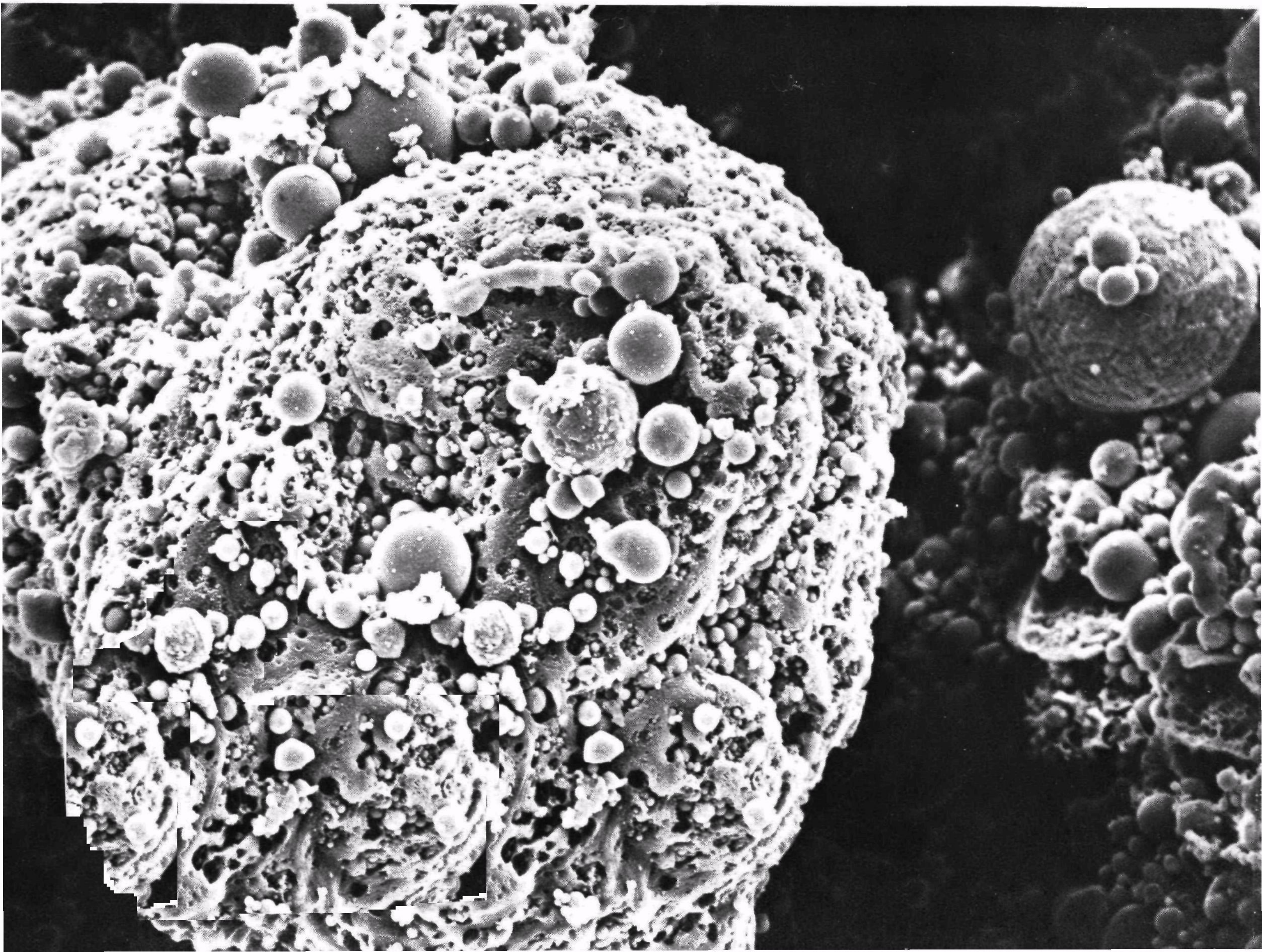
United States
Environmental
Protection Agency

Industrial
Environmental
Research Laboratory-RTP

Particulate
Technology
Branch

Controlling Emissions of Particulates



Introduction

Every year, millions of tons of particulates get into the air we breathe. Some come from natural sources like forest fires, dust storms, and volcanoes. But a growing percentage is produced by manmade sources like factories and power plants, metal processing, stone crushing, and construction projects. Even the tires on our cars release particles of rubber as we drive.

Some of these particles, like dust and dirt, are nontoxic. But others, especially those from fossil fuel combustion and industrial processes, can be very dangerous to human health. Particles containing beryllium, lead, asbestos, and certain hydrocarbons are suspected causes of cancer. And particles of sulfate, nitrate, and other chemical substances can cause respiratory disease, especially in children and older people.

Because of these dangers, particulates are one of the six air pollutants thus far identified by the Environmental Protection Agency (EPA) as 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 primary National Ambient Air Quality Standard for total suspended particulates in our air of 75 micrograms per cubic meter (annual average). Since 1970, air quality has been substantially improved in many areas. Yet today, particulate concentrations measured by half the air pollution monitoring sites in our country still exceed the standard set by EPA to protect our health. What's more, with an increasing number of industries and power plants scheduled to be built in the coming decades, particulate pollution could 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 of reducing particulates in our air.

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 standards for particulates emitted by power plants and industries all over the country.

But that's only part of the job. To help industry meet air quality standards, PATB has programs underway to improve the efficiency and cost-effectiveness of particulate collection devices in use today. New control technology is also being developed to solve the problem of particulates from advanced combustion equipment that will be used to produce our nation's energy in the future.

EPA has already made a significant contribution to improving the quality of our nation's air. Since 1970, the national average concentration of particulates in the atmosphere has dropped by almost 20 percent, and this downward trend is continuing. But a great deal of work remains to be done before we reach our national goal of safe, clean air for ourselves and our children.

The Problem of Particulates

Particulate matter comes in all shapes and a wide range of sizes — from particles as large as grains of sand to tiny particles visible only under an electron microscope.

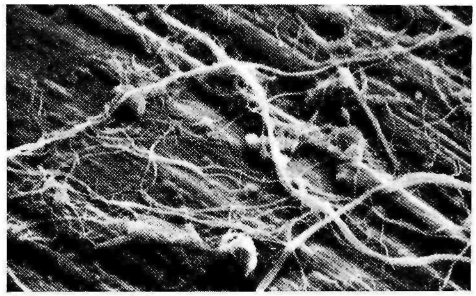
Most manmade fine particulates — about 3.5 million tons a year — come from the industries that produce our nation's power, products, and materials. Dust from stone crushing and fumes from metallurgical operations are both major contributors. But the largest source of particulate pollution is the flyash given off when coal is burned. And with coal consumption in our country predicted to double in the next 15 years, the concentration of particulate in our air could get worse without more effective controls.

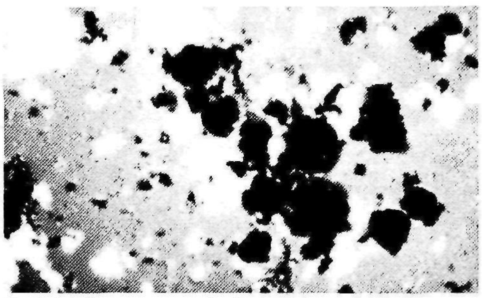
Most airborne particles — the kind that can do widespread damage to humans, animals, and vegetation — are smaller than 100 micrometers, about the diameter of a human hair. Particles under 3 micrometers — fine particulates — can be especially dangerous. Once in the air, these particles can stay suspended for days and may be spread by winds for miles, contributing to smog and even altering the weather. And, because fine particles are so small, they can pass through the natural filters in our nasal passages and damage our lungs.

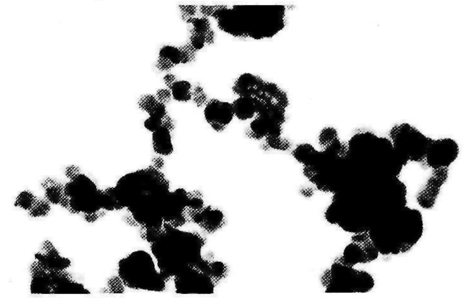
Today's particulate control devices do a good job of trapping larger particles. In many cases, those devices capture more than 99 percent (by weight) of the particulate before it reaches the air.

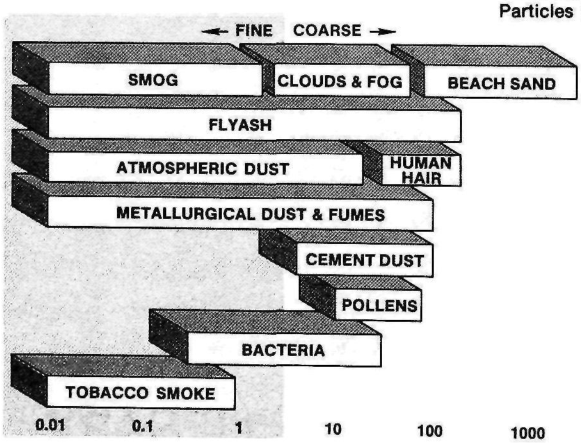
But fine particulate is a different story. Current equipment is far less effective at trapping fine particles than large ones. Collection of particles smaller than 3 micrometers can be improved with larger control devices or ones that use more energy, but only at great — or even prohibitive — expense. As a result, the particles that pose the greatest threat to human health are the ones that escape in greatest numbers to our atmosphere.

There's only one way to prevent this kind of pollution: trap particles at their sources, before they get into the air. With more than 20,000 major stationary sources of pollution in the United States, that's a big order. But it's a job that must be done to protect the quality of our air.

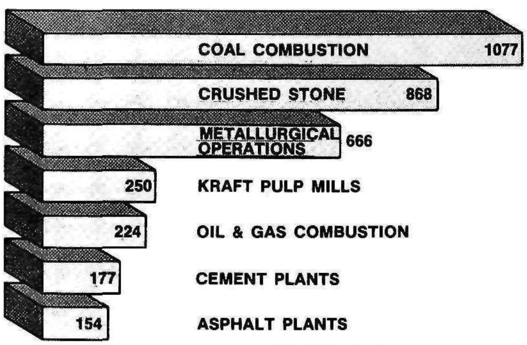

Asbestos particles


Particles from power plant


Particle chains



SIZES OF TYPICAL PARTICLES — MICROMETERS



MAJOR SOURCES OF FINE PARTICULATES — THOUSANDS OF TONS/YEAR

The Role of PATB

To support both a healthy environment and a healthy economy, the Particulate Technology Branch of IERL-RTP is working with industry to find cheaper and more effective ways to reduce particulate emissions from many different kinds of pollution sources. Since fine particles are the most serious problem today, the focus of much of PATB's work is on increasing the efficiency of devices used to control fine particulate emissions.

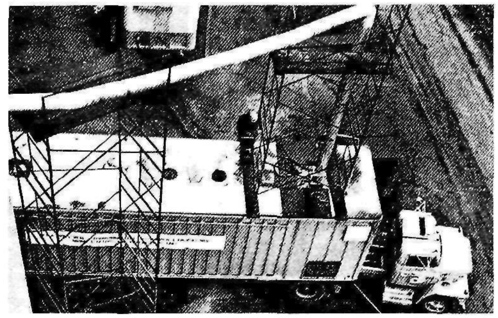
Because utilities and industries in the United States already have billions of dollars invested in particulate collection equipment, one of PATB's main aims is to improve the devices in use today. At the same time, PATB is looking ahead to the particulate problems that will be caused by fuels and combustion processes of the future.

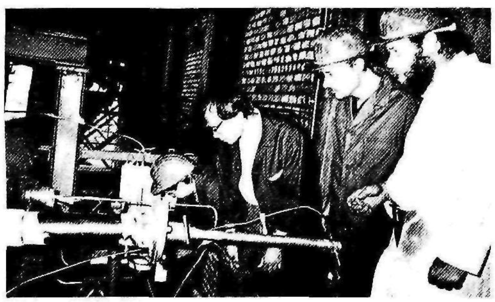
PATB's work begins with fundamental research into the basic physical and chemical mechanisms involved in particle formation and collection. These theoretical studies are helping us understand why particles behave the way they do, and how they can be collected more effectively.

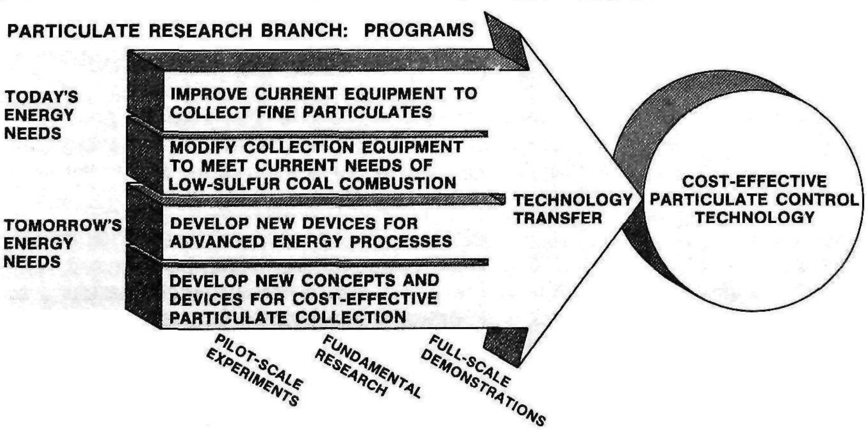
Another component of PATB's work is pilot-scale testing. Here, many different particulate collection techniques are being tried out under controlled conditions in the laboratory to determine whether they offer significant advantages in both cost and efficiency over today's equipment.

Once a technique has passed the hurdle of pilot-scale testing, it is evaluated on full-scale equipment in the field to make sure it can do the job under actual working conditions. In these tests, the effect of the control technique on fuel economy or equipment life is also studied. The result is reliable particulate collection technology that utilities and industry can depend on.

As part of both pilot-scale testing and field demonstrations, PATB operates four mobile particulate collection vans. Each van is outfitted with a specific type of particulate control device. The vans are used in the field to find the best particulate control technique for specific types of pollution sources and to test the effectiveness of a particulate control device on a pollution source before money is spent for a full-scale installation.





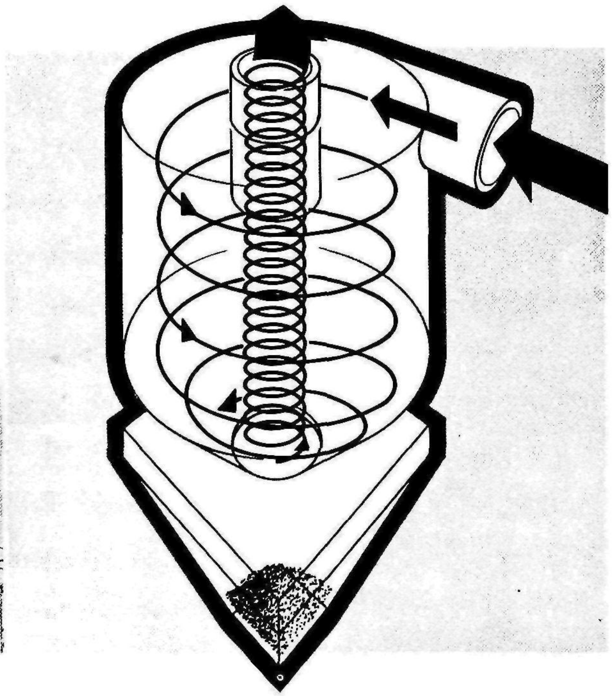


At PATB, projects are underway in every major area of particulate collection technology. To share the knowledge gained in these projects, PATB publishes articles and reports and sponsors symposia and seminars that bring industry and government together to discuss and solve the problems of particulate pollution. This technology transfer brings advances in particulate collection techniques out of the laboratory and into the field where they can make a difference.

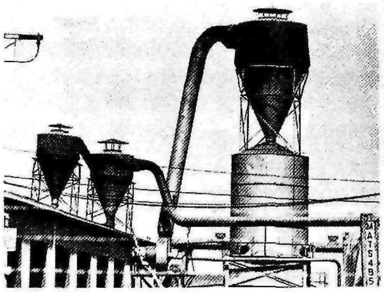
PATB's budget for programs like these was $4.7 million in 1976. That sounds like a lot of money. But in the same year, particulate control devices cost industry nearly $800 million. Furthermore, in the next 5 years it is expected that industry will spend an additional $7 billion for collection equipment.

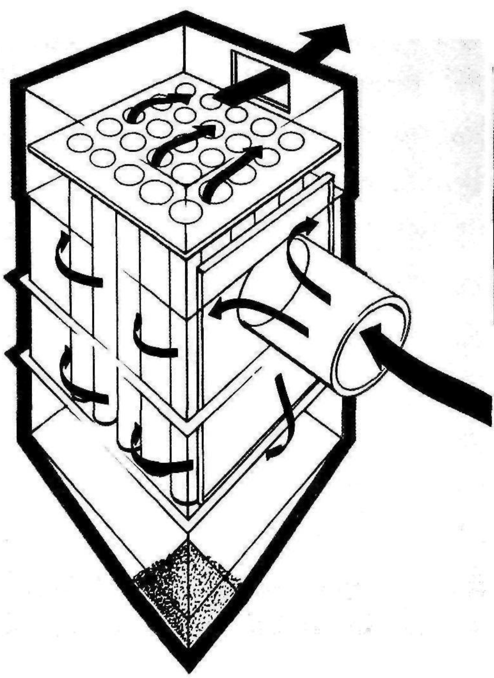
In other words, the amount spent by PATB is a small fraction of the money that goes into particulate control in the United States every year. And because PATB is working to lower the cost of collection equipment and improve efficiency, its research dollars will save utilities and industries many millions of dollars in years to come, while helping to keep our air clean in the years ahead.

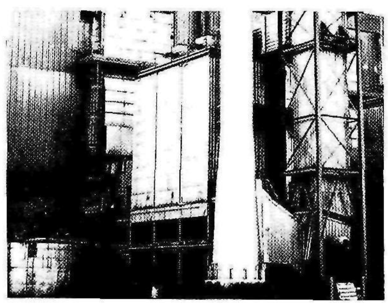
Improving Today's Control Devices



Cyclones whirl particulate-laden gas streams inside a large funnel, throwing particles outward. The particles strike the walls of the cyclone, fall to the bottom and are removed.







Gas streams enter the **baghouse** and are passed through a series of porous, flexible bags that collect the particulate. Particles are removed by shaking or flexing the fabric.

Current particulate collection devices — cyclones, baghouses, wet scrubbers, and electrostatic precipitators — are large and expensive pieces of equipment that often use tremendous amounts of energy. Baghouses, for example, can stand as high as 25 meters and cost millions of dollars to purchase and install. Scrubbers for a 1000-megawatt power plant can consume as much as 5 megawatts of electricity, enough power for over 2000 homes. This makes operating costs very high. PATB is working to reduce these costs, and to improve the efficiency of control devices at the same time.

Among the least expensive particulate collectors are cyclones. These are widely used to clean up industrial operations like grinding and polishing metals, crushing stone and gravel, and woodworking. Though cyclones are very efficient for large particles, they are only about 40-percent efficient for fine particles. The efficiency of cyclones can be improved by increasing the velocity of the airflow — but only at the cost of substantially more energy. As a result, cyclones work best on sources that do not emit many fine particles.

Fabric filter baghouses are more effective *in controlling fine particulates.* Today, baghouses are used mainly to treat process gases from operations like primary metal smelting and chemical and fertilizer production. Field tests conducted by PATB have shown that baghouses can operate with efficiencies over 99 percent, providing the filter fabric is compatible with *the chemicals, temperature, and moisture* of the gas stream.

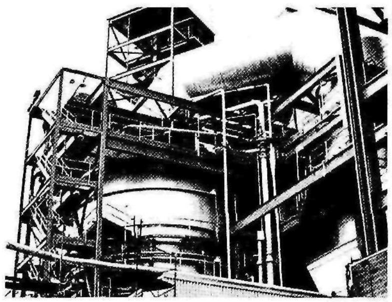
Although baghouses are currently one of the most expensive control devices, they are potentially the least expensive to operate. In one of PATB's recent programs, a full-scale demonstration baghouse with a modified design was constructed for use on a coal-fired industrial boiler. Its new design will allow it to operate with airflow velocities 3 to 4 times those of conventional baghouses. This should increase collection efficiency at greatly reduced cost.

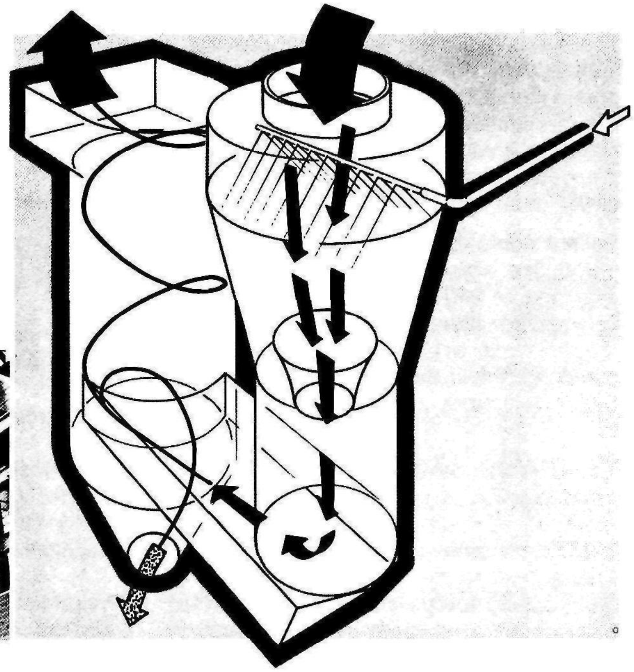
Wet scrubbers have been used as particulate collection devices since the early 1920's. Although they're inexpensive to install compared to large baghouses or electrostatic precipitators, scrubbers are costly to operate. They require large amounts of water and electricity, and create a sludge that must be disposed of. However, newer scrubbers have proved to be effective in collecting fine particles. The most promising of recent designs are flux force/condensation scrubbers. PATB is evaluating these new scrubbers in several pilot demonstration programs, including some that are cutting costs by using industrial waste heat.

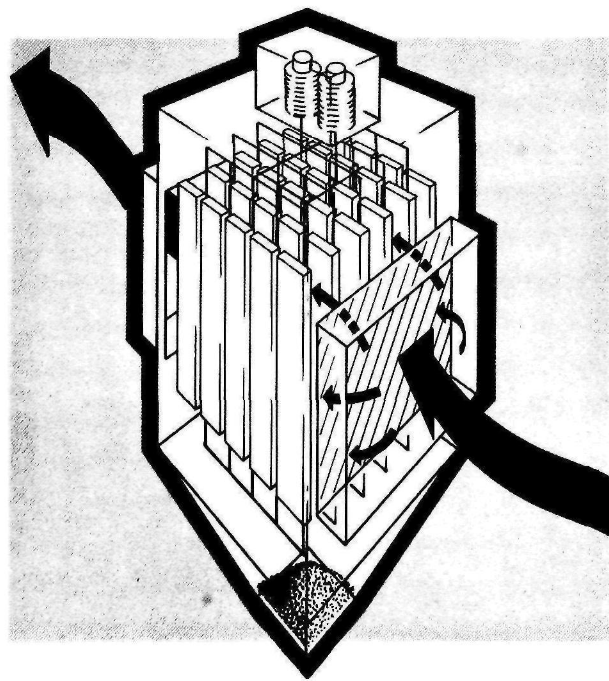
Electrostatic precipitators (ESPs) are more than 99-percent efficient for large particles, and only slightly less for some kinds of fine particulate. They cost more to install than scrubbers or fabric filters, but they're less expensive to operate. The main drawback to current ESPs is their inability to trap certain types of fine particles. To solve that problem, PATB is testing conditioning agents to reduce the resistivity of particles to electrical charge, and studying the potential of ESPs that use water to help capture particles. In another program, a computer model of electrostatic precipitation has been developed to study the effects of design changes on ESP performance.

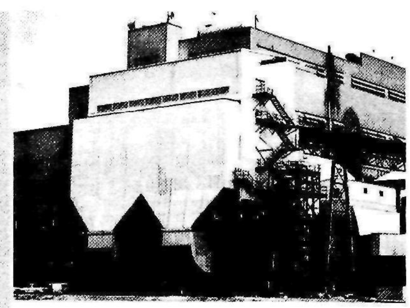
All of PATB's programs to improve current particulate control devices are helping utilities and industries find efficient ways to meet our national air quality standard for particulates. And by finding more economical ways of controlling particulates from coal combustion, PATB is making an important contribution to conserving our nation's supplies of oil and gas.

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









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

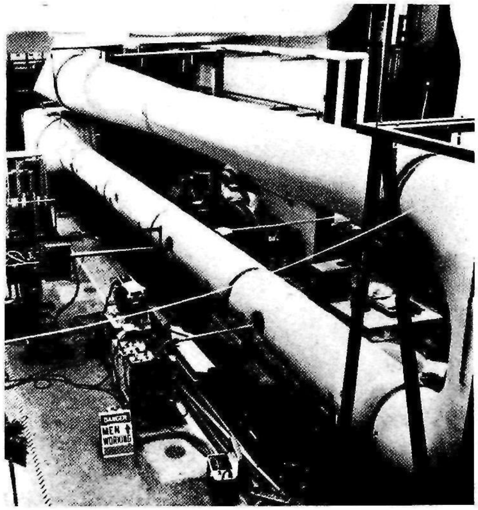
New Concepts, Novel Devices

There are two main ways to improve substantially the collection efficiency of conventional control devices, especially for fine particulates. One is to increase the collector area, and the other is to increase the power supplied to the device. In either case, costs rise enormously.

To cut costs, brand new approaches to particulate collection are needed. That's why one of PATB's most important jobs is *to seek out ideas for new collection* mechanisms, evaluate them, and support development of those that offer promise of better and more economical particulate control.

To guide the development of new concepts, PATB conducts fundamental research to improve our understanding of basic particulate collection techniques. Though we know, for example, that electrostatic forces can be used to trap particulates in exhaust streams, much remains to be discovered about how those forces actually work. As research increases our knowledge of electrostatic and other forces, better ways will be found to harness them for more effective particulate control.

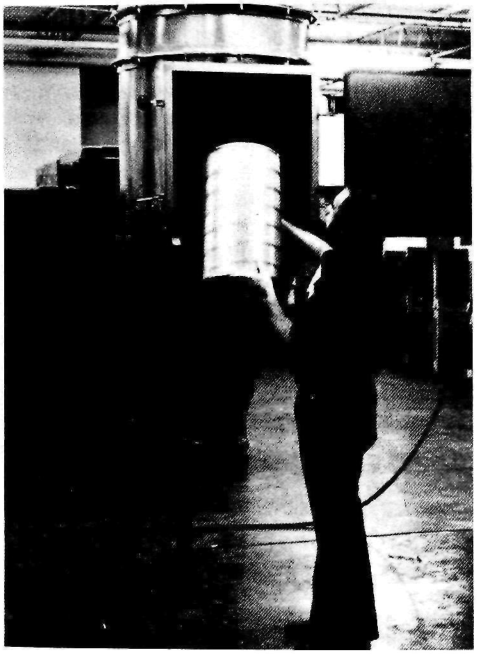
In evaluating new concepts and devices, PATB uses a number of methods. One of the most productive is mathematical modeling that simulates basic particulate collection mechanisms. These models can be used to predict the performance of innovative devices, and save time and money by eliminating concepts that are technically or economically unsound. Once theoretical studies have shown that an idea has promise, pilot-scale versions of new devices are built and thoroughly evaluated before being demonstrated in the field on full-scale pollution sources. PATB is studying and testing several new particulate collection concepts with potential for cutting costs and improving efficiency, including charged droplet scrubbers, ceramic membrane filters, magnetic filter beds, and a number of new types of fiber filters.

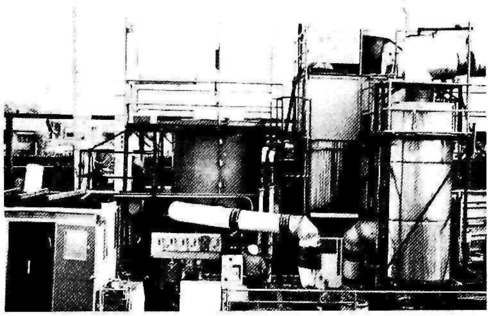


Work in advanced fiber filters is especially important today, because research and pilot-scale testing have shown that fabric, felt, or fiber bed filters can trap fine particles with very high efficiency. In addition, novel filters may also be able to reduce the size of collection equipment. Controls using cartridge filters, for example, may be 10 times smaller than current equipment. Devices using magnetic fiber beds could be 100 times smaller.

PATB is also exploring how particles behave in many different kinds of filters. It's been found that particles chain together in these filters — larger particles, in effect, acting as traps for smaller ones. Experiments are underway to find methods of taking advantage of this phenomenon to increase collection efficiency.

PATB has already reviewed over 50 new ideas for particulate control, and has identified the most promising of them. As efficient new particulate collection devices are developed from these ideas, PATB's research into innovative control techniques will help save money and reduce particulate pollution as well.





Controls For Low-Sulfur Coal

Today, power plants and industries in the United States burn about 700 million tons of coal a year. It has been estimated that, in the next 15 years, coal consumption will increase dramatically because of dwindling supplies of oil and natural gas. By 1990, our country is expected to be using close to 1.3 billion tons of coal annually — almost twice the current rate.

Most coal burned today is eastern coal mined in Pennsylvania, Illinois, West Virginia, and Kentucky. But, over the next two decades, many power plants and industries — especially west of the Rocky Mountains — will be switching to western coals mined in Montana, Wyoming, and Colorado. Part of the reason is that this coal will be used to satisfy the growing energy needs of the West. But equally important is the fact that western coal has a much lower sulfur content — less than 1 percent compared to 2 to 3 percent for eastern coal. This means that when western coals are burned, they emit much less sulfur oxides into the air. And since sulfur oxides are a dangerous pollutant, this makes western coal environmentally attractive at first glance.

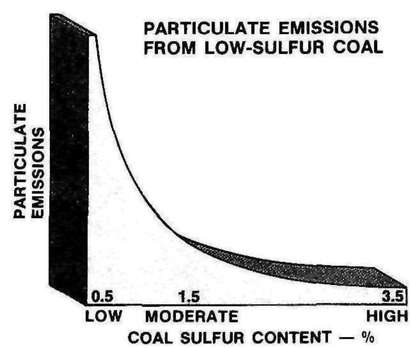
But, paradoxically, the flyash from coals with low sulfur content is much more resistant to an electrical charge than flyash from high-sulfur coals. As a result, electrostatic precipitators — the most widely used particulate control devices for power plants — are far less effective with low-sulfur coals. In fact, burning low-sulfur coal can increase particulate emissions by as much as a factor of 10 from sources equipped with conventional ESPs.

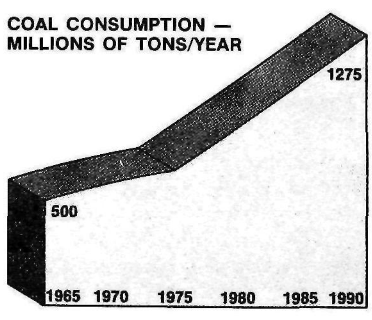
PATB is working to solve the problem of particulate emissions from low-sulfur coals in a number of different ways.

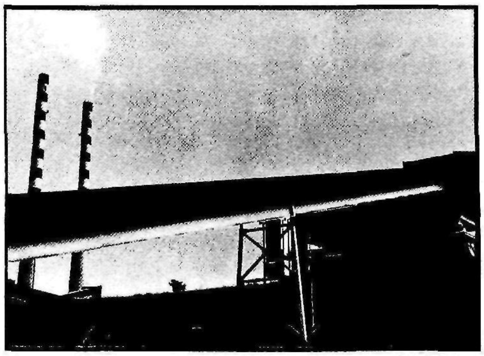
To improve our understanding of the basic physical and chemical mechanisms involved, PATB is conducting theoretical studies of the relationship between the sulfur content of coal and the resistance of flyash to an electrical charge. A comprehensive computer model of this relationship has been developed and is being used by EPA and industry to improve the design of today's electrostatic precipitators.

Building on these theoretical studies, PATB is exploring ways of modifying conventional ESPs to make them more efficient in collecting the high-resistivity flyash from low-sulfur coal. A special particulate charging device has been designed and tested in laboratory-scale experiments. Results show that the approach is technically feasible, and demonstrations of full-scale ESPs are planned for the near future.

PATB is also investigating ways of making flyash from low-sulfur coal better able to conduct an electrical charge by adding a conditioning agent to the exhaust of coal-fired boilers and furnaces before it reaches the ESP. A successful demonstration on a full-scale utility boiler has shown that sodium carbonate can lower the resistivity of low-sulfur coal flyash. Sulfur trioxide, ammonia, hydrogen chloride, and phosphoric acid have also been tested as conditioning agents. Since most of these substances are toxic, further research is needed before flyash conditioning can be considered an environmentally sound way to reduce particulate emissions from low-sulfur coal.

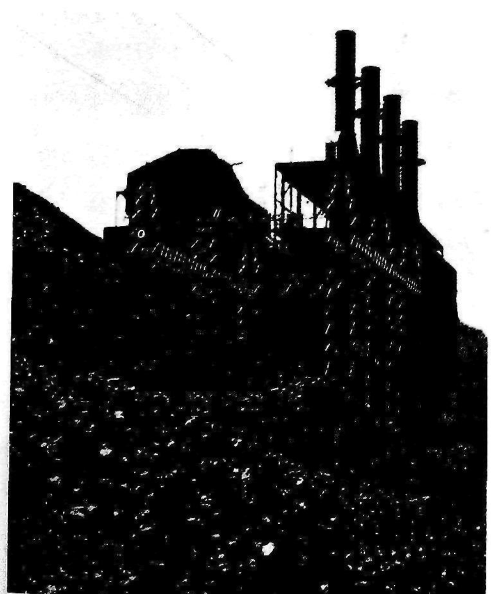


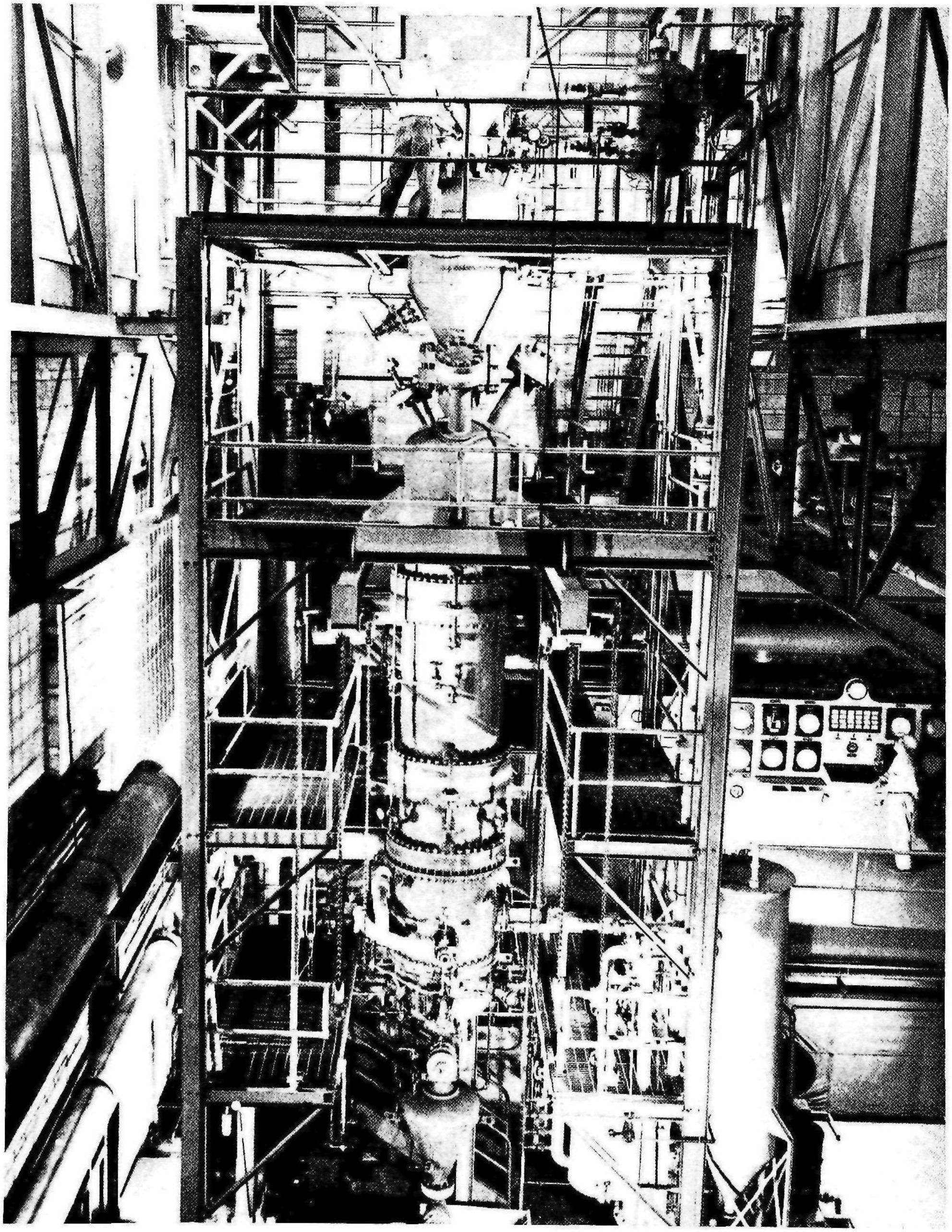


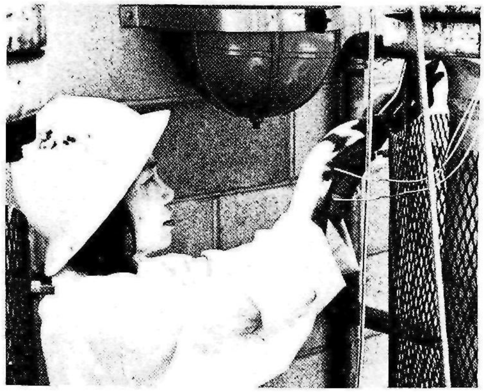


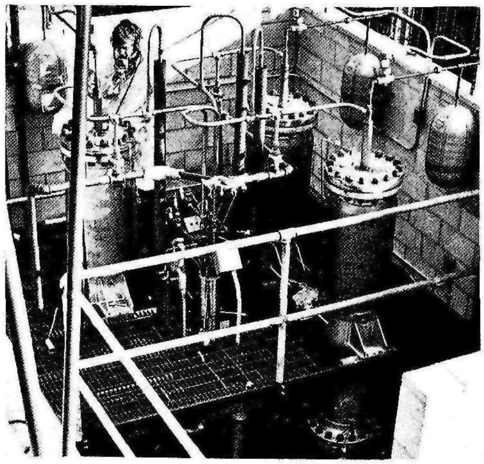
At the same time, PATB is conducting detailed evaluations of both fabric filters and scrubbers as alternatives to ESPs for low-sulfur coal. In one project, a fabric-filtration baghouse is being constructed for a 350-megawatt utility boiler that burns low-sulfur western coal. After completion in 1978, this baghouse will be operated for a year to collect data on performance, operating life, and cost-effectiveness. Full-scale demonstrations of scrubbers on utility and industrial boilers firing low-sulfur coal are also planned.

All of this research will help make low-sulfur coal an environmentally sound fuel that can help satisfy our country's demand for energy in the decades ahead.







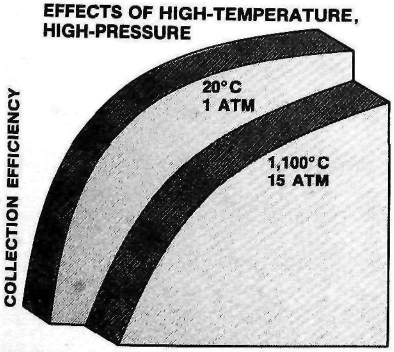


Controls For High-Temperature, High-Pressure Processes

Coal conversion is one of the most promising new technologies for meeting our country's energy requirements in the decades ahead. One of the main kinds of conversion processes is coal gasification. In this process, coal is converted to synthetic gas under carefully controlled conditions at high temperature and pressure — temperatures as high as 1800°C at 1 atmosphere and pressures up to 100 atmospheres at 900°C. Much of the energy in the coal is retained by the synthetic gas, and can be burned in gas turbines, boilers, furnaces, kilns, or heaters. As supplies of natural gas run out, it may be possible to pump synthetic gas produced by coal conversion through pipelines to industries and homes all over the country — eliminating the need to replace gas-burning equipment now in use.

Another important coal conversion process is pressurized fluidized bed combustion. Here, coal is burned under pressure in a bed of limestone or similar material. The sulfur in the coal is removed by the limestone before it can be emitted as sulfur oxides to the atmosphere. The burning process generates both heat, which produces steam for electric power or industrial uses, and hot pressurized gases, which can be used to drive gas turbines.

EFFECTS OF HIGH-TEMPERATURE, HIGH-PRESSURE



Successful development of coal gasification and pressurized fluidized bed combustion will require solving a number of problems. Both processes produce a high-temperature gas stream full of particulates that have to be removed before the gas can be used in turbines or other combustion equipment. But, today's particulate collection devices can't take the high temperatures and pressures in gasifiers and fluidized bed combustors. Moreover, theoretical studies show that conventional designs would not work efficiently at high temperature and pressure. So it's not just a matter of building scrubbers or fabric filters or electrostatic precipitators that can withstand tremendous heat and pressure. Altogether new devices need to be developed for high-temperature, high-pressure particulate control.

To help make advanced coal-conversion processes environmentally sound, PATB is exploring high-temperature, high-pressure particulate control technology. Close coordination is being maintained with the Department of Energy's advanced energy processes program.

Since coal conversion is still in the experimental stage, there is very little information today on the physical, chemical, or kinetic mechanisms of particulates at high temperature and pressure. There is also very little reliable data on the degree of particulate control that will be needed for gasifiers and fluidized bed combustors. To collect this basic information, PATB has a 2-year study underway to define the problem of particulates at high temperature and pressure, and to describe the state of the art in high-temperature, high-pressure particulate collection.

Along with this study, PATB is conducting research on advanced particulate removal devices that look promising for coal-conversion processes. These include ceramic fiber filters, ceramic membrane filters, granular bed filters, and high-temperature, high-pressure electrostatic precipitators. An initial theoretical investigation of the effect of high temperature and pressure on all these collection devices has already been completed. Results are being used to design and evaluate particulate cleanup equipment.

At present, tests of advanced particulate collection devices are being carried out on laboratory or pilot-scale facilities. In coming years, PATB will evaluate promising high-temperature, high-pressure cleanup devices on full-scale equipment in the field to find the most effective technology for coal conversion processes. The result will be reliable, economically feasible control equipment that users and manufacturers of gasifiers and fluidized bed combustors can depend on.

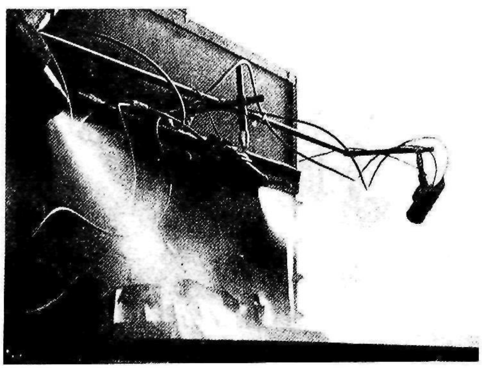
Advanced energy processes for coal and other fuels are essential to our country's future. PATB's work will ensure that we will not have to sacrifice our environment to satisfy our energy needs.

Looking Ahead

Over the next few years, one of our most critical problems in the control of particulate pollution will be control of flyash, as industries and utilities switch to coal to meet the immediate need for plentiful fuel. PATB's programs to improve electrostatic precipitators and other devices for trapping particulate from coal combustion will help us take advantage of our nation's valuable reserves of coal. At the same time, PATB will be working to solve the problem of particulates from synthetic fuels and high-temperature, high-pressure energy systems — technologies that can answer our longer-term energy requirements.

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.

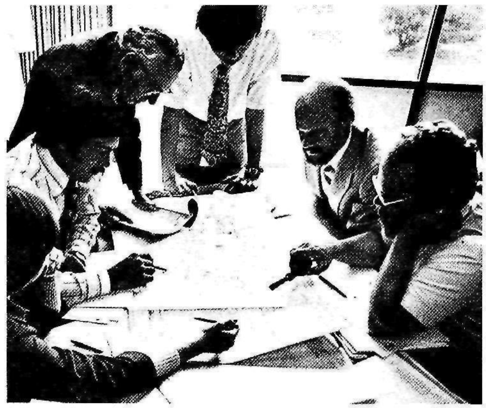
Charged-fog spray devices may be one possible solution to controlling particulates from these kinds of sources. Installed on solids-handling equipment, like hoppers or conveyors, or at strategic points in warehouses or storage yards, charged-fog sprayers could eliminate many major sources of fugitive emissions. PATB, in cooperation with the University of Arizona, has already begun to study the feasibility of this promising approach to controlling fugitive emissions.

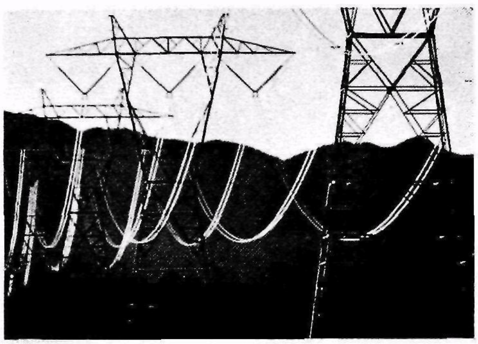


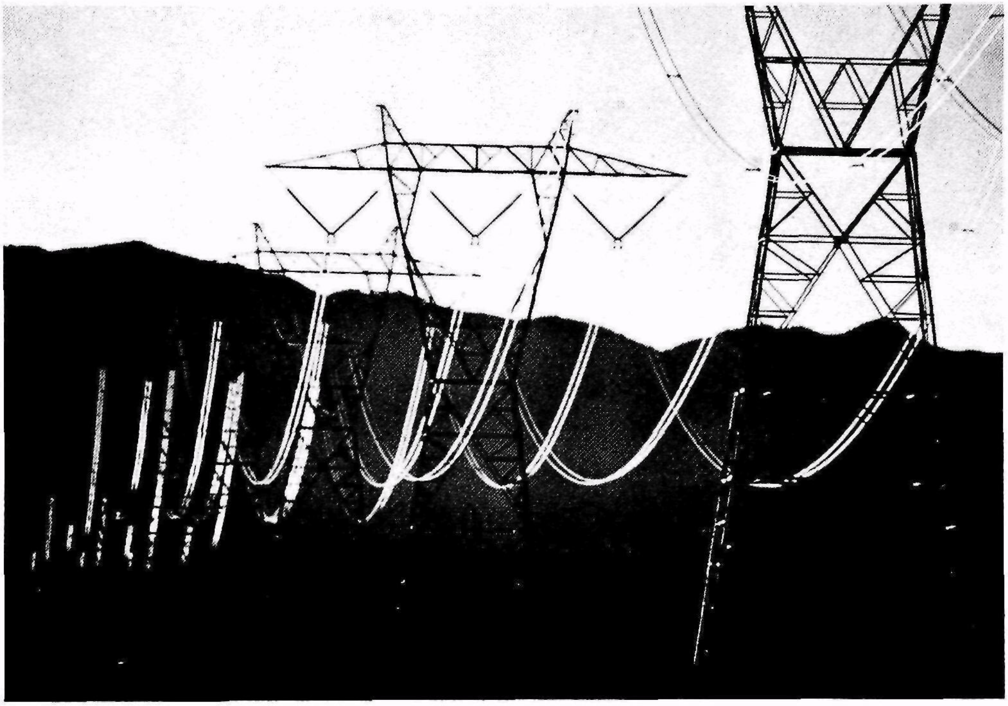
In all of this work, a great deal of new information will be generated on better, more economical ways to control particulates. And to make sure this information reaches the industrial community, PATB will be stepping up its technology-transfer program in the years ahead. Through a variety of symposia, conferences, and publications, PATB will spread knowledge of the latest developments in particulate control technology to owners and operators of factories and power plants, as well as thousands of people in government and universities all across the country.

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 new and more effective particulate control devices, air quality standards can be improved, making our air cleaner and healthier to breathe.

PATB's goal for the next 5 years is to increase the effectiveness of particulate control devices by 10 times compared to today's equipment. And, to make it practical for industry to install those devices, 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.







This report has been reviewed by the U.S. Environmental Protection Agency, and approved for publication. Mention of trade names of commercial products does not constitute endorsement or recommendation for use.

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