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Project Summary

Proceedings: Ninth Symposium on Flue Gas Desulfurization, Cincinnati, Ohio, June 1985

Franklin A. Ayer and Anna W. Wallace

The proceedings of the Ninth Symposium on Flue Gas Desulfurization (FGD) consists of two volumes: Volume 1, Opening Session, Commercial Status of FGD, Limestone FGD/Organic Acid Enhancement, FGD Reliability Improvement, Chemistry/Reagent Preparation, and Materials of Construction; and Volume 2, Panel Discussion on Retrofitting FGD Systems, Dual Alkali, Emerging Technologies, Spray Dryer FGD, FGD By-product Disposal/Utilization, Unpresented Papers (8), and Attendees Listing. EPA and EPRI cosponsored this symposium which was held in Cincinnati, OH, June 4-7, 1985.

The meeting was a forum for the exchange of technical and regulatory information and developments regarding systems and processes applicable to utility and industrial boilers. Addresses at the opening session: (1) compared regional declines of forests in Europe with those of North America and the possible role of airborne chemicals in these declines, (2) examined the current legislative/regulatory situation, and (3) gave results of a study of the economics of FGD systems in a variety of SO_2 reduction strategies for coal-fired power plants. Subsequent technical sessions dealt with new and existing FGD technologies that enabled utility and industrial users of the technology, consultants, engineering firms, equipment manufacturers, process suppliers, government agencies, academia, and research and development firms to share their experiences.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of research projects that are more fully documented in two separate reports of the same title (see Project Report ordering information at back).

Introduction

This Summary consists primarily of abstracts of presentations made and papers presented at the Ninth Symposium on Flue Gas Desulfurization. Titles and authors of several papers prepared for the meeting, but not formally presented, are also included.

Abstracts

Volume 1

Session 1: Opening Session

Comparison of Regional Declines of Forests in Europe and North America: The Possible Role of Airborne Chemicals

Ellis B. Cowling, North Carolina State University, Raleigh, NC

Human activities of many sorts have been changing the chemical climate of Europe and North America especially since the Industrial Revolution. Regional declines of forests also have been occurring in Europe for the past 200 years and in North America for at least the past century. A total of 18 regional declines of forests have been reported on the two continents. These declines are generally believed to have been caused by a combination of competitional, physical, biological, and chemical stress factors acting simultaneously or sequentially. Airborne chemicals have been implicated as an important causal factor in only 4 of the 18 cases. A consensus regarding the possible role of selected airborne chemicals is described. This judgement suggests that ozone and biologically available nitrogen compounds are among the chemical stress factors of greatest probable importance to forests. Other chemical stress factors that may also be involved include toxic gases other than ozone, toxic metals, acids, acidifying substances, and growth-altering organic chemicals. Implications of this concensus are discussed briefly with regard to management of air quality in Europe and North America.

Address on Current Legislative/Regulatory Situation

Joseph A. Cannon, Pillsbury, Madison, and Sutro, Washington, DC

No written material furnished.

The Role of FGD in SO_2 Reduction Strategies for Coal-Fired Power Plants

E. S. Rubin, M. Cushey, R. J. Marnicio, C. N. Bloyd, and J. F. Skea, Carnegie-Mellon University, Pittsburgh, PA

A newly developed computer model for detailed analysis of SO_2 control strategies and costs at the unit, state, and regional levels is described. Illustrative results are presented in which a broad range of parameters affecting FGD retrofits at existing coal-fired power plants are examined for an eight-state region of the midwest, using site-specific plant and fuel characteristics. The future cost and capacity of FGD retrofit systems are seen to depend strongly on SO_2 reduction requirements. For the highest levels of control, wet limestone scrubbing in conjunction with physical coal cleaning often provided the most economical means of compliance, particularly if only "local" coals were used. The future availability of dry SO_2 removal processes (lime spray dryer and LIMB) is seen to have a potentially significant influence on the choice of SO_2 control technology, if emission reductions of 50% or more become required in the next decade. The potential effects of plant life extension programs on the use of conventional and advanced FGD systems also are significant. The way in which overall SO_2 emission reductions are allocated to individual sources, and the degree to which utility coal choices are constrained, also have a pronounced effect on control technology selection and cost.

Session 2: Commercial Status of FGD

The Present and Future Status of FGD in the United States

Robert W. McIlvaine, The McIlvaine Company, Northbrook, IL

More than 50,000 MW of FGD systems are in operation in the U.S. More than 100,000 MW will be in operation by 1991. An upsurge in new boiler orders beginning in the next few years will raise the FGD total to close to 175,000 MW in the U.S. by the late 1990's. Acid rain control could be important in determining this total, but variations in peak load demand and boiler replacement rates will be more significant in the long term. The commercial situation is constantly changing. Architect/engineers, boiler companies, scrubber system designers, and component suppliers are attempting to take more responsibility. This is spurring competition between these groups and between individual suppliers. Integration, new technology, and internationalization are also shaping the competitive environment.

Survey Report and Assessment of Utility Flue Gas Desulfurization System Installations in Europe

William Ellison, Ellison Consultants, Monrovia, MD

This paper gives details of recent surveys of major programs for FGD and NO_x removal installation in West Germany. The paper: provides an understanding of the principal types of control system designs that are being applied, outlines technological advancements that are being achieved, and describes operating experience gained to date in expanded use of FGD and selective catalytic reduction (SCR) in Europe in the 1980s. Significant differences between FGD and NO_x removal in the U.S. and Japan are reviewed, and information that may improve the operation and reliability of new and retrofit installations in U.S. is offered.

Recent Developments in SO_2 and NO_x Abatement Technology in Japan

Jumpei Ando, Chuo University, Tokyo, Japan

More than 1400 FGD plants have been built in Japan with a total capacity of treating 130 million Nm^3/h of flue gas (43,000 MW equivalent). Thirty FGD plants have been operated treating about 90% of total flue gas from coal-fired utility boilers. All of the FGD plants for coal by-produce salable gypsum. On the other hand, the total capacity of selective catalytic reduction (SCR) of NO_x exceeded 90 million Nm^3/h (30,000 MW). Twenty coal-fired boilers use SCR in addition to FGD. All of the FGD and SCR plants have been operated with over 99% reliability. The investment cost for limestone/gypsum process FGD plants for coal-fired boilers has been lowered from about 30,000 yen/kW* in 1979-1980 to about 20,000 yen/kW in 1983-1984. The power consumption of the FGD processes was also reduced from 2.1-2.6% to 1.7-2.1%. The annualized cost of the wet limestone/gypsum process is currently about 1.4 yen/kWh including 7 years depreciation and 10% interest. The investment cost of SCR for coal-fired utility boilers is about 6,000 yen/kW, while the annualized SCR cost is 0.5-0.6 yen/kWh including 7 years depreciation and 10% interest. For the removal of acid (H^+), NO_x abatement by combustion modification is the most economical, while SCR is more costly. There have been no significant developments in simultaneous SO_2 and NO_x removal technology except that two test plants have been operated with activated carbon processes. Several indus-

*250 yen ≈ $1 (U.S.)

trial coal-fired boilers using fluidized-bed combustion have been put into operation, reducing both SO_2 and NO_x.

EPA's Stationary Source Control Technology Research Program

Carl R. Gerber, U.S. Environmental Protection Agency, Washington, DC

The reduction or control of SO_2 emissions from coal combustion—in a cost-effective manner—is a topic of widespread interest today, just as it was at the first symposium on FGD held over 12 years ago. More recently SO_2 as well as NO_x emissions have been tied to the problems of acidic deposition and visibility degradation. Research to reduce NO_x emissions has focused on combustion modification. EPA's major thrust has been to develop technology for new low-NO_x burners that may be retrofitted to existing boilers or incorporated into new designs. EPA's research on particulate technologies is directed toward reducing costs by as much as 50% and minimizing operational uncertainties. Two approaches under development are the use of a multistage electrostatic precipitator (ESP) and electrostatic enhancement of fabric filtration.

EPA's engineering program has been involved in many of the technological advances in FGD. EPA continues to conduct research to develop higher reliability and lower cost SO_2 emission reduction methods. An EPA in-house pilot plant program is focusing on spray drying FGD—particularly on reducing costs, such as the use of cheaper or more reactive sorbents. EPA is also developing several innovative concepts in SO_2 control which will offer low-cost options for acidic deposition reduction if proposed legislation calling for this reduction becomes law. EPA's largest effort among these combined emission reduction technologies is demonstration of the technology known as LIMB (limestone injection combined with low-NO_x multistaged burners). Another approach to lower cost technology combines SO_2 control with particle emission control, a concept that EPA has developed, involving spray drying in a modified ESP; this concept has been dubbed "E-SOX."

In addition to its hardware-related control technology research, EPA has a continuing effort to assess the performance and engineering costs of both commercial and emerging technologies.

Finally, a major effort in EPA's engineering program has been what many refer to as "technology transfer." This is EPA's way of disseminating data and information from technological developments by EPA and others via published papers, technical reports, industry briefings, and symposiums. Over 3 years ago, EPA joined forces with EPRI in continuing the FGD symposium series. This joint sponsorship has been highly successful in making these meetings more responsive to the needs and interests of those who need this data and information in their work, particularly the users of FGD technology. EPA also benefits from the other work discussed at these symposiums.

Session 3: Limestone FGD/Organic Acid Enhancement

Results of Using Organic Acid in San Miguel Electric's Flue Gas Desulfurization System

Jack M. Burke, Radian Corporation, Austin, TX; Robert Cmiel, San Miguel Electric Cooperative, Jourdanton, TX; and J. David Mobley, U.S. EPA, Air and Energy Engineering Research Laboratory, Research Triangle Park, NC

This paper summarizes San Miguel Electric Cooperative's first full year of operation after conversion of the Unit 1 FGD system to an organic acid enhanced limestone system. Plant operating data from 1983 (without organic acid addition) and 1984 (with organic acid addition) were reviewed. Based on that review, changes which occurred after organic acids were added to the system were identified and cost savings resulting from those changes estimated. The cost estimates showed that savings directly attributable to organic acid use exceeded the cost for organic acid by $109,000 in 1984. Further, additional cost benefits resulting from organic acid use may have been in excess of $3 million. Because of this positive experience, San Miguel continues to use organic acid in its FGD system.

State-of-the-Art Design Applications on a Closed-Loop FGD System

Dennis Laslo and Even Bakke, Peabody Process Systems, Inc., Norwalk, CT

Seminole Electric Cooperative's Units 1 and 2 in Palatka, FL, are capable of 1240 MW of generating power. The limestone-based FGD systems for both boilers incorporate an organic acid addition system for operation at high dissolved salt concentrations, and, on Unit 1, a unique double draw-off crystallizer unit operation for improved cake dewatering, and a two-tank forced oxidation system for production of gypsum. Discussions include full-scale closed-loop water management and operating experience, results from a commercial gypsum dewatering pilot plant, results of double draw-off product removal on both calcium sulfite and calcium sulfate crystals, and operating experience and economics of organic acid addition. Also, results of a successful test of sodium thiosulfate addition as a gypsum scale inhibitor are presented.

Dibasic Acid Test and Chemical Process Evaluation at Petersburg Unit 3 FGD System

D. Guetig, Indianapolis Power & Light Company, Petersburg, IN; and S. Ou and C.P. Wedig, Stone & Webster Engineering Corporation, Boston, MA

The use of dibasic acid (DBA) in a FGD system buffers the scrubber chemistry, resulting in increased scrubber SO_2 removal efficiency. The use of DBA may also result in reduced scrubber electricity consumption. It is expected that Indianapolis Power & Light Company's (IPL) Petersburg Unit 3 can burn higher sulfur coal when using DBA in the scrubber, while maintaining its current 30-day average SO_2 control. However, long-term effects of factors that may limit scrubber performance (e.g., demister pluggage or dewatering equipment performance) have yet to be determined. Other effects of DBA addition (e.g., increased corrosion rates) also must be considered in long-term use of DBA. The use of DBA at Petersburg Unit 3 did not reduce limestone consumption. The use of DBA on an annual basis or on an "as-needed basis" may result in increased scrubber reliability in that scrubber SO_2

emission excursions may be minimized. In addition, operating the scrubber with DBA, lower booster fan inlet vane settings, and continued use of presently available coal should increase scrubber reliability by minimizing wet gas recirculation to the booster fans.

Operating Results of Toyama Kyodo Electric Power's Chiyoda Thoroughbred 121 Flue Gas Desulfurization System

K. Wataya and A. Hori, Toyama Kyodo Electric Power Company, Yokohoma, Japan; N. Hashimoto and H. Koshizuka, Chiyoda Chemical Engineering and Construction Company, Ltd., Yokohama, Japan; and D. D. Clasen, Chiyoda International Corporation, Seattle, WA

This paper reviews the design and initial operating experience of two Chiyoda Thoroughbred 121 FGD plants at Toyama Kyodo Electric Power Company's Toyama Shinko Kyodo power station to treat flue gas from two 200 MW coal-fired boilers. This is the first application of the second generation CT-121 process to large electric-utility coal-fired boilers. Each CT-121 unit consists of a single scrubber, and limestone slurry preparation and gypsum dewatering equipment. Each unit also has a Ljungstrom type gas-gas heat exchanger for reheating scrubbed flue gas. Plant operation, since startup in July 1984 (Unit 1) and August 1984 (Unit 2), has been smooth and trouble free. The plants are operated at a SO_2 removal efficiency of 85%. Limestone utilization is greater than 99%, and the dry gypsum by-product is sold to cement and wallboard manufacturers. Plant reliability, including shakedown operations, has been superb: 99.9% for Unit 1 and 100% for Unit 2. Inspection of the system following shakedown revealed no scaling, plugging, or corrosion. Maintenance has been limited to routine and general servicing of equipment.

Session 4, Part I: FGD Reliability Improvement

The Sulfur Dioxide Removal System Improvement Program at Seven Units of Louisville Gas and Electric Company

M. L. McInnis, Louisville Gas & Electric Company, Louisville, KY; D. A. Froelich, S. A. Bjorklun, and G. M. Graves, Burns & McDonnell Engineering Company, Kansas City, MO

During early 1984, Louisville Gas & Electric Company (LG&E) implemented a program to upgrade its mid-1970 vintage SO_2 removal systems (SDRS) to current design standards. The goal of the project was to improve SDRS reliability to a minimum level of 90% while reducing excessive operating and maintenance expenses. This program is at its midpoint, with design and construction proceeding at the Mill Creek Station. Problem identification and engineering recommendations are in the evaluation stage for two units at Cane Run. Design is proceeding for a third Cane Run unit. This paper summarizes the project and highlights the unique problems encountered with the SDRS improvement program.

Improving the Reliability of Indianapolis Power & Light Company's Petersburg 3 Limestone FGD System

J. David Colley, Radian Corporation, Austin, TX; Steve Wolsiffer, Indianapolis Power & Light Company, Petersburg, IN; Dorothy Stewart and Richard Rhudy, Electric Power Research Institute, Palo Alto, CA; and David Balfour, Radian Corporation, Austin, TX

Preliminary results of a comprehensive program to improve the reliability of Indianapolis Power and Light Company's Petersburg 3 FGD system are presented. The objective was to identify the causes of the process problems and recommended solutions to the system's reliability problems. FGD operating guidelines developed from the information gathered during on-site testing are given. Severe mist eliminator scaling was investigated: recommended procedures were to select better control instrumentation for the scrubbers, to determine proper operating setpoints for pH and density, and to modify the mist eliminator wash system. Other testing and modifications to the system are to: (1) install and document operation of three different mechanical seals for recycle pumps, (2) modify the limestone grinding circuit and to install a particle-size monitor to determine if the monitor can indicate circuit maintenance frequency, (3) optimize adipic acid use as other process changes are made, and (4) study the problem of stack opacity as process modifications are implemented.

Results of an FGD Process Troubleshooting Program at Texas Utilities, Martin Lake Steam Electric Station

David Colley, Radian Corporation, Austin, TX; Don Mzyk and Mike Wadlington, Texas Utilities Generating Co., Tatum, TX; and Dorothy Stewart, Electric Power Research Institute, Palo Alto, CA

The objectives of the troubleshooting program at the Martin Lake Station were to reduce the operating and maintenance costs and to improve reliability of the limestone FGD system. The problem areas addressed include chemical scaling in the absorber packing and mist eliminators, process control and instrumentation, system water balance, and limestone utilization. The troubleshooting methodology used to solve the problems is outlined. A 3-month demonstration test was undertaken to verify the success of recommended process changes to reduce gypsum scale formation rates and to improve process stability. The results of the demonstration testing showed that scale formation in the absorber packing and mist eliminator can be virtually eliminated. Recommendations to convert the FGD system from a water producer to a water consumer are listed. Also, recommendations to increase limestone utilization are presented.

Availability Analyses for Flue Gas Desulfurization Improvement Decisions

Albert R. Cunningham, Philadelphia Electric Company, Philadelphia, PA; and Morton J. Smith, Pickard, Lowe, and Garrick, Inc., Newport Beach, CA

A recent study was sponsored by EPRI to determine the usefulness of availability analysis techniques for guiding decisions involving improvements on FGD systems. The study concluded that availability analyses can provide significant insight into the consequences of alternative decisions faced by responsible FGD plant personnel. These decisions can relate to matters of FGD design, operation, and/or maintenance, and can affect various levels of the system hierarchy from the overall FGD system to individual components. In addition, the results indicated that these analyses can provide plant personnel with additional value at the process variable level if the availability analysis can be combined with FGD performance models.

Session 4, Part II: Chemistry/ Reagent Preparation

A Study of Sulfur-Nitrogen Compounds in Wet Lime/Limestone FGD Systems

James B. Jarvis and Peter A. Nassos, Radian Corporation, Austin, TX; and Dorothy A. Stewart, Electric Power Research Institute, Palo Alto, CA

This paper summarizes the results of an EPRI-sponsored program to study the relationship between sulfur-nitrogen (S-N) compounds and the wet lime/limestone FGD process. S-N compounds have been identified in the Arapahoe pilot-scale FGD system and are formed through a liquid-phase reaction between SO_2 and NO_x absorbed from boiler flue gas. The program objectives were to identify the factors which promote S-N compound formation in wet FGD systems and determine if these compounds change system performance. A three-phase program was conducted which included analytical methods development, bench-scale process simulation, and pilot testing at EPRI's Arapahoe test facility. The test results include the identification of various S-N species in solution and a description of how FGD process conditions affect NO_x removal, S-N formation, and the steady-state concentrations of S-N related species in FGD systems. The test results indicate that the accumulation of S-N compounds can decrease both SO_2 removal efficiency and operating pH. In most systems, however, the concentrations of S-N compounds are expected to be low enough so that the impact on SO_2 removal efficiency is not significant.

Thiosulfate as an Oxidation Inhibitor in Flue Gas Desulfurization Processes: A Review of R&D Results

Gary T. Rochelle and David R. Owens, University of Texas at Austin, Austin, TX; John C. S. Chang, Acurex Corporation, Research Triangle Park, NC; and Theodore G. Brna, U.S. EPA, Air and Energy Engineering Research Laboratory, Research Triangle Park, NC

Sodium thiosulfate ($Na_2S_2O_3$) has been tested in a pilot plant as an oxidation inhibitor in FGD by lime and limestone slurry scrubbing with and without MgO and adipic acid additives. The effectiveness of thiosulfate is proportional to the inhibitor product, defined as the product of thiosulfate concentration (M), calcium concentration (M), and the moles of SO_2 absorbed per hour per liter of hold tank volume. Gypsum saturation was less than 100%, and scaling was eliminated when the inhibitor product exceeded 0.3×10^{-6} M^3/hr. Thiosulfate was relatively more effective in systems with chlorides and less effective in systems promoted by MgO. An inhibitor product greater than 10^{-6} M^3/hr significantly enhanced dewatering of solids from limestone scrubbing. SO_2 removal and/or limestone utilization were increased in systems that started with less than 10 mM dissolved calcium.

Lime Slaking Using Stirred Mills

N. N. Dharmarajan and R. D. Forbus, Central and South West Services, Inc., Dallas, TX

The large tonnages of reagent consumed in lime-based FGD processes require that the lime reagent be slaked at the point of use for maximizing economy of operation. Analysis of commercially available slaking equipment indicated design, operating, and maintenance limitations for our spray dryer FGD project. This necessitated our investigation of new methods for slaking lime. The vertical stirred mill appeared to offer several advantages that are desirable. Some of the perceived advantages were simplicity of design, ease of construction, reduced installed cost, ease of operation and maintenance, and reduced energy costs. This paper presents the equipment features and performance results of a pilot evaluation of a vertical stirred mill in lime slaking service. The many desirable features of the vertical stirred mill are highlighted to support its selection for Coleto Creek Unit 2 dry FGD lime-based process. This is the first known use in the U.S. of lime slaking using a stirred mill for a commercial FGD system.

Limestone Selection and Preparation for FGD

Dorothy Stewart, Electric Power Research Institute, Palo Alto, CA; and J. David Colley, O. W. (Buddy) Hargrove, and A. J. Jones, Radian Corporation, Austin, TX

Limestone properties and preparation for conventional wet scrubbing FGD systems have been investigated in the laboratory and pilot plant with some full-scale tests for comparison. Major factors affecting limestone performance are the pH of the scrubber liquor and the particle size distribution of the limestone. Utilization of the reagent is above 90% when the stone is ground to >90% passing through 325 mesh. To accomplish this grinding, the wet ball mill and tower mill have the greatest efficiency and lowest system cost. Because of the decreased requirement for −325 mesh limestone, a system to grind to 90% −325 mesh is less costly then a system producing only 80% −200 mesh. Limestone tests at the Duck Creek station of Central Illinois Light Co. show that two of the stones tested are less expensive to use than current supply and can maintain desired SO_2 removal. Laboratory evaluation of these limestones did not completely define their behavior at full scale.

Session 5: Materials of Construction

Failure Analysis of FGD System Components

Gary D. Jones, Radian Corporation, Research Triangle Park, NC; Peter F. Ellis II and Dennis M. Anliker, Radian Corporation, Austin, TX; and Dorothy A. Stewart, Electric Power Research Institute, Palo Alto, CA

As part of a program sponsored by EPRI, Radian has analyzed equipment failures at several FGD system installations. Both metallic and non-metallic material failures were encountered. Failures of non-metallic components include a variety of organic coatings applied to vessel walls and rubber linings applied to vessel walls and pump impellers. The metallic failures include air sparger anchors, nozzles, a limestone storage tank, and an agitator shaft. Although some failures were associated with installation, most were attributed to inappropriate materials or improper process operation. For each failure, the most probable cause was determined and recommendations were made to alleviate future occurrences. Several of the analyses and solutions are applicable to other systems where similar failures have occurred. The results illustrate how failure analysis of chronic problems can reduce maintenance requirements of the FGD system.

Performance of Dust and Stack Materials in Wet FGD Systems

H. S. Rosenberg, G. H. Koch, C. W. Kistler, Jr., and J. A. Beavers, Battelle Columbus Laboratories, Columbus, OH; M. L. Meadows, Black & Veatch Engineers-Architects, Kansas City, KS; and D. A. Stewart, Electric Power Research Institute, Palo Alto, CA

Previous field surveys of construction materials for wet FGD systems on utility boilers found that the major problem areas are outlet ducts and stacks. These components are critical in that a failure may result in complete loss of generating capacity for lengthy periods. As part of an EPRI-sponsored study, Battelle analyzed the field performance of two outlet duct linings and three stack materials. The duct linings included a glass-flake-reinforced polyester at San Juan and an hydraulically bonded concrete at Gibson. The stack materials included a mica-flake-reinforced polyester lining at Duck Creek, an Alloy 625 flue at Bruce Mansfield, and an acid-resistant brick and mortar flue at Phillips. The last two materials did not represent actual failures. Field visits were made to each site by specialists to: (1) obtain background information, (2) inspect the duct or stack, and (3) collect samples of the materials for detailed physical and chemical analyses. Results of the analyses were used to evaluate the performance of the materials. Performance was found to depend on the environmental conditions within the duct or stack. The most severe condition seems to occur when wet scrubbed gas is mixed with hot bypassed gas. Characterization of the environmental conditions is important in all cases in order to identify potential materials problems and solve them.

Leaning Brick Chimney Liners at Coal Fired Plants

E. R. Dille and D. L. Krueger, Burns & McDonnell Engineering Company, Kansas City, MO; and R. G. Rhudy, Electric Power Research Institute, Palo Alto, CA

Leaning brick liners in stacks downstream of wet FGD systems are a serious problem that has recently surfaced in the utility industry. While available information suggests that so far the problem affects only a few stacks, the modifications necessary to repair or replace an existing stack liner represent a major investment. To date, little information has been available to determine the nature and extent of the problem. Accordingly, EPRI has initiated a project to evaluate the severity of the problem, identify the cause or causes, and develop preventive measures. This paper documents currently known information on leaning stacks, including what is known about the magnitude and cause of the problem.

The Economics of Clad Metallic Fabrication Versus Solid Alloy Metal Fabrication

E. H. Cloth and R. Kreider, Stone & Webster Engineering Corporation, Cherry Hill, NJ

The purpose of this analysis of FGD materials is to provide economic guidance for selecting a clad metallic fabrication system versus a solid metal fabrication. A simplified FGD tower shell was designed to provide a common basis for the costs. The material and fabrication costs of solid alloys were compared with clad metal fabrications (i.e., roll-bonded, alloy lining) to determine the potential economical savings. Solid alloy materials costs spanned the $2-11/lb range, which included 316L, an austenitic stainless steel, to C-276, a nickel base alloy. The costs included plate or sheet material, weld filler material, and welding man-hour costs. The investigation indicates possible savings for clad alloy fabrications over solid alloy fabrications when the solid alloy cost is in the $2-3/lb range with savings approaching the potential of 30-60% in the higher-priced alloys such as 625 or C-276. The welding of thin alloy sheets, 1/16- and 1/8-in. thick, on a carbon steel shell can also be commercially advantageous in the higher-priced alloys.

Laboratory Evaluation as a Technique for Predicting the Behavior of Organic Coatings in FGD Systems

Malcolm L. White and Henry Leidheiser, Jr., Lehigh University, Bethlehem, PA; and G. H. Koch, Battelle-Columbus Laboratories, Columbus, OH

A laboratory evaluation of several neat resin systems commonly used as the basis for formulated organic coatings in FGD systems was carried out by exposure of coated carbon steel substrates to dilute sulfuric acid at 60°C (140°F) for as long as 3000 hours. Measurements of corrosion potential, ac conductance, tensile adhesion, and weight gain revealed distinct differences in the behavior of the resin types in protecting the steel against corrosion. These results are compared with those obtained in an 18-month field study of formulated coatings (using the same resins as a base material) exposed to the extremely aggressive environment of the outlet mixing zone of the R.D. Morrow, Sr., FGD system. The correlations of resin/coating performance in the actual and simulated FGD environments were investigated with respect to both corrosion protection of the underlying steel and in the modes of failure for those materials that showed poor performance.

Volume 2

Session 6: Panel Discussion on Retrofitting FGD Systems

TVA's SO_2 Control Program

Gerald A. Hollinden, Tennessee Valley Authority, Chattanooga, TN

In the past few years, TVA has implemented various SO_2 emission control procedures on its coal-fired plants; e.g., coal cleaning, limestone-scrubbing FGD, and switching to low-sulfur coals. These emission reduction strategies, in combination with conservation and reduced power demand, improved heat rates, and additional nuclear generation, have greatly reduced the quantity of SO_2 emitted by TVA: the 1983 SO_2 emissions are less than half the 1977 SO_2 emissions. Although great progress has been made, potential changes in SO_2 emission regulations to control acid rain could have profound effects on the use of FGD by TVA and other eastern utilities; e.g., increased use of FGD, upgrading of existing FGD systems, and the accelerated adoption of new technology. With a total FGD capacity of 2500 MW already installed and test facilities for advanced FGD and combustion technology (AFBC) planned, TVA is continuing to assess controlling SO_2 emissions in the future. Even though limestone scrubbing is expected to be the primary method, at least through the year 1999, innovations, such as the use of additives (adipic and dibasic acid), and new processes, such as limestone double alkali and dry FGD (spray dryer), should increase in importance and move into commercial use in the near future, particularly if the need for wider use of FGD occurs. AFBC, in which SO_2 removal is an integral function, is reaching an advanced stage of development and could reduce the use of FGD at new facilities by the latter half of the 1990's.

Randall E. Rush, Southern Company Services, Birmingham, AL

No abstract furnished.

A/E Perspective of Retrofitting FGD Systems

Paul A. Ireland, Stearns Catalytic Corporation, Denver, CO

From our perspective as engineers, we feel it is important to recognize the true cost of retrofitting an FGD system to an existing plant. We also feel that many acid rain related studies may be underestimating these costs. We also share utilities' concerns of minimizing outage time and maintaining existing plant services while the retrofit construction is underway. Often retrofit items can be overlooked; e.g., having to take special precautions when dealing with existing asbestos insulation or having to hand-dig foundations because of underground obstructions. Often, FGD process selection or design will be affected by the space available. Finally, if an FGD system retrofit is required for acid rain compliance, an opportunity may exist to minimize the overall cost by burning a cheaper higher sulfur coal.

The Changing FGD Marketplace

James R. Martin, Combustion Engineering Inc., Birmingham, AL

The demand in the U.S. for FGD systems at the beginning of this decade was concentrated primarily in the utility sector and consisted primarily of new systems in conjunction with utility capacity additions. During the last 5 years, we have seen that demand shrink at an average rate of 50% per year to a very low level. During the next 5 years, however, we can expect an increase in demand for FGD systems. In part, this new demand will be caused by utility capacity additions; but an increasing demand for emission control systems for refuse recovery, cogeneration, and hazardous waste incineration will have a major impact, and FGD system rehabilitation and modifications will also be important.

This presentation outlines the forces that are reshaping the demand for gaseous emission control equipment and how we can expect the technology to adapt to that changing demand.

Retrofitting FGD Systems

Howard Feibus, U.S. Department of Energy, Washington, DC

If legislation is enacted requiring control of SO_2 emissions from pre-NSPS coal-fired power plants in order to reduce acid rain precursor emissions, commercially available technology is essentially limited to coal cleaning, wet scrubbers, and spray dryers. DOE analyses indicate that commercial coal cleaning is of importance but limited value and that the last two would be prohibitively expensive. Developmental technologies that could be available in the late 1980s to mid-1990s offer the potential of improved performance in terms of cost per unit weight of SO_2. These approaches include advanced coal cleaning processes, furnace sorbent injection, fluidized-bed combustion, and duct injection FGD.

Jack F. Stewart, Babcock & Wilcox Co., Barberton, OH

No abstract furnished.

Retrofit Technology Options for Reducing Sulfur Emissions

Stephen M. Katzberger, Sargent & Lundy Engineers, Chicago, IL

A wide variety of technologies are available for reducing sulfur emissions from existing industrial and utility boilers. These technologies may reduce or capture sulfur: (1) prior to combustion by fuel switching, fuel blending, coal gasification, mechanical coal washing, or chemical coal cleaning; (2) during combustion by furnace sorbent injection or fluidized-bed boilers; or (3) after combustion by downstream sorbent injection, wet FGD, or spray drying. Each of these technologies has site-specific advantages and disadvantages in terms of level of development, cost, retrofitability and sulfur reduction potential. Even fuel switching will require equipment modifications. Switching from high sulfur Illinois coal to low sulfur eastern Kentucky coal, for example, may require only minor modifications to ensure safe operation. However, switching to a low sulfur Powder River Basin coal can seriously impact coal handling, boiler performance, gas volume which affects both the fans and ESP, ash resistivity, and ash handling. Unit outage time should be considered in evaluating retrofit options. Since a wet FGD system can be erected with the unit on line, only a 2-3 month outage would be needed to tie into existing ducts. A fluidized-bed boiler retrofit could require a unit outage of 1½ to 2 years to modify most of the boiler. The sensitivity of the total evaluated cost of each alternative to the remaining life of the unit may show that high capital cost technologies, such as wet FGD, are not economically viable for older units without unit life extension. Low sulfur coal conversion, a lower capital cost/higher operating cost option may be selected for units with limited remaining lives or low capacity factors. Furnace sorbent injection might be selected for certain boiler designs and lower sulfur reduction requirements. Similarly, fluidized-bed retrofits may be

favored for units under 200 MW. In other cases, unit retirement may be the best choice.

Issues in Utility SO_2 Control Retrofit

Stuart M. Dalton, Electric Power Research Institute, Palo Alto, CA

Cost, space, risk, energy, and waste disposal are the main issues facing utilities that are considering a retrofit FGD. Most debates have centered on FGD cost, and have normalized the cost in terms of dollars per ton of SO_2 control. Early estimates used in many political debates may have understated costs. EPRI estimates range from $560 to $1120/ton SO_2 removed for conventional wet FGD and $425 to $935 for advanced concepts such as furnace sorbent injection and Chiyoda 121 scrubbing (levelized over 30 years). Several factors cause costs to vary widely. Space constraints can cause costs to increase by over 60% and will preclude FGD on a few installations. Utilities often are unwilling to accept high risk technologies since they cannot shut down if the process doesn't work. Electric energy used for FGD (1-3% of the plant output) is unavailable to meet the peak loads and must be replaced by utilities at premium replacement rates. Waste disposal quantities for midwestern plants can double or even triple in volume compared to untreated plants. These issues make it prudent for utilities to study the alternatives available to them very carefully before committing to a single strategy for their systems.

Session 7: Dual Alkali

Development and Demonstration of a Limestone Dual Alkali FGD Process at Central Illinois Public Service Company's Newton Power Station

Jerry L. Simpson, Central Illinois Public Service Company, Springfield, IL; and James H. Wilhelm, Codan Associates, Sandy, UT

The paper describes the development, implementation, and demonstration of the CIPS/CODAN limestone dual-alkali process at the 595 MW Newton Power Station of CIPS. The paper describes the process, the changes required to convert the original lime dual-alkali process to the use of limestone, operating cost savings, performance goals, and achievements.

Current Operating Experience and Operating Costs of Double Alkali FGD at NIPSCO's R.M. Schahfer Generating Station Unit 17

R. J. Biolchini, W. L. Boward, and B. S. Camponeschi, FMC Corporation, Schaumburg, IL

This paper presents operating experience and 1984 operating costs of FMC's double-alkali FGD system, for the 393 MW, high-sulfur coal-fired boiler at NIPSCO's R.M. Schahfer Generating Station. Test results have shown that the FGD system has met the EPA's 1979 Revised New Source Performance Standards on high sulfur coal and has demonstrated collection efficiencies well above 90%. Average availability during the first 2 years of operation has been 99.97%. FGD system operating costs for 1984 were on the order of 4 mills/kWh.

Current Progress at the FMC Limestone Double Alkali Demonstration Plant

Willard L. Boward, Jr., and Robert J. Biolchini, FMC Corporation, Schaumburg, IL; and Beth A. Wrobel, Northern Indiana Public Service Company, Hammond, IN

The Limestone Double Alkali (LSDA) FGD process combines the reliability and efficiency of sodium scrubbing with the economical use of limestone as the main reagent. Studies sponsored by EPA and EPRI have shown LSDA to be economically desirable for full scale plants when evaluated against other types of wet scrubbers. An LSDA demonstration plant has been in operation since September 1984, at Northern Indiana Public Service Company's R.M. Schahfer Station. The demonstration plant treats a flue gas slipstream from Schahfer Unit 17 which burns high sulfur coal. Results of the first test period is discussed. Period 1 was used to characterize the operation of the system and determine the preferred process settings for the next test. Period 2 will be a long term test of the dependability of the system while maintaining 90% SO_2 removal and following changes in boiler operation. Plans for Period 3, which will determine how well the system responds to stresses, are also discussed. Results in the areas of SO_2 collection, limestone utilization, soda ash consumption, and filter cake percent solids have been encouraging.

Effects of Limestone Type and Grind on Dual Alkali System Performance

John C. S. Chang, Acurex Corporation, Research Triangle Park, NC; and Theodore G. Brna and Norman Kaplan, U.S. EPA, Air and Energy Engineering Research Laboratory, Research Triangle Park, NC

Pilot plant tests were conducted to evaluate the dual-alkali system performance with respect to five types and grinds of limestones. The data show that high purity, high calcium, fine grind limestone should be used for the regeneration of dual-alkali scrubbing solution. Limestone containing more than 0.5% magnesium is not suitable for the dual-alkali process. The accumulation of dissolved magnesium caused performance deterioration and system upset. Experimental techniques which can be used to characterize the limestone reactivities were also evaluated. The reactivities measured by sodium bisulfite titration agreed with pilot plant data.

Session 8: Emerging Technologies

Pilot Evaluation of Combined Particulate and SO_2 Removal Using a Fabric Filter System

Richard G. Hooper, Electric Power Research Institute, Palo Alto, CA; Verle Bland, KVB, Denver, CO; Franz G. Pohl, SoRI, Birmingham, AL; and Michael McElroy and Richard Rhudy, Electric Power Research Institute, Palo Alto, CA

The process of combining SO_2 and particulate control using dry reagents is gaining increased utility interest. This paper reviews and updates events relevant to the injection of both sodium and calcium reagents into a flue-gas stream ahead of a fabric filter. Results are reported from tests conducted at EPRI's Fabric Filter Test Facility at the Arapahoe station of the Public Service Co. of Colorado in Denver, CO, and at EPRI's High-Sulfur Coal Pilot Plant at the Scholz station of the Gulf Power Company near Sneads, FL.

With dry-sodium injection, sodium reagent is fed into the flue-gas stream ahead of a baghouse and downstream of the air heater. In the ductwork, sodium carbonate partially reacts with SO_2 in the flue gas to form a dry powder that collects along with the fly ash on the bags as part of the dust cake where it continues to remove SO_2. This paper gives results for three sodium reagents—sodium bicarbonate, sodium sesquicarbonate, and sodium carbonate. For each reagent, SO_2 removal is determined as a function of reagent particle size and normalized stoichiometric ratio (NSR), and sodium utilizations are compared.

A dry calcium reagent for SO_2 removal is injected in the same manner as sodium, except that water or steam is also injected to condition the flue gas to a desired temperature and humidity. In the duct-work, a portion of the lime reacts with SO_2 to form calcium sulfite and calcium sulfate. This paper: (1) reports on preliminary tests with pressure-hydrated dolomitic lime, and (2) compares calcium utilization and SO_2 removal for five calcium reagents—quicklime, pressure-hydrated high-calcium lime, conventionally hydrated lime, pressure-hydrated dolomitic lime, and pre-calcined pressure-hydrated dolomitic lime.

Investigation of Combined Particulate and SO_2 Using E-SOX

Leslie E. Sparks, Norman Plaks, Geddes H. Ramsey, and Richard E. Valentine, U.S. EPA, Air and Energy Engineering Research Laboratory, Research Triangle Park, NC

Research aimed at developing a low cost retrofit system (called E-SOX, for combined particulate and SO_2 removal) is described. The E-SOX concept centers on recent advances in ESP technology that make it possible to reduce the size of ESPs required for particulate control. Results of mathematical modeling and limited pilot scale experiments on the feasibility of collecting SO_2 in the freed space are discussed. The results show that the concept is technically feasible. Modest (40-65%) levels of SO_2 removal are possible with lime as the reagent. High (over 90%) levels of SO_2 removal are possible with sodium carbonate as the reagent. Order of magnitude economic analysis shows that the process is economically feasible. Plans for additional experimental and theoretical work are presented.

Mitsui-BF Simultaneous SO_x and NO_x Removal System

Yoshiro Ito, T. Fujimoto, and O. Nagaoka, Mitsui Mining Company, Ltd., Tokyo, Japan

Mitsui Mining Company, Ltd. (MMC), has been developing the Mitsui-BF system jointly with Mitsui Miike Engineering Corporation (MMEC) by using activated coke to improve a process originated by Bergbau Forschung GmbH (BF) of West Germany. A pilot plant with a capacity of 1000 Nm^3/h was operated from February 1981 to September 1983 at Tochigi Works of MMEC. Successful long-term continuous operation of the pilot plant was achieved at an efficiency of more than 99% SO_x removal and more than 80% NO_x removal. Based on the results of the pilot plant test performance, MMC gained confidence to apply the new technology to a commercial plant. MMC constructed a plant of 30,000 Nm^3/h capacity at the MMC Coal-fired Power Station in Omuta, Japan. Its commercial operation began on October 1, 1984 and the plant has been operated satisfactorily since then. MMC has been operating an activated coke (AC) production pilot plant with a capacity of 0.8 ton AC/day in an attempt to produce less expensive AC with better performance. This AC was used in the Mitsui-BF plant at Omuta and has shown very satisfactory results. After performance test operation based on a design condition of 99% $DeSO_x$ and 50% $DeNO_x$ was achieved, higher NO_x removal efficiency operation (70-80%) began in February 1985.

Operating Experiences and Developments with Ljungstroem Gas-gas Heaters in West German FGD Plants

David E. Clay, Kraftanlagen Aktiengesellschaft Heidelberg, Heidelberg, Federal Republic of Germany

Regenerative gas-gas heaters have been adopted by the German power industry as the state-of-the-art for reheating scrubbed flue gases. Anticipated fouling and corrosion have proved controllable, and the first large-scale gas-gas heater entered operation in 1982 at NWK Wilhelmshaven. Since then more than 11,000 operating hours have been achieved. Two novel features are incorporated in the design—a cold-side plastic heating element and an on-line high-pressure washing system. Anticipated future SO_2 emission limits of 200 mg/Nm^3 have led to a low leakage design (0.3-0.5%). The operating experiences and developments with the regenerative gas-gas heater are discussed.

SOXAL™ Process

K. N. Mani and F. P. Chlanda, Allied Corporation, Mt. Bethel, NJ

The SOXAL process is a regenerative wet scrubbing system that produces a concentrated SO_2 stream and is applicable for low to high sulfur coals. The SO_2 can be liquefied and converted to sulfuric acid or elemental sulfur. The process is based on the use of a high pH sodium solution as a scrubbing medium to remove the SO_x from the flue gas. The bisulfite salt in the product solution from the absorber is converted to the original sulfite and hydroxide (that are recycled) and an aqueous solution of SO_2 (that is readily stripped to recover concentrated SO_2). The heart of the process is the "Membrane Water Splitter" (AQUATECH cell) that electrodialytically converts salt solutions to their constituent acids and bases at low energy consumption. Key to the operation of the AQUATECH cell is the "bipolar membrane" developed by Allied Corporation. The SOXAL process and the associated membrane technology have been under development at Allied Corporation for over 12 years and are currently being commercialized by its AQUATECH Systems business unit.

Session 9: Spray Dryer FGD

Spray Dryer FGD Experience: Joy-Niro Installations

J. R. Donnelly, A/S Niro Atomizer, Soeborg, Denmark; S. Wilson, Joy Manufacturing Company, Los Angeles, CA; L. P. Matis, Northern States Power Company, Minneapolis, MN; R. Eriksen, Basin Electric Power Cooperative, Bismarck, ND; R. D. Emerson, Sunflower Electric Cooperative, Hays, KS; and J. C. Fooks, Platte River Power Authority, Ft. Collins, CO

Joy-Niro lime-based Spray Dryer Absorption (SDA) FGD systems are in commercial operation on the following coal-fired utility boilers: (1) Riverside Generating Station—Units 6 and 7; (2) Antelope Valley Station—Unit 1; (3) Holcomb Generating Station—Unit 1; and (4) Rawhide Generating Station—Unit 1. More than 9 years of operating experience have been accumulated by these stations. These systems employ spray dryer absorbers, equipped with single rotary atomizers, and reverse air bagfilters for SO_2 and particulate removal. The systems range in size from 0.6 to 2.1 million acfm (110 to 450 MW) and treat flue gases from the firing of North Dakota lignite, Powder River Basin subbituminous coal, and a blend of subbituminous coal and petroleum coke. Each system incorporates unique site specific design features for the flue gas cleaning systems and for waste conditioning/disposal. This paper compares the plant designs and performances. Compliance/performance test results are compared to design values. Start-up problems are reviewed, and current plant reliability is discussed. Waste conditioning and disposal practices at each site are described, and results of physical/chemical tests of the end product are presented.

Problem Solving and Results of Performance Test at United Power Association Stanton Station Dry FGD System

Ghassem B. Manavizadeh and Stefan Negrea, Research-Cottrell, Inc., Somerville, NJ; Gordon Westerlind, United Power Association, Elk River, MN; and Alan W. Ferguson, Black & Veatch Engineers-Architects, Kansas City, MO

Use of data acquisition and management techniques of solving problems associated with spray driers and fabric filters is discussed. Methods of cooperation between the owner, A/E, and the system supplier are highlighted. Results of the first FGD performance test, a 60 day reliability test, its inconclusive results and the improvements generated by its data, as well as the preliminary final performance test (1 year after the initial test) are presented. The system design, field modifications, and its operation are described. Using methods specified by EPA for compliance testing, guaranteed SO_2 removal efficiency and particulate emission were achieved at the UPA Stanton dry FGD unit. Preliminary data are also presented on use of sonic horns for reducing pressure drop in fabric filters and their effect on SO_2 removal and particulate emission.

High-Sulfur Spray Dryer Evaluations

Russell F. Robards and Robert W. Aldred, Tennessee Valley Authority, Chattanooga, TN; Thomas A. Burnett and Lynn R. Humphries, Tennessee Valley Authority, Muscle Shoals, AL; and Michael J. Widico, Research-Cottrell, Inc., Somerville, NJ

The TVA initiated a program in 1983 to evaluate a pilot lime spray dryer/baghouse FGD system treating flue gas from the combustion of high-sulfur coal (3.2% S as-fired) at the Shawnee Test Facility. Testing was performed to determine the effects of the major spray dryer operating variables on the spray dryer, the baghouse, and the overall SO_2 removal efficiencies of the system. Variables which were evaluated include lime stoichiometry, approach-to-saturation temperature, recycled solids, flue gas residence time in the spray dryer, atomizer speed, and inlet flue gas temperature. As expected, SO_2 removal efficiency is a strong function of lime stoichiometry and approach-to-saturation temperature. Recycled solids and the inlet flue gas temperature are also important, but atomizer speed and residence time seem to have little, if any, impact over the ranges tested. The most important conclusion is that a spray dryer/baghouse FGD system can attain a sufficiently high SO_2 removal efficiency to meet a 1.2 lb $SO_2/10^6$ Btu emission regulation (currently imposed at TVA's Shawnee Steam Plant) when treating flue gas from the combustion of high-sulfur coal. However, careful consideration of the major independent variables is necessary to attain this goal.

Recent Results from the EPRI 2-1/2 MW Spray Dryer Pilot Plant

Richard G. Rhudy, Electric Power Research Institute, Palo Alto, CA; and Gary M. Blythe, Radian Corporation, Austin, TX

Since January 1984, testing on the EPRI 2-1/2 MW spray dryer/fabric filter FGD pilot plant has centered on variations of the basic FGD system. Results presented in this paper demonstrate the effects of the use of several cooling tower blowdown waters for lime slaking and/or process dilution, the effects of calcium chloride as a system performance additive, and the impacts on SO_2 removal of the use of warm (spray dryer inlet) gas bypass around the spray dryer to reheat the fabric filter inlet gas by 20-40°F. Additionally, results are presented which relate process variations to fabric filter performance; e.g., corrosion tendencies and tube-sheet pressure drop. Data are presented which compare the tube-sheet pressure drop history for bags in the fabric filter compartment downstream of the spray dryer to that for bags in a control compartment that is filtering hot, untreated flue gas. Finally, data are presented which relate these process variations to the disposal properties of solids collected in the fabric filter.

Performance of a Spray Dryer/ESP Flue Gas Cleanup System During Testing at the Pittsburgh Energy Technology Center

James T. Yeh, Charles J. Drummond, and James I. Jouberg, U.S. Department of Energy, Pittsburgh, PA; and Dennis M. Tulenko, Robert R. Crynack, and Martin L. Hochhauser, Wheelabrator Air Pollution Control, Pittsburgh, PA

Wheelabrator Air Pollution Control and the U.S. DOE jointly sponsored a project to characterize the performance of a spray dryer FGD system using flue gas from the combustion of different types of coal, and to study the effectiveness of an electrostatic precipitator (ESP) in controlling particulate emissions from this system. Three different coals (low-, medium-, and high-sulfur coal) were burned in a 500 lb/hr pulverized-coal combustion test facility at the Pittsburgh Energy Technology Center. SO_2 was removed from the flue gas by injection of a lime slurry in a spray dryer. Particulate emissions were controlled using a mobile ESP. For each fuel, a three-part test program was conducted: (1) base-line ESP performance tests without spray dryer operation to determine requirements for fly ash collection; (2) parametric tests defining SO_2 removal efficiency and ESP collection efficiency at various spray dryer operating conditions; and (3) sorbent recycle tests in which the particulate collected by the ESP was recycled by injection into the spray dryer with the fresh sorbent to improve reagent utilization. Test results show that SO_2 removal efficiencies of 90% can be achieved for each of the coals tested using the combined spray dryer and ESP system for emissions control. Performance criteria for the ESP were met during all tests.

Application of Electrostatic Enhancement of Fabric Filtration to Spray Dryer Byproduct

L. S. Hovis and Bobby E. Daniel, U.S. EPA, Air and Energy Engineering Research Laboratory, Research Triangle Park, NC; Yang-Jen Chen, Joy Industrial Equipment Co., Los Angeles, CA; and R. P. Donovan, Research Triangle Institute, Research Triangle Park, NC

Experiments conducted at small pilot scale show that the pressure drop increase during the fabric filtration of redispersed spray dryer by-product (chiefly calcium salts and fly ash) is significantly reduced through electrostatic enhancement of the filtration. The pressure drop rise for a typical electrostatic augmented fabric filtration (ESFF) is only 25% or less of that of the rise for a conventional filtration cycle. The ESFF takes advantage of the relatively lower electrical resistivity of the spray dryer by-product attributable to the high moisture content and to the low temperature at which the filtration of spray dryer by-product is carried out. A low resistivity allows application of greater electrode potentials than can be used at normal fly ash filtration conditions.

Comparison of Pilot Plant Data with Predictions from the U.S. EPA SPRAYMOD Computer Program

Wayne T. Davis, Gregory D. Reed, and George P. Partridge, The University of Tennessee, Knoxville, TN; and Theodore G. Brna, U.S. EPA, Air and Energy Engineering Research Laboratory, Research Triangle Park, NC

The use of computer models allows the user to predict conditions which may not have been tested in spray dryer/fabric filter applications. This paper presents a preliminary comparison of the U.S. EPA-developed SPRAYMOD computer program with five different data bases collected at the University of Tennessee on a 1000 cfm spray dryer utilizing a $Ca(OH)_2$ slurry. Results are presented from a variety of operating conditions for the spray dryer without recycle, including:

SO_2 concentration:	1000-3100 ppm
Inlet temperature:	138-177°C (280-350°F)
Approach to saturation (AT):	9-20°C (16-35°F)

Conclusions regarding the ability of the program to predict the actual behavior of the pilot plant are: (1) with the proper choice of a reaction rate coefficient, the plug flow model reliably predicted the performance for low SO_2 concentrations (1000-1100 ppm) and approaches to saturation in the range of 16-35°F, and (2) the model tended to overpredict performance for higher SO_2 concentrations (2000-3000 ppm).

Session 10: FGD By-Product Disposal/Utilization

Gypsum By-Product FGD System

W. A. Liegois and D. A. Wicks, Stanley Consultants, Inc., Muscatine, IA

This paper summarizes the start-up of the FGD system on Unit 9 of Muscatine Power and Water. This FGD system has a guaranteed removal efficiency of 96% of the SO_2 from the flue gas and was the first unit in the U.S. designed to produce a gypsum by-product. Operating problems associated with the system are discussed, along with system availability and by-product quality.

By-Product Gypsum Production at a 2300 MW Power Plant

Don Mzyk, Texas Utilities Generating Co., Tatum, TX; and Jan Zmuda, Research-Cottrell, Inc., Somerville, NJ

The Martin Lake Station of Texas Utilities consists of three 770 MW boilers firing lignite coal. Each boiler is equipped with a Research-Cottrell limestone FGD system. The FGD systems were originally designed to produce a sulfite sludge to be blended with fly ash for disposal. In early 1983 each FGD system was retrofitted with equipment for in-situ oxidation to produce a calcium sulfate (gypsum) by-product. This paper discusses start-up and testing of the forced oxidation system. Utility operating experience, which led to the signing of a contract for the sale of commercial grade gypsum for wallboard manufacture, is also discussed.

Evaluation of Engineering Properties and Wet Stacking Disposal of Widows Creek FGD Gypsum-Fly Ash Waste

John E. Garlanger, Ardaman & Associates, Inc., Orlando, FL; Sal H. Magliente, Tennessee Valley Authority, Chattanooga, TN; Thomas S. Ingra, Ardaman & Associates, Inc., Orlando, FL; and James L. Crowe, Tennessee Valley Authority, Chattanooga, TN

Wet stacking of by-product gypsum has been practiced by the phosphate fertilizer industry for more than 25 years. The use of wet stacking for disposal of FGD gypsum was first demonstrated during an EPRI-sponsored project on Chiyoda Thoroughbred 121 FGD gypsum produced at the Scholz Electric Generating Station of Gulf Power Company in Sneads, FL. Wet stacking of FGD gypsum containing fly ash, however, has not been previously demonstrated. Accordingly, as part of an overall project investigating various FGD waste disposal alternatives, the TVA constructed a pilot-scale wet-stacking disposal facility to evaluate the feasibility of wet stacking FGD gypsum-fly ash waste produced at the Widows Creek Steam Plant in Stevenson, AL. Operational experience and results from geotechnical laboratory testing performed on the waste are presented. The results indicate that, although the Widows Creek FGD gypsum-fly ash had settling, dewatering, and structural characteristics not as favorable for stacking as phosphogypsum or CT 121 FGD gypsum, they were adequate for wet stacking. Therefore, the project findings should extend the ability of the utility industry to employ wet stacking disposal to facilities that also use FGD/forced oxidation systems as the primary particulate removal process.

Solids Handling and Dewatering Optimization at Colorado Ute's Craig Station

O. W. (Buddy) Hargrove and David R. Owens, Radian Corporation, Austin, TX; Dorothy A. Stewart, Electric Power Research Institute, Palo Alto, CA; and Jim Renner, Colorado Ute, Montrose, CO

Units 1 and 2 at Colorado Ute's Craig Station include wet limestone scrubbers for SO_2 emissions control. Because the SO_2 concentration in the gas is very low, the solids formed are completely oxidized. Normally, gypsum produced in a limestone FGD system dewaters and handles relatively well. However, the centrifuge product at Craig fluidizes when shear forces are applied and, as a result, cannot be transported in an open truck. EPRI, Radian, and Colorado Ute have been investigating the poor handling properties of these solids over the past 3 years. The fluid properties of the solids are a result of the fine crystals in the product cake which may be caused by a number of factors. This paper discusses possible causes of the cake properties and methods to optimize the performance of the dewatering equipment. A comparison of full-scale centrifuge and pilot-scale vacuum filter results is included.

EPRI Research on Management of Wastes from SO_2 Control Processes

Dean M. Golden, Electric Power Research Institute, Palo Alto, CA; and Russell H. Boyd, Envirosphere Company, Norcross, GA

EPRI is keenly aware of the many issues facing the electric utility industry in the area of controlling flue gas emissions from coal-fired power plants, particularly SO_x. Virtually all facets of the question of how to control SO_2 emissions have been or are under consideration by EPRI in one or more research programs. In closing the loop on the question of SO_2 control technologies, however, EPRI recognized that the management of solid wastes from the new control technologies had not been examined in depth. This paper describes the research EPRI is conducting with regard to management of these wastes. Preliminary results of the research project are discussed. The research project focuses on spray drying, atmospheric fluidized-bed combustion, limestone furnace addition, dry sodium addition, and advanced physical coal cleaning. Within the project are activities dealing with information surveys and assessments, waste characterization, leachate testing, conceptual designs, case studies, and utilization options. The project is comprehensive in scope and will be providing topical reports on various activities during the next 3 years.

Thermal Oxidation of Spray Dryer FGD Waste Product

S. Bengtsson and S. Ahman, Flakt Industri AB, Zaxjo, Sweden; T. Lillestolen, Flakt, Inc., Knoxville, TN; and G. Koudijs, Dorr-Oliver B.V., Stamford, CT

Spray dryer FGD for coal-fired boilers using low- and medium-sulfur coals has become an important technology. Typically, the FGD end product has been disposed of, untreated, in landfills. In some countries in Europe, disposal by these means is not permitted; i.e., the FGD end product must be reclaimed for alternate use. To meet this requirement, Flakt entered into a cooperative agreement with Dorr-Oliver to develop a thermal oxidation system based on the Dorr-Oliver FluoSolids Technology. This system provides for the calcination of the dry FGD end product to produce a technical grade, anhydrous calcium sulfate, which can be used as a setting retarder for Portland cement. This paper describes the process and presents operating experience and test results from both a pilot plant program and a demonstration plant (2.5 metric ton/hour) test program. It also describes how this process has been integrated into a commercial spray dryer FGD system recently sold by Flakt in the Federal Republic of Germany.

Unpresented Papers

Reliability Problems and Solutions of FGD Systems

D. C. Agarwal, Cabot Corporation, Kokomo, IN

Four Corners 4 and 5 Waste Processing System: An Integrated and Unique Retrofit

Alexander P. Simko, Arizona Public Service Company, Phoenix, AZ; Richard R. Lunt, United Engineers and Construc-

tors, Inc., Philadelphia, PA; and Charles S. White, Conversion Systems, Inc., Horsham, PA

Corrosion Resistance Comparison of Duplex Stainless Steel with Type 317LM in Simulated Flue Gas Scrubber Environments

Ronald E. Van Hoose and John B. Guernsey, Eastern Stainless Steel Company, Baltimore, MD

Corrosion Resistance of a Cr-Ni-Mo-Cu-Fe Alloy in Scrubber Environments and Other Chemicals

Terry A. DeBold, Douglas G. Frick, and Gerald A. Bauer, Carpenter Technology Corporation, Reading, PA

The Chemistry of Sodium Dry Sorbent Injection

A. W. Mueller and A. E. Winston, Church & Dwight Co., Inc., Piscataway, NJ

Techno-Economic Investigation into the Hybrid Technology of FGD and PCC Applied to Large Boilers of Firing Canadian Coals

R. L. Wang, Consultant, St. Catharines, Ontario, Canada

Size Measurements in Aerosols Produced in Sulphur Dioxide Removal by Electron Beams

M. D. Carabine, P. G. Clay, and G. Sisniega, Imperial College, London, England

The NOXSO Process Development: An Update

J. L. Haslbeck and L. G. Neal, NOXSO Corporation, Library, PA

F. Ayer and A. Wallace are with the Research Triangle Institute, Research Triangle Park, NC 27709.

***Julian W. Jones** is the EPA Project Officer (see below).*

The complete report consists of two volumes, entitled "Ninth Symposium on Flue Gas Desulfurization:"

"Volume 1. Sessions 1 through 5," (Order No. PB 86-138 641/AS; Cost: $34.95

"Volume 2. Sessions 6 through 10 & Appendix," (Order No. PB 86-138 658/AS; Cost: $46.95)

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