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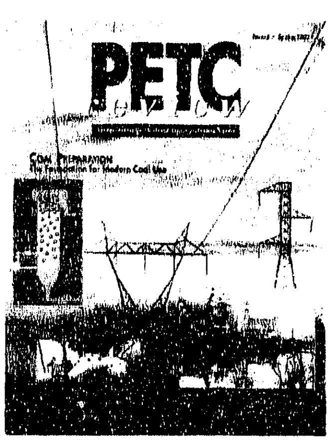


On the Cover:
About 55% of the electricity generated in the United States comes from coal. Inset photos are (starting from the left and running counter-clockwise) a flow diagram for column froth flotation (see page 7); equipment in PETC's Coal Preparation Process Research Facility (see page 22); and a typical coal preparation plant. Background photo by Comstock, Inc.\ Jack Clark.

From the Director

This issue of the *PETC Review* features a technology we consider to be of central importance to the present and future utilization of coal: coal preparation. Part mineral separation, part physics and chemistry, and more than just a little engineering, the art and science of coal preparation is not new to PETC. Our roots in the technology go back to the 1920s, decades before we became part of the U.S. Department of Energy (DOE), when "King Coal" was meeting more than half of the nation's energy needs. As researchers within the Bureau of Mines, we collaborated closely with the mining industry to seek ways to make coal a more marketable end-product, one that would be cleaner and, therefore, easier to transport and use.

The Federal government's interest in coal preparation has continued more or less unabated for over 50 years and is now focused in DOE's Coal Preparation Program. As stated in our lead article, "Coal Preparation: The Foundation for Modern Coal Use," we believe coal preparation is an *enabling* technology that supports the entire spectrum of coal use by transforming as-mined coal into a higher-value product that can meet present and future customer specifications. Continued Federal support for the Coal Preparation Program stems from the conviction that this technology will help us meet the growing energy needs of our domestic economy through the expanded use of clean coals and will lead to the production of premium coals and coal-derived fuels that will enhance the export potential and value of U.S. coals.

Sun W. Chun

Over the years, the emphasis of the Coal Preparation Program has changed to reflect the needs of the nation and the coal industry. For example, through the 1970s, the Federal program functioned largely to assist the coal industry by characterizing the cleaning potential of various coals and the performance of commercial coal-cleaning devices. During these years, the goal was to provide technical information to an industry that continued to be very much preoccupied with retaining production levels in the face of increasing competition from petroleum and natural gas and the challenge of complying with new regulations covering safety, health, and the environment. When the Federal Coal Preparation Program was transferred to the new DOE, the program goals were shifted toward longer-range, higher-risk development activities. Emphasis was given to advanced methods for deep cleaning coal, primarily for the removal of sulfur. During the early 1980s, the program invested in a broad range of advanced technologies and was able to identify a number of highly promising approaches for deeply cleaning coal. As we approached the mid-1980s, some profound changes in how people regarded the physical environment were beginning to take hold not only in the United States but throughout the industrialized world. It soon became clear that this thinking would influence the direction of national policy and would likely result in legislation that would affect the way we use coal in the future. To better prepare for that future, a major new element, the Acid Rain Control Initiative, was added to the Coal Preparation Program in early 1988. Specifically, this initiative responded to the then-pending passage of acid rain legislation that is now incorporated in the Clean Air Act Amendments of 1990.

In 1992, the Coal Preparation Program will strive to build on the technical progress of the initiative and to strengthen PETC's traditional close support of the near-term concerns of the coal and coal preparation industries (see first article). We plan to initiate two major efforts. Two solicitations (which will result in a number of contracts) will be awarded for High-Efficiency Preparation, an effort that involves the development and testing of innovative, near-term process operations associated with cleaning, handling, and delivering coal fines. PETC's Coal Preparation Process Research Facility is now coming on line; its first major mission will be to provide industry with test facilities in support of the High-Efficiency Preparation activities. In addition, one or more awards will be made for Premium Fuel Applications, a 5-year effort to establish design bases on prototype commercial processes for producing ultra-clean coals that can be substituted for oil in several diverse applications and that can serve as feedstocks for advanced pulverized-coal systems.

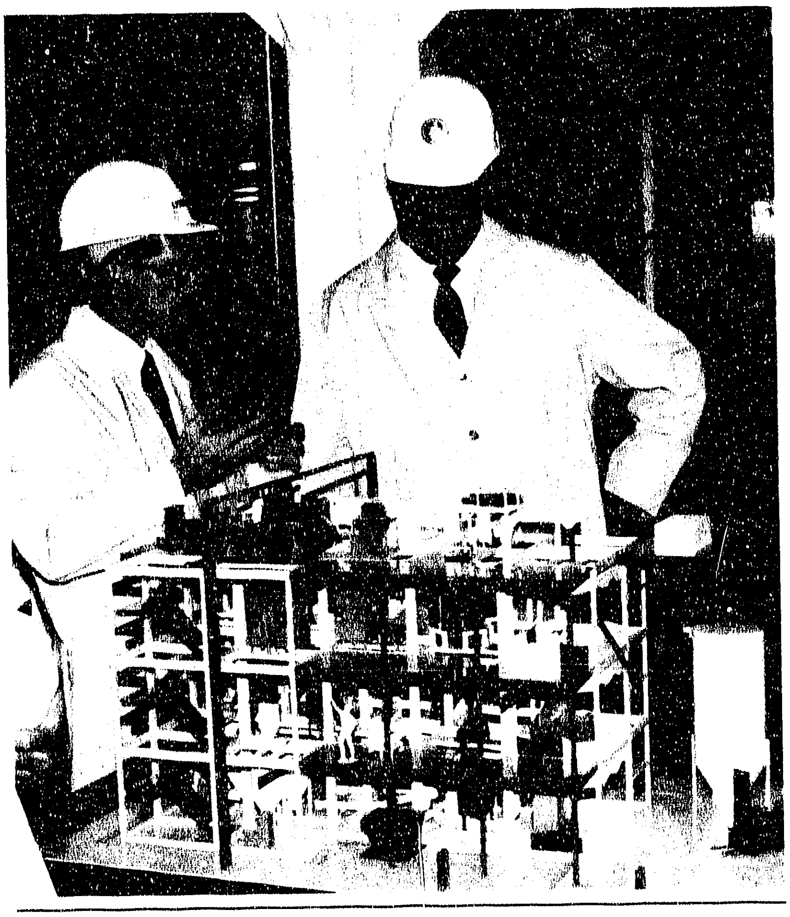
Over the next year, PETC will be working hard to strengthen the cooperation between the Federal government and the coal and coal preparation industries. We believe that our efforts will help ensure that the future expansion of coal use — the more than doubling of U.S. coal consumption to 2 billion tons/year by 2030 that is forecast in the *National Energy Strategy* — will be realized.

This issue of the *PETC Review* also includes articles describing PETC's Coal Preparation Process Research Facility, the Advanced Flue Gas Desulfurization project being conducted under the Clean Coal Technology Program, and PETC's Science Outreach Program.

I hope you find this issue of the *PETC Review* informative and that you share my belief that the technologies and activities we are pursuing will continue to shape a more secure energy future.

Director

COAL PREPARATION: THE FOUNDATION FOR MODERN COAL USE



R.P. Killmeyer (left) a group leader in the Coal Preparation Division explains the capabilities of PETC's new Coal Preparation Process Research Facility to DOE Secretary James D. Watkins via a scale model while touring the facility. The new facility reaffirms PETC's commitment to development and testing of innovative process operations.

In the U.S. Department of Energy's (DOE's) coal research and development (R&D) program, coal preparation holds a unique position. Coal preparation is the *enabling* technology, serving as the foundation for coal use across the full spectrum of current and future applications of coal. This article introduces DOE's Coal Preparation Program. Emphasis is on the key considerations that drive public investment in research and technology development directed at advanced processes for cleaning coal. The background for this discussion is the history of coal preparation technologies, the current state of the industry, and the impact of the Clean Air Act Amendments of 1990.

Development History

Raw (as-mined) coal contains mineral impurities that, upon combustion, are transformed to ash or airborne emissions of sulfur oxides (SO_x). Coal preparation involves those processes that convert raw coal to a more marketable, shippable product. These processes can be grouped into two broad classes: sizing and cleaning. Cleaning is the primary focus of DOE's Coal Preparation Program. Roughly half of the bituminous coal currently mined in the United States is sent to preparation plants that include some form of coal cleaning. At these preparation plants, coal is processed into a higher-value product that meets customer specifications. As such, a coal preparation plant is analogous to an oil refinery in that both receive raw products and convert them to useful fuels.

Until fairly recently, the history of coal preparation has been driven by the need to reduce the level of mineral impurities in coal to meet operating specifications of coal-fired equipment. In the United States, this history started soon after the beginning of significant commercial coal mining in the early nineteenth century. The earliest forms of coal preparation involved hand sorting to remove coarse shale, limestone, and clay (see Figure 1). Hand sorting

Figure 1. Primitive Coal Preparation—"Breaker Boys" hand sorting coal.

was not only labor-intensive but also highly inefficient and resulted in excessive losses of valuable combustible coal while achieving only limited removal of mineral impurities.

During the first few decades of the twentieth century, coal sorting became totally mechanized through the introduction of jigs and washing tables. The Baum jig, a widely used technology, was introduced into the United States in 1928 (see Figure 2). The first coal washing tables that emphasized current engineering principles were Deister-Overstrom tables, which were put into commercial service in the United States in 1918. These two technical developments were adequate to support the reign of "King Coal," allowing the delivery of a diversity of coal products for home and building heating, locomotion, electricity generation, town gas production, steel making, and manufacturing.

Between 1940 and 1945, a new class of coal preparation processes—dense-medium systems—was developed that more efficiently exploited the large buoyancy difference between coal's combustible matter and its mineral impurities. These systems are based on some relatively fundamental physical principles. When free of mineral impurities, bituminous coal has a relative density of about 1.25; that is, it is about 25% heavier than an equal volume of water. The mineral impurities have much higher relative densities, ranging from about 2.25 to 5.0. The large difference in relative density implies a large difference in buoyancy. These new processes are generally known as dense-medium systems and are perhaps best typified by the dense-medium cyclones that are now in widespread use in the United States and most other major coal-producing countries (see Figure 3).

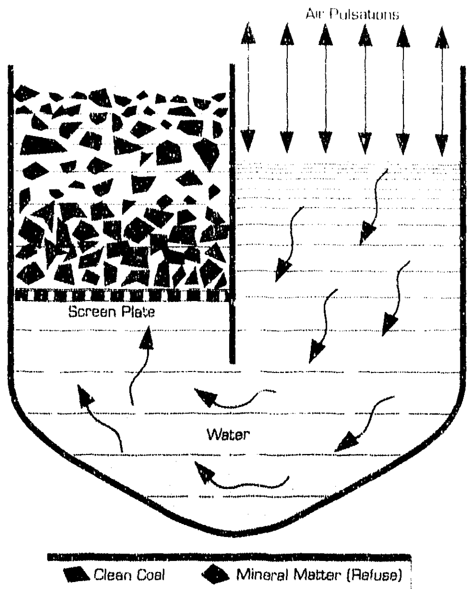


Figure 2. Jigging is a coal cleaning process in which the feed coal particles are stratified by an alternate expansion and contraction of the feed particle bed. This stratification is induced by periodic vertical pulsations of the water medium.

Most coals are highly friable (i.e., they are easily crushed or pulverized). Mining, handling, crushing, and sizing operations invariably produce coal fines—finely powdered coal that is usable but difficult to clean and handle. Starting about 1940, a new technology—froth flotation, which was originally developed for mineral processing—was adapted to cleaning coal fines (see Figure 4). Froth flotation represented a new class of coal cleaning processes that depend on the difference in the surface properties of the combustible material in coal and coal's mineral impurities. In froth flotation, small air bubbles are introduced into a suspension of coal in water. The air bubbles preferentially attach themselves to coal (see Figure 5), causing the clean coal to float on the top of a vessel. About 40% of coal cleaning capacity in the United States consists of plants that contain froth flotation circuits for the recovery of coal fines. The remaining plants either discard the coal fines as refuse or remix uncleaned coal fines with the cleaned coal for shipment to customers.

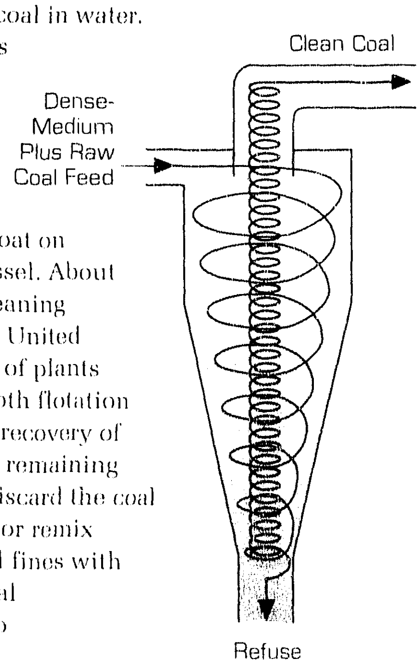


Figure 3. Dense-medium cycloning is a coal cleaning process accomplished with the aid of centrifugal force. Heavier mineral particles move, in a medium of water and magnetite, to the wall of the cyclone. These impurities are then discharged at the bottom of the cyclone, and the lighter coal particles are swept toward the central vortex and are released through an outlet at the top.

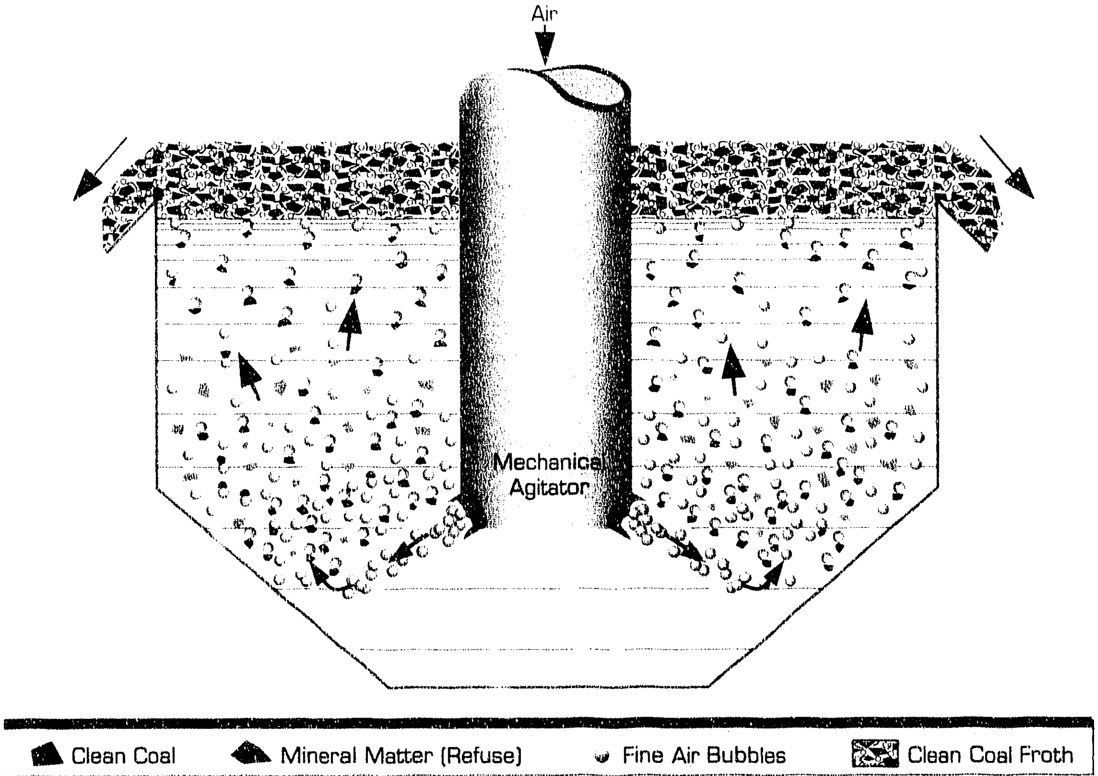


Figure 4. Froth flotation is a process for cleaning fine coal in which the coal, with the aid of a reagent, becomes attached to air bubbles in the water and rises to the top where it is skimmed off.

The State of the Industry

Today, the coal preparation industry has a suite of technologies available that can efficiently and economically clean coarse and intermediate-size bituminous coal. However, because of the relatively high cost, the processing and handling of coal fines remain problematic. Conventional froth flotation is more expensive than is coarse coal cleaning and is limited by the extent to which mineral impurities can be removed without excessive losses of combustible values. Recently, an advanced coal froth flotation technology—column froth flotation (see Microcel® highlight in *PETC Review* Issue 4 and Update in this issue)—has been introduced into commercial use (see Figure 6). Although only a few units are now in commercial service, this technology appears to be gaining industry acceptance as a more efficient method of recovering combustible values from coal fines.

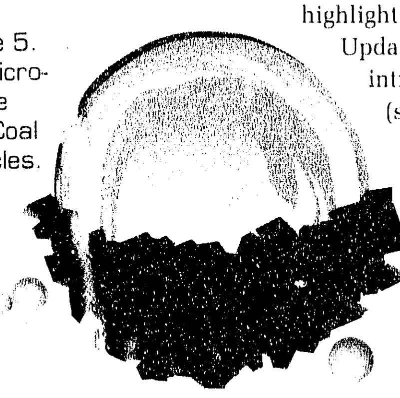


Figure 5. Air Microbubble with Coal Particles.

However, the industry's problems with coal fines extend beyond just the cleaning process. All commercial processes for cleaning coal fines involve suspending the coal fines in water. Within the coal preparation industry, the general consensus regarding coal fines is that technology is not available for economically dewatering; thermal drying; handling, storing, and delivering dry powdered fines; or reconstituting the coal fines into larger sizes (e.g., briquettes or pellets). Because of this technology gap, commercial coal mining and preparation operations attempt to minimize the production of coal fines. Specifically, almost all coal cleaned in the United States is crushed to a top size of not less than 2 inches because any further crushing would result in a greater proportion of coal fines, with attendant processing and delivery problems. By minimizing crushing operations during coal preparation, the cleaned, wet coal fines can often be combined with the plant's coarse coal output to yield a combined product with an overall size and moisture level satisfactory to customers prepared to accept shipments of lump coal (2-inch top size).

In spite of these technological limitations, it is not uncommon for coal preparation plants to receive as-mined bituminous coal with ash contents between 20 and 40% and to produce a cleaned product with an ash content of between 8 and 12%. Of the sulfur in coal, between 35 and 65% is generally associated with mineral impurities. Therefore, reducing mineral impurities also reduces sulfur levels by between 20 and 40%, depending on the type of coal delivered to the plant. The sulfur in coal that is not associated with mineral impurities is generally bonded to the organic coal matrix. This sulfur is not amenable to removal by physical processes and must be cleaned using much more forceful processes (e.g., by reaction with chemical reagents).

The cleaning methods described thus far apply mainly to bituminous coal, which is the dominant coal type found in the eastern and central regions of the United States. In the West, the dominant types are subbituminous coals and lignites. As mined, these western coals contain fairly high levels of the alkali metals sodium and potassium, which affect the physical and chemical properties of the coal ash. As a result, boilers using these coals are specially designed to avoid serious ash-related equipment malfunctions. In addition, western coals also contain high levels of moisture—30% is not uncommon—which add to transportation costs. On the positive side, subbituminous coals and lignites generally contain much lower levels of sulfur than do typical bituminous coals.

Currently, acceptable commercial technology is not available for reducing either alkali metal or moisture levels in subbituminous coals and lignites. For moisture reduction, promising technology may soon be available. In particular, DOE's Clean Coal Technology Program includes two projects for commercial plants to reduce moisture. Alkali metal reduction is another issue. In both subbituminous coals and lignites, most of the alkali metal impurities are chemically bonded to the organic coal matrix. Just as the sulfur that is chemically bound to the organic coal matrix is not amenable to removal by physical processes, the application of physical coal cleaning methods is unable to reduce significantly the alkali metal concentrations in western coals.

The Clean Air Act Amendments of 1990

In 1990, the United States witnessed a major step forward in its commitment to clean air. We have a new Clean Air Act that requires large reductions in emissions of acid rain precursors. Sulfur dioxide (SO_2) from coal firing is recognized as a major component of the total acid rain precursors emitted in the United States. The Clean Air Act Amendments of 1990 require reductions in annual emissions of SO_2 to 10 million tons below 1980 levels by the year 2000. Beyond 2000, SO_2 emissions will be capped at year 2000 levels, regardless of the amount of coal used in the United States.

The first phase of emission reductions is scheduled for 1995 and will directly affect operations of coal-fired boilers located at 110 electric generating stations. Beginning in the year 2000, the Act's provisions for SO_2 emissions reduction will extend to all existing coal-fired utility boilers. Implementation will be through a new market-oriented emission allowance system. Basically, each coal-fired boiler

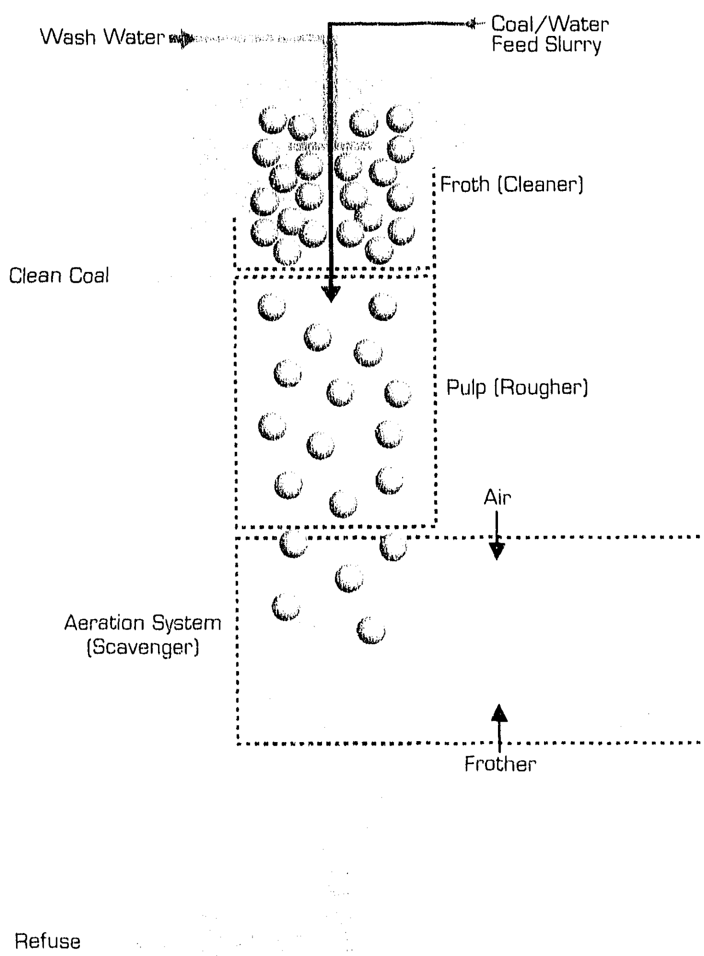


Figure 6. Column flotation is an advanced form of froth flotation (compare Figure 4) in which the cleaning is performed in a tall column, and generally involves a deep froth layer, quiescent conditions and countercurrent wash water for producing a cleaner froth, and may also entail the use of finer bubbles.

will be allocated an allowance to emit a given tonnage of SO_2 annually. Most importantly, these emission allowances will be marketable. If an electric utility can exceed its reduction target and holds unused allowances, these allowances may be sold to other utility companies. The selling price for emission allowances will be determined by market forces—supply and demand. Currently, speculation is that allowances will initially be trading at between $300 and $500 per ton of SO_2 and will rise to more than $1,000 per ton of SO_2 after the year 2000.

The Clean Air Act Amendments of 1990 will cause many existing coal-fired utility boilers to be retrofitted with flue gas desulfurization systems. However, the economical option for many operators will be to switch to lower-sulfur coals and/or to purchase emission allowances. For boilers without flue gas desulfurization, lower-sulfur coals will carry a considerable economic premium. For example, emission allowances trading at $500 per ton of SO_2 correspond to a $10-per-ton-of-coal premium for each percentage point less of sulfur contained in the delivered coal. This means that a 1% sulfur coal will command a price that is $10/ton higher than a 2% sulfur coal, all other coal properties being identical.

For the U.S. coal preparation industry, the implications of marketable emission allowances are profound. Traditionally, coal preparation has been targeted at removing mineral impurities for the purposes of preparing a lower-ash coal with improved combustion properties. In the cleaning process, sulfur levels were moderately reduced. Until now, sulfur reduction has generally been viewed as a desirable, but not essential, side benefit of coal cleaning. The Clean Air Act Amendments of 1990 now provide a strong economic motivation for enhanced sulfur removal during coal preparation.

The technical means of economically achieving more extensive sulfur removal during coal preparation are well understood. Fundamentally, greater liberation of mineral impurities occurs as the size of the coal feed is reduced. Instead of cleaning coal that is at a top size of over 2 inches, the coal preparation industry will need to shift towards more extensive size reduction. Including additional size reduction capabilities within coal preparation plants is a relatively low-cost measure. However, more extensive crushing and selective grinding will cause a significant increase in the level of coal fines that must be processed and delivered to customers. This is the major challenge facing the U.S. coal preparation industry during the 1990s and the early years of the next century. The coal preparation industry has so far taken great pains to minimize the occurrence of coal fines. Because of the Clean Air Act Amendments of 1990, the industry is now seriously evaluating options for deeper sulfur removal.

As a consequence of DOE's continuing support of coal preparation R&D, advanced technologies are available for cleaning coal fines. These technologies include column froth flotation, which has already seen limited commercial application, and advanced dense-medium systems. As mentioned earlier, the industry's problems with coal fines extend beyond just the cleaning process. To date, the DOE R&D program has primarily focused on advanced cleaning operations. Based on inputs received from industry, we have expanded the scope of our R&D program to include the development and testing of near-term approaches for process control; dewatering; thermal drying; and handling, storing, and delivering coal fines.

Evolving Toward Efficient Coal Cleaning

The near-term goal of the DOE Coal Preparation Program is to provide the U.S. coal preparation industry with technology that can foster the industry's evolution toward deeper and more efficient coal cleaning. The chances of success are high. We can identify a number of promising near-term approaches that offer economic and efficient means of processing coal fines. The benefits of success are considerable. Progressively deeper coal preparation represents a very economical alternative for boiler operators who choose not to build a flue gas treatment system. Our studies have also shown that combining coal preparation and the newly emerging duct injection systems (see Issue 1 of the *PETC Review*) is an economically attractive approach for meeting sulfur-reduction goals. As the sulfur-reduction goals of the Clean Air Act Amendments of 1990 are implemented, efficient coal preparation will allow boiler operators to continue to rely on their traditional sources of coal, thereby alleviating disruptions in coal supply patterns, especially in the eastern portion of the nation.

Beyond the mandate of the Clean Air Act Amendments of 1990, more efficient coal cleaning offers significant environmental and economic benefits. In many existing coal preparation plants, coal fines are simply being discarded as waste. Improved technology for processing coal fines will make this practice economically obsolete, yielding greater recovery of combustible coal, reducing solid refuse, and improving the total efficiency of mining and delivering coal. More extensive sulfur removal means more extensive removal of all mineral impurities found in coal. By further reducing mineral impurities, deeper coal preparation will yield a fuel with improved combustion properties and less ash. For boiler operators, this means improved boiler efficiency, reduced maintenance costs, and less ash refuse. These benefits, combined with lower sulfur levels, also increase the competitive stature of U.S. coals in the international market for coal exports.

We are also cooperating with the U.S. Environmental Protection Agency and the electric utility industry to improve our understanding of airborne toxic emissions from coal firing. Meanwhile, the evolution of the coal preparation industry towards deeper and more efficient cleaning is certainly a step in the right direction and is consistent with the commitment established in the Clean Air Act Amendments of 1990 for addressing air-borne toxic emissions. By removing greater amounts of mineral impurities from coal, coal preparation will also reduce the trace amounts of toxic metals (e.g., mercury and cadmium) that are associated with mineral impurities.

Petroleum Alternatives

An important component of the *National Energy Strategy* is the development of alternative fuels to reduce the dependence of our nation on oil. Towards this end, DOE continues to support R&D directed at reducing the cost, investment risks, and environmental impacts of producing liquid fuels and liquid fuel substitutes from coal. Our efforts are contained in two major programs managed at PETC: the Coal Liquefaction Program (see Issues 3 and 4 of the *PETC Review*) and the Alternative Fuels Program. In both programs, coal preparation serves as an important enabling technology.

Coal Liquefaction

In the Coal Liquefaction Program, our focus is on developing transportation fuels that have all the qualities of high-grade petroleum fuels. In addition to converting solid coal to a liquid fuel, a viable coal liquefaction process must be able to achieve nearly complete removal of mineral and sulfur impurities. During the 1970s, direct liquefaction research centered on process concepts capable of using uncleaned, as-mined coal. During the 1980s, engineering analyses and experimental research indicated that significant cost savings and improvements would result from processes that integrate deep coal preparation with direct liquefaction. One interesting systems integration concept involves the use of a coal cleaning system that produces two products: (1) an extremely low-ash clean coal for use as a liquefaction feedstock and (2) a moderate-ash product that could be used as a gasification feedstock to produce the hydrogen required by the liquefaction process.

Another highly promising approach builds on the Coal Preparation Program's work in selective agglomeration, which is an advanced technique for deep coal cleaning (see Figure 7). One approach to agglomeration involves adding a significant amount of

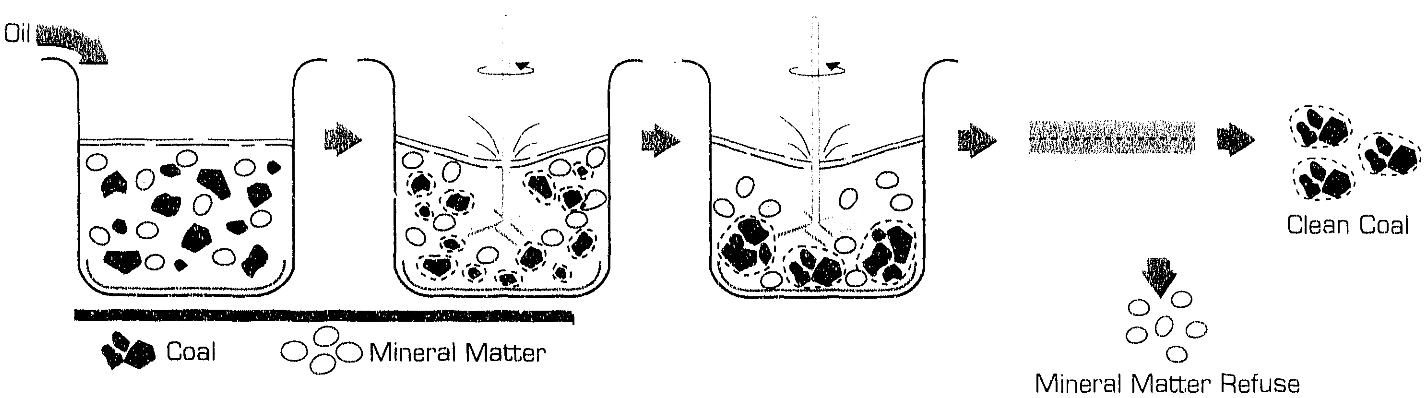


Figure 7. In a selective agglomeration process, feed coal is mixed in water, and then an agglomerating agent is added. The suspension is agitated vigorously, causing the coal particles to cluster. The agglomerated coal particles and mineral matter remain dispersed in the water. The coal agglomerates are then separated from the mineral matter, generally by screening or flotation.

agglomerating oil. In a plant that uses this approach, the agglomeration step might be followed by a second step that would recover the oil from the clean coal. However, when integrated with direct coal liquefaction, this costly second step can be completely eliminated because the first process step in direct liquefaction involves slurrying coal in a process-derived solvent. This slurry serves as the feedstock for the liquefaction process. The same process-derived solvent used in direct liquefaction can be used as a highly effective agglomerating oil in a selective agglomeration process. The resulting clean coal agglomerates, along with the agglomerating oil, can be fed to the direct liquefaction process without the need for oil recovery.

Alternative Fuels

In the Alternative Fuels Progr[illegible]m, our focus is to develop lower-cost, coal-base[illegible] [illegible]els that can substitute for lower-grade, petroleum-based products. Our near-term goal is to develop a low-cost replacement for No. 6 fuel oil (a common boiler fuel), thereby allowing coal to substitute for petroleum in a multitude of electric utility and large industrial boilers. By the year 2000, in the absence of acceptable coal [illegible]etrofit technology, U.S. electric utility consumption of premium fossil fuels is expected to nearly double, reaching the energy equivalent of about 4 million barrels of oil per day. Most of this consumption will occur in boilers that came on line after 1965 and have since experienced fairly low utilization. Our market analyses indicate that these relatively new boilers represent a potential market for over 200 million tons of coal per year. This estimate does not include the potential demand from industrial boilers that are designed for burning a heavy oil. Moreover, countries in western Europe and throughout the Pacific Rim are also dependent on oil-designed boilers for electric power generation. Our analyses show that suitable coal retrofit technology could open up a new export market for up to an additional 200 million tons per year of U.S. coals. Considering the magnitude of both domestic and export markets, it is evident that capturing even a relatively small fraction of these markets would result in a large boost in coal production and extensive commercial activity in processing coal into a fuel oil substitute.

Our Alternative Fuels Program has already made great strides toward reaching the near-term goal of developing a coal substitute for No. 6 fuel oil. DOE has fostered the successful development of coal-water fuels, which consist of a slurry of coal, water, and small amounts of additives. Stability and ease of handling have been demonstrated at coal-water ratios exceeding 70% coal by weight. Through small- and large-scale combustion tests, we have identified development measures needed to make coal-water fuels an economical and environmentally sound alternative to No. 6 fuel oil. Notably, these development needs include demonstrating the viability of producing very low-ash, low-sulfur coals for use as feedstocks for coal-water mixtures. This past November, PETC's Coal Preparation Program solicited proposals from industry for this purpose. These proposals are now under evaluation.

Over the longer term, our efforts are directed at developing coal-based alternative fuels capable of replacing lighter fuel oils. Success in this effort would allow coal to be used in a broad-range of applications, including moderate- and smaller-sized boilers and furnaces, industrial process equipment, large diesel engines, and heavy-duty turbines. Although the rewards of success are immense, the technical challenge is greater; and coal preparation is clearly the enabling technology. Specifically, this longer-term goal requires the development of coal cleaning processes that can yield an ultra-clean coal in terms of sulfur and residual minerals. Toward this end, the Coal Preparation Program continues to invest in high-risk, high-payoff concepts involving physical, chemical, and biological approaches for removing impurities from coal.

Combustion 2000

As we look beyond the year 2000, we see domestically produced coal playing an increasingly large role in serving our nation's energy needs. Consider the energy supply and demand projections used to formulate the *National Energy Strategy*. These projections show coal production and usage more than doubling by the year 2030. This much higher level of coal use is essential to our national security and economic welfare. The challenge is to expand coal use but not compromise our national commitment to a cleaner and healthier environment. Most recently, the potential climate changes related to carbon dioxide (CO_2) emissions resulting from increased coal use have received considerable public attention. To respond to this concern, DOE established and is now implementing the Combustion 2000 Program (see *PETC Review*, Issue 4). In short, this new program focuses on advanced electric power generation systems that offer dramatic improvements in environmental performance and efficiency.

Attaining higher thermal efficiency in electric power generation requires coal combustion and heat transfer at temperatures significantly beyond current practice. High-temperature materials suitable for such advanced systems are generally intolerant of coal ash. For example, at high temperatures, coal ash liquefies and literally dissolves many ceramic materials that are potential candidates for use in high-temperature furnaces. For this reason, one of the major R&D thrusts supporting our Combustion 2000 Program involves deep coal preparation in which over 90% of mineral impurities are removed before combustion. After such deep cleaning, any residual mineral matter consists of ultra-fine grains dispersed throughout the coal's organic matter. When the coal is burned, these ultra-fine grains convert to ultra-fine ash particles that tend to follow closely the gas flows within furnaces and heat exchangers. This allows the application of advanced combustion methods to minimize the interaction of residual ash with high-temperature materials in advanced combustion processes.

Developing coal-fired systems that allow heat transfer at high temperatures would provide the foundation for an entirely new class of power generation technologies that leap beyond the efficiency barriers of conventional boiler systems. Engineering analyses conducted by PETC indicate that thermal efficiencies (coal pile to busbar) of about 50% can be anticipated for advanced systems and that these systems can be available for initial commercial applications within about 10 years. Compared to present-day plants, such advanced systems would require 25 to 30% less coal to produce an equal amount of power. This translates to a 25 to 30% reduction in CO_2 emissions and an equivalent reduction in all environmental impacts associated with coal production, coal transportation, and power generation.

Beyond the economic and environmental benefits offered by improved efficiency, the Combustion 2000 Program hopes to achieve dramatic improvements in the environmental performance of advanced power generation systems. These include improved methods for the extensive control of airborne emissions of SO_x, particulates, and trace toxics, as well as a reduction of solid wastes. Coal preparation augments and combines with advanced approaches for flue gas cleanup and the economic conversion of solid waste to useful by-products.

The DOE Coal Preparation Program

In this article, we have presented a vision of the role that coal preparation can take in shoring up the future of coal in the United States. Attaining this vision requires advanced technologies for coal preparation. In some cases, the required advances are modest and can be reached within a few years via an evolutionary program of R&D. In other cases, brand-new technical approaches are needed to meet performance requirements. At PETC, we are dedicated to fully exploiting the potential of coal preparation as the critical enabling technology for coal production in the United States and for coal use throughout the world. Accordingly, the DOE Coal Preparation Program for Federally supported R&D is shaped and driven to:

- Foster the evolution of the U.S. coal preparation industry towards deeper and more efficient coal cleaning. The focus is on near-term technology that would ease the adverse economic impacts of the sulfur-emission-reduction goals of the Clean Air Act Amendments of 1990, improve the overall efficiency and environmental impacts of coal production and delivery, and enhance the competitive position of U.S. coal exports.

- Provide the technology base for producing petroleum alternatives from coal, including liquid fuels via coal liquefaction and liquid fuel substitutes (e.g., coal-water fuels). The focus is on mid- and longer-term technologies that open new markets for coal.

- Assure that greatly increased coal use in electric power generation does not compromise the nation's commitment to a cleaner, healthier environment. To achieve this end, the Coal Preparation Program integrates with PETC's Combustion 2000 Program to develop high-efficiency, high-environmental-performance systems for electric power generation.

The Coal Preparation Program is currently able to support three goal-oriented initiatives: (1) Acid Rain Control R&D, (2) High-Efficiency Fine Coal Preparation, and (3) Premium Fuels.

Acid Rain Control R&D Initiative

In 1988, in anticipation of the acid rain control provisions of the forthcoming amendments to the Clean Air Act, DOE initiated the engineering

Figure 8. Bioprocessing involves using microbes that are specifically designed to extract sulfur from coal. Shown above is a scanning electron photomicrograph of the rod-shaped microbe *Thiobacillous ferrooxidans* that will remove pyrite from coal.

development of three advanced coal cleaning processes: froth flotation, selective agglomeration, and advanced cycloning. An overview of this initiative was presented in the first issue of the *PETC Review*.

At this time, we are pleased to report that Duquesne Light Company, serving western Pennsylvania, has been selected to demonstrate the commercial feasibility of an advanced cycloning technology under Round IV of the DOE Clean Coal Technology Program. Their technical approach is based on R&D conducted at PETC's in-house laboratories under the auspices of the Coal Preparation Program. Testing and evaluation of advanced froth flotation (by ICF Kaiser Engineers) and selective agglomeration processes (by Southern Company Services) at about 3 tons per hour is scheduled for completion in 1993. Testing of advanced cycloning (by Coal Technology Corporation) will be performed at a scale of 1,000 pounds per hour.

High-Efficiency Fine Coal Preparation Initiative

During this fiscal year, the DOE Coal Preparation Program has allocated $2.9 million to support the development of technology that would enable the U.S. coal preparation industry to evolve toward deeper and more efficient coal cleaning. Through two solicitations for proposals from industry, we are prepared to support the development and testing of innovative, near-term process operations associated with the cleaning, handling, and delivery of coal fines. One solicitation supports continuous, bench-scale testing of new process concepts and equipment in PETC's new Coal Preparation Process Research Facility (see article in this issue). The second solicitation will support development and testing at off-site facilities.

Premium Fuels Initiative

Also during 1992, we will begin a program to develop (by no later than FY 1997) the design base for prototype commercial facilities that are capable of producing ultra-clean coal suitable for conversion to highly loaded, stable coal-water fuels.

This research, which exploits two of the three technologies—advanced froth flotation and selective agglomeration—being investigated under the Acid Rain Control Initiative, focuses on a broader spectrum of coals (all U.S. coals having moderate to high pyritic sulfur and low organic sulfur). Moreover, the cleaning systems to be developed under Premium Fuels will focus on the ultimate in physical liberation.

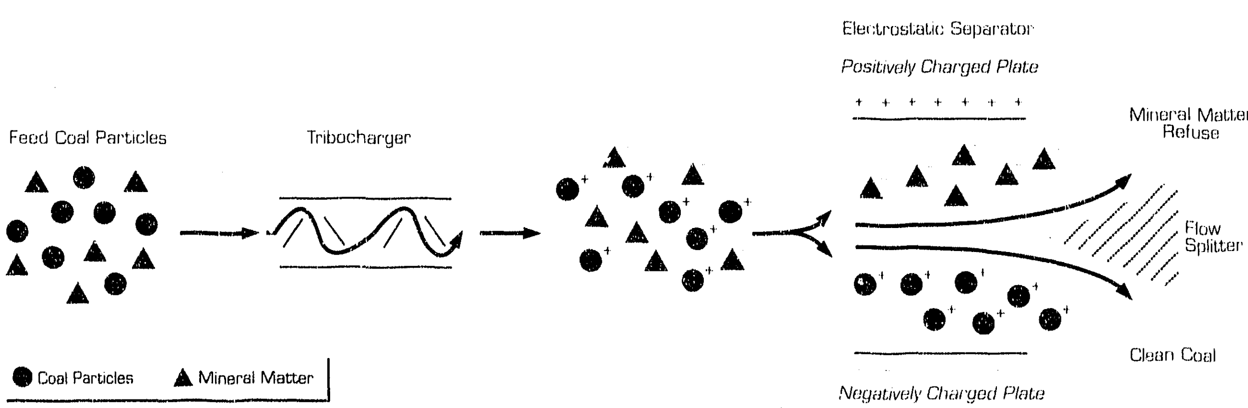


Figure 9. In the triboelectrostatic beneficiation process, the friction of particles with the walls as they flow through the tube (tribocharger) charges the coal and mineral particles oppositely—resulting in positively charged coal particles and negatively charged mineral matter.

Coals will be ground to micron sizes, and all coal cleaning and ancillary operations necessary to prepare the coal will be developed through the proof-of-concept scale.

Exploratory and Advanced Research

In addition to the three major program initiatives already described, the Coal Preparation Program also includes exploratory and advanced research. This work will lead to the next generation of candidate technologies for engineering development. Participants in the program include industry, universities, national laboratories, and PETC's in-house Coal Preparation Laboratory. These organizations are conducting exciting research on a diversity of advanced approaches (e.g., micronized magnetite cycloning and electrostatic separation) for economical, efficient, and deep cleaning of coal.

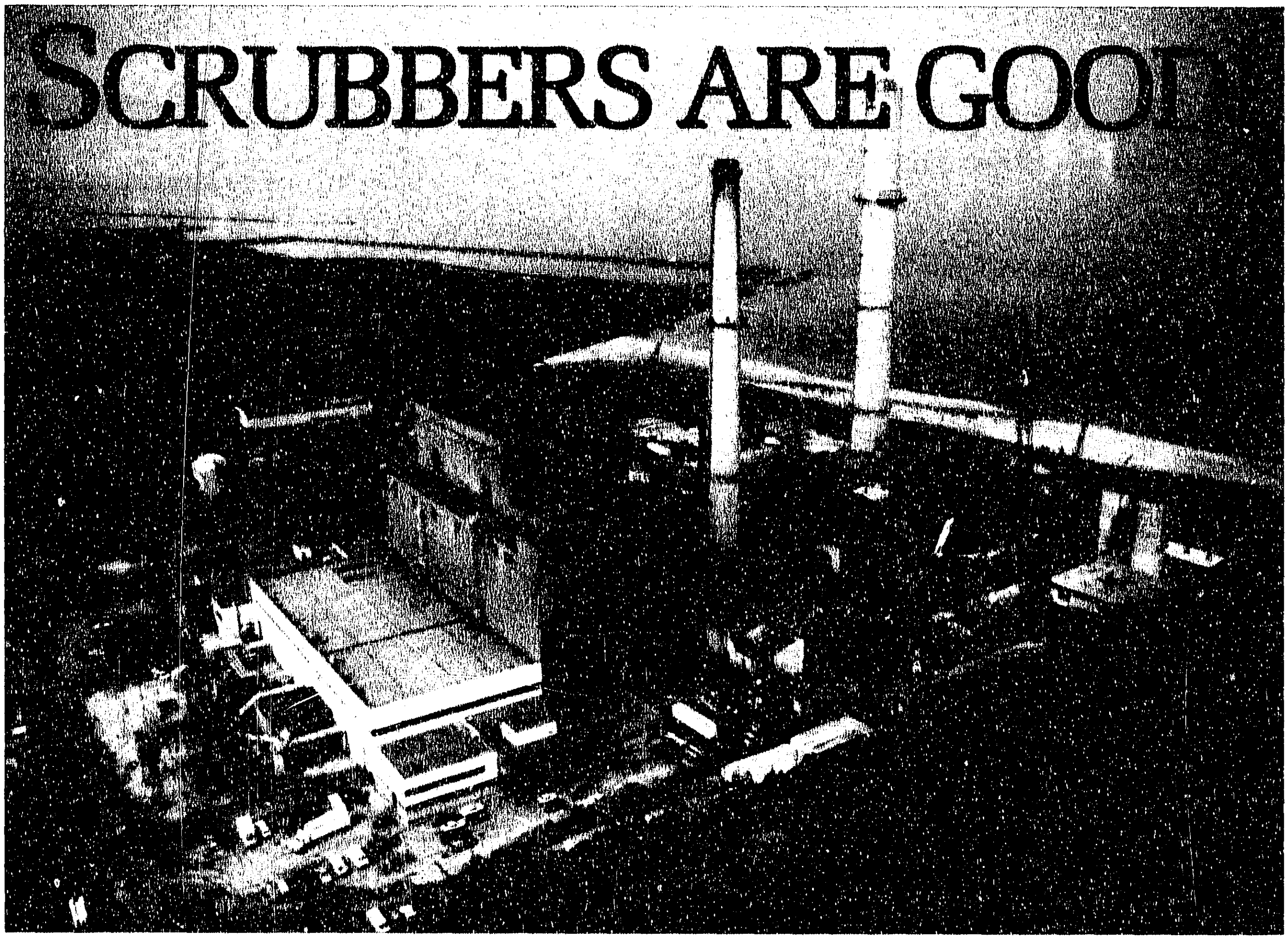
Chemical coal cleaning methods are being developed for the extensive (and, we hope, inexpensive) removal of mineral impurities and of organically bound sulfur and alkali impurities. We are building on the overall progress made in genetic engineering and investigating the feasibility of using microbes specifically designed to extract sulfur impurities from coal (see Figure 8). We are also continuing to investigate new approaches for deep coal cleaning based on exploiting differences in the surface properties of clean coal particles and mineral impurities. For example, the program has made considerable progress in understanding the fundamentals of electrostatic coal cleaning, which is based on the electrostatic principle that like charges repel and unlike charges attract each other (see Figure 9). Based on this achievement, we are now evaluating alternative approaches for moving this technology into engineering development.

More to Tell

This article presented the driving forces that shape the DOE Coal Preparation Program. In formulating this program, we have sought and received advice from industry and academia. As economic, environmental, and technological developments occur, we are committed to working with industry and academia to evolve this program in such a way as to support our nation's resolve for a secure, economically strong, and environmentally sound future. Forthcoming issues of the *PETC Review* will present in greater depth some of the exciting components of this very important program of research and technology development.

Richard E. Hucko *heads PETC's Coal Preparation and Solids Transport Division and is currently responsible for the implementation of all research activities in DOE's Coal Preparation Program. A graduate of the University of Pittsburgh, Rich has an M.S. degree in civil engineering. Initially employed at Bruceton by the U.S. Bureau of Mines in 1974, he transferred to DOE in 1977. From the outset, Rich has worked almost exclusively in the area of coal preparation research, with initial emphasis on selective flocculation and high-gradient magnetic separation and most recently in the development of technologies to mitigate acid rain precursors, to produce superclean coals for premium fuel applications, and to produce low-cost more deeply cleaned coal.*

SCRUBBERS ARE GOO



Northern Indiana Public Service Company's Bailly Generating Station along the shore of Lake Michigan.

A flue gas desulfurization (FGD) system, commonly known as a scrubber, is a separate gas cleaning facility installed at the back end of a power plant to remove sulfur dioxide (SO_2). Early, or conventional, scrubbers have had to overcome many difficulties (e.g., high costs, large space requirements, low energy efficiency, frequent breakdowns, and waste disposal problems). However, a new generation of scrubbers is now poised to overcome many of these obstacles, proving that pollution control need not be economically prohibitive.

Problems with First-Generation Scrubbers

A scrubber, whether "wet" or "dry," is actually a complex chemical plant. It can be difficult to operate and is subject to mechanical failures, corrosion, plugging, and scaling. Therefore, scrubbers are often considered unreliable and troublesome. In wet scrubbing, flue gas from burning coal is sprayed with a slurry of water and an alkaline reagent, usually limestone. The SO_2 in the flue gas reacts with the limestone to produce a mixture of calcium sulfite and calcium sulfate, which is commonly referred to as scrubber sludge. Over its life, a 500-MWe coal-fired power plant with a wet scrubber produces enough sludge to fill a 500-acre disposal pond that is 40 feet deep, thereby creating a waste disposal problem. Because scrubber sludge has the consistency of toothpaste, stabilizing additives are often required to solidify the material so that it can be more easily disposed of in a landfill.

Although conventional wet scrubbers can remove 90% or more of the SO_2 from a power plant's flue gas, they are expensive to install; capital costs of $200 to over $300 per kilowatt of capacity (or about $100 to $150 million for a 500-MWe plant) are not uncommon. Scrubbers also consume a part of the power plant's electrical output to run pumps, fans, and a flue gas reheat system, thereby reducing the power plant's net electricity output by 3 to 5%. Many scrubbers require a large amount of space, which can create problems for a facility at which space is limited. Wet scrubbers also use large quantities of water, and water availability is limited in many areas.

In a "dry" scrubber (or spray dryer), the reagent mixture (usually lime) is injected as a finely atomized mist. The droplets evaporate in the hot gas, leaving only dry particles to react with the SO_2 and to be collected subsequently as waste. Although simpler in operation and lower in capital cost than the wet scrubber, the dry scrubber has not been widely adopted for removing SO_2 from high-sulfur coals. The primary reason for this is that lime is about three to four times more expensive per ton than is limestone. As a result, dry scrubbing is generally used in low-sulfur coal applications that require much less reagent than would high-sulfur coal applications. The wet scrubbing technique is preferred when using high-sulfur coals that require greater amounts of scrubbing reagent.

First-generation scrubbers have been plagued by poor reliability, and the consequences have been heightened by government regulation. In the 1970s, clean air legislation mandated that power companies make provisions for service interruptions caused by scrubber equipment failure. Because conventional scrubbers were unreliable, utilities often found it necessary to install a spare module to back up the original scrubber. The additional module escalated the size and cost of the system. Therefore, the use of conventional scrubbers brought forth new "challenges" — largely unsought and unappreciated — for utility companies. Fortunately, a new generation of scrubbers now looms on the horizon and has the potential to reduce or even eliminate many of these problems.

Pure Air's Advanced Flue Gas Desulfurization Project

At the vanguard of this new generation is Pure Air's Clean Coal Technology "Advanced Flue Gas Desulfurization (AFGD) Demonstration Project." This unique, $150.5-million project is a cooperative effort between the U.S. Department of Energy (DOE) and Pure Air, a general partnership between Air Products and Chemicals, Inc., and Mitsubishi Heavy Industries America, Inc. This project entails the design, construction, and operation of an AFGD facility to remove SO_2 from flue gas from a 528-MWe coal-fired power plant at the Northern Indiana Public Service Company's Bailly Generating Station, which is located about 12 miles northeast of Gary, Indiana. The facility will be used to demonstrate a variety of advanced technical and business-related features during a 3-year period of operation, which is scheduled to begin in the summer of 1992.

The Pure Air scrubber is expected to operate without most of the problems associated with conventional scrubbers. The SO_2 absorber will use a high-velocity co-current design, in which the scrubbing slurry moves in the same direction as the flow of flue gas. A co-current design facilitates operation at a relatively high flue gas velocity of approximately 20 feet per second, versus 8 to 12 feet per second for a conventional counter-current scrubber. This, in turn, contributes to the relatively smaller space requirements for the AFGD system compared with a conventional scrubber.

Ordinarily, an FGD facility contains several SO_2 absorber modules, with one or two spare modules added to improve system reliability. In comparison, the AFGD facility at Bailly will use a single 528-MWe absorber module to scrub all of the flue gases from the station's two coal-fired boilers. It will be the largest-capacity SO_2 absorber in the western hemisphere and

HISTORICAL BACKGROUND

The notion of scrubbing SO_2 from coal-fired flue gases dates back to the 1920s and 1930s when the first scrubbers were built in Great Britain. These scrubber facilities were shut down in World War II so that the British power plants would not be detected by aircraft that could follow the vapor plumes resulting from scrubbing to the plant. Interestingly, even these very first scrubbers were effective at removing 90% or more of the SO_2. Scrubber technology continued to evolve through the 1960s, with installations in Europe, Japan, and the United States. However, widespread application did not occur until scrubber technology was implemented in the United States in response to the Clean Air Act Amendments of 1970 and 1977.

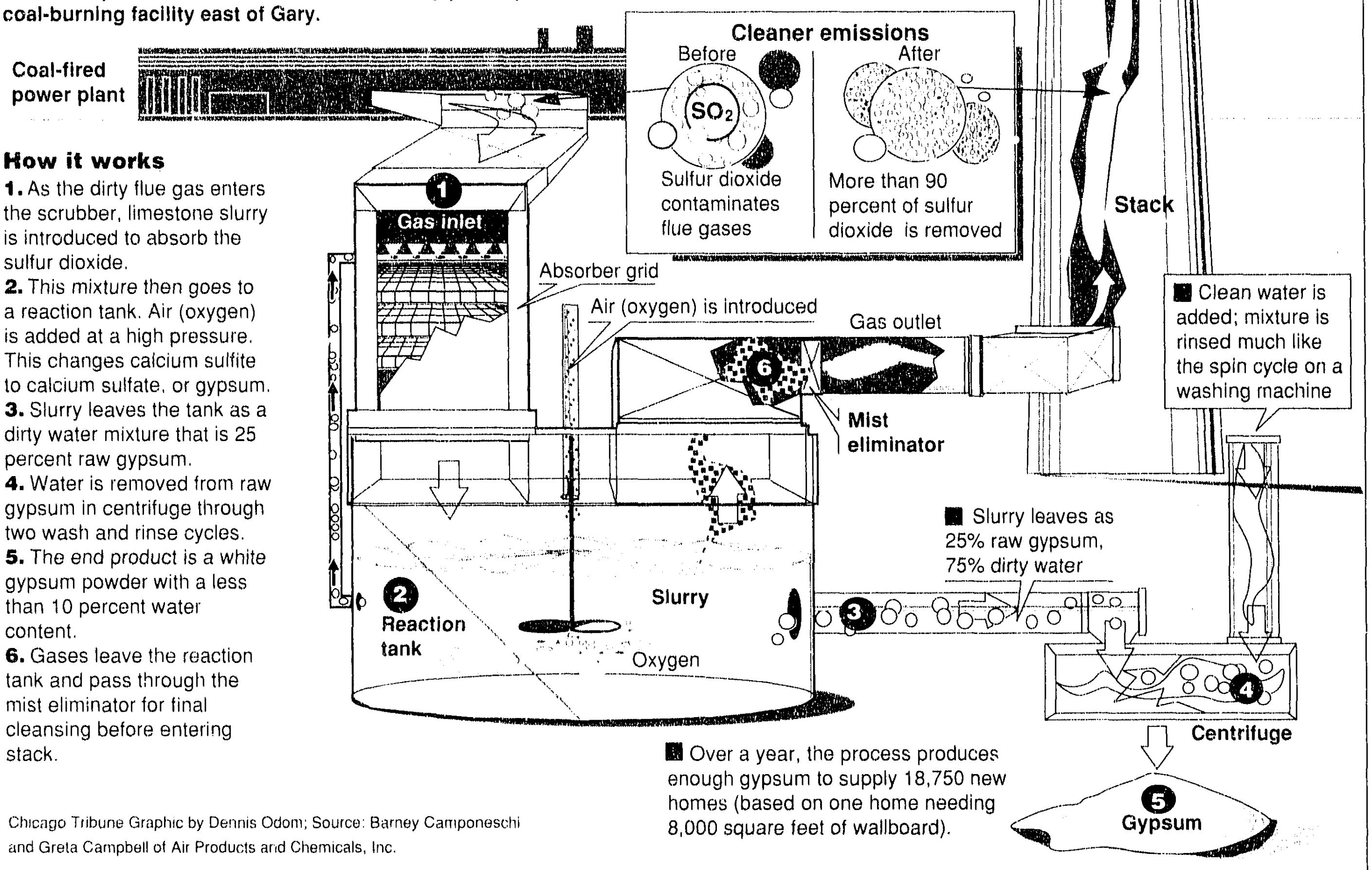
In the United States, approximately 150 coal-fired units were equipped with these conventional or "first-generation" scrubbers during the 1970s and early 1980s. These scrubbers were, for the most part, installed at newly constructed power plants because existing power plants were largely grandfathered by the Clean Air laws. When domestic power plant construction decreased in the early 1980s, the market for scrubber technology moved overseas where improvements were made. With the advent of acid rain controls mandated for the older units by the Clean Air Act Amendments of 1990, a new market for scrubber technology is emerging in the United States. Development efforts continue to improve scrubber performance and to reduce costs.

Turning pollutants into construction material

An industrial project to reduce pollutants linked to acid rain and solid waste problems from burning high-sulfur coal is underway in Indiana. The plant will reduce acid rain by cutting the amount of sulfur dioxide emitted from the burnt coal. Solid waste disposal will be eliminated by mixing limestone, water and oxygen with the remaining sulfur dioxide to create a by-product, gypsum, which has commercial uses. The plant is under construction at Bailly power plant, a Northern Indiana Public Service Co. coal-burning facility east of Gary.

How it works

1. As the dirty flue gas enters the scrubber, limestone slurry is introduced to absorb the sulfur dioxide.
2. This mixture then goes to a reaction tank. Air (oxygen) is added at a high pressure. This changes calcium sulfite to calcium sulfate, or gypsum.
3. Slurry leaves the tank as a dirty water mixture that is 25 percent raw gypsum.
4. Water is removed from raw gypsum in centrifuge through two wash and rinse cycles.
5. The end product is a white gypsum powder with a less than 10 percent water content.
6. Gases leave the reaction tank and pass through the mist eliminator for final cleansing before entering stack.



Chicago Tribune Graphic by Dennis Odom; Source: Barney Camponeschi and Greta Campbell of Air Products and Chemicals, Inc.

the largest in the world to operate with high-sulfur coal. There will be no spare or back-up modules because a high degree of system reliability is anticipated. This is a key feature of the demonstration, which is targeted at proving a substantial economic benefit of this advanced technology.

In addition to many state-of-the-art technical features, the AFGD project will showcase a novel business arrangement. Normally, utility companies contract with several different firms to design and build a scrubber; and once it is built, the utility itself operates the scrubber. (Owning the scrubber also means that the utility owns any operating problems that may develop.) By contrast, Pure Air will design, finance, build, own, maintain, and operate the Bailly AFGD facility for Northern Indiana as a contracted service. This "own and operate" approach has been employed successfully by Pure Air's parent, Air Products & Chemicals, in other business lines. The business arrangement used in this project should be attractive to many utilities because it allows them to focus on the business of electricity generation and distribution, while scrubber contractors can focus their own expertise on owning and operating the scrubber facilities. If successful, the demonstration will be followed by a long-term (17-year) commercial operation period, under the terms of to the agreement between Pure Air and Northern Indiana.

An added benefit of the project is the technology's ability to produce high-grade gypsum as a by-product instead of the waste sludge produced by the earlier scrubbers. A long-term gypsum purchase/sale agreement has already been signed by the U.S. Gypsum (USG) Corporation and Northern Indiana. Bailly's gypsum by-product will be used at a USG wallboard plant located nearby, thereby avoiding both the cost and the environmental consequences associated with landfill disposal.

Improved Environmental Performance

Conventional scrubbers typically remove 90% of SO_2; the AFGD scrubber is expected to be able to remove 95% or more of SO_2 without the use of performance-enhancing chemical additives. This 95% SO_2 removal rate was confirmed through tests conducted at the APC-200 pilot unit, located at Mitsubishi's Hiroshima Research and Development Center in Japan.

Instead of making sludge, this scrubber system will produce synthetic gypsum, a useful by-product that will have a 93% purity rating as confirmed by the APC-200 pilot plant tests and by other scrubbers utilizing Mitsubishi's technology. A high purity rating allows the gypsum to be used as a quality ingredient in the production of wallboard, cement, and other products.

Contributing to the gypsum's high degree of purity is a novel device known as an air rotary sparger (ARS) that will be demonstrated within the absorber module. The ARS combines the functions of stirring and air distribution within the absorber, thereby facilitating the oxidation of scrubber sludge to gypsum. In a conventional FGD system, stirring would be done by mixers, and oxidation air distribution would be performed by a separate fixed sparger or air pumping arrangement. Merging these functions into one piece of equipment is expected to provide better mixing within the base of the SO_2 absorber and to yield a high-purity gypsum. This concept is relatively new in scrubber applications. The performance of the ARS was confirmed by tests at Hoosier Energy's Merom Power Station.

Wastewater disposal often poses a difficult problem for scrubber operators, particularly where oxidation of scrubber sludge to gypsum is employed. The AFGD project at Bailly will also demonstrate a novel waste-water evaporation system (WES), in which process wastewater will be injected into the flue gas ductwork upstream of the existing electrostatic precipitator (ESP). The hot flue gas will evaporate the wastewater, and dissolved solids in the water will solidify so that they are collected by the ESP, along with the fly ash. Of Bailly's two boilers, the WES will be demonstrated on its larger 345-MWe unit. If successful, results from this application could lead to zero waste discharge scrubbers (i.e., scrubbers that produce a usable gypsum by-product and no wastewater effluent), certainly a very attractive environmental performance goal.

Improved Energy Efficiency

Energy consumption needed to run equipment is a critical consideration for utilities. The operation of pollution-abatement systems requires large amounts of power. As mentioned earlier, conventional scrubbers, in particular, have a high power consumption rate and can use up to 5% of a plant's electricity that would otherwise be made available for sale. Because of the engineering advances described above, the Pure Air scrubber is expected to demonstrate a greatly improved energy efficiency by consuming no more than 2% of the 528-MWe facility's electrical output.

Improved Economics

Because the Pure Air AFGD system requires less space than does a conventional system, it is an excellent candidate for retrofitting onto existing facilities, especially where space is limited. The system's high reliability allows the use of a single absorber module, with no spare or back-up modules. The high-velocity, co-current feature permits the use of a more compact absorber. Installing only one relatively small absorber translates into lower capital costs. At the Bailly Generating Station, scrubber capital costs are projected to be approximately $160 per kilowatt, which compares quite favorably with the cost of up to $300 per kilowatt for a conventional wet scrubbing system. Also, the scrubber's improved energy efficiency, high degree of reliability, and other advanced features greatly reduce its operation and maintenance cost when compared with conventional scrubbers.

Long-Range Effects

Many high-sulfur coal mine operators have expressed concern that implementation of the Clean Air Act Amendments of 1990 and the high cost of emission control systems will significantly reduce their markets.

Innovations like Pure Air's AFGD technology will allow an economical and environmentally responsive use of high-sulfur coal, thereby preserving the jobs of those working in eastern and midwestern high-sulfur coal mines.

The construction activity associated with the project will have a positive effect on the local economy near the power plant. About 150 construction workers will be employed for 1 to 2 years. The purchase of locally available construction materials will also benefit the local economy. More importantly, when construction is completed, there will be 30 new full-time positions at the facility.

Most likely, utility rates will have to be raised to cover the cost of the AFGD system, but the rate increase will be only about one-half of that which would have been required if a conventional scrubber had been used to comply with the terms of the Clean Air Act Amendments of 1990. Electricity consumers will benefit from these rates in many ways. For example, energy-intensive industrial users buy a great deal of the electrical power generated in the United States. In a very real sense, lower electricity rates will help to preserve the competitiveness of steel, aluminum, glass, paper, plastic, and other domestic industries.

Conclusion

In summary, recent public debate over acid rain control legislation revolved largely around the negative aspects of first-generation scrubbers: their high cost, large size, poor reliability, high energy consumption, and the production of large amounts of scrubber sludge. Now that the Clean Air Act Amendments of 1990 have been enacted, advanced scrubber technologies offer one of the most attractive routes for compliance. Compared with their forebears, these new scrubbers are cost-effective, easily retrofitted, highly reliable, energy efficient, and environmentally benign. Advanced scrubbers will be an important element in the spectrum of new technologies that will allow coal, especially the high-sulfur varieties, to successfully compete for energy markets in the 1990s and beyond.

THE INDIANA DUNES

Adjacent to the Pure Air project site, only about 300 feet away, are the Indiana Dunes National Lakeshore and the Indiana Dunes State Park. The State Park was established in 1926, followed by establishment of the adjacent National Lakeshore in 1966. Together, these two parks span about 20 miles.

The Indiana Dunes consist of large sand dunes at the southern edge of Lake Michigan and an area of dunes directly behind, whose cover has evolved to mature forests. With 1,445 native plant species present, the area is a botanical smorgasbord whose variety is exceeded in the United States only by the Grand Canyon and Great Smoky Mountains National Parks. Overlapping ranges of plant species converge at the dunes, where plants usually found in warmer climates (e.g., orchids, cacti, and carnivorous plants) grow alongside species more typical of Canadian forests and the tundra (e.g., Arctic bayberry, jack pine, and northern rose).

This unusual diversity of plant life serves to attract a wide variety of wildlife to the area. For example, nearly 350 species of birds have been sighted in the dunes, ranging from waterfowl (e.g., geese, ducks, and swans) to raptors (e.g., hawks, falcons, and eagles). The National Lakeshore staff even manages a nearby heron rookery unit.

From 1895 to 1934, the Indiana Dunes served as the laboratory for Henry C. Cowles, a professor at the University of Chicago who was eulogized as being America's first professional ecologist. At the Indiana Dunes, Dr. Cowles studied the effects of geological formations on plant communities and the transformation of habitat by those communities. Amidst

Thomas Sarkus *is a Technology Team Leader and Project Manager in PETC's Office of Clean Coal Technology. Currently, Tom is responsible for the technical and managerial direction of eight Clean Coal technology demonstration projects in the area of* SO_2 *control. As DOE's Project Manager of the Pure Air AFGD demonstration project, Tom utilizes his multi-disciplinary background to handle a wide variety of project-related issues, including technical, environmental, contractual, business, and regulatory concerns.*

Tom received a B.S. in Chemistry, a B.S. in Geology, and an M.S. in Earth Science — from California University of Pennsylvania. Additionally, he earned a J.D. in Law from Duquesne University and is a licensed attorney. Tom's areas of interest revolve around the common themes of energy and the environment.

the kaleidoscope of plant species found at the dunes, Cowles recognized some patterns. As the habitat changed, proceeding inland from beachfront to forested dunes, he observed a succession of plant communities—ranging from grasses that colonize the beachfront dunes to increasingly complex cottonwood, pine, oak, and beech-maple forests. This principle of ecological succession is important enough that when ten European botanists were asked what sites they wanted to see on their trip to America in 1913, they responded: the Grand Canyon, Yosemite, Yellowstone, and the Indiana Dunes. Scientific investigations are still performed at the Indiana Dunes, largely under the auspices of a staff of scientists at the National Lakeshore.

It is fitting that the AFGD demonstration project is located in the midst of this environmentally sensitive area. In addition to such features as reduced SO_2 emissions, production of commercial gypsum instead of disposable sludge, and wastewater evaporation, the project will include extensive environmental monitoring activities.

Photo courtesy of Indiana Dunes National Lakeshore.

PETC's COAL PREPARATION PROCESS RESEARCH FACILITY

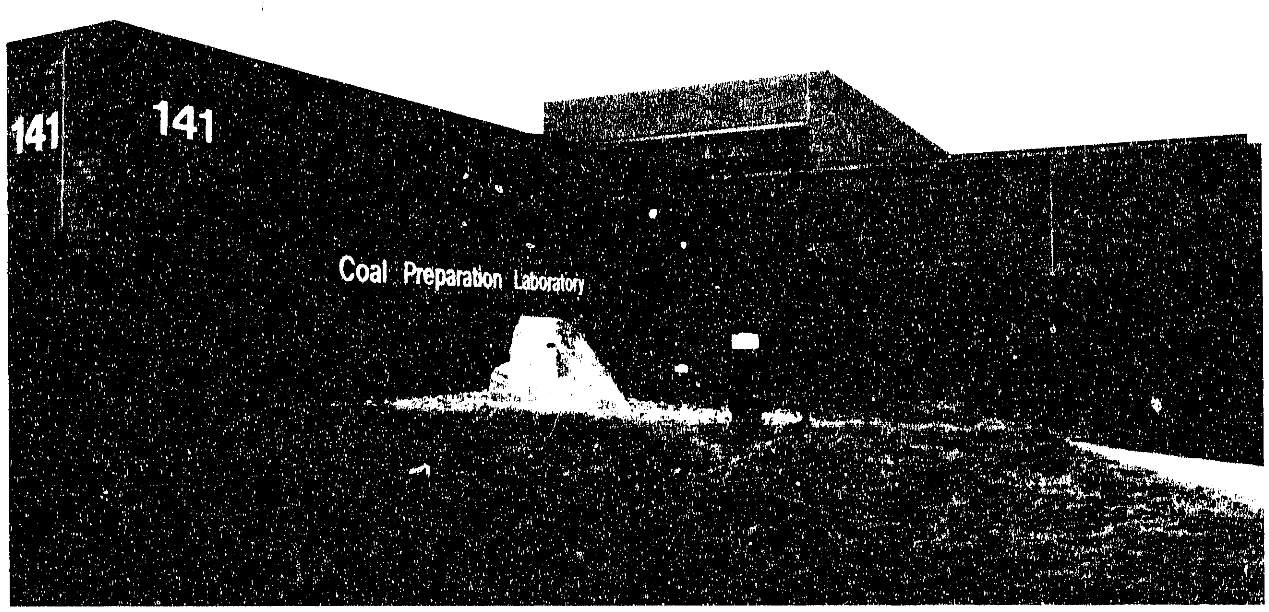
To fill a critical gap in the development of new coal preparation technologies from applied research in the laboratory to proof-of-concept (POC) or demonstration testing, PETC has recently upgraded its Coal Preparation Laboratory high-bay area to provide a state-of-the-art, continuous bench-scale test facility. The Coal Preparation Process Research Facility (CPPRF) can accommodate a wide variety of advanced fine-coal cleaning, processing, and handling equipment. It will be used for bench-scale development and testing of emerging equipment/technologies at rates of between 100 and 500 pounds of feed coal per hour. The CPPRF can also be used to provide cleaned coal to other bench-scale process development units at PETC or at private-sector laboratories, thereby helping to integrate coal preparation with other technologies in the entire coal utilization cycle.

Testing conducted in this facility will provide high-quality, bench-scale data that will allow private industry to make informed decisions about the potential of a coal preparation technology for commercialization or the next stage of development. For those who might be interested in using this facility, we offer in this article a full description of the CPPRF equipment, the mechanisms for its use, and the points of contact for obtaining more information.

Uses of the CPPRF

The CPPRF is available for use by both PETC and private industry researchers. It is intended to provide support for:

- New or Continued Development/Scale-Up of U.S. Department of Energy (DOE)-Funded Contractor Research: Concepts that were originally developed by private industry at the laboratory scale and showed enough promise to then be funded by DOE for scale-up testing.



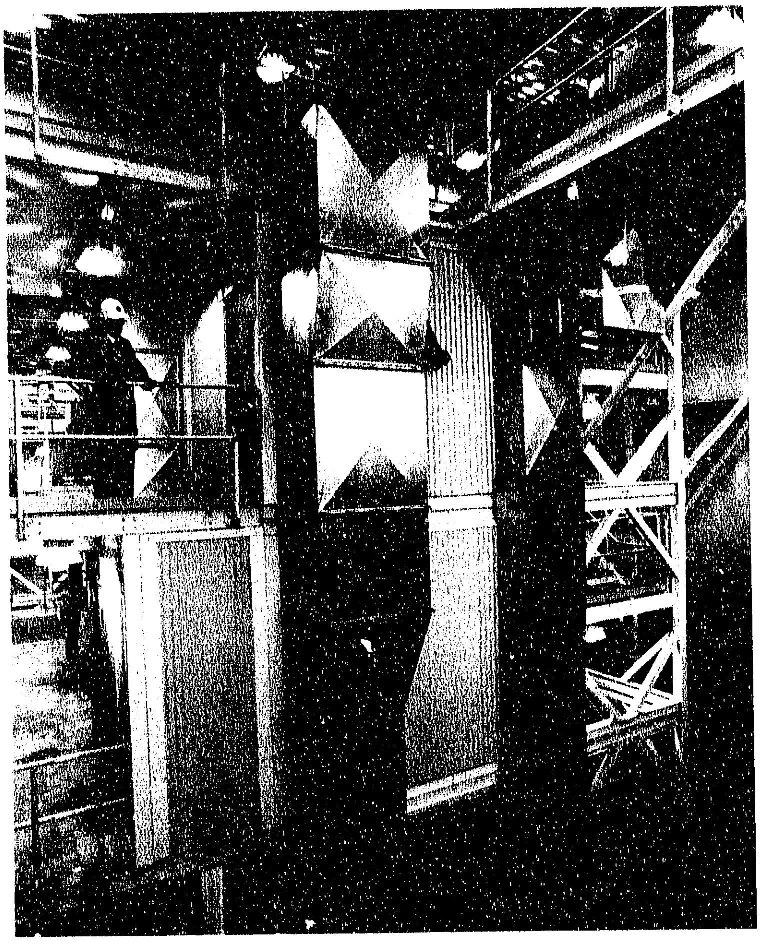
PETC's Coal Preparation Laboratory.

- Cooperative Research and Development Agreements (CRADAs) with Industry: Technologies that the private sector wishes to participate in developing, whether initiated by industry, PETC, or PETC contractors. These agreements enable the private sector to access PETC's employees, equipment, and facilities and to contribute funding, manpower, equipment, technical expertise, or other services as their share of the resources needed.

- Scale-Up of PETC In-House Research: Processes that have been tested at the laboratory scale and have demonstrated enough potential to warrant bench-scale testing.

- Integration with Other DOE/PETC Programs and Initiatives: Provision of feedstock for use in other research programs. Services could include bulk crushing, sizing, cleaning, pelletizing, and slurrying for the Coal Liquefaction, Combustion, Alternative Fuels, and Flue Gas Desulfurization programs.

- Education and Training: Opportunities for the public to get a true perspective of and appreciation for the role of coal preparation in the coal utilization cycle. For example, college students in science or engineering could gain firsthand experience in pilot plant operation and research.



A view of the permanent precleaning and comminution areas from the open area that will house emerging technologies.

Facility Description

Because the CPPRF was built within an existing high-bay area, special consideration had to be given to the layout of the facility. The high-bay area is part of the Coal Preparation Laboratory and is 81 feet long, 43 feet wide, and 40 feet high. ICF Kaiser Engineers of Pittsburgh, Pennsylvania, performed the detailed design of the facility. Based on Kaiser's advice, a modular plant design/upgrading approach was followed, allowing 10-foot cubic modules to be pre-fabricated with the process equipment inside. The modules were then transported to the site and stacked within the high-bay area. The actual fabrication and upgrading work was conducted by the Daniels Co. of Bluefield, West Virginia, under the direct supervision of Gilbert/Commonwealth, which provides on-site technical support to PETC.

The CPPRF is made up of three areas that can be operated independently or in series to provide flexibility:

- a permanent conventional precleaning circuit;
- a permanent three-stage comminution (crushing and grinding) circuit; and
- an open, emerging technology area.

The conventional precleaning circuit can process up to 1.25 tons of coal per hour. It consists of raw coal crushing and storage, desliming, two-stage dense-medium cyclone cleaning (6 mm by 0.6 mm particles), dewatering, product storage and blending, waste disposal, and water clarification. It is designed to provide between 100 and 500 pounds per hour of coal as feed to the comminution circuit or as a finished end product.

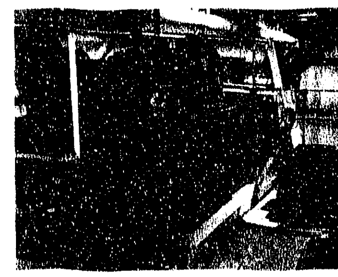
The comminution circuit consists of one stage of dry pulverizing and two stages of wet grinding. It can reduce the raw or precleaned coal to various sizes as fine as 20 microns by zero for use in the emerging technology area or as a finished end product.

The emerging technology area consists of open high-bay space for the short-term incorporation of emerging technology modules or equipment. This area will be used to develop technologies that meet the goals and objectives of DOE's Coal Preparation Program.

A simplified flow diagram of the CPPRF is shown in Figure 1. As can be seen from the flow diagram, the facility was designed with a maximum amount of flexibility to accommodate a variety of processing scenarios, depending on the type of raw coal and the desired product specifications.

The coal from the mine is delivered by truck to the raw coal receiving area located outside the building. The raw coal is unloaded and conveyed by an enclosed bucket elevator to a four-roll crusher, which reduces the particle size to a top size that is nominally less than 6 mm. The crushed coal is then transported by a totally enclosed flight conveyor into one of two 5-ton raw coal (feed) storage bins located within the building. Both of these bins, as well as the product bins, are mounted on load cells, which weigh the coal to facilitate inventory control; and each can be purged with nitrogen to provide an inert atmosphere for storage. Each bin can

Various areas in the CPPRF: Clockwise from left, Facility Control Room, Wet Conical Ball Mill, Dense-Medium Cyclones and Drain & Rinse Screens, Raw Coal Automatic Sampler, Thickener, Sludge Storage Tank.



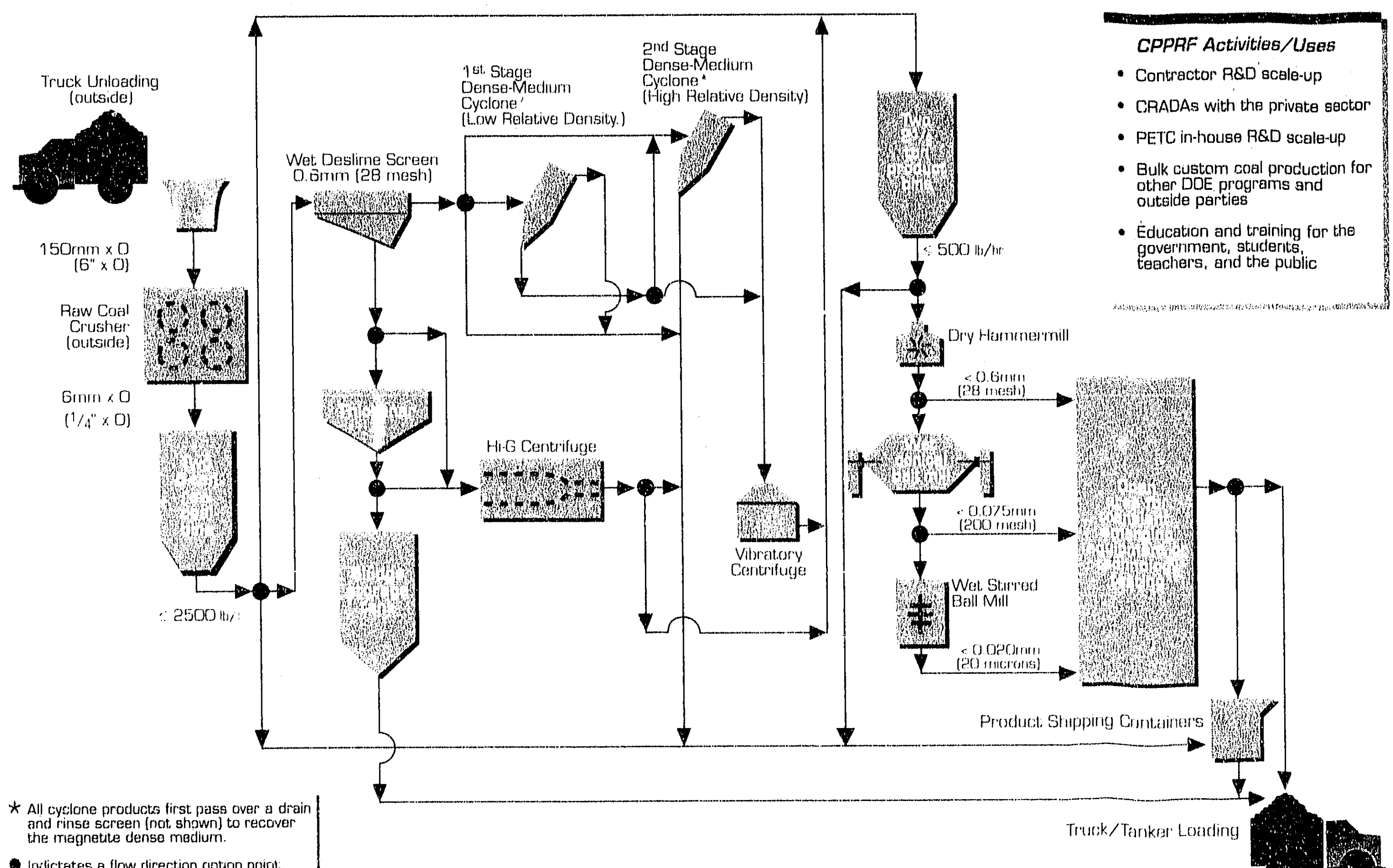
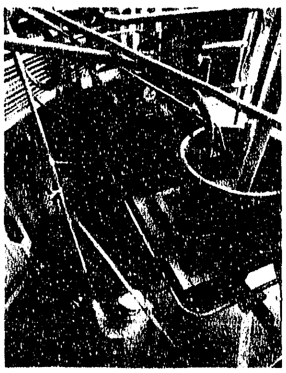


Figure 1. Simplified Flow Diagram of the DOE/PETC Coal Preparation Process Research Facility (CPPRF).

be operated independently so that two different coals can be stored at one time.

After the coal is placed in the feed storage bins, it can follow one of three flow options: it can be sent to the shipping containers, the product blending/storage bins, or the precleaning circuit. If the coal is sent to the shipping containers, up to 1 ton of coal can be stored in each container. The containers can be moved with forklifts, and one can be filled while the other is being moved to allow continuous operation. They can be loaded onto or emptied into trucks to transport the coal products.

The coal can also go from the feed storage bins directly to the product bins. Each of these bins has a capacity of 2.5 tons and is unique because its design includes special mixing augers. Using the augers, the coal can be homogenized before further processing.



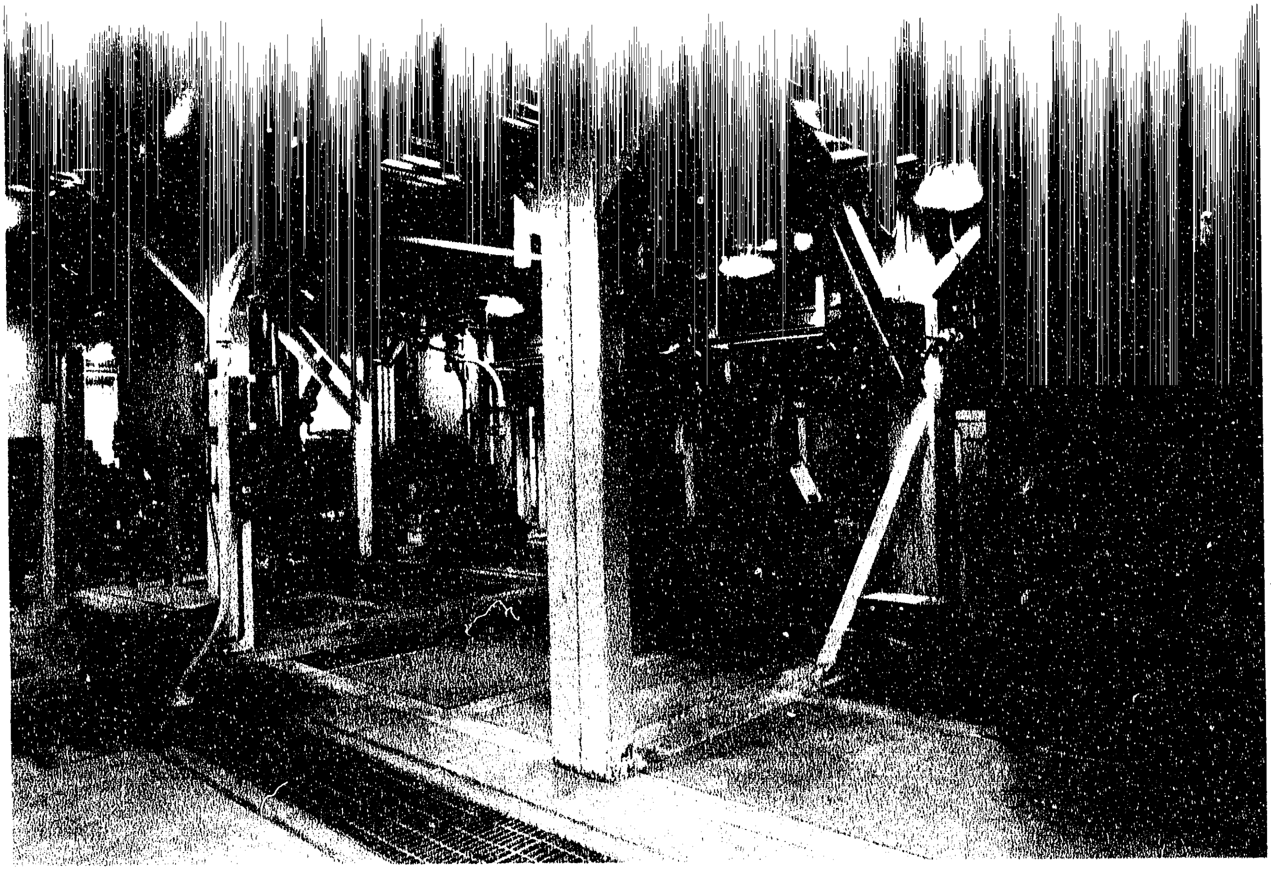
From the feed storage bins, it is most likely that the raw coal will follow the third route to the precleaning circuit. In the precleaning circuit, the coal is first deslimed, or wet screened, at a rate of approximately 1.25 tons per hour on a screen with 0.6-mm openings. The purpose of desliming is to separate the smaller coal (the fines) from the larger coal particles. The fine coal can then be processed in one of two ways:

- It can be sent to a solid-bowl centrifuge, which spins rapidly to remove the water that was added during desliming. From the centrifuge, the coal is sent either to the product blending bins for further processing or to the shipping containers.
- It can be sent to a high-rate thickener in which the fine solids are settled out by gravity or thickened. Clarified water overflows the top of the thickener and is recirculated throughout the facility. The thickener underflow can be pumped into a sludge storage tank for subsequent disposal. Material processed by the thickener is usually considered a waste product.

The oversize material (6 mm by 0.6 mm) from the desliming operation (that is, the material that does not pass through the screen) is sent to either one or two stages of cleaning using 6-inch diameter, dense-medium cyclones. A cyclone uses high gravitational forces to exploit the density difference between the coal particles (relative density of 1.3 to 1.4) and the mineral matter (relative density of greater than 2.0) and pyritic sulfur (relative density of 5.0) to separate the good organic material from the unwanted reject material. The dense medium used to make the separation is composed of finely ground magnetite suspended in water to create a pseudo-heavy liquid ranging in relative density from 1.2 to 1.8 (water has a relative density of 1.0).

When two stages of cleaning are used, three products result—clean coal, middlings, and rejects. The clean coal product would not require any further processing and would be sent directly to shipping containers. The reject material is sent to shipping containers and then, along with the thickener underflow mentioned earlier, is loaded into a truck and disposed of in a permitted landfill at a mine site. The middlings are dewatered in a vibratory centrifuge and are then sent to the product blending/storage bins. The middlings are the most difficult part of the raw coal to clean. Typically, they require fine grinding in the comminution circuit to liberate the mineral impurities, followed by advanced fine coal cleaning in the emerging technology area. Thus, a typical product from the precleaning circuit would consist of middlings and naturally occurring fines that are mixed together in the product bins for further processing.

Downstream of the product/blending bins is the three-stage comminution circuit, which can process from 100 to 500 pounds of coal per hour. In this circuit, coal first goes to a dry pulverizer, which consists of an air-swept, high-speed hammermill that can reduce the coal to a top size that is about less than 0.6 mm. The resulting pulverized coal can then be sent directly to an emerging technology processing unit or can continue to the two-stage wet grinding circuit.



View of the first floor of the CPPRF.

The first stage of wet grinding is done in a conical ball mill, which can reduce the coal to a top size that is nominally less than 0.075 mm. This product can then be sent to an emerging technology process unit or can be further ground in a vertical stirred ball mill to produce feed material that is of a top size less than 0.02 mm.

Facility Control System

The CPPRF process control system uses microcomputers that were selected to ensure real-time control response and rapid operator update. The process control system is automated to minimize operator commands/intervention and to maximize process feedback and instructional aids. The heart of the system is a large-capacity programmable logic controller (PLC), which uses programmable memory for storing the instructions that control the various processes and equipment.

The software operates on IBM AT-compatible 386/25 personal computers, and the computers form a local area network with the PLC, which allows independent access for up to three operators. Graphics are presented on three large-screen, high-resolution color monitors. The graphics presentation uses a custom symbol and color scheme standardized for all displays. The flowsheets are displayed in various levels of detail, allowing the operator to pan or zoom to the level of detail required.

Status and Initial Activities

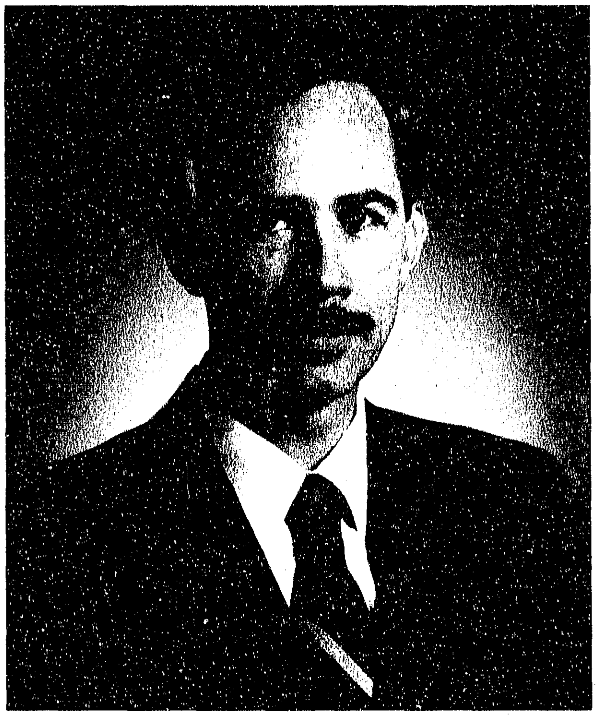
The facility is currently undergoing its initial shakedown testing during which the individual components and subsystems are operated at baseline conditions from the control room. This will culminate in a full-scale, integrated plant test in the spring. At about that time, PETC is planning to host a dedication ceremony to inaugurate the CPPRF.

Meanwhile, plans are being formulated for the first projects that will be conducted within the facility in 1992, including:

- Improved Coal Preparation Equipment/ Technologies—Proposals were recently received in response to this Program Research and Development Announcement (PRDA) solicitation and are currently being evaluated. The proposals focus on low-cost, near-term strategies for improving fine coal cleaning and handling. Contract awards will be made near the end of the summer, and hardware will be installed in the CPPRF at the end of the year.
- ASPEN-Based Coal Preparation Simulator—Under contract to DOE, Aspen Technology, Inc., is developing an advanced coal preparation simulator based on their ASPEN PLUS software. The portion of the simulator developed to date will be configured to simulate the CPPRF; PETC will then conduct tests to verify the simulator's predictions.
- CRADAs for the Micro-Mag Process and the In-Situ Cake Hardening Process—Bench-scale testing of these two PETC-developed processes will be conducted, and PETC is discussing the potential for cooperative research via a CRADA with several companies.

Obtaining Information about the CPPRF

The CPPRF will provide a much-needed user facility for producing tailored feed coal to supply other PETC and private-sector research efforts and for testing new coal preparation processes at the bench scale. PETC is eager to use the CPPRF to further the development of technologies or equipment that contribute to the goals of the Coal Preparation Program and to the *National Energy Strategy*. For information concerning (1) the availability of the facility, (2) CRADAs, (3) current projects being conducted in the CPPRF, or (4) the facility's capabilities, please contact PETC's Coal Preparation Division at 412-892-6252.



***Richard P. Killmeyer, Jr.**, is the Group Leader for Physical Beneficiation in PETC's Coal Preparation Division. Rich has worked in coal preparation research at PETC since graduating from Pennsylvania State University in Chemical Engineering in 1974. He has been involved in many different research projects dealing with advanced fine coal processing and characterization and is a coinventor of PETC's Micro-Mag Process.*

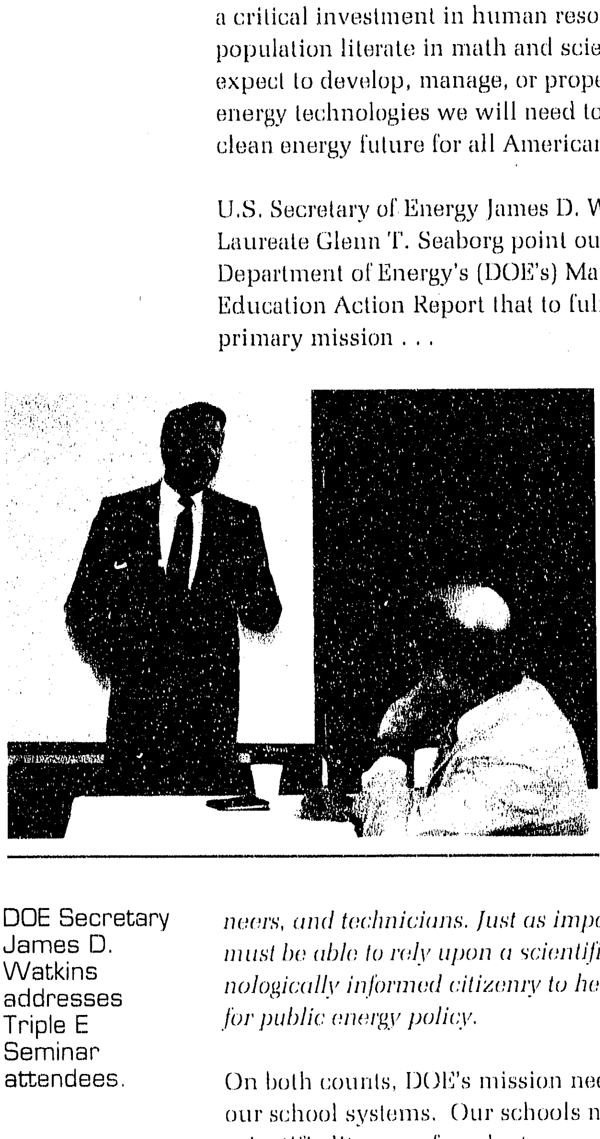
He is currently responsible for managing the in-house development of physical beneficiation technologies and the activities in the Coal Preparation Process Research Facility.

The photographs in this article were taken for DOE by Jim Schafer.

PETC's SCIENCE OUTREACH PROGRAM

As a leader in coal-related research and development, PETC is looking to the future. The recently released *National Energy Strategy* views education as a critical investment in human resources. Without a population literate in math and science, we cannot expect to develop, manage, or properly use the new energy technologies we will need to provide a secure, clean energy future for all Americans.[1]

U.S. Secretary of Energy James D. Watkins and Nobel Laureate Glenn T. Seaborg point out in the U.S. Department of Energy's (DOE's) Math/Science Education Action Report that to fulfill DOE's primary mission . . .



DOE Secretary James D. Watkins addresses Triple E Seminar attendees.

. . . to supply the nation with energy resources, technologies, and information needed for economic progress and national security . . . the Secretary of Energy must be able to staff the Department with highly qualified mathematicians, scientists, engineers, and technicians. Just as important, the Secretary must be able to rely upon a scientifically and technologically informed citizenry to help chart a course for public energy policy.

On both counts, DOE's mission needs support from our school systems. Our schools need to improve the scientific literacy of graduates, overall student achievement in mathematics and science needs strengthening, and too few teachers receive the depth and currency of training in these fields to deliver instruction in a manner that sparks student interest. PETC continues to respond to these challenges by enhancing its Science Outreach Program.

Through activities under the Science Outreach Program, PETC is reaching out to nearly all levels of science education—from kindergarten through graduate school. Originally a program to provide research opportunities to college and university students majoring in science, engineering, and mathematics, PETC's Science Outreach Program extended to high schools about 3 years ago. In 1991, for the first time, programs exclusively for elementary school teachers were included. In this way, the Science Outreach Program is becoming more and more visible to the academic community, both locally and nationally. This article discusses that portion of the program directed at elementary and high school students and teachers.

Our youth are the country's most important resource, and the President has made education, in particular science and mathematics education, a top priority for all government agencies. The *National Energy Strategy* calls for increased effort to promote science and mathematics education so that our youth will consider pursuing rewarding careers in these areas. Because many U.S. youths are instead turning away from these subjects, PETC seeks to nurture interest at the earliest possible age. By educating elementary and high school teachers in ways to make these subjects fun and exciting as well as satisfying and rewarding for students, PETC hopes to help turn the tide.

Elementary Education

At the elementary level, PETC offers two programs: (1) the Energy, Environment, and Economics (Triple E) Seminar and (2) the Elementary Teacher Research Internship (ETRI) program. The Triple E Seminar was PETC's initial entry into elementary education, and ETRI was organized as a follow-up.

[1] *National Energy Strategy*, First Edition, U.S. Government Printing Office, Washington, DC, February 1991.

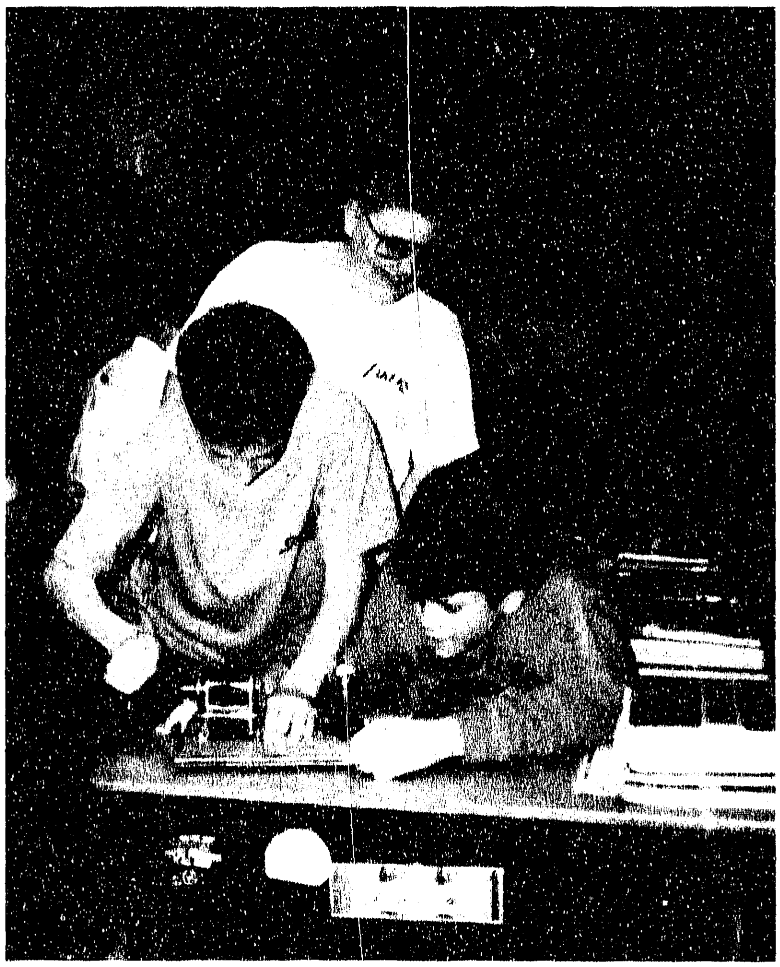
Triple E Seminar: The Triple E Seminar is a 2-day workshop consisting of lectures, demonstrations, and tours providing insight into the fundamentals of energy, environment, and economics on all levels—regional, national, and global. Speakers included PETC researchers and research contractor personnel, university professors, and innovative grade school teachers. The program was specifically tailored to provide hands-on activities for 65 kindergarten to sixth grade classroom teachers. The teachers rated the program highly, and follow-up interviews conducted several weeks later revealed that nearly all of the attendees were using information from the workshop in their classes. Former participants frequently request speakers, copies of packaged educational materials, and loans of laboratory equipment and supplies. The seminar is now being offered semiannually.

ETRI Program: Last summer, ten elementary school teachers were selected to participate in PETC's 8-week internship program, a follow-up to the Triple E Seminar. ETRI has given local teachers a new and valuable perspective on the roles and contributions of research scientists in our community. After 8 weeks of participation in the ETRI program this past summer, teachers left with a sense of enthusiasm for the value of scientific research and the role that science must play in the education of our children. As part of the internship program, teachers participated in three primary activities:

- Laboratory Work — the teachers spent three days a week in the laboratory working side by side with PETC researchers. Teachers were assigned to a laboratory supervisor, who guided their research efforts. This not only acquainted the teachers with the scientist's activities and purpose but also provided insight into the scientist's methods and character. Additionally, several teachers developed activities for their students based on their research assignment. For example, a teacher assigned to the PETC rheology laboratory will have her third-grade students estimate the relative viscosities of products found around the home and garage by measuring the time required for a BB to fall through household syrups, motor oil, and shampoo.

- Science Enrichment Activities — once a week, ETRI participants engaged in activities such as energy-related tours to an electric power plant, an experimental coal preparation plant, and an experimental coal mine. Also, roundtable discussions were held with PETC Director Dr. Sun W. Chun, project managers, and participants in other PETC Science Outreach programs. Lecture-demonstrations were held showing how scientific facts can be taught using innovative techniques. The PETC Energy Demonstration Kit, consisting of scientific equipment to teach the fundamentals of the energy conservation law, was developed during the workshop and is now available for loan to teachers.

- Curriculum Development — once a week, teachers (grouped according to grade level and paired with a PETC scientist) participated in curriculum development activities. Science demonstrations, energy-related games, videotapes, newsletters, and other supplemental materials were developed. Chocolate chip cookies depicted coal mining, marshmallows simulated the effects of pressure during coalification, red cabbage extracts were used to study acid rain, and jelly beans illustrated the limitations of our natural resources and stressed the importance of using renewable energy sources.



Students participating in hands-on activities derived from the Triple E Seminar.

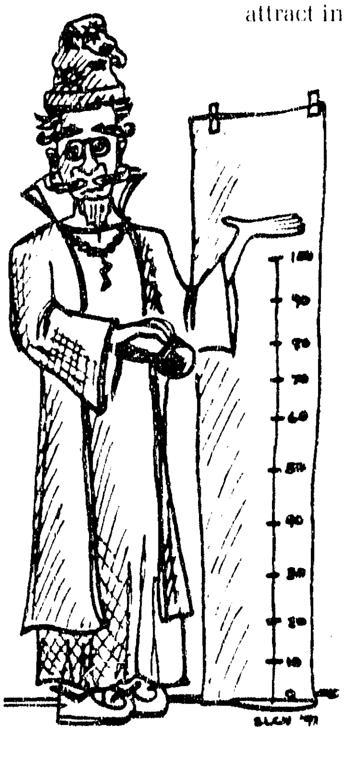
Instructions for these and other activities have been collected in a booklet entitled "Energizing Strategies for the Future," which is currently under review for eventual distribution. The booklet is generously and attractively illustrated, and features PETC's Mr. Energy which was created by one of our college internship students.

High School Education

Teachers (and, in one case, students) at higher grade levels are eligible to participate in three types of programs:

- PETC/Mon Valley Education Consortium Partnership. PETC joined with the Mon Valley Education Consortium (20 school districts in southwestern Pennsylvania) to develop a high school student research apprenticeship. The partnership emerged from a common interest in encouraging high school students to pursue educational excellence, especially in science and mathematics. During the 1990-1991 school year, ten students from the Mon Valley area served as interns at PETC one day a week for 9 weeks. They performed routine laboratory procedures under close supervision and received instruction in the proper use of apparatus and materials with emphasis on good safety practices and respect for the environment. The program, initiated in 1989, continues to attract interested students.

Mr. Energy created for PETC by Oak Ridge Associated Universities student Stephanie L. Noceti of St. Vincent College.



- Teacher Research Associate (TRAC) and Science Teacher Research Involvement for Vital Education (STRIVE) programs. Both the TRAC (funded 100% by DOE and administered by Associated Western Universities) and STRIVE (funded jointly by DOE and the National Science Foundation and administered by Oak Ridge Associated Universities) programs were established to improve the quality of education by enhancing the professional competence of science and mathematics teachers in middle schools and high schools. PETC provides research experiences, workshops, and opportunities for continued interaction and collaboration among participating teachers and research scientists. Each participant is given a specific research assignment and is assigned appropriate laboratory facilities to complete the assignment.

- Scientist/Engineer Resource Volunteers for Education (SERVE) program. PETC has assembled a group of volunteer scientists and engineers from its technical staff and support contractor personnel to act as resource persons, teacher consultants, or classroom lecturers/demonstrators. They may also serve as research advisors to teachers or students under assignment to PETC during the summer or school year. PETC personnel have overwhelmingly responded to the call for volunteers, illustrating their interest in these educational programs. Already, more than a dozen teachers and 600 students have participated in various parts of the program.

Obtaining Information about the Science Outreach Program

For further information about DOE's Science Outreach Program, please contact:

Dr. Richard E. Stephens
ER-14
3F-061/FORS
U.S. Department of Energy
Washington, DC 20585

Teachers should specifically request a copy of the U.S. Department of Energy Science Education Outreach Services catalog.

For information about local PETC Science Outreach Program initiatives, please contact:

Dr. Kee H. Rhee
Pittsburgh Energy Technology Center
P.O. Box 10940
Pittsburgh, PA 15236

The following materials are currently available from PETC:

- A listing of teacher-reviewed resource materials for kindergarten through sixth grades.
- Energy Demonstration Kits (for loan), which demonstrate basic principles of energy and the energy conservation law.
- A selection of videotapes.
- A listing of PETC SERVE volunteers.
- A listing of teacher-derived supplemental energy curriculum materials.
- *Dinosaurs and Power Plants*, an overview of fossil energy for use in grades 4-12.

SCIENCE OUTREACH PROGRAM PARTICIPANTS RESPOND

From three third grade teachers, after completing their ETRI internships:

It was a real eye-opener talking with scientists who could actually bring technical explanations of current experiments being explored in coal science in basic terminology that we could understand. Thank you PETC and DOE for offering such a worthwhile, challenging, enlightening, and exciting program. Keep up the good work.

• • • •

From a sixth grade teacher:

I hope to apply these experiences to my classroom as follows:

- *Present a workshop for science teachers in grades 3 to 5 to show them how to work with the materials we have developed.*
- *Use the material to supplement my curriculum for the eighth grade which I also teach.*
- *Make better use of the microscopes in my classroom.*
- *Be able to bridge the gap for my students between what we were doing in the classroom and what a scientist does.*

• • • •

From a DOE/TRAC program participant:

I am one of six coauthors of a physical earth science text used extensively in the State of Utah. I expect to add a new chapter on global climate change as a result of my work at PETC. I also publish a newsletter for science teachers which will include a summary of my investigations and experiences at PETC in the next issue.

Being selected for the program does a lot for the teacher's morale and prestige. It also adds credibility if one can say, when I was working at the Pittsburgh Energy Technology Center last summer....

Dr. Kee H. Rhee *is a Senior Technical Advisor in the Coal Preparation Division of the Office of Research and Development. In addition to his normal assignment serving the Division, he is currently on special assignment to develop, implement, and coordinate the Center's Science Outreach Program. He has developed highly visible programs and successfully implemented them. These programs include the Triple E Seminar for teachers, ETRI, and PETC's SERVE program.*

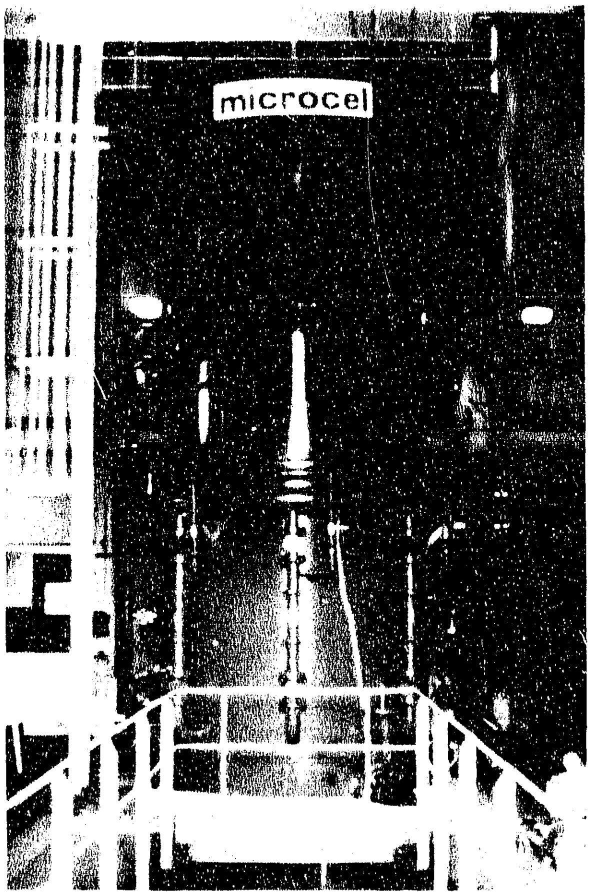
He started his career with the Federal government in the Energy Research and Development Administration in 1975 as an intermittent part-time research chemist. He became a full-time PETC employee in 1983. Before joining PETC, Kee worked at the Gulf R&D Company in Harmarville for 6 years as a Research Chemist, and after that he taught chemistry for 15 years at the Community College of Allegheny County. He is a graduate of Chosun University in Korea and holds M.S. and Ph.D. degrees in physical chemistry from Kansas State University and Tufts University, respectively.

UPDATE

Microcel® Advanced Column Flotation Technology Commercialized

As reported in the Fall 1991 issue of the *PETC Review*, an advanced column flotation technology called Microcel® was licensed to ICF Kaiser Engineers of Pittsburgh, Pennsylvania. Early research on this technology was done at PETC in 1980 and subsequent development has been performed, under DOE contracts, at Virginia Tech in Blacksburg, Virginia. Over the past year, Kaiser has had much success in marketing Microcel® technology in the coal fields of central and southern Appalachia.

The first commercial demonstration of the Microcel® was at Shell Mining Company's Marrowbone coal preparation plant in Naugatuck, West Virginia. The 8-foot diameter, 27-foot-high column was able to produce a high-Btu, low-ash product from the plant's minus 100-mesh classifying cyclone overflow stream. Marrowbone had been unsuccessful in cleaning this material with conventional flotation cells and had been discarding it as refuse. Shell Mining was pleased enough with the performance of the Microcel® that they are considering the installation of several additional columns at the Marrowbone facility.



The Microcel® advanced column flotation device.

The success of the Microcel® at Marrowbone has also helped ICF Kaiser market the technology in the coal regions of Virginia, West Virginia, and Kentucky. Two 10-foot-diameter (25-foot tall) columns have been delivered to Enterprise Coal Company's Roxana Preparation Plant in Roxana, Kentucky. These units will be used to clean 100 mesh x 0 raw coal overflow from the plant's classifying cyclones.

ICF Kaiser is negotiating several other potential sales of the Microcel®. The Race Fork Coal Corporation is considering the purchase of three units to clean a classifying cyclone overflow stream at its Luke Preparation Plant in Hurley, West Virginia; and the sale of four 10-foot-diameter columns is being discussed with the Donaldson Mining Company of Cedar Grove, West Virginia. Additionally, the Pittston Coal Management Company of Lebanon, Virginia, is looking at the application of Microcel® at three separate locations in West Virginia.

In addition to sales in the coal fields, Microcel® has made inroads into the mineral processing industry. An 8-foot-diameter by 50-foot-tall column has been sold to the Thiele Kaolin Company of Sandersville, Georgia, for upgrading fine kaolin clay. Three 5-foot-diameter by 25-foot-tall units have also been sold to the Kum-AM Graphite Co., Ltd., of Seoul, Korea, for processing fine graphite.

SOx-NOx-Rox Box Clean Coal Technology Project Completes Construction

As reported in the *PETC Review* Issue 3 article "Low-Cost Retrofit Technologies for Reducing SO_x, NO_x, and Particulates," Babcock & Wilcox (B&W) has developed the SOx-NOx-Rox Box (SNRB) process, an advanced pollution control system patented by B&W that combines the removal of sulfur oxides (SO_x), nitrogen oxides (NO_x), and particulate matter (Rox) from the flue gas of coal-fired boilers in one process unit— a high-temperature baghouse. The process employs a high-temperature baghouse to combine particulate collection, SO_x removal through injection of an alkali sorbent (such as hydrated lime or sodium bicarbonate), and NO_x reduction through ammonia injection and selective catalytic reduction (SCR). This process not only achieves compact integration of the emission control technologies but also benefits from the use of dry sorbent and by-product handling, as well as from improved SCR catalyst life because of lowered SO_x and particulate levels. Additionally, with the low SO_x concentration in the flue gas going to the air heater, the flue gas can exit the plant at a lower temperature without concern for acid condensation. This permits a significant improvement in boiler thermal efficiency.

The project objectives are to collect 70 to 90% of the sulfur pollutants and over 99% of the fly ash on the bags. The SCR step should account for a 90% reduction of NO_x. These performance objectives for SO_x, NO_x, and particulate emissions control were achieved in recently performed laboratory pilot-scale tests conducted at B&W's Alliance Research Center in Ohio. Test results indicated that 70 to 80% SO_x removal was achieved using a CA/S molar ratio of 2.0 to 2.5. Variations in the sorbent injection temperature over a range of 900 to 1,100 degrees F did not significantly affect SO_x removal efficiency. However, elevated baghouse temperatures are required to obtain greater than 70% SO_x removal. NO_x removal of 90% was achieved at an NH_3/NO_x molar ratio of 0.95 to 1.05. NH_3/NO_x stoichiometry is the primary parameter affecting NO_x removal, and the baghouse/catalyst temperature had a secondary effect on NO_x removal. Particulate emissions were held far below New Source Performance Standards, with collection efficiencies greater than 99.9%.

The Clean Coal Technology equipment has recently been installed and field demonstration began in March 1992 at the Burger Plant, which is located on the Ohio River near Shadyside, Ohio. The demonstration facility is integrated with existing equipment at the power plant and will use a 5-MWe equivalent flue gas slip-stream from boiler #8. Several alternative hydrated lime sorbents, in addition to commercial hydrated lime and sodium bicarbonate, are being evaluated to optimize SO_x removal.

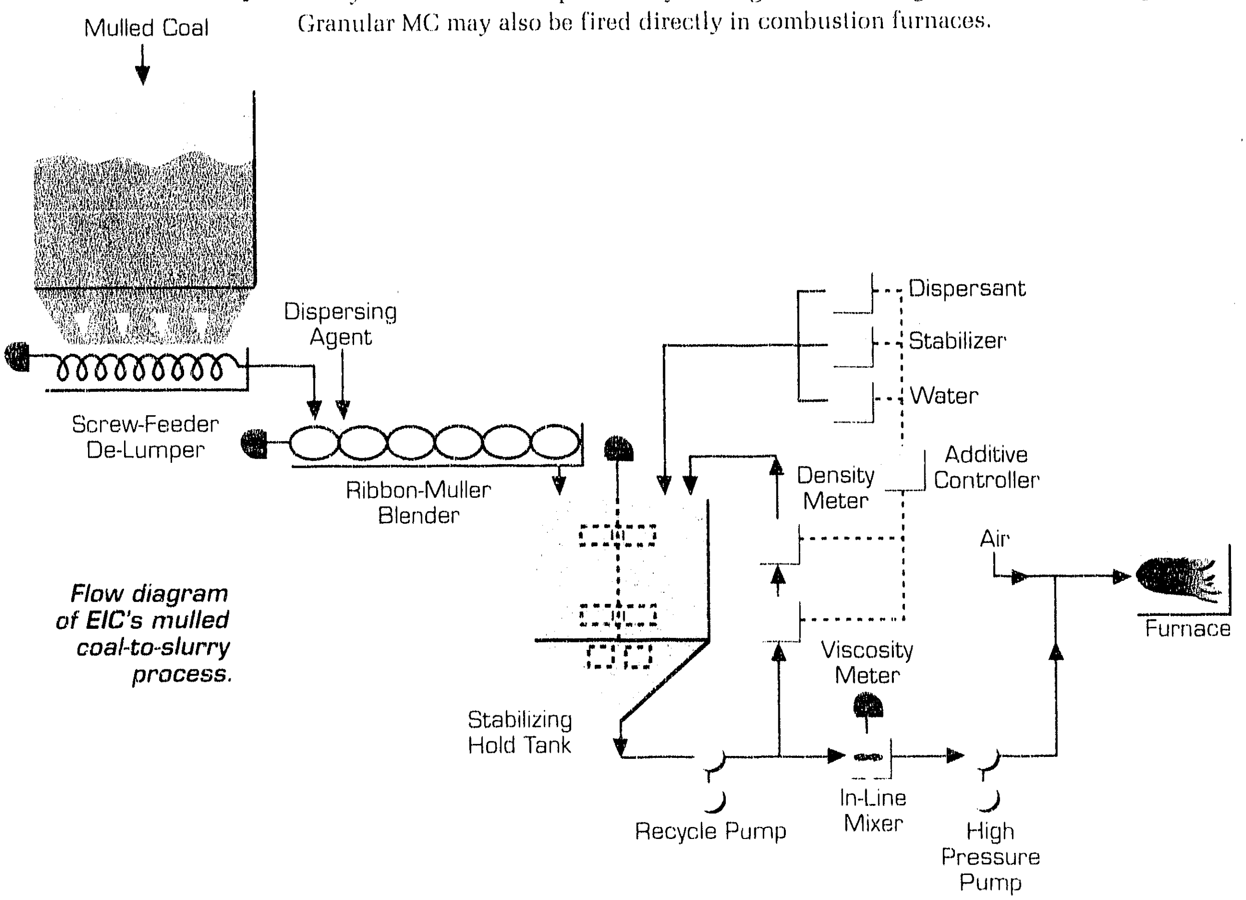
Sharing in the cost of this $11.6-million project with the Department of Energy and B&W are the Ohio Coal Development Office, the Electric Power Research Institute, Norton Company, Minnesota Mining and Manufacturing Company, and Ohio Edison Company.

HIGHLIGHTS

MULLED COAL

Processes are being developed to physically clean finely ground coal to yield beneficiated coal products (BCP) that have reduced levels of sulfur and ash-forming mineral matter. In some of these processes, the BCP are produced as wet filter cake, a mud-like clean coal product that may contain up to 50% moisture by weight. Filter cake, however, presents difficulties in transport, handling, and end use; it is particularly intractable when exposed to freezing conditions. Energy International Corporation (EIC), under contract to PETC, is meeting these technical challenges by converting filter cake into forms of clean coal that are easy to ship to the location where they will be used.

EIC has developed a process to convert wet filter cake into mulled coal (MC) in both gel and granular forms. EIC's process involves adding a proprietary, commercially available, oil-based dispersing reagent to filter cake. The reagent and cake are mixed in a muller, a piece of equipment similar to a cement mixer. Depending on the reagent selected, the filter cake is modified or mulled into gel MC (a paste-like substance) or granular MC (a fine, sand-like product). In the gel form, the coating reagent enables the wet particles to flow easily over one another. The granular form appears as a dry product because the selected reagent traps the moisture within the filter cake particles—they will not stick together and can, therefore, be picked up and transported pneumatically in air. EIC researchers were also able to convert granular MC into a slurry in a continuous process by adding a second reagent in line (see diagram). Granular MC may also be fired directly in combustion furnaces.



Flow diagram of EIC's mulled coal-to-slurry process.

UTILITY AIR TOXICS STUDY

The Clean Air Act Amendments of 1990 require all industries to apply Maximum Achievable Control Technologies (MACT) to major sources of emissions of the 190 listed hazardous air pollutants over the next 10 years. Area sources must also reduce emissions of these substances. Electric power generating units were given special consideration in the Clean Air Act Amendments of 1990. Before determining how hazardous air pollutant emissions from utilities would be regulated, the U.S. Environmental Protection Agency (EPA) is required to conduct a study of the health risks associated with these emissions. This study sets utilities apart from other industries, allowing EPA to establish regulations specifically related to the health risk identified. If no risk is established, no regulations will be required. The definitions of major source and MACT that are given in the Clean Air Act Amendments of 1990 become secondary to the findings of the utility air toxics study.

Collecting accurate emissions data from electric power generating units and understanding the effectiveness of the different types of pollution control devices to remove the 190 substances are of primary importance in determining health risk under the utility air toxics study. To accomplish this, DOE (under the Flue Gas Cleanup Program), the Electric Power Research Institute (EPRI), and the Utility Air Regulatory Group (UARG) are working together to supply emissions characterization data to EPA. By December 1992, this group will characterize emissions from approximately 20 operating power plants. These data will be collected from power plants with different types of pollution control equipment so that, by the end of the study, the effectiveness of each environmental control device in removing individual hazardous air pollutants will be known. The group will simultaneously sample gaseous, liquid and solid materials at the inlet and outlet of each of the environmental control devices. Stack emissions will also be characterized.

As a part of DOE's contribution to this effort, a solicitation was released in February 1992 for proposals to characterize emissions from eight coal-fired power plants within 8 months after contracts are awarded. The contracts will also include options for characterizing an additional eight power plants in 1993.

Later in 1992, a second solicitation will be issued for proposals to begin the development of advanced control technology to reduce emissions of hazardous air pollutants judged to pose the greatest health risks.

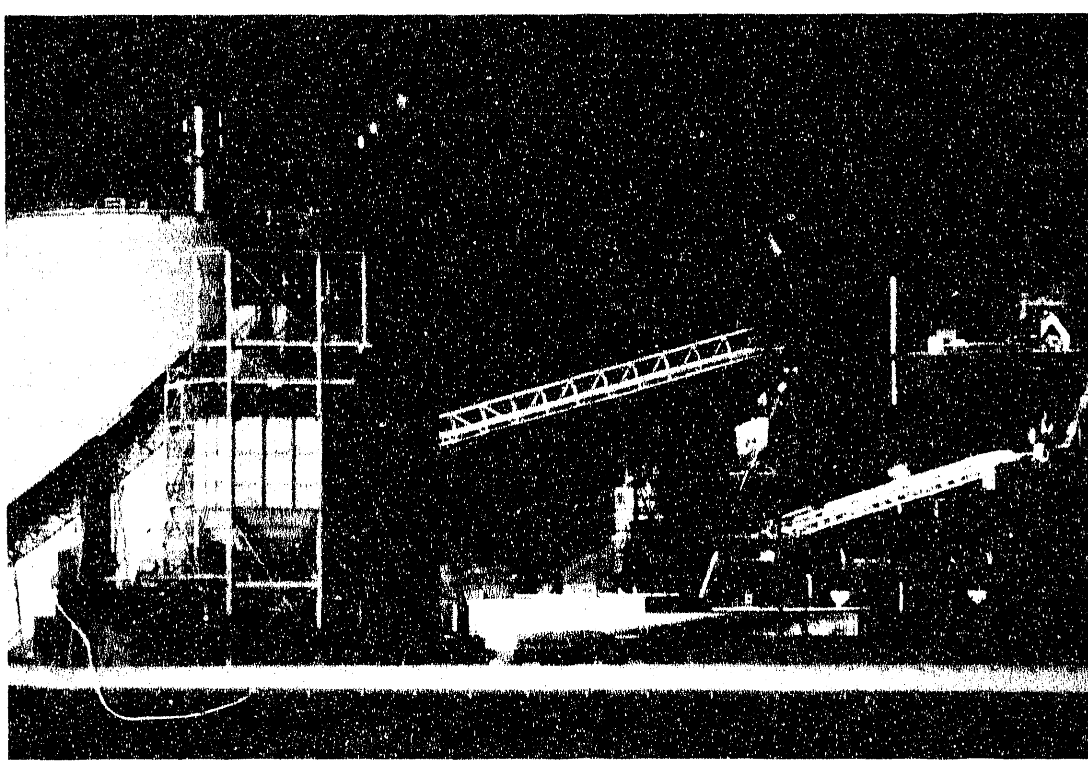
MONTANA CLEAN COAL PROJECT
Western Coal Used to Produce Versatile Solid Fuel Alternative

The Clean Coal Technology Program's Advanced Coal Conversion Process (ACCP) Demonstration Project is being built adjacent to one of the nation's largest coal mines. The ACCP process produces a syncoal that can enhance the use of vast supplies of Powder River Basin and other low-rank coals by reducing moisture, ash, and sulfur content while boosting heating value and avoiding the reabsorption of moisture by the product. This process will allow utilities to use more western coal as they face the strict requirements of the Clean Air Act Amendments of 1990.

Western Energy Company (a subsidiary of Montana Power Company) supported the development of this clean coal technology and originally signed a $69-million cooperative agreement with DOE to build and operate the demonstration project under the first round of the Clean Coal Technology Program. Subsequently, Western Energy joined with the NRG Group (a subsidiary of Northern States Power Company) to form the Rosebud SynCoal Partnership, which now owns the technology. The Rosebud Syncoal Partnership will manage the demonstration project and, most importantly, will oversee the future commercialization activities.

When operating continuously, the demonstration plant will produce 1,000 tons per day (up to 300,000 tons per year) of the syncoal product. The demonstration plant is about one-tenth the size of a 3-million-tons-of-product-per-year commercial plant (but the process equipment used in this demonstration is of commercial scale). Therefore, a full-sized plant will consist of multiple process trains.

Pilot tests at 200 pounds per hour that were conducted prior to this project confirmed the potential of the ACCP process. In these tests, syncoal produced from Rosebud seam



ACCP Demonstration Project

subbituminous coal was tested for storage, handling, transportation, and combustion characteristics. The upgraded coal product is stable and has less than 5% moisture, sulfur contents as low as 0.5%, ash content of about 9%, and a heating value of up to 11,800 Btus per pound.

There are three major steps to the ACCP process: (1) thermal treatment of coal in an inert atmosphere, (2) inert gas cooling of the hot coal, and (3) removal of ash minerals. During the thermal treatment process, raw coal from the stockpile is screened and fed into a two-stage thermal processing system. In the first stage vibratory fluidized bed reactor, surface water is removed from the coal by direct heating with a hot combustion gas. When coal exits this reactor, its temperature is slightly higher than that required to evaporate water. Coal is further heated in a second stage that removes pore water and promotes decarboxylation. Particle shrinkage during this stage destroys moisture-retention sites and causes the mineral matter to be liberated from the coal particles.

The coal then enters the cooling stage, where the temperature is reduced to less than 150° F by contact with an inert gas (carbon dioxide and nitrogen at 100° F) in a vibratory fluidized bed cooler. In the last part of the coal cleaning system, cooled coal is fed to deep-bed vibrating stratifiers to separate the liberated mineral matter by gravity from the coal. The light syncoal fractions are sent to a product conveyor, and heavier fractions go to fluidized bed separators where additional syncoal is recovered from the ash material. Fines and dust from various parts of the cleaning process are collected in baghouses and cyclones, made into briquettes, and sent to storage silos as part of the final product.

Following ground-breaking in March 1991, construction quickly progressed and is now complete. Two 6,000-ton-capacity concrete product storage silos, the main coal processing facility, and auxiliary buildings, including a main administration building with control room, have been built. Start-up and check-out of various facility process sections are underway. Full operations will start shortly, test burn activities will start during the second quarter of 1992, and the overall project is scheduled for completion by 1996.

TRIBOELECTROSTATIC DRY COAL PREPARATION

Coal preparation involves separating mineral matter from the combustible portion of coal. This separation is important to, among other things, improve the combustion characteristics of the coal and reduce the emission of sulfur oxides that results from burning the pyrite in the coal. Traditionally, coal preparation has been based on the differences in density or surface properties between the mineral matter and the coal. These types of separations, conducted in aqueous slurries, have been effective for fine coal systems; however, removing the water from the resulting fine coal slurry product can be difficult.

One way to avoid this problem is to use a dry preparation technique. This has been the subject of an extensive study at PETC on Triboelectrostatic Beneficiation. Electrostatic methods for cleaning ores have been used since the late 1800s. The application of these methods to coal also has a long history. Work at PETC has focused on the use of triboelectric charging of fine coal particles followed by separation in a static high-voltage electric field. Triboelectric charging occurs when two dissimilar materials rub against one another, and it is this process that is responsible for static cling.

A number of research groups in the United States, Canada, and Italy have worked with triboelectric systems, but the work at PETC has focused on using a totally pneumatic system for improved mineral matter removal in fine coal. In this system, the coal is ground to less than 50 microns and entrained in a gas stream that forces the particles to strike a copper surface (see Figure 9 on page 12). Impact with the copper surface causes the mineral matter to acquire a negative electric charge and the coal to acquire a positive charge. The entrained charged particles are then introduced immediately into a static voltage field, where the coal particles are attracted toward the negative plate and the mineral matter particles move to the positive plate. Because this separation involves gas-entrained fine particles, the aerodynamics (air flow and air turbulence) within the separator are very important for efficient separations. Under ideal conditions, this process has been able to separate a high-ash, high-sulfur Illinois #6 coal containing 24% ash into a clean coal fraction containing less than 5% ash and a mineral matter fraction containing more than 60% ash at a combustible recovery of greater than 70% into the clean coal fraction.

Current work on this project involves designing practical separators that can overcome the problems inherent in the continuous handling of fine, electrically charged, combustible dusts. Significant progress has already been made by processing approximately 10 pounds of coal per hour using a separator that is only 10 inches long. In an ideal separator, the coal would be separated into two streams—one mineral matter and the other clean coal—without attachment of the products to the separator plates because attachment leads to collection problems. PETC has designed and is testing this type of separation scheme.

GAS REBURNING-SORBENT INJECTION EXCEEDS EXPECTATIONS

Energy and Environmental Research Corporation's (EER's) Gas Reburning-Sorbent Injection (GR-SI) retrofit at Illinois Power's Hennepin Station is now in operation and performing better than originally projected. The emission control system has been in operation since January 1991, and recent test data based on 1- to 3-hour, short-term runs on the combined and fully integrated system have shown decreases in NO_x and SO_2 emissions in excess of 70 and 60%, respectively. These data are compared with emission levels before the boiler was modified for GR-SI. Original projections were for 60 and 50% reductions, respectively.

These preliminary test results produced an additional benefit. Even though calcium hydroxide sorbent was added to the boiler as a fine particulate to pick up SO_2, there was no detectible increase in stack plume opacity. A good plume opacity was maintained because the humidification system that had been designed and installed by EER functioned properly. Humidification is used to shrink the volume of gas entering the electrostatic precipitator and allow it to handle higher particulate loadings more effectively. With these favorable test results, it was mutually agreed in August to begin the 1-year durability test to confirm this performance in normal utility service. The 1-year durability test will prove the concept of GR-SI because load-following will be required.

The Hennepin work is one of the two GR-SI retrofits being conducted by EER as part of Round I of the U.S. Department of Energy Clean Coal Technology Program. This $30-million project is co-funded by DOE, the Gas Research Institute, and the State of Illinois. The Hennepin retrofit is on Unit 1, an 80-MWe tangentially fired boiler owned and operated by Illinois Power. The second site is Lakeside Unit 7, a 40-MWe cyclone-fired boiler operated by City Water, Light, and Power in Springfield, Illinois. Phase II was completed at the Lakeside station in December. Phase III, which includes long-term operations, reporting, and restoration, is now underway.

GR-SI integrates two emission control technologies that can be retrofitted to all types of coal-fired boilers for cost-effective NO_x and SO_2 control. Gas reburning involves firing 15 to 20% natural gas along with the coal. The gas is injected into the furnace above the main coal combustion zone. The NO_x formed from coal combustion is "reburned" by the gas and reduced to nitrogen, the main component of air. Additional combustion air is injected above the reburning zone to use the energy content of the natural gas and to complete combustion.

Original design calculations projected a 60% NO_x reduction when injecting natural gas in the range of 15 to 20% of the heat input to the boiler. At Hennepin, NO_x was reduced by 77% with an 18% input of natural gas. This reduced the cost of operation per ton of NO_x controlled by 28% when compared with the design basis of 60%. Thus far, under long-term, load-following operations, decreases in NO_x emissions have been in the range of 60 to 65% compared with the pre-GR-SI operations.

In general, sorbents react with SO_2 in flue gases to form sulfur-containing solids that are subsequently separated from the gases before they leave the stack. When calcium hydroxide is injected into the furnace, it reacts with the SO_2 to form calcium sulfate (gypsum). At Hennepin, dry calcium sulfate powder is recovered along with the coal ash in an electrostatic precipitator. The EER installation includes spray humidification to enhance precipitator performance. The Hennepin tests have also achieved the sorbent utilization originally projected. The sorbent injection rate was revised to decrease the calcium-to-sulfur ratio from 2.0 to 1.75 for better economy. The spray humidification system was effective in maintaining stack opacity at baseline levels even with the increased sorbent injection rate. Under the same long-term operating conditions cited above, during which 60 to 65% NO_x reductions were demonstrated, SO_x reductions of 50 to 55% were also achieved.

EER developed GR-SI to provide low-cost retrofit NO_x and SO_2 control for coal-fired boilers. Gas reburning can also be integrated with other control technologies to meet specific emission control goals. On another clean coal project, EER is demonstrating gas reburning when coupled with low-NO_x burners for high-efficiency NO_x control. Based on the results of these projects, EER will offer the gas reburning and integrated emission control technologies to utilities for use in complying with the Clean Air Act Amendments of 1990. The improved performance measured in these tests will translate to lower emission control costs for utilities.

RECOVERY OF FOSSIL RESINS FROM COAL

Certain bituminous coals from the western United States contain appreciable quantities of fossil resin (resinite). Such resinous coals are found in Arizona, Colorado, New Mexico, Utah, Washington, and Wyoming. Coal from the Wasatch Plateau coal field in Utah has a particularly high content of fossil resin; many seams in this field average as much as 5% resin.

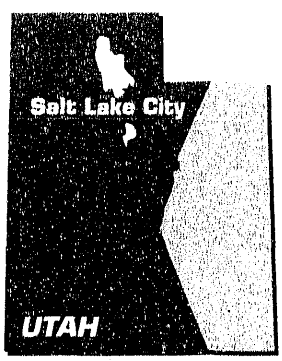
Fossil resins have been recovered intermittently from the Utah coal field since 1929 by gravity and/or flotation processes. The resin concentrates produced from flotation can be refined by solvent extraction and evaporation of the solvent. The solvent-refined product has a market value of at least $1.00/kg as a chemical commodity and can be used in the ink, adhesive, rubber, varnish, enamel, paint and coatings, and thermoplastics industries.

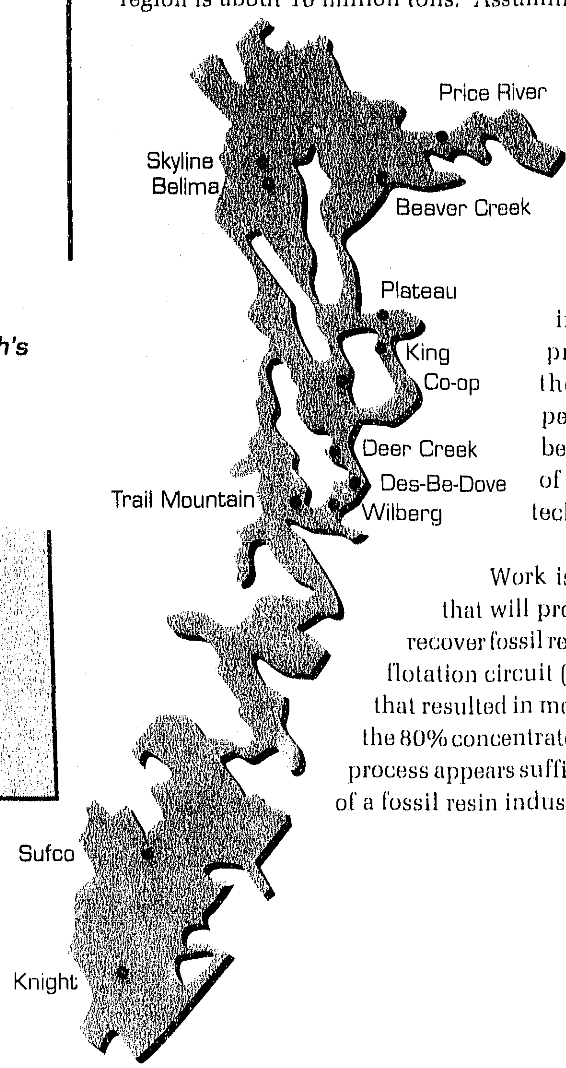
However, because of a lack of technology and the competition from synthetic resins, the valuable fossil resin resource from western coal has been wasted by being burned together with coal for electric power generation. Annual coal production from this region is about 10 million tons. Assuming that the coal contains 2% resin and has a market value of $1.00/kg ($1000/ton), the fossil resin in the coal that is burned each year for electric power generation has a value of $200 million. Therefore, the cost of the coal could be offset by the selling price of the resin.

When solvent-refined fossil resin from Utah coal is used as a feedstock in the ink industry, it can provide thermal setting properties superior to those of any of the synthetic resins available from the petrochemical industry. This feature has become particularly significant today because of the development of high-speed printing technology.

Work is in progress on new flotation technologies that will provide a highly efficient means to selectively recover fossil resin from coal. A proof-of-concept continuous flotation circuit (about 0.1 ton per hour) has been developed that resulted in more than 80% recovery of fossil resin at about the 80% concentrate grade. Economically, the selective flotation process appears sufficiently promising to justify the development of a fossil resin industry based on this new flotation process.

Mine sites in Utah's Wasatch Plateau coal field.





NO_x CONTROL PATENT LICENSED

PETC and NOXSO Corporation recently signed a license agreement that gives NOXSO the exclusive right to market a technology patented by four PETC employees. The license agreement marks the transfer of an important process patented by a DOE technology center to private industry. As cited in the *National Energy Strategy*, the Stevenson-Wydler Act made technology transfer a mission of Federal laboratories; and the subsequent Federal Technology Transfer Act, an amendment to Stevenson-Wydler, permitted laboratories to enter directly into cooperative agreements with industry and to license patents.

The patent described a process that would destroy NO_x in gas streams containing high concentrations of NO_x. The researchers discovered that adding small amounts of methane to the NO_x stream—a process called methane doping—before injecting it into a combustor, improved NO_x reduction efficiency. The NO_x can be injected into the burner and then subsequently into the combustor by various routes. Data obtained with PETC's 500-lb/hr coal combustion unit indicate that the addition of small amounts of methane to the NO_x stream greatly improves the in-furnace NO_x reduction efficiency. Tests showed near-complete reduction of recycled NO_x. Other hydrocarbons or reducing gases could also be good candidates as doping reagents for in-furnace NO_x reduction.

NOXSO is a dry, regenerable process for combined SO_2 and NO_x removal that produces a concentrated NO_x stream as part of the regeneration step. By applying the licensed technique, destruction of the NO_x can result when the stream is doped and injected into the combustor.

This patented technology will be tested as part of a larger project at a 6-million-Btu-per-hour, small-boiler simulator at the Babcock & Wilcox (B&W) Research Center in Alliance, Ohio. The B&W boiler is a single-cyclone boiler with a configuration that appropriately simulates a larger boiler at Ohio Edison's Niles generating station that will serve as the host for the first full-scale demonstration of the NOXSO process under a Clean Coal Technology award.

RD&D Awards

Research, Development, and Demonstration (RD & D) Awards are awarded by PETC as (1) grants to universities, (2) contracts, or (3) clean coal cooperative agreements with industry. They support key scientific and engineering projects identified by PETC as vital to the nation's energy interest. For reports resulting from these contracts, please contact either:

(1) for DOE employees and its contractors
Office of Scientific & Technical Information
P.O. Box 62
Oak Ridge, TN 37831
(615) 576-8401

(2) the general public
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650

Please be aware that there are fees connected with these services.

Date of Award	Awardee	Project/Contract Number
Oil Program		
08/23/91	Interstate Oil Compact Oklahoma City, OK	Evaluation Methodology for Technology Transfer FG22-91BC14818
09/06/91	State of Louisiana Office of Conservation Baton Rouge, LA	Analysis of Environmental Constraints of Expanding Reserves in Current & Future Oil & Gas Reservoirs in Wetlands FG22-91MT91004
09/12/91	National Academy of Sciences Washington, DC	Future Direction in Fundamental Advanced Extraction & Process Technology FG22-91BC14836
09/18/91	National Academy of Sciences Washington, DC	Future Direction in Fundamental Advanced Extraction & Process Technology FG22-91BC14837
09/25/91	Reservoir Engineering Palo Alto, CA	Research Consortium on Fractional Petroleum Reservoirs FG22-91BC14835

Date of Award	Awardee	Project/Contract Number
Coal Preparation		
08/23/91	Purdue Research Foundation W. Lafayette, IN	Characterization of the Organic Sulfur-Degrading Enzymes FG22-91PC91289
08/26/91	University of Alabama Mineral Resources Institute Tuscaloosa, AL	Coal-Sand Attrition System and Its Importance in Fine Coal Cleaning FG22-91PC91280
08/29/91	State of Illinois Energy & Natural Resources Springfield, IL	Support of High-Sulfur Coal Research FG22-91PC91334
08/29/91	University of Kentucky Chemical Engineering Dept. Lexington, KY	Non-Intrusive Measurement of Particle Charge: Electrostatic Dry Coal Cleaning FG22-91PC91290
09/11/91	Pennsylvania State University Earth and Mineral Science Dept. University Park, PA	Semiconductor Electrochemistry of Coal Pyrite FG22-91PC91303
09/17/91	Tuskegee Institute Kresge Center Tuskegee, AL	Liquid Chromatographic Analysis of Coal Surface Properties FG22-91PC91283
09/18/91	Virginia Polytechnic Institute and State University Blacksburg, VA	Development of the Selective Hydrophobic Coagulation Process FG22-91PC91164
Liquid Fuels		
08/23/91	Auburn University Chemical Engineering Dept. Auburn, AL	Low Severity Coal Liquefaction Promoted by Cyclic Olefins FG22-91PC91281
08/23/91	SRI International Chemistry Laboratory Menlo Park, CA	Dispersed Catalysts for Coal Liquefaction AC22-91PC91039
08/28/91	University of Kentucky Research Foundation Lexington, KY	Advanced Coal Liquefaction Concepts for PETC Generic Bench-Scale Unit AC22-91PC91040
08/28/91	Western Research Institute Laramie, WY	Use of Solid-State NMR Techniques for the Analysis of Water in Coal: Effect of Different Coal Drying Techniques on the Structure & Reactivity of Coal FG22-91PC91310

Date of Award	Awardee	Project/Contract Number
09/27/91	West Virginia University Energy & Water Research Morgantown, WV	The Economical Production of Alcohol Fuels from Coal-Derived Synthesis Gas AC22-91PC91034
09/27/91	University of Chicago Chicago, IL	Molecular Catalytic Coal Liquid Conversion AC22-91PC91056
09/30/91	Dow Corning Corporation Midland, MI	Methyl Chloride via Oxyhydrochlorination of Methane AC22-91PC91030
09/30/91	UOP, Inc. Corporate Research Center Des Plaines, IL	Develop Extraction Process for Removal of Heteroatoms from Coal Liquids AC22-91PC91057
Coal Utilization		
08/23/91	Virginia Polytechnic Institute and State University Blacksburg, VA	Alkali Corrosion of Ceramics at High Temperatures in Coal Gas Environments FG22-91PC91309
08/28/91	Brigham Young University Mechanical Engineering Department Provo, UT	Particulate Behavior in a Controlled-Profile Pulverized Coal-Fired Reactor: Coupled Turbulent Particle Dispersion FG22-91PC91308
08/28/91	Grambling State University Grambling, LA	Rheological Properties Essential for Atomization of Coal-Water Slurries (CWS) FG22-91PC91292
08/29/91	Rice University, Chemical Engineering Department Houston, TX	Coal Combustion: Effect of Process Conditions on Chain Reactivity FG22-91PC91307
08/29/91	Georgia Technology Research Corp. Chemical Engineering Atlanta, GA	Supercritical Thermodynamics of Sulfur and Nitrogen Species FG22-91PC91287
08/29/91	Georgia Technology Research Corp. Chemical Engineering Atlanta, GA	High-Temperature Electrochemical Separation of H_2S from Coal Gasification FG22-91PC91288
09/03/91	Vortec Corporation Collegeville, PA	A Coal-Fired Combustion System for Industrial Process Heating Applications AC22-91PC91161

Date of Award	Awardee	Project/Contract Number
09/11/91	University of Tennessee Knoxville, TN	Sorption and Chemical Transformation of PAHS on Coal Fly Ash FG22-91PC91306
09/13/91	Clarkson University Potsdam, NY	A Computational Model for Coal Transport & Combustion FG22-91PC91297
09/18/91	Stanford University Palo Alto, CA	Nitration of Polynuclear Aromatic Hydrocarbons in Coal Combustors and Exhaust Systems FG22-91PC91284
09/17/91	Clark Atlanta University Chemistry Department Atlanta, GA	The Role of Catalyst Precursor Anions in Coal Gasification FG22-91PC91286
09/17/91	Energy & Environmental Research Corporation Irvine, CA	Development of a Reburning Boiler Performance Model FG22-91PC91159
09/17/91	Massachusetts Institute of Technology Cambridge, MA	The Role of Core Structure on Char Reactivity FG22-91PC91294
09/18/91	Massachusetts Institute of Technology Cambridge, MA	Direct Catalytic Decomposition of Nitric Oxide FG22-91PC91293
09/19/91	Pennsylvania State University Materials Research Lab University Park, PA	Hydrothermal Reactions of Fly Ash FG22-91PC91302
09/26/91	Foster Wheeler Development Corporation Livingstone, NJ	Development of a High-Performance Coal-Fired Power Generating System with a Pyrolysis Gas & Coal-Fired High-Temperature Furnace AC22-91PC91154
09/30/91	ABB Combustion Engineering Windsor, CT	Development & Testing of Industrial-Scale Coal-Fired Combustion Systems: Phase III AC22-91PC91160
09/30/91	Coal Technology Corporation Bristol, VA	Development & Testing of Industrial-Scale Coal-Fired Combustion System AC22-91PC91162

Date of Award	Awardee	Project/Contract Number
Environmental Control Technology		
08/28/91	University of Cincinnati Aerospace Engineering & Applied Mechanical Engineering Cincinnati, OH	Low-Temperature SO_2 Removal with Solid Sorbents in a Circulating Fluidized Bed Absorber FG22-91PC91336
08/29/91	University of Michigan Ann Arbor, MI	A Novel Integrated Treatment System for Coal Wastewaters FG22-91PC91295
09/10/91	Aquatech Systems Warren, NJ	Combined SOXNOX Control via SOXAL: An Electro-Dialytic Regenerative Wet Scrubbing Process AC22-91PC91347
09/18/91	NOXSO Corporation Library, PA	An Experimental Study of NOX Recycle in the NOXSO Flue Gas Cleanup Process AC22-91PC91337
09/30/91	ADA Technologies, Inc. Englewood, CO	Flue Gas Conditioning for Improved Particle Collection AC22-91PC90364
09/25/91	Battelle Memorial Institute Columbus, OH	Characterization of Air Toxics from a Laboratory Coal Fired Combustor and Utility-Scale Power Plants AC22-91PC90366

Conference Announcement

HIGH-EFFICIENCY FINE COAL PREPARATION CONFERENCE

Mount Vernon, IL
August 12-14, 1992

Sponsors

U.S. Department of Energy - Pittsburgh Energy Technology Center (DOE/PETC)
The Center for Research on Sulfur in Coal (CRSC)

Organizers

Y.P. Chugh, Southern Illinois University (SIU)
R.H. Yoon, Virginia Center for Coal and Minerals Processing (VCCMP)

Purpose

The workshop will feature presentations by recognized experts in coal preparation processes dealing with increased yield and pyrite rejection. Participation in the event is expected from major coal companies with operations in the Illinois Coal Basin.

The purpose of the workshop is to transfer information regarding recently developed technological advances that have the potential for near-term application in the coal field. Technology transfer concerning high-efficiency coal preparation methods, in particular, will promote the coal industry's technical contributions toward achieving the environmental quality goals expressed in both the *National Energy Strategy* and the Clean Air Act Amendments of 1990.

For more information

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Ricky Honaker, SIU, 618-453-7910
Hugh Rimmer, VCCMP, 703-231-4508

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CALENDAR

April 28-May 1, 1992	**17th International Conference on Coal Utilization & Slurry Technologies** Co-sponsor with Coal & Slurry Technology Association Sheraton Sand Key, Clearwater, FL Contact: L.A. Ruth (412) 892-4461
May 4-7, 1992	**3rd International Symposium on the Biological Processing of Coal** Co-sponsor with Electric Power Research Institute Sheraton Sand Key, Clearwater, FL Contact: G. Olson (412) 892-6294
May 20-21, 1992	**Advanced Coal Cleaning as an SO_2 Emission Compliance Strategy** Westin William Penn, Pittsburgh, PA Contact: T. Feeley (412) 892-6134
June 22-24, 1992	**University Coal Research Contractors' Conference** Hyatt Hotel, Pittsburgh, PA Contact: R. Dolence (412) 892-6290
July 26-31, 1992	**8th Coal Preparation, Utilization & Environmental Control Contractors' Conference** Westin William Penn, Pittsburgh, PA Contact: O. Mills (412) 892-5890
August 12-14, 1992	**High Efficiency Fine Coal Preparation Conference** Co-sponsor: Center for Research on Sulfur in Coal, Mt. Vernon, IL Contact: W.P. Barnett (412) 892-6139 R. Honaker (618) 453-7910 H. Rimmer (703) 231-4508
October 1992	**11th IEA/Multiphase Flow Science Committee Meeting.** Pittsburgh, PA Contact: W.C. Peters (412) 892-4802
September 21-23, 1992	**Liquefaction Contractors' Conference** Westin William Penn, Pittsburgh, PA Contact: G. V. McGurl (412) 892-4462

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