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IN THIS ISSUE

This issue of the *FGD Quarterly Report* features an article on the recent Fifth EPA-Industry Briefing on FGD Lime/Limestone Wet Scrubbing. The article summarizes presentations given at the conference concerning various aspects of EPA's ongoing research and development program at the Tennessee Valley Authority's Shawnee Steam Plant in Kentucky.

This issue also includes more information on the Sixth FGD Symposium, to be held October 28-31 in Houston. The symposium, sponsored by IERL-RTP, provides a forum for exchanging information on commercial and developing FGD technology. Early registration for the symposium is recommended.

Additional topics include a new technology assessment report on FGD systems for industrial boiler applications, a report on Phase II of a dual-alkali demonstration program, and highlights of the Second Conference on Air Quality Management in the Electric Power Industry.

The *FGD Quarterly Report* summarizes recent developments in EPA-sponsored and conducted activities in flue gas desulfurization (FGD). It is distributed by IERL-RTP without charge to persons interested in FGD. Those wishing to initiate or cancel their subscriptions to the *FGD Quarterly Report* may do so by contacting the EPA Project Officer or Radian Project Director named on page 11 of this issue. Any change of address should also be reported.

EPA HOLDS FIFTH LIME/LIMESTONE SCRUBBING INDUSTRY BRIEFING

Over 100 representatives of industry, academia, and government gathered recently in Raleigh, North Carolina, for the Fifth Industry Briefing on Lime/Limestone Wet Scrubbing. Sponsored by EPA's Industrial Environmental Research Laboratory at Research Triangle Park, North Carolina (IERL-RTP), the program focused mainly on EPA's R&D program at the Tennessee Valley Authority's (TVA's) Shawnee Steam Plant near Paducah, Kentucky. Several presentations at the Industry Briefing reported recent results from studies at Shawnee and from Shawnee-related programs. These papers are summarized below.

In his opening remarks to the assembled audience, M. A. Maxwell, Chief of the Emissions/Effluent Technology Branch at IERL-RTP, noted that as EPA's research effort at Shawnee enters the 1980's, the program now spans three decades. Shawnee results have played a major role in current understanding of lime/limestone FGD. Maxwell added, "We have gone far beyond what we initially expected to learn there."

SO_2 Removal Efficiency Related to Limestone Type and Grind

R. H. Borgwardt, of IERL-RTP, reported on recent limestone type-and-grind tests at EPA's pilot plant at Research Triangle Park. Previous studies have shown that SO_2 removal efficiency is related to both the type and grind of limestone. This phenomenon has been studied further in the pilot plant scrubber, which is a single-loop turbulent contact absorber (TCA) similar to conventional FGD systems now in operation. The TCA has been operated with three types of high-calcium limestones: Stone Man, Fredonia, and Georgia Marble. The Stone Man limestone is of special interest because it is used at TVA's full-scale FGD system at Widows Creek.

The pilot plant type-and-grind tests have been conducted in preparation for more extensive study to begin next year at the

Shawnee Test Facility. Pilot plant test results thus far corroborate earlier findings that both type and grind of limestone significantly affect the SO_2 removal efficiency in the single-loop TCA. Fredonia yielded the greatest SO_2 removal, followed by Stone Man and then Georgia Marble. At a stoichiometric ratio of 1.5, SO_2 removal efficiencies were 88, 74, and 70 percent, respectively, for fine grinds of Fredonia, Stone Man, and Georgia Marble. (Stoichiometric ratio is defined as moles $CaCO_3$ fed/moles SO_2 absorbed.)

Test results also support a TVA economic study which ranked fine grinds of limestone as more cost effective than coarse grinds. To maintain a given SO_2 removal, the coarse grinds required about 50 percent greater limestone feed rates than did fine grinds. Thus, the higher capital investment and power required for the grinding equipment used to produce smaller limestone particles should be more than offset by the lower costs for raw limestone makeup and waste disposal. The latter advantage may be diminished, however, by an adverse effect of limestone grind on waste product quality; the pilot plant tests averaged about 60 percent solids in filtered wastes obtained with coarse limestone feeds, and 55 percent solids with fine-grind feeds.

Studies Confirm Advantages of Adipic Acid Addition

A major goal of EPA's alkali wet scrubbing test program over the past 17 months has been to evaluate the use of adipic acid as a scrubber additive. Adipic acid has been shown to improve SO_2 removal efficiency by buffering the pH in lime/limestone scrubbers. EPA tests have focused on the capability of adipic acid to enhance SO_2 removal and improve the reliability and economics of lime/limestone wet scrubbing. These studies have been underway both at IERL-RTP's pilot plant and at the Shawnee Test Facility. Recent results from the Shawnee test program were presented by Project Manager D. A. Burbank of Bechtel National, Inc.

Both scrubber systems at Shawnee have been operated with the adipic acid additive. One scrubber is a venturi followed by a spray tower (V/ST), with a capacity of 38,320 Nm^3/hr (23,950 scfm); the other is a turbulent contact absorber (TCA), with a capacity of 32,848 Nm^3/hr (20,530 scfm).

Test results show several benefits associated with the use of adipic acid as a scrubber additive. Adipic acid does significantly enhance SO_2 removal at an optimum concentration range of 700-1500 ppm. In addition, adipic acid can be effectively used at a relatively low scrubber inlet pH of around 5.2. This pH favors higher limestone utilization which in turn reduces the quantity of resultant waste solids and contributes to reliable scrubber operation.

Adipic acid addition has several advantages when compared to other scrubber additives, such as magnesium oxide (MgO). Unlike MgO, its effectiveness is not altered by chlorides; thus apidic acid is especially attractive for closed-liquor-loop operation. In addition, adipic acid can be effectively used during operation with forced oxidation to yield a waste product with improved dewatering properties. Finally, adipic acid has lower projected capital and operating costs than either MgO-promoted or unenhanced lime or limestone processes, and it should promote the use of limestone, a more economical and less energy-intensive reagent than lime.

EPA is continuing to study adipic acid addition during 1980. Studies are planned to evaluate further the degradation phenomenon, the effects of low pH on SO_2 removal, and economics. EPA will also undertake adipic acid addition in a full-scale power plant scrubber to demonstrate its ability for improving the overall performance of limestone FGD systems.

Computer Economics Program Is Expanded

The Shawnee lime/limestone computer economics program now has several new capabilities, according to C. D. Stephenson of TVA. The computer program, developed by TVA and Bechtel National, Inc. for EPA, is based on actual data obtained at the Shawnee Test Facility. It projects comparative investment and revenue requirements for lime and limestone scrubbing systems and estimates the relative economics of these systems for various process design alternatives as well as for variations in the values of independent design parameters. In addition to a turbulent contact absorber, a venturi/spray tower and a spray tower have been incorporated as scrubbing options. The program has also been expanded to include particulate removal costs and the alternative of using chemical additives such as adipic acid and magnesium oxide. A new forced oxidation option is now also available. More capabilities will be added later as additional test data from Shawnee are generated.

TVA has loaded a version of the program onto the Control Data Corporation's national time-sharing computer system. An outside user can access the computer by means of an interactive time-sharing terminal. TVA will also make specific computer runs for those without computer facilities. In addition, a potential user can request a tape copy of the program which TVA will provide along with available documentation for running it. Requests should be addressed to:

C. D. Stephenson or R. L. Torstrick
Emission Control Development Projects
Office of Power
Tennessee Valley Authority
Muscle Shoals, Alabama 35660

TVA has also prepared a users manual for the overall program (EPA-600/7-79-210, see "FGD Reports and Abstracts").

Additional information on TVA's FGD design and cost studies is available in the *FGD Quarterly Report*, Volume 3, Number 3.

Cocurrent Scrubbing: Efforts to Improve System Reliability

TVA has been studying cocurrent scrubbing since 1976, when it undertook a 1-year pilot test of the concept. Pilot test results showed that cocurrent scrubbing merited further consideration, and TVA subsequently designed and began operating a 10-MW prototype cocurrent lime/limestone scrubber at the Shawnee Test Facility. Funds for this initial phase of the TVA prototype study were provided by the Electric Power Research Institute (EPRI). TVA later assumed complete responsibility for the program and initiated the second phase of the Shawnee cocurrent scrubber test program.

In cocurrent scrubbing the flue gas is contacted by a cocurrent (as opposed to countercurrent) flow of scrubbing slurry. The cocurrent scrubber's smaller physical size and particular equipment configuration result in lower capital investment and operating costs, making it an attractive alternative to the more traditional countercurrent scrubber.

J. L. Henson of TVA described the highlights of both the EPRI and TVA scrubber test programs. The goals of the EPRI test program at Shawnee were to:

- Identify operating conditions that maximize SO_2 and particulate removal from the flue gas.
- Demonstrate system reliability.
- Determine design parameters for scale-up to a commercial-size unit.

During the EPRI test program, the scrubber demonstrated an SO_2 removal efficiency of greater than 90 percent and a particulate removal efficiency of approximately 99 percent. These results were achieved while the scrubber operated at a superficial gas velocity of 8.2 m/s (27 ft/s) with either a lime or limestone absorbent. However, total system reliability was not demonstrated at this scrubber gas velocity because solids were deposited in the mist eliminator and reheater.

Recent TVA testing at Shawnee has focused on eliminating the problem of solids deposition. The problem has been solved by reducing the superficial gas velocity in the scrubber to 6.1 m/s (20 ft/s). Operation at this lower velocity reduces the amount of entrained slurry leaving the absorber and improves mist eliminator efficiency.

Emphasis in the continuing TVA test program will be on achieving reliable operation of the mist eliminator and reheater when the scrubber gas velocity is 8.2 m/s (27 ft/s). Studies will also concern the use of forced oxidation in the cocurrent scrubber as a means of improving the dewatering properties of the waste solids.

Widows Creek Project Demonstrates Forced Oxidation in Full-Scale Limestone FGD System

R. A. Runyan of TVA summarized the status of the forced oxidation project which has been underway since early 1979 at TVA's Widows Creek Facility. The general goals of the project are to:

- Demonstrate forced oxidation as a viable alternative for the disposal of FGD wastes.
- Acquire data to serve as a basis for designing and installing additional forced oxidation FGD systems at Widows Creek.

Forced oxidation of calcium sulfite ($CaSO_3$) to calcium sulfate ($CaSO_4$) can significantly improve the dewatering properties of FGD wastes. This reduces the area required for disposal sites and also improves site stability.

The Widows Creek forced oxidation FGD system has achieved 95 to 99 percent oxidation of calcium sulfite to sulfate, and this, in turn, has yielded a filter cake containing 80-85 percent solids. The SO_2 removal efficiency was initially lower than the 85 percent minimum required by the test plan; however, after some scrubber modifications the system achieved 88 to 92 percent SO_2 removal. The air stoichiometry (ratio of O required to SO_2 absorbed) at these higher removal efficiencies has been 1.8 to 2.0, while the limestone stoichiometry (ratio of $CaCO_3$ required to SO_2 absorbed) has been 1.2 to 1.4

Combined Methods Improve Automatic Control of FGD Systems

Results from studies conducted by the University of Cincinnati for EPA indicate that a combination of stoichiometric and pH control is an effective method for controlling the limestone feedrate to the recirculating slurry. Proper control of the limestone feedrate is required to alleviate such major problems as internal scaling and insufficient removal of SO_2. This in turn can increase system reliability and reduce operating costs.

P. Garrett of the University of Cincinnati described the three limestone feedrate control methods that were assessed during the study:

- Stoichiometric control (based on slurry material balance measurements).
- Slurry pH control.
- Combined stoichiometric and pH control.

Although stoichiometric control and slurry pH control by themselves can improve system performance, there are deficiencies associated with each individual method. However, both methods may be applied simultaneously to control limestone feedrate and thus minimize disorders in the recirculating slurry to a greater extent than either method alone.

Mathematical process modeling and computer simulation were used to study each automatic control method. Additional experiments were conducted at the Shawnee Test Facility, where the controls were tested on the TCA limestone scrubber. The Shawnee tests confirmed that improved regulation of the limestone slurry, even with major load disturbances, is achieved by combined stoichiometric and pH control.

Waste Disposal Studies Focus on Water Quality and Land Reclamation

Chemical treatment of FGD wastes prior to disposal does reduce the environmental threats posed by these materials, according to J. Rossoff of the Aerospace Corporation. This conclusion is based on results from an ongoing 5-year study of various methods of FGD waste disposal at the Shawnee Test Facility. Both ponding and landfilling are being examined, with particular attention to water quality and land reclamation.

Some major results from these efforts are that:

- Chemical treatment of FGD wastes before ponding produces a structurally stable material and reduces concentrations of major species in the leachate (i.e., sulfates, calcium salts, and chlorides) by about 50 percent. Chemically treated wastes also show a reduced permeability coefficient (by at least one order of magnitude) compared to untreated wastes, and are capable of shedding water to prevent seepage.
- Underdraining untreated waste ponds can control seepage while simultaneously dewatering the waste materials to yield a structurally sound material; all seepage can be recycled to the scrubber.
- The load-bearing strengths of gypsum filter cakes stacked at surface sites may be vulnerable to the detrimental effects of weathering, rewetting, and reslurrying, especially in the case of small piles having large surface-to-volume ratios.
- Cost estimates for disposal (mid-1980 dollars) range from 0.65 to 1.25 mills/kWh ($5.90 to $11.85/ton of dry material). Ponding on indigenous liners was the cheapest method studied; chemical treatment was most expensive.

FGD wastes for this project are produced by each of two scrubber systems in operation at the Shawnee Test Facility: a turbulent contact absorber (TCA) and a venturi and spray tower (VST). The waste materials produced by these FGD systems include lime and limestone wastes, and wastes oxidized to gypsum.

SIXTH FGD SYMPOSIUM SCHEDULED FOR OCTOBER

EPA's Sixth FGD Symposium, scheduled for October 28-31, 1980 in Houston, Texas, will feature several new developments in FGD technology. The symposium, sponsored by EPA/IERL-RTP, is the latest in an ongoing series of information exchanges on FGD. Participants will include industry representatives, process owners and operators, vendors, researchers, and government officials. Primary emphasis will be on recent technological and regulatory developments affecting the application of FGD to utility and industrial boilers.

The symposium will be organized into several major sessions in addition to a panel discussion. The introductory session will include the keynote presentation, an energy control technologies forecast, a discussion of the implications of acid rain for FGD, and the economics of FGD. The FGD research and development plans of the Department of Energy, the Electric Power Research Institute, and the Tennessee Valley Authority will also be featured.

The keynote speaker at the Sixth FGD Symposium will be Congressman Robert Eckhardt of the 8th District of Texas. Congressman Eckhardt has extensive experience in energy and environmental legislation. He was actively involved in developing the Clean Air Act Amendments, the Resource Conservation and Recovery Act (RCRA) superfund legislation, and the Coal Slurry Pipeline Bill.

The panel discussion will consider the impacts of recent legislation and regulations. The panel, which was extremely informative at the last FGD symposium, will be chaired by W. C. Barber, Deputy Assistant Administrator for EPA's Office of Air Quality Planning and Standards.

The remainder of the symposium will consist of four major sessions:

- Utility Applications—pilot/prototype testing and full-scale utility installations.
- By-Product Disposal/Utilization—full-scale field studies, engineering cost estimates for RCRA compliance, alternate disposal options, and ash utilization/procurement guidelines development.
- Dry Scrubbing—economics, utility applications, and pilot plant and full-scale demonstration testing.
- Industrial Applications—review of industrial boiler FGD technology, status of New Source Performance Standards for industrial boilers, disposal of waste from sodium-based FGD, and commercial operating experience.

For more information concerning the technical content of the symposium, contact J. W. Jones, IERL-RTP, (919) 541-2489 or (FTS) 629-2489. Advance registration forms and hotel reservation information are available from Franklin A. Ayer, Research Triangle Institute, P. O. Box 12194, Research Triangle Park, North Carolina 27709; (919) 541-6000. Early registration is recommended.

STUDY RELATES ADIPIC ACID DEGRADATION TO SULFITE OXIDATION

A recent study supports IERL-RTP and Shawnee field tests which show that adipic acid added to an SO_2 wet scrubber is consumed during the process. *Adipic Acid Degradation Mechanism in Aqueous FGD Systems* (EPA-600/7-79-224), prepared by Radian Corporation, concludes that the degradation rate of the adipic acid depends, in part, on the degree of sulfite oxidation occurring in the scrubber system.

When added to FGD systems, adipic acid buffers the scrubbing liquid and enhances liquid phase mass transfer. This, in turn, improves both SO_2 removal and limestone utilization. However, in recent studies at IERL-RTP and Shawnee, substantial losses of adipic acid have occurred in excess of those expected. Unaccounted losses of up to 80 percent of the adipic acid makeup were observed in the Shawnee venturi/spray tower scrubber system.

The goal of this study was to verify the loss of adipic acid during scrubbing and determine its cause. Samples were collected from the Shawnee and RTP SO_2 wet scrubbers during adipic acid tests to determine the concentrations of adipic acid and any degradation products. Laboratory bench-scale studies were also conducted to determine the effect of operating variables on adipic acid degradation.

The major conclusion of the study is that adipic acid decomposition is related to sulfite oxidation. Thus, the loss of adipic acid can theoretically be minimized by lowering the rate of sulfite oxidation. The principal degradation mechanism is an oxidative decarboxylation reaction yielding valeric acid, butyric acid, glutaric acid, and CO_2. This reaction was reproduced in the laboratory.

Since the quantities of products measured in the laboratory tests accounted for only about 30 percent of the adipic acid loss, additional experiments were recommended (and are now underway) to refine the material balances.

For additional information contact the EPA/IERL-RTP Project Officer R. H. Borgwardt, (919) 541-2336 or (FTS) 629-2336. (See also the feature article and "FGD Reports and Abstracts" in this issue.)

PHASE II OF DUAL-ALKALI DEMONSTRATION COMPLETED

A two-volume publication (executive summary and full report), summarizing Phase II of EPA's full-scale dual-alkali demonstration project, is now available. The dual-alkali process developed by Combustion Equipment Associates, Inc. (CEA) and Arthur D. Little, Inc. (ADL) is installed at Louisville Gas and Electric Company's (LG&E's) Cane Run No. 6 Station. EPA has selected this system as a demonstration plant for concentrated-mode dual-alkali technology and is participating with LG&E in the design, operation, testing, and reporting of the project.

The work under the demonstration project is divided into four phases:

- Phase I—preliminary design and cost estimate.
- Phase II—engineering design, construction, and mechanical testing.
- Phase III—start-up and acceptance testing.
- Phase IV—a 1-year operating and test program.

Results from Phase I have been summarized previously (EPA-600/7-78-010 and -010a, see the *FGD Quarterly Report*, Volume 2, Number 3). The Phase II report (EPA-600/7-79-221a and -b, see "FGD Reports and Abstracts") describes final engineering design, construction, and mechanical testing, as well as the installed system capital costs shown below. These costs represent as-incurred costs plus estimated costs for completion (construction of the waste disposal facilities is not complete). Costs for spare parts are included in the material costs.

The dual-alkali system at Cane Run is designed to control SO_2 emissions to less than 200 ppm (dry basis without additional air dilution) when treating flue gas generated by burning coal containing up to 5 percent sulfur. When coal containing greater than 5 percent sulfur is fired, the system is designed to remove at least 95 percent of the SO_2 in the inlet flue gas.

The purpose of the installation and operation of this demonstration system is to establish:

- Overall performance, including SO_2 removal, lime utilization, sodium makeup, regeneration of spent liquor, water balance, scaling and solids buildup problems, materials of construction, waste cake properties, reliability, and availability.
- Economics, including capital investment and operating cost.

The demonstration is scheduled for a mid-1981 completion. For additional information, contact the EPA/IERL-RTP Project Officer, Norman Kaplan, (919) 541-2556 or (FTS) 629-2556.

Capital Costs for LG&E's Cane Run No. 6 Dual-Alkali System

Subsystem	*Material Costs*	*Engineering and Erection Costs*	*Total*
FGD	$10,256,000	$6,207,000	$16,463,000
Lime Slurry Feed	800,000	416,000	1,216,000
Waste Disposal	1,959,000	959,000	2,918,000
			$20,597,000

WASTE DISPOSAL STUDY EXAMINES LINER MATERIALS

FGD waste disposal areas are often lined with impervious materials to prevent groundwater contamination by hazardous leachates. However, little is known concerning the life expectancies of such liners, especially when exposed to FGD waste materials. In recognition of the need for such information, EPA's Municipal Environmental Research Laboratory (MERL) and the U. S. Army Engineers Waterways Experiment Station (WES) are studying the compatibility of FGD wastes with selected liner materials.

The first phase of the MERL/WES study has been completed, and the interim report is now available (EPA-600/2-79-136, see "FGD Reports and Abstracts"). The report, *Flue Gas Cleaning Sludge Leachate/Liner Compatibility Investigation: Interim Report*, describes the study approach and preliminary conclusions based on a 12-month test period. During this time, 18 different liner materials were exposed to FGD wastes. Three general types of liners were studied: admixed materials (the addition of stabilizing chemicals to the disposal site soil), spray-on materials, and membrane liners. Two FGD wastes were used, one from an Eastern coal lime-scrubbed process, and the other from an Eastern coal limestone-scrubbed process.

Preliminary results from these tests indicate that certain admixed liner materials (Portland cement, cement plus lime, and C400, a substance similar to cement) decrease soil permeability. In addition, the unconfined compressive strengths of these admixed materials substantially increased during the course of the 12-month test period. The strengths in general almost doubled, although the lime admix demonstrated a sixfold increase in unconfined compressive strength.

The compatibility of the various wastes and liner materials was studied in pressurized test cells simulating a 9-m (30-ft) deep disposal area. Physical tests of the liners were conducted before and after exposure to the FGD wastes. Chemical analyses of the waste and waste liquor that passed through each test cell were performed to determine the concentrations of heavy metals and chlorides in the waste leachate.

These studies will be continued for an additional 12-month exposure period. The final report will present the results of the full 24-month test period, along with estimates of liner durability and economics. For further information contact the EPA/MERL Project Officer, R. E. Landreth, (513) 684-7871 or (FTS) 684-7871.

FGD PROCESS EVALUATED FOR INDUSTRIAL BOILER APPLICATION

A recent technology assessment report (TAR) on FGD concludes that there is no single "best" FGD process for industrial boiler application. The report, *Technology Assessment Report for Industrial Boiler Applications: Flue Gas Desulfurization* (EPA-600/7-79-178i), is one in a series of technology assessments sponsored by EPA/IERL-RTP. The series is designed to aid in establishing the technological basis for the pending New Source Performance Standards (NSPS) for industrial boilers.

The new FGD TAR is based on a comprehensive evaluation of FGD processes in commercial use, under development, or discontinued. These processes were assessed on the basis of status of development, capital and operating costs, energy requirements, environmental impacts, and performance and operating data. From the initial list, five processes best suited to industrial boilers were selected for further study: sodium throwaway, lime/limestone, dual-alkali, spray drying/baghouse, and Wellman-Lord.

The FGD TAR concludes that each of the five candidate FGD processes examined has unique advantages and disadvantages. Thus, the selection of a "best" FGD system depends on site-specific conditions. For example, the sodium throwaway process yields an easily treated waste, has the lowest annual costs, and uses the least amount of energy (8.8 MW [30 × 10^6 Btu/hr] heat input) of those considered. Currently, this process is now used in over 75 percent of U. S. industrial boiler FGD installations. However, there may be areas where the sodium throwaway process cannot be used because of regulations on the discharge of dissolved solids. In these instances, limestone or dual alkali may be preferable.

Other reports in the technology assessment series concern:

- Population and characteristics of industrial/commercial boilers (EPA-600/7-79-178a).
- Oil cleaning (EPA-600/7-79-178b).
- Coal cleaning and low sulfur coal (EPA-600/7-79-178c).
- Synthetic fuels (EPA-600/7-79-178d).
- Fluidized-bed combustion (EPA-600/7-79-178e).
- NO_x combustion modification (EPA-600/7-79-178f).
- NO_x flue gas treatment (EPA-600/7-79-178g).
- Particulate collection (EPA-600/7-79-178h).

The complete series will be integrated, along with other information, in EPA's *Industrial Boilers—Background Information for Proposed Standards*, to be issued by EPA's Office of Air Quality Planning and Standards.

For more information on the FGD TAR, contact EPA/IERL-RTP Project Officer J. E. Williams, (919) 541-2483 or (FTS) 629-2483. (See also "FGD Reports and Abstracts" in this issue.)

FGD FEATURED AT AIR QUALITY MANAGEMENT CONFERENCE

Several FGD topics were highlighted at the Second Conference on Air Quality Management in the Electric Power Industry, held January 22-25, 1980, in Austin, Texas. The conference was sponsored by the Electric Reliability Council of Texas and Radian Corporation, and cosponsored by the Southwest Section of the Air Pollution Control Association and the Texas Air Control Board. Continuing Engineering Studies at the University of Texas at Austin administered the meeting.

A session on the control of throwaway sulfur oxides included discussions of problems encountered in nonregenerable scrubber installations, a statistical evaluation of a continuous SO_2 removal FGD data base, scrubbing additives, and operating experience with the FMC Dual Alkali process.

SO_2 dry removal processes were also the subject of a conference session. Papers covered topics such as a survey of dry FGD in the U. S., the development of dry FGD at Basin Electric Cooperative, EPA's dry SO_2 control program, and a bench-scale study of dry SO_2 removal with nahcolite and trona.

Other FGD-related sessions concerned regenerative SO_2 controls and solid waste disposal. In addition, the conference covered several other aspects of air quality management. These included coal cleaning, health effects, NO_x control programs, regulatory impacts, plant impacts, siting considerations, advanced combustion systems, coal liquefaction, and coal gasification.

The conference proceedings are available by contacting:

Continuing Engineering Studies
College of Engineering
Ernest Cockrell Hall 2.102
University of Texas at Austin
Austin, Texas 78712
(512) 471-3396

The cost per copy is $35.00; checks should be made payable to the University of Texas at Austin.

FGD REPORTS AND ABSTRACTS

This section of the *FGD Quarterly Report* contains abstracts of recently completed reports relating to flue gas desulfurization. Each listing includes date of the report, National Technical Information Service (NTIS) accession number, and other identifying numbers when available.

Requests for EPA reports should be directed to:

U. S. Environmental Protection Agency
Center for Environmental Research Information
Cincinnati, Ohio 45268
(513) 684-7562

Each report with an NTIS number can also be ordered from NTIS. The cost of paper copies varies by page count ($4.00 minimum); microfiche copies are $3. Payment must accompany order. The address is:

National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

Survey of Flue Gas Desulfurization Systems: Cane Run Station, Louisville Gas and Electric Co.

B. A. Laseke, Jr., PEDCo Environmental, Inc., Cincinnati, Ohio, August 1979. EPA-600/7-79-199c. (NTIS No. PB 80-184385.) EPA Project Officer: N. Kaplan, IERL-RTP.

The report gives results of a survey of operational flue gas desulfurization (FGD) systems on coal-fired utility boilers in the U. S. The FGD systems installed on Units 4, 5, and 6 at the Cane Run Station are described in terms of design and performance. The Cane Run No. 4 FGD system is a two-module (packed tower) carbide lime scrubber, retrofitted on a 178 MW (net) coal-fired boiler. The system, supplied by American Air Filter, commenced initial operation in August 1976. The Cane Run No. 5 FGD system is a two-module (spray tower) carbide lime scrubber, retrofitted on a 183 MW (net) coal-fired boiler. The system, supplied by Combustion Engineering, commenced initial operation in December 1977. The Cane Run Unit 6 FGD system is a two-module (tray tower) dual alkali (sodium carbonate/lime) scrubber, retrofitted on a 278 MW (net) coal-fired boiler. The system, supplied by A. D. Little/Combustion Equipment Associates, commenced initial operation in December 1978.

Adipic Acid Degradation Mechanism in Aqueous FGD Systems

F. B. Meserole, D. L. Lewis, A. W. Nichols, Radian Corporation; and G. Rochelle, University of Texas, Austin, Texas, September 1979. EPA-600/7-79-224. (NTIS No. PB 80-144595.) EPA Project Officer: R. H. Borgwardt, IERL-RTP.

The report gives results of a field and laboratory study of the adipic acid degradation mechanism in aqueous flue gas desulfurization systems. (Adding adipic acid to limestone-based, SO_2 wet scrubbers increases SO_2 removal and limestone utilization. However, as much as 80% of the adipic acid added to some systems is lost, supposedly through degradation.) The degradation is associated with the oxidation of sulfite, possibly through a free radical mechanism. At least one mechanism is an oxidative decarboxylation yielding valeric acid, butyric acid, glutaric acid, and CO_2. The quantities of products measured during laboratory testing account for only approximately 30% of the adipic acid degraded.

Flue Gas Cleaning Sludge Leachate/Liner Compatibility Investigation: Interim Report

C. Styron III and Z. Fry, Jr., U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, August 1979. EPA-600/2-79-136. (NTIS No. PB 80-100480.) EPA Project Officer: R. Landreth, MERL.

This project was initiated to study the effects of two industrial waste materials on 18 items used to contain these wastes. Seventy-two test cells, 1 ft in diameter and 2 ft high, were fabricated. Ten items were mixed with a clayey silt and compacted in the bottom 6 in. of the test cell; six spray-on and two prefabricated membrane items were placed over 6 in. of compacted soil. Four gallons of sludge were added to each test cell and enough tap water to bring the liquid to within 4 in. of the top of the test cell. Each test cell was covered and pressurized to simulate 30 ft of head.

This report lists and discusses the data following 12 months of inundation of each item with both sludges. Portland cement, cement plus lime, and C400 when mixed with the soil resulted in a significant reduction in permeability.

Overview of Pollution from Combustion of Fossil Fuels in Boilers of the United States

P. W. Spaite (Consultant) and T. W. Devitt, PEDCo Environmental, Inc., Cincinnati, Ohio, October 1979. EPA-600/7-79-233. (NTIS No. PB 80-124969.) EPA Project Officer: C. J. Chatlynne, IERL-RTP.

The report describes the fossil-fuel-fired boiler population of the U. S. It presents data on the number and capacity of boilers for categories most relevant to producing pollution. Information presented includes: type of fuel burned (coal, residual oil, distillate oil, natural gas); usage sector (utility, industrial, commercial); size category (less than 25 million Btu/hr, 25-250 million Btu/hr, greater than 250 million Btu/hr); and heat transfer configuration (water tube, fire tube, cast iron). Fuel consumption data are presented for each type of fuel burned in each usage sector. These data are used to estimate the amount of sulfur oxide, nitrogen oxide, and particulate air emissions produced by boiler operation. Other air pollutants are discussed qualitatively. Solid waste and water pollution from boiler operation is discussed generally.

Effects of Flue Gas Cleaning Waste on Groundwater Quality and Soil Characteristics

U. S. Army Waterways Experiment Station (WES), Vicksburg, Mississippi, August 1979. EPA-600/2-79-164. (NTIS No. PB 80-118656.) EPA Project Officer: R. Landreth, MERL-Cinn.

Soil and water samples from several test borings and hydrological data were collected and analyzed from three flue gas cleaning sludge disposal sites in order to assess the extent of migration of pollutants into the local groundwater and the effects on surrounding soils. Physical testing of soils indicated that two major types of sites were included: one site was underlain by impermeable materials such as clay and shale; and two other sites were underlain by relatively permeable silty sands and gravel with discontinuously distributed finer materials.

At the site underlain by impermeable substrata, no change in permeability or other physical properties of the soils could be related to the presence of the disposal site. At the two sites underlain by permeable substrata, only at one could variations in permeability, dry density, water content, and percent fines be related to the presence of the disposal site. Irregular occurrences of fine-grained materials (clays and silty sands) at the other site obscured any variations in these parameters which might have been caused by the disposal site.

Sludge/ash-derived constituents were found to have migrated out of the immediate area of the pit or pond at all three disposal sites, degrading the quality of the local groundwater.

Technology Assessment Report for Industrial Boiler Applications: Flue Gas Desulfurization

J. C. Dickerman and K. L. Johnson, Radian Corporation, Austin, Texas, November 1979. EPA-600/7-79-178i. (NTIS No. PB 80-150873.) EPA Project Officer: J. E. Williams, IERL-RTP.

The report gives results of an assessment of the applicability of flue gas desulfurization (FGD) technology to industrial boilers and is one of a series to aid in determining the technological basis for a New Source Performance Standard for Industrial Boilers. The development status and performance of alternative FGD control techniques were assessed and the cost, energy, and environmental impacts of the most promising were identified. The study concluded that there is no best FGD technology for application to industrial boilers; each alternative has advantages and disadvantages which could make it best for a specific application. Cost estimates of applying FGD processes indicated that the cost effectiveness varies significantly depending on the fuel fired, boiler size, and control level. However, boiler size is the most significant factor affecting cost effectiveness: the economy of scale causes control of large sources to be the most effective. The energy requirement of applying FGD processes varied from about 0.5% to 6% of boiler capacity, excluding stack gas reheat. The environmental impacts of each alternative were evaluated: each could be applied in an environmentally acceptable manner under existing regulations. The report does not consider combinations of technology to remove all pollutants, and these findings have not undergone detailed assessments for regulatory action.

Citrate Process Demonstration Plant Design

W. I. Nissen and R. S. Madenburg, U.S. Bureau of Mines, Salt Lake City, Utah, 1979. (NTIS No. PB 299 522.)

This Bureau of Mines report presents the design for a commercial-sized flue gas desulfurization (FGD) demonstration plant that uses the citrate process. The goal of the Bureau's citrate process is to minimize the undesirable environmental impacts of industrial plants emitting SO_2-bearing gas. The FGD plant is located at the George F. Weaton power plant, Monaca, PA. Construction was completed in April 1979 and will be followed by preliminary testing and a 1-year testing and evaluation program. Design capacity of the FGD plant is 156,000 scfm of 0.2-volume-percent-SO_2 flue gas yielding about 16 tons of sulfur per day. The plant is intended to (1) clean fly ash, SO_3, and Cl_2 from the gas while cooling the gas in a venturi scrubber, (2) absorb SO_2 from the gas using 1,200 gpm of a countercurrent-flowing citric acid/sodium citrate/sodium thiosulfate solution, (3) react the absorbed SO_2 in two 13,000-gal. stirred closed vessels with added H_2S, thus precipitating elemental sulfur and regenerating the citrate solution for recycle, and (4) recover the sulfur from the slurry by air flotation, followed by melting in a heat exchanger and separation from the occluded citrate solution in a sulfur decanter at 35 psi and 135°C.

Population and Characteristics of Industrial/Commercial Boilers in the U. S.

T. DeVitt, P. Spaite, and L. Gibbs, PEDCo Environmental, Inc., Cincinnati, Ohio, August 1979. EPA-600/7-79-178a. (NTIS No. PB 80-150881.) EPA Project Officer: C. J. Chatlynne, IERL-RTP.

The report describes a study of boiler population and characteristics, fuel consumption, emissions, and boiler costs that provides a basis from which a broader study of overall environmental impacts of non-utility boilers can be made. Boilers consume about one-third of the fossil fuels burned in the U. S. Over 40% of this is fired in industrial/commercial boilers; the rest, in utility boilers. There are about 1.8 million industrial/commercial boilers in the U. S. Only about 0.1% of these have a firing capacity greater than 73.2 MW. These larger boilers, however, represent 17% of the total U. S. capacity. About 72% of the total boilers are classified as commercial, used primarily for space heating. The industrial boilers represent 69% of the total firing capacity and are concentrated in four major industries: pulp and paper, primary metals, chemicals, and minerals. Estimated uncontrolled particulate matter emissions in 1975 from industrial/commercial boilers were about 2.5 Tg per year in addition to about 2.9 Tg per year of SO_x and 1.8 Tg per year of NO_x. CO and HC emissions are relatively minor. Using a 3.3% annual growth rate, the emissions will more than double by the year 2000. Capital and annualized operating costs were determined for 23 boiler/fuel combinations representing a cross section of boiler population.

The Use of pH and Chloride Electrodes for the Automatic Control of Flue Gas Desulfurization Systems

C. Ung, T. Acciani, and R. Maddalone, TRW Defense and Space Systems Group, Redondo Beach, California, November 1979. EPA-600/2-79-202. (NTIS No. PB 80-138464.) EPA Project Officer: F. E. Briden, IERL-RTP.

The report gives results of a study to determine the applicability of chloride and pH electrodes in automated control systems. It included a survey of chloride and pH electrodes in different flue gas desulfurization (FGD) systems and an evaluation of an industrial pH electrode system. The survey showed that chloride ion measurements were necessary only where high chloride values correspond with FGD unit corrosion and when chloride values were used as correction factors in pH calculations. Chloride ion measurements are unnecessary for most of the surveyed companies. All surveyed companies use pH measurements to control scaling or to attain optimum performance in FGD units. The most common pH electrode problem was residue buildup (scaling) around the electrode, caused by the use of non-self-cleaning (standard) pH electrodes. The performance of self-cleaning and standard industrial pH electrodes was evaluated at the EPA/TVA Shawnee FGD test facility. The electrodes were tested during a 7-week period with varying durations of continuous operation. The tests showed that: the performance of self-cleaning and standard electrodes was nearly identical, and the benefits of a self-cleaning pH electrode can only be realized if electrode scaling is a problem and if a long (2-week) continuous period of pH electrode operation is maintained.

Shawnee Lime/Limestone Scrubbing Computerized Design/Cost-Estimate Model Users Manual

C. D. Stephenson and R. L. Torstrick, Tennessee Valley Authority, Muscle Shoals, Alabama, August 1979. EPA-600/7-79-210. (NTIS No. PB 80-123037.) EPA Project Officer: J. E. Williams, IERL-RTP.

The manual gives a general description of the Shawnee lime/limestone scrubbing computerized design/cost-estimate model and detailed procedures for using it. It describes all inputs and outputs, along with available options. The model, based on Shawnee Test Facility scrubbing data, includes a combination of material balance models provided to TVA by Bechtel National, Inc., and capital-investment/revenue requirement models developed by TVA. The model provides an estimate of total capital investment, first year operating revenue requirements, and lifetime revenue requirements for a lime or limestone scrubbing facility. Also included are a material balance, an equipment list, and a breakdown of costs by processing areas. The model should be used to project comparative economics of lime or limestone flue gas desulfurization processes (on the same basis as the model) or to evaluate system alternatives before developing a detailed design. The model is not intended for use in projecting the final system design.

EPA Alkali Scrubbing Test Facility: Advanced Program, Fourth Progress Report; Volume 1, Basic Report: and Volume 2, Appendices

H. N. Head and S. Wang, Bechtel National, Inc., San Francisco California, November 1979. EPA-600/7-79-224a and -b. (NTIS Nos. PB 80-117906 and PB 80-117914.) EPA Project Officer: J. E. Williams, IERL-RTP.

The report gives results of advanced testing (late-November 1976-June 1978) of 30,000-35,000 acfm (10 MW equivalent) lime/limestone wet scrubbers for SO_2 and particulate removal at TVA's Shawnee power station. Forced oxidation with two scrubber loops was developed on the venturi/spray tower system with limestone, lime, and limestone/MgO slurries. Bleed stream oxidation was successful only with limestone/MgO slurry. Forced oxidation with a single scrubber loop was developed on the TCA system with limestone slurry. Other test blocks on the TCA were limestone wth low fly ash loadings, limestone type and grind, automatic limestone feed control, limestone reliability, limestone with Ceilcote egg-crate type packing, lime/MgO, and flue gas characterization.

Demonstration of Wellman-Lord/Allied Chemical FGD Technology: Demonstration Test First Year Results

R. C. Adams, J. Cotter, and S. W. Mulligan, TRW, Inc., Durham, North Carolina, September 1979. EPA-600/7-79-014b. (NTIS No. unavailable.) EPA Project Officers: C. J. Chatlynne and N. Kaplan, IERL-RTP.

The report gives results of the first year of a comprehensive test program to demonstrate the capabilities of a full-scale plant using the Wellman-Lord/Allied Chemical process for desulfurizing flue gas. The FGD unit is retrofitted to Northern Indiana Public Service Company's 115 MW coal-fired unit No. 11 at the Dean H. Mitchell Station. During the demonstration, which began in September 1977, operating experience was limited by boiler- and FGD-related operating problems. The FGD plant had a 50% reliability factor (hours operated/hours called upon to operate). SO_2 removal efficiency averaged 89%. Economic performance was distorted by considerable off-normal boiler operation (which limited use of the FGD plant) and by partial operation of the FGD plant during which operating costs were not substantially less than costs during full operation. A major effect on boiler operation from retrofit of the FGD plant was a boiler derating of 9% resulting from the consumption of steam by the FGD plant, a value that will be reduced by design changes at future Wellman-Lord installations. At least 1 year of additional testing will follow completion of a number of design improvements that will eliminate or minimize the problems that have limited FGD plant use.

Executive Summary for Full-Scale Dual-Alkali Demonstration System at Louisville Gas and Electric Co.—Final Design and System Cost

R. P. Van Ness, R. C. Somers, R. C. Weeks (LG&E); T. Frank, G. J. Ramans (CEA); C. R. LaMantia, R. R. Lunt, and J. A. Valencia (ADL), Louisville Gas and Electric Company, Louisville, Kentucky, September 1979. EPA-600/7-79-221a. (NTIS No. PB 80-146707.) EPA Project Officer: N. Kaplan, IERL-RTP.

The report describes phase 2 of a four-phase demonstration program involving the dual-alkali process for controlling SO_2 emissions from Unit 6, a coal-fired boiler at Louisville Gas and Electric Co.'s Cane Run Station. The process was developed by Combustion Equipment Associates, Inc., and Arthur D. Little, Inc. The program consists of four phases: (1) preliminary design and cost estimation; (2) engineering design, construction, and mechanical testing; (3) start-up and acceptance testing; and (4) 1-year operation and test programs. The report describes final engineering design, construction and mechanical testing, and installed system capital cost. Construction of the system was completed in February 1979 and system startup was initiated in March 1979. Total capital investment for the entire plant, including waste disposal, is estimated to be $20.6 million (construction of the waste disposal facilities is not complete).

Full-Scale Dual-Alkali Demonstration System at Louisville Gas and Electric Co.—Final Design and System Cost

R. P. Van Ness, R. C. Somers, R. C. Weeks (LG&E); T. Frank, G. J. Ramans (CEA); C. R. LaMantia, R. R. Lunt, and J. A. Valencia (ADL), Louisville Gas and Electric Company, Louisville, Kentucky, September 1979. EPA-600/7-79-221b. (NTIS No. PB 80-146715.) EPA Project Officer: N. Kaplan, IERL-RTP.

See EPA-600/7-79-221a for abstract.

Electric Utility Steam Generating Units—Flue Gas Desulfurization Capabilities as of October 1978 Final Report

B. A. Laseke, Jr., M. T. Melia, M. T. Smith, and T. J. Koger, PEDCo Environmental, Inc., Cincinnati, Ohio, January 1979. EPA-450/3-79-001. (NTIS No. PB 298 509.) EPA Project Officer: K. R. Woodard, OAQPS/ESED.

This study updates the previously published final report, "Flue Gas Desulfurization System Capabilities for Coal-Fired Steam Generators, Volume II," EPA-600/7-78-032b published in March 1978. This assessment was made by reviewing the changes and developments in the technology since the preparation of the March 1978 report. A substantial increase in the number and capacity of operational FGD systems, plus the additional operational experience obtained by previously identified operational systems, have resulted in a substantial increase in the amount of design and performance information. Most notably, these include dependability (availability, operability, reliability, and utilization) data, removal efficiency data (sulfur dioxide and particulate), operating problem and solution data, results from various research, development, and demonstration programs, and process and design innovations for new systems. Virtually all of the FGD operating experience gained to date has been with the wet-phase, nonregenerable, lime/limestone processes. As a direct result of this previous experience, the systems committed for operation within the next 3 to 5 years also show an overwhelming preference for lime/limestone processes. Analysis of the current status of the technology indicates that the design and operating experience gained with the first and second generation FGD systems has resulted in improved design and operation of subsequent installations. Because FGD systems that are being engineered and/or erected will incorporate many or all of these design innovations, even better performance can be expected without substantial cost increase.

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