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CLEAN COAL TODAY

A NEWSLETTER ABOUT INNOVATIVE TECHNOLOGIES FOR COAL UTILIZATION

NEWS BYTES

The DOE Office of Fossil Energy and the National Energy Technology Laboratory held a **Clean Coal Power Initiative** (CCPI) Planning Workshop, "Clean, Reliable & Affordable Electricity for America's Future," on September 28, 2001, in Pittsburgh, Pennsylvania. The CCPI is a government/industry partnership to implement the President's National Energy Policy recommendation to increase investment in clean coal technology. This recommendation, one of several dealing with electricity, addresses our national challenge of ensuring the reliability of our electric supply while simultaneously protecting our environment. The CCPI, a cost-shared partnership, proposed in the Fiscal Year

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IN THIS ISSUE

CHINA MEETINGS ADVANCE FOSSIL BILATERAL R&D EFFORTS

In late August 2001, a U.S. Department of Energy (DOE) delegation to the Peoples Republic of China (PRC), led by Fossil Energy's (FE) Acting Assistant Secretary Robert S. Kripowicz, moved bilateral R&D cooperation forward in the area of clean energy technology, including fossil energy and energy efficiency. Kripowicz traveled to Beijing to co-chair the second meeting of the Permanent Coordinating Committee, a group established to implement the U.S.-China Protocol For Cooperation in the Field of Fossil Energy Technology Development and Utilization." The protocol, signed in April 2000, has five annexes (each reflecting specialized areas of cooperation), four of which are signed and one is expected to be signed shortly. While in China, the FE team participated in two important conferences organized under the protocol and cosponsored by U.S. DOE and the Ministry of Science and Technology's (MOST) — the first U.S.-China Clean Energy Technology Forum and Exhibition, and the first U.S.-China Symposium on CO_2 Emission Control Science and Technology.

Robert S. Kripowicz, Acting Assistant Secretary for FE, and The Honorable Xu Guanhua, China's Minister of Science and Technology, in discussions before the Clean Energy Technology Forum opening

The importance of the joint R&D effort was demonstrated by an invitation from Vice Premier Li Lanqing, PRC's third highest ranking official, to meet with the U.S. delegation to discuss R&D efforts in clean energy technology. The Vice Premier expressed strong support for cooperation between the two nations and highlighted the importance of clean coal, solar, and wind technologies. Kripowicz explained cooperative work undertaken in this area, and advocated for U.S. business expertise to help meet China's R&D needs.

The Secretary General of MOST, Shi Dinghuan, opened the Coordinating Committee meeting, outlining technology goals of China's new Five Year Plan. Shi mentioned that considerable efforts would be directed toward fossil energy, including clean coal technologies, oil and gas, coalmine methane, low-

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...China continued

cost methods for reducing SO_2 and NO_x, as well as such areas as wind and solar energy. At the meeting's conclusion, six project task agreements were signed. The five agreements relating to coal are:

- On-site IGCC briefings at the Tampa Electric Clean Coal Project and at FE's Wilsonville Power Systems Development Facility.
- Electricity grid modeling to manage power flow.
- Development of a flue gas desulfurization technology manual for coal-fired power plants.
- Feasibility study on ammonia scrubbing of flue gases to remove CO_2 and produce fertilizer.
- Low-NO_x combustion and SO_2 control technologies workshop.

Other projects in the areas of alternate fuel, fuel cells, polygeneration, and climate science are planned.

As an event jointly planned and implemented through the auspices of the Protocol Agreement, the U.S.-China Clean Energy Technology Forum and Exhibition was held in Beijing, August 29–31, 2001. Over 500 people attended, with 39 U.S. presentations, and 65 Chinese presentations. The conference included technical sessions in a variety of areas ranging from power systems and environmental control technology to clean fuels and energy efficient buildings. A Technology and Equipment Exhibition with over 100 displays highlighted the technologies discussed throughout the conference, including three Office of Fossil Energy exhibits: Office of Coal & Power Systems, Ultra-Clean Transportation Fuels program, and the National Petroleum Technology Office.

U.S. Ambassador Clark T. Randt and China Science and Technology Minister Xu Guanhua opened the conference and spoke of mutual benefits of cooperation. Kripowicz addressed the opening session and cited increasing electric power demand, especially in rapidly industrializing countries such as China, as a compelling reason to develop a diversified energy strategy that balances energy and environmental issues. He noted the Bush Administration's emphasis on innovation and technology to accomplish these twin goals, and suggested that there may be parallels between China's new Five Year Plan and the Administration's plan. Prior to the Beijing conference, some 100 attendees gathered for the first U.S.-China Symposium on CO_2 Emission Control Science and Technology, held in Hangzhou, China on August 22–24, 2001. Representatives from academia and government participated in discussions focused on advanced combustion technologies and alternative energy sources, within the context of how technologies can capture and sequester CO_2. Some 40 papers, as well as poster presentations, were presented.

In all, the meetings and conferences stressed the mutual benefit that can be realized through R&D cooperation between the U.S. and China, both the world's largest energy consumers and largest emitters of greenhouse gases. General agreement was reached on the proposal to have the third meeting of the Permanent Coordinating Committee in the United States in the Spring of 2003.

DOE CLEAN COAL AND POWER CONFERENCE

The U.S. Department of Energy's Office of Fossil Energy will hold its Clean Coal and Power Conference on November 19–20, 2001, in Washington, DC. The conference, "Reliable and Affordable Energy," will focus on achievements in joint federal-state-private clean coal technology development and demonstration projects, and the new policies and innovative concepts necessary for coal to continue supplying affordable energy, both domestically and globally.

Clean coal technology is a central feature of the Administration's proposed National Energy Policy, and is receiving renewed support through the Administration's 10-year, $2 billion commitment to conduct research under the "Clean Coal Power Initiative." Congress also recently authorized a new clean coal technology development and demonstration program, the "Power Plant Improvement Initiative." These efforts come at a time when the reliability of affordable electric power is becoming a growing concern. Coal currently supplies over 52 percent of the nation's electricity and is likely to continue to supply roughly the same percentage through at least the next 20 years.

Topics will include the challenges that coal users will face in meeting environmental concerns, including global climate change, and the role of coal in the increasingly competitive electricity and fuel markets.

For more information, contact Faith Cline by phone (202) 586-7920, facsimile (202) 586-8488, or e-mail faith.cline@hq.doe.gov. Additional information can be found at the Fossil Energy website (www.fossil.energy.gov/events/cleancoal).

FIRST NATIONAL CONFERENCE ON CARBON SEQUESTRATION

The First National Conference on Carbon Sequestration, sponsored by the U.S. Department of Energy (DOE) and held May 14–17, 2001, in Washington, DC, drew over 400 representatives from the research community, academia, and industry. Some 150 papers were presented in the technical areas of geologic, terrestrial, and ocean sequestration; capture and separation; conversion and utilization; and modeling.

NETL Director Rita Bajura addressing the plenary session

In opening remarks, Robert S. Kripowicz, Acting Assistant Secretary for the DOE Office of Fossil Energy, traced the federal sequestration research program from its beginnings as a "laboratory curiosity" to an active program with 58 discrete projects cost-shared with the private sector and producing important results. Opening plenary session speaker Rita Bajura, Director of the National Energy Technology Laboratory, addressed technology options for global climate change, including advanced energy plants of the future that would use coal gasification with water gas shift, pressurized combustion with pure oxygen, and coal gasification with calcium carbonate intermediate. She also described current carbon management options being pursued as part of DOE's program — decreasing carbon intensity; improving efficiency; and sequestering CO_2 by capture, storage, or enhanced natural processes.

At the close of the conference, participants were asked to provide insights gained on DOE's sequestration program or sequestration efforts in general. In the area of public acceptance, the audience noted that the public does not realize how predominant coal is in our economy and daily lives. To gain acceptance of the need for sequestration, some thought the term itself should be changed to something more descriptive such as "carbon storage" or "carbon management."

Pricing and cost issues also were mentioned. One participant noted that reducing emissions of methane is a good, cost-effective approach to reducing greenhouse gas emissions and should be pursued. Another participant said that while a cost of 2–3 cents per kWh for carbon capture and storage may loom large to people in industry, it is little in the context of the overall economy. There is wide divergence in CO_2 capture cost estimates, and one participant noted the need for reexamination of the underlying assumptions. Another view was that lower cost sequestration technologies should be pursued more aggressively, even if their storage potential is limited compared to other methods, for example, reforestation, improved agricultural practices, and CO_2 enhanced oil recovery.

Other attendees recommended incentives to spur sequestration technology development, such as performance-based tax credits. It also was suggested that R&D should be leveraged with industry partnerships, particularly pilot demonstrations, and developing countries need to play a more active role in such ventures.

Regarding future research direction by DOE and the private sector, attendees highlighted terrestrial and ocean sequestration, as well as the potential for biogenic methane, such as landfill gases, to be put to productive use. Comments suggested that more information is needed about soil's capacity to store carbon, and methods to quantify or monitor the amount of carbon stored to pursue terrestrial sequestration. Such progress could increase the carbon emission reduction credits available per acre of land. Ecosystem impacts, particularly from ocean sequestration, were a concern to some researchers who feared interference with the ocean's ecological balance.

The conference showed an increasing level of interest by public and private participants in CO_2 sequestration. Proceedings are available at http://www.netl.doe.gov/products/sequestration/. DOE will sponsor the second annual conference, May 13–15, 2002, in Washington, DC. Increased attention will be given to emissions trading and offsets, international activities, control strategies, and implementation issues.

A young future scientist studies a DOE coalmine methane exhibit at the sequestration conference

SECOND GENERATION PFB REPOWERING SHOWS PROMISE

Coal-fired generation produces more than 52 percent of America's electricity, yet much of that generating capacity is over 40 years old and requires new equipment to bring it to today's environmental standards. Upgrading these units makes economic sense, because existing coal-fired generating units are consistently among the lowest production cost units in today's competitive electric market, and make a significant contribution to needed baseload capacity. Over the past several years, an important effort has been undertaken by the U.S. Department of Energy, Office of Fossil Energy's National Energy Technology Laboratory (NETL), to conduct feasibility studies of candidate plants for repowering with advanced pressurized fluidized-bed combustion (APFBC) technology developed by DOE and its industrial partners. The technology can extend plant life, reduce operating costs, and dramatically reduce emissions.

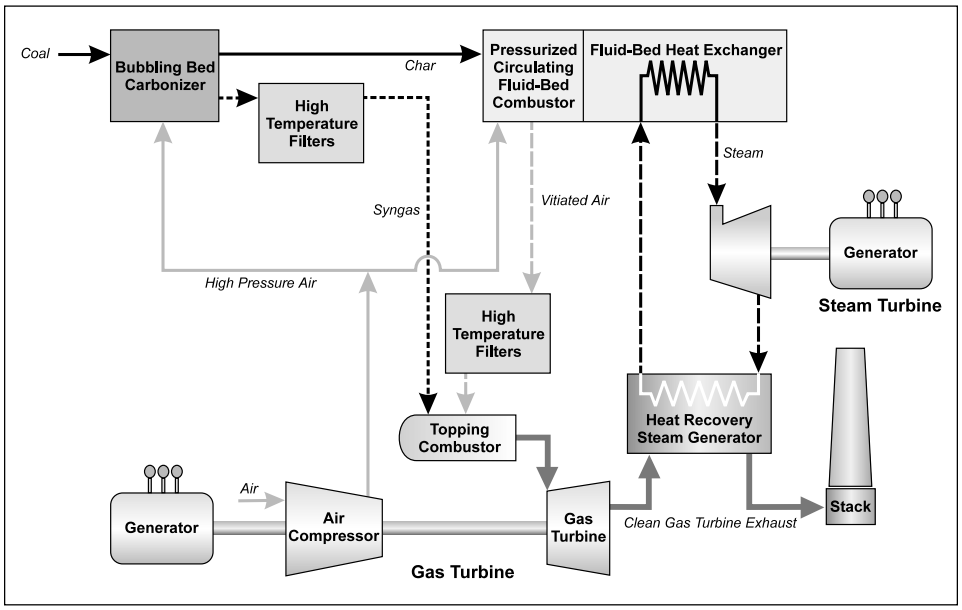
The schematic below shows the major components of an APFBC power plant. In first generation technology, all combustion takes place in the pressurized fluid-bed (PFB) combustor. Second generation technology adds a topping combustor, as well as a carbonizer to produce hot syngas. While a conventional combined cycle uses natural gas, APFBC operates at near the same efficiency but on less costly coal. The technology has wide tolerance for differing coal types and can use opportunity fuels (biomass and wastes). Sulfur, alkali, and particulate removal upstream of the gas turbine allows the gas turbine to operate free of corrosion and erosion damage, minimizing efficiency losses over time.

A particular advantage of the APFBC technology for repowering applications is that high quality steam is generated in the fluid bed heat exchangers of the APFBC system. There is sufficient temperature in the beds, about 1,600 °F, to assure that the steam conditions of an existing steam turbine, typically 1,000 °F superheat and 1,000 °F reheat, can be met. Further, it is easy to match the steam demand and conditions of an existing steam turbine because the combustor can be fed supplemental coal in addition to the char from the carbonizer to boost temperature, if necessary.

The five systems studied by NETL used a Foster Wheeler circulating pressurized FBC to develop hot vitiated (reduced oxygen) air for the gas turbine's topping combustor and steam for the steam bottoming cycle. For the studies, NETL screened a range of gas turbine equipment from Dresser-Rand, General Electric, Pratt & Whitney, Rolls Royce, and Siemens Westinghouse. Factors studied include: ability to export high pressure compressor air, burn 600–1,400 °F low-Btu syngas, use 1,000–1,550 °F or higher temperature vitiated air with low oxygen concentration, and operate with a topping combustor capable of importing hot syngas and vitiated air.

The effort was cost-shared with the participating facilities, and included the following:

- Progress Energy's L.V. Sutton Station explored options for repowering Units 1 and 2. The principal investigation used a modified Siemens Westinghouse W501F turbine and vitiated air. Three aeroderivative Pratt & Whitney Turbo Power FT8 twin gas turbines were evaluated in a 1,400 °F syngas and vitiated air application. Total plant costs were estimated at $961/kW for repowering Unit 2 alone, and $847/kW for repowering both units.
- Duke Power's Dan River Station looked at repowering of Unit 3. The principal investigation used a modified Siemens Westinghouse W501F turbine.



APFBC power system schematic

Total plant costs were estimated at $784–966/kW.

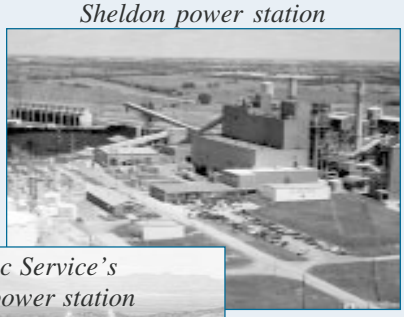
- AES Greenidge LLC's steam plant investigated repowering of Units 3 and 4. Two modified Rolls Royce Trent gas turbines serving one steam turbine were evaluated. The study assumed a 1,400 °F syngas and vitiated air. Total plant costs were estimated at $880/kW.
- Nebraska Public Power District's Sheldon Station analyzed repowering of Units 1 and 2, looking at a General Electric PG7121EA gas turbine and APFBC train. (Cost data not available.)
- Arizona Public Service's Four Corners Power Station studied options for Unit 1 and 2 looking at first generation PFBC and later conversion to second generation. The system would employ Dresser-Rand turbomachinery derived from the compressed air energy storage plant designs. Total plant costs were estimated at $1,100/kW for three units.

Repowering the five plants showed total plant costs to be comparable to other coal-fueled expansion projects. Pollution was reduced significantly over current levels. Lime or limestone in the fluid bed can remove sulfur, resulting in SO_2 emissions up to 96 percent less than the existing units. A combination of low combustion temperatures and other features can reduce NO_x to 63 percent less per kWh than an existing station. Specifically, a repowered L.V. Sutton Station, when compared to the existing station, would emit 4 percent of the SO_2, 36 percent of the NO_x, 4 percent of the particulates, and 75 percent of the CO_2.

Each of these evaluations showed that APFBC repowering was technically feasible and environmentally beneficial. Study results may help other utilities consider repowering, as many are similar in size to the five evaluated.

AES Greenidge LLC's steam plant

Nebraska Public Power District's Sheldon power station



Arizona Public Service's Four Corners power station

Progress Energy's L.V. Sutton power station

Duke Power's Dan River power station

...News Bytes continued

2002 budget, will demonstrate and accelerate deployment of advanced, coal-based power generation technologies. Approximately 150 attendees from government, industry, and academia gathered to offer views on the CCPI, its implementation, and management; and to assist DOE in designing a clean coal power investment strategy. Proceedings will be made available on the NETL website (http://www.netl.doe.gov).

Air Products Liquid Phase Conversion Company recently completed the first *in-situ* activation of methanol synthesis catalyst in a slurry bubble column as part of its **Liquid Phase Methanol (LPMEOH™) Demonstration Project** in Kingsport, Tennessee. Over 40,000 pounds of catalyst were slurried in an inert mineral oil and transferred from a storage tank to the LPMEOH™ reactor. The catalyst was then reduced or activated *in-situ* using dilute synthesis gas over a 26-hour program. In certain applications, savings in both capital and operating costs can be realized when the catalyst can be activated in the reactor instead of in a separate reduction vessel.

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R&D MILESTONES

Through the U.S. Department of Energy (DOE), Office of Fossil Energy's (FE) Vision 21 Program, a first-of-a-kind 250-kW fuel cell and microturbine hybrid power plant has begun operation at FuelCell Energy's Headquarters in Danbury, Connecticut. In August 2001, the 250-kW FuelCell Energy molten carbonate Direct Fuel Cell® (DFC) was successfully integrated with a 30-kW Capstone Turbine Corporation Model C30 microturbine at FuelCell Energy's Headquarters. The DFC/T™ does not require any combustion in the turbine or pressurization of the fuel cell. The system extends the potential fuel savings of the DFC® by combining a non-fired gas turbine and a network of heat exchangers, resulting in extra electricity and adding 10–15 percentage points to the already high efficiency of the DFC®. Vision 21 fuel cell/turbine hybrid systems are being developed for both coal- and natural gas-fueled plants and are expected to achieve electrical efficiency goals of 60 percent and 75 percent, respectively. They would operate at near-zero emissions of criteria pollutants, and greatly reduced emissions of CO_2.

With FE funding, ADA Environmental Solutions of Littleton, Colorado has developed a new chemical, ADA-43, to enhance fine particulate collection in coal combustion flue gases. The effort is part of the R&D to develop non-toxic flue gas conditioning agents to improve performance of electrostatic precipitators (ESPs). Older products (ADA-23 and -37) were successful for limited conditions of temperature and fuel types. The new chemical improves both resistivity and cohesivity, allowing the fly ash particles to become more conductive and able to be captured by the ESP. It can be used in both "cold side" (downstream of the air preheater) and "hot side" (upstream of the air preheater) ESPs operating at temperatures between 550 °F and 650 °F. Demonstration is scheduled for the fall at two 500-MW cold-side ESPs operated by Wisconsin Electric.

Coal combustion by-products are showing potential for capping contaminated sediments. Laboratory tests at FE's National Energy Technology Laboratory (NETL) have shown positive results from adsorption tests of class F fly ash, as well as topsoil, in preventing release of metal contaminants to overlying water. Fly ash enjoys a cost advantage over the more typically used topsoil and sand and, like topsoil, acts as both a physical and a chemical barrier. Researchers found that two of the five fly ash samples tested prevented release of metal contaminants to the overlying water column. NETL is looking for a field site to evaluate the technology.

NETL researchers are investigating the effects of coal dehydration on CO_2 sequestration and coalbed methane recovery. Scientists at NETL are conducting experiments to determine the extent of CO_2 sorption on several coals, including Argonne premium coals. They are also studying coal's ability to produce methane. The sorbed (sequestered) CO_2 acts to liberate methane in the coal, allowing the methane to be captured at a producing well and subsequently placed in a natural gas pipeline. Researchers have found that, under certain circumstances, CO_2 can form relatively strong physical bonds with coal while the coal is in the process of being dehydrated. This suggests that the dehydration process can enhance the ability of carbon dioxide to penetrate coal and liberate methane.

A new electronic monthly newsletter on carbon sequestration is now available. The newsletter includes summaries of news reports, announcements from NETL's carbon sequestration program, publication information, and legislative updates. For a copy of the newsletter, or information on how to subscribe, see www.netl.doe.gov/products/sequestration and click on "Reference Shelf."

ADVANCES IN THERMAL BARRIER COATINGS

Important steps are being taken to reach the goal of optimized coatings for single crystal turbine blades for "next generation" gas turbines. Turbine inlet temperatures on these advanced turbines could exceed 1,400 °C, requiring components capable of withstanding high temperatures and pressures. Current thermal barrier coatings (TBCs) are susceptible to sintering, phase degradation, and creep at temperatures over 1,200 °C that results in degraded corrosion/erosion resistance and insulation efficiency. The lack of suitable materials for vital hot-gas path turbine components — first stage vanes and blades, combustors, transitions, and shrouds — remains a critical barrier to the implementation of most advanced concepts in gas turbine technology, particularly those connected with the use of coal-derived fuels.

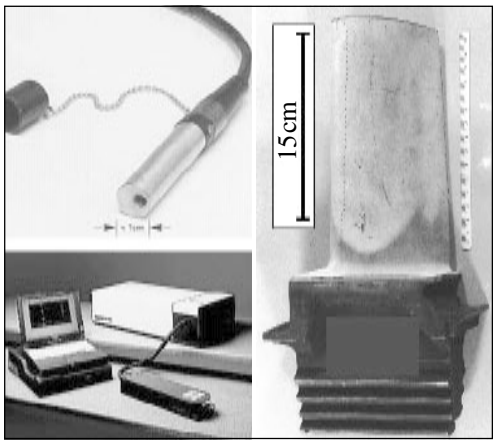
To address the need for high-temperature durability and corrosion resistance required for coal fuels, an ongoing program is developing protective coatings for hot-gas path turbine components. These include TBCs and environmental barrier coatings for superalloys. Engines developed under the U.S. Department of Energy, Office of Fossil Energy's National Energy Technology Laboratory (NETL) completed Advanced Turbine Systems (ATS) program required TBCs on turbine blades and vanes. The ATS TBCs being employed, based on yttrium-stabilized zirconia (YSZ), are derived from the airline industry and have functioned well for thousands of hours in relatively clean combustion gas environments. However, advances are needed to increase coating durability from less than 10,000 hours to greater than 30,000 hours (on natural gas), and to extend the durability to operation on coal-derived fuels.

In land-based gas turbines, surface deposits, such as glassy dust and sulfate salts, can penetrate into porous TBCs and damage their strain-tolerant microstructure, resulting in premature spalling (chipping or flaking). YSZ-based TBCs also have limited resistance to corrosive attack by sodium sulfate and sodium vanadate salts. These salts can react with the YSZ and attack the metallic bond coating, resulting in premature TBC failure. In "next generation" turbines, temperature variations of thermal cycling may be just as damaging as long-term exposure at temperatures experienced in base load systems.

Undertaking the advanced coating work is a university/industry consortium that solicits proposals for research to be conducted by universities, and administers the effort for the NETL Advanced Gas Turbine Systems Research Program. The Program began in 1992 and is run by the South Carolina Institute of Energy Studies. Recent significant accomplishments are accelerating the pace of coatings research undertaken by this group. Investigators at the University of Connecticut, in cooperation with Renishaw, a small business in Illinois, have developed a non-destructive inspection technique, based on photoluminescence phenomena, that can predict incipient failure of TBCs. Renishaw is developing a portable device to inspect coatings on turbine blades.

A team at the University of Pittsburgh has studied two systems that appear promising. One has a bond coat composed of platinum aluminide (PtAl), while the other has a Nickel-Cobalt-Cromium-Aluminum-Yttrium (NiCoCrAlY) bond coat prepared by argon-shrouded plasma-spraying. The superalloy substrates and YSZ topcoats are identical for the two systems. The thermal exposures in laboratory air include cycling from 1,100 °C to 30 °C once per hour and six times per hour. In the one-hour cycles, the PtAl system typically failed in about 1,000 hours, while the NiCoCrAlY system failed in about 300 hours. Thus, for the one-hour exposure conditions, the PtAl bond coats were much more durable. Conversely, in the more rapid cycling conditions (six times per hour), the time to spallation for the PtAl system was cut in half to about 500 hours and for the NiCoCrAlY system was essentially doubled to about 700 hours. So under more rapid cycling, the relative ranking of the two coatings was reversed. The type of thermal exposure employed also resulted in significant changes in the degradation microstructures of the coatings. Results suggest that anticipated duty cycles affect the choice of TBCs, and that comparison of experimental results between laboratories requires detailed specification of the exposure conditions used during testing.

Ongoing coatings research should improve stability of bond coatings and TBCs, with an emphasis on a systems approach. The first goal is a reliable TBC system with a 1,300 °C capability for a minimum of 5,000 hours, to be achieved by December 2002.



Portable laser piezo-spectroscope for non-destructive inspection of TBCs; and TBC-coated turbine blade

TVA MINED LAND BECOMES CARBON SINK

At the Tennessee Valley Authority (TVA) Paradise Fossil Plant in Muhlenberg County, Kentucky, researchers are demonstrating an innovative pollution prevention system that promises multiple environmental benefits. The Carbon Capture and Water Emissions Treatment System, being developed under a cooperative agreement between the U.S. Department of Energy, Office of Fossil Energy's National Energy Technology Laboratory (NETL), Tennessee Valley Authority, and the Electric Power Research Institute, is scheduled to begin construction this fall. The project is an important component of the FE terrestrial sequestration program and is expected to store a total of 60–80 metric tons of CO_2.

Paradise Fossil Plant overlooks the Green River

The demonstration-scale project will include reforestation of 100 acres of surface-mined land at the 2,558-MW Paradise Fossil Plant with native hardwood species such as red maple, sycamore, cottonwood, and tulip poplar. Prior to planting, coal combustion by-products from the power plant's flue gas scrubber system will be used to amend the soil and increase seedling survival. Throughout the growing season, trees will be irrigated with water from one of the power plant's water treatment ponds.

The 100-acre site supports a sparse grass cover. Taking this currently unproductive ecosystem and turning it into a productive forest will increase carbon storage in the vegetation and soils, offsetting some of the power plant's carbon dioxide emissions.

The coal combustion by-products will act as a mulch, keeping invasive groundcover under control and helping to increase seedling survival rates. They also will improve the soil's physical properties and increase its moisture holding capacity. Using coal combustion by-products as soil amendments often enhances vegetative growth and reduces erosion.

As an additional benefit, the nutrient-rich, ammoniated wastewater from TVA's selective catalytic reduction system may provide the trees with additional nitrogen, potentially reducing the local watershed's nitrogen loading. The restored mine land also could provide potential wildlife habitat.

Under the study methodology, a mix of flue gas desulfurization (FGD) by-product and FGD pond water will be applied to 54 treatment plots of less than 2 acres each. FGD by-product will be applied to the ground's surface before planting trees. Survival and growth responses of plant species in terms of sequestering carbon in plant material and soil will be monitored by measuring tree survival, height and basal diameters. Amounts of woody biomass sequestered will be estimated by modeling.

The whole-plant approach being employed at Paradise, integrating several pollution prevention processes, is seen as an economically attractive way for the power industry to meet future environmental regulations.

UPCOMING EVENTS

October 22–24, 2001
2001 International Ash Utilization Symposium
Location, KY
Organizers: U.S. DOE and Univ. of Kentucky Center for Applied Energy Research
Contact: Dr. Uschi Graham
Phone: 859-257-0289

October 30–November 1, 2001
Industry Partnerships for Environmental Science and Technology Conference
Location: Morgantown, WV
Sponsor: NETL
Contact: Kim Yavorsky
Phone: 412-386-6044

November 6–7, 2001
Vision 21 Program Review Meeting
Location: Morgantown, WV
Sponsor: NETL
Contact: Kanwal Mahajan
Phone: 304-285-4965

November 13–15, 2001
Beneficial Use of Recycled Materials in Transportation Applications
Location: Washington, DC
Sponsors include: U.S. DOE and NETL
Contact: Lyn Van Helden
Phone: 631-499-1085

November 19-20, 2001
Clean Coal and Power Conference
Location: Washington, DC
Sponsor: U.S. DOE
Contact: Faith Cline
Phone: 202-586-7920

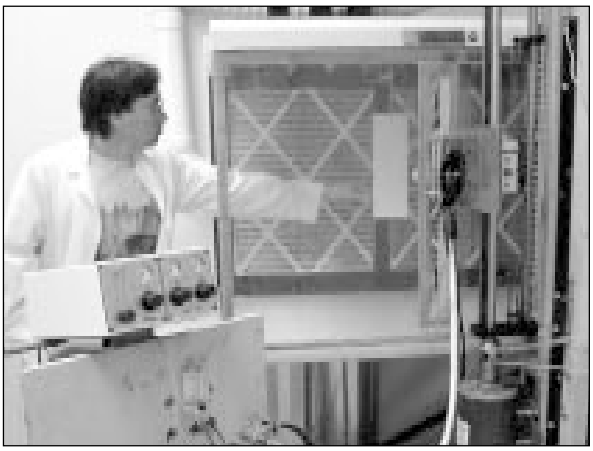
December 3–5, 2001
Next Generation Turbine and Condition Monitoring Conference and Workshop

and

December 6–7, 2001
Short Course on Gas Turbine Technology
Location: Galveston, TX
Sponsors: NETL and The Boyce Consultancy
Contact: Joan Barbish
Phone: 412-386-4933

LONG-RUNNING UNIVERSITY COAL RESEARCH PROGRAM ADVANCES SCIENCE OF COAL

The University Coal Research (UCR) Program, the federal government's longest running R&D grant program, began in 1979 and solicits proposals annually from colleges and universities to advance the science of coal and resolve energy and environmental problems. Through its annual solicitation, the U.S. Department of Energy, Office of Fossil Energy seeks projects to investigate solutions for clean and efficient use of our nation's abundant coal resources. Historically, the involvement of students and professors has been an essential element in the success of the UCR Program. Student participation especially promotes the influx of new ideas and ensures a future supply of trained scientists and engineers.



Testing at the University of Arkansas of V-ESPART, which is used for fine tuning powder coating process

Over the years, the program has resulted in a number of successes that have benefited coal-related science. The science of coal cleaning was advanced through early accomplishments of the program. In the 1980s the Microcel microbubble flotation coal cleaning process was developed by Dr. Roe Hoan Yoon and co-workers at the Virginia Polytechnic Institute and State University. The process involves fine-grinding of the coal to liberate mineral matter, followed by column flotation to separate mineral matter from coal. Improved recovery and selectivity are realized through the use of small air bubbles (less than 100 microns in diameter). The Microcel™ column is available commercially, and in the past several years, 24 Microcels™ have been sold to Australia for use in coal and kaolin mines.

Also studied as part of the early UCR program was coal cleaning by dry electrostatic separation of mineral particles. In the early 1990s, the University of Arkansas at Little Rock built the Electrostatic Spray Dynamics Analyzer to perform real time measurements of the electrostatic charge on mineral matter in coal. The device was later adapted and sold to a paint company, Courtald Coatings of Newcastle, United Kingdom, to improve the electrostatic spray properties of their powders used in copying machines and laser printers. Utilizing the results of this UCR funded project, Delsys Corporation of Princeton, New Jersey, is partnering with the university to transfer the technology to the pharmaceutical industry.

Another success of the early 1990s determined the properties of flyash that would enhance its reactivity with Portland cement in concrete and mortar. Through a UCR study, a process was developed to partially replace cement with fly ash in the manufacture of concrete and mortar. The resultant product proved to have superior compressive strength and resistance to acid and sulfates.

More recent research has involved such timely concerns as CO_2 conversion to useful products, and the production of transportation fuels. Over the past few years, University of Akron researchers developed catalysts that can convert CO_2 and water into methane and methanol. The University of New Mexico is working to develop stable catalysts to produce clean, sulfur-free transportation fuels from coal-derived synthesis gas. Still another effort is concentrated on modeling to simulate methanol synthesis and optimize the indirect coal liquefaction technology being developed at DOE's Alternate Fuels Development Unit in LaPorte, Texas.

The most recent awards, made this August, cover a wide range of research topics including innovative ways to make hydrogen for fuel cells, novel approaches to preventing greenhouse gas emissions, and the development of advanced sensors and controls for revolutionary power plants of the future.

Prototype V-ESPART analyzer

NAS REVIEW VALIDATES FE RESEARCH EFFORTS

In July, the National Academy of Science's (NAS) National Research Council released a report "Energy Research at DOE: Was It Worth It?" evaluating Energy Efficiency and Fossil Energy Research from 1978 to 2000. Secretary of Energy Spencer Abraham cited the report as generally reaffirming DOE's research efforts in these areas, in fact, returning $3 in economic benefits for every $1 invested. The NAS review also indicated this favorable investment ratio will continue to grow as industry deploys promising new systems, including integrated gasification combined cycle and advanced turbine systems. Particularly, the Secretary noted environmental benefits reported by NAS whereby reduced powerplant emissions of SO_2 and NO_x have produced benefits of almost $60 billion, amounting to $5 for every $1 invested.

The following information is summarized from the report, which is accessible on the internet through http://www.nap.edu/catalog/10165.html, and is based on case studies conducted for 22 fossil energy RD&D programs. DOE played a major role, defined as critical to program success, in the areas of:

- *Atmospheric fluidized-bed combustion* (AFBC), with the development and demonstration of industrial scale systems using low-valued, low-cost fuels such as culm, petroleum coke and medical wastes.
- *Pressurized fluidized-bed combustion*, in improving the efficiency and environmental performance of technology in large-scale demonstrations.
- *Integrated gasification combined-cycle*, with large-scale demonstrations integrating the components into a total systems for optimal electricity production and environmental performance.
- *Direct liquefaction*, in funding basic, pilot- and bench-scale R&D that improved the technologies developed by industry.
- *Stationary source fuel cells*, in cost-shared R&D of phosphoric acid, molten carbonate and solid oxide systems.

The NAS reported that DOE played a significant role, defined as an important role but not critical to program success, in the areas of:

- *AFBC*, in demonstrating systems for utility application.
- *Indirect liquefaction*, in basic, pilot- and bench-scale R&D that improved the technologies developed by industry.
- *Coal preparation*, in improving the removal efficiencies of ash, sulfur, and other impurities through fine grinding of coal and advanced separation processes.
- *Flue gas desulfurization*, in the development and demonstration of second-generation systems that offer improved process technology, removal efficiency improvements, and the ability to control emissions from a wider variety of boilers and coal types than conventional systems.
- *Nitrogen Oxides control systems*, in development and demonstration of second generation systems that offer reliable process technology, removal efficiency improvements, and the ability to control a wider range of large utility boilers.
- *Waste management and utilization*, in characterizing solid wastes from conventional and advanced coal-based systems, monitoring advanced technologies from wastes, and researching potential uses of waste by-products.
- *Air toxics*, in characterizing emissions from conventional and advanced coal-based technologies, and in researching technologies that could remove the toxic elements from feed coal and flue gas. Emphasis has recently been placed on characterization and control of mercury emissions.

The report also cited DOE as being instrumental in accelerating development of Advanced Turbine Systems, and noted a contributory role in gas-to-liquid technology.

ENERGY RESEARCH AT DOE: WAS IT WORTH IT?

ENERGY EFFICIENCY AND FOSSIL ENERGY RESEARCH 1978 TO 2000

Prepublication
Approved Manuscript

Committee on Benefits of DOE R&D on Energy Efficiency and Fossil Energy
Board on Energy and Environmental Systems
Division on Engineering and Physical Sciences

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LASER TECHNOLOGY HAS POTENTIAL TO ENHANCE GASIFIER RELIABILITY

Scientists at the U.S. Department of Energy, Office of Fossil Energy's Albany Research Center (ARC) are seeing positive results from a laser optical profiling technique that is being adapted to monitor the life of gasifier liner material. Laser profiling is one of the latest efforts to extend the service life and enhance the reliability of slagging gasifiers used in integrated gasification combined cycle (IGCC) power plants. In IGCC systems, coal, biomass, and other materials are used to produce syngas for gas turbines, or for chemical feedstocks used in other petrochemical processing activities.

IGCC plants will play an important role in meeting the nation's future energy needs because they can use low-rank (low Btu, high moisture, high ash) coals and other feedstocks to produce energy needed for the nation's economy in an extremely clean and efficient manner. However, a critical issue facing the operators of gasifiers is the life of the refractory in the gasifier reactor. Refractory liners typically are replaced every 10–18 months at costs up to $2 million. In addition the gasifier operator faces lost opportunity costs for the 30 days it often takes to reline or repair the unit. Currently, operators must take units off-line for days and allow them to cool before linings can be inspected for wear and corrosion.

Laser profiling provides the opportunity to assess the condition of the refractory lining while the gasifier remains hot. Laser profiling previously has been used in the steel industry to measure refractory corrosion/wear for approximately five years. Researchers at ARC believe that a modification of this technology can be used to help them study gasifier materials and eventually lead to a new tool that gasifier operators can use to better estimate the remaining service life of the lining.

The composition of refractory materials includes oxides, carbides, and/or nitrides of elements like Al, Si, Mg, Ca, and Cr. They are the only known materials capable of withstanding the severe service environments found in the entrained-bed slagging gasification chambers for the IGCC plants. In these systems temperatures can exceed 1,600 °C, and the molten slags, which are the non-carbon residuals from the gasifier feedstock, constantly erode and corrode the refractory lining.

Currently, the techniques used to measure the lining are inexact and only offer measurements at a few isolated points within the gasifier. Accurate measurements require that the gasifier be taken off-line for a week or more for inspection. Due to inexact current technology and potential safety issues, operators have adopted conservative replacement schedules for the refractory linings. For this reason, the lining is often replaced prematurely, or during scheduled outages, in spite of the high costs.

In a teaming effort with Process Metrix, LLC, and the Tampa Electric Company's Polk Power Plant, the partners recently demonstrated that a prototype laser contouring technology can accurately profile the interior refractory wall of a gasifier. The initial feasibility study found that the measured laser contouring profile of a newly replaced lining closely matched the original lining thickness specifications. Additional measurements will monitor wear/corrosion/erosion rates as a function of operational variables.

Further research and development efforts will address the introduction of the laser sensors into a very hot (1,600 °C), pressurized vessels containing a potentially aggressive environment. This will require protection and water cooling. Other design changes will need to be made for the fixtures, electronics and software. However, the partners are confident that this technology can be modified to meet the needs of gasifier operators.

Some of the technology's potential benefits to industry include:

- Accurate monitoring and potential reduction of thermal cycling fatigue, refractory damage resulting from thermal excursions, and differential wear of refractory linings;
- Accurate monitoring of refractory wear, and correlation of material performance in response to process variables including feedstock and operating conditions;
- Better scheduling of downtime for repair of refractory linings and a reduction in the premature (conservative) removal of refractory linings with substantial remaining life;
- Improved refractory life for longer continuous operations (campaigns) due to a better understanding of materials performance as a function of process variables and time.

INTERNATIONAL INITIATIVES

U.S. AND CANADIAN COOPERATION ON CARBON SEQUESTRATION RESEARCH

On June 11, 2001, President Bush announced initiatives to advance the science of climate change, to spur technological innovation, and to promote cooperation in the Western Hemisphere and beyond. In keeping with the President's initiatives, a number of cooperative carbon sequestration research projects are being sponsored by the U.S. Department of Energy (DOE), with Canadian partners. Cooperative research leverages scarce R&D funding and facilitates timely exchange of information.

The DOE Office of Fossil Energy (FE) will be working with Canada on an important project selected this July under the second round of awards for R&D technologies to manage greenhouse gases. The Weyburn Project in Saskatchewan, Canada will study the fate of CO_2 injected for enhanced oil recovery (EOR) flooding. The CO_2 is piped from DOE's former synfuels plant, the Great Plains Plant in Beulah, North Dakota. The project will involve a number of co-funders including Pan-Canadian Resources, which has been conducting the CO_2 flooding since last year; Canada's Petroleum Technology Research Centre; and the federal and provincial Canadian governments. The Weyburn Project is expected to sequester 20 million tons of CO_2 over its lifetime.

Knowing the fate of CO_2 in EOR operations is essential to the acceptance of EOR as a viable and environmentally acceptable sequestration mode. At Weyburn, a comprehensive mass balance study will be conducted using both surface and sub-surface monitoring. Techniques will include 4-D seismic, passive seismic in abandoned wells, instrumentation of non-active wells, and use of tracers.

In a project with the International Energy Agency (IEA), DOE will collaborate with industrial, academic, and government partners from the United States, Canada, and Britain, on a project in Alberta, Canada to study the feasibility of permanently sequestering CO_2 in deep unminable coal seams, while stimulating enhanced methane production that will help to offset costs of sequestration. Micro-scale tests have been successful, and further testing is planned. Also under IEA, DOE has been participating in an O_2/CO_2 combustion project with the Canada Centre for Mineral and Energy Technology (CANMET), as well as Canadian and U.S. industrial partners and academia. Combustion under an atmosphere of O_2 instead of air is being studied. The absence of nitrogen, a major component of air, would make it easier to capture CO_2 from flue gas.

NETL SUPPORTS COOLING TOWER EFFICIENCY TRAINING IN INDIA

To meet the increasing demand for electricity, India is planning to supplement its existing capacity by adding 100,000 MW of new capacity in the next 10 years from indigenous high-ash coals. Under the Greenhouse Gas Pollution Prevention (GEP) project, a U.S. Agency for International Development (USAID) initiative, FE's National Energy Technology Laboratory (NETL) has been assisting Indian utilities in generating electricity efficiently using coal and biomass fuels.

In a May 2001 activity under this initiative, NETL arranged training in cooling tower thermal performance improvement. Two environmental engineers from Power Generation Technologies (PGT) of Knoxville, Tennessee conducted the test and associated training at the Ramagundam coal-fired power station of the National Thermal Power Corporation (NTPC). The plant is located in the Andhra Pradesh state in southern India, where summer temperatures climb to 120 °F, making it particularly important that the towers operate efficiently.

A week-long test was carried out according to U.S. Cooling Technology Institute's ATC-105 code. Twenty engineers from NTPC's Center for Power Efficiency and Environmental Protection, other NTPC power plants, and State Electricity Boards, were trained by PGT on cooling tower evaluation. Improving water distribution by flow rate measurement, increasing air intake by fan gear box modifications, and adopting more accurate test methods were found to increase tower capability and reduce cold water temperature.

Engineers measuring wet-bulb temperature of air at the cooling tower inlet

A one-degree Celsius reduction in cold water temperature for one 500-MW unit is estimated to reduce carbon dioxide emissions by 8,100 metric tons per year. Typically, the cold water temperatures from cooling towers in India are 2–3 °C greater than the target temperatures, and this test identified significant potential to reduce these temperatures. To date, the GEP project has helped NTPC reduce carbon dioxide emissions by 1.8 million metric tons annually, by implementing various efficiency improvement measures in power generation.

ALBANY RESEARCH CENTER HOSTS INDONESIAN ENGINEERS

From June 16–26, 2001, the DOE Office of Fossil Energy's Albany Research Center (ARC) hosted a group of 11 Indonesian engineers as part of a Power Plant Life Assessment Study Tour funded by the U.S. Agency for International Development, the U.S. Asia Environmental Partnership, and private industry sponsors. Power plant life assessment is the first step in the decision making process to address life extension, repowering, component replacement, or fuel switching.

ARC employee Neal Duttlinger discusses tensile testing

The U.S. government's efforts are driven by environmental and economic concerns. Greenhouse gas emissions — exacerbated by emissions from inefficient power plants — are increasing rapidly in developing countries. Indonesian utilities also need to improve reliability and efficiency to speed recovery from the Asian economic crisis. Indonesia has the fourth largest population in the world, and electricity demand is growing at 12–15 percent annually. The country is energy-rich; it is the world's largest LNG exporter, exports high quality crude, and has large deposits of high quality low-rank coals. A number of power plants are fueled by coal.

The 10-day program consisted of lectures by ARC and private industry experts, along with visits to private companies and utilities. Participants studied the process of plant life assessment and engaged in team problem solving. ARC presented the tools it uses for chemical and physical analysis of materials, and demonstrated "destructive" analysis techniques, where a section of defective tubing might be removed, and "non-destructive" in-situ techniques such as ultrasonic testing. Other lectures included such topics as causes of materials failure, including corrosion and deposition; high-temperature applications; and effects of water quality on components. Indonesian engineers also presented a perspective of their organizations in pursuing life assessments.

Study tour participants gather at the Albany Research Center

U.S. companies participating in the tour were Portland General Electric, NDT American Products Inc., Betz-DearBorn Corporation, Alstom Power, Babcock & Wilcox, and Yxlon.

STATUS OF ACTIVE CCT DEMONSTRATION PROJECTS

ENVIRONMENTAL CONTROL DEVICES

Southern Company Services, Inc. – *Demonstration of Advanced Combustion Techniques for a Wall-Fired Boiler.* All testing on the original project has been completed and reported. Phase 4 has been extended until December 31, 2001, to evaluate the use of GNOCIS and other computerized process control software 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.* A Record of Decision under NEPA has been signed. Unit 2 achieved mechanical completion in July 2001, with first fire scheduled for November and commercial operation in March 2002, to be followed by two years of demonstration. (Jacksonville, FL)

Kentucky Pioneer Energy, L.L.C. – *Kentucky Pioneer Energy Project.* A Draft EIS is in preparation and is scheduled to be released later this year. The air quality and construction permits have been issued by the state of Kentucky. No major problems have been identified. (Trapp, KY)

Sierra Pacific Power Co. – *Piñon Pine IGCC Power Project.* The project ended January 1, 2001. Sierra 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. Successes in the project included operation of the combined-cycle portion of the plant at 98 percent availability, efficient removal (by the hot gas filter) of particulates from the dirty gas, and production of good quality syngas for over 30 hours since the first syngas was produced in January 1998. (Reno, NV)

Tampa Electric Co. – *Tampa Electric Integrated Gasification Combined-Cycle Project.* Tampa's Polk Power Station has completed over four and one-half years of successful commercial operation. As of the end of the third quarter 2001, the gasifier has operated over 24,000 hours and provided syngas to the combustion turbine to produce over 6,500,000 MWh of electricity. (Mulberry, FL)

Wabash River Joint Venture – *Wabash River Coal Gasification Repowering Project.* The Wabash River Cooperative Agreement expired on January 1, 2000. The Final Report is available from the FE website's Clean Coal Technology Compendium (http://www.lanl.gov/projects/cctc). The Post Project Assessment of the Wabash River Coal Gasification Repowering Project has been reviewed by the participant, and returned to DOE for the final revision. The Cooperative Agreement is currently in the close-out process. (West Terre Haute, IN)

Alaska Industrial Development and Export Authority (AIDEA) – *Healy Clean Coal Project*. Demonstration operation under the Cooperative Agreement was completed in December 1999. The Final Report was approved and issued for public release. The Final Report, as well as copies of all the Topical Reports describing the key technical activities carried out during the project's two years of demonstration operations, are available on the Clean Coal Technology Compendium at http://www.lanl.gov/projects/cctc/. As the result of a settlement reached in March 2000, AIDEA turned the plant over to Golden Valley Electric Association, Inc. for custodial care. Financing for a "full retrofit" to a conventional low-NO_x burner and lime spray dryer emission control system must be obtained if the plant is to operate in the future. There are no potential purchasers of the power other than Golden Valley. Low-interest federal loan funds to finance the "full retrofit" and refinance the existing debt on the Healy Clean Coal Project are currently being sought by Golden Valley in cooperation with AIDEA. (Healy, AK)

Arthur D. Little, Inc. – *Clean Coal Diesel Project.* Pilot testing of the hardened elements for the diesel engine is in progress. Operational component testing will take place at the Fairbanks Morse test facility on a small 2-cylinder diesel engine. Fuel mixes (solid loadings and additives) are being tested on the injectors to determine the best fuel for test operations. Only minor problems have been encountered. (Fairbanks, AK)

COAL PROCESSING FOR CLEAN FUELS

Western SynCoal LLC (formerly Rosebud SynCoal® Partnership) – *Advanced Coal Conversion Process (ACCP) Demonstration.* The ACCP Demonstration Project in Colstrip, Montana, has processed over 2.9 million tons of raw subbituminous coal. Nearly 2 million tons has been supplied to customers, including industries (primarily cement and lime plants) and utilities. Montana Power agreed in September 2000 to sell its coal businesses, including Western SynCoal LLC, to Westmoreland Mining LLC. Because Westmoreland cannot take advantage of synthetic fuel production tax credits due to their current tax status, operation of the ACCP is not economical under their ownership. Therefore, operations at the ACCP Facility have been suspended. Westmoreland is continuing to seek opportunities to sell the ACCP plant to parties that can use the synthetic fuel production tax advantages so operations potentially could be restarted. (Colstrip, MT)

Air Products Liquid Phase Conversion Company, L.P. – *Commercial-Scale Demonstration of the Liquid Phase Methanol Process.* The Liquid Phase Methanol (LPMEOH™) Process Demonstration Facility continues to experience stable operation on coal-derived synthesis gas. The catalyst guard bed adsorbent was replaced in April 2001. The fresh adsorbent was chemically reduced with dilute synthesis gas and placed into service. In August 2001, a successful *in-situ* activation of a full charge of methanol synthesis catalyst, over 40,000 pounds, was completed in the LPMEOH™ reactor (see "News Bytes" on page 1). Since being restarted with fresh catalyst in December 1997, the demonstration facility has approached 99 percent availability, and since April 1997, the facility has produced over 80 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, continue to be important. (Kingsport, TN)

INDUSTRIAL APPLICATIONS

CPICOR Management Company, L.L.C. – *Clean Power From Integrated Coal/Ore Reduction.* DOE has continued its work toward an Environmental Impact Statement for this project, a draft of which is expected later this year. The CPICOR Management Company (CMC) continues to perform baseline environmental monitoring and preliminary engineering and design. 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. CMC is discussing teaming arrangements with several engineering and independent power producers. (Vineyard, UT)

ThermoChem, Inc. – *Pulse Combustor Design Qualification Test.* The Public Design Review for the Pulse Combustor has been submitted to DOE and is currently in the review process. The Final Report is expected to be submitted to DOE in the near future. A no-cost time extension extends the Cooperative Agreement to October 31, 2001. (Baltimore, MD)

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