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Project Summary

Third Symposium on the Transfer and Utilization of Particulate Control Technology: Volume III. Particulate Control Devices

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Summarized herein is Volume III of the four volumes of proceedings of the Third Symposium on the Transfer and *Utilization of Particulate Control Technology* held in Orlando, FL, March 9-12, 1981. Volume III papers discuss particulate control devices other than electrostatic precipitators, and describe applications and types of scrubbers.

Volumes I, II, and IV are described in three separate project summaries.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The papers in these four volumes of proceedings were presented at the Third Symposium on the Transfer and Utilization of Particulate Control Technology in Orlando, FL, March 9-12, 1981, sponsored by the Particulate Technology Branch of EPA's Industrial Environmental Research Laboratory at Research Triangle Park, NC.

The symposium brought together researchers, manufacturers, users, government agencies, educators, and students to discuss new technology and provided an effective means for the transfer of this technology out of the laboratories and into the hands of the users.

The three major categories of control technologies—electrostatic precipitators (ESPs), scrubbers, and fabric filters—were the major concern of the symposium. These technologies were discussed from the perspectives of economics, new technical advancements in science and engineering, and applications. Several papers dealt with combinations of devices and technologies, leading to a concept of using a systems approach to particulate control, rather than device control. Additional topic areas included novel control devices, high-temperature/high-pressure applications, fugitive emissions, and measurement techniques.

The symposium was conducted as a series of parallel sessions, each containing four to six related papers. The sessions were scheduled to avoid conflict due to simultaneous sessions dealing with the same topic. Each series of related sessions represented a thread of technology. These parallel threads, extending over the total period of the symposium, provided a highly integrated approach to the total subject of particulate control technology, with strands of specialized technologies. These strands of specialized technologies, or perspectives, provided the basis for the division of the papers into four volumes, each volume containing a set of related session topics so as to provide easy access to a unified technology area.

Volume III Papers

Volume III, summarized here, is a collection of papers describing particulate control devices other than ESPs. The largest section in Volume III deals with fabric filters. Several papers dealt with the electrostatic enhancement of fabric filters both from a theoretical and practical operating perspective. Measurement and diagnostics of filter capabilities with regard to flyash size distribution were widely treated, as were the more conventional problems dealing with pressure drop and cleaning of filters. Several papers were devoted to granular beds with emphasis on moving beds. Collection efficiencies and electrostatic augmenta-

tion of mechanical collectors were interspersed with troubleshooting and design and fabrication of these devices. A session on novel devices treated magnetic separation phenomena, electrostatically enhanced wet scrubber applications, sintered metal filters, fiber bed filters, and a wet-wall ESP.

Another small section deals with mechanical collectors (including electrostatically augmented devices). Several novel devices are described in yet another section of Volume III. These devices include magnetic separators for use in the iron and steel industry, electrostatically augmented filter devices, sintered metal filters, special venturis, and fiber bed devices.

Section A—Scrubbers

The Calvert Scrubber

S. Calvert, Air Pollution Technology, Inc.

The Calvert Scrubber is a very energy-efficient fine-particle scrubber and is especially well suited to utilities applications because it can meet both particulate and SO_2 removal requirements in a single-control device. Other potential applications include metallurgical industries, chemical industries, and any other industry where fine-particle scrubbers are used.

Pilot scrubbers of up to 3,000 cfm capacity have been built and tested. Experimental data for fine-particle collection and SO_2 removal are presented. Collection efficiency data are presented as a function of particle aerodynamic diameter. The 50% cut diameter is presented as a function of pressure drop and energy input to the scrubber. Performance is compared to conventional venturi scrubbers and other fine particle scrubbers.

Flux Force/Condensation Scrubber System for Collection of Fine Particulate Emissions from an Iron Melting Cupola

S. Calvert, Air Pollution Technology, Inc.

A flux force/condensation (F/C) scrubber was designed, built, and operated by Air Pollution Technology, Inc., to control particulate emissions from an iron and steel melting cupola. The cupola melt rate was approximately 14,000 kg/hr (15 tons/hr), with an exhaust gas flow rate of 8.5 kg/s (14,000 dscfm). The major scrubber system components included an afterburner, spray saturator, condenser, and scrubber. A cooling tower rejected heat from the scrubber system.

Performance data were obtained by sampling for particle size distribution and concentration at several locations. Experimental performance data were compared with theoretical predictions of particle collection as a function of particle size. The F/C scrubber system was capable of meeting the emission limit with a power input of only 65% of the power consumption required for a conventional high energy scrubber.

Demonstration of High-Intensity Ionizer-Enhanced Venturi Scrubber on a Magnesium Recovery Furnace Fume Emissions

A. Prem, Pollution Systems

A 33,960 m^3/hr (20,000 acfm) permanent demonstration system, consisting of the Air Pollution System's High Intensity Ionizer (HII) and a variable-throat venturi scrubber, has been installed on a magnesium recovery furnace at Teledyne Wah Chang Albany, Albany, OR. The particulate emission from this source is predominantly submicron in nature. Fairly high stable electric fields of 10-12 kV/cm have been successfully maintained in the HII. Comparing the measured charge/mass, and the calculated charge/mass based on the measured particulate size distribution at the outlet of the scrubber, the HII appears to be imparting fairly high charge to the incoming particulate. Preliminary performance test results indicate higher performance of the venturi scrubber when the HII is energized for all the venturi pressure drops tested. The penetration reduction due to HII increased as the venturi pressure drop was increased, and as the particle size decreased.

A New Entry in the High Efficiency Scrubber Field

L. C. Hardison, Air Resources, Inc.

The use of venturi flooded-disk, and various orifice-type scrubbers for wet collection of fine particles at high energy levels and high levels of particulate collection efficiency is well known. In general, these scrubbers may be characterized as roughly equivalent in performance level, and various models are competitive only with respect to price and mechanical considerations and ease of maintenance or operation.

The MVS (Modular Venturi Scrubbe the latest entry into this competitive fie has several advantages in size, cost, a simplicity over more conventional d signs. This paper describes the desi and operation of the MVS units.

Performance of Particulate Scrubbers as Influenced by Gas/Liquid Contactor Design and by Dust Flocculatio

K. T. Semrau, SRI International

Comparative performance studies gas/liquid contactors, using standardiz test dusts, included several venturi a rangements, orifices, a sparger tub sparger nozzles, and fiber packs. Over range of operating variables, the colle tion efficiencies of the units were cor pared as functions of the effective fricti loss. Test dust was used in both floc lated and deflocculated states. With given dust, the different contactors gene ally gave about the same efficiency at given effective friction loss, but significa differences in performance in som ranges of operating variables appear with certain contactors, the fiber-packe contactors consistently giving high efficiencies. Flocculated dust gave high collection efficiencies than did deflocc lated dust unless the contactor desi permitted redispersal of the dust befo contact with the liquid.

Investigation of Venturi Scrubber Efficiency and Pressure Drop

R. Parker, Air Pollution Technology, Inc

The venturi scrubber performan model (EPA-600/2-77-172; NTIS P 271515) gives good results when used predict the performance of industri scrubbers. However, no detailed par metric evaluation of this model has bee conducted to properly predict ventu scrubber performance in non-conver tional environments, such as high pre sure gas streams. Pilot plant data on a 7. cm (3 in.) throat diameter venturi scrubb are presented. Flow rates from 10-2 m^3/min and liquid-to-gas ratios from 1 t 3 l/m^3 were used. Throat and diffus lengths were also varied. Throat velocitie from 40 to 70 m/s and pressure drop from 1 to 5 kPa were measured. Exper mental data generally showed highe penetrations than predicted, especiall for particles larger than 1 or 2 μr aerodynamic diameter.

Scrubber Technology and the Interaction of a Unique Structure as Mist Eliminator

G. C. Pedersen, KIMRE, Inc.

The role of this unique patented structure as a mist eliminator for other scrubbing devices is considered. The range of physical properties yields new capabilities in system. This approach is being used with good success on four continents and is a standard for many U.S. scrubber manufacturers.

Novel Annular Venturi Scrubber Design Reduces Waste Discharge Problems

H. P. Beutner, Interel Corp.

Characteristics of a new type annular venturi scrubber system, which was developed by L. Leisegang of West Germany, are presented.

The scrubber has internal circulation of the scrubbing liquid and allows solids buildup in the liquid to 20% or more. The liquid spray is generated without use of nozzles by contact of the gas with the liquid surface. Solids are discharged either as concentrated slurry or as sludge by means of a scraper.

The annular venturi scrubber achieves highest energy efficiency at any pressure drop from 1 to 80 in. WG. It can be operated as variable venturi by regulating the water level. Fractional particle removal efficiencies as a function of pressure drop are shown. Examples of installations on product dryers, incinerators, foundry, and steel mill operations are presented.

Consideration of the Pertinent Design and Operating Characteristics Essential for Optimization of Venturi Scrubber Performance

H. S. Oglesby, NCASI

The use of medium- to high-energy venturi scrubbers in the pulp and paper industry has increased substantially over the past 8 to 10 years. Accompanying this increased use is a wider spectrum of applications and a demand for a sustained higher level of performance to meet the current and emerging regulatory requirements. Accordingly, there is a need to review the critical factors affecting performance relative to optimization, process compatibility, and minimizing the energy requirements. In this respect, it is essential that considerations be given to the pertinent design and operation parameters in assessing performance. This paper addresses these issues and a methodology for troubleshooting scrubber performance.

Application of Scrubbers for Particulate Control of Industrial Boilers

M. Borenstein, Neptune Airpol

Cyclone dust collectors, formerly used to control dust on bark boilers, are no longer adequate. More stringent requirements call for higher efficiency collection, and scrubbers have been successful in meeting the codes. This paper explores the operation parameters, operating experience, and test results of scrubbers on coal-, oil-, and wood-fired boilers, particularly in the pulp and paper industry. It also reviews the power requirements, maintenance schedules, and instrumentation required for successful operation of the scrubber.

Application of High Energy Venturi Scrubbers to Sewage Incineration

F. X. Reardon, Metcalf & Eddy, Inc.

The most critical components required for the upgrading of the four, flash drying, sludge incinerators in 1968 during the formulation of EPA's New Source Performance Standards, and the Allegheny County Health Department, Rules and Regulations, Article XVII, Smoke and Air, were the incinerator scrubbers.

Responding to contract requirements for venturi scrubbers operating with a pressure drop of 20 to 25 in. WG, flooded disk scrubbers were installed. The engineering application of the scrubbers to the furnaces, problems encountered and resolved during the break-in period, the test results, and the continuing operating history are presented.

An Incinerator Scrubber That Works: A Case Study

C. Menoher, ZURN Industries

A midwestern chemical company has recently started up a medium energy scrubber on an industrial trash burning incinerator. Compliance testing verified an outlet particulate loading of less than the guaranteed 0.15 lb/1,000 lb of dry gas. This level of performance was achieved with 30 in. W.C. of venturi pressure drop, with final subcooling to remove volatiles and condensibles. This system was purchased because of the horsepower savings when compared to the "conventional" venturi scrubber that asks for 60 in. W.C. or more of pressure drop. The savings will pay for the scrubber system in 4 years.

Evaluation of Entrained Liquor Contribution to Total Mass Emissions Downstream of a Wet Scrubber

W. D. Balfour, Radian Corp.

As flue gas passes through a wet scrubber, both SO_2 and particulate matter can be removed. The scrubber can, however, contribute mass through entrainment of scrubber liquor high in suspended and/or dissolved solids. The contribution of mass by a variety of scrubbing systems has been calculated using the concept of a chemical element balance.

Particulate compositions into and out of the scrubber were obtained from chemical analyses (ion chromatography and inductively coupled argon plasma emission spectroscopy) of total particulate catches. Scrubber liquor composition was obtained by similar analyses of liquor samples collected during the particulate sampling. A multiple variable regression analysis was performed on the set of equations (for each chemical species).

Results for a limestone tandem venturi scrubber indicate that primary particle penetration is very small (approximately 0.10%). The scrubber liquor, however, contributes 40% of the total mass emissions. Additionally, 90% of the sulfate aerosol emissions are generated by the scrubber.

Section B—Fabric Filters

A Dual-Beam Backscatter Beta-Particle Gauge for Measuring the Dust Cake Thickness on Operating Bag Filters Independent of Position

R. P. Gardner,
North Carolina State University

A dual-beam backscatter beta-particle gauge for measuring the filter cake thickness on operating bag filters has been designed, and a prototype device has been constructed and tested. The device uses two beta-particle sources (Kr-85 and Sr-90) with an end-window GM counter so that the measurement of filter cake thickness is essentially independent

of the position of the bag in relation to the gauge. A plastic rotating shutter shield operated by a small electric motor provides signals alternately from each source. The shutter position is sensed by an infrared detector, and the response to each source is appropriately routed to separate counters. The low-energy Kr-85 source provides a backscatter response that depends only on filter position, while the high-energy Sr-90 source provides a backscatter response that depends on both filter position and filter cake thickness. The real-time simultaneous solution of appropriate models for the two responses with a microcomputer gives the filter cake thickness, an estimate of the standard error of filter cake thickness due to statistical counting rate fluctuations, and the filter position for each set of responses. Laboratory and pilot plant results indicate that the gauge is accurate and will be useful for control purposes.

Diagnosing Filter Fabric Capabilities with Light Scattering and Nuclei Detecting Instrumentation

R. Dennis, GCA/Technology Division

Fabric penetration characteristics based on long-term averaging periods (on the order of hours) reveal neither the probable range of outlet concentrations and size properties, nor short-term effects, that can play important roles in the selection of fabric and collector design and operating parameters. Laboratory tests at ambient temperatures using a single-particle light-scattering device and a condensation nuclei counter to augment mass and size determinations by filter and cascade impactor measurements, respectively, permitted short-term resolution (on the order of seconds) of changes in effluent properties. Data are presented relating particulate emission measurements to variations in inlet concentration, fabric structure, frequency and method of cleaning, and filtration velocity. The presence of fabric defects or the impact of dust cake disturbance is traced over typical filtration cycles for various aerosols with woven glass, cotton, and Dacron fabrics.

Acid Dewpoint Corrosion in Particulate Control Equipment

T. E. Mappes, PEDCo Environmental, Inc.

This paper described the impact of corrosion on particulate control device performance and reliability. Many of the corrosion problems observed during this study were the result of flue gas temperatures falling below the sulfuric acid dewpoint. During the study, 11 fabric filters and 1 ESP that suffered from acid dewpoint corrosion were investigated. The study also includes comments on acid dewpoint corrosion made by design engineers at 5 fabric filter manufacturers and 2 ESP manufacturers. Results of this study indicate that acid dewpoint corrosion is a serious problem in many particulate control devices and can destroy expensive particulate control equipment after only a few years of service. This paper discusses how many corrosion problems can be prevented or ameliorated.

Second Generation of Emissions Control System for Coke Ovens

J. D. Patton, MikroPul Corp. USF

The information presented in this paper is directed to top management, environmental directors, and technical personnel interested in the latest technology for controlling hot gases and more positive capture of particulate during the operation of pushing hot coke on coke ovens.

There are 6 points of interest: (1) more positive capture of emissions, (2) simple modular design, (3) erection during operations, (4) reliability close to 100%, (5) unique baghouse filter system incorporated inside coke side shed emissions control structure, and (6) residue recycling (optional).

In the past 5 years, the coke side sheds have been set aside in favor of other control systems. Some of these systems, such as traveling hoods and hot cars, have not worked out as expected. Some properly built coke side sheds have accumulated a number of successful years of operation with a minimum of maintenance.

The intent of this paper is to inform interested parties of the latest in capture control of emissions, and a unique in-house bag type filter system.

Effects of Flyash Size Distribution on the Performance of a Fiberglass Filter

W. T. Frazier, University of Tennessee

The purpose of this study was to investigate the performance of a fabric filter under various operating conditions at a low filtration velocity. The detailed proje objectives were: (1) evaluate the perforn ance of a fabric filter when exposed flyash with mass mean diameters (MMD of 3.5-13 μm (performance—evaluate on fully conditioned fiberglass fabrics was measured by comparing fabric filt pressure drop (delta P) and filter efficien as a function of fabric loading); (2) mea ure the effects of reverse air ratio (clea ing intensity) and inlet dust loading c filter performance; and (3) incorpora the collected data into a format compatib with the EPA's Filtration Model for Co Fly Ash with Glass Fabrics (EPA-600/ 77-084, NTIS PB 276489).

Predictive equations have been deve oped to allow the user to incorporate siz distribution effects into the EPA filtratic model. Graphs are also included showir the experimentally measured relatio ships between particle penetration, r sidual pressure drop, and coefficient resistivity for the 5 flyash size distrib tions that were tested.

Fundamental Study of a Fabric Filter with a Corona Precharge

K. Iinoya, Kyoto University

The effects of a corona precharger o the performance of a fabric filter hav been studied experimentally in air wit controlled humidity. Test dusts, fine ca cium carbonate, and flyash, are pre charged and then ducted to a test fabri Charged dust often reduces the pressur loss across the filter at low filtratio velocity and low relative humidity. On th other hand, the collection efficiency of fabric filter can usually be improved b using a corona precharger.

Economic Evaluation Factors i Bid Evaluations—A Sensitivity Analysis

J. G. Musgrove, Bechtel Power Corp.

The trend to evaluate major utili equipment bids on life cycle costs rath than just on capital costs has increase due to an awareness of the costs equipment maintenance and of borrowin money. The rapidly changing econom climate and changes in interest rat affect the utility's economic evaluatio factors.

An analysis has been conducted determine the extent to which changes the basic economic factors (interest rat rate of return on investment, and pla life) alter the economic evaluation facto (fuel charge, demand charge, and dra

loss penalty) used in competitive bid evaluations. This analysis determines to what extent these changes alter the outcome of recent budgetary studies comparing baghouses and cold-side ESPs. They have been analyzed to determine the sensitivity of the equipment selection to the economic factors employed.

Flyash Re-Entrainment in a Baghouse—What Does It Cost?

J. Musgrove, Bechtel Power Corp.

The re-entrainment of flyash from the hoppers of utility baghouses is considered by baghouse suppliers to be inconsequential. A concern about the cost of re-entrainment in a baghouse designed for a 550 MW utility generating station led to an analysis of its costs. The analysis hypothesizes the impact on baghouse operation that would be caused by re-entrainment and estimates its present worth cost as a function of draft loss across the baghouse. An estimate is also made for the cost of conducting a scale-model test program to determine the actual degree of re-entrainment. The analysis then suggests a method of determining the component costs of implementing corrections to reduce re-entrainment. From the costs of correcting re-entrainment, curves of equal cost are presented to suggest when re-entrainment should be determined and corrected and when it should be ignored.

Why Perform Model Study of Fabric Filter Collector?

W. Langan, Buell Envirotech Corp.

The industry historically has modeled ESPs to achieve good gas flow distribution in the field unit. Standards for ESPs are well developed and field experience has proven such modeling is important to achieve high collection efficiency for this particulate collection equipment.

This paper presents results of the impact of a model study for several major utility fabric filter facilities. These include: TVA's Shawnee Units 1-10, Arizona Public Service's Four Corners Units, Plains Electric, and Baltimore Gas and Electric's Crane Units.

Based on these model study experiences, this paper presents data on: (1) what hardware design parameters the model study should impact, and (2) how model study standards should ensure successful operation of the field unit.

Experiences of a Small Insulation Manufacturer in Maintaining Compliance with Air Pollution Control Regulations

R. L. Hawk, PEDCo Environmental, Inc.

This paper describes the experiences of a typical rockwool insulation manufacturer in the operation and maintenance of air pollution abatement equipment required to comply with state and local air pollution regulations. The paper discusses in detail the effect of process variables, equipment design deficiencies, and operation and maintenance problems on achieving continuous compliance. It also describes the special problems that the small industrial source encounters in the permitting process as a result of the interaction required with regulatory agencies and the manufacturing of air pollution control equipment.

Advanced Fabric Filter Technology for Difficult Particulate Emissions

H. P. Beutner, Interel Corp.

The paper discusses fabric filter technology developed by H. Luhr of West Germany specifically for control of difficult submicron emissions from metallurgical furnaces, arc furnaces, and glass and brick kilns.

The baghouse uses a dust conditioning drum, located in the hopper in place of a screw conveyor, to pretreat the gas entering the baghouse with dust returned from the bags. This approach reduces the baghouse pressure drop and required frequency of bag cleaning. The drum also can hold additives in the baghouse for removal of gaseous components, such as HCl, HF, and SO_3. The baghouse utilizes horizontally mounted, flat Twin-Bags and either low pressure reverse-air or pulse-jet cleaning.

Another element of the Luhr technology is an air-to-gas heat exchanger that cools high temperature exhaust gases to the temperature acceptable in the baghouse. The gas cooler, equipped with an automatic cleaning mechanism, can be designed as an integral part of the baghouse and dust conditioning system.

Development of Guidelines for Optimum Baghouse Fluid Dynamic System Design

D. Eskinazi, Dynatech R&D Co.

One aspect of baghouse technology which is of major importance in minimizing the size, cost, and operating pressure drop is ductwork designs which achieve uniform gas and dust distribution. A recently completed modeling program focuses on developing design guidelines concerning the optimization of fluid mechanic performance of baghouses. Tasks include evaluation of current technology regarding baghouse systems, formulation of the appropriate modeling techniques for analysis of flow of dust-laden gas through the collector system, and extensive experimental analysis of fabric filter duct system designs. A matrix of geometric configurations and operating conditions was experimentally investigated to establish the characteristics of an optimum system, to identify the fluid mechanic integrity of current designs, and to validate the development of new ideas and designs. This analysis shows that the fluid mechanic design of fabric filter systems can be improved significantly.

Theoretical Aspects of Pressure Drop Reduction in a Fabric Filter with Charged Particles

T. Chiang, Buell Envirotech Corp.

Various and frequently disputed mechanisms have been presented in the past to explain the reduced pressure drop observed in a conventional fabric filter augmented with particle precharging. Such mechanisms involve dendrite formations, polarizations, surface collections, and electric contact potentials. This paper presents yet another mechanism due to asymmetrical dust distribution. Artificial step and bell-shape distributions are modeled to show the reduction of pressure drop without the assumption of a more porous cake. Laboratory experiments with metallic screens are used to verify the proposed mechanism. Fundamental behavior of charged aerosols, either in a self space-charge field or an externally applied field, is discussed to further support the theory.

Experimental Correlation of Dust Cake Porosity, Air-to-Cloth Ratio, and Particle-Size Distributions

T. Chiang, Buell Envirotech Corp.

Experimental values of the mean specific resistance coefficients obtained from a full-scale utility baghouse and a slip-stream 16-bag (30 x 1 ft dia) R&D pilot baghouse were used to obtain the cake porosities using the Carman-Kozeny

equation. Functional relationships between the calculated porosity and the volume-to-surface mean diameter of the particles could not be found. However, a log-log plot of the porosity vs. the particle Reynolds number indicated a functional dependence of minus two-thirds power to exist. Utilization of this experimental functional dependence provides us more confidence to design baghouses for new applications.

Model for Dust Penetration Through a Pulse-Jet Fabric Filter

D. Leith, Harvard University

No comprehensive model is available to interpret or predict dust penetration through a pulse-jet cleaned fabric filter. This paper presents a model which considers penetration straight through the filter and penetration by seepage. Many studies have been devoted to penetration by the straight-through process; however, a comparison of data from the literature with the present model indicates that seepage and not straight-through penetration accounts for virtually all penetrating dust. Although insufficient information is available to use the model to predict penetration, the model does show trends that should occur with changes in filter operating variables such as filtration velocity and pulse pressure, and suggests areas in which further research is necessary.

Performances of Dust Loaded Air Filters

C. Kanaoka, Kanazawa University

Dust loading in an air filter enhances both particle collection and pressure drop across the filter. However, it was almost impossible to predict its effects on both properties properly. In this study, growing processes of particle dendrites on a fiber were simulated. Then, they were compared with experimental observations of collection efficiency, pressure drop, and particle agglomerates on a fiber for various filtration conditions and times. Finally, enhancements of filter performances were discussed.

Electrostatically Enhanced Fabric Filtration of Particulates

T. Ariman, University of Tulsa

Recent experimental and analytical investigations have shown that the electrostatic charge on fibers and/or particles effectively assist filtration by attracting particles from a greater distance, and influencing particle agglomeration and thus collection efficiency and service life. The first part of the paper reviews some of the recent developments in the analytical investigations of electrostatically enhanced fibrous filters. Recently, an external electric field has also been considered in fabric filtration of industrial dust with promising results. An increase in the collection efficiency, especially for fine particulates, and a decrease in pressure drop were observed. The second part of the paper discusses recent developments in electrostatic fabric filtration of industrial dust and its possible extension to the control of diesel emissions.

A Staggered Array Model of a Fibrous Filter with Electrical Enhancement

F. Henry, Brunel University

The staggered array of parallel circular cylinders (fibers) is proposed as a model for a fibrous filter. The electrical enhancement of the model is accounted for by the method of images. Stokes' approximation is utilized in the analysis of viscous flow around fibers. The predicted pressure drops and collection efficiencies are compared to experimental data. The model is shown to overpredict the pressure drop, but gives reasonable predictions of collection efficiencies in certain cases.

Section C—Granular Beds

Aerosol Filtration by a Cocurrent Moving Granular Bed: Penetration Theory

T. W. Kalinowski, Harvard University

A penetration model for aerosol filtration by a cocurrent moving bed of granules has been developed. The model incorporates straight-through penetration and reentrainment of previously collected dust due to granule motion, both mechanisms having been found significant in experiments. The model is an extension of classical clean-granular-bed theory, utilizes the familiar concept of a single granular coefficient for collection, and proposes a similar coefficient for reentrainment.

Experiments have confirmed the ability of the cocurrent moving granular bed filter to operate in a continuous mode and to enhance submicron particle filtration by the controlled formation of an intergranular dust deposit. Reentrainment was found to be a function of particle size and other factors, such as gas velocity, granule velocity, and the extent of intergranular dust deposit. The single granule reentrainment coefficient, n_R, was found to depend on the product of intergranular dust deposit and the square root of particle diameter ($K\sqrt{dp}$) for particle diameters between 0.16 and 5.5 μm.

Fundamental Experiments on a Granular Bed Filter

K. Iinoya, Kyoto University

The filtration performance of a granular packed bed has been studied experimentally. The filter media are silica sand and glass beads of various sizes ranging from 1 to 5 mm. The test dust is calcium carbonate, and the filtration velocities are 20, 30, and 40 cm/s.

The additional pressure loss due to the collected dust load does not depend on the filtration velocity because of pinhole formation at higher velocities. The collection efficiency is improved at higher velocities and for heavier dust loads collected in the filter. The dust distributions in the filter media are also measured by chemical analysis.

Dry Dust Collection of Blast Furnace Exhaust Gas by Moving Granular Bed Filter

A. Wakabayashi, Kobe Steel Ltd.

In succession to the small-scale pilot plant test reported at the second symposium in Denver, an actual sized plant of one module having the throughput capacity of 80,000 Nm^3/h was installed to ensure performance and reliability in field operation, where it proved to have sufficient applicability in various operating conditions.

Two-staged filtering by moving granular beds, located in equicentrally circular double rows, proved to have the exit gas dust content of 5 mg/Nm^3 for the inlet gas of 2 to approximately 5 g/Nm^3.

A more efficient way of energy recovery from the top gas of blast furnaces is now accessed to open by utilizing the dry dust collection in front of turbines rather than wet scrubbing by venturi scrubbers.

Section D—Novel Devices

Iron and Steel Air Pollution Control Using Magnetic Separation

D. C. Drehmel, USEPA

A relocatable pilot plant was built and tested at a Pennsylvania sintering plant to

determine the effectiveness and economics of magnetic filtration. The pilot plant consisted of two magnetic systems so that media could be regenerated in one while the other treated the total flow of 3,000 cfm. The pilot plant collected 90% of the iron bearing particles, but overall efficiency was lower because of fine alkali-chloride aerosol in windbox gas. In addition to parametric tests, the pilot plant was operated over 450 hours with no significant problems. Analysis of the results indicates that high efficiency collection can be achieved economically if magnetic filtration is applied to dusts that are more homogeneous and more strongly magnetic than the sinter dust tested.

Technical and Economic Evaluation of Two Novel Particulate Control Devices

R. R. Boericke, General Electric Co.

A system-level comparison study is made for two novel particulate removal devices, based on technical and economic considerations. The two novel devices are an Acoustic Agglomerator and an Electrocyclone. These devices are considered in combination with conventional cyclones, ESPs, and a baghouse.

To investigate high temperature and high pressure applications, particulate-control systems are designed for a 626 MWe Pressurized Fluidized Bed (PFB) coal-burning electric power plant. For atmospheric pressure and low temperature applications, the systems were designed for a new 400 MWe conventional pulverized coal-burning plant. The results of the technical and economic feasibility evaluation are analyzed to develop conclusions regarding potential applications for the two novel cleanup devices. Both the Electro-cyclone and the Acoustic Agglomerator appear economically attractive for PFB power plants, but are not competitive with ESPs for conventional pulverized coal-burning plants.

The Electroscrubber Filter—Applications and Particulate Collection Performance

D. Parquet, Combustion Power Co.

The Electroscrubber is an electrostatic granular filter used to remove particulate in a dry form from gas streams. Achieving "the best of both worlds" of the dry scrubber granular filter and electrostatic collection, the Electroscrubber utilizes a moving bed of filtering media, and is self-cleaning while operating on a continuous basis. The concept, development, and principle of operation are discussed, along with a description of tests results from several Electroscrubber installations.

High Efficiency Particulate Removal with Sintered Metal Filters

B. E. Kirstein, Science Applications, Inc.

From October 1978 through February 1980, a laboratory test program was conducted to verify the particulate removal performance and collection efficiency of sintered metal filters (SMFs). A test apparatus with a capacity of 170 m^3/h was designed and built. Using flyash (particle size range of less than 1 μm to 30 μm) at a concentration of 6 to 10 g/m^3, the particulate removal efficiencies of several types of SMFs were measured over a range of operating conditions.

Over 4,900 hours of SMF operations were completed with no significant operational failures. In no case was the SMF efficiency measured less than 99.999%. No evidence of filter plugging or failure was observed. The operating condition variables included superficial velocities, SMF blowback methods, temperature, and humidity. The effects of these variables on the system pressure drop and particulate removal efficiencies are discussed.

Application of Electrostatic Techniques to the Removal of Dust and Fume from the Industrial Environment

S. A. Hoenig, University of Arizona

In earlier reports, we discussed the use of fog to control fugitive dust. Fogging units are now sold commercially, but in many areas it is impractical to use any water.

For one application of this type, we have designed and tested an electrostatic dust rejector that removes dust from the air being drawn into the turret of a military vehicle. Another system of this type is used to clean air before it is drawn through the air filter of an internal combustion engine. In both situations, the dust is not "collected," but rather simply rejected to the environment, thereby simplifying the overall system.

Dust rejection can also be used to collect dust from air that is to be passed from a source to a cyclone or baghouse. This reduces the load on the regular control facilities while at the same time improving the overall system operation by taking out the small (under 10 μm) particulates.

The Dry Venturi

R. J. Roy,
Teller Environmental Systems, Inc.

The major problem in particulate emission recovery is the reliability of collecting submicron particles. The use of ESPs has often resulted in time degradation of performance and that of baghouses in blinding or low bag life. A dust agglomeration and capture process (dry venturi) with a pressure drop of 0.2 kPa, providing removal of the submicron particulate in the duct prior to the final collector, increases effectiveness and reliability in the operation of the final collector. The system has been successfully operated in the fiberglass, municipal incineration, combustion, secondary aluminum, and fertilizer industries.

Fiber Bed Filter System Control of Welding Particulates

J. A. Bamberger,
Battelle Pacific Northwest Laboratories

The welding industry is a major source of emissions of highly resistive particles with submicron- to micron-size distribution. The Electrostatic Fiber Bed Filter (EFBF) developed at the Pacific Northwest Laboratories of Battelle Memorial Institute is a highly effective method for removal of particles with a high electrical resistivity in the submicron size range. The system incorporates a particle-charging section with a highly porous fiber filter mat to produce a highly efficient particle collection system with a very low pressure drop through the system.

This paper discusses the concept of the EFBF system, its application to the removal of welding particulates, and the results of a parametric study conducted under laboratory conditions to evaluate the EFBF's ability to effectively control particulates generated during routine welding. The results of the parametric analysis include the dependency of the collection efficiency on electric field strength, face velocity, and fiber bed void fraction.

The Use of Glass Capillary Filters to Classify Actinolite Fibers

J. W. Gentry, University of Maryland

This paper describes the use of filters consisting of glass capillary arrays for the

separation of fibers from the more abundant isometric particles. A six stage impactor was designed and calibrated with PSL aerosols with sizes between 0.5 and 0.8 μm at Stk approximately 0.04. The major collection occurred at the interstitial area between pores. A significant amount of reentrainment was observed. Comparison of these measurements with the theory of Manton and Pich is discussed.

Actinolite fibers—non-asbestos mineral fibers with similar morphology to amosite—are produced using a vibrating bed generator. The paper describes the generator, the analysis of the fractional penetration, and preliminary measurements.

Finally, an extension of the method developed by Manton to account for collection in the interstitial area between pores is described. Numerical simulations are compared with scanning electron micrographs.

Ultra-High Efficiency Filtration Systems (Air Recirculation)

R. Potakar,
General Motors Technology Center

The metal casting industry is becoming increasingly aware of the role energy availability and its efficient use has on productivity and profitability. A major use of energy in a foundry is for heating and distributing makeup air. Efficient filtration and recirculation of presently exhausted air could be a viable technique for energy conservation in some cases. This paper reviews new hardware and test data from pilot testing sponsored by the American Foundrymen's Society (AFS) which indicates that particulate removal efficiencies in excess of 99.96% are feasible from casting cleaning.

In addition, guidelines for a complete system design are presented.

The Wet Wall Electrostatic Precipitator

J. Starke,
Bischoff Environmental Systems

The incentive to develop a new variation of the wet ESP—the wet wall electrofilter—derived from investigations on removal of particulates from waste gas from a plant designed to incinerate organically loaded wastewaters having a high salt content.

The most efficient and economical solution proved to be a wet ESP of new design with vertical, water-cooled ground electrodes. The water film resulting from vapor condensation on the cool electrodes instantaneously dissolves the soluble particulates and suspends the insoluble dusts, flushing both from the discharge zone. Thus, the efficiency of such an ESP remains constant since it is free of dust deposits and uninterrupted by flushing cycles. Of several different applications tested in the field, the most promising were those dealing with submicron particulates and aggressive gases.

Section E—Mechanical Collectors

Troubleshooting Multiple Cyclones on Fuel-Oil-Fired Boilers

F. Crowson,
Naval Surface Weapons Center

The body of information presented in this paper is directed to the particulate control of boilers fired with No. 6 fuel oil, a problem when stringent standards must be met. The success of meeting regulatory standards is highly dependent on the availability of data for emission characterization, as well as the availability of space and funds for control equipment. Early efforts toward controlling emissions from boilers fired by No. 6 fuel oil at two Navy shore facilities resulted in the selection of multiple cyclone collectors. Since their installation, both facilities have failed to meet compliance with local standards. A study was made to troubleshoot the boilers and their associated pollution control equipment. The problems associated with the multiple cyclone collector design, installation, and operation are examined.

Collection Efficiencies of Cyclone Separators

P. W. Dietz, General Electric Co.

An improved model for particle collection in cyclone separators is presented. The model is predicated on the identification of three regions: the inlet, the downflow, and the core.

In each region, turbulent mixing is assumed to result in a uniform radial concentration profile. The effects of cyclone geometry on the gas flow pattern are included so that the model incorporates the distribution of gas residence times.

Experimental results from several sources are compared to the model predictions, and favorable agreement obtained.

Electrostatically Augmented Collection in Vortical Flows

P. W. Dietz, General Electric Co.

Electrostatic forces have been demo strated to provide significant enhanc ment in the efficiency of cyclone sep rators. To study these effects, expe ments have been performed in a tw dimensional vortical flow. In these expe ments, the effect of an applied elect field on collection efficiencies has be measured for a range of flow rates f 2.02 μm particles. These measured ef ciencies are compared with an analy model and excellent agreement is demo strated.

High Performance Cyclone Development

W. B. Giles, General Electric Co.

The results of ongoing cyclone develo ments at atmospheric conditions a reported using the air shield concept wi and without electrostatic augmentatio and are contrasted with convention cyclone art.

The conventional high flow cyclo configuration appears significantly unde rated in the literature, and very superi performance is obtained with the a shield design, even without the use clean air. It is theorized that these gai are due principally to improved inlet sw flow uniformity, a vortex shield to mi mize dust reentrainment, and increas exit swirl to produce a high capaci cleanup device of high performance.

Test results of electrostatic enhanc ment are also reported where it is fou that both internal corona and volta fields are required to improve perfor ance. These improvements are found principally enhance small particle colle tion and to mitigate loss in performan at lower flow velocities.

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***Dale L. Harmon** is the EPA Project Officer (see below).*
The complete report, entitled "Third Symposium on the Transfer and Utilization of Particulate Control Technology: Volume III. Particulate Control Devices," (Order No. PB 83-149 609; Cost: $37.00, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
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