



Project Summary

Evaluation of the Limestone Dual Alkali Prototype System at Plant Scholz: System Design and Program Plan

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The limestone dual alkali process developed by Combustion Equipment Associates, Inc. (ownership of CEA's Air Pollution Division was sold to Thyssen-CEA Environmental Systems, Inc. in late 1980) and Arthur D. Little, Inc. will be tested at an existing 20 MWe prototype facility at Gulf Power Company's Scholz Steam Plant. The intent of this project is not only to demonstrate the technical feasibility of the process at a prototype level but also to supply technical and cost information related to implementation of the process at a full commercial scale.

The project will be carried out in three phases: Phase 1 - Project Planning; Phase 2 - Procurement, Recommissioning, and Construction; and Phase 3 - Startup, Testing, Decommissioning, and Data Analysis.

This report covers Phase 1, including: the design and description of the limestone dual alkali system at Scholz; the test program itself; recommissioning and construction costs; and projected costs for a full-scale 500 MW utility system.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report

of the same title (see Project Report ordering information at back).

Introduction

Background

Combustion Equipment Associates, Inc. (CEA)¹ and Arthur D. Little, Inc. (ADL) developed, over the past few years, a dual alkali process for removing SO₂ from flue gas generated in coal-fired utility boilers. The CEA/ADL dual alkali process is based on the absorption of SO₂ in an alkaline sodium solution, followed by regeneration of the absorbing solution by reaction with a second alkali, calcium. These reactions generate insoluble calcium-sulfur salts which are discharged from the system as a moist cake.

The CEA/ADL process presents two significant advantages over conventional direct lime or limestone scrubbing. First, it uses a clear liquor, rather than a slurry, for scrubbing the flue gas. Second, the regeneration of the scrubbing solution and precipitation of waste solids take place outside the absorber. Thus, the potential for scaling and plugging in the absorber is minimized; the formation of solids with good dewatering properties is more easily controlled; and high SO₂ removal efficiencies (>90%) are easily achieved.

¹CEA's Air Pollution Division was sold to Thyssen-CEA Environmental Systems, Inc. in late 1980.

with alkaline sodium scrubbing solutions by simple manipulation of the scrubber operating pH.

The CEA/ADL dual alkali process has been tested extensively at laboratory, pilot plant, and prototype levels using lime as the source of calcium for the regeneration reactions.² The performance of the process in these tests prompted the EPA to select the CEA/ADL dual alkali process for a demonstration plant. This lime-based demonstration plant has been installed on a 300 MW boiler at Louisville Gas and Electric's Cane Run Station. The system is currently undergoing a 1-year test program.

Although the lime-based system is technically and economically viable, a source of calcium cheaper than lime would increase the economic attractiveness of the process. Limestone was recognized early on as a potential, cheaper, source of calcium for the dual alkali process. Extensive testing of limestone was undertaken by ADL at laboratory and pilot plant levels under funding both by EPA^{3,4} and CEA. Successful pilot operations using limestone were achieved in 1977.

The successful performance of the system during the laboratory and pilot plant tests revealed the potential of the limestone-based dual alkali process for full-scale applications. This project is aimed at confirming this potential as well as providing information for its full-scale application.

Project Objectives

The purpose of this program is to evaluate the performance, at a prototype scale, of the CEA/ADL limestone dual alkali technology for application in flue gas desulfurization (FGD) of high-sulfur-coal-fired boilers.

Under this program, the 20 MW lime dual alkali system at Gulf Power Company's (GPC) Scholz Steam Plant will be modified and converted for the use of limestone as the regenerating material. After modification and conversion to a limestone-based process, the system will be tested to evaluate its performance with respect to capabilities for removal of SO₂, raw materials and

energy requirements, quality of the waste material generated, and reliability and ease of operation of the system. Furthermore, capital and operating costs will be estimated for full-scale utility applications of the limestone dual alkali FGD technology. The project is being carried under the sponsorship of EPA, CEA, GPC, and Southern Company; the principal cost of the project is being shared by EPA and CEA. CEA (and later TESI)⁵ as the prime contractor to EPA has the overall responsibility for all aspects of the project. ADL, as a subcontractor to CEA, will provide process engineering support to CEA in designing the modifications to the system, developing the test plan, and assisting CEA in the startup of the process and in coordinating and supervising the test program.

Parallel to this EPA program, the Electric Power Research Institute (EPRI) is sponsoring a program to study and evaluate the landfill disposal of the waste cake generated by the limestone dual alkali system. Prior to its disposal, the FGD waste cake will be treated with fly ash and lime. The EPRI test program will consist of: monitoring the waste disposal system to characterize its operation, analyzing the physical and chemical properties of the treated waste during and after disposal operations, and establishing the potential for revegetation of the waste disposal area. The natural interdependency between the FGD and the waste disposal system calls for close coordination between the EPA and EPRI programs.

Schedule

The work is divided into three phases:

- Phase 1 - program planning.
- Phase 2 - procurement and construction.
- Phase 3 - testing.

This report covers Phase 1, during which CEA and ADL were to:

- Design the necessary modifications to the existing prototype facilities.

⁵On October 20, 1980, Combustion Equipment Associates, Inc. filed a petition for financial reorganization pursuant to Chapter 11 of the U.S. Bankruptcy Code. Thyssen-CEA Environmental Systems, Inc. (TESI) bought the CEA Air Pollution Division and began administering this EPA contract in early December 1980. TESI assumed financial responsibilities retroactive to October 21, 1980. Although the EPA contract, subject of this project, was formally assigned to TESI in March 1981, CEA is mentioned in this report in connection with work or contributions actually made by CEA.

- Develop an overall program schedule.
- Develop a detailed test plan.
- Estimate capital and operating costs for a full-scale limestone dual alkali system.

Work on Phases 1 and 2 commenced immediately after EPA awarded the contract to CEA in October 1978. Phase 1 covered a period of 17 months, ending in February 1980. Phase 2, modification of the system, was completed in March 1980. The system was started up in August 1980. In the interim, the system was operated mechanically in order to prevent mechanical deterioration of the equipment. The delay was caused by equipment delivery problems encountered in the installation of the EPRI waste disposal system. As previously indicated, EPRI is sponsoring a parallel test program to study the landfill disposal of waste generated by the limestone dual alkali process.

The EPA test program of the FGD system was originally scheduled to last 6 months, exclusive of start-up procedures, and was to be conducted in two periods. During the first period, approximately 2 months, a baseline for the operations of the system was to be established. The second period, approximately 4 months, was to consist of variational testing of the system. However, because of budgetary constraints, due to actual costs exceeding those budgeted, delays due to the need to coordinate with the EPRI program, and additional delays caused by CEA's declaration of bankruptcy, the testing period has been reduced from 6 to 2 months. These 2 months will be devoted, primarily, to baseline testing, which began in February 1981. The test program presented here represents the original test program issued in draft form in March 1980.

The Limestone Prototype System at Scholz

Limestone Dual Alkali Technology

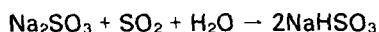
The CEA/ADL limestone dual alkali technology incorporates SO₂ absorption, absorbent regeneration, waste solids dewatering, and raw materials storage and feed preparation.

SO₂ is adsorbed by contacting the flue gas with a sodium sulfite/bisulfite solution. The sodium sulfite reacts with the SO₂, producing additional sodium bisulfite:

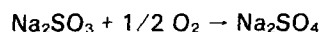
²LaMantia, C.R., et al., "Final Report Dual Alkali Test and Evaluation Program," Volumes I-III, EPA-600/7-77-050a,b,c (NTIS PB 269904, 272770, 272109), 5/77

³Ibid

⁴Oberholtzer, J.E., et al., "Laboratory Study of Limestone Regeneration in Dual Alkali Systems," EPA-600/7-77-074 (NTIS PB 272111), 7/77.

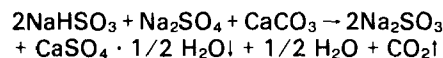
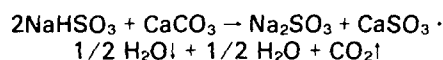


During absorption, and to a lesser extent throughout the remainder of the system, some sulfite is oxidized to sulfate:



The level of oxidation experienced during absorption is generally a function of the scrubber configuration, oxygen content of the flue gas, and scrubber operating temperature. At excess oxygen concentrations normally encountered in utility power plant operations, the level of oxidation is expected to be on the order of 5 to 10% of the SO₂ removed (for medium and high sulfur coal).

The spent scrubbing solution is reacted with limestone to regenerate the absorbent. The reaction precipitates mixed calcium sulfite and sulfate solids, resulting in a slurry containing up to 5 wt. % insoluble solids. The regeneration process basically involves:



Following regeneration, the insoluble calcium-sulfur salts are separated from the regenerated liquor. After settling in a thickener, the insoluble salts are vacuum-filtered prior to being discharged as a moist cake. The clarified liquor from the thickener is returned to the scrubber, closing the process liquor loop.

The filter cake is washed to recover most of the soluble sodium salts in the mother liquor. A portion of the sodium salts remains occluded in the cake and is lost. Thus, some Na₂CO₃ is added to the system to make up for these sodium losses. Typically, the Na₂CO₃ makeup amounts to less than 5 mole % of the SO₂ removed.

The amount of limestone added to the system for absorbent regeneration is reduced slightly due to the soda ash makeup. Under normal conditions, the limestone feed stoichiometry will be slightly less than 1.0 mole of CaCO₃ per mole of SO₂ removed.

Description of the Limestone Dual Alkali System at Scholz

The dual alkali system will take flue gas from the Scholz Steam Plant Unit No. 1, a 40 MW nominal capacity (47 MW peak capacity) Babcock and Wilcox pulverized-coal-fired power boiler. The

flue gas from the boiler passes through a high efficiency, sectionalized electrostatic precipitator (ESP) designed to remove up to 99.5% of the particulate matter. Part of the gas discharged from the ESP is directed to the limestone dual alkali system, which is designed to handle flue gas flow rate equivalent to a 20 MW boiler load. The remaining gas is sent directly to the stack.

The limestone dual alkali system at Scholz is a modification of a lime dual alkali system previously installed and operated at the plant for a test program sponsored by Southern Company and jointly funded with EPA and EPRI. The modified dual alkali system consists of four sections as discussed previously: absorption, regeneration, waste solids dewatering, and raw materials storage and feed preparation. A process flow diagram for the limestone dual alkali system for Scholz is given in Figure 1.

The absorption system consists of a venturi scrubber followed by an absorption tower. The venturi can be used for SO₂ absorption and/or particulate removal; the absorption tower can be operated as a tray tower, spray tower, or a deentrainment separator. For operation in the limestone dual alkali mode, the tower will be operated with two trays. The bottom tray is equipped with a spray underneath to wet the bottom side of the tray.

An SO₂ injection system is provided to increase the SO₂ concentration in the flue gas entering the dual alkali system by 500 ppm or more. The SO₂ is injected upstream of the booster fan before the gas enters the venturi scrubber.

A booster fan directs the SO₂-rich flue gas exiting the ESP into the scrubber, where it contacts the scrubbing liquor. The liquor is collected at the bottom of the scrubber in the internal recycle tank. After being quenched and water-saturated, the partially desulfurized gas enters the bottom of the absorption tower. Gas passes upward through the trays and through a deentrainment separator. The deentrainment separator is operated dry, without mist eliminator wash water. Scrubber flue gas leaving the tower is finally reheated by the injection of the hot gas from an oil-fired reheater before being discharged through the stack on top of the absorber.

The scrubbing solution, fed to the top tray of the absorber, flows countercurrent to the gas through the tray system. This counterflow permits high SO₂ transfer from gas to liquid phase. The

liquor is collected at the bottom of the absorber in the internal recycle tank, which serves as the supply for the liquor sprays beneath the bottom tray.

A bleed from the absorber liquor recycle line is sent forward to the venturi recirculation loop where it is used to quench the gas and provide additional SO₂ removal. A bleed stream of spent liquor is drawn from the venturi recycle line and is fed to the absorbent regeneration system.

Slurry from the reactor system is pumped to the center well of the slurry thickener. Clear liquor overflow from the thickener is collected in a thickener hold tank which acts as surge capacity for the absorbent liquor feed to the scrubber system. Process makeup water is added to this tank to make up for the total water lost due to evaporation and moisture in the cake.

The regeneration system consists of five separate reactor tanks in series, with a total design holdup time of approximately 100 minutes. The bleed from the scrubber system can be fed either to the first or second stage reactor. Similarly, the modified limestone silo feed chute can feed dry limestone to either tank. Thus, the modified reactor system can be operated as either four or five reactor tanks in series with dry limestone feed, or four reactor tanks in series with slurried limestone feed prepared in the first stage reactor. The first four tanks operate on overflow; the last tank is on level control so that the effluent can be pumped to the thickener.

The thickened slurry is fed to a rotary drum vacuum filter. A series of wash sections are used to wash the filter cake to recover valuable process liquor. Solids from the filter cake are discharged to a weigh belt conveyor for transport to a waste processing system. The mixed filtrate and wash liquor from the filter are returned to the thickener.

Two raw materials are required for operation of the system—limestone for absorbent regeneration and soda ash to make up for losses of sodium salts in the waste filter cake.

Limestone will be received, stored, and, under normal conditions, fed to the system in a dry form: it can be fed to either the first or second reactor tank. For operation with limestone slurry, limestone would be fed to the first reactor tank along with water, and the scrubber bleed diverted to the second reactor tank.

Dense soda ash will be used to make up for sodium salt losses. Provisions have been made to prepare soda ash solutions using either river water or clarified liquor from the thickener hold tank. The soda ash solution can be fed to the thickener, thickener hold tank, absorber recycle, or venturi scrubber recycle. Normally, it will be fed to the thickener hold tank.

The waste processing system will be installed and operated as part of a separate test program funded by EPRI. It is briefly discussed here to indicate the overall plant operation.

The moist waste cake discharged from the vacuum filter will be mixed in a pug mill with fly ash and lime. The amount of ash added will range from 0.5 to 1.5 parts of ash per part of dry solids in the cake. Lime will be added at a rate of 2 to 5 wt. % of the dry solids contained in the mix of cake and fly ash.

The mix discharged by the pug mill will be loaded onto trucks and transported to a sectioned landfill area. Three test areas will be used for disposing of the processed limestone dual alkali waste. Each test area will be filled with a different waste material mix involving different combinations of filter cake, fly ash, and lime.

System Design

The modified limestone dual alkali process has been designed to operate as a closed-loop system in accordance with the following criteria:

- Operation in a "concentrated" alkali mode (>1.0 M active alkali).
- Operation with minimum sodium consumption.
- Operation with minimum calcium consumption (95% limestone utilization).
- Removal of more than 95% of the incoming SO₂.
- Production of a solid waste filter cake containing a minimum of 55% insoluble solids (calcium sulfite/sulfate).
- Reliable system operation with normal variation of:
 - Flue gas composition from the power plant.
 - Boiler load.
 - ESP operation.
 - Limestone quality.

During the test program, the boilers at Scholz will be fired with coal containing 2.9 to 3.4 wt. % sulfur. The corresponding SO₂ levels in the boiler flue gas have been estimated to be on the order of

1900 to 2300 ppm. During the test program, it may be desirable to increase these levels by injecting SO₂ into the flue gas stream before it enters the scrubber. The modification of the dual alkali system has been designed to accommodate operation under normal conditions without SO₂ injection, as well as operation with SO₂ injection. The design bases for each operating mode are given in Table 1.

Normal Operation

Under normal operation without additional SO₂ injection, the flue gas taken by the dual alkali system (40,000 scfm)* would be equivalent to a load of approximately 18 MW, with an SO₂ level of 2200 ppm (dry basis). Removal of 95% of the SO₂ present in the inlet gas would generate about 38 tons/day of moist waste cake. The solids content of this filter cake is assumed to be about 55%. Limestone would be added to the system at a rate of 23 lb/min (0.986 moles of CaCO₃/mole of ΔSO₂) and soda ash at a rate of less than 1 lb/min (0.035 moles Na₂CO₃/mole of ΔSO₂).

*Metric equivalents are provided later in this Summary

Internally, the regenerated solution would be fed to the absorber/scrubber module at a total rate of about 167 gpm (corresponding to an L/G = 3.1). The active sodium concentration in this solution is 1.7 M, with a [HSO₃⁻] to [SO₃⁼] ratio of 1.34. The spent solution with a [HSO₃⁻] to [SO₃⁼] ratio of 3.0 would be bleached to the regeneration reactors at about 145 gpm. The remaining 22 gpm would be evaporated in bringing the incoming hot flue gas to saturation.

The reactor effluent would be a slurry containing about 2 wt. % insoluble solids. The solids concentration would be increased to about 25 wt. % in the thickener and finally to a minimum of 55 wt. % in the filter cake.

Maximum Operation with SO₂ Injection

At maximum load and with additional SO₂ injection, the flue gas treated by the system would amount to 45,000 scfm, roughly equivalent to a 20 MW boiler load. The SO₂ loading would be increased by about 20% to 2650 ppm by the injection of SO₂. Removal of 95% of the incoming SO₂ would produce about 55 tons/day of moist cake (at 55 wt. % dry

Table 1. Design Conditions

	Normal Operation	SO ₂ Injection
Inlet Gas:		
Flow rate, scfm (dry)	40,000	45,000
SO ₂ , lb/min. (ppm dry)	14.9 (2200)	20.2 (2650)
C1 ⁻ , lb/min.	0.12	0.12
O ₂ , vol. %	5	5
Moisture, wt. %	6.0	6.0
Removal Efficiency:		
SO ₂ , %	95	95
C1 ⁻ , %	100	100
Absorber Feed Concentration:		
Na ⁺ associated with SO ₃ ⁼ , M	1.02	1.02
HSO ₃ ⁻ , M	0.68	0.68
Oxidation and Evaporation:		
Oxidation, mole % of ΔSO ₂	7	10
Evaporation in absorber, gpm	22	24.7
Soda Ash and Limestone Feed:		
Soda ash feed rate, mole Na ⁺ /mole ΔSO ₂	0.07	0.081
Limestone purity, wt. %	95	90
Limestone feed rate, mole available CaCO ₃ /mole ΔSO ₂	0.986	1.010
Waste Solids:		
Wash ratio, displacement washes	4	4
Insoluble Solids, wt. %	55	55

solids). Limestone would be added to the system at a rate of 34 lb/min (1.010 moles CaCO₃/mole of ΔSO₂), and soda ash at a rate of 1.3 lb/min (0.040 moles Na₂CO₃/mole ΔSO₂).

The regenerated scrubbing solution would be fed forward to the absorber/scrubber module at a rate of 205 gpm (equivalent to an L/G = 4.5). The liquor feed to the absorber has an active sodium concentration of 1.7 M and an [HSO₃⁻] to [SO₃⁻] ratio of 1.34. The spent solution, with an [HSO₃⁻] to [SO₃⁻] ratio of 3.2, would be bled to the regeneration reactors at a rate of 180 gpm. The difference in flows, about 25 gpm, represents the water evaporated to saturate the incoming flue gas.

The solids concentration in the resulting slurries are consistent with those generated in normal operation. The reactor effluent would contain 2.2 wt. % solids, the thickener underflow about 25%, and the filter cake a minimum of 55%.

Test Program

The start-up and break-in testing of the system will last approximately 2 months; immediately following, the system will undergo a 6-month period of testing to characterize its operations.

This test program is aimed at evaluating the following aspects of the limestone dual alkali system performance:

- SO₂ capabilities.
- Consumption of raw materials—soda ash, limestone, and water—not only as a measure of the efficiency of the system in utilizing these materials in the removal of SO₂ but also as a measure of the ability of the system to maintain a closed-loop operation.
- Consumption of energy—electrical power, and fuel for the gas reheater.
- Levels of sulfite oxidation experienced by the system as well as the ability of the system to tolerate such levels of oxidation.
- Waste cake properties—dewatering, handling, and washability.
- Particulate matter removal (during periods of planned ESP turndown) by the system and the effect of ash on process chemistry.
- Sulfate emissions in the processed flue gas.

The test program will be conducted in two phases. During Phase 1, a baseline for the operation of the system will be established. Phase 2 will consist of variational tests of the system.

Start-Up and Break-In Testing

During start-up and break-in testing, not only will the system be started up, but it will also undergo preliminary testing. Information from these tests will be used to optimize and finalize the control set points and to verify the suitability of the testing and analytical procedures. Furthermore, test results will be used to make any necessary adjustments to the system, to the system operations, and to the test plan.

The preliminary tests will include the determination of: (a) SO₂ removal efficiency at various gas loadings, inlet SO₂ concentrations, and scrubber operating pH's; (b) regeneration efficiency as a function of reactor configuration and type of limestone—if possible, the effect of limestone particle size will also be evaluated; and (c) waste solids properties and conditions for operation of the thickener, filter, and cake wash system. A list of the projected operating conditions during start-up and the test program is given in Table 2.

Phase 1 — Baseline Testing

In previous pilot plant and laboratory studies, the general effect of process parameters and operating conditions on

Table 2. Prototype Test Program Projected Operating Conditions

Period	Nominal Load (MW)	Nominal Inlet SO ₂ (ppm dry)	Limestone Type*	Reactor Configuration	Inlet O ₂ Vol. %	Particulate Loading	Comments
2 Months	10-20	1800-2800	A/B	Variable	4.5-6	None	Finalize control set points. Evaluate testing and analytical process. Perform preliminary evaluation of the system response to boiler load, SO ₂ load, reactor configuration, and type of limestone. Characterize filter performance. Check gas flow vs. fan amperage correlation.
Phase 1 2 Months	18-20	2000-2500	A or B	Standard	4.5-6	None	Baseline Testing
Phase 2 4 Months							
3 wks	10-20	2000-2500	A or B	Standard	4.5-6	None	Boiler (scrubber) load testing
1-2 wks	18	1500-2000	A or B	Standard	4.5-6	None	SO ₂ load testing
1-2 wks	18	2000-2800	A or B	Standard	4.5-6	None	SO ₂ load testing
2 wks	18	2000-2500	A or B	Variable	4.5-6	None	Reactor testing
2 wks	18	2000-2500	A or B	Standard	4.5-10	None	Scrubber oxidation
2-3 wks	18	2000-2500	A1 or B1	Standard	4.5-6	None	Limestone testing
2-3 wks	18	2000-2500	C	Standard	4.5-6	None	Limestone testing
2 wks	18	2000-2500	A, B, or C	Standard	4.5-6	Variable	Particulate load testing

*A, B, C—Different types of limestone. A1, B1—Different particle size.

the performance of limestone-based dual alkali systems was determined. The process parameters/operating conditions and the performance variables that they affect are listed in Table 3. The baseline testing for this program will focus on confirmation and additional characterization of these relationships. Most important, baseline testing will provide a quantitative evaluation of the overall system performance for an extended period for at least one (nominal) set of process parameters/operating conditions. Subsequent variations in selected process parameters/operating conditions and their effect on the performance of the system will be studied in Phase 2.

Phase 2 — Variational Testing

Phase 2 will last approximately 4 months. The results of this variational test will provide the technical information needed to determine the range of application and limitations of the limestone dual alkali technology. The

various conditions under which the system will be operated will involve, primarily, variations in those conditions which could be expected to be encountered in full-scale applications:

- Boiler load fluctuations.
- Inlet SO₂ concentrations.
- Type of limestone used and/or particle size.
- Reactor configuration and residence time.
- Boiler excess air (O₂ concentration in inlet flue gas).
- Particulate loading.

The operation of the system, while evaluating the effect of each of the above variables, will constitute a discrete testing period. Each testing period will last 2 or 3 weeks unless the operating conditions or other situations dictate a more reasonable or convenient period. A summary of the various projected operating conditions is given in Table 2.

Table 3. Process Parameters and Other Conditions Which Affect the Performance of the Limestone-Based Dual Alkali System

Performance Variable	Parameters/Conditions
SO ₂ Removal Efficiency	Inlet SO ₂ concentration/gas flow Scrubber configuration (venturi + absorber, venturi alone) Scrubbing liquor pH (inlet and outlet) Venturi pressure drop Active sodium concentration
Limestone Consumption	Inlet SO ₂ and O ₂ concentration/gas flow Type of limestone and particle size Reactor configuration Reactor holdup time
Soda Ash Consumption	Inlet SO ₂ and O ₂ concentration/gas flow Liquor entrainment in scrubber section Cake wash efficiency/wash ratio
Energy Consumption	Gas flow Inlet SO ₂ concentration
Oxidation	Inlet O ₂ concentration Scrubber configuration Scrubber temperature
Cake Properties	Type of limestone Reactor configuration Reactor holdup time Reactor pH Filter operation
Particulate Removal	Inlet particulate concentration/gas flow Scrubber configuration
Process Operability	Operational upsets in system conditions (equipment failure, operator error, etc.) Scaling, pluggage, spills

Economic Considerations

Generalized Cost Estimates for A New 500 MW System

In general, a dual alkali flue gas desulfurization system (FGD) consists of several subsystems for the performance of specialized functions: absorption of SO₂ from the flue gas, regeneration of the spent scrubbing solution and precipitation of the waste solids, separation of the regenerated solution from the solid waste generated, storage and preparation of raw materials, disposal of the waste, and provision of utilities. Basically, the system under consideration is assumed to be designed for 95% SO₂ removal efficiency when burning coal containing 3.5% sulfur. The dual alkali system is assumed to be installed in a new 500 MW boiler located in the Midwest. The base year for cost estimates is mid-1979.

Although the dual alkali process is capable of removing particulate matter, this capability is not incorporated in the system under consideration. Thus, the absorbers are assumed to take flue gas, through booster fans, from high efficiency ESPs. The booster fans for the dual alkali system also serve as induced draft fans for the boiler. The system is modular, with four-absorber/two reactor trains. Each absorber is sized to handle 135 MW. Consequently, there is a 10% spare capacity at full load; the system can treat at least 80% of the design flue gas load with one absorber down. Similarly the reactor system can handle a full system load with one reactor train down for short periods. The vacuum filters are operated and controlled independently and the number of filters in operation depends on the system load. Three filters are included—two operating and one full spare filter when operating at design conditions.

Cost of Modifying the Scholz Prototype System

The modification and conversion of the 20 MW lime-based dual alkali system for operation with limestone is being performed under Phases 1 and 2 of the project. The cost of modifying the system is being shared by EPA and CEA. The overall projected cost for the modification of the system was originally estimated at \$613,500. The fraction of the total cost to be reimbursed by EPA would amount to \$366,300; CEA's contribution would be \$247,200. (The actual CEA contribution amounted to over \$400,000.)

The estimated total capital investment for a generalized 500 MW limestone dual alkali system is \$47.4 million (see Table 4), which is equivalent to \$94.8/kW. This cost does not include waste cake processing or disposal, which are considered operating costs.

The process equipment and other material costs amount to \$16 million. The cost of erecting the system is estimated at 50% of the process equipment and additional material costs. The service, utilities, and miscellaneous costs are taken as 6% of all other direct costs. The indirect costs are estimated in direct proportion to the total direct costs: engineering at 9% construction field expense at 11%; contractor's fee at 5%; and contingency at 20%.

The estimated annual operating costs of a 500 MW system are given in Table 5. Capital charges, including interest, depreciation, return on investment, taxes, and insurance are taken at 14.6% of the total fixed plant investment.

The annual operating cost amounts to \$15.7 million, equivalent to an annualized cost of 4.5 mills/kWh or \$191/ton SO₂ removed.

Table 5. Estimated Annual Operating Costs for a 500 MW Limestone Dual Alkali System (1979 Dollars)

<u>Direct Costs</u>	<u>(000's)</u>
Raw Materials	1,930
Utilities	2,072
Labor and Maintenance	1,521
Waste Disposal	2,780
	<u>8,303</u>
<u>Indirect Costs</u>	
Capital Charges	6,607
Overhead	792
	<u>7,399</u>
Total Annual Operating Cost	15,702
Mills/kWh	4.5
\$/ton SO ₂ Removed	191

Table 4. Estimated Capital Investment for a 500 MW Limestone Dual Alkali System (1979 Dollars)

	<u>(000's)</u>
● Direct Costs	
Process Equipment and Materials	16,090
Erection Costs	8,050
Services, Utilities, and Miscellaneous	1,450
	<u>25,590</u>
● Indirect Costs	11,510
● Allowance for Start-up and Interest During Construction	8,150
	<u>45,250</u>
TOTAL DEPRECIABLE	
● Spare Parts, Land, Working Capital	2,140
TOTAL INVESTMENT	<u>47,390</u>

Applicable Conversion Factors English to Metric Units

<u>British</u>	<u>Metric</u>
1 ft ³	0.0283 meters ²
1 lb (avoir.)	0.4536 kilogram
1 ton (short)	0.9072 metric tons
1 gal.	3.7853 liters

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The complete report, entitled "Evaluation of the Limestone Dual Alkali Prototype System at Plant Scholz: System Design and Program Plan," (Order No. PB 81-247 421; Cost: \$8.00, subject to change) will be available only from: National Technical Information Service 5285 Port Royal Road Springfield, VA 22161 Telephone: 703-487-4650

The EPA Project Officer can be contacted at: Industrial Environmental Research Laboratory U.S. Environmental Protection Agency Research Triangle Park, NC 27711

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