United States
Environmental Protection
Agency

Industrial Environmental
Research Laboratory
Research Triangle Park
North Carolina 27711

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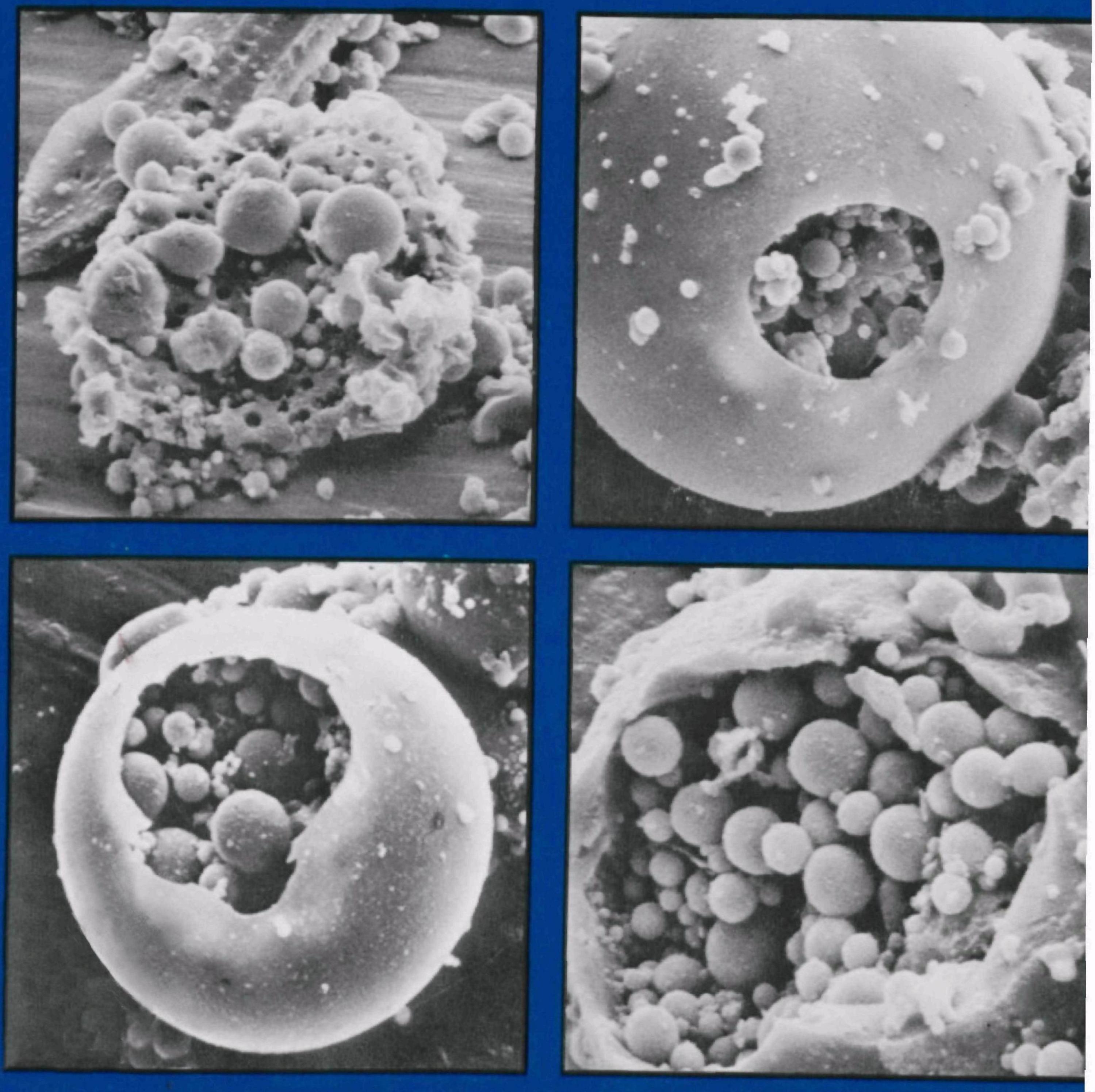
EPA

Controlling Particulate Emissions from Coal-Fired Boilers



Introduction

Every year, millions of tons of particulates are emitted into the air we breathe. Most come from natural sources like forest fires, dust storms, and volcanoes. But a growing percentage is produced by manmade sources like factories and powerplants.

Some particulates are nontoxic. But others, especially those from fossil fuel combustion and industrial processes, can be dangerous to human health. That's why the Environmental Protection Agency (EPA) has identified particulates as one of the six air pollutants having "potential for widespread adverse effects on human health and welfare." Acting on the authority of the Clean Air Act Amendments of 1970, EPA has set a National Ambient Air Quality Standard for total suspended particulates in our air of 75 micrograms per cubic meter (annual average).

Since 1970, the national average concentration of particulates in the atmosphere has dropped by almost 20 percent, and the downward trend is continuing. But we still have a long way to go before we can meet the National Ambient Air Quality Standard. With an increasing number of industries and powerplants scheduled to be built in the coming decades, particulate pollution will get worse — unless we take steps to control it.

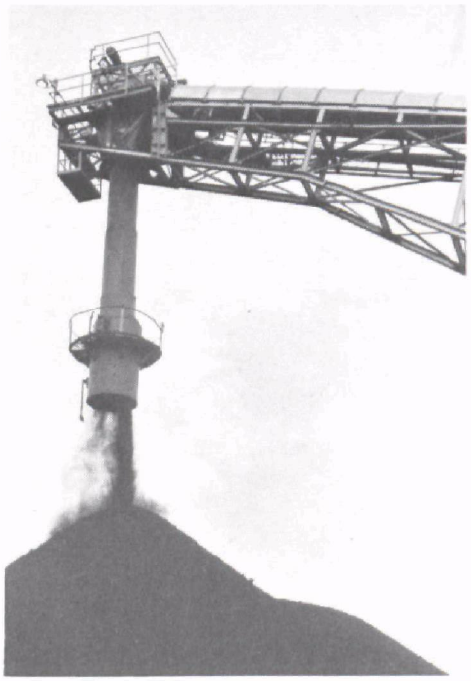
That's exactly what's happening at the Industrial Environmental Research Laboratory (IERL), part of EPA's Office of Research and Development in Research Triangle Park, North Carolina. There, the Particulate Technology Branch (PATB) is working to find more effective and economical ways to reduce the amount of particulates emitted into our air.

Because coal combustion is currently the largest source of manmade particulate pollution, a major focus of PATB's work is on controls for flyash. Electric utilities now burn about 700 million tons of coal per year — discharging more than 3 million tons of flyash into the atmosphere. And with dwindling supplies of oil and natural gas, coal consumption is expected to double in the next 15 years.

As coal consumption increases, more stringent particulate emission standards will be required to keep our air safe to breathe. Like other branches of IERL-RTP, PATB supports EPA's Office of Air Quality Planning and Standards by providing technical information for setting realistic, attainable limits for particulate emissions.

But that's only part of PATB's job. To help utilities and industries meet air quality standards, PATB has programs underway to improve the efficiency and cost-effectiveness of the three particulate control devices in use today — electrostatic precipitators, wet scrubbers, and fabric filter baghouses.

Electrostatic Precipitators



For many years, electrostatic precipitators (ESP's) have been the mainstay of the utility industry's particulate control program. With low maintenance requirements and high collection efficiencies, ESP's have gained widespread acceptance. But the proposed tightening of particulate emission standards and the growing dependence on low-sulfur coal could greatly increase the costs of installing and operating ESP's. As a result, some utilities are now considering alternative control devices.

When utilities burn high-sulfur coal, conventional ESP's can easily meet the current New Source Performance Standards (NSPS) of 43 ng/J (0.1 lb/10^6 Btu). With design and operating modifications, they may be able to meet the proposed standards of 13 ng/J (0.03 lb/10^6 Btu). But costs increase markedly as collection efficiency is improved. To cut emissions in half, costs go up nearly 20 percent.

ESP collection efficiency becomes an even more serious problem with low-sulfur coal. Most coal burned today is eastern coal mined in Pennsylvania, Illinois, West Virginia, and Kentucky. Over the next two decades, however, many powerplants will be switching to western coal mined in Montana, Wyoming, and Colorado. Since western coal has a lower sulfur content — less than 1 percent compared to 2 to 3 percent for eastern coal — it emits fewer sulfur oxides into the air.

But there's a trade-off. Flyash from low-sulfur coal has higher electrical resistivity than flyash from high-sulfur coal. This means that low-sulfur flyash is more difficult for conventional ESP's to collect. To solve this problem, three techniques to increase ESP collection efficiency are currently being tested: 1) enlarging the specific collecting area, 2) raising the operating temperature, and 3) adding conditioning agents to the exhaust gases.

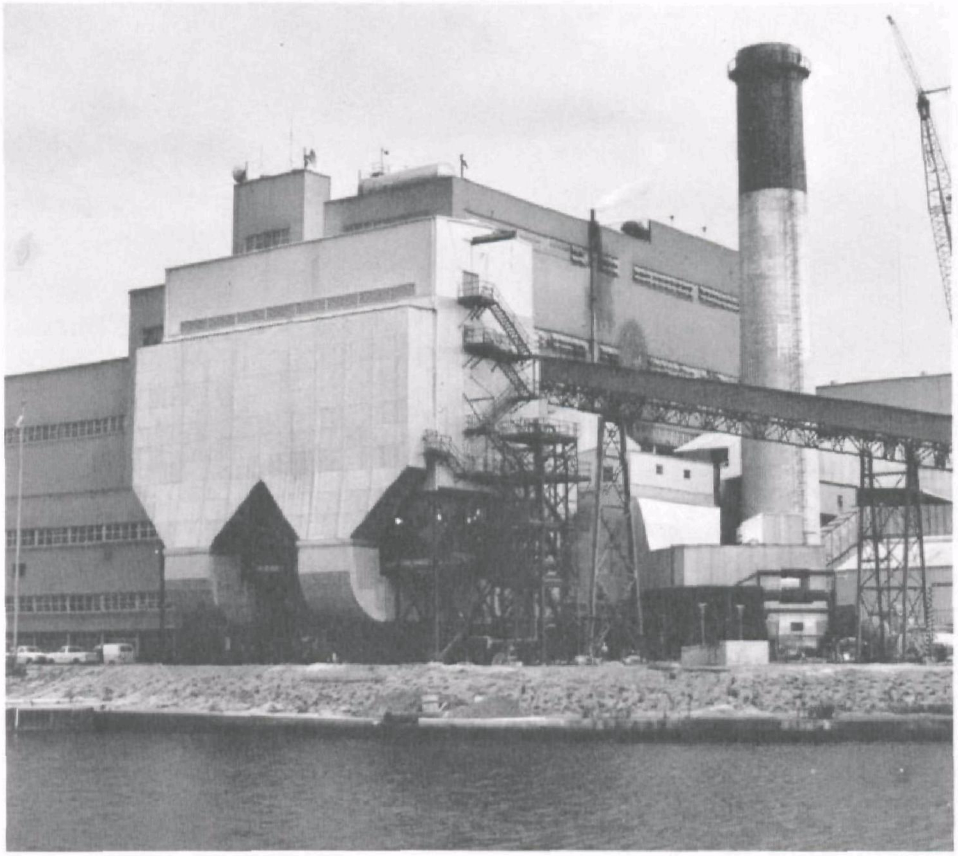
Enlarging the specific collecting area (SCA) significantly improves ESP efficiency. But it also increases capital, operating, and land investment costs. Utilities switching from high-sulfur to low-sulfur coal usually increase ESP specific collecting area by a factor of 3.

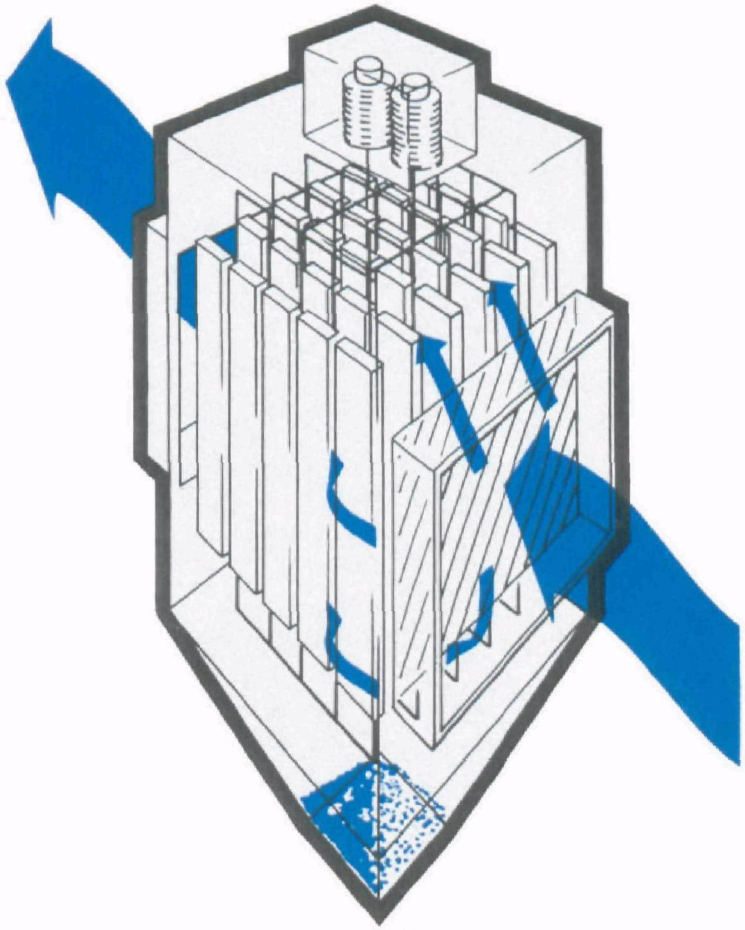
Raising the operating temperature of ESP's is one of the newest ideas for improving collection of flyash from low-sulfur coal. Conventional ESP's operate at 150°C or below. Recent tests show that when ESP's are installed in the flue gas duct upstream of the air heater, where they operate at 250-400°C, the resistivity of most flyashes is reduced.

The use of hot-side ESP's is increasing despite some initial problems with materials and temperature. Several units are now in service and operating satisfactorily. The choice of a hot-side ESP depends on fuel characteristics and the size of the conventional unit that would otherwise be required.

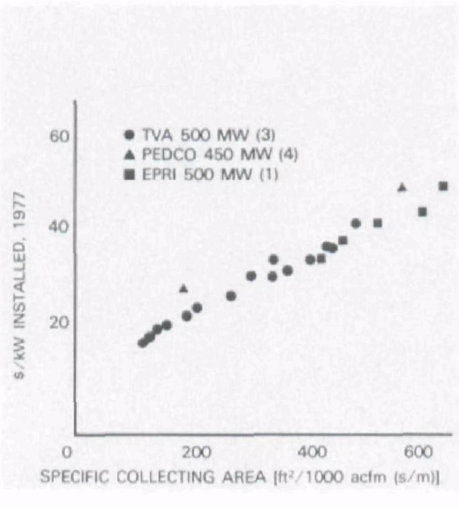
Adding conditioning agents to the exhaust gases may be the least expensive approach to increasing ESP collection efficiency. However, this technique may produce secondary emissions that must be carefully evaluated.

Further research is needed to find other ways to improve ESP efficiency. Meanwhile some utilities are turning to wet scrubbers or fabric filter baghouses as alternative particulate control devices.

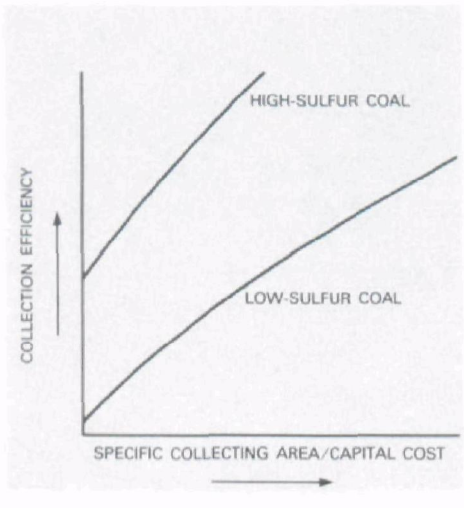




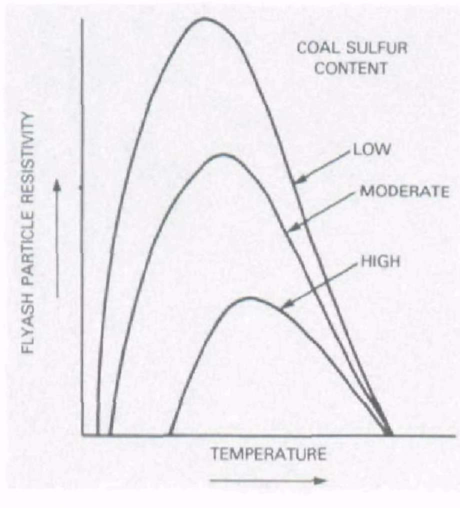
Electrostatic precipitators put an electric charge on particles in the gas stream, collect the particles on a grounded metal plate, and remove them periodically by flushing or vibrating the plate.



Capital cost of cold-side ESP's increases significantly as specific collecting area is increased.[1]

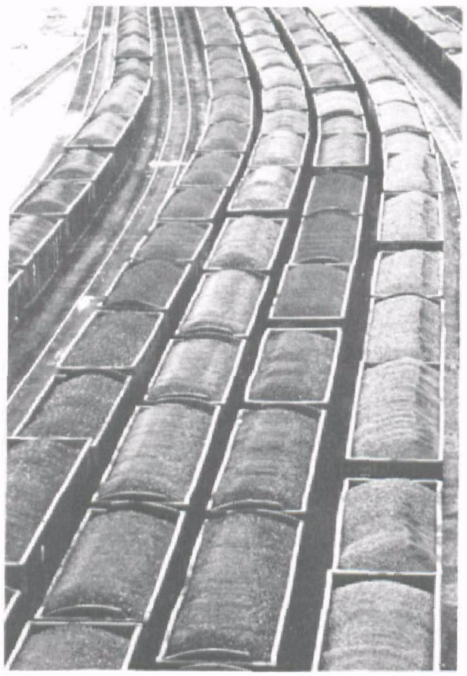


Low-sulfur coal requires greater collection area for the same efficiency.[2]



At the higher temperatures of hot-side ESP's, flyash resistivity drops.[3]

Scrubbers



Wet scrubbers have been used as particulate collection devices for more than 50 years. Although they are less expensive to install than baghouses or electrostatic precipitators, scrubbers cost more to operate. They require large amounts of water and electricity and usually create a slurry that must be processed separately. They also tend to be less efficient than the other control devices, particularly for capturing fine particles.

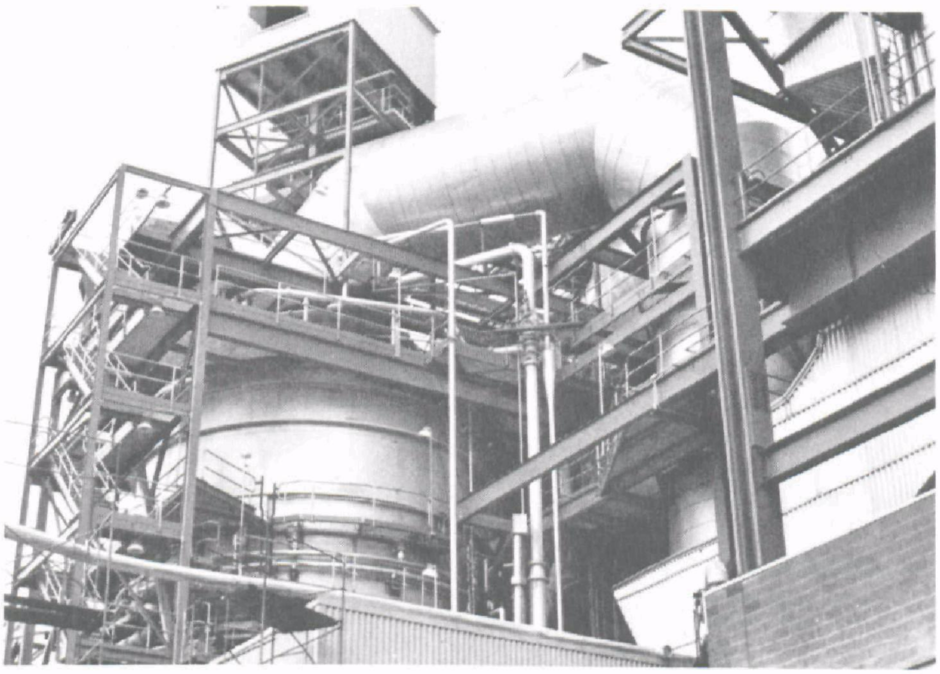
But efforts are underway to reduce costs, and some new scrubber designs are now being tested. One of these is the mobile bed scrubber. Commonly used in powerplants to control SOx emissions, mobile bed scrubbers are also used in a few powerplants for particulate control. Performance of mobile bed scrubbers for particulates is being studied at the TVA Shawnee Power Station in Paducah, Kentucky.

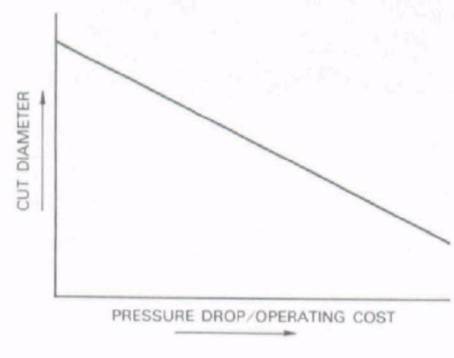
Another type of wet scrubber, a venturi/spray tower, is also being tested at the Shawnee Power Station. In this wet-scrubbing system, the flue gas is cleaned with a slurry of lime or limestone. Sulfur dioxide is absorbed into the liquor, and flyash is removed by impact with the slurry droplets. This scrubber system removes more than 99 percent of the flyash while collecting over 80 percent of the SOx.

One way of evaluating scrubber systems is to compare cut diameters at various pressure drops. Cut diameter is the particle size for which the scrubber collection efficiency is a specified value, usually 50 percent. Pressure drop is a measure of the unit power consumption of the scrubber.

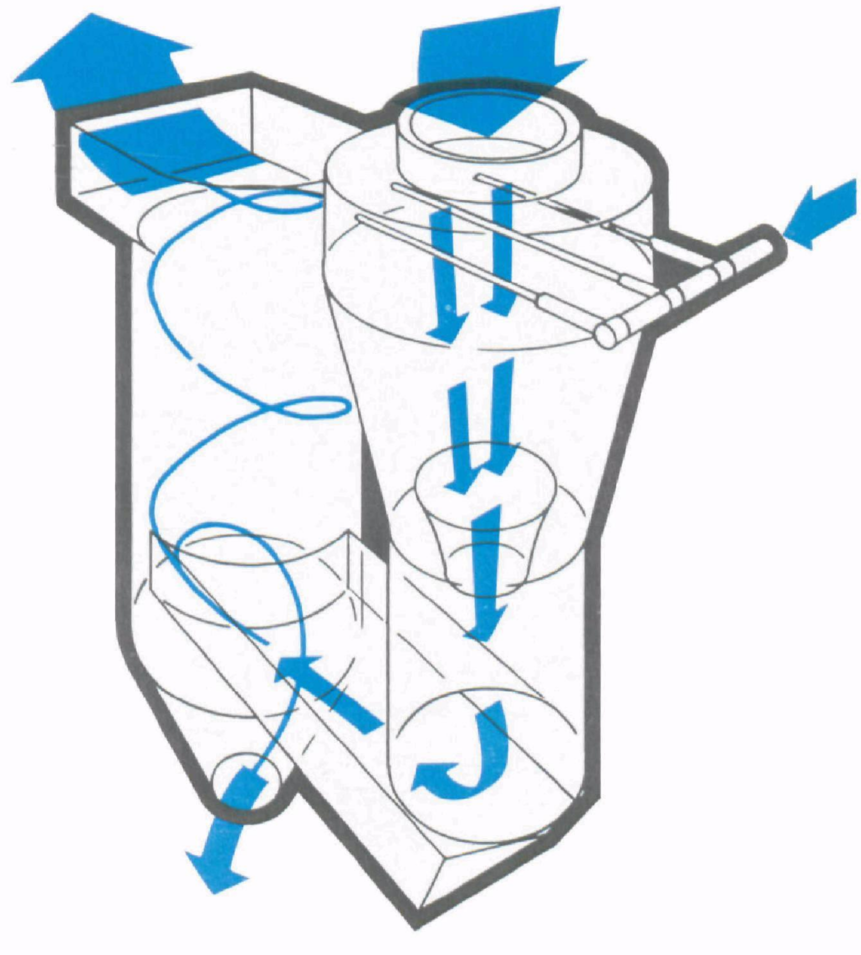
High collection efficiency for fine particles requires a high pressure drop. But a high pressure drop means increased energy consumption and, therefore, greater cost. Power requirements for reasonably efficient, high-energy venturi scrubbers can reach 3 percent of the net plant output.

Various types of wet scrubbers have been used for years to control particulate emissions from industrial sources. However, significant improvements will be necessary before wet scrubbers can be used effectively and economically on tomorrow's coal-fired boilers.



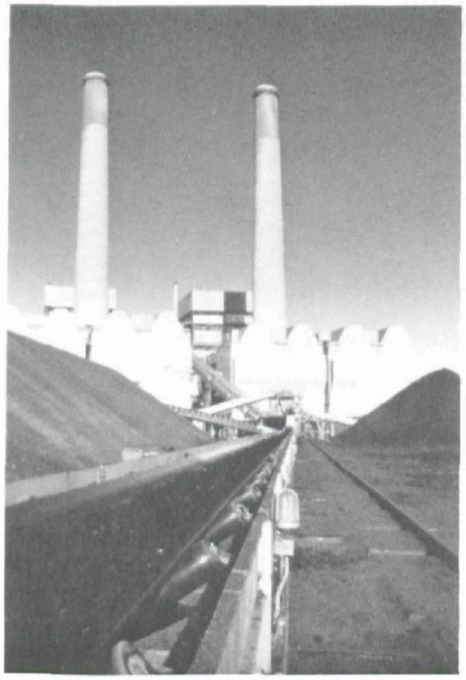


Higher pressure drop allows collection of smaller particles. But as pressure drop increases, so does operating cost.[2]



Scrubbers spray small droplets of water into particle-laden gas streams. Particles collect on the water droplets and are removed with the water.

Baghouses



Since the early 1900's, fabric filter baghouses have been widely used to treat gases emitted from industrial processes like metal smelting and chemical and fertilizer production. Only recently have baghouses become an attractive option to the electric utility industry. Utilities are now interested in fabric filter baghouses because they are highly efficient for collecting fine particles. Even more important, the type of coal burned has little effect on collection efficiency. Advances in fabric durability and versatility have also made baghouses more widely usable.

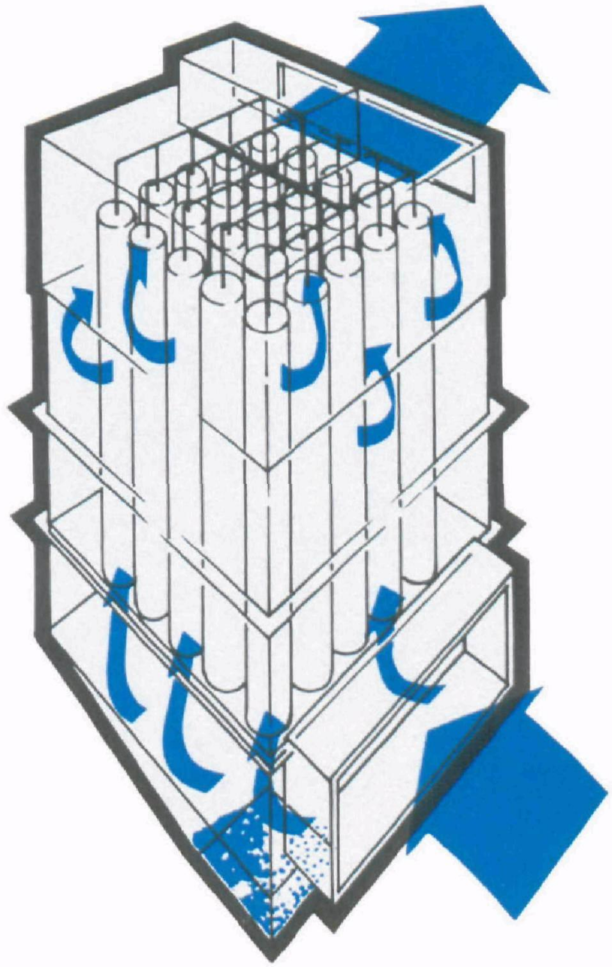
Two coal-fired powerplants have been using fabric filters successfully since 1973 — the Nucla Plant of the Colorado Ute Electric Station and the Sunbury Station of the Pennsylvania Power and Light Company. Both installations can easily meet today's particulate emission standards and the proposed future standards.

Another fabric filter baghouse has been installed at a Southwestern Public Service powerplant in Amarillo, Texas. PATB is now evaluating this baghouse — collecting data on performance, operating life, and cost effectiveness. Currently, about 50 baghouses are operating, under construction, or on order for utility boilers.

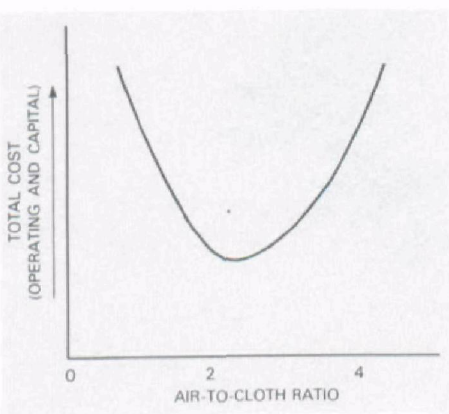
Baghouse performance and costs primarily depend on air-to-cloth (A/C) ratio, the volume of gas to be cleaned divided by the area of fabric used. The optimum A/C ratio for most utility baghouses is between 2 and 3. Lower A/C ratio improves collection efficiency but requires larger equipment, increasing capital cost. Although higher A/C ratio requires smaller equipment, the lower capital cost is offset by an increase in operating cost. This is because more energy is needed to move the gas against a higher pressure drop and bags must be replaced more frequently.

Although the durability of fabric filters has been a problem in the past, improvements have been made to ensure adequate bag life. Effective air seals, good flow distribution, adequate insulation, and other precautionary measures can now prevent corrosion and filter plugging.

Utilities burning low-sulfur coal may find fabric filter baghouses to be the most cost-effective control device for new powerplant installations.



Gas streams enter the baghouse and are passed through porous, flexible fabric filters. Trapped particles are removed by shaking or flexing the fabric.



Air-to-cloth (A/C) ratio affects the cost of fabric filter baghouses. The optimum A/C ratio for most utility baghouses is between 2 and 3.[1]

Economics

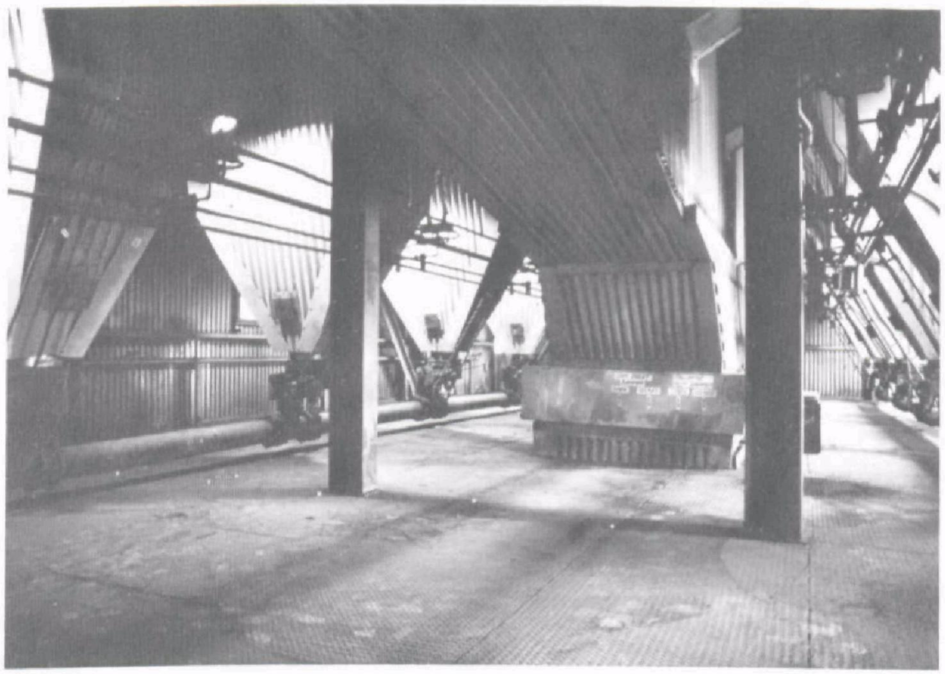
During the next few years, more utilities will be considering wet scrubbers and fabric filter baghouses as alternatives to ESP's. As this happens, utilities will need as much information as possible to be able to compare cost and performance of all three devices.

Electrostatic Precipitators
ESP performance varies with the type of coal burned. Efficient control of flyash from low-sulfur coal requires the use of oversized conventional precipitators, hot-side precipitators, or flue gas conditioning agents. But costs are high for each of these alternatives. In most cases, however, ESP's cost less to operate than the other control devices.

Scrubbers
Scrubbers are frequently the least expensive control device to purchase. But because they must operate at high pressure drops to meet present particulate emission limits, they are often the most expensive to operate. In addition, scrubbers have difficulty meeting opacity standards because of their low efficiency for collecting fine particulates. (Opacity standards are presently at 20 percent.) In the future, scrubbers may be used most effectively as particulate control devices in conjunction with flue gas desulfurization (FGD) systems.

Baghouses
Fabric filter baghouses are highly efficient for collecting fine particulates — and their efficiency does not depend on the type of coal burned. For low-sulfur coal, installation and annual operating costs appear to be less than for ESP's. Interest in baghouses may increase as particulate emission standards become more stringent. This has already happened in the State of New Mexico. New Mexico restricts emissions to no more than 22 ng/J (0.05 lb/10^6 Btu) of total particulate and no more than 9 ng/J (0.02 lb/10^6 Btu) of particulate less than 2 micrometers in diameter. Fabric filter baghouses can easily meet these standards.

The following tables and graphs show general cost and performance comparisons for the three control devices. PATB does not recommend one over another. Each has certain advantages and disadvantages for a given situation. PATB's goal is to optimize the technology for each of the devices so that utilities can make reliable choices for specific applications.

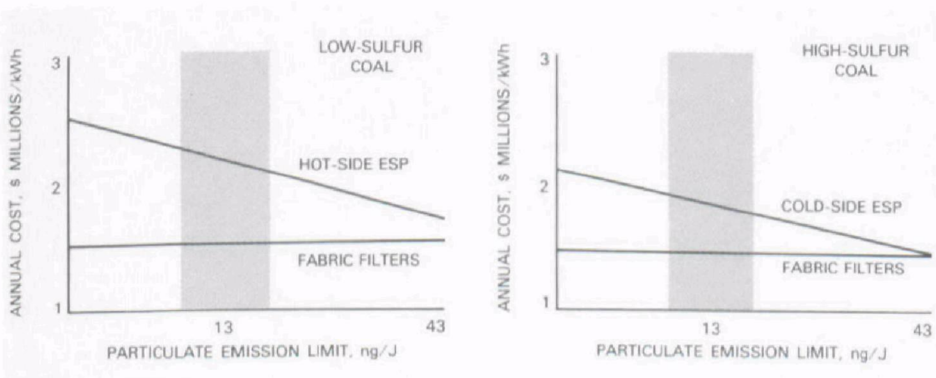


INSTALLED CAPITAL COSTS FOR CONTROL DEVICES
ON 500 MW POWERPLANTS, PROJECTED 1980 $/kW

LOW-SULFUR COAL						
		ESP		FABRIC FILTER		VENTURI SCRUBBER
		EPA	EPRI	EPA	EPRI	EPA
EMISSIONS	43 ng/J	$53/kW	40	58	36	59
	22	68	47	58	36	73
	13	81	52	58	36	NA
HIGH-SULFUR COAL						
		ESP		FABRIC FILTER		VENTURI SCRUBBER
		EPA	EPRI	EPA	EPRI	EPA
EMISSIONS		$27/kW	38	52	36	59
		28	43	52	36	73
		32	52	52	36	NA

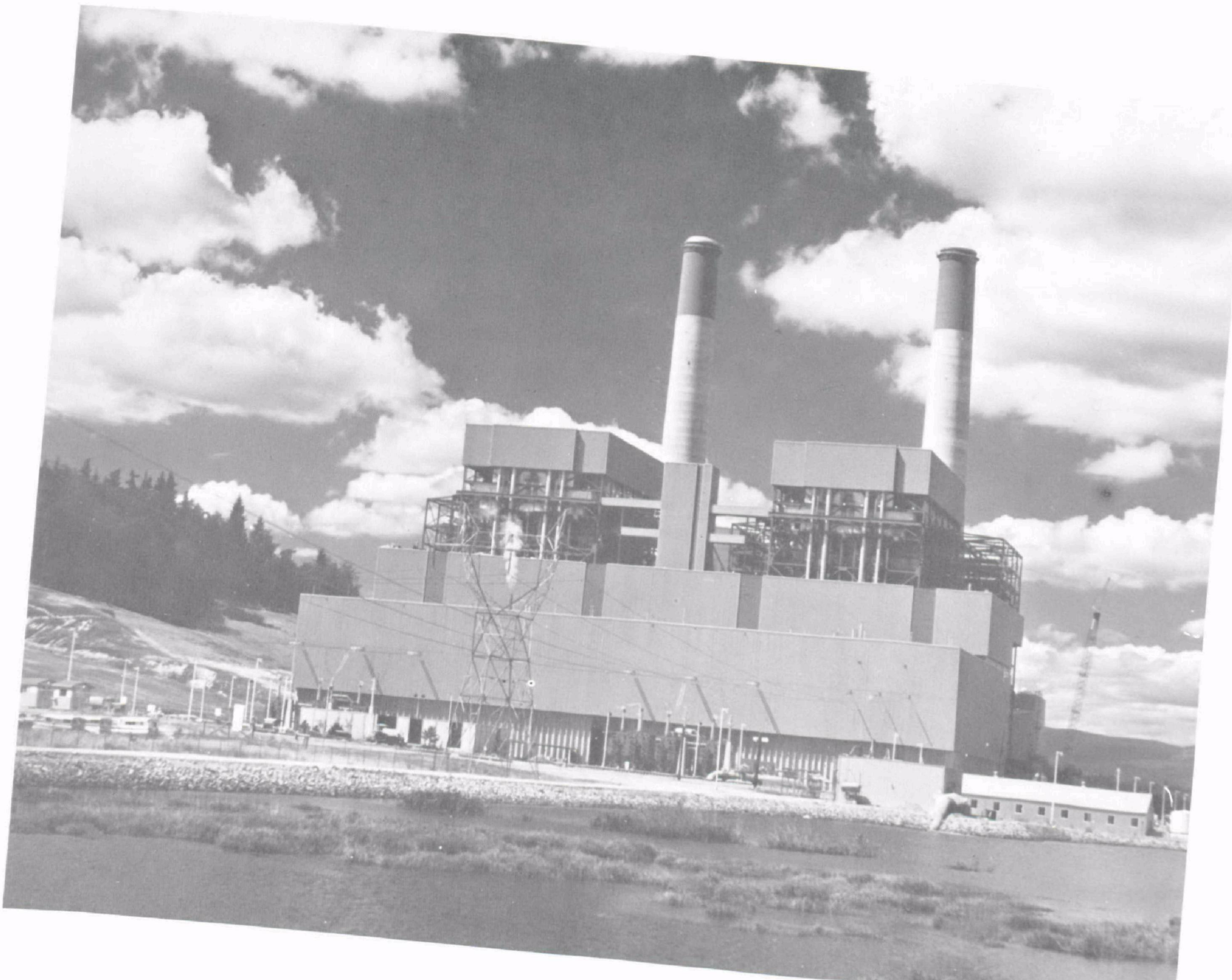
Compared to ESP's and venturi scrubbers, fabric filters become more cost-competitive as particulate emission standards become more stringent. (Based on data from the Electric Power Research Institute and EPA.)[1]

ANNUAL COST (CAPITAL AND OPERATING) FOR CONTROL DEVICES
ON 500 MW POWERPLANTS, BASE YEAR 1978

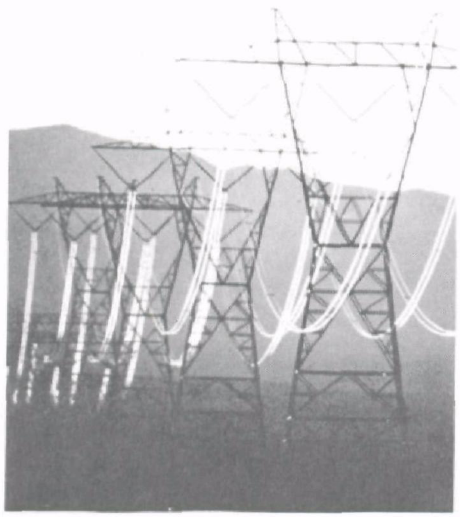


At the proposed particulate emission limit of 13 ng/J, fabric filters appear to cost less than ESP's, especially for low-sulfur coal. (Current limit is 43 ng/J.)[1]

Devices	Advantages	Disadvantages	Cost Considerations
ELECTROSTATIC PRECIPITATORS **Critical Parameter** Specific collecting area (SCA), usually measured as $ft^2/acfm$ (s/m)	1) Most cost-effective for moderate efficiency, high-sulfur coal 2) High efficiency with low pressure drop	1) Problem collecting flyash from low-sulfur coal or mixed fuels 2) Collection efficiency varies with nonuniform inlet loading, gas flowrate, and temperature	1) More expensive than scrubbers, comparable to baghouses to purchase 2) Generally least expensive of devices to operate
WET SCRUBBERS **Critical Parameter** Pressure drop, power consumption per unit volume of air flow, usually measured as cm H_2O	1) Can be used for high-temperature, explosive gas streams 2) Can remove gases as well as particulates 3) Compact, easier to retrofit than baghouses or ESP's	1) High water usage, high energy consumption 2) Slurry disposal can be a problem	1) Varies greatly with application and scrubber type 2) Generally less expensive than ESP's and baghouses to purchase, more to operate
BAGHOUSES **Critical Parameter** Air-to-cloth ratio, gas volume to be cleaned divided by cloth area, usually measured as $ft^2/acfm$ (s/m) of cloth	1) Highly efficient for a variety of coals 2) May be easier to retrofit to boiler burning low-sulfur coal than to install hot-side ESP	1) Limited bag life (about 4 years) 2) High pressure drop required for efficient, fine particle collection	1) More expensive than scrubbers, comparable to ESP's to purchase 2) Generally less expensive than scrubbers, more than ESP's to operate 3) Bag replacement cost is major maintenance item



Looking Ahead



In the coming decades, the most critical problem in the control of particulate emissions will be collection of flyash from coal combustion. PATB has programs underway to improve the three most effective control devices available today. These programs will help utilities meet clean air standards as they switch to coal to meet our Nation's immediate need for plentiful fuel.

Pilot-scale testing to improve electrostatic precipitators began in late 1977. The program has two goals: 1) to reduce problems in new installations caused by flyash resistivity, and 2) to demonstrate environmentally acceptable flue gas conditioning agents for retrofit situations.

PATB is also working to develop more effective wet scrubbers for use with both low- and high-sulfur coals. The goal is to design an optimum scrubber system — one that improves collection efficiency and mist elimination while reducing energy requirements.

As part of the program to improve fabric filter systems, PATB is testing the use of baghouses for combined SOx and particulate control. Work is also continuing to determine the life expectancy, cleanability, and physical and chemical resistance of different fabric media.

PATB will also be focusing attention on pollution problems that haven't been addressed before — like fugitive emissions from hard-to-control sources such as mining sites, conveyors, and storage piles of coal and other materials.

As these programs progress, new information will be generated. To make sure this information reaches everyone concerned, PATB will be sponsoring a variety of technology-transfer symposia, conferences, and publications.

One of the most important effects of PATB's work in coming years will be improved standards for the quality of our Nation's air. By law, emissions limits must be backed up by technology that's proven to be efficient and economical. As PATB develops and tests more efficient and cost-effective particulate control devices, emission standards can be improved, making our air cleaner and healthier to breathe.

PATB's goal for the next 5 years is to make particulate control devices 10 times more effective than today's equipment. At the same time, PATB is aiming to cut costs by a factor of 10.

That's an ambitious goal. But to provide the energy we need — without damaging the air we breathe — it's a goal that must be achieved.

References

1. Data supplied by GCA/ Technology Division, EPA Contract No. 68-02-2177, 1978.
2. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, Annual Report, 1976.
3. Oglesby, S. and G. Nichols, "A Manual of Electrostatic Precipitator Technology," Parts I and II, Southern Research Institute, EPA Reports APTD 0610 and 0611 (NTIS PB 196380 and 196381), August 1970.

Prepared by Acurex Corporation under EPA Contract 68-02-2611; Task 14. Photos courtesy of Acurex Corporation; U.S. Environmental Protection Agency, IERL-RTP; U.S. Environmental Protection Agency, Project Documerica; Envirotech Corporation; Pacific Power & Light Company; Salt River Project.