Department of Environmental Protection

Jeb Bush
Governor

Marjory Stoneman Douglas Building
3900 Commonwealth Boulevard
Tallahassee, Florida 32399-3000

David B. Struhs
Secretary

March 6, 2002

CERTIFIED MAIL – RETURN RECEIPT REQUESTED

Ms. Beverly Spagg, Chief
Air and EPCRA Enforcement Branch
U.S. EPA – Region 4
61 Forsyth Street, S.W.
Atlanta, Georgia 30303-8960

Re: Big Bend Generating Station BACT/BOP for Particulate Matter

Dear Ms. Spagg:

Per your request, the Department reviewed the letter dated September 18, 2001 from Tampa Electric Company (TEC) to EPA Region 4 together with the accompanying documents entitled:

- Big Bend Generating Station Best Available Control Technology For Particulate Matter (BACT), and
- Big Bend Generating Station Best Operating Practices For Particulate Matter (BOP).

The documents were submitted pursuant to the Consent Decree between EPA and TEC. EPA is responsible for all matters related to that Consent Decree. Our comments, provided at your request, do not constitute formal recommendations regarding decisions to ultimately be made by EPA.

Big Bend Generating Station Best Operating Practices For Particulate Matter (BOP).
This report was prepared by the Electric Power Research Institute (EPRI) and Southern Research Institute (SRI). The report may best be described as detailing "reasonable measures" that can be taken to effect low cost reductions at an existing facility such as Big Bend.

Section 4, "Operations and Maintenance Guidelines," refers to an SO_3 Conditioning System for the purpose of improving particulate collection efficiency. A review of the present Title V Permit does not indicate that such a system is installed. It is not clear whether the EPRI/SRI submitted BOP guidelines are generic in nature (i.e., not specific to TEC Big Bend), or whether such a system is installed. In any case, such systems have been demonstrated to improve ESP performance by reducing resistivity, and they should be reviewed for the Big Bend units. The systems should be reflected in the Title V permit and their use required during operation (if such systems actually exist at the facility).

Big Bend Generating Station Best Available Control Technology For Particulate Matter (BACT).
This report was prepared by TEC and Environmental Consulting and Technology (ECT). We offer the following comments:

1) It does not appear that the BACT analysis was completed using traditional EPA methodology. The analysis uses as "baseline emissions," test data from tests that were (indicated to have been) conducted during 1999-2000. This has the effect of increasing (by approximately a factor of 2) the cost per ton of particulate matter removed. EPA guidelines require a BACT analysis to be conducted by comparing past actual emissions to the "potential to emit" (PTE) of each BACT alternative.

   Normally, the Department considers CEMS data when available or data reported to the Department in the Annual Operating Report (AOR) as more representative of baseline emissions rather than a special purpose test. The rationale for this is that AOR data has been previously reported to the Department by the applicant with the only intention of providing an accurate representation of actual emissions.

A similar issue arose during TEC's repowering of the Bayside/Gannon Station. TEC wished to utilize CO emission test data (which they contended was more accurate than previously submitted data on AOR's) and thus avoid a PSD Review for CO. In that case, the Department applied the AOR data in lieu of the TEC submittal of test data, determined that PSD was triggered, and made a BACT determination.

We note that a report is due on March 1 detailing the feasibility of CEMS for particulate matter (PM).

Enclosed is an Excel spreadsheet that we prepared, which shows the results of revising the BACT submittal using the AOR-submitted PM emission levels for years 1999-2000.

2) There appear to be some inconsistencies regarding the cost-effectiveness thresholds used for selecting BACT. For example, Option 1 was selected as BACT for Unit 1 at a submitted cost effectiveness of $1035 per ton of PM removed, yet Option 2 on Units 2 and 3 were rejected at submitted cost-effectiveness values of $731 and $971 per ton of PM removed (respectively). These options were rejected by TEC because of submitted incremental cost effectiveness values, which were higher than the straight-run cost effectiveness. As indicated below, cost effectiveness thresholds are not standardized, let alone incremental thresholds.

3) The Department did not find any published EPA (bright line) lower threshold for the cost-effectiveness of PM reduction options. However an Interagency Group in the previous Administration provided an indication on the upper threshold of "reasonable" cost-effectiveness in the "Implementation Plan for Revised Air Quality Standards," that was approved by former President Clinton.[1] Excerpts are enclosed.

   According to the Interagency Plan, "It was agreed that $10,000 per ton of emission reduction is the high end of the range of reasonable cost to impose on sources . . . . the EPA will encourage the States to design strategies for attaining PM and ozone standards that focus on getting low cost reductions and limiting the cost of control to under $10,000 per ton for all sources".

4) The Bay Area AQMD and the San Joaquin Valley UAPCD in California have established $5300 and $5700 per ton as the upper limits of cost-effectiveness for PM controls. A recent study (excerpts attached) on small wood-fired boilers was prepared by a consultant for Vermont, New Hampshire and Massachusetts.[2] This study was completed for the evaluation of PM controls as they relate to the biomass energy industry. It is instructive nevertheless as the author's opinion is that $1000 per ton is "within the range of control cost acceptability" and "$3500 are at the high end for control costs".

5) The Department has no published bright line upper or lower thresholds for the cost-effectiveness of PM reductions. The Department conducts more PSD and BACT reviews than practically any other state and has a number of individuals who prepare and seal such determinations. The unanimous opinion of these experts was that none would reject PM controls where cost-effectiveness (as calculated by the standard EPA methodology) was determined to be in the range of $2000 per ton or less for a new source. The same holds for an existing source particularly when implementation would result in achievement of the New Source Performance Standard such as 40 CFR 60, Subpart Da.

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1 Memorandum. William Clinton, President, to Administrator of the Environmental Protection Agency. "Implementation of Revised Air Quality Standards for Ozone and Particulate Matter". The White House, Washington D.C., July 16, 1997.

2 Report. Resources Systems Group, Inc. "Air Pollution Control Technologies For Small Wood-Fired Boilers". July 2001.

Note that this value does not set a bright line for the Department. For example, we did not inquire whether the same experts would reject a strategy having a cost-effectiveness of $3,000 per ton of PM removed. The Department reserves the right to make such determinations on a case-by-case basis and to consider the type of industry and the purpose of the strategy (e.g. SIP compliance versus PSD/BACT) when making such decisions.

6) Depending on EPA's application of cost-effectiveness ranges for BACT at an existing source it is possible that Options 2, 4 (see below) and 3 might be acceptable for Units 1, 2 and 3 respectively, based upon the BACT evaluation submitted by TEC and ECT.

7) We reviewed an article co-authored by Dr. Ralph Altman, who is the leader of EPRI's ESP research program and a lead member of TEC's review team.[3] The enclosed article highlights the following three technologies:

- Performance monitoring software,
- Compact hybrid particulate collector (COHPAC) and
- Separator technology that illustrate a range of particulate control technologies.

It appears that these technologies were indeed included as options within the evaluation, but some discrepancies may exist. Partial text from the referenced article follows:

Field tests conducted in 1997 on an exhaust gas slipstream from Alabama Power Co.'s Miller Unit 3, Birmingham, Ala. These tests confirmed the system could capture between 95 percent and 98 percent of particulate matter left after gases exit the ESP.

A comparative economic and engineering analysis of various ESP upgrade options showed that the capital and levelized costs of an ESP upgraded with the system were less than half the costs of a wet ESP with the same collection efficiency. The economic assessment projected that a 250-MW unit could be retrofitted with a separation and recirculation process for approximately $6.25 million, a capital cost of $25/kW. O&M costs also promised to be reasonable. The system operates at a pressure drop of less than 1.0 inch of water. This is significant because the existing draft fan can be used without modification. In addition to low capital and operating costs, the system has other advantages, including a high capacity for removing PM2.5 particles, fuel flexibility and no re-entrainment losses from rapping.

As indicated, the COHPAC system option was included in the submitted Appendix of the BACT analysis, but rejected for all units as being overly expensive, with installed cost stated as ranging from $35 to $40 per kilowatt. Within the attached Excel spreadsheet, the Department provides EPA with an estimate of the cost-effectiveness of this system (Option 4), using the submitted numbers as well as numbers which are consistent with the above referenced article. Of interest, it appears that the combined installation of COHPAC on all three units would yield an estimated cost effectiveness of just under $1000 per ton, when applying the values from the article within the framework of the standard EPA cost effectiveness methodology.

8) The Department is aware of an additional option, which does not appear to have been included in the analysis. This is an "Advanced Hybrid Particulate Collector" (AHPC) with technical support provided by the US DOE.[4] A summary from DOE's website is enclosed. It appears to be a variation of COHPAC. Although the Department is not clear as to whether this option qualifies within the terms of the EPA Consent Decree, it may provide an additional option for BACT review purposes.

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3 Article. Easom, B.H.; Burlatsk, S.F; Altman, Ralph F.; and Chang, R. "Particulate Control Technologies For Power Generation". Pollution Engineering. July 1999.

4 Website. http://www.netl.doe.gov/coalpower/environment/pm/con_tech/hybrid.html. Accessed 3/1/2002.

Of interest, AHPC is also claimed to remove 90% Hg and should complete full scale testing in 2002-2003.

9) For informational purposes, the Department recently permitted the JEA Northside coal plant with a 0.011 lb/mmBtu-emission limit for particulate matter. Our review of the BACT Clearinghouse indicates that currently established emission limits for coal-burning power plants typically vary from 0.01 to 0.02 lb/mmBtu. This compares to the NSPS limit of 0.03 lb/mmBtu promulgated in 1978 (40CFR60, Subpart Da). For reference, TEC is proposing approximately 0.04 lb/mmBtu. Given that the COHPAC system is touted as being capable of reducing 95% of the existing (ESP outlet) PM emissions, the application of this technology to the Big Bend Units would seem to allow for PM emission levels in the 0.01 to 0.02 lb/mmBtu range to be attained.

If you have any questions regarding this matter, please call me at 850/921-9503 or Al Linero at 850/921-9523.

Sincerely,

for C. H. Fancy, P.E., Chief
Bureau of Air Quality

Enclosures:

cc: Jerry Kissel, DEP SWD
Jerry Campbell, Hillsborough County EPC

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1. Article Addressed to:

Ms. Beverly Spagg, Chief
Air & EPCRA Enforcement Branch
U.S. EPA - Region 4
61 Forsyth Street, S. W.
Atlanta, GA 30303-8960

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PS Form 3800, January 2001 See Reverse for Instructions

Unit 1 with Heat Input: 4037	Option 1	Option 2	Option 3	Option 4	*Option 4 notes*
AOR Past Actual TPY 1371					
TEC Expected Emission lb/MMBtu	0.045	0.031	0.021	0.027	
MMBtu/yr @ 100% C.F.	35364120	35364120	35364120	35364120	
TEC TPY emitted at target lb/MMBtu	796	548	371	477	
lb/MMBtu red from tested 0.055 lb/MMBtu	0.01	0.024	0.034	0.028	
TEC TPY Red from tested 0.055 lb/MMBtu	177	424	601	495	
TEC Annualized Cost - $/year	$183,051	$777,471	$1,371,892	$2,279,082	
TEC Cost Effectiveness - $/ton	$1,035	$1,832	$2,282	$4,603	
FDEP TPY red. from AOR past actual	575	823	1000	1302	*(<- 95% reduct)*
FDEP Cost Effectiveness - $/ton	$318	$945	$1,372	$1,250	*(ratio of 25/35)*

Unit 2 with Heat Input 3996	Option 1	Option 2	Option 3	Option 4	
Past Actual TPY 2360					
TEC Expected Emission lb/MMBtu	0.042	0.032	0.022	0.025	
MMBtu/yr @ 100% C.F.	35004960	35004960	35004960	35004960	
TEC TPY emitted at target lb/MMBtu	735	560	385	438	
lb/MMBtu red from tested 0.088 lb/MMBtu	0.046	0.056	0.066	0.063	
TEC TPY Red from tested 0.088	805	980	1155	1103	
TEC Annualized Cost - $/year	$122,424	$716,845	$1,311,265	$2,279,082	
TEC Cost Effectiveness - $/ton	$152	$731	$1,135	$2,067	
FDEP TPY red. from past actual	1625	1800	1975	2242	*(<- 95% reduct)*
FDEP Cost Effectiveness - $/ton	$75	$398	$664	$726	*(ratio of 25/35)*

Unit 3 with Heat Input 4115	Option 1	Option 2	Option 3	Option 4	
Past Actual TPY 1611					
TEC Expected Emission lb/MMBtu	0.036	0.03	0.02	0.021	
MMBtu/yr @ 100% C.F.	36047400	36047400	36047400	36047400	
TEC TPY emitted at target lb/MMBtu	649	541	360	378	
lb/MMBtu red from tested 0.070 lb/MMBtu	0.034	0.04	0.05	0.049	
TEC TPY Red from tested 0.070 lb/MMBtu	613	721	901	883	
TEC Annualized Cost - $/year	$105,358	$699,779	$1,294,200	$2,331,714	
TEC Cost Effectiveness - $/ton	$172	$971	$1,436	$2,640	
FDEP TPY red. from past actual	962	1070	1251	1530	*(<- 95% reduct)*
FDEP Cost Effectiveness - $/ton	$110	$654	$1,035	$1,088	*(ratio of 25/35)*

TECO Proposal Cumulative Summary				
TEC Submitted Annual Costs	$410,833	$2,194,095	$3,977,357	$6,889,878
TEC Submitted TPY reduction	1595	2125	2658	2481
TEC Submitted Cost Effectiveness	$258	$1,032	$1,497	$2,777
FDEP TPY reduction	3162	3693	4225	5075
FDEP Cost Effectiveness	$130	$594	$941	$970

THE WHITE HOUSE

WASHINGTON

July 16, 1997

MEMORANDUM FOR THE ADMINISTRATOR OF THE ENVIRONMENTAL PROTECTION AGENCY

SUBJECT: Implementation of Revised Air Quality Standards for Ozone and Particulate Matter

I have approved the issuance of new air quality standards to provide important new health protection for all Americans by further controlling pollution from ozone and particulate matter. These new standards promise to improve the lives of millions of Americans in coming years.

Consistent with my Administration's approach to regulatory decision making, I also want to ensure that these new standards are implemented in a common sense, cost-effective manner. It is critically important that these standards be implemented in the most flexible, reasonable, and least burdensome manner, and that the Federal Government work with State and local governments and other interested parties to this end.

I have determined that there are certain essential elements of an approach to implementation that will accomplish these goals. I direct you to use the following elements when implementing the new air quality standards:

1. Implementation of the air quality standards is to be carried out to maximize common sense, flexibility, and cost effectiveness;

2. Implementation shall ensure that the Nation continues its progress toward cleaner air by respecting the agreements already made by States, communities, and businesses to clean up the air, and by avoiding additional burdens with respect to the beneficial measures already underway in many areas. Implementation also shall be structured to reward State and local governments that take early action to provide clean air to their residents; and to respond to the fact that pollution travels hundreds of miles and crosses many State lines;

3. Implementation shall ensure that the Environmental Protection Agency ("Agency") completes its next periodic review of particulate matter, including review by the Clean Air Scientific Advisory Committee, within 5 years of issuance of the new standards, as contemplated by the Clean Air Act. Thus, by July 2002, the Agency will have determined, based on data available from its review, whether to revise or maintain the standards. This determination will have been made before any areas have been designated as "nonattainment" under the $PM_{2.5}$ standards and before imposition of any new controls related to the $PM_{2.5}$ standards; and

4. Implementation is to be accomplished with the minimum amount of paperwork and shall seek to reduce current paperwork requirements wherever possible.

Excellent preliminary work on the strategy for carrying out these implementation principles has been accomplished by an interagency Administration group and I commend that group for these important efforts. The group's work is set out in the attached plan, which is hereby incorporated by reference.

In order for the implementation of these standards to proceed in accordance with the goals I have established, I hereby direct you, in consultation with all affected agencies and parties, to undertake the steps appropriate under law to carry out the attached plan and to complete all necessary guidance and rulemaking no later than December 31, 1998.

This memorandum is for the purposes of internal Administration management only, and is not judicially reviewable.

You are authorized and directed to publish this determination and plan in the Federal Register.

William J. Clinton

Implementation Plan for Revised Air Quality Standards

An interagency Administration group has discussed and evaluated approaches for the common sense, flexible, and cost effective implementation of the revised National Ambient Air Quality Standards (NAAQS) for ozone and particulate matter (PM). This document reflects the preliminary work by that group on a strategy for implementing these health-based standards consistent with the principles discussed by President Clinton in his announcement of the standards. The Environmental Protection Agency (EPA) will continue to work with other Federal agencies, State and local governments, small businesses, industry, and environmental and public health groups to fully develop and implement this strategy.

This implementation plan provides a road map for areas to attain the standards and protect public health without sacrificing economic growth. The goals of the plan are to: 1) maintain the progress currently being made toward cleaner air and respect the agreements and technological progress already made by communities and businesses to pursue clean air; 2) reward State and local governments and businesses that take early action to reduce air pollution levels through cost-effective approaches; 3) respond to the fact that pollution can travel hundreds of miles and cross many State lines; 4) work with the States to develop control programs which employ regulatory flexibility to minimize economic impacts on businesses large and small to the greatest possible degree consistent with public health protection; 5) minimize planning and regulatory burdens for State and local governments and businesses where air quality problems are regional, not local, in nature; 6) ensure that air quality planning and related Federal, State, and local planning are coordinated; and 7) recognize the substantial lead time necessary for State and local governments and businesses to plan for and meet standards for a new indicator of PM.

The Clean Air Act (CAA) requires the EPA to set air quality standards to protect the public health and the environment without consideration of costs. The 1997 revisions to the NAAQS for ground level ozone and PM fulfill this requirement. However, the Act recognizes that the EPA and the States must work together to develop cost-effective, flexible, and fair implementation plans if the standards are to be met as expeditiously as practicable.

There are a number of important linkages between these pollutants. There is also a linkage between these pollutants and their precursors and regional haze problems. Promulgation of the two standards simultaneously provides a more complete description

States are required to submit within 3 years of a NAAQS revision. Once those areas have an approved SIP, the EPA will take action so the standard no longer applies. In addition, the EPA will take action within 3 years to designate areas for the revised PM_{10} standards.

Cost-Effective Implementation Strategies

There is a strong desire to drive the development of new technologies with the potential of greater emission reduction at less cost. It was agreed that $10,000 per ton of emission reduction is the high end of the range of reasonable cost to impose on sources. Consistent with the State's ultimate responsibility to attain the standards, the EPA will encourage the States to design strategies for attaining the PM and ozone standards that focus on getting low cost reductions and limiting the cost of control to under $10,000 per ton for all sources. Market-based strategies can be used to reduce compliance costs. The EPA will encourage the use of concepts such as a Clean Air Investment Fund, which would allow sources facing control costs higher than $10,000 a ton for any of these pollutants to pay a set annual amount per ton to fund cost-effective emissions reductions from non-traditional and small sources. Compliance strategies like this will likely lower the costs of attaining the standards through more efficient allocation, minimize the regulatory burden for small and large pollution sources, and serve to stimulate technology innovation as well.

Additional Future Activities and Coordination with Other Federal Departments and Agencies

The approaches outlined above for implementation of the current and new ozone standards will be developed in the future in much greater detail. In order to ensure that the final details are practical, incorporate common sense, and provide the appropriate steps toward cleaning the air, input is needed from many stakeholders such as representatives of State and local governments, industry, environmental groups, and Federal agencies. The EPA will continue seeking such advice from a range of stakeholders and, after evaluating their input, propose the necessary guidance to make these approaches work. Moreover, the EPA will continue to work with a number of Federal agencies to ensure that those agencies comply with these new standards in cost-effective, common sense ways. The guidance and rules (e.g., revisions to NSR and conformity) will be completed by the end of 1998.

The EPA will continue to work with the Small Business Administration (SBA) because small businesses are particularly concerned about the potential impact resulting from future control measures to meet the revised PM and ozone standards. The EPA, in partnership with SBA, will work with the States

RESOURCE
SYSTEMS GROUP
INCORPORATED

AN EVALUATION OF AIR POLLUTION CONTROL TECHNOLOGIES FOR SMALL WOOD-FIRED BOILERS

Prepared for:

Vermont Department of Public Service

Vermont Department of Environmental Conservation, Air Pollution Control Division

New Hampshire Governor's Office of Energy Resources and Community Services

Massachusetts Division of Energy Resources

July 2001

331 Olcott Drive, White River Junction, Vermont 05001

EXECUTIVE SUMMARY

Resource Systems Group, Inc, has undertaken An Evaluation of Air Pollution Control Technologies for Small Wood-Fired Boilers. This is focused on boilers in the size range of approximately 3 to 10 MM Btu/ hour heat output although reference is made to boilers slightly smaller and considerably larger in obtaining data for the analysis. The analysis is generic in that it is applicable to any manufacturer or type of wood-fired boiler in this size range for any location. Attention has been given to boilers in this size range manufactured by the companies that are active in marketing boilers in the northeastern states.

The conclusions of the study are that small wood-fired boilers using staged combustion or gasifier designs are able to achieve lower emission rates for particulate matter when compared to many larger wood-fired boilers and small units with older designs. However, the analysis has demonstrated that lower PM10 emissions can be achieved with appropriate add on control systems at reasonable cost. The best available control for PM10 is an LSR Core Separator with an emission rate of less than 0.1 lb/MM Btu. This technology will also bring about some reduction in particulate toxic emissions.

A review of control technologies for other criteria pollutants concluded that there was no economically practical control technology available that could bring about a reduction of emissions from wood-fired boilers in this size category especially when these boilers would be primarily used for space heating in institution or commercial situations.

A comparison of boiler emissions fired by wood, distillate oil, natural gas and propane shows that wood has lower sulfur dioxide and net greenhouse gas emissions than distillate oil. Nitrogen oxide emission rates from wood are close to the emission rates from distillate oil. Particulate matter, carbon monoxide and total organic compound emissions are higher than oil.

INTRODUCTION

Resource Systems Group, Inc. under contract to the Vermont Department of Public Service, the Vermont Department of Environmental Conservation, Air Pollution Control Division, the Massachusetts Division of Energy Resources and the New Hampshire Governor's Office of Energy Resources and Community Services, has undertaken "An Evaluation of Air Pollution Control Technologies for Small Wood-Fired Boilers." The study is intended for research and informational purposes by state agencies in Vermont, Massachusetts, New Hampshire and elsewhere and by energy planners and others with an interest in biomass energy systems. The conclusions and the opinions are those of the principal author Dr. Colin J. High and do not necessarily reflect the opinion of the sponsoring agencies. Although the study has been guided by the methods used in the EPA Best Available Control Technology (BACT) analysis process, it is not intended to define BACT for regulatory purposes or to imply that any of the sponsoring states intends to establish a BACT requirement for wood-fired boilers of this class. Reference to manufacturers names and the performance characteristics of specific equipment is for informational purposes. Neither the author nor the sponsoring agencies endorse these products or performance claims.

This study is focused on boilers in the size range of approximately 3 to 10 MM Btu/hour heat output, although reference is made to boilers slightly smaller and considerably larger in obtaining data for the analysis. The analysis is generic in that it is applicable to any manufacturer or type of wood-fired boiler in this size range for any location. Attention has been given to boilers in this size range manufactured by companies that are active in marketing boilers in the northeastern states. The analysis is also guided by the regulatory requirements in the states of Massachusetts, New Hampshire and Vermont. The results are however, relevant beyond these specific terms of reference.

Formal BACT analysis for wood-fired boilers in this size range is somewhat uncharted territory because typically, smaller wood-fired boilers have not needed to demonstrate BACT, and they rarely use state-of-the-art control technologies. In consequence, the control engineering and costs for this size range are not well demonstrated. Therefore in some cases it has been necessary to use technology and cost information for somewhat larger systems and then use general engineering principles to scale the appropriate control systems to this size of boiler.

The second component of this study is to make a comparison between wood-fired systems and comparably sized systems burning fuel oil, natural gas or propane in terms of emissions and control technology for relevant pollutants. This comparison will provide the basis for making overall comparisons that may provide input to public policy decisions. It should be recognized that the second part of the analysis is inherently more difficult because it involves comparisons among pollutants that the existing regulatory frameworks do not consider.

The Core Separator[1]

The Core Separator is a relatively new mechanical collector system produced by LSR Technologies. It works on the same general principles as a cyclone but the processes of separation and collection are accomplished separately by two different components: a core separator and a cyclone collector. The Core Separator consists of multiple cylindrical units each with a single inlet and two outlets. One outlet is for the cleaned gas stream and the other contains a concentrated recirculation stream. The recirculation stream is cleaned by being passed through a cyclone, after which it is returned to the separator unit. The core separator has very high collection efficiency, comparable to an ESP, for particles above about 2.5 micrometers but collection efficiency falls to below 50% for particles below 1 micrometer. Its overall performance falls between an ESP or fabric filter and a cyclone. There are several units installed on wood and coal fired boilers and field test results are available for wood-fired applications. In tests on a boiler fired by a wood gasifier with uncontrolled total particulate emission rates that averaged 0.17 lb/MM Btu, the core separator reduced the emissions to an average of 0.07 lb/MM Btu[2]. The overall average collection efficiency was 56%. This collection efficiency reflects the low initial emission rate and resultant particle size distribution. The collection efficiency over the whole range of uncontrolled wood-fired boiler emissions may be as high as 90%

Based on the test results the core separator working on a boiler that is well controlled through good combustion practices can probably achieve controlled emission rates for total particulates of 0.07 lb/MM Btu over a wide range of load conditions. The capital cost and annual operating costs of a core separator are given in Tables 2 through 5. The unit cost for PM10 removed ranges from approximately $1,000 per ton to $3,500 per ton at 30% capacity factor. The cost for a 7.5 MM Btu boiler operating at 75% of annual capacity is about a $1,000 per ton which is within the range of control cost acceptability. At 30% of capacity the control cost of about $3,500 are at the high end for control costs. If this same technology were to be applied to a 3 MM Btu size boiler then capital cost per ton controlled would further increase by at least 12%.

The core separator when operating either on a well controlled or poorly controlled wood-fired boiler can be expected to control PM10 to below 0.1 lb/MM Btu. This would constitute BACT for at least boilers of 7.5 MM Btu and up. For smaller boilers at about 3 MM Btu being used for space heating and operating at an annual capacity factor of 30% or less the control costs rise. An argument could be made that a less expensive cyclone would be acceptable.

Venturi and Wet Scrubbers.

Venturi and other wet scrubbers are more efficient than multicyclones especially in size fractions below 1 micrometer. The AP-42 indicates a control efficiency for wet scrubbers of 93% for PM10. Overall performance across the particle size range is comparable to the LSR Core Separator. No wet scrubbers

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[1] The Core Separator is a registered trademark of LSR Technologies of Acton MA.

[2] Particulate Emission Evaluation Boiler and Core Separator System Exhaust: Report of Tests at Allard Lumber Company Brattleboro Vermont, December 1996 and January 1997. LSR Technologies Inc. 898 Mains St, Acton MA 01720. 1997.

July 1999

Pollution Engineering Online

Particulate Control Technologies for Power Generation

State-of-the-art upgrades can help utilities keep pace with increasingly stringent regulations.

by Bruce H. Easom, S. F. Burlatsky, Ralph F. Altman and Ramsay Chang

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The high-resistivity ash produced by burning most low-sulfur coals generally reduces the particulate collection efficiency of electrostatic precipitators (ESPs) — the devices used most often in electric utilities. Consequently, utilities are looking for relatively inexpensive ways to overcome this problem and increase fuel flexibility. Several technologies under evaluation can improve ESP performance in a cost-effective manner, increase fuel flexibility and help plants prepare for regulatory changes.

Given near-term uncertainties about the regulation of airborne trace substances (air toxics), many utilities planning ESP upgrades are considering improvements that also could facilitate compliance with stricter future emissions limits at a moderate additional cost. In addition, to cope with uncertainties about the future ownership of power plants in an increasingly competitive environment, utility managers are placing a premium on low-cost options for extending the life of ESPs, or enhancing their performance.

This article highlights three technologies — a performance monitoring software, the compact hybrid particulate collector (COHPAC) and a separator technology — that illustrate a range of particulate control technologies.

These products are designed to provide:

- Enhanced ESP performance at a low capital cost.
- Lower operation and maintenance (O&M) costs.
- Increased fuel flexibility.
- Compliance with more stringent emissions standards.
- Integrated multipollutant control.

Optimizing electrical operation

New digital controls for ESPs can help restore or increase ESP effectiveness by continuously optimizing the electrical operation of a precipitator. For some marginal ESPs, the improved performance is sufficient to meet emissions requirements. A new ESP performance monitoring and troubleshooting software program can further enhance the capabilities of a new digital control system. The software monitors ESP operation online, evaluates performance and recommends corrective actions when performance problems arise. Its ability to continuously predict performance, including opacity, helps plant personnel interpret and im-prove ESP performance, reduce ESP-related operation and maintenance (O&M) costs, troubleshoot problems when experienced ESP specialists are not available, continue to meet applicable emissions and opacity standards and avoid expensive derating imposed by regulators. See Figure 1.

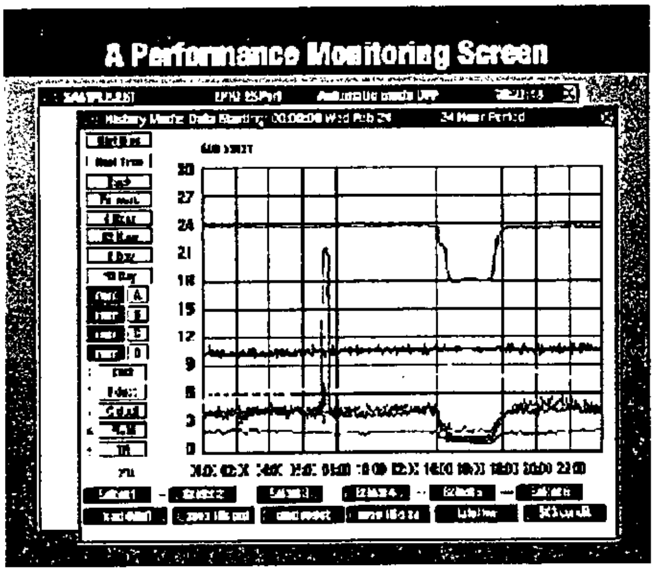

Figure 1. This screen was generated offsite. Off-site capability allows engineers to monitor ESP operations from remote locations. Note the red spike between 6 a.m. and 8 a.m. The continuous emissions monitoring system was being calibrated, resulting in incorrect measured opacity readings for this period.

The performance calculation ability helps plant owners decide how to upgrade ESPs. For an individual unit, operators can model ESP performance over a range of operating conditions and fly ash properties. Using this model, they then can make refined, site-specific predictions concerning how ESP upgrades would affect performance. In addition, because the software can help define the range of coal and fly ash properties that ESPs can handle effectively, utilities can use it to screen low-sulfur coals. This reduces to a manageable number the pool of candidate coal sources without costly and time-consuming test burns.

Improved baghouse technology

Particulate control options that provide high collection efficiencies include large ESPs and reverse-gas (RG) or pulse-jet (PJ) baghouses. In addition, smaller, less-expensive and easier-to-retrofit technologies are in the early stages of development. Over the past 10 years, domestic utilities have equipped 20,000 megawatts (MW) of capacity with RG baghouses. A survey of recent user experience and measurements at various pilot- and full-scale plants show that baghouses readily keep outlet emissions below the New Source Performance Standard of 0.03 pound/million Btu. Well-maintained baghouses generally achieve good bag life — averaging more than four years, with many lasting more than eight years in RG applications. However, although PJ baghouses are used widely abroad, they have seen only limited, utility-scale applications in this country.

A novel and less expensive method of obtaining the very low emissions levels achieved with baghouses is COHPAC. The basic concept of this process is simple: Install a filtering system — typically, a PJ baghouse operated at a higher air-to-cloth ratio than is used in conventional PJ baghouses — downstream of an existing ESP. This removes any uncollected particles. COHPAC enables utilities to improve ESP performance and meet present and possibly more stringent future regulatory requirements in a cost-effective manner.

An extension of the basic concept involves retrofitting a baghouse into the last field of an ESP, forming an even more compact, high-efficiency particulate collector. Texas Utilities Electric uses an 1100-MW COHPAC unit downstream of small coldside ESPs to improve performance at its Big Brown Station in Athens, Texas. Alabama Power has installed a 275-MW COHPAC unit to improve hotside ESP performance at its Gaston Station in Willsonville, Ala., and is installing a second unit that will operate in confined spaces.

Refining the technology

The potential for injecting sorbents between the ESP and a COHPAC baghouse to capture acid gases, sulfur oxides, mercury and/or other gas/vapor phase contaminants is being evaluated. In this configuration, the fly ash and sorbents are collected separately, permitting separate disposal, sale or recovery of fly ash and sorbents. A current project is looking at the impact of additional sorbent loading and of sorbent size distribution on COHPAC baghouse performance.

Advanced barrier filters can provide very high collection efficiencies. All are suited for stand-alone applications and are being considered for use in COHPAC applications, especially in cases where space is at a premium. The devices include high-surface-area pleated bags made from commercial polymers, and membrane-coated and layered ceramic filters. The ceramic filters are capable of withstanding temperatures as high as 1600°F. In some instances, they could be coated with NOX-reduction catalysts. To assess their potential for long-term performance, pilot-scale testing is being performed at utility sites.

Joining forces

A new technology combines electrical and mechanical forces to separate a flue gas into one clean stream and one containing a high concentration of particles. Flue gas enters the separation and recirculation process' cylindrical separators through a tangential slot. See Figure 2. The tangential flow creates a circular motion, which forces larger particles toward the outside of the cylinder. A "bleed flow," with a high concentration of particulate matter, is withdrawn from the system through a second slot in the cylinder wall opposite the entering flow. Clean gas is withdrawn through short cylinders, called "vortex finders," located at the system's center.

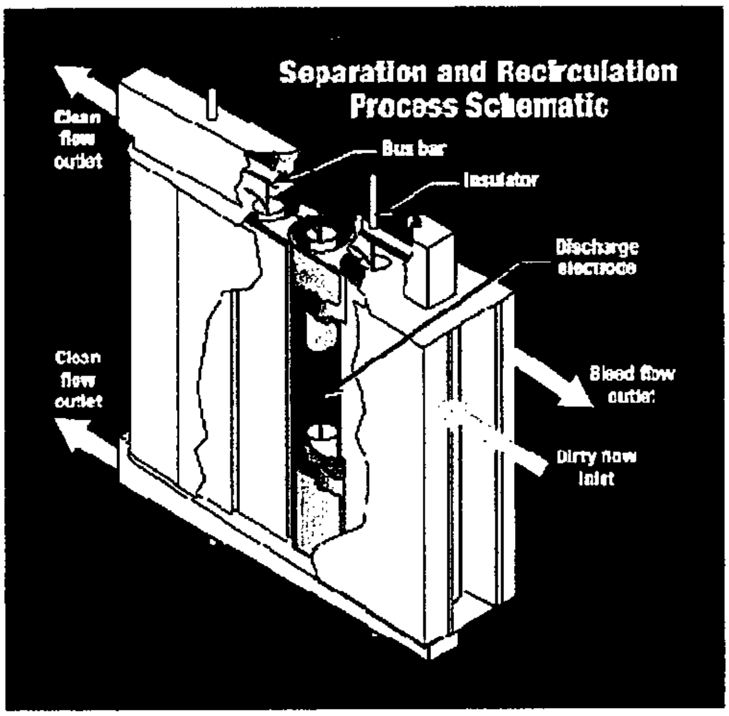

Figure 2. The system achieves gas/solids separation through the synergistic action of centrifugal and electrostatic forces.

The system's mechanical separation mechanism is augmented electrostatically by placing a high charge on particulate matter entering the separator. Forces induced by the electric field created by a high-voltage electrode prevent charged particles from penetrating the clean flow outlet. Gas/solids separation is achieved through the synergistic action of centrifugal and electrostatic forces.

Particles enter the unit tangentially along the wall, while the bleed flow containing the dust particles exits tangentially. The system's aerodynamic design avoids the secondary flows that form in conventional cyclonic collectors. These secondary flows often are responsible for particle re-entrainment that ultimately limits separation efficiency. Because no particulate collection occurs, the separation and recirculation process is not prone to reentrainment effects or to back corona limitations. As a result, it has high

separation efficiency and is unaffected by variations in dust resistivity or dust loading.
Because the technology requires a separate collector, it is well suited for retrofit applications where the existing ESP can be used as a collector. The system can be added using a variety of flow configurations. The basic configurations are illustrated in Figure 3.

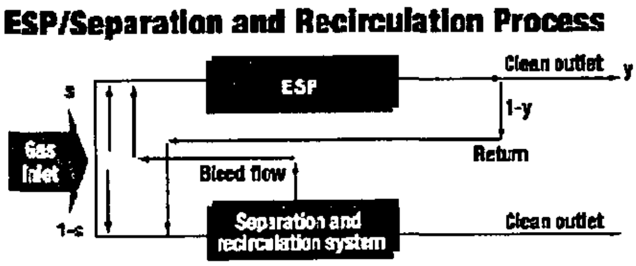

Figure 3. The basic ESP/separation and recirculation system is well suited for retrofit applications.

The particulate-laden inlet gas can be split with the ESP in any proportion defined by the inlet split ratio "s." The bleed stream is directed to the ESP inlet. The ESP outlet flow also can be split between the clean flow and return line by the outlet split ratio "y." Clean flow is extracted from the system outlet along with that portion of the ESP outlet flow that is not returned to the system. The separation and recirculation process' efficiency is calculated with the equation:

$$\eta_{SYS} = \eta_{ESP} \frac{s(1-\eta_{EC}) + \eta_{EC}}{1-\eta_{EC}(1-\eta_{ESP})(1-y)}$$

where ηSYS is the system collection efficiency, ηEC is the system separation efficiency and ηESP is the collection efficiency of the ESP.

Figure 4 shows the overall system collection efficiency vs. the efficiency an ESP would have if it were treating the total gas flow.[1] There are two reasons for the efficiency improvement. First, the ESP treats only a portion of the total gas. This increases its effective specific collection area. In the limiting case where s = 0, the ESP treats only the bleed flow directed from the system, or approximately 10 percent of the total flow. This significantly increases the efficiency of the ESP.

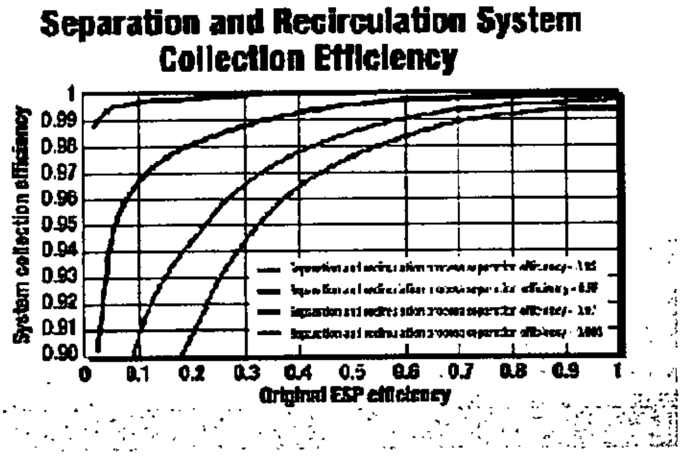

Figure 4. The figure shows the separation and recirculation system collection efficiency vs. the efficiency of an ESP treating the total gas flow.

Second, because of recirculation, the system continually directs a fraction of the particulates that escape from the ESP back to the system. In an ideal system with 100-percent system efficiency and y = 0, no particles could penetrate the exhaust gas, and the system efficiency would be 100 percent. In an actual separation and recirculation system, the efficiency is higher than either the separation and recirculation system efficiency or the ESP efficiency individually. It also is relatively independent of ESP performance. Thus, almost any ESP, regardless of its performance, can be retrofitted with a separation and recirculation system. In most cases, the sophisticated arrangement shown in Figure 3 is not necessary. It may be possible to remove the last section of the ESP and install the system inside the existing housing to achieve high system collection efficiency.

Initial laboratory testing of a system prototype used a simulated exhaust gas stream mixed with plant fly ash. The device demonstrated efficiencies higher than 99 percent. Field tests conducted in 1997 on an exhaust gas slipstream from Alabama Power Co.'s Miller Unit 3, Birmingham, Ala. These tests confirmed the system could capture between 95 percent and 98 percent of particulate matter left after gases exit the ESP.

A comparative economic and engineering analysis of various ESP upgrade options showed that the capital and levelized costs of an ESP upgraded with the system were less than half the costs of a wet ESP with the same collection efficiency. The economic assessment projected that a 250-MW unit could be retrofitted with a separation and recirculation process for approximately $6.25 million, a capital cost of $25/kW. O&M costs also promised to be reasonable. The system operates at a pressure drop of less than 1.0 inch of water. This is significant because the existing draft fan can be used without modification. In addition to low capital and operating costs, the system has other advantages, including a high capacity for removing PM2.5 particles, fuel flexibility and no re-entrainment losses from rapping.

References

1. The dependence of the ESP efficiency on the gas flow was estimated with a modified Andersen-Deutch model. Splitting parameters y and s were optimized for maximum system efficiency by a specially designed computer program.

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Pollution Engineering- July 01, 1999

Control Technology
Advanced Hybrid Particulate Collector

Under DOE-NETL sponsorship, the University of North Dakota, Energy and Environmental Research Center (UND-EERC) has developed a new concept in particulate control, called an advanced hybrid particulate collector (AHPC). In addition to DOE and the EERC, the project team includes W.L. Gore & Associates, Inc., Allied Environmental Technologies, Inc., and the Otter Tail Power Company. The AHPC utilizes both electrostatic collection and filtration in a unique geometric configuration that achieves ultrahigh particle collection with much less collection area than conventional particulate control devices.

The primary technologies for state-of-the-art particulate control are fabric filters (baghouses) and electrostatic precipitators (ESPs). A major limitation of ESPs is that the fractional penetration of 0.1- to 1.0-μm particles is typically at least an order of magnitude greater than for 10-μm particles, so a situation exists where the particles that are of greatest health concern are collected with the lowest efficiency. Fabric filters are currently considered to be the best available control technology for fine particles, but emissions are dependent on ash properties and typically increase if the air-to-cloth (A/C) ratio is increased. In addition, many fabrics cannot withstand the rigors of high-SO_2 flue gases, which are typical for bituminous fuels. Fabric filters may also have problems with bag cleanability and high pressure drop, which has resulted in conservatively designed, large, costly baghouses.

The design configuration of the AHPC is unique because, instead of placing the ESP and fabric filter sections in series (as is done with other dual-mode particulate collection devices), the filter bags are placed directly between the ESP collection plates. The collection plates are perforated (45% open area) to allow dust to reach the bags; however, because the particles become charged before they pass through the plates, over 90% of the particulate mass is collected on the plates before it ever reaches the bags. When pulses of air are used to clean the filter bag surfaces, the dislodged particles are thrown back into the ESP fields where they have another opportunity to be collected on the plates. Operating experience suggests that since the bags will not need to be cleaned as often as in typical baghouses, they will provide excellent performance over a long operating life. This leads to low operating costs since filter bag replacement is a key cost component.

A demonstration unit has been operational since July 1999, filtering 15,000 m^3/hour of flue gas from the Otter Tail Power's Big Stone (South Dakota) coal-fired power plant. The cyclone-fired boiler at Big Stone burns Powder River Basin Coal, whose fly ash has traditionally been found to be difficult to collect with ESP's because of its high resistivity. The pilot AHPC unit has exhibited very stable operating levels while maintaining low energy consumption during continuous operation, with on-line bag cleaning. Tests to date show that the AHPC provides over 99.99% particulate collection efficiency for all particle sizes, at a cost that is competitive with or lower than existing technologies.

Photo Gallery:

- Otter Tail Power Company Big Stone Power Plant in Big Stone City, SD

Related Papers and Publications:

- Advanced Hybrid Particulate Collector [PDF-1334KB] (Project Factsheet) *U.S. DOE Supports New Clean Air Technology for Coal-Fired Power Plants*
- Quarterly Progress Report, January 1 - March 31, 2001 [PDF-370KB]
- **Patent Awarded to University of North Dakota Energy and**

Environmental Research Center for PM Control Technology

A U.S. Patent (US5938818) was issued to the Energy and Environmental Research Center Foundation at the University of North Dakota on August 22, 1999, for the "Advanced Hybrid Particulate Collector (AHPC) and Method of Operation." The AHPC is being developed under DOE Contract DE-AC22-95PC95258 as part of NETL's PM Control Technology program. The device is for controlling particulate air pollution and combines filtration and electrostatic collection. Specifically, the invention includes a chamber housing a plurality of rows of filter elements. Between each row of filter elements is a grounded plate. Between the grounded plates and the filter elements are electrode grids for creating electrostatic precipitation zones between each row of filter elements. In this way, when the filter elements are cleaned by pulsing air in a reverse direction, the dust removed from the bags will collect in the electrostatic precipitator zones rather than on adjacent filter elements.

A pilot-scale AHPC is currently being tested on a 9,000 acfm slipstream of the Otter Tail Power Company Big Stone power station in Milbank, South Dakota. The unit has shown excellent particulate capture, exceeding 99.99% removal of particles ranging in size from 0.01 to 10 microns. The device has also shown promise in capturing mercury and other gas-phase HAPs when used in conjunction with sorbent injection.

A copy of the patent can be found by visiting a patent search engine, such as at www.delphian.com and searching for U.S. Patent 5938818.

Contacts:

- For further information on this project, contact the NETL Project Manager, William Aljoe or Stanley J. Miller, EERC's Project Manager.