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Project Summary

Fourth Symposium on the Transfer and Utilization of Particulate Control Technology: Volume II. Electrostatic Precipitation

F. P. Venditti, J. A. Armstrong, and M. D. Durham

Summarized herein is Volume II of three volumes of proceedings of the Fourth Symposium on the Transfer and Utilization of Particulate Control Technology held in Houston, Texas, October 11-15, 1982. Volume II papers discuss theoretical and applied aspects of electrostatic precipitation.

Volumes I and III are described in two separate project summaries.

This Project Summary was developed by EPA's Air and Energy Engineering 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 three volumes of proceedings were presented at the Fourth Symposium on the Transfer and Utilization of Particulate Control Technology in Houston, Texas, October 11-15, 1982, sponsored by the Particulate Technology Branch of the Air and Energy Engineering Research Laboratory of EPA 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 two major particle control technologies—fabric filters and electrostatic precipitators (ESPs)—were the primary concern of the symposium. These technologies were discussed from perspectives of economics, new technical advancements in science and engineering, fundaments, and applications. Several papers dealt with the interaction of sulfur dioxide control and particulate control. Additional topic areas included mechanical collectors, coal characterization, inhalable particulate matter, novel devices, and advanced energy applications for particulate control.

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 three volumes, each volume containing a set of related session topics so as to provide easy access to a unified technology area.

Volume II Papers

Volume II, summarized here, is a collection of papers describing various aspects

of electrostatic precipitation. A section on advanced ESP technologies contains several papers describing laboratory and pilot plant results of advanced technologies such a prechargers, wide plate spacing, and pulsed excitation. The improvements in ESP performance that can be obtained with flue gas conditioning using sulfur trioxide and ammonia are described in a series of papers. Various aspects of ESP modeling are also discussed including the use of modeling for sizing ESPs and the importance of loss mechanisms in models. Theoretical aspects are covered in a section covering positive polarity, particle charging, dust layer breakdown, back corona, and the electrohydrodynamic effects of turbulence. Practical aspects such as air flow distribution, rapping strategies, electrode design, high voltage control systems, operation and maintenance, and industrial applications are also discussed.

Section A - Industrial Applications

Modeling of Wet Bottom Agitator Systems for Electrostatic Precipitators on Recovery Boilers

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Wet bottom precipitator designs are becoming more common on black liquor recovery boiler applications. A black liquor-filled pan under the precipitator mixes the collected salt cake as it is circulated with rotating agitators. Undesirable buildup can result due to improper mixing and poor flow patterns. In order to verify that the design of a complex wet bottom agitator system is adequate, three dimensional scale modeling should be employed. The paper presents the results of several such model studies. The results discussed include (a) visualization of flow and mixing patterns, (b) identification of poor mixing areas, (c) specification of location and size of baffles to improve areas of poor mixing, (d) determination of agitator speed and direction of rotation, (e) evaluation of paddle design and orientation, and (f) location of feed and drain pipes. The theory of modeling, which considers the temperature and viscosity of the black liquor and which establishes the scaling factors and model fluid parameters, is also discussed. This modeling technique provides a valuable tool for users, consultants, and manufacturers to minimize on-line problems.

Design and Performance of Electrostatic Precipitators Utilizing a New Rigid Discharge Electrode Design

Gary R. Gawreluk
Robert L. Rump
Research-Cottrell, Inc.

A survey of recent electrostatic precipitator buying practices indicates that rigid electrodes, as compared to weighted wires and rigid frames, are becoming more and more the electrode of choice for new equipment purchases. This paper presents some of the reasons behind this trend and discusses the rigid electrode design of one manufacturer. Additionally, the design and performance of three installations that are utilizing this rigid electrode are examined.

Development and Evaluation of a New Precipitator Emitter Electrode

R. Adams
P. Gelfand
Air Correction Division, UOP, Inc.

This paper reviews the laboratory and field development and evaluation associated with the development, of a new rigid emitter. The paper discusses the experimental procedures and establishes the comparative criteria for the evaluation of different electrodes. Laboratory studies were conducted to measure the current density patterns formed by various electrode designs. Final laboratory data are presented comparing three different types of emitters, two rigid and one wire. The data result in comparison of emitter performance on a theoretical basis. Final field data on a full-scale precipitator are presented which verify the laboratory results.

Industrial Applications of Two Stage Tubular Electrostatic Precipitators

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Beltran Associates, Inc.

Two stage Tubular precipitators incorporate best features of both the single stage and two stage type designs. Extremely high collection efficiency in submicron regions makes these precipitators ideal choices for processes having a very high concentration of sub-micron organic mist like Retort Oil Shale or Coal/Wood gasification. Design parameters, field test data and operating data from installations on these processes are discussed in this paper.

Tubular precipitators have also found wide acceptance in ferrous and nonferrous metallurgical applications involving sub-micron emissions, most notably from smelting, sintering, and scarfing operations. Installations on Electric Arc and Rotary Hearth Furnace exhausts are described.

Several installation details from chemical processes like Sulfuric Acid Manufacturing, Sulfonic Acid Production, Ammonia Scrubbing of SO_2, etc. are covered in the paper. Comparisons with single stage type precipitators are made wherever applicable.

Section B - Advanced Technology

Pilot Demonstration Two-Stage ESP Test Results

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Southern Research Institute

Results of the evaluation of the performance of a large pilot scale two-stage ESP under a range of operating conditions are presented in this paper. A three electrode precharger, followed by four collector sections with a total SCA of 286 ft^2/kacfm (56 $m^2/m^3/s$) and a gas flow capacity of 30,000 acfm (850 m^3/min), was tested under two ash resistivity conditions. Background information on system operation since start-up in early 1981 as well as results from recent tests are presented.

Evaluation of Prechargers for Two-Stage Electrostatic Precipitators

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Donald Rugg
Michael Durham
Denver Research Institute

Two-stage precipitators are being considered for high resistivity dust collection. Indications are that the size of a two-stage precipitator for this application may be considerably smaller than a conventional wire plate design. DRI is presently evaluating two-stage designs using a 7.08 m^3/s (15000 ACFM) pilot plant and slipstream of the Valmont Power Plant in Boulder, Colorado. Results of the evaluation of two precharger designs are given.

This paper has been reviewed in accordance with the U.S. Environmental

Protection Agency's peer and administrative review policies and approved for presentation and publication.

Initial Experiments with an Electron Beam Precipitator Test System

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Morgantown Energy Technology Center
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As part of the Department of Energy's Advanced Environmental Control Technology Program, a laboratory-scale Electron Beam Precipitator test system (EBP) has been designed and constructed at the Florida State University to investigate particle charging and collection under a wide variety of experimental conditions. The system consists of a rectangular, closed-circuit wind tunnel composed of a number of interchangeable modules including an electron beam (e-beam) precharger followed by a collecting section. A model aerosol enters the e-beam precharger, is charged in an ionization zone, and then passes downstream to the collector. At a gas velocity of 10 ft/sec through the precharger the velocity in the collector is 2.5 ft/sec, giving the collector an SCA of 200.

Experimental results are presented of a preliminary investigation of e-beam precharger ionization for a wide range of electron beam currents and precharger electric fields. Experiments planned with the EBP include the determination of the charging and collection efficiency of the system using resuspended particles with properties similar to high resistivity fly ash.

Experiments with Wide Ducts in Electrostatic Precipitators

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Helmut Wiggers
University of Essen

The repeatedly observed enhancement of the effective migration velocity with increasing duct width holds out the prospect of less expensive electrostatic precipitators. Vagueness still exists regarding the optimum of the width and the influencing factors on it. Based on laboratory experiments indicating almost a proportionality between migration velocity and duct width up to 715 mm, a pilot precipitator with a maximum flow rate of 36,000 m^3/h was constructed. Parallel to large scale conventional electrostatic precipitators for a coal-fired power station and the room dedustion of a sinter plant duct width up to 1,000 mm were tested. Besides a far reaching conformity with the laboratory results an optimum width was ascertained, which is influenced for instance by the gas velocity. Moreover, with a theoretical precipitator model it succeeded to explain the corresponding influences on the migration velocity.

A Reconciliation: Wide Versus Narrow Spaced Collecting Plates for Precipitators

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Misaka of Hitachi, amongst others, has presented evidence for the improvement of electrostatic precipitator performance, using much wider gas passage spacing than normal (typically 20 in.). Such designs are now in general use.

This appeared to be directly contrary to the experience of Peabody Sturtevant who, on very large utility ESP plants treating highly resistive particulates, produce remarkable efficiencies with narrower spacing than normal (typically 8 in.-9 in.) using a design first developed during the mid-1960's.

In developing his reconciliation, the author uses observations of the actual internal construction of different designs of precipitators and the effect that increasing variance from perfect electrode geometry has upon total power input and field intensity at various plate spacings.

This return to basic precipitation electrostatic theory demonstrates not only that Peabody Sturtevant is right to pursue its narrow spacing design but other companies, with their own particular standard of construction, may be equally right in developing wider spacer techniques.

Pulse Corona as Ion Source and Its Behaviors in Monopolar Current Emission

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The pulse voltage applied to a discharge electrode produces a weakly ionized plasma with about 5×10^9 ions/cm^3 in ion concentration in a very short time of about 10-100 nanoseconds. The monopolar ions are extracted by an externally applied dc field towards the charging area from this plasma, and the current pulse lasts for a substantially longer time of about 1-3 milli-seconds. This is due to a long life time of the plasma which disappears by recombination and charge separation. The expansion of the monopolar ion cloud during its migration across the charging area also contributes to the increase in the duration time of the current pulse measured at the counter electrode. The theory explaining the wave form of the

Section C - Fundamentals

A New Correction Method of Migration Velocity in Deutsch Efficiency Equation for Conversion of Electrostatic Precipitator Sizing from a Pilot-Scale to a Full-Scale

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Research Laboratory

In order to confirm the validity of the Deutsch efficiency equation, the deposition rate distribution of the collecting electrode wall of a small size cylindrical type precipitator having a diameter of 30 mm and length of 400 mm was measured by utilizing a radioactive aerosol tracer technique.

The Thorium B solid particles as testing radioactive aerosols having a relatively uniform particle size of approximately 0.1 microns were used. As a result the concept of the Deutsch efficiency equation was held tolerably good in the range of the gas velocity of 0.35-1.0 m/s, S.C.A. of 35-106 s/m and corona current density of 2.5-13 $\mu A/cm$.

Accordingly, in order to put the Deutsch migration velocity to practical use in industry and to predict the required sizing and S.C.A. for a full-scale precipitator on the basis of the test results in a pilot-scale one, such a new correction formula for the migration velocity in the Deutsch efficiency equation which can be corrected as a function of the aspect ratio of collecting electrode, spacing of electrode, treating gas velocity, S.C.A., corona current density, particle size distribution, a wide spacing effect and re-entrainment effect, was proposed. Furthermore, according to this formula the performance characteristics curves of collection effici-

ency versus S.C.A. for a pilot-scale and full-scale precipitator were given in comparison with both in the range of industrial use such as a coal-fired boiler plant.

Distortion of Pulse Voltage Wave Form on Corona Wires Due to Corona Discharge

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A very short pulse voltage travelling on a corona transmission line producing streamer coronas is subjected to a time-dependent distortion of its wave form owing to energy consumption by corona. There are two different streamers in the case of a parallel-wire transmission line. The first streamer is launched from the negative wire at the leading part of the pulse crest voltage, while the second streamer is emitted from the positive wire at its rear part. The first (negative) streamer produces a small distortion in the leading part, whereas the second (positive) streamer causes a great lowering of voltage wave form in the rear part. The time-dependent equivalent surge impedance of the line also shows a concurrent lowering owing to these streamer activities.

Electrostatic Precipitator Analysis and Synthesis

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General Electric Environmental Services, Inc.

An analytic model using the modified Deutsch approach has been developed to describe the overall performance of an electrostatic precipitator comprising two different configurations or energization methods in tandem. Measurements of the overall collection efficiency and the collection efficiency of either configuration provide sufficient information to isolate the performance contributed by the other. Field data, obtained with pulse energization at the outlet half of the plate area and conventional dc energization at the inlet half of a full-scale utility precipitator, are presented to illustrate the method.

Computer Model Use for Precipitator Sizing

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Combustion Engineering, Inc.

The design of utility industry precipitators is typically based on a historical data base of performance and operating characteristics gathered from full scale units. Development over the last ten years of first principal analytical models for performance prediction offers new tools for the precipitator designer. The EPA/SORI model has been selected by the Combustion Engineering Environmental Systems Division for refinement to the C-E precipitator design. The current historical data sizing procedure and performance prediction approach is described followed by a discussion of the EPA/SORI model and refinements required to make it fit the C-E design.

Improvements in the EPA/SRI ESP Performance Model

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R. B. Mosley
J. R. McDonald
Crestmont Associates, Inc.
L. E. Sparks
Air and Energy Engineering Research Laboratory
Environmental Protection Agency

Revision 3 of the ESP performance model developed for the EPA at Southern Research Institute has been completed. This version features a reduction in required computer time of about a factor of 10 over revision 1 for the rigorous calculation of collection efficiency. In addition, several new procedures have been added to the model. One of these allows the calculation of plume opacity. Another calculates the effects of rapping reentrainment through a dynamic process which examines the results of each rap as it occurs. These changes and others will be described.

This paper has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and approved for presentation and publication.

Numerical Simulation of the Effects of Velocity Fluctuations on Electrostatic Precipitator Performance

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A numerical scheme for including the effects of velocity fluctuations in plate-wire electrostatic precipitators arising from turbulent diffusion, within the framework of the already developed trajectory method for precipitator performance evaluation, is described. The predictions of the scheme are shown to be in agreement with classical solutions based on Fickian diffusion for some simple configurations.

Corona-Induced Turbulence

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The results of previous experiments with a bench-scale precipitator (5 cm plate-to-plate spacing) have shown that moderate levels of turbulence can be maintained in the presence of a corona discharge, and that in accord with theory, significant gains in precipitator efficiency are possible. In this paper hot-wire anemometer measurements in a laboratory-scale precipitator (25 cm plate-to-plate spacing) are presented that support the previous results and suggest that similar improved performance is possible in larger-scale commercial precipitators. The measurements also provide a further explanation for the reduced migration velocity previously reported by other workers at low gas velocities.

Velocity and Turbulence Fields in Negative Corona Wire-Plate Precipitator

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Back-scatter laser Doppler anemometry has been used to obtain distributions of mean and rms values of particle velocity in horizontal planes perpendicular to electrodes in a 0.3 m wide by 0.6 m high wire-plate electrostatic precipitator for four types of electrodes and a mean velocity of 1 m/s. Particle motion reveals complex three-dimensional flow patterns with rolls of axial vorticity which are most regular for barbed wire electrodes with axial needles. The turbulence level is shown to depend on current density and mean velocity and to disappear when the inverse electrical Froude number is below

about 0.2. However, rolls persist. Results are discussed in terms of the turbulent kinetic energy production.

The Effect of Turbulence on Electrostatic Precipitator Performance

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Washington State University

The turbulent character of the gas flow found in an electrostatic precipitator (ESP) affects the motion of the particles (dust) and, therefore, the unit's performance through two mechanisms. The mean velocity profile found in an ESP conveys the particles both longitudinally through the precipitator and in the transverse direction. Particle motion is also strongly affected by turbulent diffusion. The magnitude of the turbulent diffusion is expressed through a particle turbulent diffusivity which depends on the turbulent character of the gas, particle size, and the crossing trajectories effect.

A particle diffusion equation is developed and the coupling with the gas flow field and electric field is discussed. Finally, techniques for estimating the particle diffusivity are presented.

Factors Leading to Electrical Breakdown of Resistive Dust Layers and Sustained Back Corona

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Recent theoretical work modeling the resistive dust layer has shown considerable enhancement of the electric field at the points of contact between particles. These theories are examined with regard to evaluating the conditions leading to electrical breakdown and sustained back corona discharge via the Townsend avalanche mechanism. Among other factors, the particle size distribution is shown to have a significant effect on the internal field in the layer. The resulting breakdown characteristics of the resistive layer can be used to obtain the proper operating current density for the precipitator and to evaluate the effects on collection of excursions into the back corona regime.

This paper has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and approved for presentation and publication.

Electrical Breakdown of Particulate Layers

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A theoretical analysis of electrical breakdown of a current-carrying particulate layer modeled as a regular array of equi-sized resistive spheres having combined surface and volume conduction is presented. This analytical treatment is based on an extension of a theory of electromechanics of the layer and predicts the onset of electrical breakdown of the layer in the form of intermittent microsparks in the gap between the contacting particles when the electric field at the contact or in the surrounding gap exceeds the threshold breakdown value. The occurrence of breakdown is due to the existence of a very strong electric field in and around the contact region as a result of current constriction at the contact area. Two possibilities of breakdown are examined: (i) breakdown in the gap where the gap height, d, is larger than the gas mean free path, λ; and (ii) vacuum breakdown at the contact where $d < \lambda$.

The electrical behavior of the layer after breakdown is also analyzed in terms of a simplified equivalent lumped circuit using methods of conventional transient circuit theory. In this analysis the layer is modeled as a number of capacitive spark gaps in series, separated by high resistances. In effect, the discharge propagates through the layer as a cascade of microsparks, which discharges the layer locally. The theory predicts increases of sparking frequency and average current as the applied average field E_A, exceeds the threshold average field for the onset of breakdown E_{AB}.

Experiments with glass beads demonstrate the existence of intermittent microsparks after the onset of breakdown, whose frequency of occurrence increases with increasing E_A.

Electromechanics of Particulate Layers

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In previously reported work, a comprehensive theory of the electromechanics of a particulate layer was developed, treating it as a regular cubic array of equisized resistive spheres, allowing for both volume and surface conduction, and taking account of self-compression of the layer. The theory gives expressions for various quantities of interest including the contact angle Θ_o, the maximum electric field E_{max}, the average compressive stress P_E and the apparent resistivity p_A, all in terms of the average layer current density J_A (or average field $E_A = p_A J_A$) and the system parameters.

In the present paper this theory is extended in two ways. First, explicit expressions for the quantities Θ_o, E_{max}, P_E and p_A are given in the form of power laws (in E_A) in which the coefficients and exponents depend on the system parameters, in particular the resistivity ratio $o = sa/p$, where a is the particle radius and s and p are, respectively, the (intrinsic) surface and volume (material) resistivities of the particles. These expressions should be operationally useful for interpreting experimental data. Second, the theory has been extended to include all of the six classical modes of compaction for equisized spheres. The results are qualitatively similar to those for the cubic array and are related to them by a set of multiplicative constants which are of order unity.

Measurements of the resistivity characteristics p_A (E_A) of layers of glass beads confirm the theoretical results both qualitatively and quantitatively.

Lateral Propagation of Back Corona in Twin-Electrode Type Precipitators

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University of Tokyo

The lateral propagation of back corona, discovered to occur in a tri-electrode corona system, also occurs in a conventional electrostatic precipitator of the twin-electrode system under certain circumstances. The primary factor in initiating this phenomenon is the mutual excitation of the wire corona discharge and back corona. At high resistivity of dust deposit and with small discharge wire diameter, this mutual excitation becomes dominant and the lateral propagation occurs from a single back corona on a plate appearing at a local spot. The dc base voltage in a pulse charging system must be selected in careful consideration of this phenomenon. The detailed conditions of its initiation and extinction in air

at NTP are presented in relation to various modes of corona discharge.

First Measurements of Aerosol Particle Charging by Free Electrons

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Southern Research Institute
Leslie E. Sparks
Air and Energy Engineering Research Laboratory
Environmental Protection Agency

The charging of fine aerosol particles by free electrons has been isolated from negative ionic charging and measured for the first time. The charge and size of individual particles were measured in a Millikan cell, with charging electric field from 0.82 to 8.2 kV/cm. In the particle size range 0.5 to 3.5 μm diameter, the particle charge values are much larger, and increase faster with particle size, than those predicted and observed for negative ionic charging. The particle charge values show only slight dependence on the charging electric field.

This paper has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and approved for presentation and publication.

Section D - Operation & Maintenance

Gas Flow Distribution Model Testing

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Uniform gas distribution is critical to the operational efficiency of both electrostatic precipitators and structural baghouses.

The relationship of collection efficiency to gas distribution criteria is discussed. The Deutsch-Anderson equation modelled into a computer gas distribution program indicates the effects of gas distribution deviations on efficiency performance

Unique characteristics of the Lodge-Cottrell approach to gas flow distribution, pressure loss, and dust fallout testing are discussed, as are the proprietary distribution devices used. Test objectives and methods used are described.

These preceding discussions identify the need for gas flow correction technology and its role in fulfilling today's technological requirements.

The need for gas flow correction in structural baghouses is discussed, and some results presented.

Finally, model vs. field test results will be compared for both the electrostatic precipitator and the structural baghouse.

Acknowledgements—The authors wish to express their appreciation to Dresser Industries, Inc., for granting permission to publish this information and also our thanks to our colleagues at Lodge-Cottrell U.K. and U.S. for their assistance.

Air Flow Model Studies

L. H. Bradley
United Engineers and Constructors

This paper establishes the need for strict control of air flow model studies and the higher acceptance standards for test results which are required to obtain the collection efficiencies needed to satisfy regulatory requirements. The importance of flow patterns and minimum pressure losses is reviewed and discussed including the importance of dimensionless ratios such as Reynolds Number, modified Fraude Number, and the momentum ratio. The requirements for design, scale, model limits, fabrications and test procedures as established by I.G.C.I. Standards and additional requirements are shown and discussed. Data collection methods including limitations and evaluation methods for test data are presented and discussed. Examples from recent air flow model studies are presented and reviewed to illustrate items which should be considered. Based on these results, a comparison of deviation from design collection efficiency as a function of root mean square deviation is shown.

Collecting Electrode Rapping Designed for High Efficiency Electric Utility Boiler Electrostatic Precipitators

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Lodge-Cottrell Limited

The influence of collecting electrode rapping on the efficiency of an electrostatic precipitator is examined. Particular emphasis is placed upon the limitations caused by dust re-entrainment.

The way in which the effectiveness of the dislodgement blow is often specified in terms of measured shock acceleration on the collecting electrode, is shown to be unsatisfactory in view of plate and accelerometer response variations.

The means by which re-entrainment can be minimized is discussed and a theory which can be used to explain observed performance is advanced.

Long term performance of an Electric Utility gas cleaning plant designed to achieve the best compromise of rapping requirements is reviewed. Examples of 500 MW power plant precipitators, and larger, operating satisfactorily over periods up to 17 years after commissioning, are cited.

Electrostatic Precipitator and Fabric Filter Operating and Maintenance Experience

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Burns and Roe
W. Piulle
Electric Power Research Institute

This paper summarizes the "Reliability Assessment of Particulate Control Systems" (RP 1401) performed by Burns and Roe, Inc., for the Electric Power Research Institute. Its purpose was to determine the performance and availability of electrostatic precipitators and fabric filters used to control flue gas particulate emissions from coal fired electric utility power plants. Representative precipitator and fabric filter installations, with associated ash handling systems, were studied. Operation and maintenance histories were compared. The results are presented in graphic form.

Section E - Conditioning

Economical Fly Ash Collection by Flue Gas Conditioning

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Wahlco, Inc.

This paper discusses the application c sulfur trioxide flue gas conditioning to th collection of high resistivity fly ash i coal-fired power plants. A large portion c the world's coals produce ash falling i this category. Peformance figures for 600-MW U.S. plant having this type c equipment in operation are given. Th plant had conditioning installed as a pa of the original plant equipment. A con parison of emissions to those of ba houses is included, along with data c maintenance and operating costs.

Experiences at Detroit Edison Company with Declining Performance of Sulfur Trioxide Flue Gas Conditioning Equipment

L. A. Kasik
W. A. Rugenstein
J. L. Gibbs
Detroit Edison Co.

The generation of sulfur trioxide in some of our Company's sulfur-burning flue gas conditioning systems has been found to decrease significantly over a period of a few years. The deteriorating performance went undetected because SO_2 to SO_3 conversion efficiency was measured with what later proved to be an inadequate procedure. A fall-off in SO_3 output can seriously affect precipitator collection efficiency resulting in opacity and/or mass emission excesses. The vanadium pentoxide catalyst bed was suspected to be at fault because in some systems very little heat was being generated in the bed. A new test procedure, a modified EPA Reference Method 8, was used to overcome the inadequacies of the old procedure. Using the new procedure, conversion efficiency on one particular boiler was found to have dropped from about 80 percent to about 30 percent after five years of service.

ESP Conditioning with Ammonia at the Monroe Power Plant of Detroit Edison Company

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J. P. Gooch
G. H. Marchant, Jr.
Southern Research Institute

An investigation of ammonia conditioning was conducted recently at Monroe Unit 1, a 720-MW unit burning coal with about 2% sulfur and collecting fly ash in cold-side ESPs around 270°F (132°C). Experience has shown that 8 ppm of ammonia substantially lowers stack opacity. Tests confirmed the 99.72 to 99.83% on an overall mass basis and from 99.20 to 99.68% for particle sizes below 6 μm. Particle-size data and ESP electrical data indicate that conditioning mechanisms include space-charge enhancement of the electric field by means of a fume of ammonium sulfate or bisulfate. The resistivity of the ash without conditioning ($\pm 1 \times 10^{10}$ ohm-cm) was not altered by ammonia addition. Data on outlet particle sizes show evidence of reduced rapping reentrainment through increased ash cohesiveness.

Fly Ash Chemistry Indices for Resistivity and Effects on Electrostatic Precipitator Design and Performance

Herbert J. Hall
J. J. Hall Associates, Inc.

Field data on coal-ash properties and in situ fly ash resistivity measurements for 24 cases of cold side precipitators are correlated with various ash chemistry indices for resistivity prediction. Coals studied, principally low sulfur, are from eastern and western U.S.A., western Canada, and several other countries; boiler sizes are 50-800 MW. Most universally applicable general indices for low S coals seem to be those based upon sodium content, per se, and on a silicate type index long used by the author. Under special conditions, other indices may also be useful. Ash chemistry indices proposed by investigators such as Selle, Dunston, Matts, Soviet ESP designers, Bickelhaupt, Hall, and others are reviewed. Comparisons of useful indices with resistivity data calculated from a computer program based on Bickelhaupt's work are illustrated for an additional 16 cases which are also compared with the in situ field data. Some quantitative aspects of coal-ash properties as affecting precipitator design and performance are discussed.

Section F - Control Systems

A New Energization Method for Electrostatic Precipitators Mitsubishi Intermittent Energization System

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Mitsubishi Heavy Industries, Ltd., developed a new energization system for ESPs and has proved its favorable performance on many operating full-scale ESPs with high resistivity ash. This paper is to introduce the new equipment named Mitsubishi Intermittent Energization System (abbreviated to MIE) which supplies high voltage to ESP intermittently with adjustable supplying and suppressing times by means of power control thyristors with electronic circuit. MIE mitigates the degradation of collecting efficiency due to back corona and its effect can be estimated by voltage-current characteristics at gas load operation. The best improvement is expected for the case of low voltage and large current. A long term actual operation on an iron ore sintering machine has shown that the modified migration velocity w_k of 100% at conventional energization is improved to 147% by MIE and at the same time the power consumption of 100% is reduced to 20%.

The advantages of MIE can be summarized as follows:

(1) improvement in collecting efficiency for high resistivity ash;
(2) energy saving; and
(3) small additional cost.

This paper includes explanation of equipment, result of laboratory test and measurement of full-scale ESPs.

Some Measured Characteristics of an Electrostatic Precipitator Obtained Using a Microcomputer Controller

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Z. Herceg
K. J. McLean
University of Wollongong

This paper presents a new microcomputer control system for electrostatic precipitators. The system, currently in its second stage of development, is capable of actively controlling, monitoring and recording the characteristics of an electrostatic precipitator.

The results of tests carried out on the precipitator along with the output of a dust monitor mounted on the precipitator output are also presented in an attempt to determine the optimum operating conditions.

Electrostatic Precipitator Energization and Control Systems

K. M. Bradburn
K. Darby
Lodge-Cottrell Dresser

This paper reviews the development of systems for the energization and control of electrostatic precipitators, ranging from heavy duty thyristors used to control the input to the T/R set to the use of microprocessor technology which gives the facility for a precipitator total energy management system (TEMS). The impact of these changes is described first on the T/R set, then on the automatic voltage control system to maximize precipitator efficiency.

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Reference is made to the electrical demands of a precipitator, under varying operating conditions, to justify the advantages of the TEMS concept.

The system comprises a local control and power unit for each T/R set, a supervisory control unit and a control room monitor which allow visual (CRT) display and print out of operating data and parameters remote from the precipitator.

In addition to improved automatic voltage control, TEMS offers the facility for integrating additional operations and parameters such as stack opacity, rapping, hopper heating, hopper ash level alarm, precipitator startup and shutdown. This results in complete system control and improved operation with lower power consumption and operating costs.

Using a telephone modem, precipitator engineers remote from the plant can accurately and instantaneously monitor and adjust precipitator operation and give technical support to plant engineers for prompt correction of any operating problems.

Applying Modular Microcomputer Control Elements in a Precipitator Control System

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Environmental Elements Corporation

The declining cost of microcomputers allows the control designer to implement microcomputers into individual components of a precipitator control system. This distributed processing technique allows the integration of the individual controls with a master computer, and also provides the controls with intelligence required to operate independently, should the need arise. The individual microcomputer elements used to control transformer/rectifers, rapping systems and alarm systems are described. Techniques used to integrate these elements with a master precipitator controller providing data acquisition, energy management, and control optimization are also defined. In addition, a fail-safe operating philosophy which takes advantage of the intelligence designed into the individual controls is presented. Finally, the impact of this technology on the end user is discussed, using an actual installation at a utility boiler.

Section G - Plenary Session

The Current Status, Future Directions, and Economic Conditions in the Applications of ESP's

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The subjects being most widely discussed for advancements in electrostatic precipitators are conditioning to modify dust resistivity, pulsed power supplies, precharging, wide-plate spacing, microcomputer controls, alternative rapping schedules, and different electrode geometries. There are some relatively new concepts in conditioning, such as addition of sodium compounds to coal to reduce resistivity of fly ash for hot-side precipitators, and the use of ammonia compounds to achieve better performance in some precipitators by reducing both resistivity and reentrainment or increasing the collection electric field by space charge enhancement.

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The complete report, entitled "Fourth Symposium on the Transfer and Utilization of Particulate Control Technology: Volume II. Electrostatic Precipitation," (Order No. PB 85-161 909/AS; Cost: $40.00, Set of three volumes PB 85-161 883/AS; Cost: $95.50, subject to change) will be available only from:
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