Office of Fossil Energy, U.S. Department of Energy • DOE/FE-0215P-51 Issue No. 51, Fall/Winter 2002

CLEAN COAL TODAY

A Newsletter about Innovative Technologies for Coal Utilization

News Bytes

The U.S. Department of Energy has received 36 proposals for projects valued at more than $5 billion, in response to the **Clean Coal Power Initiative** solicitation. The projects are the first in response to President Bush's pledge to invest $2 billion in federal funding over the next 10 years to advance technologies that can help meet growing demand for electricity, while simultaneously protecting the environment. For this first solicitation, the government has offered approximately $330 million in matching funds. Selections are expected to take place in January 2003. Roughly half of the new proposals are for advanced methods of reduc-

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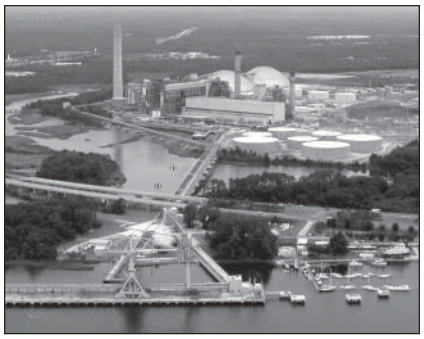
In This Issue

Powerplant Award, Multiple Visits Precede JEA Dedication

Two circulating fluidized-bed (CFB) combustors have received two prestigious awards, piqued the interest of both the U.S. Environmental Protection Agency (EPA) Administrator and the Lieutenant Governor of Florida, and prompted a national utility group to write a letter to President Bush in support of his Clear Skies Initiative. One CFB comprises the JEA clean coal technology demonstration project, which was dedicated on October 14, 2002.



Aerial view of JEA's Jacksonville, Florida facility

It is clear that the twin 300-MW CFBs in Jacksonville, Florida have been receiving attention since they initiated a start-up in February 2002 and began producing electricity in the late spring. One of the two boilers, Unit 2, was installed under a $74 million cost-share agreement with the U.S. Department of Energy (DOE). The DOE Clean Coal Technology Demonstration (CCT) Program is responsible for developing, testing, and demonstrating advanced, coal-based technology concepts. The other unit, Unit 1, is funded entirely by the host utility, JEA (formerly Jacksonville Electric Authority).

The technology will officially begin its two-year clean coal demonstration period in January 2003, and will yield data that will be of much interest to many organizations in the United States and abroad. In the CFB technology, crushed limestone is added to coal, removing 90 percent of SO_2. An added "polishing" scrubber will bring SO_2 removal up to 98 percent — the first ever to be used in conjunction with a CFB. The "slow burn," made possible by the fluid motion of the bed, also acts to minimize NO_x formation. Finally, the flue gas is sent through fabric filters to remove particulates.

The fact that the CFBs are a popular attraction is evidenced by the large number of visitors who have traveled to see the facility — 86 tours have been given since January 2000. Recently, from February through July 2002, there have been 24 delegations or representatives from government, community, media, or other utilities visiting the Northside Station.

The renovated facility also was heralded as the 2002 Powerplant of the Year by *Power*, a magazine that chronicles the progress of power-generation technologies. *Power* magazine highlights one new technology each year that

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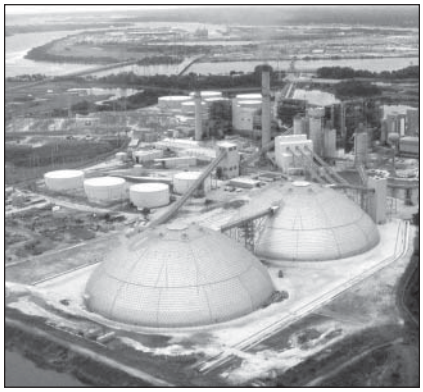
"JEA" continued...

exemplifies efficiency, uses innovative power-generation cycles to improve the economics of electricity production, or runs on "opportunity" fuels. The technology was selected because it represents "the development of a successful repowering strategy for converting existing oil/gas-fired steam plants to solid fuels to increase efficiency while reducing



Two 400-foot diameter aluminum geodesic domes for solid fuel storage at JEA Unit 2

both emissions and the cost of electricity." JEA, the nation's eighth largest municipal utility, was defined in *Power* as a trailblazer because it will burn petroleum coke and coal in what are believed to be the world's largest CFBs in commercial operation. The plant is equipped with the largest fuel-storage facility in the western hemisphere. The project also has been lauded by the Florida Engineering Society — Robert A. Dyr, JEA engineer and project manager, received the Technical Achievement Award 2002 for his work on the plant.

Accolades are not new for projects in DOE's CCT Program. The CFBs mark the sixth clean coal technology to receive the *Power* magazine award, considered to be the energy industry's most prestigious citation.

Prior to installation and operation of the CFBs, JEA had been using two oil and natural gas boilers (Units 1 and 2) at its Northside Station in concert with a 518-megawatt unit (Unit 3) to provide power to 380,000 customers. JEA provides water and wastewater services, along with electricity, to more than 1 million people in northeast Florida. The first two units were installed in 1966 and 1972, respectively, and operated on more costly oil and gas. In addition, Unit 2 was put in cold storage in 1983 because of boiler and reliability problems. All of that changed when the two units were repowered with CFBs.

While many utilities would like to reduce electricity production costs by using low-grade fuels, this is not an option for most traditional boilers. CFBs however, are very fuel-flexible, and are capable of running on a variety of solid and low-grade fuels (coal-fuel blends like coal/pet coke) while holding emissions to very low levels. In fact, the CFB units at JEA allow the plant to produce 2.5 times the power it did before the CFBs went on line, with a 10 percent reduction in air emissions. For every year they are operational, the CFBs are preventing a quantity of NO_x emissions equal to what would have been emitted by 19,000 average-size cars.

"CLEAR SKIES" FOR CFBS

Although the CFB technology predates the President's Clear Skies Initiative by years, it answers the Clear Skies summons to dramatically lower SO_2, NO_x, and mercury emissions. Clear Skies is a cleanup approach anchored in promoting technological advancements that will make deep reductions in power plant emissions from 2000 levels by 2020. Nationwide, the Clear Skies Initiative promises to cut SO_2 emissions by 73 percent from 2000 standards, NO_x output by 67 percent, and mercury emissions by 69 percent.

The multi-pollutant control capabilities of CFBs prompted EPA Administrator Christie Whitman, accompanied by Florida Lieutenant Governor Frank Brogan, to tour the Northside Station on September 27, 2002. JEA also received a letter from the Large Public Power Council (LPPC), composed of representatives of the 24 largest power systems in the United States, that supports the Clear Skies Initiative. In their letter to the President, the group promised to "...stand ready to work with you and the Congress ... to pass balanced, multi-pollution legislation for the power generation sector."

Referring to JEA as "an impressive facility that is generating electricity with some of the cleanest coal technologies in the world," Ms. Whitman applauded the LPPC for its support. "Only by working together can we ensure the continued stewardship of our country's precious natural resources and a future of cleaner air, purer water and better protected land for ... future generations."

Rita Bajura, Director of DOE's National Energy Technology Laboratory, was on hand two weeks later at the dedication ceremony held October 14, 2002. "It is this type of technology that can help the United States meet its future power needs in terms of cost and emissions," observed Ms. Bajura. "The CFBs also represent the best that can be achieved when the federal government and private industry work together to reach a common goal."

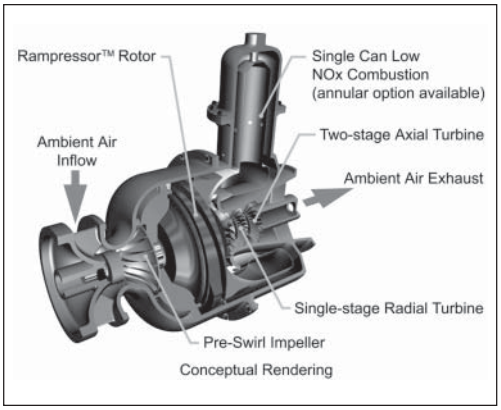
Bajura was among other officials to recently view the facility, which has generated interest from at least six nations including Canada, England, Hungary, China, Korea, and South Africa. According to one JEA official, some countries are interested because of JEA's fuel flexibility, while others are more interested in environmental performance.

RAMGEN DEMONSTRATING NEW TURBINE CONCEPT

The U.S. Department of Energy (DOE), in partnership with Ramgen, is moving closer to bringing efficiencies inherent in ramjet propulsion technology to stationary power generation through an emerging turbine technology. Ramjets use supersonic shock waves, in lieu of direct mechanical means, to rapidly and efficiently compress the large volumes of air needed for high-energy combustion. In the Ramgen power generation technology under development with DOE support, supersonic shock waves are produced by high-speed rotation of a disk that has raised elements equally spaced around the periphery and extending across the disk thickness. The raised elements are shaped to most effectively impart the shock waves, much like the stationary nose in a ramjet.

The initial Ramgen design incorporated combustion and thrust nozzles on the disk periphery, along with the compression elements, to power the unit. While this design proved the feasibility of the concept, a simpler modular design emerged from a "blue ribbon" design review in the spring of 2002. Participating in the design review were eminent scientists and engineers from DOE, the U.S. Department of Defense, and the National Aeronautics and Space Administration. The Ramgen design decouples compression and combustion for a modular configuration where the combustor is no longer on the rotating disk, but rather in a stationary mode. It uses trapped vortex combustion principles for flame stability and low-NO_x emissions (see Vortex Combustor article, *Clean Coal Today* Spring 2002). Single-digit NO_x emissions as low as 5 parts per million are projected, enhancing the system's value in view of increasingly tough emission regulations. Also, the revised design uses a standard gas turbine power unit to generate power and drive the compressor disk.

The newly designed Ramgen Turbine engine (shown conceptually in the figure below) offers a number of advantages over conventional turbine design. The new Ramgen design significantly reduces technical complexity and risk, and the time and cost of developing a commercial unit. Market entry manufacturing costs are estimated at a competitive $300/kW. A Ramgen Turbine engine is expected to be tested in 2003 and demonstrated in 2004. Market acceptance is improved by limiting major design changes to a single component — the compressor. Removing the combustor from the rotating disk enables the Ramgen technology to be applied to smaller units (down to 300 kW). The size range projected is 300 kW to 8,000 kW based on scalable mass flow rates. A separate combustor allows both gas and liquid fuels to be used, and expands the market for Ramgen technology by being able to offer the compressor alone as a dual component product (compressor and turbine).



The Ramgen Turbine engine has the potential to be up to 10 percent more efficient than a conventional gas turbine unit at comparable compression ratios (10:1 to 30:1). For smaller units, the efficiency gain can be far greater because the Ramgen Turbine engine can generate high compression ratios even at the smaller sizes, while conventional gas turbines cannot. The difference lies in efficiency of compression. Conventional turbine compressors rely on thousands of turbine and stator blades to axially compress incoming air through flow turning (50 percent of the energy) and direct action of the turbine blades on the air. The leading edges of the thousands of turbine and stator blades produce large viscous drag losses. The Ramgen compressor does not use flow turning and has few leading edges.

It is estimated that a 300-kW Ramgen Turbine engine can operate at nearly 40 percent efficiency in a simple cycle mode. Comparably sized commercial gas turbine units have simple cycle efficiencies of approximately 28 percent. Moreover, the Ramgen Turbine engine offers inherent cost and maintenance advantages by replacing thousands of blades in a multi-stage axial compressor with a single-piece machined disk.

The performance advantages offered by Ramgen, particularly in the small size range, combine with compactness of the unit and low cost to make it an ideal candidate for distributed generation applications — applications at or near customer sites — for enhanced reliability and power quality. A 400-kW Ramgen Turbine is one-third the length and one-half the height of a conventional turbine of comparable capacity and the projected $300/kW manufacturing cost makes it highly cost competitive. Moreover, Ramgen Turbines offer the advantage of being able to operate on dilute fuels like landfill gas, coalbed methane, and coal- and waste-derived synthesis gas.

FIRST PPII PROJECTS SUCCESSFULLY NEGOTIATED

Agreements for two important projects selected for negotiation under the Power Plant Improvement Initiative (PPII) have recently been fully implemented. The technologies being developed offer particulate matter reduction as well as other environmental benefits. Otter Tail Power Company has installed a first-of-a-kind hybrid device — the Advanced Hybrid Particulate Collector (AHPC) — capable of removing 99.99 percent of particulate matter from coal-fired power plant flue gas. In another project, Tampa Electric Power Company will demonstrate "Neural Network-Based Sootblowing Optimization." Following the 2001 brownouts and blackouts primarily in California, the PPII was initiated by the U.S. Department of Energy (DOE) (and implemented by the DOE Office of Fossil Energy's National Energy Technology Laboratory) to target new technology that could help coal plants improve their efficiency, environmental performance, or cost competitiveness.

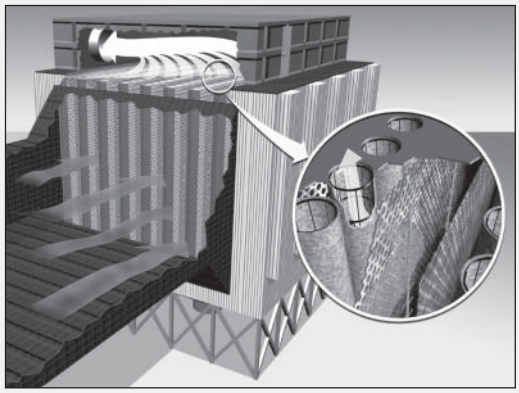
Under the first PPII cooperative agreement, Otter Tail will receive $6.5 million from DOE. The Otter Tail Power Company, headquartered in Fergus Falls, Minnesota, and W.L. Gore & Associates of Newark, Delaware, will fund the balance of the $13.4 million retrofit project to be located at the 450-MW Big Stone Plant near Milbank, South Dakota. DOE will provide $900,000 for the Neural Network Project at Tampa Electric's Big Bend Power Plant, while Tampa Electric will contribute the remaining $1.5 million.

OTTER TAIL'S HYBRID PARTICULATE COLLECTION

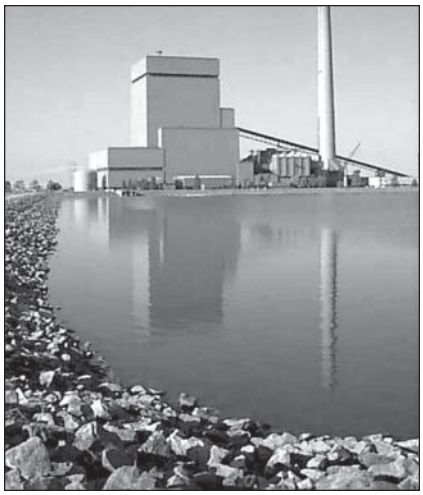
AHPC (being marketed by W.L. Gore and Associates under the trade name of Advanced Hybrid™ Filter) combines the most successful features of fabric filtration and electrostatic precipitators in the same housing. This combination provides ultra-high collection efficiency for even the finest of particles. The concept was originally developed at the University of North Dakota's Energy and Environmental Research Center (EERC), and successfully tested at Otter Tail's Big Stone Plant via a 2.5-MW scale slipstream. With this technology, the Big Stone Plant could become the lowest particulate emitting coal-fired power plant in the world, with emissions at 0.007 lb./MMBtu or lower. This rate is four times cleaner than that required by current law.

As the U.S. Environmental Protection Agency (EPA) considers tightening standards for $PM_{2.5}$, emergence of the new hybrid is particularly timely. Currently, 75 percent of the national ESP inventory on coal-fired boilers is over 20 years old and some are operating at marginal performance levels. There is a growing number of power plants being derated because the existing ESPs cannot provide necessary fine particulate removal to meet opacity requirements at peak load. The new hybrid also has the advantage of being smaller and thus can retrofit or convert existing equipment into the Advanced Hybrid™ design. It can operate on any coal, overcoming dust capture/resistivity problems currently associated with Powder River Basin coals. Trace elements such as mercury also have the potential to be controlled, via use of an appropriate sorbent. Mercury control is not part of this demonstration project.

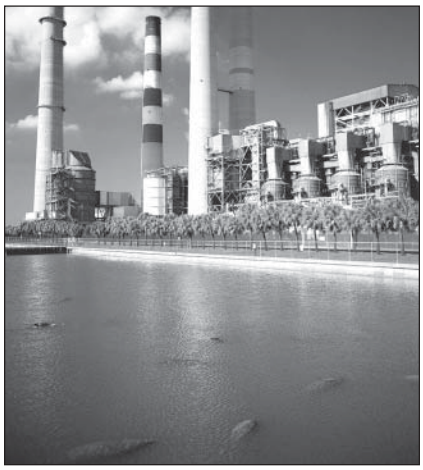
The new hybrid improves both the baghouse and particulate concepts. Baghouses operate like vacuum cleaners and use fabric filters to trap and separate particles from the combustion gases. Electrostatic precipitators rely on charged electrodes to create an electric field that charges particles in the gas stream, so that the charged dust particles cling to grounded collection plates. In the AHPC, approximately three out of every four rows of bags are removed from a conventional baghouse configuration, and a set of grounded perforated plates is placed between adjacent remaining rows of bags. High-voltage corona rigid discharge electrodes are installed between each set of plates. Particles are collected on either the grounded plates or the filtration surface, and the dust is transferred to a collection hopper (see figure above). The alternating rows



Particulate-laden flue gases flow into the AHPC between the vertical collection plates. After giving up most of the particles to the plates, the gases are directed, through holes in the plates, to the GORE-TEX® filter bags where more particles are collected. The cutaway depicts a set of collection plates and electrodes sandwiched between two rows of filter bags.



The Big Stone Power Plant near Milbank, South Dakota is a 450-MW cyclone boiler firing Powder River Basin coal



Tampa Electric's Big Bend station has four pulverized coal electric generating units. The project is to apply the NN-ISB system to Unit #2, a 445-MW wet bottom unit firing high-sulfur eastern bituminous coal

of bags, plates, and discharge electrodes act as an electronic trap to prevent the re-entrained dust from being re-collected on the same bags. The plates prevent the dust from being re-collected on adjacent rows of bags. Ultrahigh fine-particle collection is achieved by removing as much as 90 percent of the dust before it reaches the fabric filters. A GORE-TEX® membrane fabric collects, with high-efficiency, the particles that reach the filtration surface. This combination of ESP components and fabric filtration allows the AHPC to operate at 2.5 to 4 times the face velocity or throughput of a conventional pulsed jet baghouse.

Startup, which began in October 2002, has proceeded according to plan, with the plant successfully reaching full load operation. The demonstration will run to November 2004. Even though stack opacity readings have been in the 1–2 percent range, or below the reliable accuracy of the existing opacity measurement device, optimization of operating parameters continues. The Energy & Environmental Research Center Foundation holds the patent for the technology, and W.L. Gore (makers of GORE-TEX®) holds an exclusive license to sell the technology to the utility sector.

BIG BEND EMPLOYS "INTELLIGENT" SOOTBLOWING

The Tampa Electric Company's Big Bend Plant's Neural Network Sootblowing System will employ "intelligent" sootblowing in conjunction with state-of-the-art controls and instruments to optimize the operation of a utility boiler and systematically control boiler fouling. Fouling within the boiler from ash and slag formation and deposition adversely affects the rate at which heat is transferred to the working fluid (water or steam). Fouling also leads to poor efficiencies because useable heat that normally would be transferred to the working fluid remains in the flue gas stream and exits to the environment. This loss in efficiency translates into higher consumption of fuel for equivalent levels of electric generation, and increased gaseous emissions.

With current equipment, it is unrealistic for a control room operator to optimize sootblowing to simultaneously address the objectives of heat rate improvement *and* NO_x and particulate reduction. Computerized sootblowing systems used to date have provided impressive results; however, they have not taken the systems to their logical conclusion through the use of neural network control and state-of-the-art boiler and slag monitoring equipment. The Big Bend neural network sootblowing system will collect hundreds of "real time" data inputs to assess the operating condition of the unit and determine how best to achieve performance goals. The system is designed to recognize soot buildup and manage the sequence of cleaning based on actual real-time needs. Moreover, it can detect which specific sections of the boiler need cleaning and will activate blowers accordingly.

Neural networks have established themselves in a variety of industries to satisfy multiple goals or objectives in highly complex systems. These intelligent computer systems have the ability to "learn" extremely complex relationships and trends between literally hundreds of input variables and then determine what control parameter changes are necessary to achieve the predetermined goals.

The sootblowing system was installed during a recent scheduled plant outage. The plant was again started up in late December 2002, and sootblower system testing and integration are planned for early January 2003.

These first projects selected under the PPII support the underlying premise of the Initiative that the United States will continue to rely on fossil fuels for a major share of its electricity, transportation fuels, and chemicals well into the 21st century; and that research and development to resolve energy and environmental issues can find affordable ways to make energy conversion systems meet strict environmental standards.

OHIO, A PARTNER IN CLEAN COAL

The research, development and deployment of advanced technologies to improve environmental performance and power generation of the existing fleet of coal-based electric power plants, as well as the development of ultra-clean, super efficient plants of the future is an undertaking that demands many dedicated partners in the private and public sectors. The Ohio Coal Development Office (OCDO) is one of these partners.

The Ohio Coal Development Office, located in the Ohio Department of Development, was created in late 1984. Its primary purpose is to support the research, development and deployment of emerging technologies that can use Ohio's vast reserves of high-sulfur coal economically and within environmental limits. OCDO's projects are funded by the sale of general obligation bonds. OCDO may have up to $100 million in debt outstanding at any one time. As the debt is retired, usually a 10-year cycle, the bonds may be reissued.

Over the course of its history, OCDO has co-sponsored nearly 300 projects, with a total commitment of approximately $164.2 million in state funds, and approximately $173.6 million in federal and $335.3 million in private-sector contributions. OCDO can fund projects ranging from applied research all the way up to the first installations of new, advanced technologies. Cost share is required, as is remuneration to the state should the technology result in a commercially successful product. OCDO is overseen by a 13-member Technical Advisory Committee, which reviews the Office's policy and projects and makes funding recommendations.

The majority of OCDO's lab-based, applied research projects emerge from its Ohio Coal Research Consortium. The Consortium includes five universities that are actively engaged in various aspects of coal R&D: Case Western Reserve University, Ohio University, Ohio State University and the Universities of Akron and Cincinnati. Projects in the consortium cover a range of topics, such as sulfur capture; nitrogen oxide and air toxics removal; development of new, more effective sorbents; carbon dioxide capture and sequestration; and cleanup of hot flue gases. Several patents have emerged from this work, as have numerous new, advance-degreed engineers now working in the power and related U.S. industries.

While OCDO has a larger census of smaller applied research projects, OCDO's top priority is the larger-scale demonstration and deployment of projects that can cleanly, efficiently and cost-effectively use high-sulfur coal. Although it is somewhat difficult to determine, Ohio may well have constructed more clean coal technology pilot and demonstration projects than any other state engaged in coal R&D, and it is in this category that the majority of OCDO funds are dedicated. Currently, several completed, former OCDO projects remain on-line and operating, contributing to the clean use of coal in Ohio. A 50-MW slipstream, multi-pollutant control technology demonstration designed to reduce sulfur dioxide, nitrogen oxide, mercury and particulates is under construction at a power plant along the Ohio River. In another major project, demonstrations of additives to enhance the capture of mercury in wet flu gas desulfurization scrubbers are underway at two electric utilities. These are just a few examples of successful OCDO funded projects.

Demonstrations can also include field work initiatives, such as the examination of terrestrial carbon sequestration on recently reclaimed surface minelands or personal exposure in a discrete population to fine particulate matter.

OCDO's program looks at the use of coal in a holistic manner, incorporating the cost of coal utilization byproducts (CUBs) into the R&D mix with the goal of turning a byproduct into a value-added product. Consequently, OCDO has supported numerous projects involving safe uses of CUBs in highway and civil engineering applications, mine reclamation activities and agricultural uses. More than 200 livestock feedlots have been installed using CUBs, along with several highways and embankments, holding ponds and synthetic liners for wetlands. Much of this work was facilitated by Ohio State University's Coal Utilization By-Products Extension effort, supported by OCDO. Even more exciting is the use of coal ash in the formation of aluminum metal composites and foams. These hybrids are similar in strength to regular aluminum, but lighter weight and with improved "crush" properties. These last two qualities can improve fuel efficiency and safety in trucks and cars, making the coal ash/aluminum product of significant interest to the automotive industry.

OCDO projects also investigate the use of coal as a feedstock, as well as a fuel. One promising technology is using a small, pilot-scale high-sulfur coal gasifier to produce carbon nanofibers. Carbon nanofibers have numerous uses in advanced lightweight, high-strength applications from the automotive to the aerospace industry. Currently, commercial orders for the product exceed the production capacity.

A hallmark of OCDO's larger projects is that they usually include numerous participants. These typically include one or more private sector companies, often at least one federal agency, and sometimes a university. Such collaborations are specifically encouraged in OCDO's public solicitations. One notable example is a consortium of four U.S. boiler manufacturers, a national research institute, a not-for-profit entity experienced in metallurgy, OCDO and U.S. DOE, all of which are engaged in the development of ultra super critical materials necessary for the advanced power plant designs anticipated by 2020. This consortium is also drawing upon specific research expertise found at Ohio universities and metallurgical research centers, as well as a military base.

OCDO released it's latest solicitation in October, with a deadline for letters of intent/time extension of January 10, 2003. The solicitation and its requirements can be accessed at: http://www.odod.state.oh.us/tech/coal/html/rfprelease.htm.

Guest article prepared by Jacqueline F. Bird, Director, Ohio Coal Development Office

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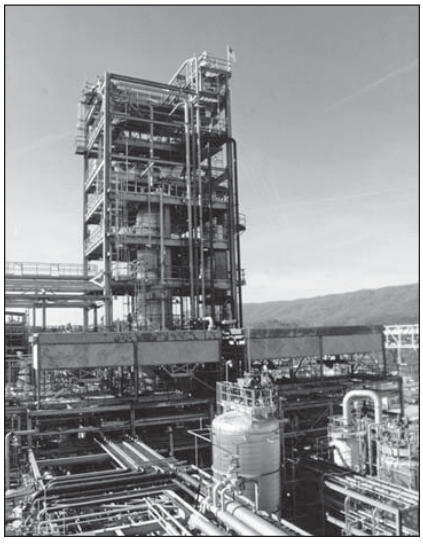
"News Bytes" continued...

ing sulfur, nitrogen, and mercury pollutants, either by cleaning the exhaust gases of coal boilers or converting the coal into clean-burning gas. Other proposals include co-production, upgrading coals, by-product use, and improved instrumentation and controls.

High, on-stream availability continues to be the signature trademark of **Air Products Liquid Phase Conversion Company, L.P.'s Liquid Phase Methanol (LPMEOH™) Process Demonstration Project** located in Kingsport, Tennessee. For the fourth time in its history, the LPMEOH™ Process Demonstration Unit enjoyed an uninterrupted period exceeding 50 days of stable, trouble-free operation. Previous uninterrupted periods of 94, 65, and 55 days were logged in October 1998, April 1998, and May 2002, respectively. Overall availability now approaches 98 percent. Since startup in April 1997, the LPMEOH™ Process Demonstration Unit has produced over 100 million gallons of methanol, all of which was accepted by Eastman Chemical Company for use in downstream chemical processes. Stable operation and optimized production, using temperature programming, is now the main thrust of the program.



NETL Director Rita A. Bajura was awarded the 2002 Pittsburgh Coal Conference Award for Innovation in Coal Conversion. Bajura is the 19th recipient of this award, and the first woman among the recipients. CONSOL Energy, Inc. sponsors the award for individuals who have made recent significant contributions to new technologies, procedures, and policies in coal utilization.

In November 2002, DOE signed a cooperative agreement with **Universal Aggregates** of Bridgeville, Pennsylvania for design, construction, and operation of a lightweight aggregate manufacturing plant at the Mirant-Birchwood Power Plant in King George, Virginia. The technology turns spray dryer ash and bottom ash into lightweight aggregates for masonry blocks or concrete. Ground breaking is scheduled for January 27, 2003.

UPCOMING EVENTS

— February 20–21, 2003 —
Valuing Externalities Workshop
Sponsor: NETL
Location: McLean, VA
Contact: Kimberly Yavorsky
Phone: (412) 386-6044
Email:
kimberly.yavorsky@netl.doe.gov

— February 26–27, 2003 —
Gas Turbines for a National Energy Infrastructure
Sponsor: NETL
Location: Arlington, VA
Contact: Kimberly Yavorksy
Phone: (412) 386-6044
Email:
kimberly.yavorsky@netl.doe.gov

— April 15–16, 2003 —
4th Annual Solid State Energy Conversion Alliance Workshop
Sponsor: NETL
Location: Seattle, WA
Contact: Kimberly Yavorsky
Phone: (412) 386-6044
Email:
kimberly.yavorsky@netl.doe.gov

— May 5–8, 2003 —
Second National Conference on Carbon Sequestration
Sponsor: DOE and NETL
Location: Alexandria, Virginia
Contact: Kimberly Yavorsky
Phone: (412) 386-6044
Email:
kimberly.yavorsky@netl.doe.gov

INTERNATIONAL INITIATIVES

CHINA EETC WORKSHOP AND PLANT TOURS

In September 2002, the U.S./China Energy and Environmental Technology Center (EETC) hosted a workshop and plant tours, both in Pennsylvania, with the purpose of promoting information exchange between U.S. and Chinese coal researchers, technology developers, and vendors. EETC was established in 1997, and is run jointly by Tsinghua and Tulane Universities, with funding from the U.S. Department of Energy. The EETC mission is to enhance competitiveness of U.S. clean coal technology (CCT), equipment, and services.

The "Clean Energy Opportunities in China" workshop, attended by over 70 participants, was held on September 6, 2002, at Lehigh University in Allentown, Pennsylvania. U.S. participants gave presentations on a range of technologies thought to be of interest to the Chinese. These technologies included coal preparation, flue gas desulfurization (FGD), limestone sourcing and processing, circulating fluidized-bed (CFB) combustion, and integrated gasification combined-cycle systems. Of particular interest were the issues associated with expanding China's coal-fired generation capacity base, improving emissions performance of Chinese plants, and satisfying the Beijing Green Olympics program. It is anticipated that China will invest billions of dollars to improve Beijing's air quality in preparation for the Olympics (see *Clean Coal Today* Spring 2002).

Chinese participants discussed the overall need to restructure the country's utility industry. The Chinese State Power Corporation is in the process of being dismantled. Ultimately, generators may have to compete in the power market. In the near- to mid-term, necessary investment in the power sector could total some tens of billions of U.S. dollars, representing a significant potential export market for U.S. technology. New coal preparation capacity is also needed.

In a separate activity, EETC hosted plant tours for representatives of the Zhejiang Provincial Energy Group (ZPEG) and the China Coal Research Institute (CCRI). ZPEG is in the process of becoming an independent power producer, and has $3.8 billion in generating assets, using some 50 million metric tons of coal/year. One of ZPEG's plants has a U.S.-made FGD system under construction. CCRI has over 5,000 employees and is actively involved in a wide range of technology development activities related to coal production and use, and in particular, coal preparation and mine fire abatement.

The primary focus of the tour was to show the Chinese visitors American technologies and explain business practices related to power generation from coal and its sale in a deregulated market. Eco-industrial development with clean coal technologies was an important area of emphasis.

In Homer City, Pennsylvania, the group visited the Homer City Coal Cleaning Plant, a facility using dense medium cyclones and operated by CLI Corporation. At Colver, Pennsylvania, at the Greystone Materials processing plant, the group examined the processing of limestone for desulfurization. This facility is located adjacent to the Colver 100-MW CFB power plant, operated by AC Power Operations, and is fired with local coal waste. Discussions at the Greystone plant covered technologies for processing limestone, as well as American practice of identifying resources of stones for cost-effective operation.

Near Frackville, Pennsylvania, the group toured the eco-industrial complex of Waste Management Processors, Inc. (WMPI) and its affiliated power plants, Gilberton Power Company (GPC) and Schuylkill Energy Resources (SER). The GPC facility is an 80-MW CFB power plant, which came on line in 1987. The SER facility, also an 80-MW CFB plant, went on line in 1989. Both of these facilities serve as hosts for a unique set of eco-industrial businesses, which have been developed to produce useful materials from coal by-products.

The WMPI presentation included developments in the production of concrete products from CFB ash and preparation plant refuse. The group also discussed the utilization of CFB ash and bio-solids to re-vegetate

environmentally damaged land. Later, the group toured the fish farm where tilapia are produced that is hosted by the SER plant.

The group was hosted by the Hunlock Station of UGI Corporation, a Pennsylvania-based electric and gas utility located near Wilkes-Barre, Pennsylvania. Hunlock features a 50-MW pulverized coal plant designed for anthracite firing, as well as a recently installed combustion turbine plant. The Hunlock plant is capable of firing a wide range of fuels, including bituminous coal and fuel recovered from anthracite coal waste. UGI has developed an efficient low-cost fuels and operations management system capable of being responsive to increasingly stringent emissions regulations.

Hu JinChao (left), CEO of the Zhejiang Provincial Energy Group, and John Rich, CEO of Gilberton Power Company, at the tilapia fish farm

Following the plant tours, the group was hosted by the UGI Electric Division for discussions on the business implications of a deregulated utility market. The tour concluded with a combined presentation by the PJM Interconnect (the Mid-Atlantic Regional Independent System Operator) and the Pennsylvania Public Utility Commission. The presentation discussed the evolution of the PJM Interconnect LLC, as well as the broader subject of the ISO systems in the United States. The Pennsylvania Public Utility Commission gave a presentation on the successful electric utility deregulation program in Pennsylvania.

The workshop and plant tours made an important contribution to collaborative work between China and the U.S. in clean coal technologies. EETC is also continuing its joint work with DOE in reducing emissions from stoker-fired boilers in China, and in Beijing's air quality improvement program in anticipation of the 2008 Olympics.

CLIMATE TECHNOLOGY AWARD GOES TO NETL PARTNER

India's Centre for Power Efficiency and Environmental Protection (CENPEEP), an active partner in NETL climate change mitigation activities, has received the "2002 Climate Technology Award." This award was presented at the eighth session of the Conference of Parties of the United Nations Framework on Climate Change, held in late October 2002 in New Delhi, India. The CENPEEP was established in 1994 by India's National Thermal Power Corporation (NTPC) to implement the Efficient Power Generation component of the Greenhouse Gas Pollution Prevention (GEP) project, an initiative of the U.S. Agency for International Development.

Mr. B. N. Ojha (left), Director of Operations, NTPC, receives the "Climate Technology Award"

The award is given every year by the Climate Technology Initiative (CTI). The European Commission and 23 IEA/OECD countries launched CTI at the COP 1 in Berlin in 1995. CTI's mission is to foster international cooperation for accelerated development of climate-friendly technologies and practices. CENPEEP was selected for its accomplishments in promoting climate-friendly technologies in developing countries, and specifically reducing greenhouse gas emissions from coal-fired power generation in India.

Under the GEP, NETL provides technical assistance and training support to the CENPEEP in a variety of areas. New technical initiatives include a mine-mouth coal washery to demonstrate the benefits of using washed coals in pit-head power generation; mine backfilling of coal-derived ash to demonstrate the benefits of large-volume ash utilization and abandoned mine land reclamation for afforestation (converting bare or uncultivated land to forest); evaluation of integrated gasification combined-cycle (IGCC) technology for significant thermal efficiency improvements in new coal-based power generation; and regional centers for CENPEEP to expedite heat-rate improvements in additional power plants.

IGCC BRIEFINGS COMPLETED UNDER U.S.-CHINA PROTOCOL

As a project under the U.S.-China Protocol signed in August 2001, IGCC briefings took place last summer. The project was sponsored as part of the Annex I/Power Systems project task agreement. The Tampa Electric IGCC Project and DOE's PSDF Facility in Wilsonville, Alabama hosted the 11-member Chinese delegation. The delegation consisted of key staff from the State Power Corp., Shandong Power Group, Huabei Design Institute, Thermal Power Research Institute, the Ministry of Science and Technology, and the Yantai Power Group. The Yantai Power Group plans to add an IGCC unit fueled by indigenous high-sulfur coal at its existing plant in Shandong Province. The group viewed presentations by TECO, Southern Company Services, Chevron/Texaco, and General Electric.

Tampa Electric IGCC project in Lakeland, Florida

PSDF facility in Wilsonville, Alabama

The briefings were particularly timely because China had issued a solicitation for bids for the 300- to 400-MW Yantai project and acquired information helpful in evaluating U.S. technology bids. The Chinese government has, in fact, authorized two IGCC operations, but a second would depend on the success of Yantai. Construction of the Yantai IGCC is expected to begin in spring 2003 and should be completed two years later.

The Chinese visitors expressed particular interest in building their own IGCC simulator, using U.S. technology, for training operators on site. To this end, an additional Protocol task is being developed. In addition, EETC is working with SPC on an application for World Bank Global Environmental Facility Funding. Jiang Zhesheng, Vice Director of SPC and delegation head, raised the possibility of joint research between China's Thermal Power Research Institute and PSDF, in the Annex V, Climate Science area.

Following the DOE-sponsored briefings, the Chinese delegation visited Bechtel Corp., in Houston, Texas, and EPRI in Palo Alto, California.

IEA COMMITTEE DISCUSSES PROGRESS UNDER MULTIPHASE FLOW AGREEMENT

More than 25 years of successful International Energy Agency (IEA) collaboration in the development and analysis of energy technologies have created a network of experts who have contributed to the IEA's goals of energy security, economic growth and environmental protection through a strong R&D focus. As part of this activity, the U.S. Department of Energy (DOE) is signatory to the IEA Implementing Agreement on Multiphase Flow (MPF) Sciences. The MPF Executive Committee gathered at the DOE Office of Fossil Energy (FE) National Energy Technology Laboratory (NETL) in September 2002 for its annual meeting. Australia, Canada, Mexico, Norway, and the UK are co-participants with the United States. The goal of the meeting was to exchange information and coordinate complementary research tasks, which are undertaken separately by the signatory countries.

MPF is any mass flow phenomena associated with obtaining energy from fossil fuels, wherein some combination of solids, liquids, and gases is involved. MPF relates to all aspects of fossil fuel systems such as fuels, processes, or equipment (i.e., coal slurries, granular flow in silos, or slurry bubble column reactors). Improved knowledge of multiphase flow can lead to more efficient and cost-effective energy production, transportation and end-use technologies. In coal-related research, emphasis has been on granular material flows, theory and computer codes for modeling, and advanced instrumentation for measuring and characterizing flow behavior. The Agreement is also facilitating information exchange in transport and handling of pulverized coal in power stations and emulsions of crude oil in water. In one success story, the group has been sharing information from on-line analyzers based on neutron-induced gamma radiation, to measure fuel heating value, and ash and sulfur content. Through joint efforts, ultrasonic particulate flow meters have also been installed in several power stations in Australia, and can be monitored remotely.

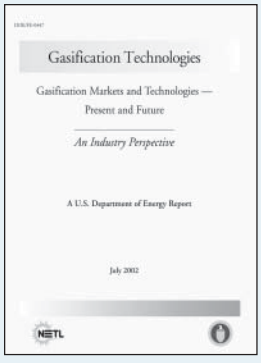
Delegates at the meeting had an opportunity to see a demonstration of the NETL-developed MFIX computational fluid dynamics code for the simulation of heavily loaded gas-particle flows, and specifically fluidized beds. MFIX allows the simulation of gas-particle hydrodynamics and heat transfer with chemical reactions. (MFIX can be accessed on the internet at www.mfix.org.) The code has been applied to simulate many processes in DOE's Office of Fossil Energy programs. MFIX development also has been supported by DOE's Multiphase Fluid Dynamics Research Consortium (www.mfdrc.org), operating under the DOE Energy Efficiency Office of Industrial Technology program. Through this effort, MFIX is applied to enhance the use of computational fluid dynamics in the simulation of chemical processes. Illustrative of international collaboration, a Norwegian PhD candidate is working at NETL, studying simulation of gas/solid fluidized beds.

NETL Director Rita Bajura (center), and NETL personnel at Morgantown's Cold Flow Circulating Fluid-Bed unit

Also of interest to the visitors was the Cold Flow Circulating Fluid-Bed unit (see photo above), where validation experiments are performed to improve reliability and accuracy of computer models needed for new fluid-bed process design and optimization. The Cold Flow unit is capable of simulating fully integrated operations for solids transfer and control systems common to many advanced coal-fired power systems, such as advanced pressurized fluidized-bed power trains, and IGCC plants. NETL's objective is to further the development of circulating fluid-bed systems through validation of computational fluid dynamics models, analysis of existing plants, optimization of plant operations, and evaluation of new designs.

In all, the recent MPF meeting facilitated valuable information exchange among IEA members pursuing research.

GASIFICATION MARKETS AND TECHNOLOGIES REPORT



DOE has published "Gasification Markets and Technologies — Present and Future," providing an industry perspective on issues critical to commercial development and deployment of gasification technology. The report reflects a representative cross section of views from a complex and diverse gasification industry. Interviews were designed to elicit an industry perspective on gasification markets between now and 2015, and to obtain industry expert insights on critical near- and long-term technology research and development needs. Representatives of the Gasification Technology Product Team at DOE's Office of Fossil Energy and National Energy Technology Laboratory met with 22 organizations, including equipment developers and manufacturers, energy companies, chemical companies, power generators, research and development and trade institutions. The team spoke to a variety of executives, researchers, project development, and operational management personnel.

The report addresses such topics as market definition and drivers, environmental issues, and technology needs for all gasification technology systems, and suggests an appropriate government role and incentives. A comprehensive discussion is provided on issues relevant to technology deployment, although consensus is not necessarily reached on issues, nor are the appropriate parties identified to address defined needs. DOE is evaluating the data provided from the interviews and is incorporating report findings into its ongoing gasification technology roadmap development effort. The report can be found at www.netl.doe.gov/coalpower/gasification.

WEYBURN DEMONSTRATING NEW CO_2 STORAGE, MONITORING, AND VERIFICATION TECHNIQUES

CO_2 injector

Well testing facility, above

Oil producing wells (above and right)

Through a recently signed bilateral agreement between the U.S. Department of Energy (DOE) and Natural Resources Canada, DOE is joining the world's first large-scale project to monitor the capacity, movement, and fate of CO_2 injected into a depleting oil reservoir geological formation for purposes of permanent storage — the Weyburn CO_2 Sequestration Project. The project, located at an enhanced oil recovery operation in southeastern Saskatchewan, is being facilitated by the International Energy Agency and involves a number of participants from the U.S., Canada, France, Norway, Italy, and Japan. The project links with an important FE success story funded in the 1980s — the Great Plains Coal Gasification Synfuels plant in Beulah, North Dakota. This facility, run by the Dakota Gasification Company, is transporting some of its CO_2 by-product via a new 204-mile pipeline especially built for the project.

The Weyburn project represents an opportunity on many fronts. It is the only new large-scale CO_2 enhanced oil recovery (EOR) project started in North America for some time, and demonstrates new techniques to determine how injected CO_2 behaves in a depleted reservoir with the goal of storing the CO_2 permanently. Some 20 million metric tons of CO_2, equivalent to 0.3% of the world's total annual emissions would be stored. For Canada, it is a chance to decrease oil imports by recovering 130 million barrels of oil over its 25-year lifetime. For the oil field producer, EnCana, the project is a chance to store CO_2 "credits" in anticipation of possible greenhouse gas reduction regulation in Canada. For fossil-fired power plants in the United States, Canada, and elsewhere, knowledge obtained from monitoring the fate of injected CO_2 could show that depleted oil fields are a viable location for storing large quantities of sequestered CO_2. While it is preferable to use CO_2 found close to the storage sites, the long-distance pipeline is an opportunity to demonstrate the economics of long-distance CO_2 transport.

U.S. participation is supported by a Project Annex to the Implementing Agreement between DOE and the Department of Natural Resources Canada for Cooperation in the Area of Fossil Fuels, which was signed in 2000. The U.S. share is $4 million, which represents about 14 percent of the total project cost of $28 million.

Predicting the economic limits of cost-effective CO_2 storage is also vital. Economic models would be developed to evaluate the economics of sequestration. Furthermore, an important objective of the monitoring is to test new technology that could later be used at other storage sites, both in the immediate Williston Basin and elsewhere. One end result of the monitoring activity would be an assessment of the permanent containment capability of a formation, as determined by predictive simulations and formal risk assessment. Analysis would have to be sufficiently rigorous to satisfy regulatory/permitting authorities about the long-term security of stored CO_2.

Seismic monitoring and long-term modeling techniques used in the project are expected to generate significant data for the establishment of geological storage as a viable policy option for greenhouse gas control. In the test program, monitoring CO_2 movement is done via a series of comprehensive, high-resolution time-lapse seismic monitoring surveys designed to determine the dynamic response of the reservoir to injection of CO_2. Seismic survey results are to be converted to engineering parameters that can be input into numerical modeling of the reservoir.

The prediction of CO_2 storage performance involves the collection and analyses of fluid samples to determine changes in composition during the 4-year monitoring period. Short-term numerical simulations of several patterns within the oil reservoir will then be scaled up to a full suite of patterns, and long-term modeling and risk assessment criteria. Storage economics are being evaluated through the development of a CO_2 EOR/storage economic model for pre- and post-EOR operations. This model will be used to assess different injection and production strategies and their impact on oil production and CO_2 storage. Success at Weyburn may lead to other similar CO_2 storage projects throughout the United States and Canada.

MERCURY/PM 2.5 CONFERENCE ADDRESSES REGULATORY AND TECHNOLOGY ISSUES

The International Conference on Air Quality — Mercury, Trace Elements, and Particulate Matter, was spearheaded by the University of North Dakota's Energy and Environmental Research Center (UNDEERC), and recently provided 400 attendees with important information on regulatory controls, and the state of science and control technology for these key pollutants. The conference was co-sponsored by the U.S. Department of Energy's Office of Fossil Energy (FE), the U.S. Environmental Protection Agency (EPA), FE's National Energy Technology Laboratory, and the Electric Power Research Institute. Dr. Gerald H. Groenewold, UNDEERC Director, spoke of UNDEERC's emphasis on going beyond R&D to technology commercialization by working with private partners. UNDEERC is a not-for-profit, "business within a university," with expertise in advanced energy systems and prevention of air, water, and soil pollution. UNDEERC began as a lignite R&D facility in 1951 under the Bureau of Mines; was defederalized in 1983; and assumed its current name and functions in 1989.

The conference took place over three days with separate tracks for mercury and trace elements of PM. Mercury is facing domestic regulation for the first time, even though the problem is global in nature, and control and monitoring technologies are not yet fully developed. Coal-fired power plants are thought to contribute 33 percent of domestic mercury emissions. $PM_{2.5}$ also faces a number of new rules. In addition, the extent to which sulfates and nitrates contribute to health hazards, and the effect of additional power plant controls on visibility in pristine western areas, are widely debated.

An important conference focus was on regulatory perspectives for mercury, and how the upcoming MACT (Maximum Achievable Control Technology) rule would mesh with the Clear Skies legislation introduced in July 2002. Ellen Brown, Policy Analyst from the EPA Office of Air and Radiation, discussed policy developments related to upcoming mercury controls. According to EPA's interpretation of the Clean Air Act, the proposed coal-fired utility regulation has to take the form of a MACT standard. This requires that existing facilities must not emit more than the average emissions limit achieved by the best performing 12 percent of sources. For new facilities, MACT must be at least as stringent as the emissions limit achieved by the best controlled existing source. The Clear Skies multi-pollutant approach is favored by EPA, as well as DOE and industry, because it eliminates regulatory uncertainty and allows the regulated community to plan with full knowledge of the timing and the levels of control they will face in the future. It also could reduce costs and allow industry to optimize pollutant control technology when making technology choices.

> MACT regulation would be the final step under EPA's December 2000 decision to regulate mercury from power plants. The draft rule is due in December 2003, with the final regulation a year later, and compliance from existing units by December 2007. Under Clear Skies, mercury emissions would be capped at 26 tons in 2010 (reduced from the current 48 tons), and 15 tons in 2018. Compliance under Clear Skies is flexible, using allowances and trading.

Presenters gathered at the International Air Quality Conference in Arlington, Virginia

Some industrial representatives at the conference believe that an industry-wide MACT program is unachievable at anticipated removal limits due to the time constraints (compliance of all utilities by December 2007) coupled with limited applicability of available mercury control technologies to all fuel types. On the other hand, they cite by comparison how Clear Skies would allow time to develop cost-effective mercury control technologies for all coal types. Environmental groups, while not opposing Clear Skies, sense that MACT might offer greater, nearer-term controls. They also expressed concern as to whether market mechanisms would work for mercury as they have for SO_2, given differences in deposition patterns, transport, and uneven exposure for mercury (since mercury exists in both an elemental and an oxidized form, and each form has a different range of transport). In response to audience questions, speakers from EPA stressed that MACT is dictated by law, is proceeding on its mandated schedule, and would not be dropped unless superceded by an enacted Clear Skies program.

Michael T. Rossler of the Edison Electric Institute presented the utility

See "Conference" on page 14...

"Conference" continued...

industry's perspective on the choices being considered by EPA's MACT Working Group, in which EEI has participated over the last several months. The Working Group is tasked with making recommendations on MACT specifics by year's end. One issue is adequacy of data. The existing mercury database is a result of EPA's Information Collection Request (ICR) effort that compiled data from some 80 plants, which is believed by some as being too few. Industry supports "subcategorization" — different MACT "floors" based on such features as coal rank and chlorine content, various process considerations, and separate categories for innovative technologies like IGCC or FBC. Category refinements are important, since many variables affect mercury control technology performance and applicability to various air pollution control equipment.

The conference featured much discussion on available mercury control technologies (no method is considered fully commercial). Most mercury control processes are "co-control," where mercury is removed with other pollutants such as SO_2 and NO_x. Reynaldo Forte of EPA's Clean Air Markets Division presented an overview of multi-pollutant technologies. Those controlling SO_2, NO_x, and mercury are: activated coke (commercially available in Japan and Germany); SCR/wet FGD (in wide commercial use and being tested for mercury control); and Electro-Catalytic Oxidation™ (tested at pilot scale). Supercritical plants also offer promise for removal of these pollutants. For SO_2 and mercury removal, Forte listed dry scrubbers, advanced dry FGD, wet FGD/wet EXPO, and combined mercury/SO_2 sorbents, such as activated carbon injection.

NETL Director Rita Bajura cited various uncertainties in mercury control technology development. Emissions are influenced by a wide range of factors: coal type, mercury content and speciation of the coal, power plant configuration, and existing flue gas emissions controls. Studies have shown a wide variability in mercury emissions from plants that, on the surface, appear quite similar. Bajura noted that carbon injection into ESPs (used in 80 percent of U.S. power plants versus the 20 percent using fabric filter baghouses) could cause overload problems because most ESPs already operate at design limits.

Bajura also noted that low-rank coals tend to emit flue gases with high concentrations of difficult-to-remove elemental mercury. She further spoke of the general need to resolve by-product mercury contamination issues, and develop automated continuous emissions monitors to determine whether controls are working. Insufficient understanding of mercury control science, she said, tends to make startup an exercise in "tweaking" the plant to achieve maximum performance.

Bajura outlined results of FE's short-term field tests (see table on page 15). The most promising technology for the short-term scenario appears to be activated carbon injection into a fabric filter. Unknown is the impact of long-term injection on bag life (due to an increased need for cleaning), and space requirements (as large quantities of used sorbent would have to be disposed of in solid waste landfills). While short-term mercury removal test results were encouraging, it is still too early to extrapolate these results to the multitude of existing coal-fired plants. According to Bajura, EPA favors selective catalytic reduction (SCR) technology followed by wet FGD for mercury control. However, results from UNDEERC's SCR tests show that not all coal types resulted in a

higher oxidized mercury concentration across the SCR vessel. Primary questions about SCR involve size of the vessel and age of the catalyst. As the SCR unit gets smaller and the catalyst ages, oxidation of mercury declines. NETL is planning a solicitation for longer-duration testing to fully understand not only these issues but also other balance-of-plant issues, mercury speciation and removal from low-rank coals (lignite and Powder River Basin coals), and mercury capture resulting from a larger selection of current and future air pollution control device configurations.

In contrast, major issues discussed on $PM_{2.5}$ were health effects and regional haze, rather than technology readiness. In fact, current ESPs and fabric filters generally remove 99.5 percent of primary $PM_{2.5}$ generated by coal boilers, and are able to meet the New Source Performance Standards and stay within opacity limits. Remaining problems stem from secondary particles, sulfates, and nitrates, which degrade visibility and have been statistically associated with adverse health effects. Thus, $PM_{2.5}$ control at coal plants is a function of SO_2 and NO_x control. Although there is no pressing regulation dictating that new and better technologies be developed, there are many regulations in the picture, e.g., possible revision of NAAQS for $PM_{2.5}$, attainment/nonattainment designation of $PM_{2.5}$ areas, regional haze plans, and assorted paths for regional haze compliance including source-specific BART controls and special options for Grand Canyon Visibility Transport Commission ar-

eas. As for the impact of Clear Skies, some participants noted that Clear Skies reduction alone might be sufficient to bring a significant portion of the eastern U.S. into compliance with the $PM_{2.5}$ NAAQS and/or visibility improvement goals.

In the eastern U.S., the primary concern is health effects of $PM_{2.5;}$ and to this end NETL and others are actively monitoring $PM_{2.5}$ pathways. Some health studies show that sulfates and nitrates from coal plants are much less harmful to human health than carbonaceous and/or metal particles, which are emitted primarily by sources other than coal plants. Some conference participants noted that epidemiology study results linking sulfates and nitrates from coal plants to adverse health effects are still in question. To date, these studies have failed to account for other key components of the $PM_{2.5}$ mixture (notably carbonaceous species) that could have been responsible for the observed health effects.

The conference provided an important forum for government, industry, and the environmental community to share insights on issues related to mercury, $PM_{2.5}$, and trace elements. The next conference, "Air Quality IV," is scheduled for September 22–24, 2003, in Arlington, Virginia.

RESULTS OF NETL'S LARGE-SCALE, SHORT-TERM, PHASE I MERCURY CONTROL FIELD TESTS

Participating utility	Michigan South Central Power Agency	Cinergy	Southern Company	We Energies	PG&E Utility National Energy Group
Host/ Site	Endicott/ Litchfield, MI	Zimmer/ Moscow, OH	Gaston/ Wilsonville, Al	Pleasant Prairie/ Kenosha, WI	Brayton Point/ Somerset, MA
Test size (MWe)	55	1,300	135	150	122
Coal type	High-sulfur, eastern bituminous	High-sulfur, eastern bituminous	Low-sulfur, eastern bituminous	Low-sulfur, PRB subbituminous	Low-sulfur, eastern bituminous
Average Hg in coal (ppm)	.21	.15	.06-.13	.10-.13	.03-.08
Hg control approach	Additive injection upstream of limestone, forced oxidation wet FGD system	Additive injection upstream of magnesium-enhanced lime with *ex-situ* oxidation wet FGD system	Sorbent injection upstream of compact hybrid particulate collector (COHPAC) baghouse	Sorbent injection upstream of cold-side ESP	Sorbent injection upstream of cold-side ESP
Injection rate	1 gal/hr	27 gal/hr	1.5-3 lbs sorbent/ million actual cubic feet (acf) flue gas	11 lbs sorbent/ million acf flue gas	10-20 lbs sorbent/million acf flue gas
Average Hg removal in short-term tests (%)	77	51	87	70	85
Cost estimate of variable additive cost (equipment already present)	.18 *mills/kWh*	.18-.23 *mills/kWh*	.3-.5 *mills/kWh*	2-3 *mills/kWh*	1.7-2.5 *mills/ kWh*
Test completion	October 2001	December 2001	March 2001	November 2001	July 2002

More information is available at www.netl.doe.gov/coalpower/environment/mercury/index.html

INTERAGENCY GROUP FOSTERS TURBINE TECHNOLOGY

In pursuit of efforts to develop coal-based, high-efficiency engines and turbines, the U.S. Department of Energy (DOE) is leveraging resources by collaborating with other government agencies in areas of common interest. Through the Propulsion and Power Systems Alliance (PPSA), DOE is partnering with the National Aeronautics and Space Administration (NASA), Department of Defense (DoD), and the Federal Aviation Administration (FAA). PPSA has established Technology Area Teams (TATs) in Joint Testing, Compressors, Combustors, Turbines, Materials, Structures, Mechanical Components, Design Tools and Engine Simulation, and Instrumentation and Controls. DOE is participating in the Materials and Combustors TATs. The TATs formulate goals and technology roadmaps and oversee implementation of collaborative plans. On October 31, 2002, the TATs met in Cleveland, Ohio to assess progress on current tasks and to initiate new ones.

Advanced high-temperature turbine materials were once the sole domain of DoD and NASA as they pushed the performance envelope to higher stresses and temperatures. Materials technology for power generation gas turbines has lagged behind aircraft technology by 10–20 years. However, the push to increase stationary gas turbine power system efficiencies, led by DOE's National Energy Technology Laboratory (NETL), has driven firing temperatures for stationary applications into the realm of aero-application turbines. Under DOE's Advanced Turbine Systems (ATS) program, thermal barrier coatings (TBC) for hot gas path components became a necessity. Materials remain the primary limitation for further increases in gas turbine firing temperatures and consequent performance and efficiency gains, regardless of application. As a result, NETL is working jointly with NASA, DoD, and FAA under PPSA to further capitalize on high-temperature materials developments, and to develop next-generation ceramic materials.

Barrier coatings are critical to furthering high-temperature material applications, and are an integral part of PPSA collaboration in materials research. Ceramics resist temperature better than metallic alloys, but some types, unless protected, undergo a destructive surface consumption process called "recession." Recession is combined oxidation and volatilization of component materials that can occur rapidly at the high temperatures found in combustion turbines, and results in short life spans for ceramic components. Environmental barrier coatings (EBCs) are needed to prevent such accelerated deterioration. NETL is bringing the results of the ATS program to bear on TBC and EBC evaluation. For example, a non-destructive inspection (NDI) method, developed by one of the universities supporting ATS development, is being tested that has the potential to make accurate barrier coating lifetime predictions. Effective EBCs will make it possible to apply promising structural ceramics, such as silicon nitride. Silicon nitride has application to turbine combustors, vanes, and blades; and has the potential to move gas turbine operating temperatures almost 300 °F above those sustained by superalloys, while performing comparably to superalloys.

Component size and operating conditions differ between aero- and stationary-application gas turbines. They may operate under significantly different pressures and temperatures, and use different fuels. To help determine applicability of new materials, collaborative research is establishing a basic scientific understanding of responses to varying temperature regimes, chemical environments, and mechanical stresses.

Through PPSA, DOE also is collaborating on advanced low-emission combustion. Some of the basic concepts for emission reductions are shared between the aero- and stationary-turbine combustor technologies, such as advanced mixing and flame stabilization concepts. Thus, advanced technologies such as the trapped-vortex combustor (see *Clean Coal Today*, Summer 2002) have been investigated through the PPSA, to the benefit of both DOE and DOD.

In support of low-emission combustion research, collaboration is ongoing in advanced modeling. Growing interest in fuel-flexible power generation will require meeting stringent emission goals on widely variable fuels, including synthesis gas with variable levels of hydrogen content. To ensure that combustors can be designed with this type of fuel flexibility, advanced simulations validated by benchmark data are needed. Both aero- and stationary-turbine development benefit from such modeling. NASA recently collected data on 100 percent hydrogen combustion that can be used to assess the performance of lean-direct injection hydrogen combustion, and validate numeric models. In a similar shared test and model validation effort, NETL and Sandia National Laboratory are investigating hydrogen supplements to gaseous combustion to evaluate the performance of another low-emission combustion concept known as lean-premix.

Collaboration through PPSA is accelerating advancements in gas turbine technology and, in the process, contributing to both national and energy security.

R&D MILESTONES

Monterey Bay Aquarium Research Institute, working with NETL, has successfully conducted a CO_2 ocean storage experiment off the California coast. The experiment, conducted in Monterey Canyon, showed that liquid CO_2 released into the ocean behaves as predicted by laboratory experiments, and shows no obvious adverse biological effects. The dissolution rate of CO_2 in the ocean was measured and compared with theoretical models and laboratory studies. Spectrometry was also used to study the chemical structure of man-made CO_2 ice-like hydrates deposited on the ocean floor. The physical and chemical structure of hydrates are important in determining their ultimate fate in the ocean. Since many power plants are located near the ocean, it offers the potential for sequestering significant quantities of domestic CO_2.

According to DOE sponsored research at Prairie View A&M University, waste coal fines slurried with coal can produce a combustion mix acceptable to industry. In the U.S., 30–50 million tons per year of coal fines (smaller than 28 mesh size) are discarded from coal cleaning plants. Some 500 million to 2 billion tons of fines are estimated to be stored in waste ponds. These fines not only represent a loss in Btu value but pose a hazard — the possibility of leaks. Prairie View prepared a slurry fuel using the fines, which averaged an 8 micron size, with a regular coal feed of 85 percent coal and 15 percent fines. This mixture was tested at the University of North Dakota Energy and Environmental Research Center to determine combustion stability, ash behavior, and emissions of SO_2, NO_x and particulates. Tests were conducted at three different firing rates and the results demonstrated combustion characteristics consistent with industry standards. Use of waste fines lower fuel costs, and the high moisture content of the slurry results in lower combustion temperature and consequently decreased emissions of NO_x.

Researchers at Praxair, working under a cooperative agreement with NETL, reached a 1,000-hour operating milestone for their ceramic membrane to separate oxygen from air. The process is important for IGCC advanced power plants, as well as for industries that require pure oxygen. Air by itself contains nitrogen that would contaminate the gas stream. The membrane works at high temperatures, avoiding the costly energy-robbing cryogenic cooling now used in commercial air separation plants. Praxair has demonstrated that its membrane can produce oxygen at greater than 95 percent purity for more than 1,000 hours at the target flux under simulated operating conditions.

As part of the Vision 21 research effort sponsored by DOE, Eltron Research has made substantial progress in developing a seal for an advanced ceramic hydrogen transport membrane. Hydrogen separation is an important enabling technology for the operation of virtually non-polluting energy plants anticipated for the future, and DOE is attempting to discover new materials for construction of a prototype membrane module. Operation of ceramic separation membranes at high temperatures and pressures requires chemically resistant seals with mechanical and expansion characteristics similar to the membrane itself in order to avoid structural failure. The membrane seal tested has shown record performance, operating continuously over 340 hours at 280 psig and 800 ^{o}C. The seal development technology could also help reduce R&D time for other important membranes under development by DOE, *e.g.*, the ion-transport membrane for oxygen production.

In-house researchers at NETL have developed a method to remove mercury from flue gas produced from coal-firing in a power plant. The technique is based upon the photochemical reaction of mercury and certain flue gas components under the influence of ultraviolet light. Experiments with simulated flue gases suggest that a high level of elemental mercury removal can be achieved by irradiation with light of 253.7-nm wavelength. The process can use simple equipment similar to that used in water treatment plants for the eradication of microbes. A preliminary analysis suggests that annual operation costs for the process will be lower than that for activated carbon injection systems.

STATUS OF ACTIVE CCT DEMONSTRATION PROJECTS

ENVIRONMENTAL CONTROL DEVICES

Southern Company, Inc. – *Demonstration of Advanced Combustion Techniques for a Wall-Fired Boiler.* All testing on the original project has been completed and reported. Phase 4 had been extended until December 31, 2002, to evaluate the use of GNOCIS and other computerized process control software. These techniques will attempt to further optimize operation of Unit 4 by controlling additional processes, including ESPs, sootblowers, and steam side equipment at the plant. (Coosa, GA)

ADVANCED ELECTRIC POWER GENERATION

City of Lakeland, Department of Water & Electric Utilities – *McIntosh Unit 4A PCFB Demonstration Project and McIntosh Unit 4B Topped PCFB Demonstration Project.* Lakeland Electric continues to evaluate its options to meet future power demand. During this internal review, Lakeland, Foster Wheeler, DOE, and others have been reviewing the system concept, siting, and financial issues in order to improve the project. (Lakeland, FL)

JEA – *ACFB Demonstration Project.* Construction of Unit 2 at the Northside Station was completed in December 2001. The DOE demonstration is planned for January 2003 followed by a two-year period testing coal-fuel blends. (Jacksonville, FL)

Kentucky Pioneer Energy, L.L.C. – *Kentucky Pioneer Energy Project.* The Notice of Availability was published in the *Federal Register* on December 13, 2002. After a 30-day comment period, DOE will issue a Record of Decision, completing the NEPA process. The fuel cell portion of the project was re-sited to Global Energy's Wabash site in West Terre Haute, Indiana. (Trapp, KY and West Terre Haute, IN)

Sierra Pacific Power Co. – *Piñon Pine IGCC Power Project.* The project ended January 1, 2001. Sierra has submitted the Final Technical Report to DOE. Integrated operation of the gasifier, hot gas cleanup system, and gas turbine had not been achieved when the project ended. Because the state of Nevada repealed electric deregulation and placed a moratorium on the sale of power plants in the state, the pending sale of Sierra's Tracy Station (which includes the Piñon Pine plant) to WPS Power Development, Inc., was suspended. DOE is preparing a post-project assessment report. (Reno, NV)

Tampa Electric Co. – *Tampa Electric Integrated Gasification Combined-Cycle Project.* Tampa's Polk Power Station completed its operational period at the end of October 2001 with over four and one-half years of successful commercial operation. The Final Report has been accepted by DOE, and copies were due to be delivered to DOE by the end of December 2002. (Polk County, FL)

TIAX (formerly Arthur D. Little, Inc.) – *Clean Coal Diesel Project.* Due to TIAX's reorganization, testing of the hardened engine parts has been delayed. Problems associated with oil leakage and the cooling system of the large diesel at University of Alaska, Fairbanks are being addressed at this time. Changes to the testing program also are being considered; however, the details of the change have not been determined. The details of the changes to the test program will be available in early calendar year 2003. (Fairbanks, AK)

COAL PROCESSING FOR CLEAN FUELS

Western SynCoal LLC (formerly Rosebud SynCoal® Partnership) – *Advanced Coal Conversion Process (ACCP) Demonstration.* DOE is negotiating with Westmoreland Mining LLC, owner of the Western SynCoal LLC, to complete the Final Report for the project. Current projections are that the report will be completed in June 2003. (Colstrip, MT)

Air Products Liquid Phase Conversion Company, L.P. – *Liquid Phase Methanol Process Demonstration Project.* The Liquid Phase Methanol (LPMEOH™) Process Demonstration Facility continues to experience stable operation on coal-derived synthesis gas. Following the second successful *in-situ* activation of methanol synthesis catalyst completed in late June 2002, catalyst performance has exceeded all expectations. The overall catalyst deactivation rate during the first five months of operation was about 0.1 percent per day. This rate is significantly better than the baseline catalyst deactivation rate of 0.4 percent per day that was achieved at the LaPorte Alternative Fuels Development Unit using synthesis gas derived from natural gas. This catalyst deactivation rate is also significantly lower than the average of 0.6 to 0.7 percent per day that has been generally calculated over the past two years at Kingsport. This improvement may be related to the successful reduction of

catalyst during the second *in-situ* activation, the improved performance of the adsorbent in the catalyst guard bed, and the continued operation at low reactor temperature (215 °C, the initial temperature for demonstration operations being conducted in a temperature-programming mode). Since startup in April 1997, the demonstration facility has operated at an availability approaching 98 percent, and has produced more than 100 million gallons of methanol, all of which was accepted by Eastman Chemical Company for use in downstream chemical processes. Monitoring all potential catalyst poisons and methods for their removal and control continues to be important. (Kingsport, TN)

INDUSTRIAL APPLICATIONS

CPICOR Management Company, L.L.C. – *Clean Power From Integrated Coal/Ore Reduction (CPICOR).* Preparation of the Environmental Impact Statement for the CPICOR project has been placed on hold until further notice. The CPICOR Management Company (CMC) continues to work toward arranging the financing necessary to move the project into Budget Period 2. CMC also continues to work closely with the Australian developers of the HIsmelt Process and iron/steel engineering firms to establish a process and mechanical design database for this project. This project will be designed to produce 3,300 tons per day of liquid iron and approximately 160 MWe from the by-product gases. DOE is waiting for a revised Continuation Application from CPICOR Management Company to move into Budget Period 2. Upon receipt and review of the Continuation Application, DOE will make a decision on the future of this project. (Vineyard, UT)

ThermoChem, Inc. – *Pulse Combustor Design Qualification Test.* The Final Report has been submitted and accepted by DOE, and the Cooperative Agreement is in the close-out process. A draft of the Post Project Assessment has been prepared and is under review by the participant. It is anticipated that the Post Project Assessment will be finalized in early calendar year 2003. (Baltimore, MD)

CLEAN COAL TODAY

Published quarterly by:
The Office of Fossil Energy
U.S. Department of Energy (FE-24)
Washington, DC 20585
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19901 Germantown Road
Germantown, MD 20874

FE-24

Printed with soy ink
on recycled paper