CLEAN COAL TECHNOLOGY

THE INVESTMENT PAYS OFF

A REPORT BY THE ASSISTANT SECRETARY
FOR FOSSIL ENERGY

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Contents

The Investment Pays Off

This document summarizes some of the achievements to date resulting from one of the most successful government/industry partnerships ever implemented—the Clean Coal Technology Demonstration Program (CCT Program).

Presented here is solid evidence that the taxpayers' investment has paid real and measurable dividends. Technological innovation introduced through the CCT Program now provides consumers cost-effective, clean, coal-based energy. Further, the pioneer power systems introduced have laid the foundation for a new generation of power systems responsive to worldwide concern about global climate change.

In the coming years, our nation must make the best use of all domestic energy resources, including coal. Our reliance upon coal for the foreseeable future necessitates development and deployment of the cleanest, most efficient technologies possible.

Clean coal technologies can produce reliable, low-cost energy. With them, the United States can achieve continued economic growth and enhanced technological leadership in the global marketplace. This can improve the quality of our lives, as well as the lives of our global neighbors, while keeping our commitment to a cleaner, healthier environment.

The number and magnitude of demonstration projects put in place by the CCT Program is unprecedented, as is the extent of industry cost-sharing. More than $5.6 billion is being expended, with industry and states investing two dollars for every one from the federal government. The investment has resulted in 40 projects in 18 states. Over half the projects have already reached successful completion.

The technological successes are evident. SO_2 and NO_x control technologies emerging from the CCT Program have moved into the utility and industrial marketplace and now provide cost-effective regulatory compliance. A new generation of advanced coal-based power systems has been placed in commercial service that represents a quantum leap forward in terms of efficiency and environmental performance. These advanced power systems projects will provide a springboard for widespread, global deployment. This in turn will contribute greatly to reductions in greenhouse gas emissions.

The CCT Program has brought together the best resources available from industry, universities, and state and federal governments ensuring that clean coal technologies can turn today's vision into tomorrow's reality. The drawing board designs of the 1980s are today becoming the concrete and steel of a new generation of clean, efficient coal-based systems.

The Clean Coal Investment

The CCT Program represents the nation's single largest successful investment in environmental technology.

Five competitive solicitations sponsored by the U.S. Department of Energy resulted in selection of the most advanced coal-based technology concepts available anywhere in the world. Federal funding was leveraged twofold through partnerships encompassing utilities, state governments, technology developers, and research organizations.

Creating a Cleaner Environment

In 1986, the U.S. and Canadian Special Envoys on Acid Rain recommended a multi-billion dollar effort to address acid rain. The President responded the same year with the present day CCT Program, which built on a program begun by Congress a year earlier. The initiative created a government-industry partnership to expand the "menu of control options" for acid rain. The CCT Program has met the acid rain challenge. A wide range of control options emerging from the Program aided response to the first phase of Clean Air Act Amendments of 1990 (CAAA) reductions in acid rain precursors, which went into effect in 1995. A portfolio of cost-effective control options is also in place to meet the more stringent second phase of CAAA provisions in 2000. Moreover, technologies developed will serve as a foundation for meeting the increasingly stringent air quality requirements evolving to meet urban "soot and smog" concerns in the post-2000 era.

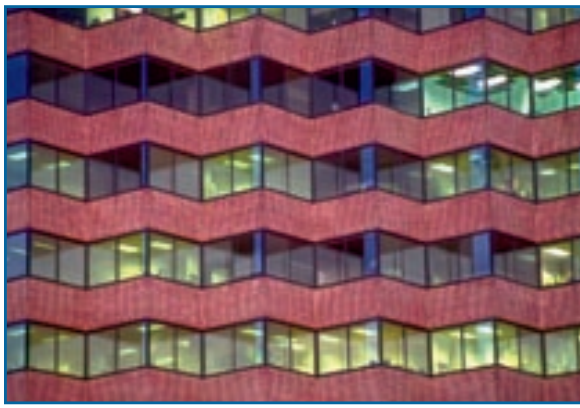
Global climate change became a major issue over the course of the CCT Program, prompting action to reduce carbon dioxide (CO_2), a greenhouse gas that is a product of combustion. In response, the CCT Program placed increased emphasis on development of a new generation of coal-based power systems characterized by high efficiency, as well as very low pollutant emissions. Today, first-of-a-kind demonstration units are fulfilling that objective by operating in commercial service and producing follow-on commercial sales.

Fueling an Expanding Economy

Economic growth requires affordable energy. To keep energy costs low, coal must remain a major percentage of the U.S. energy mix as demand for electric generating capacity increases. The Energy Information Administration (EIA) forecasts that 363 gigawatts of new generating capacity (more than 1,200 plants) will be needed by 2020 to meet growing demand and to offset retirements.

In 1997, coal supplied over 53 percent of the nation's electricity. Despite increased contributions from natural gas and renewables, EIA projects that coal will be the mainstay of electricity generation through 2020, and will continue to account for about half the total capacity. To ensure that coal-based systems meet these expectations, the CCT Program is providing the environmentally acceptable systems needed.

Creating Productive Jobs



A healthy environment means a better future for generations of Americans to come. Beyond a cleaner environment, the CCT Program has created jobs for Americans: designing, constructing, and operating advanced systems that clean the air and provide new sources of energy. Thousands of jobs alone resulted from implementing the program. Many more will be created downstream as the technologies are commercialized both in domestic and international markets.

A typical retrofit pollution control project, for example, employs 100-200 construction workers, while an advanced power generation project can require thousands. As many as 50-130 permanent jobs can result from a single new plant. Indirect benefits accrue as well, such as maintaining vital coal-producing and equipment-manufacturing industries.

Making the United States More Competitive

The world market for clean energy technologies is expanding at an unprecedented rate. Global demand for power generating technologies and services is anticipated to create a $480 billion export market over the next three decades and support more than 600,000 jobs in the U.S. power-equipment industry. Electrification in developing nations, modernization of outdated energy facilities in newly emerging democracies, and economic expansion in much of the Pacific Rim are creating enormous opportunities for U.S. companies to export equipment and coal-based fuel products that enhance efficiency and environmental performance.

The CCT Program positions the United States to capture a growing share of these markets. In no other country can prospective customers see the range of actual working systems that is being demonstrated in the United States. Other U.S. Department of Energy activities are aimed at creating a favorable export climate for U.S. coal and coal technology.

Creating a New Government-Industry Partnership

The CCT Program was created as a joint government-industry initiative. It is a partnership in which the federal government sets performance objectives, founded in national environmental concerns, and asks industry to respond with technical solutions. After the U.S. Department of Energy selects the projects most suited to accomplish solicitation objectives and establishes performance measures, industry takes the lead in project management and assumes responsibility for commercialization. In this cooperative effort, industry retains its rights to the real and intellectual property generated through the development and commercialization of the technology in return for assuming at least 50 percent of the project costs.

Taking on Smog

Expanded Options for Controlling Nitrogen Oxides

- Nitrogen oxides (NO_x) became the focus of a series of regulatory actions to severely limit emissions after having been identified as a source of both acid rain and urban smog. Coal-fired boilers represent a primary source of NO_x emissions and a specific target of regulatory action.
- Prior to the Clean Coal Technology Demonstration Program (CCT Program), NO_x control technology proven in U.S. utility service simply did not exist. Today that situation has changed dramatically. The CCT Program has met the regulatory challenge by forging emerging NO_x control technologies into a portfolio of cost-effective regulatory compliance options for the full range of boiler types.
- The resultant technology portfolio and associated databases and experience have:
  - Provided real-time data in formulating regulatory provisions;
  - Built the foundation for meeting NO_x emissions limits well into the 21st century; and
  - Positioned U.S. industry to export NO_x control technology.
- Products include:
  - Low-NO_x burners and reburning systems that modify the combustion process (combustion modification) to limit NO_x formation;
  - Selective catalytic and non-catalytic reduction technologies (SCR and SNCR) that act upon and reduce NO_x already formed (post combustion processes); and
  - Artificial intelligence-based control systems that effectively handle numerous dynamic parameters to optimize operational and environmental performance of boilers.
- As a result of the CCT Program, nearly one-half of U.S. coal-fired generating capacity has installed low-NO_x burners, with sales to date exceeding $1.5 billion. Reburning and artificial intelligence-based control technologies have made significant market penetration as well. All demonstration sites have retained the technologies for commercial use.

"Our experience with the Clean Coal Program allowed us to make informed decisions on how to best control NO_x emissions throughout our four-state service area. It has saved our customers millions of dollars."
Randall Rush
Southern Company Services, Inc.

Low-NO_x burners control the mixing of fuel and air during combustion. Reburning systems inject fuel into combustion products to strip oxygen away from the NO_x and introduce air above the reburn zone to complete combustion gradually in a cooler environment. Selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR) use chemicals to transform NO_x into nitrogen and water. Artificial intelligence controls measure key parameters and control their interactions to optimize performance against set values. The approaches can be combined to meet site-specific performance objectives.

LNCFS™ Low-NO_x Burner at Plant Lansing Smith

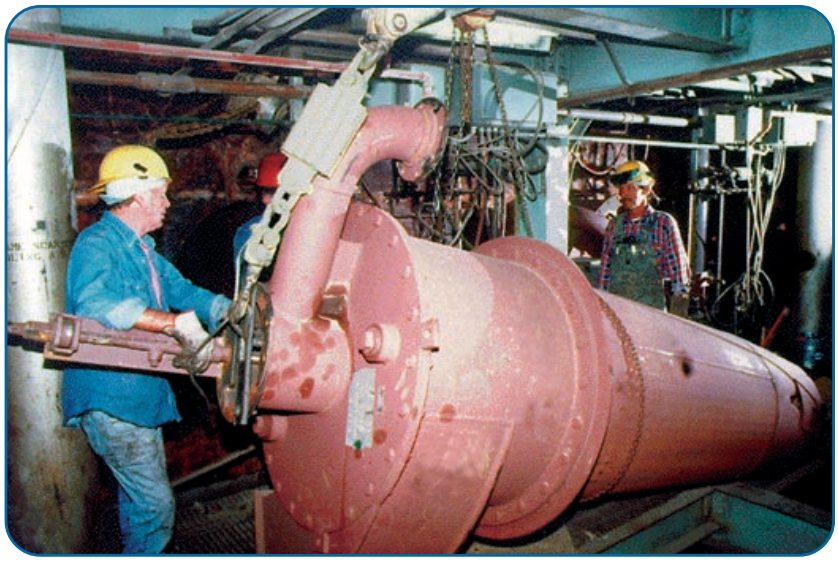
Low-NO_x Burners

ABB Combustion Engineering's LNCFS™ low-NO_x burner successfully completed demonstration at Gulf Power Company's Plant Lansing Smith, and at New York State Electric & Gas Corporation's (NYSEG) Milliken Station.

Utilities subsequently installed LNCFS™ and its derivative technology TFS 2000™ on an estimated 116 pulverized-coal tangentially-fired boilers, representing 25,000 MWe of generating capacity.

Tangentially-fired boilers constitute about 42 percent of the U.S. coal-fired capacity built before New Source Performance Standards (NSPS) were implemented. ABB Combustion Engineering is the primary manufacturer of tangentially-fired boilers. *(Demonstration sponsors: Southern Company Services, Inc. and NYSEG)*

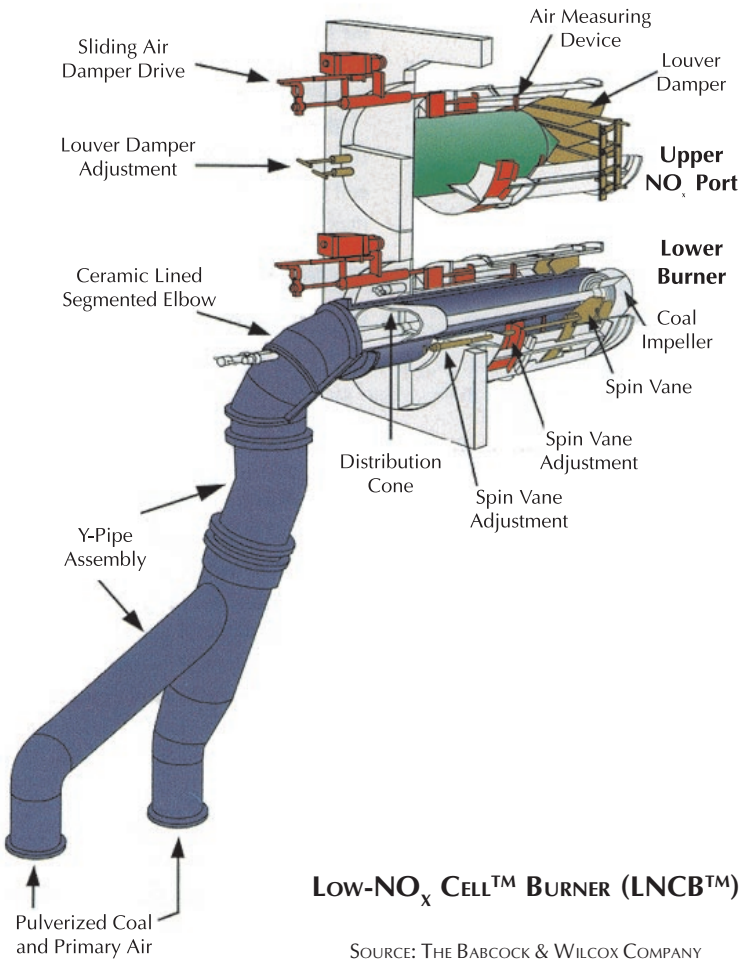
Dry bottom wall-fired boiler capacity in the U.S. approaches that of tangentially-fired boilers at about 37 percent. The two major wall-fired boiler manufacturers are The Babcock & Wilcox Company and Foster Wheeler. Both companies engaged in several successful demonstrations of their low-NO_x burners. Shown below is a Foster Wheeler burner being installed at Gulf Power Company's Plant Hammond. Foster Wheeler subsequently equipped 86 boilers with its low-NO_x burners (51 domestic and 35 abroad), totaling 1,800 burners for over 30,000 MWe of generating capacity. These installations have an estimated value of $35 million. The Babcock & Wilcox Company has signed contracts to equip 124 boilers with 2,428 DRB-XCL® burners, valued at $240 million and representing 31,467 MWe of generating capacity. *(Demonstration sponsors: Southern Company Services, Inc.; The Babcock & Wilcox Company; and Public Service Company of Colorado*)



Foster Wheeler Low-NO_x Burner installation at Plant Hammond

Babcock & Wilcox also developed and demonstrated a low-NO_x cell burner, LNCB®, for application to the highly efficient, but high NO_x emitting cell-burner boiler. Cell-burner boilers represent about 7.4 percent of the pre-NSPS coal-fired boiler population, but produce a disproportionately high percentage (about 11.3 percent) of the NO_x emissions.

The characteristic high heat release, causing the excessive NO_x emissions, precluded the conventional approach to modifying the burner for NO_x control. Successful demonstration of the LNCB® at Dayton Power & Light Company's 605-MWe J.M. Stuart Plant led to seven commercial contracts for 172 LNCB®s on 4,900 MWe of capacity valued at $27 million.



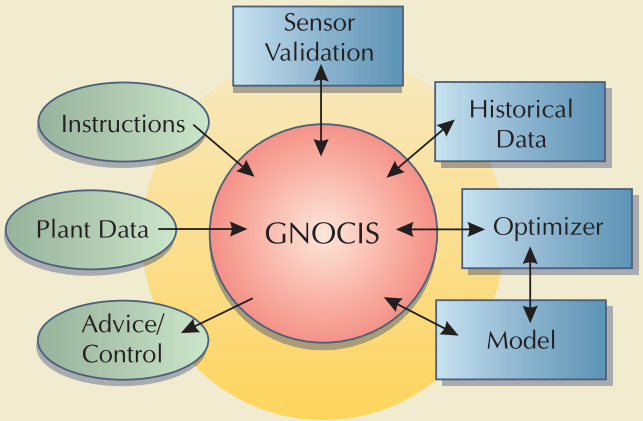
Low-NO_x Cell™ Burner (LNCB™)

Source: The Babcock & Wilcox Company

Advanced Control Systems

Advanced control systems are essential to handle the large number of parameters that must be controlled to effect optimum performance. Two artificial intelligence-based control systems proved their value through two separate demonstrations. The Electric Power Research Institute's Generic NO_x Control Intelligence System (GNOCIS) underwent successful demonstration at Gulf Power Company's Plant Hammond. GNOCIS installations are underway or planned at 26 commercial installations representing over 12,000 MWe of capacity. Below, the major elements of GNOCIS are illustrated, which are characteristic of artificial intelligence-based systems. DHR Technologies, Inc.'s Plant Emissions Optimization Advisor (PEOA™) proved enhanced performance at NYSEG's Milliken Plant. There have been six modules of the PEOA™ sold with an estimated value of $210,000 and bids are outstanding in Korea.

Major Elements of Generic NO_x Control Intelligent System (GNOCIS)



Natural gas injector at Hennepin Station

Coal pulverizer used to supply Babcock & Wilcox reburning system at Nelson Dewy Station

Reburning

Reburning is applicable to virtually any boiler type separately or in conjunction with low-NO_x burners because it works in association with the primary combustion process. But for cyclone boilers, reburning is the only combustion modification technology shown to be feasible for controlling NO_x emissions. The importance of having a NO_x control capability lies in the fact that cyclone boilers represent 8.5 percent of the pre-NSPS boiler population, yet contribute approximately 12 percent of the NO_x. The elevated NO_x levels are attributable to high combustion temperatures generated in the cyclones.

The Energy and Environmental Research Corporation (EER) successfully demonstrated gas-reburning on three boiler types. Demonstration sites include:

- City Water, Light & Power's 33-MWe Lakeside Station (cyclone);
- Illinois Power Company's 80-MWe Hennepin Plant (tangentially-fired); and
- Public Service Company of Colorado's 172-MWe Cherokee Station (wall-fired).

Gas-reburning crossed the commercial threshold with three installations in New York state and one in Colorado. Moreover, in late 1997 EER announced two major contracts to equip five cyclone boilers with gas-reburning for NO_x control. Use of the technology also extends to overseas markets. In 1993, one of the first installations of the technology took place at the Ladyzkin State Power Station in Ladyzkin, Ukraine.

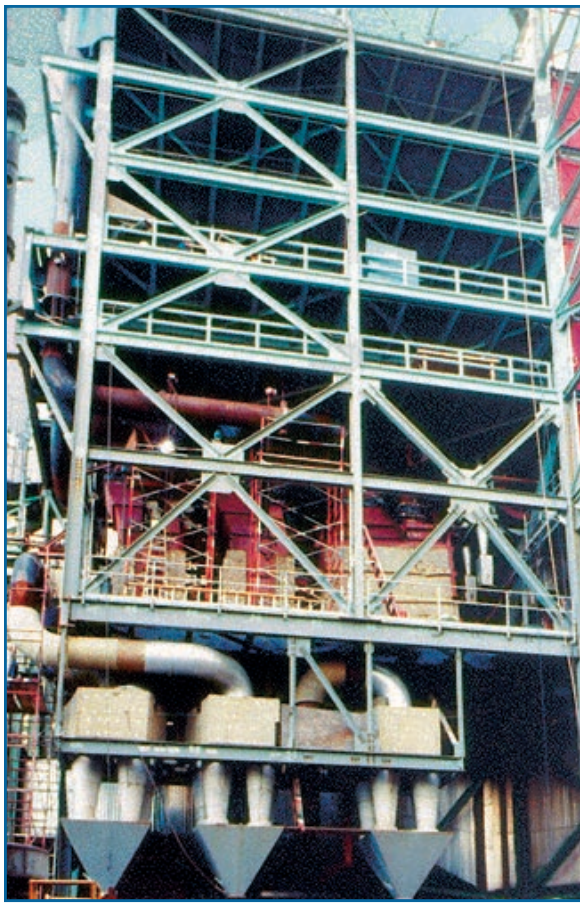
Babcock & Wilcox developed a project to prove the commercial viability of a coal-reburning system. The demonstration took place on a 100-MWe cyclone boiler at Wisconsin Power and Light Company's Nelson Dewy Station in Cassville, Wisconsin. Boiler modifications included provisions to inject up to 30 percent of the fuel as pulverized coal through reburn burners located above the primary combustion zone. In addition to achieving excellent NO_x control, the system avoided boiler derating when using low-rank coals because of the increased fuel feed capacity.

Post-Combustion NO_x Control

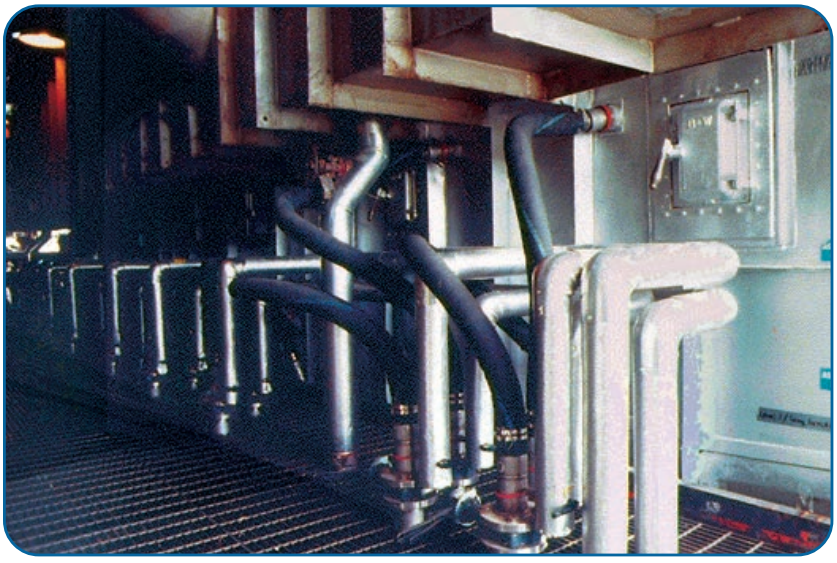
Although SCR had realized commercial acceptance abroad by the late 1980s, U.S. utilities were reluctant to consider SCR as a viable compliance option. Questions remained regarding performance with U.S. coals under U.S. operating conditions. To address these uncertainties, Southern Company Services' Gulf Power Company hosted SCR tests at Plant Crist near Pensacola, Florida. The tests evaluated eight commercially available catalysts with various shapes and chemical compositions to assess process chemistry and economics of operation. Both high- and low-dust loading conditions were tested.

The Gulf Power tests established SCR as a viable U.S. compliance option and aided utilities in developing the most cost-effective, site-specific applications of SCR.

The Public Service Company of Colorado evaluated SNCR, using in-furnace urea injection, in combination with low-NO_x burners, at its 100-MWe Arapahoe Station, Unit 4. The technologies proved to be complementary, achieving high levels of NO_x reduction.



Tests at Gulf Power Company's Plant Crist demonstrated that SCR can perform in accordance with design specifications under conditions reflective of U.S. utility operations.



SNRC installation at Arapahoe Station

Super Scrubbers

- The Clean Air Act Amendments of 1990 (CAAA) sent a clear signal to industry: SO_2, a primary precursor to acid rain, must cease to be a major pollutant emission by the beginning of the 21st century.
- Interim response included fuel switching, allowance trading, and some installation of SO_2 controls. But, a post-2000 CAAA cap on SO_2 emissions will ratchet down emission limits as new capacity is added, requiring high capture efficiency controls.
- Prior to the CCT Program, scrubbers capable of high SO_2 removal:
  - Were costly to build;
  - Difficult to operate and maintain;
  - Placed a significant parasitic load on plant output; and
  - Produced a sludge waste requiring extraordinary disposal measures and land use.
- The CCT Program redefined the state-of-the-art in scrubber technology through use of innovative capture techniques that:
  - Nearly halve capital and operating costs;
  - Produce valuable by-products such as gypsum instead of waste;
  - Mitigate plant efficiency losses; and
  - Capture multiple air pollutants.

Pure Air's scrubber at Bailly Generating Station

Advanced Flue Gas Desulfurization

Two clean coal projects demonstrated advanced wet flue gas desulfurization technology. Although significantly different in design, both the Pure Air and CT-121 systems combined several functions, provided for high flue gas flow, and offered unique features to achieve high SO_2 capture efficiency. This resulted in far more compact, efficient, and environmentally superior units compared to conventional technology at the time. Moreover, advanced designs precluded the need for spare absorber modules, significantly reducing capital cost.

The Pure Air system is installed at Northern Indiana Public Service Company's Bailly Generating Station in Chesterton, Indiana. The host site became the first power plant to reduce emissions and comply with Phase I of the CAAA using advanced technology. The Pure Air scrubber was, by far, the highest capacity single module unit of its time. It handled the flue gas from two generating units totaling 528 MWe and produced gypsum from the calcium sulfates formed from contact of SO_2 with the calcium-based sorbent. In one year, the unit produces enough wallboard-grade by-product gypsum to construct nearly 19,000 homes, while eliminating more than 70,000 tons of SO_2 emissions. In addition to removing SO_2 emissions at an average 95 percent efficiency, the system also removes almost all hydrogen chloride and hydrogen fluoride acid gases and trace elements.

Pure Air's scrubber, recipient of awards in 1992 and 1993 for excellence, continues in commercial service, providing wallboard grade gypsum to a local manufacturer.

Southern Company Services installed a Chiyoda CT-121 scrubber at Georgia Power Company's 100-MWe Plant Yates in Newnan, Georgia. The project used the first ever on-site fiberglass-reinforced-plastic (FRP) construction for major scrubber components. FRP construction included the unique Jet Bubbling Reactor, shown on the left, which captures SO_2 as the flue gas bubbles up through a sorbent slurry.

Chiyoda CT-121 Jet Bubbling Reactor constructed on-site using fiberglass-reinforced-plastic

FRP-fabricated equipment proved durable both structurally and chemically. It eliminated the need for two process steps normally taken to protect equipment from corrosion. The unique design of the absorber module makes it an efficient control device for particulate matter as well as gaseous pollutants. By-product gypsum at the Georgia Power site, in addition to use as wallboard, proved useful in soil amelioration for agricultural applications.

The CT-121 project received a series of awards from 1993 to 1995, recognizing the technical and environmental achievements. The unit, with its distinctive externally supported fiberglass stack shown below, continues to operate commercially at Plant Yates, consistently removing greater than 90 percent SO_2. Since the CCT Program demonstration, over 8,200 MWe equivalent of CT-121 capacity has been sold to 16 customers in 7 countries.

CT-121 installation at Plant Yates

SNOX™ system at Niles Station

Combined NO_x/SO_2

The CCT Program also sought integrated systems that could remove high percentages of NO_x as well as SO_2. These technologies would have application primarily in ozone nonattainment areas.

ABB Environmental Systems successfully demonstrated Haldor Topsoe's SNOX™ process shown above at Ohio Edison Company's Niles Station in eastern Ohio. SNOX™ relies on catalysts rather than sorbents to remove more than 95 percent of the SO_2 and 94 percent of the NO_x. Instead of solid wastes, SNOX™ produces a commercial-grade sulfuric acid as a salable by-product. Absence of an alkali reagent eliminates secondary pollutant streams and increases in CO_2 emissions. As a further benefit, SNOX™ captures excess heat from the process, which can be cycled back into the plant, improving plant efficiency and saving money.

Haldor Topsoe's SNOX™ system has become a permanent part of the power plant and is a key element of the utility's CAAA compliance strategy. Commercial SNOX™ systems are also operational on a coal-fired unit in Denmark and a petroleum coke unit in Sicily.

Babcock & Wilcox successfully demonstrated a high-capture-efficiency control system for particulates as well as SO_2 and NO_x—SNRB™, or SO_x-NO_x-Rox Box™. Babcock & Wilcox carried out the demonstration at Ohio Edison Company's R.E. Burger Plant in Dilles Bottom, Ohio. SNRB™, a high-temperature baghouse, integrates newly developed high-temperature fabric-filter bags, cylindrical SCR catalysts to fit within the bags, and a dry sorbent system. SNRB™ offers the flexibility to adjust to a wide range of pollutant control requirements at lower costs than a combination of conventional systems. The SO_2 control component can accommodate abrupt changes in coal sulfur content and the SCR catalyst can be designed for whatever level of NO_x emission reduction sought.

The SNRB™ appears in the background and the SCR catalyst holder in the foreground at the R.E. Burger Plant

Milliken Station

New York State Electric & Gas Corporation successfully demonstrated a total environmental and energy management system at the 300-MWe Milliken Station, Units 1 and 2, in Lansing, New York (shown above). Several flue gas cleanup technologies were used in combination to remove 95-98 percent of the SO_2, produce salable by-products and no waste water, and achieve low-energy consumption.

The system includes a Saarberg-Hölter-Umwelttechnik (S-H-U) formic acid-enhanced wet limestone scrubber, Stebbin's tile-lined split-module absorber, ABB Combustion Engineering's LNCFS™ low-NO_x burners, DHR Technologies' PEOA™ control system, and ABB's Air Preheater heat-pipe air-heater system.

Unique features include installation of the scrubber absorber module below the stack as a space-saving measure. S-H-U has established the U.S. company, SHN, to market the scrubber. As stated previously, there have been six commercial sales of the PEOA™, with an estimated value of $210,000.

Low-Cost Retrofits

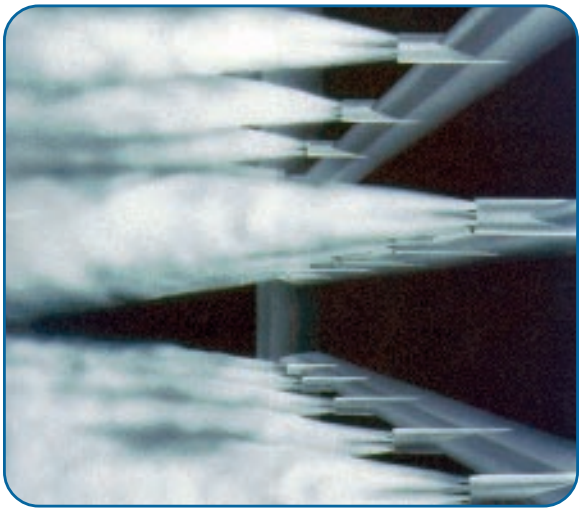
- Because of age, size, or space limitations, many existing coal-fired boilers do not warrant or permit installation of large, high-capture-efficiency scrubbers. For many of these units, however, some degree of control will be needed to meet post-2000 CAAA requirements.
- For severely space-constrained applications, the CCT Program demonstrated relatively simple dry sorbent injection technologies to work within the confines of existing equipment and achieve up to 70 percent SO_2 removal.
- Also, a spray dryer demonstration addressed applications where space permits integration of a reactor vessel into the flue gas stream to enhance dry sorbent injection conditions. Benefits include SO_2 removal up to 90 percent.
- In addition to domestic markets, these low-cost technologies are likely to find large markets in emerging economies of Eastern Europe and the Newly Independent States of the former Soviet Union, or in the rapidly expanding Asian and Pacific Rim nations.

"For (CAAA) Phase I utilities that have chosen fuel switching or Phase II utilities that burn low-sulfur coal...low-capital-cost technologies like lime-based sorbent injection scrubbing may be the least-cost option."
Power Engineering
August 1993

Furnace Sorbent Injection Processes

Two processes demonstrated the use of furnace sorbent injection to enable the use of limestone in lieu of lime and to reduce operating costs (limestone cost is 1/3 that of lime). Heat from the furnace calcines the limestone, making it reactive with SO_2.

Babcock & Wilcox tested its limestone injection multistage burner (LIMB) process at Ohio Edison Company's 105-MWe Edgewater Station, Unit 4, in Lorain, Ohio. LIMB removed about 50 percent of the SO_2 with fine grinding of limestone and heavy humidification. Injection of lime, in lieu of limestone, increased SO_2 removal to up to 61 percent, using less humidification. An independent power project in Canada chose a commercial version of LIMB for its emission control.



Humidifier at Edgewater Station

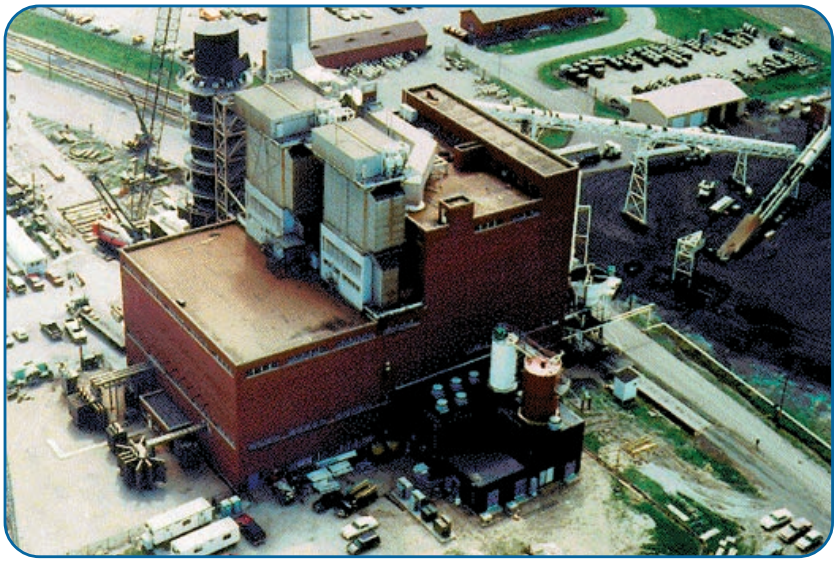
The humidifier proved critical to effective performance of LIMB and downstream particulate capture in the electrostatic precipitator. It consisted of an in-duct spray nozzle array located in a straight horizontal portion of the ductwork.

LIFAC installation at Whitewater Valley Station

LIFAC-North America demonstrated its furnace sorbent-injection process at Richmond Power & Light's 60-MWe Whitewater Valley Station, Unit 2, in Richmond, Indiana. In the process, limestone absorbs some of the SO_2 in the flue gas as it is blown into the upper part of the boiler. A vertical humidification chamber downstream captures additional SO_2 through a series of chemical reactions.

Long-term testing showed that the process removes 70 percent or more of the SO_2. The compact, low-capital-cost technology enables power plants with space limitations to use high-sulfur, high-Btu mid-western coals.

The demonstration at the Richmond Power & Light plant was the first power plant application of LIFAC using high-sulfur coal. The municipal utility has decided to retain the LIFAC system. There are also 10 full-scale LIFAC units in operation or under construction in Canada, China, Finland, Russia, and the United States.



Whitewater Valley Station, constrained by space restrictions and endeavoring to cut operating costs by using indigenous high-sulfur coals, chose LIFAC to meet regulatory compliance requirements.

In-Duct Sorbent Injection

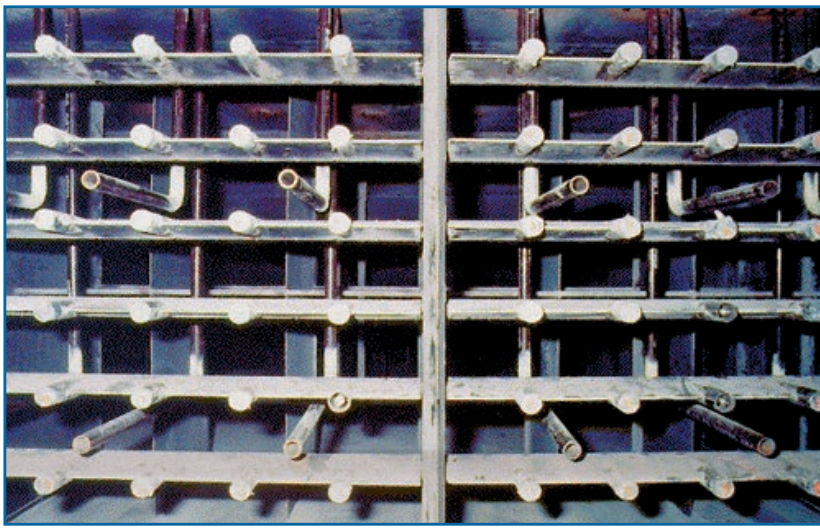
Three in-duct sorbent injection systems underwent demonstration. This approach avoids boiler penetrations and use of reactor vessels. The technology hardware largely resides within the ductwork, making it particularly attractive for space-constrained units. In lieu of limestone, the systems rely on processed sorbents such as lime, lime with sodium-based additives, or sodium-based sorbents alone.

Bechtel CZD installation at Seward Station

Bechtel Corporation demonstrated its confined zone dispersion (CZD) process at Pennsylvania Electric Company's 147-MWe Seward Station, Unit 5, in Seward, Pennsylvania. As shown in the adjacent photograph, the CZD process used a 100-foot section of straight ductwork just ahead of the electrostatic precipitator. Up to 50 percent SO_2 removal resulted from injection of a finely atomized slurry of lime, which forms a zone of droplets in the middle of the duct, confined in an envelope of hot flue gas.

Consolidation Coal Company, in a companion effort with the LIMB demonstration, demonstrated the Coolside process at the same Ohio Edison power plant. The Coolside process injects dry lime, with a sodium-based sorbent additive, into the flue gas ductwork downstream from the boiler. A humidifier, downstream of the sorbent injection, provides a high concentration of water vapor. The Coolside process routinely achieved 70 percent SO_2 removal using commercially available hydrated lime while burning high-sulfur coal.

Public Service Company of Colorado demonstrated SO_2 emissions control at its 100-MWe Arapahoe Station, Unit 4, near Denver, Colorado. An integrated dry sorbent injection/humidifier shown in the adjacent photograph provided the means for SO_2 removal. Testing included both sodium- and calcium-based sorbents. Sodium-based sorbent injection achieved 70 percent SO_2 removal at high sorbent utilization rates. Also, SNCR interacted synergistically with sorbent injection to reduce ammonia slip and NO_x emissions. The Colorado utility decided to retain the technology for commercial use.



Integrated dry sorbent injection/ humidifier at Arapahoe Station

Advanced Spray Dryer

AirPol, Inc. demonstrated the gas suspension absorption (GSA) process developed by its parent company, FLS miljo Inc. at the Tennessee Valley Authority's Center for Emissions Research in West Paducah, Kentucky. The AirPol project was the first North American demonstration of this technology.

The GSA system consists of a vertical reaction chamber and integral cyclone separator, which uses a single nozzle to suspend recycled reaction products and sorbent for flue gas treatment. GSA, while burning high-sulfur coal, showed that the SO_2 removal efficiency for the overall system was about 90 percent when operated in conjunction with an electrostatic precipitator for particulate removal. In combination with a pulse-jet baghouse, GSA removed 96 percent of the SO_2.

As a result of this successful demonstration, a GSA unit, valued at $10 million, was sold to the city of Hamilton, Ohio for installation on their 50-MWe municipal power plant. The Ohio Coal Development Office subsidized the project, recognizing the technology's potential. The GSA technology proved to be the least-cost alternative for the city to meet CAAA compliance requirements.

AirPol, Inc. GSA reactor

Also, AirPol has sold GSA systems in Taiwan, Indonesia, and India having a combined value of $20 million. Furthermore, Taiwan contracted for technical assistance and proprietary equipment valued at $1.0 million.

The U.S. Army procured a $1.3 million unit for a hazardous waste disposal plant.

In addition, operators of a 4-million-ton-per-year iron ore sinter plant in Sweden selected GSA technology to meet national air quality standards, requiring 90-95 percent SO_2 removal efficiency.

- Today, more than half of the electricity generated in the United States comes from domestic coal reserves. Worldwide, coal fuels more than a third of electricity production. Even with maximum attention to energy conservation and increased use of renewable energy and natural gas, coal must continue to supply over half the nation's and over a third of the world's power needs well into the 21st century.
- A new generation of coal-based power systems is required to provide the energy to sustain economic growth domestically and internationally, while addressing global and regional environmental concerns.
  - SO_2 and NO_x emission levels become capped in the U.S. and subjected to increasingly stringent regulations abroad;
  - Particulate matter in the inhalable and respirable ranges ceases to be tolerated worldwide;
  - Vapor phase mercury emissions will be subject to control; and
  - Perhaps most importantly, global climate change concerns place a premium on efficiency to reduce one of the greenhouse gases, carbon dioxide (CO_2).
- Nearly half of the world's energy growth is seen to occur in coal-dependent developing Asia, primarily China and India. Advanced coal-based power generation systems are needed to prevent staggering growth in global greenhouse gas emissions and to comply with increasingly stringent pollutant standards.
- Domestically, energy forecasts suggest that new coal-fired baseload capacity will be required no later than 2005.
- In response to these needs, the CCT Program is demonstrating technologies that are not only redefining the state-of-the-technology in electric power generation but also are providing the building blocks for achieving:
  - Low-cost production of electricity, process heat, and high-value fuels and chemicals from a multiplicity of feedstocks (e.g., coal, biomass, and wastes);
  - Virtually no pollutant emissions; and
  - Efficiencies greater than 60 percent.
- In the 1970s, such power plants existed only as the hopes of researchers. Today, due largely to the CCT Program, these clean, highly efficient technologies are a reality, with further enhancements and advances on the horizon.

"We view our Clean Coal Technology project as a natural solution. Our customers will benefit from a reliable, economical fuel. Our environment will benefit from superior emissions reduction performance. And our company will benefit by producing reliable generation in a way that more than meets the Clean Air Act."
Girard F. Anderson
President, Tampa Electric Company

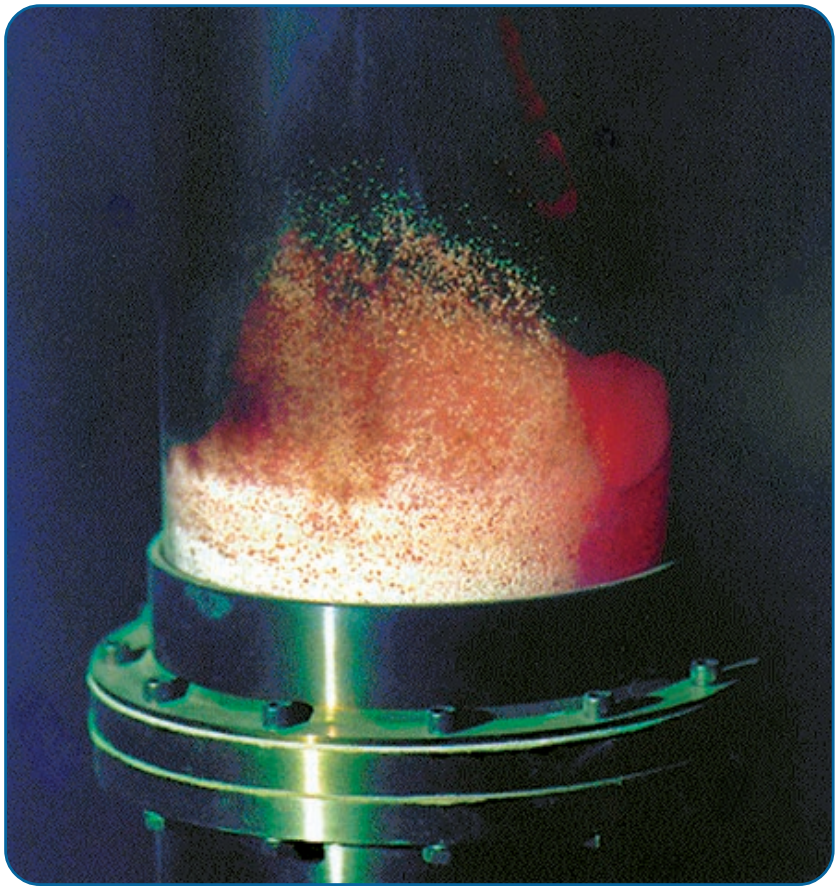
"Power" magazine called the development of fluidized-bed coal combustion "the commercial success story of the last decade in the power generation business." This success, perhaps the most significant advance in coal-fired boiler technology in more than half a century, resulted largely from research, development, and demonstration sponsored by the Department of Energy and its predecessors.

Fluidized-Bed Combustion

The CCT Program has been instrumental in providing the operating experience essential to commercial acceptance of fluidized-bed combustion for utility applications. The program's portfolio includes five fluidized-bed combustion demonstrations: two using atmospheric systems, and three using pressurized systems.

Fluidized-bed combustion reduces SO_2 and NO_x emissions by controlling combustion parameters and by injecting a sorbent (such as crushed limestone) into the combustion chamber along with the coal. The mixing action of the fluidized-bed, induced by jets of air, promotes efficient, homogeneous combustion and effective sorbent contact with SO_2. This enables efficient combustion at temperatures about half that of a conventional boiler, and below the temperature at which thermally induced NO_x is formed. Resultant SO_2 and NO_x emissions are quite low. The waste is a dry, benign solid that can be disposed of easily or used in agricultural or construction applications. Furthermore, the nature of fluidized-bed combustion makes it highly fuel-flexible.

Fluidized-bed combustion can be atmospheric or pressurized. Pressurized boilers operate at 6-16 times the pressure of atmospheric systems. Pressurized units offer potentially higher efficiency and, consequently, reduce operating costs and waste relative to atmospheric units.



Fluidized-bed research vessel used to study bed material movement

Atmospheric Fluidized-Bed Combustion

The Tri-State Generation and Transmission Association, Inc. demonstration of a 110-MWe atmospheric circulating fluidized-bed (ACFB) at Nucla Station, Nucla, Colorado precipitated commercialization of the technology. When constructed in 1988, the unit was 40 percent larger than any other ACFB at the time.

In a cooperative effort between DOE, the host utility, EPRI, and a Technical Advisory Group comprising interested utilities, the 110-MWe unit underwent an extensive test program to evaluate performance. The resultant comprehensive database and operating experience provided sufficient foundation for the technology supplier, Foster Wheeler, to offer the technology commercially at utility scale.

Today, all major boiler manufacturers offer an ACFB in their product lines. Since the demonstration, commercial sales of 29 units greater than 100 MWe have been realized, representing 6.2 gigawatts of capacity and nearly $6 billion.

A second demonstration project, located in Jacksonville, Florida, will carry on where Nucla left off. It will have the distinction of being the largest ACFB combustor in the world as well as one of the cleanest. At nearly 300 megawatts, the Jacksonville project will more than double the size of the Colorado unit.

During 15,700 hours of operational demonstration, Nucla achieved up to 95 percent SO_2 removal and averaged NO_x emissions of a very low 0.18 lb/10^6 Btu. The demonstration also resulted in the most comprehensive database on ACFB technology available to date. Using this knowledge, vendors were able to offer and build additional utility-scale units for commercial applications.

Nucla Station

Pressurized Fluidized-Bed Combustion

The attractiveness of PFBC technology lies in the benefits derived by pressurizing combustion to about 175 psi. Pressure enhances combustion efficiency and heat transfer, which permits use of a small, compact unit. High-pressure gas exiting the boiler drives a gas turbine and waste heat contributes to steam generation in a combined-cycle mode, providing a significant efficiency advantage. The Tidd unit shown here achieved greater than 95 percent SO_2 capture and NO_x emissions well within air quality limits without add-on pollution controls.

Tidd 70-MWe PFBC

The nation's first large-scale PFBC power plant began operating in December 1990 at American Electric Power's (AEP) Tidd Plant in Brilliant, Ohio. The 70-MWe Tidd Plant used ABB Carbon P200 bubbling bed technology (licensed to Babcock and Wilcox).

AEP, one of the nations largest utilities, invested four years to fully test and evaluate the technology. Numerous design improvements resulted as AEP worked through a series of challenges that compromised performance. After 49 months of coal-fired operation and 95 individual tests, the Tidd project met its objective—the performance potential of PFBC was established and the foundation for commercialization was laid.

The success of the project has led Babcock and Wilcox, a major domestic boiler manufacturer, to invest in the technology and acquire domestic licensing rights. The technology is experiencing commercial success abroad as shown below:

- Vartan in Sweden is operating two P200 units to produce 135 MWe and 224 MWt.
- Escatron in Spain is operating one P200 unit to produce 80 MWe.
- Wakamatsu in Japan is operating one P200 unit to produce 71 MWe.
- Cottbus in Germany is operating one P200 unit to produce 71 MWe and 40 MWt.
- Karita in Japan will begin this year to operate one P800 unit to produce 360 MWe.
- Other projects under consideration are in China, South Korea, UK, and Israel.

Work has begun under the CCT Program to demonstrate a second generation PFBC at Lakeland Electric's McIntosh plant, using a Foster Wheeler circulating fluidized-bed system. The 240-MWe second generation system incorporates a carbonizer (pyrolysis unit) to produce synthesis gas for combustion in the gas turbine (solid product goes to the combustor). The additional energy developed in the more efficient gas turbine significantly enhances efficiency— 45 to 50 percent depending on the gas turbine used.

Integrated Gasification Combined-Cycle

Four integrated gasification combined-cycle (IGCC) projects in the CCT Program will demonstrate a full range of variations of the IGCC process: different gasifiers, different sizes, different coals, different cleanup systems, and different applications (greenfield and repowering).

Tampa Electric Company, as part of a major expansion over the next decade, has built a 250-MWe IGCC facility as a greenfield plant in Florida. Polk Power Station, Unit 1, began commercial operation in September 1996. Since then, the unit has logged over 15,000 hours and produced over 3,500,000 MWh of electricity on syngas.

The project couples Texaco's oxygen-blown, entrained-flow pressurized coal gasifier to a power island consisting of both a combustion turbine and a steam turbine. The project also incorporates an innovative hot-gas-cleanup system to boost efficiencies even further. The plant uses high-sulfur coals.

Worldwide commercialization of IGCC has already begun. General Electric has identified 21 IGCC projects (11 installed and 10 moving forward), representing approximately 5.1 gigawatts of capacity. Unit sizes range from 40 MW to 550 MW and include a variety of fuels, 10 different gasifiers and a variety of applications. Ten of the projects use Texaco gasifiers. Furthermore, Texaco and ASEA Brown Boveri have formed an alliance to market the Texaco IGCC technology in Europe.

Polk Power Station is the first greenfield IGCC unit in commercial operation. In achieving this accomplishment, both the environmental and technical community bestowed accolades on Tampa Electric. The site was chosen through formal environmental consensus, cleaning up an abandoned phosphate-mined area and expanding wetlands in the process. For its technical efforts, the Polk Power Station received *Power* magazine's 1997 Powerplant Award. The utility's contributions to the innovative siting process garnered the 1993 Ecological Society of America Corporate Award, the 1993 Timer Powers Conflict Resolution Award presented by the state of Florida, and the 1991 Florida Audubon Society Corporate Award.

Integrated gasification combined-cycle (IGCC) systems offer another clean, highly efficient means of power generation. IGCC converts coal into a gaseous fuel, which lends itself to pollutant removal. The clean fuel gas is then combusted in a gas turbine to generate electricity. Excess heat is put to work in a conventional steam turbine generator, producing even more electricity.

Typically, more than 99 percent of the sulfur pollutants are captured and converted into sulfuric acid or elemental sulfur, both salable by-products. Nitrogen oxide emissions are about one-tenth those of a conventional power plant. Any trace elements in the coal stay with the ash, which is either converted to an inert glass-like slag or a dry solid with cement-like properties.

Polk Power Station 250-MWe IGCC facility

Wabash River Coal Gasification Repowering Project Joint Venture repowered one of six units at CINergy's Wabash River Generating Station in West Terre Haute, Indiana. The demonstration unit generates 262 MWe using an IGCC system, making it the world's largest single-train IGCC plant currently in operation.

The project demonstrates Dynegy's two-stage, oxygen-blown, entrained flow pressurized coal gasifier, which produces a medium-Btu syngas from high-sulfur coal. The technology boosted the efficiency of the repowered unit by about 20 percent, decreasing CO_2 emissions by a comparable percentage. Emissions of SO_2 and NO_x are well within compliance requirements and the solid by-product (a glassy inert slag) has value as an abrasive or construction material.

The unit began operations in December 1995 and went into commercial service. CINergy preferentially dispatches the unit second behind its hydroelectric facilities on the basis of environmental performance and efficiency.

Since beginning operation in 1995, the Wabash River Generating Station 262-MWe IGCC unit has operated on coal for over 12,400 hours and processed more than one million tons of coal. The unit has achieved monthly production levels of one trillion Btus of syngas on several occasions. *Power* magazine presented the Wabash River project the 1996 Powerplant Award. That same year, Sargent & Lundy won the American Consulting Engineers Council Excellence Award for their efforts on the Wabash River project.

Wabash River Generating Station 262-MWe IGCC

Sierra Pacific Power Company's 99-MWe IGCC

Sierra Pacific Power Company hosts the latest IGCC demonstration at its Tracy Station near Reno, Nevada. The 99-MWe (net) unit uses KRW's air-blown pressurized fluidized-bed gasifier and hot-gas-cleanup to produce low-Btu syngas.

Sierra Pacific Power Company completed construction in early 1995 and began start-up efforts in mid-1996. The General Electric combustion turbine at the unit is the first of its kind in the world and was successfully fired for the first time in August 1996 using natural gas. The combined-cycle part of the plant began commercial operation on natural gas in November 1996. Operational testing will continue through July 2000.

Efforts continue to increase the hours of gasifier operation. A key feature of the project is the use of fluidized-bed gasification, which affords tremendous fuel flexibility. In approving the project, the Public Service Commission of Nevada cited the technology's advantages of "flexibility, diversity, and reliability." Low-sulfur western coal will be used in the plant as the baseline fuel, although high-sulfur eastern coals also will be tested.

Clean Energy Partners Limited Partnership, the fourth IGCC project, will demonstrate a British Gas/Lurgi slagging fixed-bed gasification system coupled with Fuel Cell Engineering's molten carbonate fuel cell. Conventionally cleaned medium-Btu fuel gas fires the gas turbine in the IGCC power island. A small portion of the hydrogen-rich clean gas fuels the fuel cell.

Advanced Combustion Technologies

The Alaska Industrial Development and Export Authority is sponsoring a demonstration of TRW's advanced slagging combustor in a 50-MWe unit near Healy, Alaska. Power is purchased by Golden Valley Electric Association (GVEA).

Healy Generating Station

The combustors stage combustion to minimize NO_x emissions. Low SO_2 emissions result from limestone injection into the combustor and coupling the combustor with a dry scrubber. The demonstration unit is designed to operate on a blend of up to 35 % run-of-mine and 65 % waste coal. High combustion temperatures convert ash to a salable inert, glass-like slag.

Start-up of the TRW entrained slagging combustion system began in January 1998 and results show very low NO_x and SO_2 emissions, 0.25 lb/10^6 Btu and 0.08 lb/10^6 Btu, respectively (below permitted levels). Almost all of the ash is being converted to slag before entering the furnace. To address concerns about potential impact to the nearby Denali Park and Preserve, DOE, GVEA, the National Park Service, and the project sponsor took action to reduce emissions from the existing coal-fired unit. TRW is offering licensing of its technology worldwide and already has a licensing agreement in place in China.

Arthur D. Little, Inc., plans to demonstrate a 6.4-MWe Coltec coal-fired diesel engine at the University of Alaska in Fairbanks. The university also will assemble and operate a coal-water fuel-processing plant that will utilize local low-rank coal. The coal-water fuel also serves as an alternative to fuel oil in conventional oil-fired industrial boilers.

Coltec coal-fired diesel engine

The Coltec engine is best suited for dispersed power applications in the 5–20 MWe range. The high overall system efficiency (41-48 percent) and very low pollutant emissions make it very competitive with similarly sized fuel-oil-fired and coal-fired systems. The U.S. diesel market is expected to exceed 60 gigawatts through 2020 alone. The market in developing Asia for coal-based distributed power is far greater.

Preventing Pollution

Economical Methods for Making New Fuels from Coal

- Almost 90 percent of coal mined in the United States goes to power plants to produce electricity. Ideally, power plants desire high-energy-density (high-heating-value), low-sulfur, low-ash coal for operational and environmental performance considerations.
- Typically, eastern and mid-western U.S. coals are bituminous coals with inherent high heating value, but they often contain high levels of sulfur. Western U.S. coals, on the other hand, are largely subbituminous or lignite and are characteristically low in energy density (low-rank), but also low in sulfur content.
- Both eastern/mid-western and western U.S. coals have some percentage of unwanted mineral matter. The mineral matter contains metallic trace elements identified as hazardous air pollutants when released to the environment upon combustion.
- The CCT Program technologies enhance utilization of our vast coal resources by transforming them into clean, high-quality fuels and by providing users with the tools to select the most cost-effective clean fuel option for specific boilers.
    - Technologies are converting low-rank western coals, which contain up to 40 percent water, to dry, stable high-heating-value solid fuels and clean liquid fuels. This improvement significantly lowers transportation and handling costs and makes the western coal fuels viable in the larger, but distant mid-western and eastern power generation sectors.
    - For the eastern and mid-western coals, the focus of the CCT Program is demonstration of a conversion process that takes high-sulfur bituminous coal and produces methanol and other compounds for use as a fuel or chemical feedstock.

Clean Coal Fuels:

- *Prevent pollutant emissions from forming by removing precursors from the source,*
- *Enhance power generation efficiency by improving fuel quality, and*
- *Allow full utilization of the nation's largest fossil energy resource without compromising the environment.*

Tank car loading facility for Coal Derived Liquid® at ENCOAL demonstration plant

Converting Low-Rank Coals

The ENCOAL demonstration plant near Gillette, Wyoming uses a unique mild gasification process to convert low-rank coals into two valuable fuels: a clean coal-derived liquid (CDL®) that can be directly substituted for boiler fuels, and a clean, dry process-derived fuel (PDF®) for utility boilers that can meet CAAA standards without additional pollution control equipment. The ENCOAL project is demonstrating SGI International's Liquids-From-Coal (LFC®) process.

The product fuels proved to be economic in a broad range of commercial boiler applications and reduced SO_2 and NO_x emissions significantly at utility and industrial facilities currently burning high-sulfur bituminous coal or fuel oil.

The PDF® contains 0.36 percent sulfur and has a heating value of 11,200 Btu/lb, whereas feed coal contains 0.45 percent sulfur and has a heating value of 8,400 Btu/lb. The CDL® contains 0.6 percent sulfur and has a heating value of 140,000 Btu/gallon, whereas the No. 6 fuel oil has a sulfur content of 0.8 percent sulfur and a heating value of 150,000 Btu/lb. The fuels contain no EPA-listed toxins in concentrations anywhere near the federal limits.

The plant officially entered production in June 1994 at a coal feed rate of 500 tons per day. By the end of the demonstration, nearly 260,000 tons of coal had been processed into more than 120,000 tons of PDF® and 121,000 barrels of CDL®. Over 83,500 tons of specification PDF® had been shipped to seven customers in six states, as well as 203 tank cars of CDL® to eight customers in seven states. PDF® also showed promise as a reductant in the direct iron ore reduction process and as a blast furnace injectant.

The ENCOAL demonstration plant proved the commercial feasibility of the SGI International Liquids-From-Coal (LFC®) process. The plant also attracted a large number of international visitors, especially from Pacific Rim countries, interested in either using the technology with their own coal supplies or purchasing the derived products. Partners in the project completed five detailed commercial feasibility studies—two Indonesian, one Russian, and two U.S. projects. Permitting of a 15,000 metric-ton/day commercial plant in Wyoming is nearly complete.

ENCOAL Demonstration Plant

The Rosebud SynCoal® Plant

The Rosebud SynCoal® plant, adjacent to the Rosebud coal mine in Colstrip, Montana, is demonstrating another route to producing high-quality fuel from low-rank coals. This advanced coal conversion process (ACCP) upgrades low-rank coal (with moisture contents of 25-40 percent, sulfur contents of 0.5-1.5 percent, and heating values of 5,500-9,000 Btu per pound) to SynCoal® with a moisture content as low as 1 percent, sulfur content as low as 0.3 percent, and heating value up to 12,000 Btu per pound.

The process uses combustion gases, devoid of oxygen, to drive off moisture, volatile organic sulfur, and other unwanted compounds; to mitigate spontaneous combustion by changing surface characteristics; and to fracture the coal, liberating ash.

The plant has the capacity to process about 1,800 tons of raw coal per day. By September 1999, more than 1.4 million tons of SynCoal® had been produced. Nearly 1.3 million tons has been supplied to industrial applications (primarily cement and lime plants) and utilities.

Rosebud SynCoal® Partnership continues to operate under an 8-year contract to supply SynCoal® to Montana Power's 330-MWe Colstrip No. 2, using a dedicated pneumatic feed system. The SynCoal® product both enhances boiler efficiency and reduces SO_2 emissions.

Rosebud SynCoal® Partnership has also signed a technology marketing agreement with Ube Industries, Ltd., of Tokyo, Japan. Under the agreement, Ube Industries has been granted a non-exclusive right to represent Rosebud in marketing and commercialization of the SynCoal® technology outside the United States, including Thailand, the Phillippines, and Indonesia.

Converting Bituminous Coals

The Air Products Liquid Phase Conversion Company, L.P., is demonstrating the Liquid Phase Methanol (LPMEOH™) process to produce methanol from coal-derived synthesis gas. Air Products and Chemicals, Inc., and the Eastman Chemical Company have formed a limited partnership to manage and execute the demonstration project, which is located at Eastman Chemical's integrated coal gasification facility in Kingsport, Tennessee.

The LPMEOH™ process has been developed to enhance integrated gasification combined-cycle power generation facilities by co-producing a clean-burning storable liquid fuel from coal-derived synthesis gas. The production of dimethyl ether (DME) as a mixed co-product with methanol will also be demonstrated. Methanol and DME may be used as a low-SO_2, low-NO_x alternative liquid fuel, a feedstock for the synthesis of chemicals, or new oxygenate fuel additive.

LPMEOH™ installation at Eastman Chemical Company

The process differs from other commercial methanol processes in that catalysis occurs in a liquid phase, which allows effective process heat removal. This feature permits the direct use of synthesis gas (derived from gasification of high-sulfur bituminous coal) as feed to the reactor without the need for phase-shift conversion.

The first stable operation of the unit at nameplate capacity of 80,000 gallons per day was achieved in April 1997 only four days after start-up. A test period at methanol production rates over 92,000 gallons per day revealed no system limitations.

During 1998 and 1999, the demonstration unit operated at an availability of over 99 percent. Operation at design catalyst loadings over 151 percent produced no indications of mass transfer limitations. Catalyst life has met or exceeded the design target. Since start-up, the demonstration facility has produced over 35 million gallons of methanol, all of which has been accepted by Eastman Chemical Company for use in downstream chemical processing.

A recent economic study of the LPMEOH™ process as an addition to an IGCC power plant indicates that cost-savings are realized when utilities manufacture and sell co-products: electricity and methanol. Costs compare favorably to those at new world-scale chemical-grade methanol plants.

Coal Fuel Selection Tool

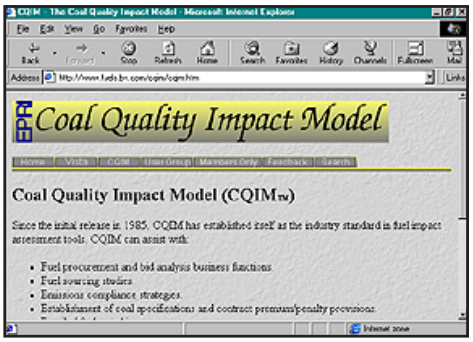
ABB Combustion Engineering, Inc. and CQ Inc. have demonstrated a computer model that provides coal-burning utilities with a predictive tool to assist in selecting optimum quality coal for a specific boiler, based on operational efficiency, cost, and environmental emissions. The Coal Quality Expert® (CQE®) model can predict the operating performance of coals that previously have not been burned at a plant. The CQE Acid Rain Advisor, released in 1993, is a stand-alone tool for utilities to evaluate planning and CAAA compliance strategies.

A CD-ROM containing CQE® software was issued in December 1995. The Electric Power Research Institute (EPRI) owns the software and distributes it to EPRI members for their use. CQE® is available to others in the form of licenses. CQ Inc. (EPRI's licensing agent) and Black & Veatch have each signed commercialization agreements that give both companies non-exclusive worldwide rights to sell users' licenses and to offer consulting services that include the use of CQE® software.

More than 35 U.S. utilities and one U.K. utility have received CQE® through their EPRI membership. Two modules of the Acid Rain Advisor valued at $6,000 have been sold. Proposals have been received from several non-EPRI-member U.S. and foreign utilities to license the software. It is estimated that CQE® saves U.S. utilities some $26 million.

The CQE® team has a Home Page on the World Wide Web (http://www.fuels.bv.com:80/cqe/ cqe.htm) to promote the software, facilitate communication between CQE® developers and users, and allow future software updates to be distributed over the Internet. The Web site also provides an on-line, updatable User's Manual. The site also helps attract the interest of foreign utilities as well as consulting firms.

In 1996, the Energy Secretary and the EPRI President recognized the CQE® project as the best of nine DOE/EPRI cost-shared utility research and development projects under the Sustainable Electric Partnership Program.



Contributing to Cleaner Industry

Clean Systems for the Nation's Basic Industries

- In addition to clean energy options for the electric power industry, the CCT Program is demonstrating technologies to address significant environmental issues and barriers associated with coal use in industrial processes.
- Coke production and use are critical environmental concerns to the steel industry because of associated pollutant emissions. The CCT Program is demonstrating approaches that either displace a portion of the coke or preclude the need for coke.
- Because production costs are largely driven by fuel cost, coal is often the fuel of choice in cement production. The drive to use indigenous coal often leads to burning high-sulfur coals.
- Benefits of the CCT Program in this area include:
  - Enhanced U.S. competitiveness in basic industries;
  - Cleaner industrial operations;
  - Exportable technologies; and
  - Lower consumer product costs through lower material costs.

At Bethlehem Steel's Burns Harbor facility, BFGCI is injecting coal and displacing coke, the primary blast furnace fuel and reducing agent, just about pound for pound. Elimination of the need for coke production also means there is a significant reduction in NO_x, SO_2, and air toxics emissions associated with the coke-making process. This new technology gives the steel industry a clearly superior economical and environmental alternative to the traditional coke oven.

Displacing Coke

At its Burns Harbor, Indiana site on Lake Michigan, the Bethlehem Steel Corporation has installed British Steel's Blast Furnace Granular Coal Injection (BFGCI) technology on two high-capacity blast furnaces.

BFGCI injects granular coal into the blast furnace in place of natural gas (or oil) as a fuel supplement. The injected coal also displaces coke, the primary blast furnace fuel and reducing agent, just about pound for pound. Elimination of the need for coke production also means there is a significant reduction in NO_x, SO_2, and air toxics emissions associated with the coke-making process. Because coal can displace up to 40 percent of the coke requirement, this coal injection technology has significant potential to reduce pollutant emissions and enhance blast furnace production.

Emissions generated by the blast furnace itself remain virtually unchanged by the injected coal. The gas exiting the blast furnace is clean, containing no measurable SO_2 or NO_x. Sulfur from the coal is captured by the limestone flux and bound up in the slag, which is a salable by-product. In addition, by maintaining high raceway temperatures, blast furnace production increases.

At Burns Harbor, the BFGCI is operating in a commercial mode on each of two units that process 7,000 net tons per day of hot metal. Coal injection design rates have been met or exceeded. A BFGCI system has recently been sold and installed at a similar facility owned by United States Steel Corporation.

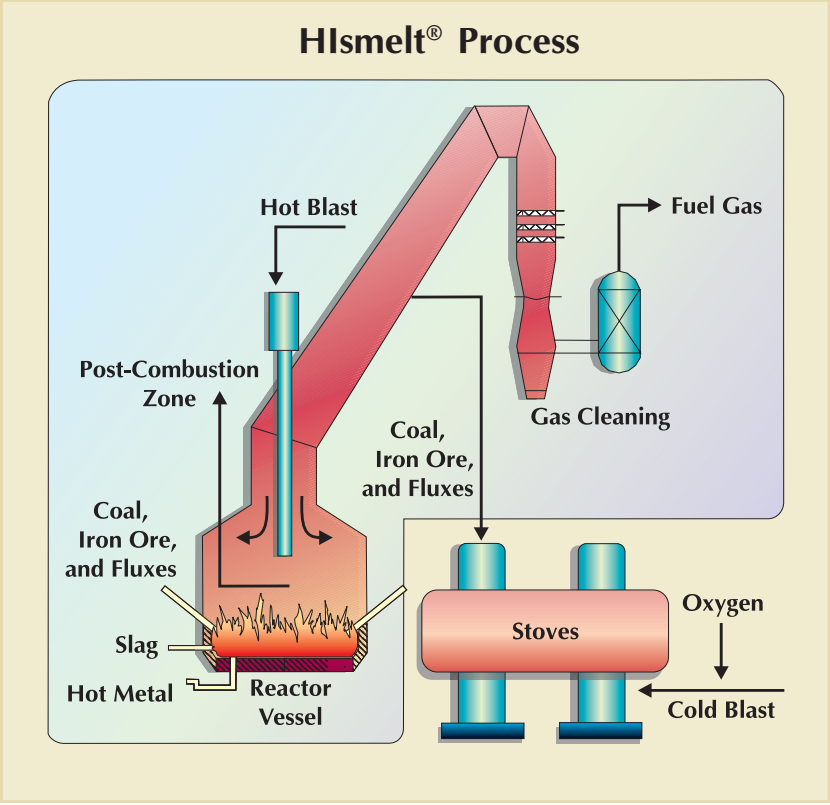
Eliminating Coke Use

The CPICOR™ Management Company is sponsoring a project to demonstrate the integration of a novel direct iron-making process with the production of electricity at Geneva Steel's mill in Vineyard, Utah.

From a number of options, CPICOR™ chose the HIsmelt® process because of its compatibility with western coals and raw materials. The direct iron-making process avoids altogether the need for coke production and thus eliminates emissions normally associated with coke ovens.

Approximately 3,300 tons/day of liquid iron will be produced along with 170 MWe of electric generating capacity. The integrated system includes a smelter with coal injection, which generates gas for use in drying and reducing iron ore. Sufficient heat is produced to melt the resulting iron. Excess reducing gas and recovered process heat go toward generating electric power in a combined-cycle power plant.

Construction is scheduled to start in late 2000 and continue to the spring of 2003. Operational testing will be conducted for approximately two years.



At Dragon Product's cement plant, the Passamaquoddy Technology Recovery Scrubber™ successfully demonstrated use of cement kiln dust, otherwise discarded as waste, to control SO_2 emissions, convert sulfur and chloride acid gases to fertilizer, return the solid by-product as cement kiln feedstock, and produce distilled water. No wastes are generated and the cement kiln dust is recycled.

Cement-Making Industry

At Dragon Products Company's 450,000 tons/year cement plant in Thomaston, Maine, the Passamaquoddy Tribe demonstrated an innovative clean coal technology that solved two environmental problems—air pollution and waste disposal—and, in doing so, the system paid for itself.

The successfully demonstrated Passamaquoddy Technology Recovery Scrubber™ uses cement kiln dust, otherwise discarded as waste, to control SO_2 emissions, convert sulfur and chloride acid gases to fertilizer, return the solid by-product as cement kiln feedstock, and produce distilled water. No wastes are generated and the cement kiln dust is recycled.

The innovative scrubber captured more than 90 percent of the plant's SO_2 emissions. The process also reduced particulate emissions to less than one-tenth the current limit for cement plants, reduced NO_x emissions by up to 25 percent, and produced no wastes, only salable or reusable by-products.

Savings on tipping fees for waste disposal, reuse of the waste products, and sale of the by-products not only offset costs but enable the cleanup system to operate at a profit.

For More Information

To learn more about the Clean Coal Technology Program, contact the U.S. Department of Energy at (301) 903-2624 or write the Office of Coal and Power Systems (FE-20), U.S. Department of Energy, Washington, DC 20585.

The following reports provide additional information about the CCT Program and clean coal technologies:

- ***Clean Coal Technology: The New Coal Era.*** A 40-page description of the different types of clean coal technologies and an overview of the joint U.S. government-industry demonstration program.
- ***Clean Coal Technology Demonstration Program: Program Update.*** An annual status report of the CCT Program with project-by-project descriptions and results achieved to date.
- ***Clean Coal Technology Demonstration Program: Project Fact Sheets.*** A mid-year status update on CCT projects.
- ***Clean Coal Today.*** Quarterly newsletter and annual index. Contains feature articles on recent project accomplishments, updates of project status, international activities, commercialization briefs, and relevant state activities.
- ***Topical Reports:*** Brief reports prepared at key stages in the projects.
- ***Project Performance Summaries:*** A 12-page project synopsis prepared for completed projects, highlighting operational, environmental, and economic performance.
- ***Annual Clean Coal Technology Conference.*** Technical papers presented during technical sessions and proceedings of papers presented during plenary and panel sessions.
- ***CCT Program Bibliography of Publications, Papers and Presentations.*** Identifies materials published on all CCT Program demonstration projects.
- ***Clean Coal Technology Program: Lessons Learned.*** Summarizes the programmatic and procedural lessons learned in conducting this unique and highly successful joint government-industry program.
- ***Clean Coal Technology Export Markets and Financing Mechanisms.*** A summary of the potential markets in developing countries for exporting clean coal technologies. Includes an assessment of financing mechanisms for preliminary activities and the construction of the project itself.
- ***Foreign Markets for U.S. Clean Coal Technologies.*** Presents an assessment and prioritization of foreign markets that have the most potential for the export of clean coal technologies that are developed, manufactured, or controlled by U.S. firms.

The Department of Energy's Office of Fossil Energy electronic information services:

- ***World Wide Web Home Page.*** Access to clean coal technology and other information via the Internet. The Fossil Energy Home Page (http://www.fe.doe.gov) offers general information and a gateway to more detailed information.
- ***Fossil Energy TechLine.*** An automated fax-on-demand system that provides news announcements on all ongoing clean coal technology projects and other information about federal fossil energy research, development, and demonstration programs. Call (202) 586-4300 from any touch tone telephone and follow the voice instructions. Call (202) 586-6503 for additional TechLine information.
- ***Computer Bulletin Board.*** Dial (202) 586-6495 via modem.
- ***CCT Compendium.*** Provides an electronic database, incorporating the CCT Program publications that can be accessed on the Internet (http://www.lanl.cov/projects/cctc).