



## Project Summary

# Proceedings: Sixth Symposium on the Transfer and Utilization of Particulate Control Technology

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The proceedings of the Sixth Symposium on the Transfer and Utilization of Particulate Control Technology consist of three volumes: Vol. 1, Plenary, Scrubbers, Opacity/Measurements, Advanced Energy Applications I, Advanced Energy Applications II, Integrated Control Processes I, and Integrated Control Processes II; Vol. 2, Electrostatic Precipitator Technology: Hot-Size Precipitator Studies, Performance Enhancement I, Performance Enhancement II, Performance Estimating (Modeling), Advanced Technology, Fundamentals I, Controls and Energy Consumption, Fundamentals II, and Design Considerations; and Vol. 3, Fabric Filtration (FF): Advanced Concepts I, FF: Advanced Concepts II, FF: Practical Considerations, FF: Pilot Scale Studies, Operation and Maintenance, and Fugitive Emissions. EPA and EPRI co-sponsored the symposium held in New Orleans, LA, February 25-28, 1986.

*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 three volumes of the same title (see Project Report ordering information at back).*

### Introduction

The papers in these three volumes were presented at the symposium and provided the forum for researchers, manufacturers, users, government agencies, educators, and students to discuss

new particulate control technologies and to share experiences of using existing technologies.

The major particulate control technologies — electrostatic precipitators (ESPs) and fabric filters (FFs) — were the primary concern of the symposium. These technologies were discussed from perspectives of economics, new technical advancements in science and engineering, fundamentals, applications, and operation and maintenance. Additional topics dealt with integrated control processes, advanced energy applications, wet scrubbers, opacity, fugitive emissions, and novel concepts.

The symposium was conducted as a series of parallel sessions, each containing two to six related papers. The sessions were scheduled, however, to avoid any conflict that might be caused by simultaneous sessions dealing with the same topic. The papers, therefore, have been divided into three volumes. Each volume contains a set of related session topics so as to provide reasonably ready access to a unified technology area.

Asterisks precede the titles of papers prepared by EPA or its contractors.

### Volume 1 Papers

Volume 1 describes various aspects of particulate control. The keynote address presented in the opening plenary session addressed the rapidly advancing particulate matter control technology. Improved wet scrubber particulate control technology, modeling of stack opacity and control of aerosols to meet opacity standards, and application of technologies

such as ceramic filters, granular beds, high temperature electrostatic precipitators and a cross-flow filter to the control of high temperature and pressure processes in advanced energy systems were presented and discussed. Integrated control processes covered a variety of technologies for control of particulate and SO<sub>x</sub> and/or NO<sub>x</sub>, such as spray dryers, the EPA developed E-SOX process, and firing of enhanced emulsified fuel oil.

### **Plenary Session**

Keynote Address: Particulate Matter Control - The Rapidly Advancing Technology

Grady B. Nichols,  
Southern Research Institute

### **Session C-1: Scrubbers**

Development of Improved Single Drop Collection Efficiency Correlations for Microcomputer Modeling of Venturi Scrubber Performance

K. Ellwood, A. W. Gnyp, C. C. St. Pierre, University of Windsor;  
and S. Viswanathan,  
Clayton Environmental Consultants, Ltd.

Fume Filtration Through a Dynamic Liquid Spray Curtain

H. H. Elliott, H. L. Marschall,  
D. G. Jones, EMCOTEK, Inc.

### **Session C-2:**

#### **Opacity/Measurements**

\*Options for Controlling Condensation Aerosols to Meet Opacity Standards

A. S. Damle, D. S. Ensor,  
Research Triangle Institute; and  
L. E. Sparks, U.S. EPA/AEERL

\*Relationship of Opacity to the Loss Mechanisms in ESPs

D. S. Ensor, P. A. Lawless,  
Research Triangle Institute; and  
L. E. Sparks, U.S. EPA/AEERL

Stack Opacity Model

D. J. Mormile, G. C. Stegmann,  
Consolidated Edison Co. of N.Y.;  
and B. F. Piper, KVB, Inc.

The Collection of Fine Particulate in Power Plant Electrostatic Precipitators

L. T. McEvoy, K. R. Parker  
and A. Russell-Jones,  
Lodge-Cottrell, Ltd., UK

Predicting the Particle Size Distribution of Fly Ash

R. S. Dahlin, J. P. Gooch,  
Southern Research Institute; and  
L. Y. Sadler, III,  
University of Alabama

\*Quality Assurance Considerations for Particle Sizing Measurements

G. L. Johnson,  
U.S. EPA/AEERL; and C. E. Tatsch,  
Research Triangle Institute

### **Session C-3: Advanced Energy Applications I**

Technical and Economic Evaluation of High Temperature and High Pressure Particulate Cleanup Systems

R. Zaharchuk, L. N. Rubow,  
Gilbert Associates, Inc.

Particulate Control at High Temperature and Pressure for Emerging Electric Power Generation Technologies

R. C. Bedick, R. J. Dellefield,  
U.S. DOE

The Testing and Evaluation of Ceramic Filter Fabrics

R. Chang, J. Sawyer, H. Lips,  
Acurex Corp.

R. C. Bedick, R. J. Dellefield,  
U.S. DOE

Hot Gas Clean-Up by Means of Porous Ceramic Filter Elements

P. Eggerstedt, J. F. Zievers,  
Industrial Filter & Pump  
Manufacturing Co., Inc.

### **Session C-4: Advanced Energy Applications II**

Results of Parametric Tests on an Electrostatic Precipitator Operating at High Temperature and High Pressure Conditions

G. A. Rinard, D. E. Rugg, M. Durham,  
J. Armstrong,  
Denver Research Institute

Design of Baghouse and Electrostatic Precipitator for the Coal-Fired Flow Facility

J. P. Foote,  
The University of Tennessee Space  
Institute

Granular Bed Filter Component Design for High Temperature and High Pressure

K. B. Wilson,  
Combustion Power Co.

The Interaction of a Gas with Solid and Liquid Particles in a Rotating System

H. Heshmat, O. Pinkus,  
Mechanical Technology, Inc.

### **Session C-5: Integrated Control Processes I**

Particulate Control Integration with Wet Scrubber SO<sub>2</sub> Removal and Waste Generation

P. M. Maroney, S. A. Davidson,  
Brown and Caldwell Engineers;  
S. M. Katzberger,  
Sargent and Lundy Engineering; and  
J. E. Cichanowicz,  
EPRI

\*Kinetics of Reaction Between Hydrated Lime and Sulfur Dioxide

A. S. Damle, K. Ramanathan,  
Research Triangle Institute; and  
D. L. Harmon,  
U.S. EPA/AEERL

\*Mini-Spray Dryers for Low-Cost SO<sub>2</sub> Control

C. B. Sedman, L. E. Sparks,  
U.S. EPA/AEERL

Electrostatic Precipitator Performance Characterization in Spray Dryer Flue Gas Desulfurization Systems

G. E. Bresowar,  
Combustion Engineering, Inc.; and  
R. F. Robards, R. A. Runyan,  
TVA

Fabric Filter Operating Experience on Dry FGD System at Austell Box Board Corporation

W. H. Bradley,  
Austell Box Board Corp.

### **Session C-6: Integrated Control Processes II**

\*Results of Pilot-Scale Tests of E-SO<sub>2</sub>

L. E. Sparks, G. H. Ramsey,  
R. E. Valentine, N. Plaks,  
U. S. EPA/AEERL

Researches for Optimal Integrated Flue Gas Treatment

G. Dinelli,  
Italian National Electricity Board,  
Italy; and M. Rea,  
University of Padua, Italy

Utility Case History on Firing Enhanced Emulsified Fuel Oil to Reduce Particulate and NO<sub>x</sub> Emissions

E. S. Behrens,  
Fuel Tech, Inc.

Particulate Control Devices for Municipal Refuse-to-Energy Plants

M. Kapner,  
New York Power Authority  
Integrated Control Device for Micro and Submicronic Particulate and Acid Gas Control

T. K. Ewan, O. L. Holland,  
Hydro-Sonic Systems

### **Volume 2 Papers**

Volume 2 describes various aspects of electrostatic precipitation. Papers are presented that describe design and operating considerations to improve performance of hot-side ESPs. Papers describe lining improvements and experienced ESP performance using SO<sub>3</sub>, NH<sub>3</sub>, and tri-ethyl-amine (TEA) conditioners, high voltage pulsing, and microprocessor control are presented. Papers are also presented that describe performance modeling (modeling) by predicting fly ash resistivity from ultimate coal analysis.

selection of critical parameters for ESP design and performance evaluation, prediction of ESP performance based on coal and ash chemistry, and a method to calculate characteristics of contaminated wire and strip discharge electrodes. Advanced ESP technologies including wide-plate spacing, intermittent energization, and a moving electrode type ESP are discussed. Theoretical and experimental presentations were made covering medium-sulfur coal fly ash resistivity, the effect of high mass loading, the effective dielectric constant of fly ash, diagnostic technology of ESP operation, electric field measurements in an operating ESP, finite-diffusivity effects in single-stage ESPs, three-dimensional calculations of negative tuft corona, simulation of corona discharge under practical ESP conditions, and electrical characteristics of back corona. Papers are presented on measurement of ESP power, management of ESP energy, evaluation of tests and the economic implications of power reduction on ESPs, and application of a new micro-processor-based distribution control system for ESPs. Various design considerations (e.g., laboratory measurement of electrical parameters in conventional and wide duct ESPs, influence of gas distribution on ESP performance, development and testing of a collecting curtain for an ESP, and characterization of discharge electrode performance) were discussed.

### **Session A-1: Hot Side Precipitator Studies**

Hot Precipitators and Duct Design Considerations

J. A. Werhane, W. G. Doran, O. Zaben, Sargent and Lundy Engineers  
Considerations for the Cyclic Operation of Hot-Side Electrostatic Precipitators  
F. C. Southworth, R. K. Miller, Dayton Power & Light Co.; and  
C. A. Altin, EBASCO Services, Inc.

### **Session A-2: Performance Enhancement I**

A Comparison of Electrostatic Precipitator Performance Enhancement Technologies

J. Dalmon, G. L. Dalton, R. S. Hansen, Electric Supply Commission, South Africa

Baltimore Gas and Electric Experience with Combined SO<sub>3</sub>/NH<sub>3</sub> Injection for Precipitator Performance Improvement

W. E. Cummings, Jr., Wahlco, Inc.; and

W. H. Reamy, Baltimore Gas and Electric Co.  
A Design Methodology for Optimized Water Conditioning of High Resistivity Fly Ash

N. W. Frisch, N. W. Frisch Associates, Inc.; and  
W. T. Hartshorn, Sonic Development Corp.  
A New Chemical Conditioner Together with Good Operations and Maintenance Program Management Helps Meet Emissions Objectives

R. K. Sinha, Calgon Corp.

### **Session A-3: Performance Enhancement II**

Evaluation of Broad and Narrow Pulse Energization of a Cold-Side Electrostatic Precipitator

H. R. Osmers, D. J. Sugumele, Rochester Gas & Electric Corp.  
Full Scale Demonstration Results of Electrostatic Precipitator Pulse Energization

T. W. Lugar, J. M. Friday, General Electric Environmental Services, Inc.  
Field Evaluation of Pulse Energization Under Different Operating Conditions  
S. Masuda and S. Hosokawa, University of Tokyo, Japan  
Long-Term Experience with Pulsed Energization of ESPs at a Danish Power Station

K. Porle, R. Karlsson, FLAKT Industri AB, Sweden; and  
B. Kirkegaard, Ensted Power Station, Denmark

### **Session A-4: Performance Estimating (Modeling)**

\*An Improved Model for Predicting Fly Ash Resistivity

R. E. Bickelhaupt, Bickelhaupt Associates, Inc.; and  
L. E. Sparks, U.S. EPA/AEERL

A Selected Review of Critical Parameters and Formulae for Design and Performance Evaluation of Electrostatic Precipitators

H. J. Hall, H. J. Hall Associates, Inc.  
Predicting Cold-Side Precipitator Performance Based Upon Coal and Ash Chemistry

F. A. Horney, V. H. Belba, Stearns Catalytic Corp.

\*Approximate Method to Calculate Characteristics of Contaminated-Wire and Strip-Discharge Electrodes

K. J. McLean, University of Wollongong, Australia; and  
L. E. Sparks, G. H. Ramsey, U.S. EPA/AEERL

### **Session A-5: Advanced Technology**

Pilot-Scale Evaluation of ESP Wide-Plate Spacing

R. F. Altman, EPRI; E. C. Landham, Jr., J. L. DuBard, Southern Research Institute; and  
H. L. Wheeler, Combustion Engineering, Inc.

Pilot-Scale Evaluation of ESP Intermittent Energization

E. C. Landham, Jr., J. L. DuBard, Southern Research Institute; and  
W. E. Piulle, L. F. Rettenmaier, EPRI

Operating Results of Moving Electrode Type Electrostatic Precipitators for Coal-Fired Boilers

H. Asano, H. Yabuto, M. Ohtsuka, Hitachi Plant Engineering and Construction Co., Ltd., Japan

### **Session A-6: Fundamentals I**

\*Medium-Sulfur Coal and Fly Ash Resistivity

W. A. Harrison, J. K. Nicholson, Southern Company Services; J. L. DuBard, Southern Research Institute; and  
L. E. Sparks, U.S. EPA/AEERL

\*The Effect of High Mass Loading on Fly Ash Precipitators

M. G. Faulkner, J. L. DuBard, Southern Research Institute; and  
L. E. Sparks, U.S. EPA/AEERL

\*The Effective Dielectric Constant of Fly Ash

R. P. Young, J. L. DuBard, Southern Research Institute; and  
L. E. Sparks, U.S. EPA/AEERL

Diagnostic Technology of Precipitator Operation

S. Masuda, T. Itagaki, S. Hosokawa, University of Tokyo, Japan

### **Session B-6: Controls and Energy Consumption**

Electrostatic Precipitator Power Measurements

P. Gelfand, P. Gelfand Associates, Inc.;

E. C. Landham, Jr., Southern Research Institute; and

L. F. Rettenmaier, EPRI

ESP Energy Management and Optimization of Collection Efficiency

B. Borowy, M. McLaughlin,  
W. F. Frazier,  
Virginia Electric Power Co.

The Evaluation of Tests and the Economic Implications of Power Reduction on Electrostatic Precipitators

D. L. Lueckenotte, V. L. Kunzweiler,  
Burns and McDonnell

First Utility Application of a New Micro-processor-Based Distributed Control System for Electrostatic Precipitators

G. R. Gawreluk, M. Barav,  
Research Cottrell, Inc.; and  
S. R. Coco,  
Lutz, Daily, and Brain

Power Consumption of Opacity Feedback Controlled Electrostatic Precipitator Transformer-Rectifiers

J. J. Roosma,  
General Electric Environmental  
Services, Inc.; and  
J. B. Howard,  
Alabama Electric Cooperative, Inc.

### **Session A-7: Fundamentals II**

Electric Field Measurements in an Operating Precipitator

J. L. DuBard, E. C. Landham, Jr.,  
Southern Research Institute;  
and R. F. Altman,  
EPRI

Finite-Diffusivity Effects in Single-Stage Precipitators Theory and Experiment

S. A. Self, M. Mitchner, D. H. Choi,  
K. D. Kihm, R. Leach,  
Stanford University

\*Three-Dimensional Calculations of Negative Tuft Corona

M. K. Owen, T. Yamamoto,  
P. A. Lawless,  
Research Triangle Institute; and  
L. E. Sparks,  
U.S. EPA/AEERL

The Simulation of Corona Discharges Under Practical Precipitator Conditions

I. Gallimberti,  
University of Padua, Italy

\*Some Electrical Characteristics of Back Corona

K. J. McLean,  
University of Wollongong, Australia;  
and L. E. Sparks, G. H. Ramsey,  
U.S. EPA/AEERL

### **Session B-7:**

#### **Design Considerations**

Laboratory Measurements of Some Electrical Parameters in Conventional and Wide Duct Precipitators

A. A. Elmoursi, G. S. P. Castle,  
The University of Western Ontario,  
Canada

Influence of Gas Distribution on Precipitator Performance

L. Lind, F. L.  
Schmidth and Co.,  
Denmark

Development and Testing of a Collecting Curtain for an Electrostatic Precipitator

H. L. Engelbrecht, R. J. McMullan,  
Wheelabrator Air Pollution Control  
Characterization of Discharge Electrode Performance: Results of Laboratory and Pilot Plant Experiments

L. A. Hawkins, H. L. Wheeler,  
Combustion Engineering, Inc.

### **Volume 3 Papers**

Volume 3 describes various aspects of fabric filtration, operation and maintenance (O&M), and fugitive emission control. Advanced fabric filtration concepts were covered in two sessions that dealt with electrostatically stimulated fabric filtration (ESFF) fundamentals, modeling, laboratory and field evaluations, and economics. Practical considerations of fabric filtration were covered in a session that dealt with evaluation of acid-resistant synthetic needled felt, laboratory studies of the filtration performance of various media under simulated field conditions, filter bag evaluation, and aerosol deposition in fabric filters. Papers are presented that discuss pilot scale studies to evaluate fabric filter performance on high-sulfur coal-fired power plants and flue gas cleaning to improve fabric filter performance. A session on O&M included papers on fabric filters and ESPs, which provided insights into O&M problems and methods used to eliminate the problems. A session on fugitive emission controls covered review of an EPA manual on identification, assessment, and control of fugitive particulate emissions, and an EPA manual on hood capture systems. Papers are also presented on field evaluation of windscreens and measurement of fugitive emissions in a coal-fired power plant.

### **Session B-1: FF:**

#### **Advanced Concepts I**

\*Distribution of Fly Ash in a Filter Bag Operating with a Charged Axial Electrode

G.E.R. Lamb, K. T. Duffy,  
Textile Research Institute

\*Study of Electrostatically Stimulated Filtration Fundamentals

D. W. VanOsdell, A. S. Viner,  
K. D. Carter,  
Research Triangle Institute; and  
L. S. Hovis,  
U.S. EPA/AEERL

### **Session B-2: FF:**

#### **Advanced Concepts II**

\*Mathematical Model for Advanced Electrically Stimulated Fabric Filtration

T. Yamamoto D. S. Ensor,  
Research Triangle Institute; and  
R. B. Mosley, L. S. Hovis, N. Plaks,  
U.S. EPA/AEERL

\*Advanced ESFF Laboratory Test Results

R. B. Mosley, L. S. Hovis, B. E. Daniel,  
U.S. EPA/AEERL

\*Advanced ESFF Applied to a Stoker Coal-Fired Boiler

G. P. Greiner, ETS, Inc.; A. S. Viner,  
Research Triangle Institute;

L. S. Hovis,  
U.S. EPA/AEERL; and

R. Gibbs,  
U.S. Dept. of the Navy

\*Advanced Electrostatic Fabric Filtration Experience at Southwestern Public Service Company

R. Serrurier,  
Southwestern Public Service Co.

\*Economics of Advanced Electrostatic Stimulation of Fabric Filtration

L. S. Hovis,  
U.S. EPA/AEERL; and

A. S. Viner,  
Research Triangle Institute

### **Session B-3: FF:**

#### **Practical Considerations**

Evaluation of Acid-Resistant Synthetic Needled Felt Filter Media in Coal-Fire Boiler Pulse-Jet Baghouses

W. T. Grubb,  
W. W. Criswell Co.

Laboratory Studies of the Filtration Performance of Various Filter Media under Simulated Field Conditions

P. E. Frankenburg,  
E. I. DuPont de Nemours and Co.

Evaluation of a Specific Type of Filter Bag Supplied by Various Vendors

Y. J. Chen, P. N. Roberts, T. D. Tarn,  
Joy Manufacturing Co.

Catenary Analysis of a Fabric Filter Bag During Reverse-Gas Cleaning

E. A. Samuel,  
General Electric Environmental  
Services, Inc.; and

J. G. Musgrove,  
Bechtel Power Corp.

\*Aerosol Deposition in Fabric Filters

D. S. Ensor, T. Yamamoto, A. S. Viner,  
Research Triangle Institute

### **Session B-4: FF:**

#### **Pilot Scale Studies**

Performance of a High-Sulfur-C Pilot-Scale Fabric Filter

R. F. Heaphy, R. R. Wilson,  
Southern Research Institute; and  
W. E. Piulle,  
EPRI  
Flue Gas Conditioning for Improved  
Baghouse Performance  
D. L. Laudal, S. J. Miller,  
University of North Dakota

### **Session B-5: Operation and Maintenance**

\*Operation and Maintenance Experi-  
ence at Harrington Station  
W. Hooks, O. Plunk,  
Southwestern Public Service Co.; and  
D. L. Harmon,  
U.S. EPA/AEERL  
\*Computer Monitoring of Pilot Plant  
Baghouse Performance  
A. S. Viner, L. M. Fickel,  
Research Triangle Institute, and  
L. S. Hovis,  
U.S. EPA/AEERL  
The Design of Repairs to Upgrade  
10-Year Old Industrial Precipitators  
V. L. Kunzweiler, J. B. Landwehr,  
Burns & McDonnell  
Performance Improvement History of  
Inadequately Performing Precipitators  
J. G. Musgrove, W. R. Lane,  
Bechtel Power Corp., and  
M. W. Wei,  
Aluminum Company of America  
Performance Improvement and Fire

Prevention in Fly Ash Collection System  
at a 500 MW Wood-Fired Power Plant  
E. Gal, M. Murphy,  
General Electric Environmental  
Services, Inc

### **Session C-7: Fugitive Emissions**

\*Identification, Assessment, and Con-  
trol of Fugitive Particulate Emissions  
C. Cowherd, Jr., J. S. Kinsey,  
Midwest Research Institute, and  
D. L. Harmon,  
U.S. EPA/AEERL  
\*Process Fugitive Particulates — Design  
Methods for Enclosures  
H. D. Goodfellow, T. Cesta,  
Hatch Associates, Ltd., Canada;  
E. R. Kashdan, D. W. Coy, J. J. Spivey,  
Research Triangle Institute; and  
D. L. Harmon,  
U.S. EPA/AEERL  
\*Field Evaluation of Windscreens as a  
Fugitive Dust Control Measure for  
Materials Storage Piles  
R. A. Zimmer, K. Axetell, Jr.,  
T. C. Ponder, Jr.,  
PEI Associates, Inc.  
Measurement of Fugitive Emissions in  
a Coal-Fired Power Plant  
G. E. Muleski, F. J. Pendleton,  
Midwest Research Institute; and  
W. A. Rugenstein,  
The Detroit Edison Co.

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*Dale L. Harmon is the EPA Project Officer (see below).*

*The complete report consists of three volumes, entitled "Proceedings: Sixth  
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(Set Order No. PB 87-147 609/AS; Cost: \$99.50)*

*"Volume 1," (Order No. PB 87-147 617/AS; Cost: \$36.95)*

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*"Volume 3," (Order No. PB 87-147 633/AS; Cost: \$36.95)*

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*U.S. Environmental Protection Agency*

*Research Triangle Park, NC 27711*

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