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CLEAN COAL TODAY

A NEWSLETTER ABOUT INNOVATIVE TECHNOLOGIES FOR COAL UTILIZATION

NEWS BYTES

The Port Authority of Port Arthur, Texas and Sabine Power I Ltd have announced plans to develop one of the world's largest petroleum coke gasification facilities and related electrical generation. The gasification step will use the E-GAS™ coal gasification process developed by Global Energy Inc. Global Energy designed, owns, and currently operates the award-winning **Wabash River Coal Gasification Repowering Project** in Terre Haute, Indiana. The Wabash River Project was funded under Round IV of the Clean Coal Technology program, and the cooperative agreement expired January 1, 2000. The industrial participant was a joint venture between Destec Energy, Inc. and PSI Energy.

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IN THIS ISSUE

NEW CLEAN COAL EFFORTS GAIN MOMENTUM

Secretary of Energy Spencer Abraham speaks of new budget initiative to promote clean coal technologies

As part of the U.S. Department of Energy (DOE) Fiscal Year 2002 budget request submitted to Congress, the Administration has requested $150 million for a "Clean Coal Power Initiative." The proposed competitive procurement is described by Secretary of Energy Spencer Abraham as a "down payment" on what may become a $2 billion, 10-year clean coal technology initiative. Also, on April 19, 2001, industry made an enthusiastic showing in response to a DOE solicitation issued last November under the Power Plant Improvement Initiative, submitting 24 proposals valued at $535 million. These events, coupled with an important position for fossil energy in the National Energy Policy proposed this May (see box on page 2), signal a higher profile for coal, which already supplies over 50 percent of the nation's electric power needs.

Speaking before a congressional committee, Fossil Energy's Acting Assistant Secretary Robert S. Kripowicz indicated that DOE will seek industry help in shaping the Clean Coal Power Initiative program. DOE, he said, will explore such mechanisms as consortia and industry boards to help in the planning process. DOE intends to hold a workshop later this year with utilities, equipment manufacturers, fuel suppliers, universities, and others to solicit their views. Industry would be required to share costs, the share rising to 50 percent or more by the time new technologies are ready for market entry testing.

In the more current effort, selection of projects under the Power Plant Improvement Initiative is scheduled for August 2001. The $95 million Initiative, part of the Fiscal Year 2001 budget from redirected Clean Coal Technology funds, is focused on coal for power generation, and to demonstrate new near-term technological advances to bolster the reliability of the nation's electric power supply. The Initiative would create government/industry partnerships to demonstrate innovations to allow coal-fueled plants to meet environmental regulations, while potentially increasing their power output, and without imposing large new financial burdens on ratepayers. The

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...Coal continued

24 proposals cover such areas as efficient power generation; environmental controls, including NO_x, SO_2, particulate, acid gas, and mercury reduction; CO_2 capture and recovery; improved power plant components; conversion of waste to energy; coproduction; and biomass cofiring.

In recent remarks to the National Coal Council, Kripowicz noted that the new clean coal efforts are an opportunity to extend successes of the Clean Coal Technology Program, the joint government/industry effort begun in 1986. He cited a utility analysis estimating that the government/industry $4 billion investment in CCTs has translated into $100 billion in benefits to ratepayers and consumers. Kripowicz noted that the original CCT program has produced 22 commercially viable technologies.

NATIONAL ENERGY POLICY HIGHLIGHTS

The National Energy Policy, issued on May 16, 2001, is the result of months of work by the National Energy Policy Development Group headed by Vice President Cheney. Certain aspects of the Policy could be implemented through Executive Order or regulation, and other provisions would require congressional approval. While the document covers many aspects of energy production, energy conservation and efficiency, and adequacy of infrastructure, the following are some of the highlights that relate to the DOE Office of Fossil Energy programs.

- √ Require Energy Impact Statements on all regulations
- √ Develop educational programs for energy development and use
- √ Provide multi-pollutant legislation to reduce and cap emissions
- √ Rationalize permitting for energy production
- √ Support development of environmentally acceptable CCTs
- √ Provide greater regulatory certainty for coal electricity generation
- √ Develop next generation technology such as hydrogen and fusion
- √ Encourage development of combined heat and power projects
- √ Strengthen global energy alliances to enhance national security

The full text of the National Energy Policy can be found on the Fossil Energy home page (http://www.fe.doe.gov).

...News Bytes continued

According to data collected by the DOE Office of Fossil Energy, sales of the **"low-NO_x concentric firing system"** (LNCFS)™, developed under the Clean Coal Technology (CCT) Program, now have topped $1 billion. The system reduces NO_x by 40 percent in older coal-burning plants, and has been put into service in plants that now generate a total of 56,000 MWe of power. The advanced burner was first installed in 1992 by Alstom Power Inc., formerly ABB Combustion Engineering, on Gulf Power Company's Plant Lansing Smith in Lynn Haven, Florida. The project was carried out jointly with Southern Company Services, the technology arm of The Southern Company, which owns the Lynn Haven power plant. The CCT project, selected in Round II, was completed in 1994.

April 2, 2001, marked the fourth anniversary of demonstration operations at **Air Products Liquid Phase Conversion Company's Liquid Phase Methanol (LPMEOH™) Demonstration Process** in Kingsport, Tennessee. One of the most recent accomplishments of the four-year operating program was achieved in March 2001, when a successful demonstration of the load-following capabilities of the LPMEOH™ facility was completed. In a commercial coproduction scheme where electrical demands must be met, the ability of the LPMEOH™ facility to rapidly and reliably cycle between operating and standby conditions is critical. During several tests, the minimum target ramp rate of 5 percent of full load per minute was achieved. In each case, the performance of the LPMEOH™ facility returned to prior operating conditions after each test period. The LPMEOH™ project, selected under Round III of the Clean Coal Technology Program, has operated at greater than 97 percent availability since startup in April 1997, and has produced over 78 million gallons of methanol, all of which has been accepted by Eastman Chemical Company for use in downstream chemical processes.

VIRTUAL ENERGY PLANTS OF THE FUTURE

Advances in computer simulation and visualization are revolutionizing the way plants can be conceived and designed. Aircraft are being designed without building prototypes, nuclear explosions can be simulated inside computers, and candidates for successful pharmaceuticals can be selected using computational chemistry and three dimensional (3D) visualization studies. Under a new "focus area" established last year at the Department of Energy's (DOE) National Energy Technology Laboratory (NETL), efficient processes are being developed to combine simulation with experimental testing. Virtual simulations will provide a powerful and cost-effective tool for developing and transferring advanced energy technologies to a broad spectrum of stakeholders. They are key to the success of the Office of Fossil Energy (FE) Vision 21 program to foster development of a near-zero-polluting, highly efficient range of technologies to be available by 2020.

West Virginia Governor Wise, and NETL Director Rita Bajura viewing simulations on an advanced visualization system

In this first year of the Computational Energy Sciences focus area, modeling has been initiated for critical components of clean coal plants, such as circulating fluidized-beds, fuel gas reactors, and fuel cells. Virtual representations of simple projects have been achieved, and the integration of computational models into these virtual projects initiated. A virtual environment center, featuring workstations with 3D modeling and simulation capability, is under construction at the NETL Morgantown campus. Partnerships to achieve high speed Internet and supercomputing capability have been formed, and partnering with many of the other National Laboratories, universities, and industry is leading to a diverse team to achieve computational science goals.

FE has 20 years of successful work in modeling and simulation of power generating technologies. The core of this expertise lies within process modeling and computational fluid dynamics (CFD) capabilities. They have been used to evaluate advanced energy systems performance in steady state and transient conditions. Unit operations such as fluidized-bed combustion, gasification, and flue gas cleanup have been evaluated over a wide range of process design conditions. A matrix of advanced power generation system configurations have been studied for their impact on cost and performance.

The Clean Coal Technology Program, managed by FE and NETL, was the first coal-based technology program in which modeling and simulation played an important role in design, construction, start-up, and cost reduction. For example, CFD models were used to fine-tune the performance of large-scale combustion systems. Expert systems were developed to evaluate the effects of fuel properties on coal-fired power plants. Operator training at integrated gasification combined-cycle power plants was improved by simulating the power plant, which facilitated cost-effective operator learning.

While a substantial range of modeling and simulation tools now are available, an integrated platform for performing complete virtual simulations of advanced fossil energy systems is needed. Currently, most process engineering applications for systems — such as architectural and engineering design, heat and mass constitutive simulations, cost estimations, and synthetic environment visualizations — are self-contained, and each provides its own user interface. By integrating this software, an opportunity exists to fully complement fossil fuel technology demonstrations with virtual simulations of relevant technologies tailored to the goals set forth in Vision 21.

The virtual demonstration concept is envisioned to combine dynamic process simulations with a 3D immersive visualization of a plant, thus allowing the users to "walk through" a proposed energy plant and see it operate. The virtual environment can be used as the front-end of a greatly expanded total information system containing all of the design, construction, operation, research-scale, pilot-scale, and economic information available on the system.

The benefits of providing virtual representations to the fossil energy industry are potentially staggering, yet are just beginning to be recognized by the industry. Through its computational energy sciences activities, DOE is positioned to play an important role in stimulating, developing, and testing this cost-effective development of new advanced energy systems, and thus ensuring the vitality and vibrancy of the U.S. energy industry in competitive global markets.

SULFUR REMOVAL FROM GASIFICATION-DERIVED SYNGAS

Gas stream cleanup is one of the key enabling technologies in the U.S. Department of Energy (DOE) Office of Fossil Energy (FE) Vision 21 Program designed to eliminate environmental concerns associated with fossil fuel use. Included in the gas stream cleanup effort are removal of sulfurous gases, particulate matter, nitrogen oxides, and hazardous air pollutants (HAPs) to near-zero levels from syngas generated by gasification of carbonaceous fuels. While removal of all contaminants to extremely low levels is critical to meeting Vision 21 objectives, one important aspect of FE's gas cleanup program deals with sulfur removal, some details of which follow.

Gasification technologies offer particular promise for near-zero emissions and very high efficiency when integrated with advanced systems such as fuel cells and newly developed high-temperature gas turbines. Such systems are highly sensitive to the presence of sulfur, both hydrogen sulfide (H_2S) and carbonyl sulfide (COS). Also, gasification technologies that co-produce clean fuels and chemicals rely on sorbents that are readily poisoned by sulfur and other trace compounds.

Currently, amine systems are the commercial standard sulfur removal technology, but they are not trouble-free and have significant operating costs. They operate in liquid phase at ambient conditions, requiring cooling of the syngas to nearly ambient temperatures, thus resulting in loss of valuable sensible heat. These amine-based processes are also subject to process equipment corrosion, foaming, and amine-solution degradation and evaporation; require extensive wastewater treatment; and cannot remove COS from the syngas without preconversion to H_2S. DOE is exploring alternative technologies for sulfur control including regenerable metal oxide sorbents, process reactors to enable effective regenerable sorbent use, and advanced and novel process concepts.

REGENERABLE METAL OXIDE SORBENTS

Metal oxides are used in a two-step process to remove H_2S. In the first step, sulfur is adsorbed on the metal element and the oxygen combines with the hydrogen to form water. Following this desulfurization, the metal/adsorbed sulfur is oxygenated and regenerates the metal oxide, producing SO_2 in concentrated form.

The main criteria for a metal oxide to be suitable for this process include: reactivity with both H_2S and COS at desired temperatures and pressures; absorption capacity; favorable thermodynamics to reduce the sulfur level to a desired value; mechanical and chemical stability in reducing and oxidizing conditions; and easy regeneration under oxidizing conditions without formation of undesirable side products such as metal sulfates.

Commercially available zinc oxide (ZnO) meets the basic criteria, and combining ZnO with a second oxide has resulted in a catalyst with the desired properties. Three mixed-metal oxide sorbents showing promise are being tested at pilot- to demonstration-scale: Z-Sorb® (ZnO on a proprietary matrix), EX-SO_3 zinc titanate (ZnO and titanium dioxide), and RVS-1 (ZnO on a patented matrix). As a group, these sorbents are capable of removing sulfur over a wide temperature range (400–760 °C) in power generation applications, while meeting O_2 emission requirements.

Z-Sorb® was developed by Phillips Petroleum Company for use at Tampa Electric Company Polk Power Station's 250-MWe integrated gasification combined cycle unit. It showed excellent performance at pilot-scale, but was incompatible with the plant's design.

Further research efforts to find a durable sorbent capable of operating in fluidized-bed or entrained-bed mode led to a zinc titanate formulation designated as EX-SO_3. After verifying performance at bench-scale and in a transport reactor test unit, a 50,000 pound batch of the EX-SO_3 sorbent produced by the Intercat Development Corporation was loaded into the external desulfurizer used on the 99-MWe Piñon Pine IGCC demonstration unit. The Piñon Pine plant uses a transport-bed reactor system for hot-gas desulfurization. This transport reactor system, developed by the Kellogg, Brown and Root (KBR) Company, requires the sorbent to be both highly reactive and attrition-resistant. During ongoing startup efforts, the EXSO$_3$ had no attrition problems while loading and testing through hot cycles and continuous circulation validation trials. Actual desulfurization testing is to begin shortly.

The RVS-1 sorbent developed by DOE/NETL under an in-house R&D program is of particular interest because it is the only one of the acceptable sorbents capable of reducing sulfur emissions in fuel gases to one part per million (ppm) by volume at moderate operating temperatures. Research is continuing to demonstrate RVS-1's further improvement to a parts-per-billion sulfur control range and at much lower temperatures

(120–400 °C). This work received an R&D 100 award in 2000, and is being seriously considered for further development and application by industry in gasification operations.

PROCESS REACTORS

After selection of a suitable sorbent composition, the next vital piece of a sulfur removal system is the process reactor design. Fluidized-bed reactors may be the most prudent choice for conducting desulfurization. They have several advantages over fixed- or moving-bed reactors, including excellent gas-solid contact, rapid kinetics, particle handling, and temperature control of highly exothermic reactions. However, the sorbent must be highly reactive and attrition-resistant for a fluidized-bed reactor to work successfully.

The transport reactor is a derivative of a fluidized-bed reactor, whereby the material is entrained in a fluidized state in two continuous loops. Compared to fluidized-bed reactors, transport reactors have a far smaller sorbent inventory requirement, shorter residence time for adsorption and regeneration, regeneration temperature control without need of a diluent, and a lower sulfur capacity requirement for the sorbent.

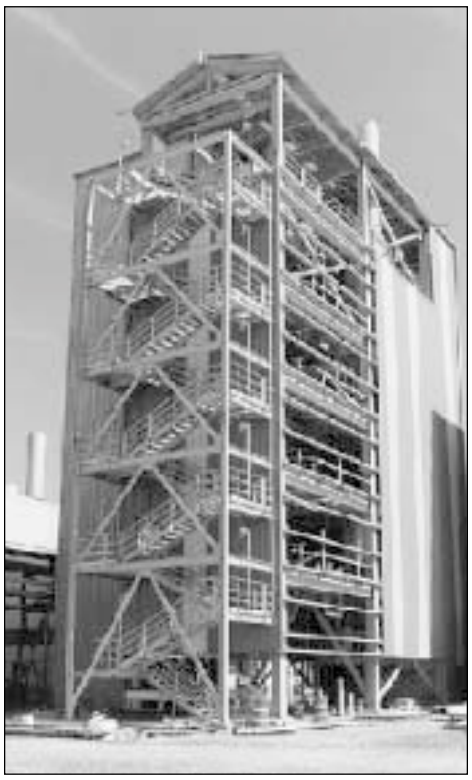
DOE/NETL completed the construction and shakedown of a Gas Process Development Unit (GPDU) in 2000. The GPDU is designed to test both fluid-bed and transport contacting in two transport reactors and two fluid-bed reactors. The GPDU can provide continuous recirculation in either transport or fluid-bed reactor mode, and uses a coupled configuration to continuously circulate sorbent between any two reactors. It is large enough to translate performance to commercial-scale units.

ADVANCED AND NOVEL PROCESSES

The Direct Sulfur Recovery Process (DSRP) is being developed by Research Triangle Institute (RTI) to catalytically reduce SO_2 produced during regeneration of the sorbent into elemental sulfur, and currently is being evaluated at the Power Systems Development Facility, Wilsonville, Alabama. The process converts up to 99 percent of the SO_2 produced during regeneration to elemental sulfur, but requires two moles of reducing gas (H_2 + CO) for each mole of sulfur. This results in the need to recycle a large amount of synthesis gas back to the DSRP unit. To reduce this energy penalty, a Single-Step Sulfur Recovery Process is being developed at warm temperatures that hold much more promise.

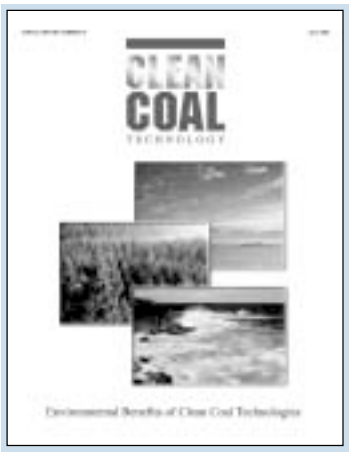
Under a multi-contaminant control program, the Siemens Westinghouse Power Corporation is working with the Gas Technology Institute to develop a two-stage novel "Ultra-Clean Gas Cleanup Process" for warm syngas cleanup, which employs a moving-bed filter-reactor and second stage barrier filter-reactor. The technique can be utilized for both polishing and ultra-cleaning in cases where significant sulfur removal (down to 50 ppm) is completed in the gasifier or has been removed in a primary desulfurization step, or where low-sulfur syngas fuel is generated from a low sulfur-containing feedstock such as biomass.

RTI is also developing novel technologies for gaseous contaminant control. RTI is working with SRI International, MEDAL (Membrane Separation Systems DuPont Air Liquide), the Prototech Company, and North Carolina State University. The process employs a polymer membrane and a regenerable ZnO-coated monolith combined to remove: sulfur species to sub-ppm levels; hydrogen chloride vapors to sub-ppm levels by using an inexpensive (disposable), high-surface-area material; and ammonia (NH_3) with acidic adsorbents followed by conversion of the NH_3 into nitrogen and water. It is contemplated that various individual modules can be used in a "mix and match" fashion depending on the type and level of contaminants and cleanup requirements. RTI projects a 50 percent cost reduction over a conventional amine system, and the process is being analyzed. In addition, a concentrated CO_2 stream can be obtained, allowing effective CO_2 sequestering.



The Gas Process Development Unit is a sorbent and reactor configuration testing facility

ENVIRONMENTAL BENEFITS TOPICAL REPORT PUBLISHED



Environmental Benefits of Clean Coal Technologies, a topical report just issued by the DOE Office of Fossil Energy, touts the environmental successes of the Clean Coal Technology Program since its inception in 1985 through five rounds of competitive awards. A few of the highlights include:

- NO_x reduction technologies have been retrofitted to three-quarters of U.S. coal-fired generation capacity.
- Low-NO_x burners are now available at a fraction of the cost of NO_x controls existent in the 1980s.
- The state-of-the-art for scrubber technology has been redefined, enabling industry to respond to stringent air pollution standards. The United States has the largest number of flue gas desulfurization installations in the world. Investment in these systems is estimated to have saved $40 billion over the last 30 years.
- New integrated gasification combined-cycle (IGCC) power generation systems have been developed that remove 99 percent of the SO_2, 99.99 percent of particulates, and 90 percent of the NO_x, and reduce CO_2 by 25 percent over conventional coal-fired power plants.

The topical report (#18 in a series on the CCT Program) is available on the DOE's Clean Coal Technology Compendium at http://www.lanl.gov/projects/cctc/topicalreports/topicalreports.html

R&D MILESTONES

Five-year effort results in two commercial products to reduce NO_x from coal-fired plants. Under the auspices of NETL, Reaction Engineering International and its project team from the University of Utah, Brown University, and Babcock Borsig Power (DB Riley, Inc.) have completed a modeling and industry application study to address the problem of unburned carbon levels in coal ash resulting from in-furnace NO_x control techniques. These techniques, including staged low-NO_x burners, reburning, selective non-catalytic reduction, and hybrid approaches, are cost effective, but have the disadvantage of raising unburned carbon levels. Two commercial products resulted from this effort: the Configured Fireside Simulator and a corrosion-resistant monitoring device for evaluating waterwall wastage. Power plant operators can use these products to determine the optimum low-NO_x firing configuration.

University of Kentucky researchers, under NETL-sponsored research, have produced high-strength alloys for gasification environments. In their current state, corrosion resistant alloys such as chromium-tantalum are too brittle for commercial use. Using a process known as directional solidification, researchers produced an alloy that has mechanical strength in environments as hot as 1,000 °C. Such alloys are expected to improve the efficiency of power plants through increased operating temperatures and decreased cooling requirements, and will be an important feature in the Vision 21 plant of the future.

Siemens Westinghouse has developed an approach to greatly reduce costs of bonded vanes, a crucial gas turbine component. To circumvent high costs of large, single crystal vanes used in land-based gas turbines, researchers are casting and assembling smaller single-crystal segments using a transient liquid bonding process. The approach combines smaller, high-yield cast parts with high quality bonding to make first-stage stationary vanes. New technology will reduce costs by a factor of ten and advance the goal of a cost-competitive gas turbine system for the post-2005 power generation market. The effort is part of NETL's work in materials technology to keep pace with improvements in gas turbine designs, which are raising rotor inlet temperature to 2,600 °F while increasing thermal efficiencies to 60 percent in combined-cycle configurations.

DOE OFFICES COORDINATING HYDROGEN ACTIVITIES

The U.S. Department of Energy (DOE) Hydrogen Program Strategic Plan 20 Year Vision indicates that hydrogen and electricity ultimately will come from sustainable renewable energy sources, but fossil fuels will be a significant transitional resource. At present, fossil fuels are the lowest-cost resource capable of producing hydrogen at the needed scale. With this goal in mind, and consistent with the strong recommendation of the November 1997 President's Council of Advisors on Science and Technology report, *Hydrogen Production from Fossil Fuels with Carbon Sequestration*, the DOE Offices of Fossil Energy (FE) and Energy Efficiency and Renewable Energy (EERE) began discussing coordination of hydrogen activities in 1998. Discussions were focused upon the many years of FE experience in hydrogen production in gasification, pyrolysis, liquefaction, catalysis, gas processing, and separation programs, which could complement EERE's activities in hydrogen storage and handling, distribution systems, and small-scale fuel cells. The result of these discussions was the signing in March 1999 of a Memorandum of Agreement to work together on hydrogen projects of mutual interest. FE's goals were to bring the technologies being developed by FE that allow the centralized production of large volumes of low-cost hydrogen to the hydrogen program, while avoiding any duplication with EERE's efforts.

Production of hydrogen from coal begins with gasification. In this process, coal and water (as steam) react at temperatures from 1,800–2,600 °F and at pressures from 200–1,200 psi to produce a raw synthesis gas. The gas, a mixture of hydrogen, carbon monoxide, carbon dioxide, and other gases, is cleaned to remove sulfur-containing components and other impurities. At this point, the gas stream is further processed to produce more hydrogen from reaction of the carbon monoxide with additional steam that produces a mixture of carbon dioxide and hydrogen. These gases then are separated into pure streams of hydrogen and carbon dioxide. This concentrated carbon dioxide stream then may be readily sequestered, if desired.

Once hydrogen is produced, it may be used directly or compressed and stored or distributed as either a high-pressure gas or cryogenic liquid. Currently, most hydrogen is produced by reforming methane with steam, a process chemically identical to that described for coal, and is used primarily in the petrochemical industry, with a small amount employed as a rocket propulsion fuel by the National Aeronautics and Space Administration. The DOE hydrogen program's goals are to expand the use of hydrogen to commercial and private transportation vehicles and to distributed power. These applications could use hydrogen in fuel cells, reciprocating engines, or hydrogen turbines. A major barrier to these applications is the lack of a storage and distribution infrastructure. Other concerns are the safety of handling and storing hydrogen, and the cost of sequestration when the hydrogen is produced from fossil fuels.

One major activity shared with EERE was a workshop in September 2000 at the National Energy Technology Laboratory in Pittsburgh, Pennsylvania. The meeting brought together over 60 stakeholders from government, industry, and academia who were interested in accelerating technology development to enable production of large volumes of low-cost hydrogen from fossil fuels prior to the development of renewable hydrogen sources. Participants discussed varied aspects of hydrogen utilization, process technology, implementation strategy and integrated systems demonstration, and the potential of hydrogen generation in power generation and as a transportation fuel. Participants agreed on the need for improvements in technology to separate hydrogen from synthesis gas, and for government incentives to overcome high carbon sequestration costs. While hydrogen transportation fuels would be pollution free, educational efforts would be required to convince the public that hydrogen is safe.

In other areas, FE and EERE have conducted systems studies for hydrogen production from low-rank coals and dense-phase ceramic gas separation membranes. These membranes have the potential for reducing hydrogen production costs 25 percent below currently available techniques because of the expense of present separation processes. Future DOE plans include studies to reduce the cost of hydrogen compression, and development of hydrogen by biological processes.

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GASIFICATION TECHNOLOGIES WORKSHOP FOR ENVIRONMENTAL REGULATORS

In order to familiarize state and federal environmental agency personnel with gasification technologies, while at the same time providing private sector managers the opportunity to listen to issues of concern from the regulators, the U.S. Department of Energy arranged for a one-and-one-half day workshop in March 2001 in Tampa, Florida. The workshop included a site visit to the Tampa Electric Company (TECO) Polk Power Station. The event was co-sponsored by the Southern States Energy Board and the Gasification Technologies Council, and was attended by 14 state regulators from federal region IV (southeastern states), two representatives from the U.S. Environmental Protection Agency (EPA), 33 industry leaders, and other state representatives.

Gasification is being incorporated into an increasing number of power producing and industrial facilities, such as power plants, refineries, and chemical/fertilizer plants. One purpose of the workshop was to familiarize state and federal regulators with the environmental performance characteristics of gasification technologies, in order to facilitate permitting of future gasification plants. Likewise, industry participants were to gain a better understanding of the permitting process. Attendees were briefed by industry specialists on gasification technology and applications, as well as worldwide gasification industry trends. Speakers addressed topics such as the Wabash integrated gasification combined-cycle (IGCC) CCT project, and opportunities for the use of refinery and chemical industry wastes as feedstocks for gasification technologies. These wastes include petroleum coke and other refining "bottoms," and chlorinated hydrocarbons. An afternoon visit to the 250-MWe TECO IGCC project was provided to familiarize regulators with state-of-the-art IGCC technology.

Regulators were concerned about environmental issues such as NO_x and mercury emissions. One participant suggested that tradeoffs might be made for NO_x in view of the other benefits of gasification, such as reduced SO_x, higher efficiency/lower CO_2 emissions, lower particulate emissions, and a benign slag by-product in lieu of wastes. Participants discussed whether selective catalytic reduction is an option for additional NO_x control, and cited the need to produce more information on hazardous air pollutants, and particularly mercury. Also mentioned was the need for more data on slag characteristics in order to address environmental and health issues, as well as beneficial uses of slag.

Wabash River Generating Station repowered with a 262-MWe IGCC unit

TECO's 250-MWe Polk Power Station, Unit 1 IGCC facility

The workshop took an important step in establishing an ongoing communications process and structure between the regulators and industry. Participants evaluated the workshop as beneficial and recommended holding additional meetings in other regions. The EPA expressed interest in co-sponsoring follow-on events with the current sponsors. Preliminary plans call for the next workshop to be held as early as September 2001 (covering federal region V, which includes Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin) in Indianapolis, Indiana.

NETL HOSTS SENSORS AND CONTROLS WORKSHOP

Operational efficiency, emission reduction, and lower operating costs are benefits that the power industry can realize with the utilization of sensors and controls. However, for the power industry to derive the maximum benefit from sensors and controls, improvements in existing technologies and/or novel approaches to challenging measurements are needed. For the DOE Office of Fossil Energy Vision 21 Program as well as clean coal activities under the Power Plant Improvement Initiative and the proposed Clean Coal Power Initiative, development of sensor and control systems is critical.

Artist's rendering of a Vision 21 plant

The Vision 21 Program is aimed at providing technologies for ultra-clean fossil fuel-based energy production with 60–75 percent efficiencies and near-zero emissions. The program also takes a modular approach to present opportunities to not only generate power, but also co-produce clean fuels, chemicals, steam and other useful products. The ultra-high efficiency and environmental performance would require the plants to operate at optimum conditions, while undergoing changes in demand and feedstock. This situation results in challenging tasks for control and sensing systems. One cost-effective method of improving existing plant performance is to update its sensors and control systems. Advanced systems cost significantly less than replacing single, big hardware equipment, and offer improvement to the overall system.

Recognizing the importance of sensors and controls, the Office of Fossil Energy's Advanced Research Program is supporting the development of high-risk, possibly revolutionary technologies. On April 17–18, 2001, DOE's National Energy Technology Laboratory (NETL) sponsored a workshop on sensors and controls in Washington, DC. Attendees included 46 experts from 29 organizations, including private industry, research laboratories, academia, and government agencies.

The meeting opened with keynote speakers from NETL and the private sector. NETL officials spoke of the Vision 21 and Advanced Research programs, while the private sector noted success stories in the area of sensors and controls. Robert Frank, Director of the Instrumentation and Control Center for the Electric Power Research Institute presented the results of a demonstration project for retrofitting the Tennessee Valley Authority's Kingston Station Power Plant with advanced sensors and controls. Benefits derived from that project included improvements in heat rate, reduction in loss-on-ignition, and reduction in NO_x formation. Galen Fisher of Delphi Research Lab spoke of improved efficiency and reduced emissions that sensors, controls, and diagnostics have brought to the automotive industry.

The workshop held parallel discussions on advanced combustion/gasification, turbines, fuel cells, and environmental controls, to identify and prioritize the near-term (0–5 years) and long-term (5–15 years) sensors and controls needs. The near-term needs may serve to improve existing power plant performance as well as the Vision 21 Program, while the long-term needs were aimed, primarily, at supporting the Vision 21 Program. With the prioritized needs identified, discussion sessions were held on emerging technologies.

The results indicated that sensors need to be developed or improved for on-line or *in-situ* applications where conditions are extremely harsh (high temperature, high pressure, corrosive environment, and presence of particulates). Sensor development needs to focus on robustness and accuracy, while balancing longevity with cost. Self-diagnostic and drift quantification capabilities of individual sensors will be an essential feature of new "smart" sensors.

Balancing the fuel/air ratio was identified as a high priority to improve power generation efficiency, as well as reduce emissions. To achieve an optimum fuel/air ratio, where thermal NO_x formation is lowest and flame stability is acceptable, several areas of measurement and control are essential: flame quality, fuel supply, as well as physical conditions and chemical composition in the combustion zone. While flame quality data can be extracted by a variety of methods including acoustics, electrical, and optical techniques, the challenge is to transform the data into meaningful information that can be interpreted by the control system.

In the area of fuel supply, an accurate on-line measurement of solid

See "Workshop" on page 10...

...Workshop continued

fuel flow needs to be developed. While microwave, electric, and acoustic techniques have been attempted, much work still is needed in this area. In addition to flow rate, feedstock characterization was identified as a long-term need for use with advanced control systems. As alternative feedstocks are utilized, this measurement will grow in importance. Accurate on-line feedstock characterization should help proper mixing of fuels, ensure appropriate heat content, allow predictive control of the combustion process, and manage contaminants appropriately throughout the system.

Techniques for combustion zone measurement long have been recognized as a high-priority need because current on-line techniques cannot withstand the harsh conditions inside a gasifier, boiler, or turbine. While specific applications for a gasifier and turbine differ, the primary need is to develop materials and techniques capable of accurately detecting gas path and surface temperatures (as high as 2,600 °F for gasifiers and 4,000 °F for turbines) in high-pressure corrosive environments.

On-line, *in-situ* measurement systems, capable of withstanding the combustion zone environment, are seen as essential for an active, integrated control system where the emission information is used as an input to adjust the plant operation. Examples include on-line mercury measurements, *in-situ* NO_x sensors, on-line particulate monitor (size and concentration), *in-situ* ammonia sensor, HCl monitor, and alkali monitor. Some of these methods are commercially available, but need improvement.

The development and implementation of advanced controls were discussed in every session and were identified as important needs for both existing and future power generation facilities. Participants recognized that existing combustion facilities could benefit substantially from implementing advanced computerized control systems that are commercially available. Identified areas of interest included integrated control for total plant optimization, improved modeling of combustion and instability, standardization, and dynamic controls. To facilitate DOE's Vision 21 Program, with its modular yet interdependent components, an umbrella approach was deemed necessary. A central control system also may be used for tracking feedstock supply, system output, maintenance, and cost. At the individual modular system level, the need was discussed to develop smart feedback or feedforward controls utilizing neural networks and predictive models. Validation of models was also deemed an important feature of advanced controls development.

The information compiled from the workshop will be used to align FE's Advanced Research Program sensors and controls development efforts with both the DOE Vision 21 Program and the Power Plant Improvement Initiative. The information also may serve as a basis for the research and development community to focus its efforts more effectively in high-priority areas.

UPCOMING EVENTS

August 20–24, 2001
Combined Power Plant Air Pollution Control Symposium "The Mega Symposium"
Location: Chicago, IL
Sponsors: EPA, DOE, EPRI
Contact: Denise Stotler
Phone: 412-232-3444, ext. 3111

August 22-24, 2001
1st U.S.-China Symposium on CO_2 Emission Control Science & Technology
Location: Hangzhou, China
Sponsors: U.S. DOE and Ministry of Science and Technology, P.R. China
Organizer: Zhejiang University
Contact: Kim Yavorsky
Phone: 412-386-6044
E-mail: Kimberly.Yavorsky@netl.doe.gov

August 29–September 1, 2001
Clean Energy Technology Forum and Technology & Equipment Exhibition
Location: Beijing, China
Sponsors: U.S. DOE, and Ministry of Science & Technology, P.R. China
Contact: Dr. Sun W. Chun
Phone: 412-386-4795 or 202-586-6660
E-mail: chun@netl.doe.gov

September 30–October 5, 2001
11th International Conference on Coal Science
Location: San Francisco, CA
Sponsor: DOE/NETL, IEA, USGS, Alstom Power, and ACS
Contact: Kim Yavorsky
Phone: 412-386-6044
E-mail: Kimberly.Yavorsky@netl.doe.gov

November 19-20, 2001
Clean Coal and Power Conference
Location: Washington, DC
Sponsor: U.S. Department of Energy
Contact: Faith Cline
Phone: 202-586-7920
Fax: 202-586-8488
E-mail: faith.cline@hq.doe.gov

INTERNATIONAL INITIATIVES

APEC EXPERTS GROUP ON CLEAN FOSSIL ENERGY

The Experts Group on Clean Fossil Energy (EGCFE) is one of five Experts Groups under the Asia Pacific Economic Cooperation (APEC) Energy Working Group. The various Experts Groups concentrate on specific themes of economic and strategic importance to the economies of the region from an energy perspective. The EGCFE has focused programs in coal technology, coal policy, and oil and natural gas.

The U.S. Department of Energy (DOE) Office of Fossil Energy (FE) has chaired the EGCFE for over seven years. Dr. Sun Chun, Senior Advisor for International Issues, is the current chair and Dr. Lowell Miller, Director of Coal Fuels and Industrial Systems, chaired the Group for the prior four years. Early next year, Scott Smouse, Senior Management & Technical Advisor – International at DOE's National Energy Technology Laboratory (NETL), will become the EGCFE Chair for the next four years. The mission of the EGCFE is to encourage the use of clean fuels and energy technologies that will contribute to both sound economic performance and achieve high environmental standards. Emphasis is on sharing technical and economic information on the use of cleaner fuels and clean coal technologies. Increased emphasis is being given to the examination of options to mitigate local, regional, and global environmental impacts of fossil energy use.

Attendees at the 21st APEC Energy Working Group meeting in Malaysia in May 2001

The EGCFE has been conducting a number of technical and market studies. "The Role of Petroleum Based and Alternative Transportation Fuels in Reducing Emissions in the APEC Region" study recently was completed, which reviews the current and planned specifications for diesel fuels, jet fuel, and gasoline in the APEC region and examines the role of alternative fuels in meeting environmental and security objectives. Another study, "CO_2 Reduction Options in the APEC Region (Phase I)," has been initiated, while a Request for Proposals for Phase II of the study is planned for release later this year.

In the conference area, the EGCFE organized several events as part of an APEC conference entitled "The Clean and Efficient Use of Fossil Energy for Power Generation in Thailand," which was held in Bangkok, Thailand late last year. The conference featured the 3rd Coal Trade and Investment Liberalization Facilitation Workshop, the 7th Coal Flow Seminar, and the 8th Clean Fossil Energy Technical Seminar.

The events were attended by some 170 energy experts from 11 economies: Australia, Canada, China, Indonesia, Japan, Malaysia, Philippines, Singapore, Chinese Taipei, United States, and Vietnam. A similar series of events will be held next fall in Kuala Lumpur, Malaysia.

Copies of the APEC reports can be obtained through the EGCFE Secretariat, Ken Hong, of the Office of Fossil Energy (kenneth.hong@hq.doe.gov).

See "International" on page 12 ...

...International continued

NEW COAL ASH NEWSLETTER LAUNCHED IN INDIA

Under an agreement with the U.S. Agency for International Development (USAID) and the Government of India, the National Energy Technology Laboratory (NETL) has been providing technical assistance for implementation of the Greenhouse Gas Pollution Prevention (GEP) Project. This project is designed to improve the efficiency of existing coal-fired power plants, improve environmental controls, and promote adoption of advanced power generation technologies at future Indian coal-fired power plants. NETL has supported six coal- and power-related projects in India for USAID since 1982.

As part of this long-standing partnership, a new coal ash newsletter has been launched. While the newsletter emphasizes coal ash issues in India, contributions from the entire southeast Asian region are welcomed. Coal-fired power plants in India currently produce more than 90 million tons of ash per year, which takes thousand of acres of land out of valuable agricultural or other usage. Alternatives to current stockpiling of fly ash and other solid combustion by-products are a high priority of the Government of India. The USAID Program devotes significant resources to ash reduction/remediation/re-use projects. The newsletter will help to disseminate current information on ways to increase ash utilization. The first issue was published in March 2001. The editor, Vivek Hajela, can be reached at cycom@mantraonline.com.

FE HOSTS WORKSHOP TO PROMOTE JOINT RESEARCH WITH UK

Representatives from FE and the UK Department of Trade and Industry convened in Knoxville, Tennessee to plan bilateral cooperative efforts

In early May, the U.S. Department of Energy (DOE) Office of Fossil Energy (FE) held a workshop in Knoxville, Tennessee as the first step toward developing the first Implementing Arrangement under a Memorandum of Understanding (MOU) signed last November between DOE and the United Kingdom (UK) Department of Trade and Industry for cooperative work in energy R&D. The "Introductory Meeting on Potential US-UK Interactions in Fossil Energy" was attended by over 30 representatives from government and private industry, and included 14 participants from the UK.

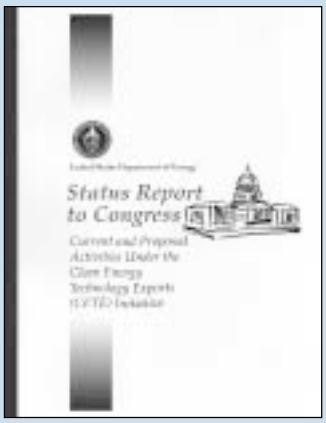
The two-day meeting featured talks on various coal and power systems research areas with a goal of identifying common points of interest in order to draft an annex or Implementing Arrangement to carry out MOU goals. DOE already collaborates with the UK, under auspices of the International Energy Agency, in such research areas as multiphase flow, clean coal science, and the IEA Clean Coal Centre, which operates in London and publishes numerous reports on coal R&D. Topics of interest at the Knoxville workshop included such advanced technologies as IGCC, fuel cells, advanced process and environmental control systems, CO_2 sequestration, transportation fuels and chemicals, as well as crosscutting research in advanced materials, and advanced modeling and instrumentation. Once the annex is signed, one of the first tasks is expected to relate to advanced materials. In that area, participants discussed needed research in ultrasupercritical power plants, NDE techniques for assessing the remaining life of gas turbine materials, and ceramic composites for combustor liners.

Workshop participants view country collaboration as a tool for reducing overall costs by researching complementary subject areas. Being part of a broad-based effort can also help countries obtain more internal funding. At the meeting, attendees gained perspective on internal and export energy markets, as well as potential business opportunities. Future workshops to carry out FE's part of the MOU are envisioned to be held annually in conjunction with established conferences in the U.S. and the UK, with the next workshop targeted for Spring 2002.

NETL TO SUPPORT TCAPP ACTIVITIES IN CHINA

The U.S. Environmental Protection Agency (EPA) has requested assistance from the DOE Office of Fossil Energy's National Energy Technology Laboratory (NETL) in implementing a Technology Cooperation Agreement Pilot Project (TCAPP) in China. TCAPP helps developing countries design and implement actions to attract investment in clean energy technologies that will meet their economic development goals, while mitigating greenhouse gas emissions. TCAPP projects in various countries are supported by the EPA, the U.S. Agency for International Development (USAID), and DOE. In China, TCAPP activities are implemented through the Cleaner Air and Cleaner Energy Technology Cooperation (CACETC) with China's State Development Planning Commission. Three fossil energy-related projects are planned: Clean Coal Technology, Improving Efficiency of Coal-Fired Industrial Boilers, and Natural Gas Combined Cycle Power Generation. The first two projects have been started this year, while the natural gas project is planned for next year.

A TCAPP/CACETC meeting was held January 9, 2001, in Beijing to launch the CCT and Industrial Boiler Projects. The CCT Team agreed to focus on advanced CCTs for power generation, such as integrated gasification combined cycle and pressurized fluidized-bed combustion, and prepared a two-year strategy including exchange of information on CCT RD&D activities in both countries. The plan also includes a study tour by senior Chinese experts to review U.S. CCT experience, visit demonstration plants, meet manufacturers, and discuss ideas with U.S. CCT suppliers and financial institutions on how to remove barriers to CCT transfer to China. The Industrial Boiler Team's action items include a U.S. study tour on advanced boiler products and concepts, and possible establishment of a Chinese Industrial Boiler Owners Association, as well as convening an International Conference on Technical Improvements to Chinese Industrial Boilers to Reduce Greenhouse Gas Emissions.



INTERAGENCY GROUP DRAFTING PLAN FOR CLEAN ENERGY TECHNOLOGY EXPORTS

The U.S. Department of Energy (DOE) Fiscal Year 2001 budget calls for development of a strategic plan to promote the export of clean energy technologies to growing global energy markets. To this end, the Clean Energy Technology Exports (CETE) Working Group — composed of DOE (including the Office of Fossil Energy), USAID, and the Department of Commerce — is working on a plan expected to be released this summer in draft form for public review. Clean energy technologies are defined as energy technologies, products, and services that can improve environment, health, and safety. CETE group activities are cited in the May 2001 National Energy Policy. In preparing the draft strategic plan, the group is concentrating on five objectives to promote markets in key developing countries: increasing U.S. clean energy technology exports by increasing U.S. market shares and/or promoting expansion in the overall market size; improving energy security by increasing availability of affordable energy service; reducing increases in fossil fuel emissions; improving oil security by diversifying supplies of oil and oil substitutes; and by lowering the rate of increase in domestic oil consumption and reducing risks of nuclear proliferation by exporting U.S. nuclear technologies and institutional approaches.

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 19 months to evaluate use of GNOCIS and other computer programs to decrease NO_x and LOI and increase efficiency by optimizing the use of additional plant equipment, including ESPs and sootblowers. (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.* In September 1997, DOE signed an agreement with JEA to cost-share refurbishment of the first (Unit 2) of two units at the Northside Generating Station. A Record of Decision under NEPA has been signed. Unit 2 is scheduled for mechanical completion in July 2001, with first fire in October, 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 in mid summer 2001. The Public meeting for air quality permits was held in early May. No major comments or 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. Since 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 second quarter 2001, the gasifier has operated over 23,500 hours to provided syngas to the combustion turbine to produce over 6,400,000 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, and the Final Report was issued for approval. Copies of 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. AIDEA has initiated negotiations to secure a plant operator and an agreement for the sale of the power and intends to restart plant operations as soon as possible. (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. Testing is scheduled to continue until Fall 2001. Shakedown of the demonstration diesel on fuel oil is complete and break-in is in progress. Only minor problems have been encountered. (Fairbanks, AK)

COAL PROCESSING FOR CLEAN FUELS

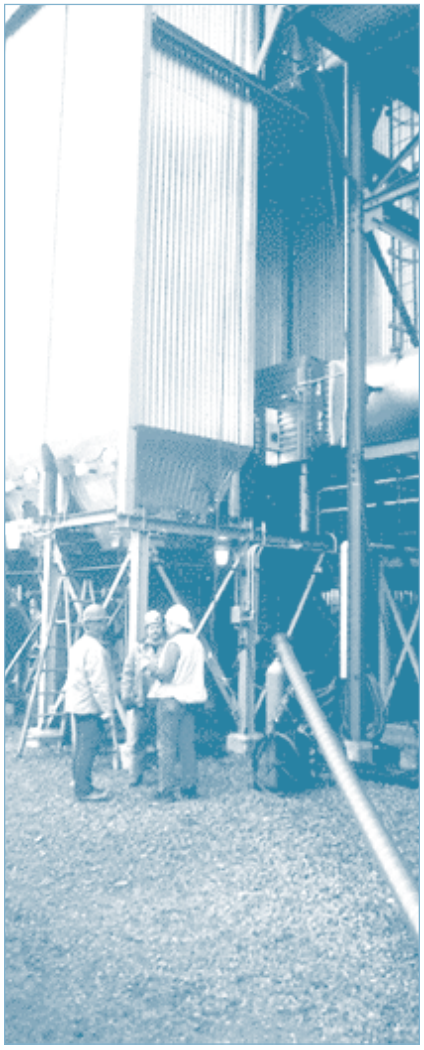
Western SynCoal LLC (formerly Rosebud SynCoal® Partnership) – *Advanced Coal Conversion Process (ACCP) Demonstration.* The ACCP Demonstration Project in Colstrip, Montana, has processed over 2.9 million tons of raw subbituminous coal. Nearly 2 million tons has been supplied to customers, including industries (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. That transaction closed on April 30, 2001. Because Westmoreland cannot monetize the synthetic fuel production tax credits, operation of the ACCP is sub-economic under their ownership without a subsequent tax credit transaction. Therefore, operations at the ACCP Facility have been suspended. Westmoreland is continuing to seek opportunities to sell the ACCP plant to a party (or 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. During April 2001, a code inspection of all pressure vessels was completed. All vessels inspected showed no evidence of erosion, pitting, or fouling. Engineering modifications required for the upcoming *in situ* catalyst activation were also completed during this outage. 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 78 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 IPP firms. (Vineyard, UT)

ThermoChem, Inc. – *Pulse Combustor Design Qualification Test.* Testing of the 253-tube heater bundle is complete and the results are satisfactory. The measured temperature profiles were in general agreement with model/code projections. The Public Design Report is complete; however, it has not been submitted to DOE. Testing of the two tube unit is also complete and samples are being analyzed. (Baltimore, MD)



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