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CLEAN COAL TODAY

A Newsletter about Innovative Technologies for Coal Utilization

News Bytes

In March 2005, Energy Secretary Samuel Bodman announced the award of $62.4 million for 32 clean coal research projects to advance the Administration's goal for coal-fired zero-emissions power plants. Awards were made under a broad-based solicitation issued in July 2004 to promote efficient use of coal. Research areas include carbon sequestration, power systems advanced research, advanced gasification, and coal fuels and hydrogen.

DOE's 4th Annual Conference on Carbon Capture and Seques-tration, held in Alexandria, Virginia, May 2–5, 2005, drew over 450 attendees, including many international participants. The successful event featured

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In This Issue

DOE and China Negotiate New R&D Protocol

In early April 2005, Mark Maddox, the U.S. Department of Energy (DOE) Principal Deputy Assistant Secretary for Fossil Energy, led an Office of Fossil Energy (FE) delegation to China for important discussions on cooperative research, and to sign a five-year extension of the April 2000 Protocol. The Protocol for Cooperation in the Field of Fossil Energy Technology is composed of Annexes in Power Systems, Clean Fuels, Oil and Gas, and Energy & Environmental Control Technologies. Another Annex is on Climate Change Science, which is the responsibility of DOE's Office of Science. Maddox and Ma Songde, Vice Minister of the Ministry of Science and Technology (MOST), signed the Protocol extension, and the FE delegation and their Chinese counterparts discussed new initiatives and signed a Record of Meeting for each Annex.

Last year, China experienced a 30,000-MW electricity shortfall, and estimated that 120 GW of new power capacity will be needed over the next two years, representing a significant opportunity for clean coal technologies. China is the leading world producer of coal, and U.S. vendors already have made inroads into the Chinese market for pollution control equipment and low-NO_x burners.

FE Principal Deputy Assistant Secretary Mark Maddox, and MOST Vice Minister Ma Songde sign Protocol extension

The annual business meeting, a major feature of the Protocol activity that culminated in signing the new agreement, took place on April 5, 2005, in Beijing. Shi Dinghuan, former Secretary General of the Ministry of Science and Technology (MOST) (and current Science Advisor to the State Council), and Mark Maddox each delivered keynote remarks. Shi spoke of the economic and environmental benefits of bilateral cooperation, while Maddox noted commonalities between the two countries that give impetus to a joint clean energy agenda. Maddox indicated that the Protocol is an important companion to multilateral efforts, such as the Carbon Sequestration Leadership Forum (CSLF) and the International Partnership for a Hydrogen

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Economy (IPHE). Maddox stressed the importance of China and other coal-reliant countries joining FutureGen — a DOE-led effort for a near-zero emission integrated hydrogen and sequestration research prototype — as a signal of their commitment to developing technological answers to global concerns about economic growth, energy availability, and environmental integrity.

Madame Zhang Xiaolu, Vice President of the China Power Investment Corporation (CPI), indicated that one of China's power investment companies is interested in participating in FutureGen. CPI is one of the five privatized companies that were created after dissolution of the State Power Corporation, and is responsible for the Power Systems Annex under the Protocol. Cooperative activities include workshops, site visits, training in grid design and planning, integrated gasification combined-cycle (IGCC) technology, NO_x and SO_x reduction, power plant optimization, and fuel cells. Annex I representatives attending the working session recommended future studies that included a study of Chinese gasifier operating performance that could be applicable to IGCC; information exchange on lignite drying and handling, as well as coal ash utilization; fuel cell exchange activity leading to a possible demonstration of fuel cells in China, and power plant software training.

Representatives from the National Development and Reform Commission (NDRC), the newly designated coordinator for the Clean Fuels Annex, and the DOE Annex Coordinator introduced and discussed several potential projects. Meeting participants agreed to continue a cooperative study by West Virginia University on the long-term environmental and economic impacts of coal liquefaction in China based on data from the China Shenhua Coal Liquefaction Co. Ltd. two-stage direct liquefaction project in Inner Mongolia. The project employs the Headwaters Incorporated direct coal liquefaction technology, which was developed through the R&D support of the DOE Office of Fossil Energy. Other discussion topics included: establishment of an indirect liquefaction research center; carbon capture and storage at a direct liquefaction plant; a coal conversion workshop in Shanghai; and small gasifiers, a source of alternate fuel or co-products in China's industrial sector.

The Energy and Environmental Control Systems Annex has been a very active area of cooperation, and efforts in NO_x/SO_2 controls, De-NO_x technology (including selective catalytic reduction, selective non-catalytic reduction, and hybrids), mercury, and CO_2 will continue. A NO_x/SO_2 control workshop and two wet flue gas desulfurization (FGD) training sessions were successfully completed. A De-NO_x study is ongoing to investigate post-combustion NO_x control options for China's power plants. The controls are needed for the power plants to meet the country's new, more strict NO_x regulations. Case studies are being developed for several Chinese power plants. The results are to be presented at a De-NO_x workshop in Dalian, China in early August, being held in conjunction with the Second U.S.-China NO_x/SO_2 Control Workshop. Over 150 Chinese are expected to attend, and more than a dozen U.S. companies have already confirmed their participation. In the mercury area, Zhejiang University and the U.S. Environmental Protection Agency are cooperating in compiling an inventory of emissions. A workshop on the benefits of co-control of mercury and other pollutants is being considered for the fall. Researchers also wish to scale up a joint project of FE's National Energy Technology Laboratory and the China National Power Plant Combustion Engineering Research Center. This project uses aqueous ammonia for CO_2 removal, while creating a fertilizer by-product. In addition, a CO_2 Science and Technology Workshop is being considered as a follow up to the successful 2001 workshop held with Zhejiang University.

Extension of the China Protocol, coupled with other DOE work to assist China in achieving a "Green Olympics," as well as work by Tsinghua and Tulane universities at the DOE-funded Energy and Environmental Research Center, will further advances in clean coal technologies to meet China's energy needs.

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panels on a variety of technical and policy topics, including CO_2 capture and separation; geologic sequestration; measuring, monitoring, and verification technologies; and international initiatives.

Phase I of the Regional Carbon Sequestration Partnerships has been successfully completed and a report is available at www.fe.doe.gov (click on Carbon Sequestration, News/Events tab, May 2, 2005). Phase I has provided key regulatory, infrastructure, and site-related information, preparatory to Phase II field tests.

30th Annual Clearwater Coal Conference

In April 2005, some 275 participants from industry, government, and academia gathered for the 30th Annual International Technical Conference on Coal Utilization and Fuel Systems — the Clearwater Coal Conference — a hallmark gathering of coal technical experts from around the world. The conference is supported by the U.S. Department of Energy (DOE), and the DOE National Energy Technology Laboratory (NETL), the Power Division of the American Society of Mechanical Engineers, and the Coal Technology Association. This year's conference featured representatives from 17 nations, including first-time representation from Serbia and Montenegro. Over the four days, a variety of plenary and technical sessions, as well as tutorials, addressed coal's prospects for the future, the role of FutureGen and hydrogen, diminishing conventional liquid fuel supplies, and the overarching issue of global warming.

At the keynote session, "Coal Technology — Yesterday, Today, and Tomorrow," the senior U.S. policy official at the conference, Fossil Energy Principal Deputy Assistant Secretary Mark Maddox, relayed the Administration's commitment to coal. He referenced President Bush's remarks in Columbus, Ohio this past March, in which he praised DOE's proposed FutureGen project as a groundbreaking development, and forecast that clean coal technology advances would make our society better off and less dependent on foreign sources of energy. Maddox spoke of the audience's key role as industrial experts with a "keen sense of the market's practical requirements." He detailed technological successes thus far in R&D and spoke of the need to speedily deploy new technologies such as IGCC as a "transformative" technology, because it leads to a chain of events that can eliminate nearly all emissions from power production. He said that our goal should be to leave a legacy of needed baseload capacity that can meet paired challenges of energy demand and global climate change, benefiting energy users worldwide.

Sho Kobayashi (left) receives the ASME Percy Nichols award from ASME and AIME, for notable scientific or industrial achievement in the field of fossil fuels

Members of the keynote panel endorsed Maddox's vision and gave their perspectives of what the future could look like. Stuart Dalton of EPRI noted that most plans for new generation in the United States utilize conventional pulverized coal. Dalton sees potential for IGCC in the United States, while Europe and Japan face higher fuel costs and seem to favor ultra-supercritical pulverized coal technology. Gasification systems of tomorrow will be selected to meet multiple ends — synthesis gas, hydrogen, and CO_2 capture. Speaking at a later session, Dalton detailed EPRI's "Coal Fleet for Tomorrow" effort that is exploring incentives for IGCC, such as loan guarantees, tax credits, and availability insurance. IGCC costs need to be lowered by risk reduction, augmented RD&D, and standard design guidelines. Permitting is seen as a barrier in that regulators do not yet fully understand IGCC technology. For example, they are using natural gas-based systems as a basis for determining Best Available Control Technology (BACT).

John L. Marion of ALSTOM Power Inc., speaking from the combustion standpoint, noted that all energy supply projections point to an increased use of coal. With below-average consumption of electricity applicable to over 75 percent of the world's population, there is clearly a growing market. Likewise, the market for environmental control technologies also will grow. However, Stanley Harding of N.S. Harding & Associates stressed the need for rational thinking in developing multi-pollutant controls because pollutants removed at one end can reappear in by-products. In terms of liquid fuels from coal, David Gray of Mitretek noted that these ultraclean fuels, unlike hydrogen, can use the existing transportation infrastructure and could be available at $40/barrel at non-sequestration co-production plants. Future coal-to-liquids cost with carbon capture would depend on success in developing new technologies, but is estimated at between

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$35 and $40/barrel.

A number of conference sessions highlighted the most innovative technology fronts — FutureGen and hydrogen from coal. FutureGen has been gaining momentum in the past few months, with submittal of the Program Plan to Congress, and internal approval of DOE's Acquisition Strategy. Appropriations have been secured for the first two years of the project, and National Environmental

Policy Act planning has begun. DOE is currently negotiating a cooperative agreement with the "FutureGen Alliance." The Alliance now consists of 10 organizations representing over 20 percent of U.S. coal-fired electricity generation and 40 percent of U.S. coal production.

The DOE hydrogen-from-coal program is also growing, and is intertwined with FutureGen. Interest in hydrogen is international, and DOE's Lowell Miller spoke of coal strategies in Australia, Japan, New Zealand, and China, all of which include hydrogen. Sixteen countries and the European Union also participate in the DOE-led International Partnership for a Hydrogen Economy. Several conference speakers noted the misconception that hydrogen from coal involves an energy-intensive combustion electrolysis step. Rather, hydrogen from coal would be produced cleanly from gasification, whereby the produced clean synthesis gas is converted to hydrogen and CO_2, and the CO_2 is sequestered. IGCC plants provide the option of efficient hydrogen production with the ability to co-produce electricity and clean liquid fuels. DOE's program focuses on centralized production of hydrogen, achieving 60 percent efficiency by 2015, which reduces the cost of hydrogen 25 percent compared to current technology. Current IGCC plants operate at efficiencies of about 42 percent using cryogenic air separation, gas turbines not optimized for synthesis gas fuel, and cold gas cleanup systems. With current technology, hydrogen production costs from coal with carbon capture are in the range $2.60–3.25 per thousand cubic feet ($1.10–1.35/kg) depending on the technology and configurations used.

The importance of technology development progress, as reported at the conference, was underscored by a concern that conventional world petroleum production could be close to peaking, and that greenhouse gas issues remain unresolved. Robert L. Hirsch of SAIC emphasized that oil "peaking" (reaching maximum production) would be the world's first forced energy transition. There are varying forecasts as to the date of the peak — as early as 2006, as late as post-2025, or not at all. Sources of energy to meet a shortfall, which should be developed considerably in advance of the peak time, could include coal-to-liquids; gas-to-liquids including gas from methane hydrates, heavy oil, and oil sands; enhanced oil recovery; and fuel efficiency. In spite of regulatory uncertainties, Dr. Mark Trexler of Trexler Climate + Energy Services stressed that global climate change must be treated as a material business issue, about which assumptions are required to enable strategic planning. He noted that traditional approaches to commodity forecasting are unsuited to greenhouse gas credits where policy affects both demand and supply. Other speakers presented perspectives on climate modeling and the accuracy of scientific data, and described an initiative of the northeast states to develop a CO_2 cap and trade program. The Regional Greenhouse Gas Initiative would operate much like the European Union trading scheme, and expects to have a functioning program in place in the 2009–2010 timeframe.

In all, the 2005 gathering of coal experts at Clearwater provided an important overview of advancing technology vital to global energy efficiency and environmental prog-

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NO_x CONTROL PROGRAM ADDRESSES CAIR

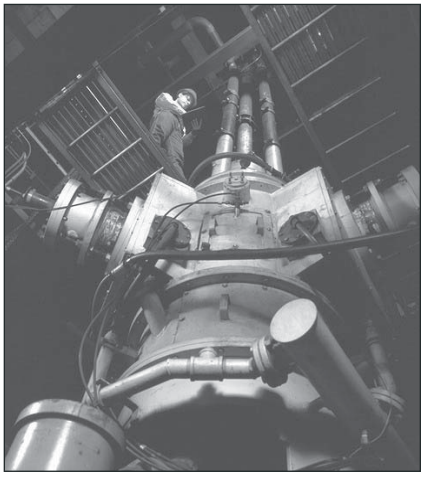
Emissions of NO_x, as well as SO_2, from U.S. coal-fired boilers have steadily decreased since passage of the 1990 Clean Air Act Amendments. NO_x contributes to acid deposition, ozone, and fine particulate formation. As a result, NO_x emissions have faced a variety of controls in the form of regulations for ground level ozone, nitrification of aquatic systems, ambient fine particulate matter, and regional haze. Most recently, the ratcheting down of emissions by the U.S. Environmental Protection Agency's Clean Air Interstate Rule (CAIR) will require the effective NO_x emissions of Eastern U.S. plants to be reduced to 0.15 lb/MMBtu by 2009 and to 0.12 lb/MMBtu by 2015. In response to these environmental goals, the U.S. Department of Energy, Office of Fossil Energy's National Energy Technology Laboratory (NETL) is carrying out a comprehensive, integrated NO_x R&D effort under its Innovations for Existing Plants (IEP) Program. The overall goal of the IEP Program is to enhance the efficiency and environmental performance of the existing 320-GW fleet of fossil fuel-fired power systems, as well as to apply knowledge gained toward the development of advanced power systems.

The NO_x effort focuses primarily on developing in-furnace control systems capable of reducing emissions to a level of 0.15 lb/MMBtu by 2006 and 0.10 lb/MMBtu by 2010, while achieving a levelized cost savings of at least 25 percent compared to state-of-the-art selective catalytic reduction (SCR) control technology. A longer-range goal is to further develop a combination of advanced combustion and SCR control technologies that can achieve a near-zero NO_x emission rate of 0.01 lb/MMBtu by 2020. The research also provides an improved understanding of the impact of these advanced technologies on related issues such as unburned carbon, waterwall wastage, and mercury speciation and capture. The IEP portfolio of NO_x control technology R&D projects encompasses laboratory studies, modeling, and pre-commercial full-scale field testing. The success of the program is intimately tied to key collaborations and partnerships with industry, federal, state, and local agencies, and the academic and research communities.

To comply with CAIR regulations, power producers will need to retrofit existing boilers with additional NO_x control technologies, some of which will adversely impact plant efficiency and performance. Hardest hit economically will be the smaller, older, less efficient facilities that are not good retrofit candidates for the current state-of-the-art SCR NO_x control equipment because of space constraints and the reluctance of owners to invest in the aging plants during a period of increasing market competition. These facilities, generally no more than 300 MW in size, comprise 66 percent of the boilers in the U.S. and are on an average 15 years older than the remainder of the fleet.

In light of these demands, NETL issued a solicitation for NO_x control technology that addresses cost and performance concerns for this group of existing boilers. As a result, five new NO_x R&D projects were announced in November 2004. These projects will be performed during the subsequent three years. The benefits of this program will be realized by both the existing fleet and new capacity generators as the targeted NO_x control technologies are adopted. The following new projects are in progress.

Enhanced Combustion Low-NO_x Pulverized Coal Burner – ALSTOM will develop an enhanced combustion, low-NO_x pulverized coal burner. The objective is to optimize combustion via control of near-burner time, temperature, turbulence, and stoichiometry. Candidate low-NO_x burner components for testing include up to four enhanced ignition coal nozzle tips, as well as internal and external air and fuel separators. These components will be integrated into ALSTOM's latest generation of the TFS 2000 firing system that includes enhancements developed in the recently completed "Low-NO_x Firing System for Tangential Boilers" project. The enhanced low-NO_x burner is designed to achieve an emission rate of less than 0.15 lb/MMBtu and have minimal balance-of-plant impacts while burning a high-volatile bituminous coal. The project includes computational fluid dynamics (CFD) modeling and large pilot-scale testing to provide the information to design a full-scale version of the enhanced low-NO_x burner.



ALSTOM's Experimental Pulverizer

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Advanced In-Furnace NO_x Control for Wall- and Cyclone-Fired Boilers – Babcock & Wilcox will develop and demonstrate an advanced NO_x control technology capable of achieving an emission rate of 0.10 lb/MMBtu while burning high-volatile bituminous coal. The NO_x control technology is based on a "layered" strategy that combines deep air staging, continuous corrosion monitoring, advanced combustion-control enhancements, and a proprietary combustion technique using oxygen injection. Wall- and cyclone-fired pilot-scale testing will be used to evaluate the oxygen injection process. Results from the pilot-scale testing will be used to design and prepare a cost estimate for a full-scale version of the technology.

In Situ Device for Real-Time Catalyst Deactivation Measurements in Full-Scale SCR Systems – Fossil Energy Research Corporation (FERCo) will demonstrate the use of an in situ catalyst deactivation measurement device to reduce SCR operating costs through optimized catalyst management. The device will collect real-time SCR performance data by continuously measuring catalyst activity. Subsequent analysis will provide information on boiler operating conditions that negatively impact catalyst activity, so that the catalyst replacement schedule can be optimized. Testing will be conducted at a Southern Company Services, Inc. coal-fired power plant equipped with SCR.

Cyclone Boiler Field Testing of Advanced Layered NO_x Control Technology – Reaction Engineering International (REI) will conduct CFD modeling and full-scale field testing to evaluate Advanced Layered Technology Application (ALTA) to achieve a NO_x emission rate of near 0.10 lb/MMBtu in a cyclone boiler. ALTA combines deep staging using overfire air, Rich Reagent Injection, and a novel SNCR approach. Testing also will evaluate potential balance-of-plant impacts such as the amount of unburned carbon in the ash, slag tapping, waterwall corrosion, ammonia slip, and heat distribution. Testing will be conducted at AmerenUE's 500-MW Sioux Station. This project is a follow-up to the recently completed "Rich Reagent Injection for Cyclone Burners." For this new project, the cyclone burner barrel stoichiometry will be reduced from 0.95 to 0.85.

AmerenUE's Sioux Power Station, site of the proposed field testing

Pilot-Scale Demonstration of Advanced Layered NO_x Control Technology for Coal-Fired Boilers – REI will develop and verify the performance of the ALTA NO_x control technology for wall-fired boiler applications to achieve an emission rate of less than 0.15 lb/MMBtu. The burner will be designed for complete near-burner combustion, rather than traditional staged combustion. The objective of the burner design is to achieve homogeneity of the combustion products in the boiler. Not only does this create ideal conditions for combustion-related control of NO_x, it also results in a stoichiometry and temperature distribution above the burners that is ideal for the chemistry involved in Rich Reagent Injection. REI will conduct CFD modeling and pilot-scale testing to optimize the near-burner combustion system and reagent injection.

While knowledge of the formation and capture of NO_x from coal-fired power plants has greatly advanced over the past 15 years, many challenges remain. DOE is continuing to partner with industry and other key stakeholders in carrying out a comprehensive advanced NO_x control technology R&D program. A preliminary NETL assessment shows a U.S. market potential for approximately 150 GW of advanced NO_x combustion control technologies that could cost-effectively replace 75 GW of new SCR controls required for compliance with the Administration's proposed Clear Skies Act. Additional information on NETL's advanced NO_x emissions control activities can be found at: http://www.netl.doe.gov/coal/E&WR/NOx/index.html.

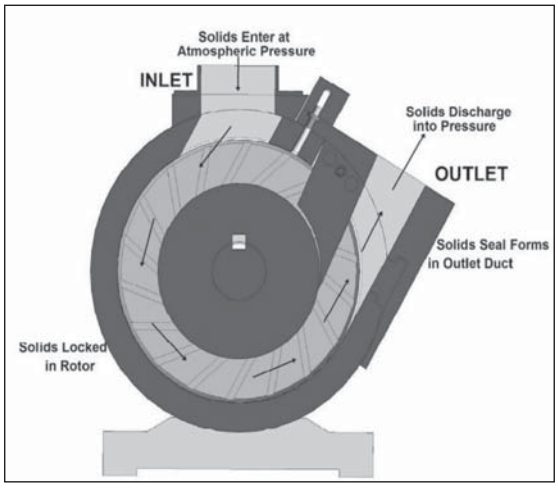
DOE-STAMET INC. HIGH-PRESSURE FEEDER RESEARCH PROGRAM

The U.S. Department of Energy (DOE) continues working toward the commercialization of more efficient and cleaner coal-based power production technologies, with Integrated Gasification Combined-Cycle (IGCC) as a key technology for near-zero emission power, as well as hydrogen production. IGCC offers the potential for 45–50 percent efficiency and capital costs less than $1,000/kW. However, a major barrier to the commercial implementation is feeding solid fuel into the gasifier pressure envelope. Limitations inherent in the batch process of existing lock hopper and piston pump paste systems prevent controlled, continuous, level delivery of the coal. Existing systems also have high capital and maintenance costs, impose significant gas losses and have substantial risk of downtime. In an effort to address these problems, DOE has supported research by Stamet Inc. to develop its unique "Posimetric® Solids Pump" technology to a level where it will be able to feed and meter coal under current and future gasifier pressures.

THE POSIMETRIC® PUMP TECHNOLOGY

The Stamet machine utilizes the unique concept of Posimetric® solids feeding. This feeder technology was initially developed by Stamet Inc. for atmospheric feeding applications, and there are now over 400 units in operation, including approximately 250 in existing U.S. power plants.

The Posimetric® machine relies on a single continuously rotating element to provide precise flow control without valves or pressure vessels. A spool formed of disks on a central hub rotates within a housing having inlet and outlet passages. An abutment, extending between the discs to the hub, separates the inlet from the outlet. Material entering the pump inlet under gravity becomes locked or bridged between the disks and is carried around by its rotation. This principle of lockup, with no relative motion between the rotor and the pumped material, means the pump experiences very low wear and provides for extremely accurate metering, with the output flow-rate being directly proportional to rotational speed. This flow-rate accuracy has been demonstrated to 99.5 percent or better. The abutment diverts the material between the disks into the outlet duct, preventing the feed from being carried around for a full rotation.



Pressure pump assembly

For pressure applications, the Stamet Posimetric® Pump retains the simplicity of only one moving part, with the abutment guiding material into an upward facing outlet duct where a gas seal is formed by a moving material plug.

RESEARCH PROGRAM

The just completed DOE-funded research program comprised two phases, with goals of first 300 psi and then 500 psi. The program was conducted using coal supplied to currently operating gasifiers, with no additional preparation, and included testing in both summer and winter conditions.

The Phase 1 target of 300 psi was achieved in December of 2003. A program of testing, modification, and optimization followed, and in January 2005 the Stamet Pump exceeded the Phase 2 target, achieving continuous injection of coal at pressures of 560 psi.

Subsequently, the Stamet Posimetric® feeder has been repeatedly operated successfully at pressure, while confirming its ability to start and stop under load and to operate under varying conditions. The duration of test runs was limited only by the capacity of the receiving pressure vessel.

The pump demonstrated consistent output per revolution independent of output pressure or rotational speed, thus confirming output accuracy and simple control. Of particular significance to practical applications was the operation of the feeder at these pressures while requiring very little make-up gas compared with lock-hopper system requirements. The test pump required only 1 scfm of make-up gas when operating at 500 psi. Also, over the course of the program, optimization efforts resulted in

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improved efficiencies that reduced the drive power requirements for the pump by over 50 percent.

BENEFITS

The successful operation of the Stamet Posimetric® feeder at pressures over 500 psi is the achievement of a major milestone for gasification systems. Feeder development is continuing to achieve the higher injection pressures (up to 1,300 psi) that will be needed for next generation gasifier systems. Feeder designs for existing and planned commercial gasifiers are on the drawing board.

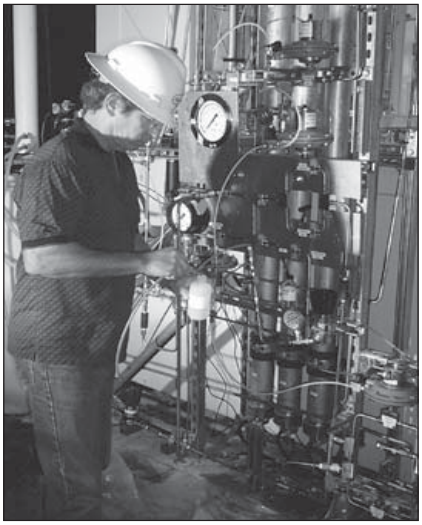
Major benefits of these feeders will include:

- Significant capital cost reduction with preliminary cost estimates indicating savings in the order of $100/kW.
- Significant operation cost reduction, with the virtual elimination of make-up gas for lock hopper operation, and reduced energy cost to raise coal into plant storage bins.
- Greatly simplified control systems, combined with the ease of maintenance of a machine with one moving part, should provide for improved reliability and availability of the system.
- Stabilized operation of combustor/gasifier from controlled feed rates and accurate turn down offering optimized performance.

First in line for a test unit will be the DOE/NETL-funded Power Systems Development Facility in Wilsonville Alabama, where Stamet anticipates having the first machine installed for semi-scale commercial testing before the end of 2005.

FIELD TESTS VALIDATE GEOSEQUESTRATION

As part of its Carbon Sequestration Program begun in 1997, the U.S. Department of Energy (DOE) Office of Fossil Energy's National Energy Technology Laboratory has been working with a variety of industrial partners in first-of-a-kind field tests to validate geological sequestration — storing CO_2 from large point sources into depleted oil and gas reservoirs, saline formations, and coal seams. These formations are thought to have sufficient storage capacity for several centuries worth of CO_2, and appear to be the most viable near-term sequestration options. The projects, most of which are in the post-injection stage, have improved understanding of CO_2 trapping mechanisms and, in some cases, have allowed researchers to actually see CO_2 movement in the reservoir. The projects also are evaluating measuring, monitoring, and verification (MM&V) technologies that allow for verification of predictive models. Technology developers have worked closely with communities at sequestration sites, helping to gain future public acceptance of widespread geosequestration.



Surface laboratory at Frio uses pilot "U tube," designed by Lawrence Berkeley National Laboratory, to extract hourly brine and gas samples for analysis

SEQUESTRATION AND ENHANCED OIL RECOVERY

The longest running geosequestration field test is being conducted at the Weyburn enhanced oil recovery project in Saskatchewan, Canada (see Clean Coal Today, Fall/Winter 2002). The project is spearheaded by the International Energy Agency and supported by a variety of international partners including DOE. Since 2001, several tons per day of CO_2 have been pumped into the Weyburn field for enhanced oil recovery and CO_2 storage. The project has been successful in expanding the understanding of formation capacity for CO_2, as well as transport, fate, and storage integrity of CO_2. EnCana, the oil field producer, and Dakota Gasification Company are utilizing new reservoir mapping and predictive tools, including surface seismic and tracer injection methods. The CO_2 is being transported by pipeline from the Great Plains Synfuels Plant in Beulah, North Dakota, itself a DOE success story funded in the 1980s. It is expected that half the CO_2 will remain sequestered, while the other half will be recycled back into the reservoir. The project is targeted to run for 15 years and store a total of 20 million tons of CO_2. DOE's role has been primarily in MM&V, and results to date are included in a September 2004 report, "IEA GHG Weyburn CO_2 Monitoring and Storage Project Summary Report." In Phase II, the project will build on Phase I data with the goal of developing a "best practices" manual that will provide an international standard by which to compare CO_2 storage/injection projects.

Starting in December 2003, at West Pearl, New Mexico, some 2,200 tons of CO_2 were injected into a depleting oil reservoir over a 42-day period. The primary emphasis of the project is to test tracer and seismic MM&V technologies, and to examine alternative CO_2 trapping mechanisms. Researchers are currently comparing the 3-D seismic results from before and after injection.

Saline Formations

Saline formations are widespread throughout the United States and have potential to store up to 500 billion metric tons of CO_2. Additionally, most existing large CO_2 point sources are within easy access of saline formations. The Frio, Texas project has attracted a great deal of international attention including a 3-month stay by an Australian study team. The project is led by the Texas Bureau of Economic Geology in conjunction with DOE's Lawrence Berkeley National Laboratory. For 10 days in October 2004, 1,600 tons of CO_2 were injected into high permeability brine-bearing sandstone. An important goal at Frio has been to test as many measuring tools as possible. Distribution of CO_2, was tested with saturation logs, cross-well seismic, and casehold EM. Results showed that the preferred measuring method will vary across the reservoir, depending on such factors as saturation state of CO_2, conductivity of fluid, and salinity. Researchers were also able to measure CO_2 plume movement in the reservoir, and found that it acted as their models had predicted. Frio has enjoyed local community support due to outreach efforts by the sponsors.

American Electric Power (AEP) and Battelle Memorial Institute have conducted a site assessment at AEP's Mountaineer Plant, in New Haven, West Virginia in the Ohio River Valley. The deep sandstone saline formation is thought to be ideal in terms of geology and is also near the largest concentration of fossil-fuel power plants in the United States. A seismic survey was completed and a 10,000-ft well drilled to study the target area and overlying sediment layers. Unfortunately, the injection well revealed low permeability in the target zone. Researchers are currently evaluating potential storage capacity in shallower formations.

Coal Seams and Methane

Coalbed methane recovery has been combined with CO_2 sequestration in some field projects. The recovered methane provides a value-added revenue stream to offset sequestration costs. In Marshall County, West Virginia, CONSOL Energy R&D, in conjunction with CNX Gas and CNX Land, are cooperating with DOE in a seven-year field project to evaluate both coalbed methane (CBM) recovery and CO_2 adsorption capacity of an unmineable coal seam. A series of wells will be drilled 3,000 feet horizontally in the subsurface, to drain CBM from two overlying coal seams. The same wells will later be used for CO_2 injection and sequestration, which will further enhance CBM recovery at the exterior wells. Using this unique approach, CBM will be recovered from a mineable seam, rather than vented to the atmosphere. The project is currently in the pre-injection phase. Approximately 26,000 tons of CO_2 are to be injected over a one-year period after degassing and dewatering operations are complete.

In San Juan Basin, New Mexico, Advanced Resources International and its partners are undertaking the world's only long-term, multi-well enhanced CBM project to evaluate the viability of storing CO_2 in deep, unmineable coal seams (see Clean Coal Today, Summer 2002). The two field pilots, the Allison Unit (operated by Burlington Resources) and the Tiffany Unit (operated by BP) are demonstrating, respectively, CO_2 and nitrogen (N_2) enhanced CBM recovery technology. The effect of N_2 on methane recovery has important implications for power plant flue gas injection, since N_2 is the primary constituent of flue gas. Currently, the cost of separating CO_2 from flue gas is high. Nitrogen also is an effective methane displacer, improving methane recoveries and further decreasing the net cost of CO_2 sequestration. The project is also improving understanding of coal swelling and ability to predict CO_2 storage capacity.

At the Landfill Gas Sequestration project in Johnson County, Kansas, the Kansas Geological Survey is exploring the possibility of injecting untreated landfill gas into subsurface coal beds, with the goal of using natural processes to separate the methane and CO_2 constituents, and eliminate the need for processing facilities. Some 4.5 million cubic feet of landfill gas is collected each day. A goal is to produce 3 million cubic feet per day of pipeline quality natural gas.

Data from these DOE-sponsored field tests also should provide valuable input to the Carbon Sequestration Regional Partnership effort, a national effort to determine sequestration options for specific areas of the country.

Technology Development through High-Performance Computing

In recent years, computer-based research has become an integral part of technology development, particularly in the area of advanced coal-fueled power systems. With the tremendous advances in computing power and affordability, the U.S. Department of Energy, National Energy Technology Laboratory (NETL) is committed to the use of high-performance computing in its R&D programs. As a part of that commitment, NETL's in-house research group — working with private partners — is developing a world-class modeling and high performance computing infrastructure to aid in the computational fluid dynamics (CFD) and computational chemistry aspects of developing the next generation of highly efficient, clean fossil energy technologies. This enhanced computing capability adds to the attractiveness of NETL as a focal point for important joint research with the private sector.

High-Performance Computing

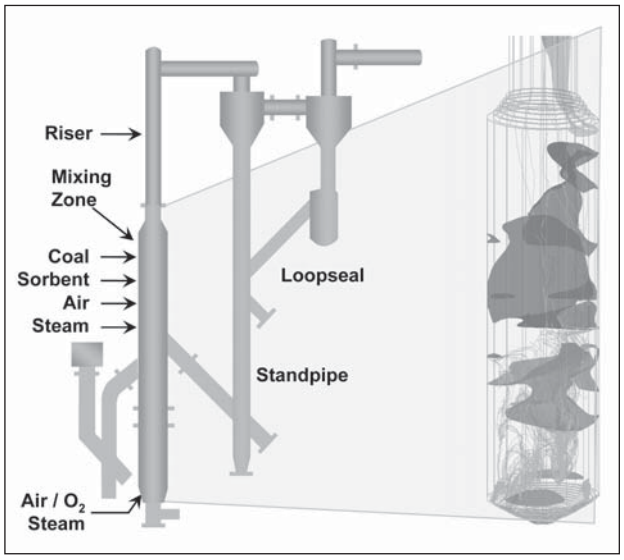
High-performance computing focuses on the development of very fast and large computers (clusters and supercomputers) together with corresponding software. Problems that run on these machines typically are divided into smaller problems that can be solved simultaneously (parallel processing). NETL's clusters are composed of many relatively inexpensive computers locally connected. The performance of the latest two clusters at NETL (256- and 232-processor clusters) is comparable to computers currently listed in the top 500 in the world. A 256-processor cluster has been optimized for computational fluid dynamics calculations with 256 Xeon 3.0-GHz processors with gigabit ethernet interconnection. A 232-processor cluster has been optimized for computational chemistry calculations and consists of 232 Opteron 2-GHz processors with gigabit ethernet interconnection. Furthermore, 3.5 terabytes of mirrored raid level 5 data storage are available at both NETL campuses (Morgantown, West Virginia and Pittsburgh, Pennsylvania).

NETL also is developing leading edge software and systems to provide visualization support for fossil energy research. Simulations completed on the clusters can be visualized in 3-D, facilitating understanding of complex hydrodynamics and chemistry. Ensight© by CEI and Paraview is the software used to visualize CFD results.

High-performance computing at NETL is further enhanced through a regional super computing science consortium — SC². This consortium is a partnership between NETL, the Pittsburgh Supercomputing Center (PSC), and sponsors from academia and government. Through SC², researchers have remote access to a variety of cluster and supercomputing platforms located at the PSC. The high-speed optical network established between NETL and the PSC terascale computer — the "Lemieux" — is the fastest open research supercomputer in the nation. Researchers are able to transfer gigabytes of data from simulations completed at PSC back to NETL for post-processing and visualization, all in a matter of minutes.

Success Stories

The use of high-performance computing is allowing scientists at NETL to determine the physical/chemical properties of matter in the nanoscale range. Data at the molecular level is very difficult to obtain using experimental methods, and would require the use of expensive surface science techniques such as the scanning tunneling microscope. With the new high-speed clusters, behavior of an ensemble of atoms and molecules now can be studied using both quantum and classical parallel codes. A few examples of computational chemistry providing important scientific answers are:



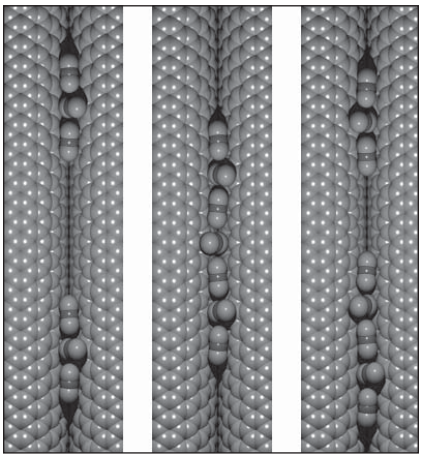
Transport Gasifier and MFIX projection of particle trajectories and oxygen concentration

dynamics of atomic or molecular systems interacting with catalyst surfaces, separation of gaseous mixture by alloy membranes, and storage

and separation properties of gaseous systems in porous or carbonaceous materials.

One recent accomplishment has been the NETL work with Carnegie Mellon University to predict the transport properties of hydrogen through a copper palladium separation membrane. Such membranes are vital to production of hydrogen from coal. High-speed computers performing computational chemistry analysis can allow screening of a variety of alloys with properties tailored to specific purposes — for example, for future hydrogen production.

Other important developments in the use of high-performance computing have taken place at the Power Systems Development Facility (PSDF), located in Wilsonville, Alabama. The PSDF is a joint project of DOE, Southern Company Services, Inc. (SCS), Kellogg Brown & Root (KBR), and other industrial partners to demonstrate an advanced coal-fueled power system (see Clean Coal Today Winter 2004 and Summer 2002). Given the large scale of the KBR Transport Gasifier, transient three-dimensional computer simulations require a tremendous amount of computing power to generate a statistical set of data. Simulations that previously required months now can be done in days. Hundreds of processors allow researchers to run a variety of scenarios simultaneously and continuously. At the PSDF, engineers follow both air- and oxygen-blown operating conditions for bituminous and sub-bituminous coals. They track flow rates and location and orientation of gas and/or solid inlet ports. Pressure effects and the effects of particle size are also important.



Simulation of CO_2 adsorbed in the groove site of nanotube bundles

In particular, researchers at NETL are using the two-fluid model MFIX (Multiphase Flow with Interphase eXchanges) to model hydrodynamic behavior inside the KBR Transport Gasifier, and account for chemical reactions and heat transfer. Two-fluid hydrodynamic models (Eulerian-Eulerian models) treat the fluid and solid as two continuous and fully miscible phases. This approach results in mass, momentum, and energy balance equations for both the gas and solids phases. The MFIX model has been in use at the NETL for over 15 years and has become internationally recognized as one of the premier two-fluid models available to researchers. Fully optimized to run on high-performance computers, its open source format and FORTRAN coding of subroutines and versatile post-processing tools make MFIX an ideal platform to develop, validate, and test sub-models (e.g., coal combustion and gasification) within a two-fluid framework.

One of the greatest benefits of the high-performance computing infrastructure is the ability to apply computer models to commercial scale operations of high temperature/pressure facilities, where actual experimental data would be difficult and costly to obtain. Under the Clean Coal Power Initiative, DOE is in the process of negotiating an agreement with SCS, KBR, and Orlando Utilities Commission to construct a commercial-scale 285-megawatt coal-based gasification plant in Orlando, Florida. This plant will scale up a KBR Transport Gasifier perfected at the PSDF. To help address scale-up issues, and with funding from NETL's Advanced Research Program, NETL, SCS, and KBR have performed several simulations based on a conceptual design. High-performance computers at NETL allowed scientists to simulate a variety of operating conditions simultaneously and consider varying scenarios related to gasifier operation. Rapid turnaround time for simulation results provided engineers with transient three-dimensional detailed information from inside the gasifier. These simulations required well over a million computational cells to adequately resolve design issues for the gasifier.

NETL's high-performance computer capability will prove vital in efforts to bring important new technologies to the marketplace.

INTERNATIONAL INITIATIVES

INDIA REGULATORY WORKSHOP

India's power sector plans to add 100,000 MW of new capacity — based mostly on domestic coal — over the next decade to meet the country's surging demand for electricity. At the same time, regulatory reforms are changing the way business is done, with the goal of ensuring more security for investors, and reliable and adequate supply of power at reasonable rates for consumers. While the Electricity Act 2003 calls for a multi-layered industry structure, India's power sector is still only quasi-privatized. Federal and State governments control the majority of generation and distribution assets, and regulatory treatment is not uniform for central, state and private power plants.

Fossil Energy's National Energy Technology Laboratory (NETL), providing technical assistance to the U.S. Agency for International Development (USAID) through a participating agency service agreement, teamed with the National Association of Regulatory Utility Commissioners (NARUC) and India's National Thermal Power Corporation (NTPC) to organize a workshop — Electricity Market in India and Learnings from Developed Markets that provided a forum for Indian and U.S. regulators to exchange ideas. The workshop, which attracted more than 250 representatives from the Indian power sector, was held March 1–2, 2005, at the India Habitat Centre in New Delhi, India. Workshop participants addressed a spectrum of issues affecting the regulatory process, such as market reform and monitoring, consumer protection, rulemaking and tariff structures, federal/state jurisdictional questions, and infrastructure protection.

Attendees discussed a variety of alternative rate and tariff structures to guarantee reasonable rates of return for investors, and provide a necessary boost for the power market in bridging the widening gap between supply and demand. A market-driven power exchange market was considered a vital platform for the development of a competitive power market in India. The group also considered new settlement mechanisms for real-time imbalances as the market matures. Availability Based Tariffs (ABT), a new performance-based mechanism that has brought grid discipline to the central sector is scheduled to be implemented intra-state in 2006. Pool tariffs — rates established for a power pool, as opposed to the present system of negotiated rates between a generator and individual distribution companies — are also an option.

Sponsors viewed the workshop as being successful, and follow-on activities are being discussed where NETL's technical expertise and that of other U.S. organizations can help India address problems in its coal-dependent power sector.

U.S.–UK WORKSHOP ON ADVANCED MATERIALS

Under an agreement signed in March 2003 by the Secretary of the U.S. Department of Energy (DOE) and the UK Department of Trade and Industry, researchers from both countries met in Knoxville, Tennessee, May 11–15, for the Second Joint Workshop in Advanced Materials. UK aspects of the work are now being managed by the UK Department of Energy. The DOE's National Energy Technology Laboratory coordinates the U.S. materials work.

The Implementing Arrangement on Clean Fossil Energy aims to promote fuel diversity, environmental protection, energy security, and international trade, and is responsible to a broad Memorandum of Understanding on energy R&D signed by the United States and the UK in 2000. Activities include joint planning, information and personnel exchange, integrated work tasks, and joint workshops. These efforts are designed to leverage resources, make possible accelerated testing, and take advantage of unique research facilities of the collaborating country.

International Initiatives

Advanced materials, capable of withstanding the high-temperature environments of advanced coal processes, continue to be a priority R&D activity for joint collaboration. Areas of common interest, as reported at the workshop, include steam oxidation behavior of a wide range of materials — ferritic and austenitic steels as well as Ni-based superalloys. U.S. and UK researchers are generating data on scale growth and spallation for selected alloys in order to fill gaps in the database and confirm accuracy of operating data for critical temperature and pressure regimes. The main focus is on newer alloys required for advanced steam conditions. Boiler corrosion, protective coatings, and the effects of syngas in gas turbine are also areas of materials study. A separate effort is underway in virtual plant simulation including shared platforms, computational fluid dynamics modeling, and security controls.

In addition to DOE, participants in the UK materials work included: ALSTOM Power; Cranfield University; Corus; E.ON UK Ltd., Howmet Corp.; Liverpool University; Loughborough University; Mitsui Babcock Energy, Ltd.; National Physical Laboratory; Siemens Industrial Turbines; and RWE Power.

2005 Clean Coal and Power Conference

November 21–22, 2005
Renaissance Mayflower Hotel
Washington, DC

Organized by the United States Energy Association, in conjunction with the U.S. DOE and the National Mining Association.

Will rapidly advancing technologies for clean coal and advanced power systems live up to their promise? The Conference will focus on political, environmental, economic, and social issues related to growth in global energy demand, and will explore the role of coal as a viable fuel to meet that demand. Competition in electricity and fuel markets, utility restructuring, environmental regulations, and global climate change initiatives will be among the topics addressed.

For exhibiting information, contact Rob Donovan at 202-312-1238, or rdonovan@usea.org

For registration and other information, contact Faith Cline at 202-586-7920, or faith.cline@hq.doe.gov

Unburned Carbon Conference Joins World of Coal Ash

Over 500 international representatives from government, academia, and industry gathered in Lexington, Kentucky, on April 11–15, 2005, for the first World of Coal Ash conference. The conference brought together under a single banner several previous coal by-product conferences and meetings, including the DOE/NETL Unburned Carbon (UBC) Conference. Co-sponsors include the American Coal Ash Association, University of Kentucky's Center for Applied Energy Research, U.S. Department of Interior, and DOE/NETL. The conference presented the latest R&D developments in the use and disposal of bottom ash, fly ash, fluidized-bed combustion ash, and solids from dry and wet flue gas desulfurization systems.

The UBC Conference was held as a separate track at World of Coal Ash. Speakers discussed such topics as combustion efficiency improvements, UBC control by boiler fine tuning and advanced combustion diagnostics, new on-line carbon-in-ash analyzers, and ash beneficiation techniques. New developments reported at the conference included a report by Alstom Materials regarding UBC as an agent in boiler wastage. GE Energy discussed its research showing UBC can remove up to 80 percent of mercury in flue gas when combined with optimized reburning. Proceedings of the UBC conference can be found at http://www.netl.doe.gov/ and click on Publications. For information on the umbrella World of Coal Ash Conference see http://www.worldofcoalash.org/.

Active CCT Demonstration, PPII, and CCPI Project Status

CCT Demonstration Status

JEA – ACFB Demonstration Project. The four planned demonstration phase test burns, which began January 13, 2004, were completed on August 12, 2004. Fuels and fuel blends tested during the period included 100% Pittsburgh #8, a 50/50 blend of Pittsburgh #8 and petcoke, 100% Illinois #6, and a 80/20 blend of petcoke and Pittsburgh #8. The tests were conducted at 100, 80, 60, and 40 percent of full load. The four test report emissions were monitored at each load level and were well below permitted values. (Jacksonville, FL)

Kentucky Pioneer Energy (KPE), L.L.C. – Kentucky Pioneer Energy Project. KPE submitted a Continuation Application (CA) in May 2005 to proceed to the next phase. The CA is currently being reviewed. (Trapp, KY and West Terre Haute, IN)

TIAX (formerly Arthur D. Little, Inc.) – Clean Coal Diesel Project. The project remains in a holding pattern pending the outcome of the preferential payment claims lawsuit. The date of the hearing has not been scheduled yet. (Fairbanks, AK and Beloit, WI)

PPII Status

Otter Tail Power Company – Demonstration of a Full-Scale Retrofit of the Advanced Hybrid Particulate Collector (AHPC) Technology. After completing more than two years of commercial demonstration, the AHPC project is to conclude June 30, 2005. Otter Tail plans to continue operating the AHPC indefinitely. To date, the AHPC has demonstrated superior particulate removal when the integrity of filter bags remains intact. However, superior particulate removal has been accompanied by greater operating costs due to increasing overall pressure drop or premature bag failure. Otter Tail has made a proposal to DOE for joint funding of a unit modification and 2 years of additional testing to enhance the operating performance of the unit. (Big Stone City, SD)

Sunflower Electric Power Corp. – Demonstration of a 360-MWe Integrated Combustion Optimization System. The combustion optimization sensors package is operational. Data are being archived on the MKE computer and by EtaPRO. The low-NO_x burner modifications and coal-balancing dampers have been installed and are operational. All five pulverizers are equipped with an automated coal-flow balancing system. Sunflower continues to evaluate the impacts of overfire air on furnace exit gas temperature. Despite slagging, the boiler continues to operate satisfactorily. Sunflower is presently evaluating proposals from vendors that include bid specifications for new low-NO_x burners and overfire air system. Sunflower has submitted a continuation application to DOE for proceeding to Phase III Budget Period 2 of the project. (Garden City, KS)

Tampa Electric Company, Big Bend Power Station Tampa – Neural Network Sootblower Optimization Project. The neural network was successfully implemented to optimize sootblowing on Unit 2, a 455-MWe boiler, at Tampa Electric Companies Big Bend Station. The project applied a neural network intelligent sootblowing (NN-ISB) system in conjunction with state-of-the-art controls and instruments to optimize the operation of a utility boiler and systematically control boiler slagging/fouling. The objectives of the intelligent sootblowing system are to reduce NO_x and particulate matter emissions, and to improve unit efficiency. After implementation of the NN-ISB, NO_x reductions up to 8.5%, opacity improvements during sootblowing activities up to 1.5%, and unit efficiency improvement up to 1.3% were reported. In addition, total sootblower work was lower with the optimization system engaged; full integration of sensors technology and optimization was completed; the human-machine-interface (HMI) portion of the project improved daily operation; boiler steam drum and pressure operation improved; and steam tube temperatures showed less deviation at high load conditions. (Apollo Beach, FL)

Universal Aggregates, LLC – Commercial Demonstration of the Manufactured Aggregate Processing Technology Utilizing Spray Dryer Ash. The project is in the operations phase. Universal Aggregates has successfully run the entire plant process including mixing, extrusion, curing, crushing, screening, and recycling screened fines. The plant has shipped finished product to their distributor on a limited basis. The facility is now staffed 24/7 as efforts are made to adjust material additives and equipment configurations to produce a consistent product from the spray dryer ash removed from the Birchwood Power Generation Facility. Universal Aggregates has indicated that they will request an extension beyond the scheduled June 30, 2005, project end date while modifications and improvements are being made to lengthen the continuous run time and increase the plant availability rate. (King George, VA)

CCPI Status

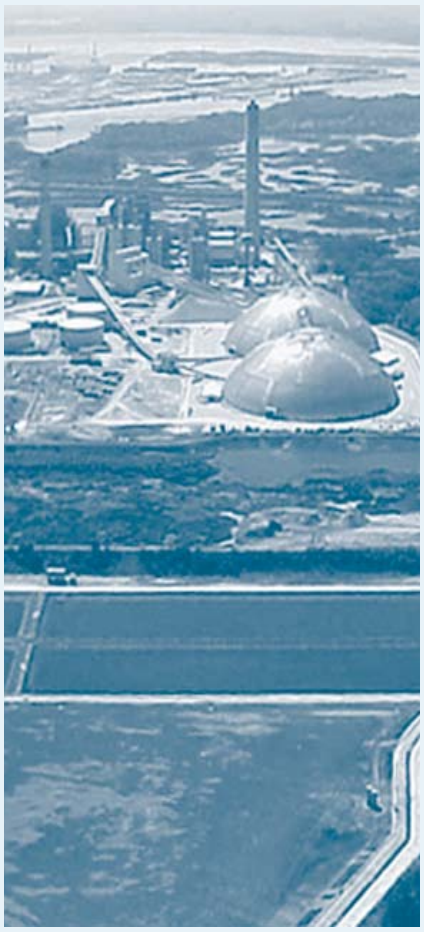
NeuCo, Inc. – Integrated Optimization Software. The project at Dynegy's Baldwin Energy Complex has been under way for over a year, and there has been substantial progress and results, including significant NO_x reductions and improved slag control at the two cyclone boilers. NeuCo continued the CombustionOpt V1.2 and ProcessLink design work. Substantial effort has been dedicated to the user interaction of CombustionOpt with other ProcessLink optimizers. The other area of design relates to the back end technology that facilitates multiple optimizer communications. NeuCo has continued work on defining additional PerformanceOpt and MaintenanceOpt functionality both from a configuration engineer's point of view as well as that of the plant personnel end user. (Baldwin, IL)

University of Kentucky Research Foundation – Advanced Multi-Product Coal Utilization By-Product Processing Plant. The first budget period (Project Definition) of the project is well under way. Progress to date has focused on a detailed assessment of the two potential sources of feedstock for the ash benefication demonstration project plant: ash as produced by Kentucky Utilities' 2,200-MW Ghent Generating Station and the lower ash pond at Ghent. Sedimentation, stratigraphy, and resource assessment of the pond was investigated using vibracoring and three-dimensional computer-modeling techniques. Analysis indicates that the pond volume exceeds 200 million cubic feet and contains more than 7 million tons of ash, including over 1.5 million tons of coarse carbon and 1.8 million tons of fine (<10 µm) glassy pozzolanic material. Due to the size, quality, and consistency of the ponded material, it has been concluded that the demonstration project plant will be fed entirely from the ash pond. Preliminary product testing results at CEMEX, the commercialization partner, using initial samples of the Ghent pozzolanic material, are encouraging and suggest that performance parameters could exceed cement specifications. Initiated in November 2004, the Project Definition Phase goes through May 2006. (Ghent, Carroll County, KY)

We Energies – TOXECON™ Retrofit for Mercury and Multi-Pollutant Control. Engineering and design for this project are complete, and the project is in the construction phase. Vendors have been selected for all major equipment supply and construction activities. Wheelabrator is supplying the baghouse, and Norit is supplying the activated carbon storage and injection systems. Construction of the foundations was initiated in September 2004 and completed in January 2005. Installation of the Unit 7 diverter damper into existing duct work was completed in November 2004, and installation of the Unit 8 diverter damper into the existing duct was nearly complete in May 2005. Phase I of the duct work installation is complete, and structural steel installation is ongoing for the baghouse and fan enclosure. Installation into the baghouse structure has begun. Project construction is expected to be complete by the end of calendar year 2005, with system operation in January 2006. Thermo Electron launched its new mercury continuous emission monitor, which has been partially developed and tested under this project. (Marquette, MI)

Western Greenbrier Co-Generation, LLC – Western Greenbrier Co-Production (WGC) Demonstration Project. WGC has signed a memorandum of understanding (MOU) with an "A-rated" commercial entity to purchase the power output from the Western Greenbrier Co-Production Plant. The potential buyer and partner expresses keen interest in developing, owning, marketing, and operating additional waste-coal fired facilities beyond the Rainelle, West Virginia demonstration. The MOU outlines terms and conditions being considered to create a power purchase agreement between WGC and its potential partner. The parties anticipate completing negotiation of the agreement sometime this summer. (Rainelle, WV)

Great River Energy (GRE) – Lignite Fuel Enhancement. The prototype dryer construction was initiated in February 2005. GRE also received various pieces of equipment at the Coal Creek Station: crusher, bucket elevator, coal feed conveyors, baghouse, dampers, and dry coal conveyors. About 70% of the structural steel has been installed. (Underwood, ND)



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