United States
Environmental Protection
Agency

Industrial Environmental
Research Laboratory
Research Triangle Park NC 27711

Research and Development

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Project Summary

Proceedings: Eighth Symposium on Flue Gas Desulfurization, New Orleans, LA, November 1983

Franklin A. Ayer

The symposium provided a forum for the exchange of technical developments and regulatory information on flue gas desulfurization (FGD) systems and processes applicable to utility and industrial boilers. The keynote address described the National Acid Precipitation Assessment Program. Other opening-session presentations were on the status of air quality legislation/regulations, the status of solid waste regulations, and trends in commercial application of FGD technology. Subsequent sessions dealt with FGD economics, materials of construction, dry furnace absorbent injection, dual alkali FGD, flue gas treatment (combined SO_x/NO_x removal), FGD chemistry, the architect-engineer's role in FGD applications (panel discussion), limestone/organic acid, waste disposal/utilization, and dry FGD systems. Participants represented electric utilities, equipment and process suppliers, state environmental agencies, coal and petroleum suppliers, EPA and other Federal agencies, and research organizations.

Julian W. Jones, Industrial Environmental Research Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, NC, and Thomas M. Morasky, Coal Combustion Systems Division, Electric Power Research Institute, Palo Alto, CA, were Symposium Chairmen.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC, to announce symposium presentations that are fully documented in a separate document of the same title (see ordering information at back).

Session 1. Opening Session

Julian W. Jones, Chairman
Industrial Environmental
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U.S. Environmental Protection
Agency
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Welcome and Introduction

Michael A. Maxwell
Industrial Environmental
Research Laboratory
U.S. Environmental Protection
Agency
Research Triangle Park, NC

Stuart M. Dalton
Coal Combustion Systems
Division
Electric Power Research Institute
Palo Alto, CA

Introduction of Keynote Speaker

Frank T. Princiotta
Industrial Environmental Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC

Keynote Address: National Acid Precipitation Assessment Program: Status and Outlook

J. Christopher Bernabo
National Acid Precipitation Assessment Program
722 Jackson Place, NW
Washington, DC

The National Acid Precipitation Assessment Program is designed to successively improve our understanding of the causes and effects of, and possible solutions to, the acid rain problem. The Program includes research, monitoring, and assessment activities that emphasize the timely development of a progressively firmer scientific basis for decision making by the Congress, regulatory agencies, private sector managers, environmental groups, and the public. The National Program consists of over 200 projects and hundreds of scientists in government, academia, and the private sector.

The Status of the Clean Air Act Reauthorization

Sheldon Meyers
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency
Washington, DC

The remarks opened with the statement, "The Clean Air Act Reauthorization is as yet unenacted." Light was shed on why the Congress had not acted on the reauthorization so far, and some reasons were suggested for the assignment's being so difficult. Some of the areas of the Act were identified as causing EPA problems, and some elements were listed which should be included in any discussion of a reauthorization. In closing it was pointed out that any discussion of problems should not obscure the fact that, despite its complexity, the Clean Air Act has worked: the public health is better served now than it was before the Act became law in 1970.

The Resource Conservation and Recovery Act: Current and Projected Regulations

Stephen A. Lingle
Office of Solid Waste
U.S. Environmental Protection Agency
Washington, DC

This was a verbal presentation; no abstract or paper was submitted.

Trends in Commercial Application of FGD Technology

Bernard A. Laseke, Jr.,* Michael T. Melia
PEDCo Environmental, Inc.
Cincinnati, OH

Norman Kaplan
Industrial Environmental Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC

PEDCo Environmental, Inc. has been monitoring and reporting on the status of utility FGD technology since 1974. From 1974 to 1982, this effort was supported by the U.S. EPA under the direction of the Industrial Environmental Research Laboratory-RTP. Starting this year, this effort is now jointly sponsored by EPA and the Electric Power Research Institute (EPRI). Project direction from EPRI is provided by the Coal Combustion Systems Division.

Information for this program is obtained by visits to plants having operational FGD systems and through regular contacts with the owner/operator utilities who are presently operating or planning FGD installations. Supplemental information is also solicited from FGD system and equipment suppliers, design/engineering firms, research organizations, and regulatory agencies.

The information collected in this program is stored in the FGD Information System (FGDIS), which is a collection of computerized data base files containing descriptive, design, performance, and cost data for all the FGD systems identified in FGDIS. FGDIS has the dual capability of generating periodic survey reports (now available through EPRI) as well as permitting immediate access to the data files via remote terminal. This latter feature allows private and government users to access FGDIS directly at any time, to conduct custom-designed data analyses, examine detailed data that may be too specific to be conveniently included in the survey report, or review information that has been loaded into the system but not yet published.

This paper summarizes the status of FGD technology as of June 1983 and highlights the status of the electric utility power industry and projected growth of coal-fired power generation, the present status and future trends in the growth of FGD, developments in system design and application, current operating experience and costs.

As of June 1983, 114 FGD systems in service represented 45,750 MW (gross of equivalent power generating capacity). Another 100 systems representing 59,324 MW were under construction or planned. Approximately 16 percent of the present coal-fired generating capacity is controlled by FGD. This figure is projected to rise to 34 percent during the next 10 years.

Session 2. Economics

Thomas M. Morasky, Chairman
Coal Combustion Systems Division
Electric Power Research Institute
Palo Alto, CA

Computer Economics of Physical Coal Cleaning and Flue Gas Desulfurization

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Tennessee Valley Authority
Muscle Shoals, Al

James D. Kilgroe
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U.S. Environmental Protection Agency
Research Triangle Park, NC

A computer model that simulates the performance and calculates the economics of a coal-cleaning process, a FGD process, and a combination of the two processes for electric utility boilers has been developed by the Tennessee Valley Authority (TVA) under sponsorship of the U.S. Environmental Protection Agency (EPA). The model also determines other economic benefits and penalties

*denotes speaker

overall power plant operations that are associated with the use of cleaned coal. The model is described and its use is illustrated for selected design and economic premises. The present status of the model is assessed and possible future studies are discussed. The illustrative examples show that in some instances a combination of coal cleaning and FGD for SO_2 emission control can be more economical than FGD alone.

For the cases studied, it was found that the use of coal cleaning in combination with FGD can have a varied effect on the levelized annual cost of power production. This effect, which is dependent on the coal and the specific operating conditions, ranges from 0.5% increase to a 22.6% decrease in those costs.

The methods used to determine many of the other economic benefits and penalties of coal cleaning are necessarily general in nature because detailed data relating specific coal properties to boiler performance and operating costs are scarce. Thus, development and incorporation of more detailed and quantitative data in the model would greatly increase the usefulness of the model in assessing overall economic effects of coal cleaning.

Economic Evaluation of FGD Systems

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Stearns-Roger Engineering Corporation
Denver, CO

Thomas M. Morasky
Electric Power Research Institute
Palo Alto, CA

This paper estimates the cost of 17 throwaway and regenerable FGD systems based on December 1982 cost and technology. These systems were also evaluated for operability, technical merit, and commercial availability. The FGD systems were evaluated for high sulfur coal applications at a hypothetical 1000 MW (two 500 MW units) power plant in Kenosha, WI. This arbitrary reference plant was selected to ensure consistent comparisons, and to increase the relative accuracy of the costs presented.

A flow sheet, material balance, equipment list, system description, and utility consumption list form the basis of each FGD evaluation. Cost information was obtained from process vendors, Stearns-Roger information, and published reports. Capital costs were estimated by factoring costs of process equipment (i.e., an EPRI Class II estimate). Operating costs were estimated from reagent and utility consumption. The levelized capital and operating costs were developed using EPRI's standard economic premises. The costs reported in this study are estimated within an absolute accuracy of ±30%. However, since methodology, scope and unit costs are consistent, the relative accuracy between processes is about ±15%.

Estimating Procedure for Retrofit FGD Costs

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Stearns-Roger Engineering Corporation
Denver, CO

Thomas M. Morasky
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Palo Alto, CA

A procedure has been developed for utility engineers to estimate site-specific FGD retrofit costs on existing power plants. This procedure has been developed for six FGD processes: limestone, lime dual alkali, lime spray drying, limestone forced oxidation, Wellman-Lord, and Chiyoda 121. Economic results from the calculation procedure include capital cost, operating and maintenance (O&M) costs, levelized cost, and cost per ton of SO_2 removed.

Comparative Costs of SO_2 Removal Technologies

John O. Milliken
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Research Triangle Park, NC

The costs of retrofitting four types of in-plant SO_2 control technologies are compared for a 500 MW pulverized-coal-fired utility boiler. Technologies examined are at various stages of commercialization and market penetration, and include: (1) fully commercial - limestone FGD, (2) early commercial - adipic acid enhanced FGD, (3) early commercial - lime spray drying, and (4) developmental - limestone injection multistage burners. Cost comparisons are made by process subarea, by operating cost categories, by capital to operating cost ratio, and by overall sulfur removal effectiveness.

Session 3. Materials of Construction

Charles E. Dene, Chairman
Electric Power Research Institute
Palo Alto, CA

EPRI Research on Corrosion and Degradation of Materials for FGD Systems

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An EPRI survey of materials problems in full-scale lime/limestone wet scrubbers in the U.S. revealed that the most frequent and most critical failures occurred in the outlet ducts and the stack, but that a significant number of failures also occurred in the prescrubbers, absorbers, reheaters, dampers, pumps, piping, and valves. The root cause of most of these failures was corrosion or degradation of the materials of construction. Over the last few years, EPRI has initiated many projects aimed at understanding and eliminating corrosion induced failures in scrubbers. Primary emphasis has been on metallic materials, but an increasing amount of effort is being directed toward coatings, nonmetallic materials of construction, and corrosion control techniques. The range of EPRI's research on corrosion and degradation of materials for FGD systems is described in this paper.

Simultaneous Design, Planning, and Materials of Construction Selection for FGD Systems

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R.F. Miller, W.L. Silence
Cabot Corporation
Kokomo, IN

Processes and systems designed for emissions control from fossil fuel fired boilers for electric generating stations are many and varied, as are the choices of materials of construction. Good performance, efficiency of operation, and maintenance of FGD systems can be enhanced by the simultaneous selection of the process, design, and materials of construction of the system. The wet lime and limestone systems are the dominant processes for removing SO_2 from coal-

fired boiler flue gases and will remain so for the next several years, based on EPA surveys. The choices of material include carbon steel, coatings and linings that can be applied over carbon steel, a wide range of alloys that can be used in place of lined carbon steel, and various nonmetallic materials. This paper discusses the corrosion and abrasion resistance of these materials and shows how each may be most advantageously used in the design of an FGD system.

Acid Deposition in FGD Ductwork

Daniel A. Froelich,* Carl V. Weilert, Paul N. Dyer
Burns & McDonnell Engineering Co., Inc.
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In the mid 1970's first generation wet lime/limestone FGD systems were included in the design of many new coal-fired power plants across the U.S. in response to federal, state, and local SO_2 emission control regulations. At the time, the primary concern in the electric power industry was whether the new systems would work at all. In retrospect, the overall performance of these FGD systems has been good. Based on data from the best of these first generation systems, Congress and EPA have effectively mandated the use of FGD systems on all future coal-fired power plants. Continuous SO_2 reduction is the law of the land. Reliability is the new watchword for the utility industry.

For owners and operators of existing FGD systems and for designers and suppliers of new systems, problems with ductwork corrosion represent a major obstacle to the goal of 100% reliability. Corrosive failure of materials of construction in FGD system ductwork is a leading contributor to low reliability in existing FGD systems.

The corrosion experiences at the R.D. Morrow Station are the prime example of this industry-wide problem. The corrosion rates of the alloys and coating materials used at R.D. Morrow have been much higher than anticipated in the design. Some alloy materials chosen for repair of the initial corrosion (on the basis of the results of laboratory corrosion tests in simulated FGD environments) have also experienced rapid corrosion. In most cases, even coupon spool tests conducted at R.D. Morrow have been unable to predict the severe corrosion that has occurred when the test material was installed full-scale in the ductwork.

Based on this experience it was concluded that: (1) the corrosive environment in the ductwork is more aggressive than that to which the spool coupons are exposed; and (2) the corrosive environment in the ductwork is more aggressive than that which had previously been simulated in the laboratory. It was clear that more and better data were needed to define the conditions that existed in the ductwork.

There was not sufficient information available regarding the chemical composition of the material that collects on the FGD ductwork surface. Collection, preservation, and analysis of duct surface deposits obtained during periodic inspections at the time of system outages had proven to be difficult. Data from this type of sample were inconsistent and misleading. It became clear that there was a critical need for a method by which ductwork deposition samples could be obtained while the FGD system was operating.

Burns & McDonnell has identified and developed two innovative methods for characterizing the corrosive environment in FGD system ductwork. A predictive technique based on vapor/liquid equilibrium data for acid solutions is used to estimate acid concentrations in ductwork condensate. An extractive test method utilizing a controlled-temperature condenser is used for on-line collection of duct deposits from FGD system ductwork. Working under contract with EPRI (Research Project 1871-4), Burns & McDonnell conducted a test program at R.D. Morrow to evaluate the two methods. This paper describes the two methods and their applicability to the solution of corrosion problems in FGD system ductwork.

In Situ Evaluation of High Performance Alloys in Power Plant Flue Gas Desulfurization Scrubbers

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Preliminary data from ongoing in situ FGD scrubber exposure tests, involving specific high performance stainless steels, and nickel-base and titanium alloys are presented and discussed. Spool rack exposures of 4-9 months involving candidate alloys—Titanium Grades 2 and 12, 904L stainless steel, and nickel-base alloys 625 and C-276—were conducted in the inlet quench and outlet duct zones of several operating power plant FGD scrubber systems. In general, the performance of titanium alloys was equal or superior to that of the steel and nickel alloys, particularly in outlet ducts. The 904L alloy consistently exhibited poor resistance to localized attack, while 625 and C-276 alloy performance was varied. These findings are discussed relative to specific environmental considerations and parallel laboratory and field studies reported in the literature.

Session 4. Dry Furnace Absorbent Injection

Randall E. Rush, Chairman
Southern Company Services, Inc.
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Results from EPA's Development of Limestone Injection into a Low NO_x Furnace

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This paper updates the status of EPA Limestone Injection into a Multistage Burner (LIMB) development, from the time of the paper presented at the previous FGD meeting (May 1982) Florida. The LIMB program is an EP effort to develop effective and inexpensive emission control technology for coal-fired boilers that will reduce SO_x and NO LIMB technology represents a low cost alternative to currently available S control approaches; e.g., FGD, co cleaning, and coal switching. LIM technology is attractive if coal combustion must be controlled to minimize emissio of acid rain precursors because LIME easily retrofitted to large and small co fired boilers, is lower in cost than a available alternative, and can contr both SO_x and NO_x—the two major a rain precursors. The technical goals the program are: (1) for retrofits, achi 50-60% reduction of both SO_x and N

from uncontrolled levels, (2) for new systems, achieve 70-80% NO_x and 70-90% SO_x reduction from uncontrolled levels; and (3) for both retrofits and new systems, achieve the above goals at costs at least $100/kW less than the major technology alternative, FGD.

Review of EPRI Research on Furnace Sorbent Injection SO_2 Control

Michael W. McElroy
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Direct furnace injection of alkaline material is currently under development as a potential low cost SO_2 control approach for new and existing coal-fired boilers. Major developmental efforts now focus on (1) understanding process fundamentals, (2) process optimization for both new and retrofit applications, and (3) the resolution of power plant impact issues and costs. Current and planned EPRI research projects in these areas are reviewed.

Direct Desulfurization Through Additive Injection in the Vicinity of the Flame

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L & C Steinmuller GmbH
West Germany

After a short description of the staged mixing burner, the report deals with the process of direct desulfurization in the furnace of a steam generator by injection of additives around the flame. Further, the results from tests with a pilot burner and intermediate results from tests in a full-size boiler are given. Finally, the possible applications and economic aspects of direct desulfurization are discussed.

Session 5. Dual Alkali

Norman Kaplan, Chairman
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Utility Double Alkali Operating Experience

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Evansville, IN

Richard J. Grant
Central Illinois Public Service Co.
Springfield, IL

L. Karl Legatski*
FMC Corporation
Schaumburg, IL

James H. Wilhelm
Codan Associates
Sandy, UT

Beth A. Wrobel
Northern Indiana Public Service Co.
Wheatfield, IN

On April 6, 1983, Northern Indiana Public Service Company started up its Schahfer Unit 17, the first high-sulfur coal boiler required to be in compliance with the 90% SO_2 removal provision of the 1979 revisions to the New Source Performance Standards. This is the fourth utility double alkali FGD system to come on line in the last 4 years. All have consistently met their SO_2 performance criteria. This paper summarizes cost and availability data for three of these systems. While capital costs vary with site-specific design criteria, operating costs exclusive of capital charges are typically 4 mills/kWh. Availabilities for the double alkali systems as a group are consistently higher than for direct limestone. Unique features of the NIPSCO design and operation are discussed, as well as some important recent improvements implemented at the Southern Indiana Gas and Electric Co. and Central Illinois Public Service Co. installations.

Pilot Evaluation of Limestone Regenerated Dual Alkali Process

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Research Triangle Park, NC

Norman Kaplan
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Research Triangle Park, NC

This paper reports on the results of tests (between February 1982 and March 1983) on a pilot-scale limestone dual alkali FGD system established by EPA/IERL-RTP. This recent pilot plant testing showed that significant improvement in soda ash consumption and filter cake quality can be achieved with proper system control. The causes of system upset by nonsettleable solids were also identified and demonstrated in tests. The objectives of this paper were to give highlights of recent pilot plant testing and to discuss, generally, limestone dual alkali processes.

Session 6. Flue Gas Treatment (Combined SO_x/NO_x)

J. David Mobley, Chairman
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Status of the DOE Flue Gas Cleanup Program

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The U.S. Department of Energy directs a substantial R&D effort to develop advanced environmental control technology for coal-fired stationary sources. The Flue Gas Cleanup Program is aimed primarily at post-combustion cleanup of SO_2 and NO_x; a small part of the program is directed at characterization and improved control of respirable particulates. The programmatic goal established at Fossil Energy Headquarters is the development of technology options for 90% removal of both SO_2 and NO_x, while controlling particulates to the New Source Performance Standards (NSPS). Emphasis is placed on developing process concepts that offer potential cost reductions of 20% to 25%, compared to commercially available technology (Selective Catalytic Reduction of NO_x followed by a wet limestone scrubber and the necessary baghouse or ESP). The commercialization or application period is expected to be in the late 1980s or early 1990s.

The Flue Gas Cleanup Program is implemented by the Pittsburgh Energy Technology Center (PETC). PETC is also responsible for implementation of other related research programs, including coal preparation and direct coal combustion,

and has been involved in flue gas cleanup since the late 1950s.

The current DOE program is being conducted by a cross-section of industrial organizations, not-for-profit research laboratories of universities, national laboratories, and in-house research. Many of the projects are new, and the research is just beginning. A chronology and overview of the program, together with brief descriptions of the status of individual projects, are given.

Status of SO_2 and NO_x Removal in Japan

Jumpei Ando
Chuo University
Tokyo, Japan

FGD capacity in Japan has increased rapidly from 1970, reaching 10^8 Nm^3/h (33,000 MW equivalent) in 1976, and increasing slowly since. For NO_x removal, selective catalytic reduction (SCR) of NO_x has been used in addition to combustion modification. The SCR capacity increased from 10^6 Nm^3/h in 1976 to 7×10^7 Nm^3/h in 1982. A combined flue gas cleaning system (including SCR, ESP, and FGD) has been applied to industrial boilers and furnaces since 1975, and to coal-fired boilers since 1980 to remove 50-90% of NO_x and 90-95% of SO_2. The combined cleaning for coal costs 2-3 yen/kWh (244 yen = $1 as of 8/5/83), including 7 years depreciation. Many new coal-fired boilers with the combined cleaning system have been planned because of their economic advantage over the use of low- or high-sulfur oil with FGD, although the recent decrease in oil price has reduced considerably the economic advantage. Simultaneous SO_2 and NO_x removal processes were studied eagerly between 1973 and 1978 and applied to several small industrial boilers and furnaces, but have not been used at a large scale because of the problems involved.

Panel: The Architect-Engineer-Middleman Between Utility and FGD Supplier

Archie V. Slack, Chairman
SAS Corporation
Sheffield, AL

Panel Members: Edward W. Stenby, Gene H. Dyer, Paul R. Predick, Michael L. Meadows, Douglas B. Hammontree, Christopher P. Wedig, Richard Rao

Panel Discussion. The A-E - Middleman Between Utility and FGD Supplier

Edward W. Stenby*
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Denver, CO

The A-E is hired to represent the owner through all phases of a scrubber system selection and installation. In this capacity, the A-E is expected to exercise good judgement in the areas of design and cost. The owner, depending on the size of his staff and his experience, may leave all or most decisions to his A-E or he may participate fully. We feel it is very important that the owner participate fully in all aspects of the scrubber system design and installation, since he will be left to operate the system after the vendor and A-E have left.

The A-E's objective is to specify and procure the most reliable scrubber system at a low evaluated cost. The scrubber business, however, is highly competitive and the vendor's objective is to win the award, knowing that low cost is one of the primary selection parameters. The document used by all parties to arrive at the appropriate selection is the specification. In Stearns-Roger's opinion, a good spec will detail not only basic design criteria, but also minimum levels of quality in equipment components, materials of construction, and equipment-sparing philosophy. A very important area is performance guarantees. A conservative spec may tend to drive the capital cost of the scrubber system upward, but we consider it to be the best means currently of achieving high operating reliability. However, a very detailed spec can conflict with the owner's desire to obtain maximum vendor exposure on equipment guarantees and performance guarantees. By dictating too much of the system detail design, the A-E and owner take some of the risk.

The current fixed-price nature of the FGD business forces the vendor to absorb the risk of cost overruns. During the proposal stage the vendor usually does minimal engineering to prepare his bid. Under these circumstances there will be a tendency for the successful vendor to protect his profit by calling for an extra, every time the A-E or owner makes a comment. The vendor will try to minimize or prevent the owner and A-E from interfering with the design and construction if they conform with the spec and the intent of the spec. Again, the spec becomes the all important document in interpreting what is required and what is acceptable. It is absolutely essential, therefore, that a good spec be developed.

In order to ensure that a good proposal is prepared, it is suggested that the owner consider paying for the proposal. In this manner, vendors will be encouraged to do more engineering and provide better detail of his proposed design. A limited bidder's list goes hand in hand with this approach.

One last thought...it must be remembered that there are many "gray" areas in scrubber design, and it is difficult, if not impossible, to get all the details spelled out clearly during the bidding phase. A goal of the A-E is to interpret and help coordinate the owner's requirements into positive action by the vendor during the design and construction phase. The owner also has a responsibility to know what he is buying and to apply standards of operation and maintenance for the scrubber system that are consistent with the rest of the plant.

The Role of Engineer-Constructors in Flue Gas Desulfurization

Gene H. Dyer
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San Francisco, CA

First, I would like to note that I have recast the title, since we think of ourselves as being Engineer-Constructors rather than Architect-Engineers. We believe that to be a distinct difference, in that it provides an ability to provide a continuity between engineering and construction activities that is vital to the timely and successful completion of jobs involving complex systems.

Second, in the short time available, would like to concentrate on the Engineering end of this subject.

Lastly, as a representative of the Research and Engineering part of the Bechtel Group of Companies, I would like to explain our views of developmental aspects of FGD, as well as its production engineering aspects.

Session 7. FGD Chemistry

Dorothy A. Stewart,
Chairwoman
Coal Combustion Systems Division

Electric Power Research
Institute
Palo Alto, CA

Influence of Chlorides on the Performance of Flue Gas Desulfurization

William Downs*
Babcock & Wilcox
Alliance, OH

Robert W. Aldred, L. Victoria
Tonty, Russell F. Robards,*
Richard A. Runyan
Tennessee Valley Authority
Chattanooga, TN

Dennis W. Johnson
Babcock & Wilcox
Barberton, OH

A pilot plant test program was performed to determine what effect high concentrations of chloride might have on the performance of limestone-based FGD processes. This test program took place during January and February 1983 at TVA's Shawnee Steam Plant. The specter of high chloride concentration arises from a trend toward closed-loop operation. The influence of chlorides on SO_2 absorption was examined: 161 limestone tests were completed. The principal conclusion that can be drawn from this test program is that chlorides generally inhibit SO_2 absorption. The severity of this effect can vary widely, however, depending on the design and method of operation.

Effect of High Dissolved Solids on Bench-Scale FGD Performance

James B. Jarvis,* Timothy W.
Trofe
Radian Corporation
Austin, TX

Dorothy Stewart
Electric Power Research
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Palo Alto, CA

To minimize wastewater treatment costs, utilities are evaluating the use of cooling tower blowdown as makeup water for wet limestone FGD systems. If closed-loop operation is employed, the dissolved species in the makeup water can be concentrated to significant levels. Additional ions may enter the scrubbing liquor through the absorption of chemical species in the flue gas. An important example is the absorption of HCl produced during the combustion of high chloride coal.

The effect of various high total dissolved solids (TDS) solutions on SO_2 removal and other system variables was evaluated in a bench-scale limestone FGD system. Five salts ($CaCl_2$, $MgCl_2$, NaCl, $MgSO_4$, and Na_2SO_4) were evaluated under both natural and forced-oxidation conditions. Additional laboratory testing was conducted to isolate specific effects observed in the more complex bench-scale tests. These tests were designed to illustrate the effect of high TDS solutions on chemical equilibria and gas/liquid mass transfer in the absorber.

The results of this investigation show that the performance of the FGD system is determined by the effect of the added salt on: (1) the concentration of dissolved ions in the scrubbing slurry, (2) the solubility of dissolved SO_2, (3) mass transfer enhancement through the formation of bi-sulfite ion pairs with the added cation, (4) sulfate/bisulfate buffering in high sulfate systems, and (5) the mass transfer rate of diffusing species through the liquid film at the gas/liquid interface. The bench-scale test results also compare favorably to the results from similar tests conducted at TVA's Shawnee Test Facility in Paducah, KY, and EPA's pilot facility at Research Triangle Park, NC.

Pilot Plant Tests on the Effects of Dissolved Salts on Lime/Limestone FGD Chemistry

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John C.S. Chang
Acurex Corporation
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J. David Mobley
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This paper is an overview of pilot plant testing from September 1981 through June 1983 of the effects of dissolved salts on a lime or limestone FGD system at EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC. Tests were conducted using a three-stage turbulent contact absorber (TCA) with a typical gas flow rate (G) of 465 m^3/hr (0.1 MW) and absorbing slurry chloride ion (Cl^-) concentrations ranging from 160 to 180,000 ppm.

The FGD processes investigated include conventional lime/limestone, magnesia enhanced limestone, and limestone with two-tank forced oxidation. Data indicate that the effects of Cl^- on the performance of the absorber are a function of the cations associated with Cl^- and scrubber operating conditions. The accumulation of calcium chloride decreased system pH and SO_2 removal efficiency, occasionally decreased slurry settling rate, and increased gypsum scaling potential. When magnesium was the cation, the increase of Cl^- concentration improved SO_2 removal efficiency at Cl^- concentrations below 40,000 ppm. No significant effects were observed using sodium chloride at Cl^- concentrations less than 50,000 ppm. However, when Cl^- concentrations were greater than 70,000 ppm, SO_2 removal efficiency and system pH declined with the accumulation of either magnesium or sodium chloride. Significant decreases in SO_2 removal efficiency were also observed when lime was used in the natural oxidation mode with high inlet SO_2 concentrations. Calcium chloride had minor effects on the performance of a DBA enhanced limestone scrubber. Most gypsum specifications required for wallboard manufacturing were met by washing cake using a pilot belt filter.

Modeling of SO_2 Removal by Limestone Slurry Scrubbing: Effects of Chlorides

Pui K. Chan, Gary T. Rochelle*
University of Texas at Austin
Austin, TX

A model of limestone slurry scrubbing with staged contacting has been developed by integrating gas/liquid mass transfer of SO_2, CO_2, and O_2 and dissolution of limestone and calcium sulfite solids. The model was used to predict SO_2 removal as a function of NaCl and $CaCl_2$ accumulation in the solution. Experimental data from three different pilot plants were accurately simulated. Chloride accumulation reduces SO_2 removal by its effects on the SO_2 hydrolysis equilibrium. Calcium accumulation reduces SO_2 removal by its effect on $SO_3^=$ and HCO_3^- in the scrubber solution. Sulfite oxidation in the scrubber can obscure the effects of $CaCl_2$ accumulation. The model predicts the effect of dibasic (glutaric) acid on SO_2 removal with solutions containing 0.7 M $CaCl_2$.

Influence of High Dissolved Solids on Precipitation Kinetics and Solid Particle Size

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This paper presents results of a study to screen the effects of high concentrations of dissolved ions on the precipitation of calcium sulfate dihydrate, gypsum, and the solid solution of sulfate with calcium sulfite hemihydrate. A series of precipitation measurements were conducted in the presence of combinations of magnesium, sodium, calcium, chloride, and sulfate at total dissolved solids levels up to 240,000 mg/L.

Significant differences in the precipitation rates and habit and size of the precipitated solids were observed for several of the test solutions as compared to precipitation from dilute solutions. Gypsum precipitation rate in high TDS solutions was accelerated in high TDS solutions, especially those containing chloride ion. The calcium sulfite/sulfate hemihydrate solid solution precipitation rate was faster in sulfate ion solutions.

These results suggest that the operation of FGD systems at high dissolved solids concentrations can alter the precipitation kinetics. Attempts to model these effects will require the incorporation of the concentrations of specific ions in the kinetic relationships.

Effect of Limestone Grinding Circuit on FGD Performance and Economics

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Results of several recent EPRI sponsored programs investigating technical and economic issues of limestone preparation for SO_2 scrubbing are presented in this paper. Variables important in the selection of a limestone for FGD application are discussed. The most common method used by vendors for sizing limestone ball mills is identified. Correlation of this method with the chemical, physical, and petrographic characteristics of several different limestones was investigated.

Pilot-scale testing with a wet ball mill, air-swept ball mill, tower mill, ring roller mill, and hammer mill was conducted with three of these limestones. Selection of the stones was based on the strength of the material. Hard, medium, and soft stones were used so that the effect of this variable on each machine's performance could be measured. Data were collected on the performance of these machines in grinding these limestones to various particle size distributions. Product samples collected from each were tested in laboratory equipment to measure the effect of grinding method on limestone dissolution rate.

Full-scale testing at Central Illinois Light Co.'s Duck Creek Unit 1 measured the effect of the limestone mill circuit operation on the product particle size distribution. Testing also quantified the effect of the limestone size distribution on its utilization in the scrubbers. The economic tradeoffs of producing the finer size product were estimated based on data collected during the on-site testing.

Session 8. Limestone/Organic Acid

J. David Mobley, Chairman
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Process Troubleshooting at a Utility Limestone FGD System

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Central Illinois Light Co.'s Duck Creek Unit 1 experienced significant reliability and operating problems with its limestone FGD system following start-up in 1979. CILCo entered into a testing and evaluation program co-funded by the Electric Power Research Institute in late 1981 to verify the feasibility of using additives to improve the system's low SO_2 removal efficiency. A second objective of the work was to improve the system's reliability, which averaged slightly better than 60% prior to testing. Severe mist eliminator scaling that was causing routine outages was primarily responsible for the reliability problems. The 8-month program that followed involved extensive chemical process troubleshooting.

Two types of organic acid buffers were tested along with the addition of magnesium oxide during the period. Both dibasic acid and the magnesium proved capable of enhancing SO_2 removal to levels sufficient to maintain the unit in compliance with the 1971 SO_2 NSPS. An economic analysis was performed based on the data collected during this testing. The cost study compared capital and annual operating and maintenance costs for each option over the remaining life of the plant.

Work was conducted with the additive testing to solve the mist eliminator scaling. The cause of the scaling was identified and effectively stopped by switching to a fresh water wash, adjusting the wash sequence, and improving limestone utilization. Limestone utilization was improved by optimizing the operation of the mill circuit to provide a finer, more reactive product. Since completion of the program, the FGD system has consistently achieved reliability greater than 95% while, at the same time, lowering operating and maintenance costs.

Technical/Economic Feasibility Studies for Full Scale Application of Organic Acid Technology for Limestone FGD Systems

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The application of organic acid buffe enhancement to FGD systems is a recer development that has resulted in lowere costs and improved performance fc systems that have adopted its use. process which uses organic acids as a additive has several advantages ov conventional limestone scrubbing sy tems, including system flexibility (e.g ability to respond to unplanned fluctu

tions in coal sulfur content), and improved process reliability. This paper summarizes the results of several cost analyses which were performed to evaluate the potential economic benefits of converting operating FGD systems to organic-acid-enhanced limestone scrubbing systems. Also, since the last FGD symposium, two full-scale utility limestone scrubbing systems have converted to organic-acid-enhanced operations. A summary of the first year of operation for one of those systems—City Utilities' Southwest Power Plant—is also included.

Session 9. Waste Disposal/Utilization

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Full-Scale Field Evaluation of Waste Disposal from Coal-Fired Electric Generating Plants

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Cambridge, MA

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This paper summarizes results of a 3-year study of current coal ash and FGD waste disposal practices at coal-fired electric generating plants. The study, conducted by Arthur D. Little, Inc., under EPA contract 68-02-3167, involved characterization of wastes, environmental data gathering, evaluation of environmental effects, and engineering/cost evaluations of disposal practices at six sites in various locations around the country. Results of the study are expected to provide technical background data and information to EPA, state, and local permitting officials, and the utility industry for implementing environmentally sound disposal practices.

Data from the study suggest that no major environmental effects have occurred at any of the six sites; i.e., data from wells downgradient of the disposal sites indicate that waste leachate has resulted in concentrations of chemicals less than the EPA primary drinking water standards. A generic environmental evaluation based on a matrix of four waste types, three disposal methods, and five environmental settings (based on climate and hydrogeology) shows that, on balance, technology exists for environmentally sound disposal of coal ash and FGD wastes for ponding, interim ponding/landfilling, and landfilling. For some combinations of waste type, disposal method, and environmental setting, mitigation measures must be taken to avoid adverse environmental effects. However, site-specific application of good engineering design and practices can mitigate most potentially adverse effects of coal ash and FGD waste disposal. Costs of waste disposal operations are highly system and site specific.

Operations History of Louisville Gas & Electric FGD Sludge Stabilization

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The Louisville Gas & Electric Company (LG&E) has been an industry leader in the deployment of FGD technology from its very inception. LG&E was one of the first major utilities to install SO_2 scrubbers; it now operates seven scrubbers serving a combined generating capacity exceeding 2200 MW. These scrubbers, purchased from several manufacturers, represent a broad spectrum of scrubber technologies including dual alkali, lime, and limestone systems.

The bleed stream from these scrubbers is dewatered, and the resulting solids are chemically and physically stabilized in processing plants purchased from Conversion Systems, Inc. (CSI), a pioneer in the field. Unit 6 at Cane Run, a 270-MW unit with a dual alkali scrubber, is served by a stabilization facility which began operations in April 1980. Units 4 and 5 at Cane Run have a combined capacity of 360 MW and are equipped with lime scrubbers. The waste from these scrubbers is combined and treated in another stabilization facility. The four units at Mill Creek have a combined capacity exceeding 1600 MW and are also equipped with lime scrubbers. One large stabilization facility was installed to handle the combined bleed from the four Mill Creek scrubbers.

The stabilization plants have run for about 3 years and are operated and maintained by LG&E personnel with advisory assistance supplied by CSI. The knowledge gained from the experiences of LG&E and CSI in the last 3 years of operation would be useful both to current operators of stabilization facilities and to those who are anticipating the procurement of scrubbers and stabilization facilities.

This paper presents some of the operating and maintenance history which has been obtained from these plants. Included are discussions on reliability of individual equipment and discussions of some modifications which were made to improve reliability. Operating problems are addressed, including some of the inherent difficulties encountered in processing scrubber sludge and fly ash.

In addition, the landfill operation which is an integral part of the stabilization process is discussed, as well as the results of several years of landfill investigation. Also discussed is the impact of the landfill operation and plant control on the environmental properties of the final landfilled material.

Coal Waste Utilization in Artificial Reef Construction

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The technology of coal combustion has improved greatly over the last few decades. One result of the elaborate

emission control equipment required on coal plants to meet stringent air quality requirements is the large amount of waste that must be utilized or disposed of safely. FGD sludge and fly ash may be produced at the rate of as high as 1,000 tons/day at a typical coal-fired power plant. Waste disposal, especially in urban coastal areas, has become a major obstacle to conversion to coal combustion for generating electricity.

To assess a possible solution to the waste disposal problem, 500 tons of FGD sludge and fly ash were stabilized into blocks and placed in the ocean as an artificial reef. Previous laboratory investigations had indicated that no toxic chemical or physical effects should occur in the marine environment. After 3 years in the sea, the coal waste blocks support a diverse community of reef fish and invertebrates and have maintained their structural integrity. No adverse environmental effects have been detected.

Assuming that the coal waste blocks continue to be environmentally acceptable in the marine environment, the engineering and economic feasibility of this method of disposal should be confirmed.

Solid Waste Environmental Studies at Electric Power Research Institute

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Solid Waste Environmental Studies (SWES) at Electric Power Research Institute (EPRI) is a comprehensive research project aimed at generating predictive methods and the essential data bases to evaluate the effect of disposal and reuse of solid waste produced from fossil fuel combustion and flue gas cleanup operations on groundwater quality. EPRI has developed detailed research plans and has initiated research in leaching chemistry, chemical attenuation mechanisms, groundwater transport processes, and the evaluation of existing geohydrochemical models. For the next 3 or 4 years, fundamental research in geochemistry and geohydrology is expected to yield quantitative data on release rates, transformation characteristics, and subsurface transport of inorganic solutes leached from waste. Results of the research will be integrated by improving or developing new predictive methods and by validating the results with data from operating facilities.

Session 10, Part I. Dry FGD: Pilot Plant Test Results

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Current Status of Dry SO_2 Control Systems

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This paper updates commercial applications and research and development (R&D) activities involving three dry SO_2 control technologies: spray drying, dry injection, and electron-beam irradiation.

Spray drying continues to be the only commercially applied dry FGD process, with two additional spray drying systems sold since mid-1982. To date, 17 commercial utility spray drying systems have been sold, totaling over 6800 MWe. Six of these systems are currently operational; two of them have been turned over to the utility. In addition to the utility applications, there are 21 industrial spray drying units, 7 of which are expected to start up in the next 2 years. Demonstration- and pilot-scale testing of the spray dryer process is continuing with emphasis on high sulfur applications.

The first planned commercial application of dry injection technology has been announced for a 500 MWe utility. The recent demonstration-scale testing on a 22 MWe unit has been completed.

The electron-beam process is also in an early developmental state. Pilot-scale testing of the electron-beam/lime spray drying version of the process is scheduled to begin this fall.

Acid Rain Prevention Through New SO_x/NO_x Dry Scrubbing Process

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Acid rain has attracted much attention both in the U.S. and in Europe. To cope with problems associated with acid rain, Niro Atomizer is developing a dry scrubbing process for simultaneous removal of SO_x and NO_x.

A description of the process is given in this paper. The equipment used is essentially the same as used in the over 5000 MW utility dry scrubbers currently in operation, start-up, or under construction.

Pilot plant test results from the Copenhagen dry FGD facility and results achieved during a full-scale demonstration of the process at one of Joy/Niro's operating dry scrubbers are presented.

Waste product characteristics are shown and compared with EPA standards.

Finally, the process economics are analyzed and compared with other existing processes for SO_x/NO_x removal.

Process Characterization of SO_2 Removal in Spray Absorber/Baghouse Systems

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A new equation for correlating SO_2 removal with stoichiometric ratio, approach to saturation, inlet SO_2 concentration inlet temperature, and inlet moisture content is proposed. It reveals essentia information about the kinetics of the SO_2 removal process. The chemical reaction between the SO_2 and lime appears to limit the rate of SO_2 removal in the spray

absorber. The effect of recycle enhancement of SO_2 removal may be understood in terms of this model. The model also permits a classification of fly ash suitable for designing dry flue gas desulfurization (DFGD) systems.

DFGD pilot plant results are reviewed from theoretical and mechanistic viewpoints. SO_2 removal as a function of the gas flow rate (or average residence time) and the angle of the secondary swirl vanes in the absorber gas disperser is discussed relative to the velocity flow field in the absorber. SO_2 removal efficiency is also discussed as a function of the atomizer angular speed.

When the gas flow rate and approach to saturation are fixed, SO_2 removal efficiency in the spray absorber increases with increasing stoichiometric ratio and inlet temperature and decreasing inlet moisture content and SO_2 concentration. An explanation of these effects is given by their impact on the droplet diameter integrated over the lifetime of the droplets. Another effect that increases the time-integrated droplet diameter is the decrease in the volume of the core of solids (lime) for smaller slurry droplets.

Partial recycle of the spent products, in the absence of externally injected fly ash, results in SO_2 removal efficiency being nearly independent of SO_2 concentration. Thus, the enhancement from recycle is greater for the higher SO_2 concentrations. SO_2 removal performance with recycle was improved by injecting fly ash derived from a low sulfur Texas lignite and from high sulfur eastern coals. The enhancement with recycle in the latter case is dramatic and supports DFGD applicability to high sulfur coal.

Dry Scrubber, Flue Gas Desulfurization on High-Sulfur, Coal-Fired Steam Generators: Pilot-Scale Evaluation

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This paper describes the pilot-scale investigation of methods for adapting dry FGD to utility steam generators burning high-sulfur coal. Development of the dry scrubber for FGD was initially directed toward reducing SO_2 in steam generators burning low-sulfur western coals. The reason for limiting dry scrubbing to low-sulfur coals was two-fold: first, federal New Source Performance Standards (70% reduction) were less stringent; and second, western coals generally contain less sulfur and large amounts of ash alkali, contributing significantly to the effectiveness of the dry scrubbing process. Several potential drawbacks (both technical and economic) limiting dry scrubber technology to western coals are discussed.

The Department of Energy (DOE) conducted dry scrubber FGD tests in 1981. Preliminary results indicated dry scrubbing could remove more than 90% of the sulfur released from the combustion of eastern coals at less-than-anticipated levels of lime consumption. The Babcock & Wilcox Company, under DOE contract, has tested the dry scrubbing process to evaluate the variables that have a major effect on SO_2 capture.

There are ways of increasing SO_2 capture by dry scrubbing. One method requires limestone injection into the boiler furnace (reducing SO_2 levels to the scrubber), calcines limestone to more reactive lime, and simulates a high-alkali-ash, high-sulfur coal. Other methods include recycle and dry scrubber approach to saturation at temperatures less than 20°F to obtain high SO_2 capture.

EPRI Spray Dryer/Baghouse Pilot Plant Status and Results

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In February 1982, the Electric Power Research Institute (EPRI) initiated a 2.5 MW spray dryer/baghouse FGD pilot plant program at their Arapahoe test facility. The objective of the pilot plant program is to confirm the capabilities of the FGD process and to provide the electric utility industry with reliable design and operating information for spray dryer/baghouse FGD systems. The pilot unit was described, and initial results for sodium carbonate and once-through lime operation were presented at the May 1982 FGD symposium in Hollywood, FL. This paper presents the results of test work conducted from May 1982 through August 1983.

Most of the test work has been conducted with lime reagent in the recycle, rather than one-through mode. Effects of a number of variables have been studied. Spray dryer inlet SO_2 concentrations have been varied from a nominal 350 ppm up to 2000 ppm. Other variables examined have included reagent ratio, recycle rate, system flue gas flow rate, atomizer feed slurry preparation and feeding configurations, and approach to adiabatic saturation at the dryer outlet. A significant result has been the observation that recycle operation greatly improves spray dryer operation in addition to improving SO_2 removal performance.

The fabric filter has been shown to contribute significantly to overall system SO_2 removal, particularly at higher system removal levels (80% and greater). No bag/fabric-related problems have been observed. However, corrosion of mild steel baghouse walls and mild steel caps on bags near the walls has in some instances been severe. The corrosion has been largely attributed to insufficient insulation of baghouse surfaces, and to the fact that the pilot-scale compartment shares no common walls with other compartments. As a result of several bag cap failures, the fabric filter compartment was re-bagged in April 1983. The new bags were brought on-line with no conditioning by fly-ash-only operation, and (after 4 months) continue to operate at a very low pressure drop.

Session 10, Part II: Dry FGD: Full Scale Installations

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Field Evaluation of a Utility Dry Scrubbing System

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This program, cofunded by the U.S. Environmental Protection Agency and the Electric Power Research Institute,

has resulted in an evaluation of a full-scale utility spray-dryer/baghouse dry FGD system. The system is installed at the Northern States Power Company's Riverside Station and treats flue gas from a nominal 100 MW of coal-fired power generation. This has been the first independent evaluation of a full-scale spray-dryer/baghouse system.

For the test program, two coals were used as boiler fuels: a subbituminous coal and coke mixture with a nominal 1.2% sulfure content, and a 3.4% sulfur Illinois bituminous coal.

During the test program, SO_2 removal, particulate emissions, sulfuric acid removal, and extensive process data were recorded. The test program was conducted from July to October 1983, so only preliminary results are presented. Low sulfur coal tests indicated up to 90% SO_2 removal was achievable in the short term with slightly sub-stoichiometric amounts of lime addition. A similar removal was achieved in short term tests with high sulfur coal at reagent ratios of 1.3 to 1.4. Calcium chloride addition was found to reduce the lime addition requirements for high sulfur tests by about 25%.

Overview and Evaluation of Two Years of Operation of the Riverside Spray Dryer System

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Initial operation of the 100 MW spray dryer system at Northern States Power Company's Riverside Generating Station began in November 1980. At that time, a comprehensive test program was initiated to demonstrate the suitability of dry FGD for utility coal fueled boilers. Since initial operation of the Riverside spray dryer began, other publications have described individual aspects of this system's performance. This paper provides a comprehensive analysis and overview of the performance test data collected during the initial 2 years of operation of the Riverside spray dryer.

Overall data correlations describing important variables in spray dryer operation and performance are established from test results obtained during operation of the Riverside spray dryer system under a wide range of conditions. Correlations between total and fabric filter SO_2 removal and parameters such as lime stoichiometric ratio, total alkalinity, and approach temperature are presented for several different coals. Variations in moisture content of the solids collected in the spray dryer and fabric filter are evaluated to establish their sensitivity to a wide range of operating variables. In addition, system operation and control experiences are described to illustrate the interaction between flue gas flow, feed slurry flow, absorber outlet temperature, and SO_2 emissions during normal operation, as well as during transient conditions such as start-up, shutdown, and load swings. The effects of boiler soot blowing on the flue gas saturation temperature and system control are also discussed.

Design and Initial Operation of the Spray Dry FGD System at the Marquette Michigan Board of Light and Power Shiras #3 Plant

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This paper discusses the design issues, design decisions, start-up, and early operation of the Spray Dry Flue Gas Desulfurization (SDFGD) system which went into operation at the Marquette (MI) Board of Light and Power's Shiras Unit 3 in May 1983. This 44-MW unit (consisting of a rotary atomizer reactor, reverse air fabric filter, lime preparation, and reagent recycle system) was engineered in the 1980-82 period utilizing pilot plant and prototype industrial system results as a design basis.

The initial operation of the unit is discussed, as is the success of the scaleup from pilot plant to commercial size boiler.

Start-up and Initial Operating Experience of the Antelope Valley Unit 1 Dry Scrubber

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The first competitively bid and awarded utility dry scrubbing system utilizing lime as the scrubbing reagent was for Basin Electric's Antelope Valley Station Unit 1. Awarded in 1978 to Joy Manufacturing with Niro Atomizer as the major subcontractor, the system was scheduled to start up in 1981; however, due to reduced load growth, start-up was delayed until this year.

The dry scrubbing system treats flue gases from a 435-MW lignite-fired boiler and consists of reagent preparation equipment, five spray dryer absorbers, and two fabric filters.

Initial operation on coal began in May 1983, and commercial operation of the system is scheduled for July 1984. This paper reviews the start-up procedure, problems which have developed thus far and how they have been handled, and results of the operation of the system to date.

Characterization of an Industrial Spray Dryer at Argonne National Laboratory

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Argonne National Laboratory (ANL) i operating an industrial-scale coal-fire boiler with a flue gas cleaning (FGC system consisting of a spray dryer an fabric filter. This paper describes the FG system and gives the status of an EPA sponsored project being carried out b ANL to characterize the operation of th system. This project involves a design ar economic analysis of the FGC syster determination of waste characteristic and analysis of system operation throug monitoring of inlet/outlet gas strean and sampling of various process stream Preliminary data and material balanc are presented in the paper, as well as proposed performance model based o an analysis of key operating paramete

Unpresented Papers

An Economic Evaluation of Limestone Double Alkali Flue Gas Desulfurization Systems

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Considerable work was done at the EPA Scholz plant in defining the process parameters for limestone double alkali flue gas desulfurization systems. In general this study proved the viability of the process but uncovered several less than optimum operating parameters that needed further work. FMC and others have continued to work with the process and have defined operating parameter changes necessary to make the system commercially viable.

Limestone double alkali is especially appropriate for FGD systems applied to boilers burning relatively high sulfur (2% and greater) fuel. A discussion of site-specific design criteria which impact on the selection of FGD technology is included with a definition of the optimum parameters for the applications of limestone double alkali.

An in-depth economic analysis of the system is included with comparisons to conventional limestone scrubbing technology. Cost comparisons are made by subsystems such as absorber system, reagent handling, storage and preparation system, and solids waste production and disposal. The economic data presented are primarily a result of work done by TVA under contract from the EPA.

Developments and Experience in FGD Mist Eliminator Application

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This paper details available mist-eliminator technology and assesses U.S. practices and experience in utilizing these sub-systems of FGD processes. Pertinent trends in FGD system design and operation tied to the criticality of mist eliminator performance are identified and discussed, and advancements in eliminator selection and application are reviewed. Case histories of several significant existing mist eliminator facilities are described, and the importance of selection of internals design and arrangement permitting use of elevated mist-eliminator inlet-face gas velocity to enhance droplet separation forces is emphasized.

FGD Gypsum: Utilization vs. Disposal

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This paper gives a technical and economic evaluation of alternative means of managing wastes collected in forced-oxidation (FO) FGD systems. Worldwide application of FO-FGD is described, and environmental considerations in selection of waste management alternatives - gypsum utilization vs disposal - are reviewed. Feasibility of and barriers to commercial gypsum from FGD in North America during the 1980s are analyzed. The impetus, method of implementation, and potential for gypsum use are addressed for major by-product gypsum FGD installations now in operation, under construction, or being designed. It is concluded that, in many instances, the production and sale of usable gypsum from FGD would be a benefit and a source of direct profit to the utility plant owner, but that in most cases the gypsum depletion allowance under IRS Code 613B will continue to be a major disincentive for purchase of by-product gypsum by vertically integrated gypsum companies in U.S.

Operating Experience with the Chiyoda Thoroughbred 121 Flue Gas Desulfurization System

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This paper reviews the design and operating experience of the Chiyoda Thoroughbred 121 FGD system installed and operated by Mitsubishi Petrochemical Company at their Yokkaichi, Japan, complex.

The plant consists of a single scrubber and treats 260,000 Nm^3/h (162,000 scfm) of flue gas from a 280 T/h (87 MW equivalent) boiler burning high sulfur oil. Plant operation, since start-up in May 1982, has been smooth and trouble free over a wide range of operating conditions. Plant reliability has been 100%. The plant is operated at a SO_2 removal efficiency of 97-99% for inlet SO_2 concentrations ranging between 1000 and 2000 ppm. Limestone utilization is greater than 99%, and the dry gypsum by-product is sold to a wallboard manufacturer. Operating and maintenance functions for the system are minimal and completely absorbed by normal boiler plant operations.

Operation Experience with FGD Plant II at Wilhelmshaven Power Plant, West Germany

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Power Plant Wilhelmshaven
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H. Weissert
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Essen, West Germany

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The Nordwestdeutsche Kraftwerke Aktiengesellschaft (NWK) has been operating a 720 MW coal-fired power plant in Wilhelmshaven, West Germany, since 1976. In March 1982, the second FGD plant (called REA 2) was placed in operation after a 2-year construction period. Start-up and checkout proceeded without major difficulties and was completed within about 3 months. Beginning in June 1982, NWK accepted the plant. Since then, REA 2 has been in operation without significant interruptions, effectively reducing SO_2 emissions of the power plant.

The Sulf-X Process

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This paper reports the status of development of Sulf-X technology for FGD and reviews the design and applicability of the process in boiler service firing diverse coal fuels. Details are given of process chemistry, design and operation, economics, and past and future system demonstration programs. The flexibility and attractiveness of the technology is shown in its use either for SO_2- removal-only or for simultaneous SO_2/NO_x removal.

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***Julian W. Jones** is the EPA Project Officer (see below).*
The complete report consists of two volumes, entitled "Proceedings: Eighth Symposium on Flue Gas Desulfurization, New Orleans, LA, November 1983:"
"Volume I," (Order No. PB 84-226 638; Cost: $38.50)
"Volume II," (Order No. PB 84-226 646; Cost: $37.00)
The above reports will be available only from: (cost subject to change)
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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