet 6 inches long. The horizontal chamber is connected to the main flue by ductwork and a series of dampers.

Humidification of flue gas takes place in a chamber located beyond the boiler, between the air heater and the ESP. Humidification changes the characteristics of the flue gas so that emissions control and particulate collection are more effective.

Flow Diagram of the Humidification Chamber





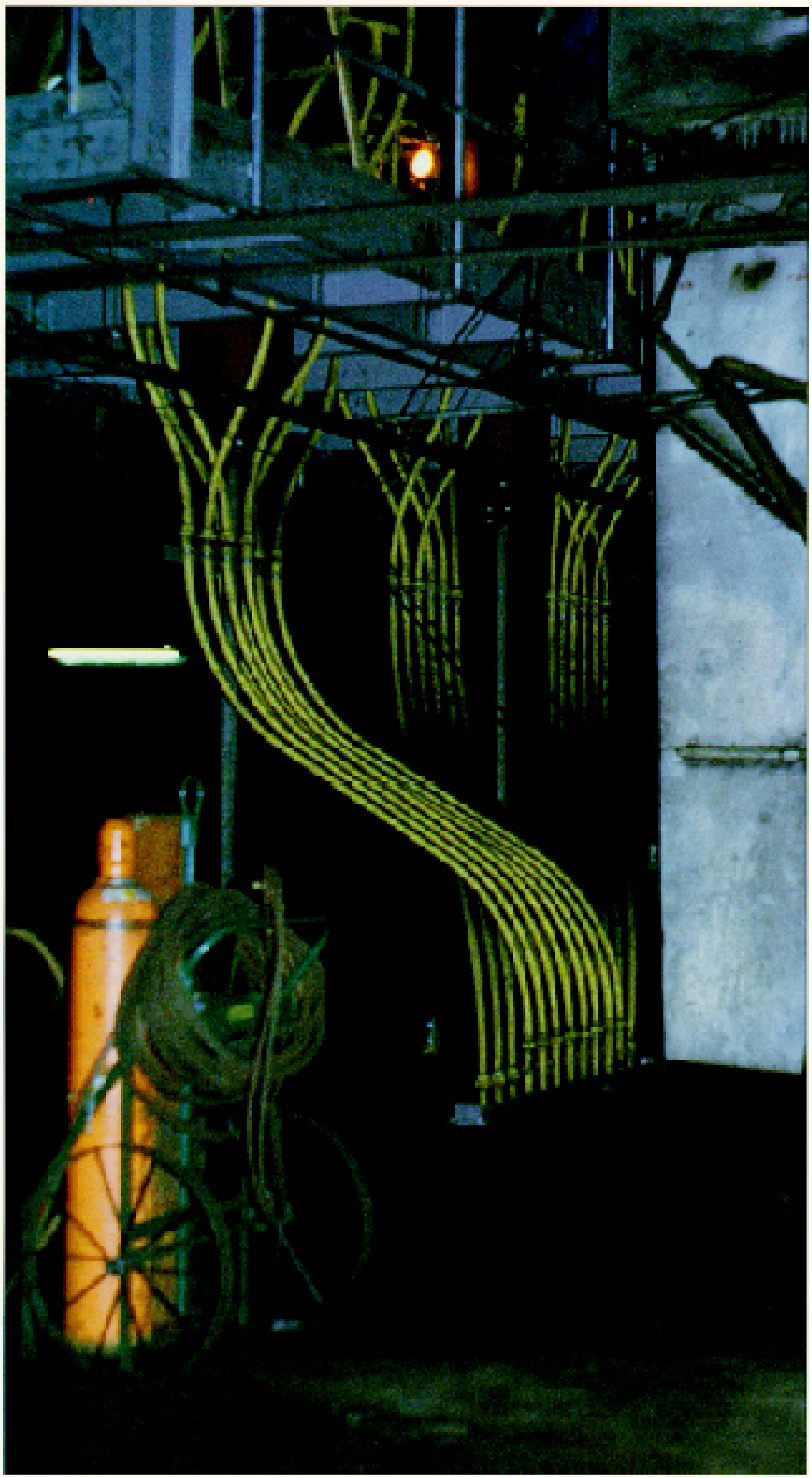
At the chamber's entry is an atomizer array that sprays a fine mist of water into the flue gas. The array consists of 110 atomizers supported in 22 lances. These lances enter the chamber from each side and meet in the center.

Turning vanes in the bends of the duct minimize pressure drop and distribute the gas flow. Residence time within the chamber is about 2 seconds at full load.

Again because of the risk of scaling and plugging, the humidifier was located over four existing hoppers that were originally part of Edgewater's retired precipitator. As a further precaution, baffles were installed on the hoppers to minimize the effects of gas recirculation that would have occurred had it been necessary to operate with the hoppers open. Fortunately, the design was sufficiently sound that LIMB and Coolside have been run exclusively with all hoppers and baffles covered by a removable floor.

Guillotine and louvered dampers are used to extract the gas flow from the main duct into the bypass duct and through the humidification chamber. All of the flue gas is channeled into the bypass duct and through the humidifier unless test conditions require a split in flow. If a problem occurs, all or part of the hot flue gas can be diverted back to the main duct. The boiler can continue or resume normal operation. The boiler need not be shut down to repair or re-solve any problems that might occur in the humidification chamber during demonstration tests. The guillotine dampers provide a tight shut-off to divert

By opening guillotine dampers at each end of the bypass duct (as shown in the photo), the gas flow can be channeled through the humidification chamber. If a problem occurs, all or part of the gas flow can be diverted back to the main duct, and the boiler can continue or resume normal operation. Also, because the guillotine dampers provide a tight shut-off of gas flow, personnel can safely enter the area to make repairs while the boiler is on line.



flue gas away from the humidification chamber to allow personnel to enter the area safely while the boiler is on line.

(Also see pages 15-17 for additional information about humidification and the equipment installed at Edgewater.)

Particulate Control System

The Edgewater ESP, a conservatively designed Lodge-Cottrell unit, was substantially oversized when retrofitted in 1982, so no ESP modifications were made for the demonstrations.

A reheater installed at the precipitator outlet is used as necessary to increase the flue gas temperature to maintain plume buoyancy. The reheat system is similar to several others designed by B&W. The boiler steam drum supplies steam to the reheater. Steam from the drum is regulated to 350 psig to protect the reheater from over pressure conditions.

Waste Disposal Systems

The solid waste produced by a commercial-size utility boiler retrofitted with LIMB technology consists of fly ash, unreacted lime, and sulfated calcium sorbent. The ash contains about 30% free lime and is highly alkaline.

The Dravo-Wellman waste handling system being used can handle both wet and dry ash. The system's capacity is 60 tons per hour, more than the expected maximum load. Modifications to the system have been made to enable a controlled amount of water to be added to the ash in order to hydrate the free lime for safe handling and disposal.

LIMB Test Program

Several combinations of coals and sorbents are being tested during the extended LIMB demonstration. Four sorbents are being selected based on expected SO, capture, cost, availability, and ash generated. Three bituminous coals are being selected based primarily on sulfur content.

The first sorbent being tested is a lignosulfonated lime and is the most reactive of the four test sorbents. The second sorbent is a ground limestone and has the lowest cost. The third test sorbent is the same hydrated calcitic lime used in the EPA base LIMB project. (This sorbent is being used with the two coals not tested in the base LIMB project.) The fourth sorbent is a dolornitic lime readily available locally.

Two bituminous coals selected for testing have nominal sulfur contents of 1.5% and 3.0%. The nominal 3.0% sulfur coal is the same coal used in the EPA base LIMB project. The nominal 1.5% sulfur coal is typical of coal used at Edgewater before it was retrofitted.

The third coal is to be representative of high-sulfur coal. Selection of this coal has been deferred temporarily pending a decision on regulatory issues concerning potential emissions levels. During the demonstration, the plant must remain in compliance with emissions regulations. Test coals may not exceed the emission control capabilities of Edgewater.

Each combination of coal and sorbent is being tested for about a month. The test is divided into three distinct periods: change over, optimization, and continuous operation. During change over, the previous coal and sorbent combination is purged from the system and operation on the new combination is established. The optimization period for each combination is 8 to 10 days. Ca/S molar ratios from 1.0 to 2.5 are tested. Combinations of three injection levels in the boiler are being used to determine the effect of injection location on SO, removal.

Remaining fixed for each combination being tested are the following set of operating conditions: injection velocity adjusted to load, optimum burner setting, and excess air.

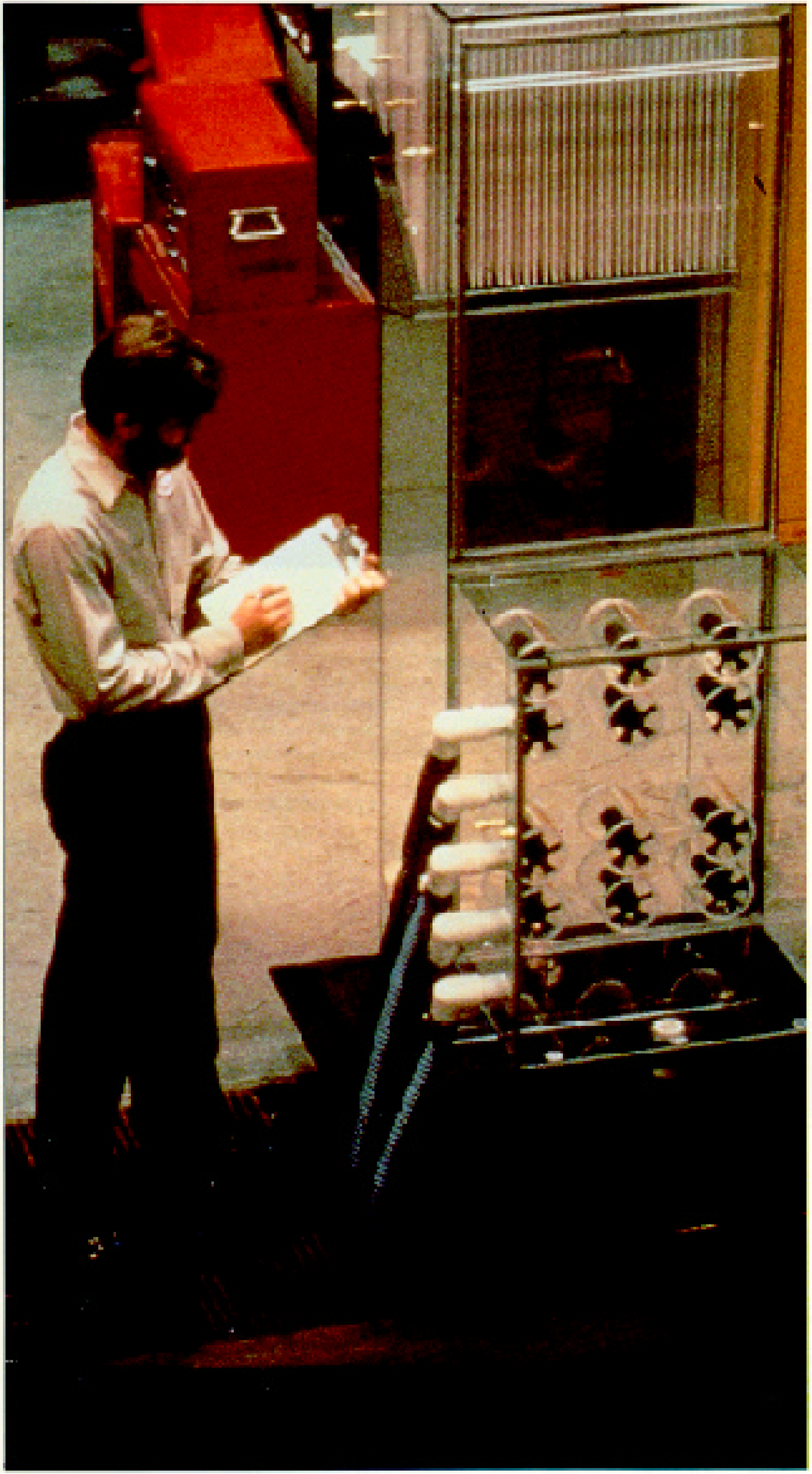
A period of continuous operation follows the optimization tests. The boiler is operated in its normal load-following mode at the optimum conditions determined for each coal and sorbent combination. Data on system operation and performance are collected for each combination of coal and sorbent. In order to produce accurate and reliable performance data, a full range of data collection techniques are used.

An existing B&W Boiler Performance Diagnostic System 140 is gathering information on boiler operation and performance, including steam flows, temperatures, and pressures; gas and air flows, temperatures, and pressures; coal flow and coal composition; and combustion efficiency.

The LIMB test plan also specifies the collection of other boiler data related to boiler reliability and operability. These data include steam production, furnace absorption and cleanliness, convective surface cleanliness, sootblower

Each load of coal delivered to Edgewater for the demonstration tests is sampled and characteristics are analyzed. The extended LIMB demonstration will test three coals. Two bituminous coals have been selected: one with a nominal sulfur content of 1.7% and the other with 3.0%. Pending a decision is a coal representative of high-sulfur coal.

Opposite:
Fresh sorbent is conveyed into distributor bottles located in the vicinity of the boiler. Feed lines bring the sorbent down from the distributor bottles to injection nozzles in the boiler. The extended LIMB demonstration will test four different sorbents.



effectiveness, and required maintenance. Measurements of characteristics of gaseous emissions and solids exiting the boiler also are being made.

For continuous LIMB operation, the amount of inlet sulfur to the boiler is being calculated by the data acquisition system from the coal analysis and from a series of heat and material balances derived from boiler measurements. The calculated inlet sulfur is the basis for the sulfur term in the Ca/S ratio and is being compared with the outlet SO., to calculate SO, removal efficiency. This is considered the only practical method of determining removal efficiency during the LIMB demonstration because continuous measurement of SO., concentration in the lower furnace is impossible.

Manual gas analysis and particulate sampling also are being performed. The information, along with the data from the System 140 and routine operating data, will be used to characterize the operation and performance of the process.

The analytical results of the testing are expected to provide the basis for evaluating SO., removal performance, ESP efficiency, and process controllability. The SO., removal and process performance results will serve as the basis for determining the process economics for LIMB.

Environmental Monitoring

Air, wastewater, solid waste, and groundwater are being monitored during the LIMB tests.

Air Monitoring

The air monitoring plan for the project extension includes specifications for point source emissions, fugitive dust emissions, and ambient air concentrations. As part of the demonstration, NON, SO,, CO. CO.,, and 0, are being monitored frequently or continuously; measurements are also being taken of particulate loading and particle size. Data are being collected at both inlet and outlet points at the ESP.

Compliance monitoring of point source emissions is being conducted for SO,, opacity, and particulate loading. Supplemental monitoring is being conducted for particulates (including particle size distribution), SO_2, NO, and CO. Substances being monitored are regulated by the state air permit or are criteria pollutants under the NAAQS. CO., and 0, also are being monitored to aid in the interpretation of data relating to SO,, NO~, and CO levels.

In addition to point source emissions, the air monitoring plan covers fugitive dust emissions and ambient air concentrations. Fugitive dust emissions are regulated by existing permits and are being monitored for compliance; supplemental monitoring is not considered necessary. Ambient air monitoring is conducted by the state. The impact of SO.,, NO, CO, and particulate emissions on ambient concentrations is being estimated using a dispersion model.

Wastewater Monitoring

Because large quantities of sorbent chemicals are being injected into different parts of the boiler during the demonstration of the LIMB process, additional sampling and analysis of wastewater are being performed. This supplemental monitoring is primarily measuring calcium and pH levels.

Solid Waste and Groundwater Monitoring

The plan for monitoring solid waste addresses the increased volume of ash generated. The chemical and physical nature of ash from the Edgewater ESP is expected to change considerably with the different sorbents and coals being tested. Thus, groundwater in the vicinity of the ash disposal site will continue to be monitored after the operational phase.

Environmental Advantages of LIMB and Coolside

LIMB and Coolside have the potential to reduce an existing plant's SO_2 emissions by 50% or more in a cost-effective and timely manner without reducing overall ESP performance.

Low-NOx burners can be used with either process to reduce NOx emissions by about 50%.

Compared to conventional wet scrubbers, LIMB and Coolside offer these advantages:

- Lower capital costs
- Lower waste handling costs
- Fewer modifications
- Smaller space requirements
- Shorter construction times
- Lower NOx emissions.

Opposite:
At the beginning of the LIMB project, a flow model was used to determine the best placement of sorbent injection nozzles in the boiler. A researcher is shown collecting data from the flow model during the tests.

To Receive Additionsl Information

To be placed on the Department of Energy's distribution list for future information on the Clean Coal Technology Program and the demonstration projects it is financing, contact:

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