OFFICE OF FOSSIL ENERGY, U.S. DEPARTMENT OF ENERGY • DOE/FE-0215P-50 ISSUE NO. 50, SUMMER 2002

CLEAN COAL TODAY

A NEWSLETTER ABOUT INNOVATIVE TECHNOLOGIES FOR COAL UTILIZATION

NEWS BYTES

For the third time in its history, the **Air Products Liquid Phase Conversion Company's Liquid Phase Methanol (LPMEOH™) Demonstration Project**, in Kingsport, Tennessee, operated commercially for an uninterrupted period of over 50 days. The 55-day run ended on May 23, 2002. Previously, a 65-day run ended in April 1998. The longest run, 94 days, occured 1998. Exceptional performance periods such as these demonstrate the unit's extremely high overall availability — 97.7 percent since startup in April 1997. To date, the unit has produced over 94 million gallons of methanol.

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IN THIS ISSUE

GASIFIER TESTING AT PSDF

The Power Systems Development Facility (PSDF), located near Wilsonville, Alabama, is a large pilot plant designed to provide an engineering-scale demonstration of advanced coal-fueled power systems and key components at sufficient scale to provide data for commercial scale-up. It is a joint project of the U.S. Department of Energy (DOE), Southern Company Services, Inc. (SCS), and other industrial participants currently including the Electric Power Research Institute (EPRI), Siemens Westinghouse Power Corporation, Kellogg Brown & Root (KBR), and Peabody Energy.

The Power Systems Development Facility as seen at night

The PSDF started operations in 1992. Coal was first fed to the KBR Transport Reactor operating as a combustor in August 1996, during which time it achieved stable operations for a broad range of coals and sorbents tested. Coal conversion was greater than 99.9 percent at the typically low reactor temperatures (1,600 °F). Sulfur removal efficiencies exceeded 99 percent at low calcium (in the sorbent) to sulfur ratios — 1.2 to 1.3 — with coal and other fossil fuels containing up to 5.3 percent sulfur. Emissions of nitrogen oxides (NO_x) were less than 0.10 pounds per million Btu (lb/10^6 Btu).

During combustion testing, more than 20 types of filter elements were tested in high-temperature, high-pressure particulate control devices (PCD) designed for candle filter elements. These filter elements included monolithic ceramic oxides, monolithic silicon carbide, composites, and metallic materials.

RECENT PROGRESS

After 5,000 hours of combustion testing, the Transport Reactor was modified for operation as an air-blown gasifier (Transport Gasifier), as shown in the Figure on page 2. Coal was first fed to the Transport Gasifier in September 1999, and over 2,700 hours of gasification testing have been completed to date. The Transport Gasifier operates at considerably higher circulation rates, velocities, and riser densities than conventional circulating beds, resulting in higher throughput, better mixing, and increased mass and heat

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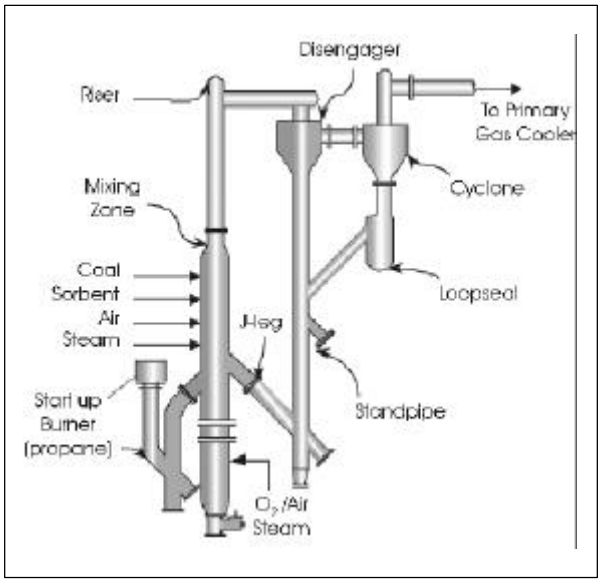
...PSDF continued

transfer rates. It represents a major efficiency gain relative to slagging gasifiers for applications using high-ash, high-melting point coals. It does not depend on slagging (melting) the ash to remove minerals from the process. Slagging of coal ash requires a large amount of energy which cannot be recovered. In addition, non-slagging conditions are more conducive to long refractory life. Other advantages over current gasifiers and combustors include high carbon conversion due to excellent gas/solids contact and high-percentage solids recirculation, high sulfur capture, high throughput, and high heat release rates that contribute to a small footprint and a simple mechanical design. Synthesis gas quality from a Transport Gasifier makes it applicable to fueling a combustion gas turbine for the production of power, powering a fuel cell, or producing fuels or chemicals.



Transport gasifier schematic

In the Transport Gasifier, fuel, sorbent, steam, and air are combined in the mixing zone with solids recirculated from the standpipe. The gas with entrained solids moves up through the mixing zone into the riser (which has a slightly smaller diameter), and exits the riser to enter the "disengager." The larger particles in the synthesis gas are removed by gravity separation in the disengager. Most of the remaining particles are removed in the cyclone. The synthesis gas stream exits the cyclone through a gas cooler to enter a PCD for final particulate removal. Solids collected by the disengager and cyclone are recycled to the mixing zone through the standpipe and J-leg. Heat is supplied by burning the carbon in the recirculated solids in the lower part of the mixing zone before they come in contact with the coal fed at the top.

Initial test runs on the Transport Gasifier were hampered by poor PCD operation due to high solids loading resulting from unsteady gasification system operation. Solid particle characteristics changed dramatically from those encountered during combustion. The syngas and char caused filter materials problems and contributed to large pressure drops; particulate-laden syngas sometimes leaked through the filter holders. Also, the carbon content in the circulating solids was found to be extremely low due to inefficient solids collection and recirculation. The high carbon-containing solids loading on the PCD also resulted in lower carbon conversion to synthesis gas.

After the initial runs, the Transport Gasifier was modified to improve solids collection and recirculation by adding a loop seal underneath the primary cyclone, and lengthening the cyclone disengager barrel. In addition, PCD operating conditions were adjusted, iron aluminide filter material (in lieu of composites or monolithic silicon carbide) was selected for better compatibility with the synthesis gas and particulate matter, and the design of the filter holder was improved. These gasifier modifications lowered solids loading in the PCD and increased char retention in the reactor loop, resulting in a higher carbon monoxide (a synthesis gas constituent) to carbon dioxide ratio and higher carbon conversion. With gasifier and PCD changes, particulate matter collection problems also were overcome.

A second test run of 242 hours was conducted to evaluate effectiveness of the gasifier and PCD modifications, and further assess the Transport Gasifier system. This second equipment commissioning run was completed in March 2001. A Powder River Basin (PRB) coal blend with Bucyrus limestone from Ohio was used — a selection based on the initial test run which showed that PRB sub-bituminous coals produced the highest synthesis gas heating values due to its high reactivity. Gasifier and PCD operations were stable, but the coal feed system experienced problems with finely ground coals. Based on the experience of this run, several additional modifications were made to the system. To prevent tar formation during startup, a coke breeze feed system was installed that raises the gasifier temperature to 1,600 °F before starting coal feed.

Long-term testing for the purposes of data collection under steady-state conditions was initiated in July 2001. Gasifier and PCD operations, which continued until September 2001, were very stable with the longest period of continuous operation being more than 500 hours. Synthesis gas heating values, corrected for heat losses and dilution effects, were between

100 and 120 Btu per standard cubic foot, and cold gas conversion efficiencies, with the same corrections, were between 70 and 75 percent. Corrections were based on the assumption that a commercial Transport Gasifier will be larger and have less heat loss, and will not use nitrogen for coal conveying or the same volume of nitrogen for instrumentation purges. The Transport Gasifier consistently achieved carbon conversion rates of over 95 percent. Modifications are under way that will allow finer coal to be reliably fed, which will further improve carbon conversion and overall operations.

Iron aluminide filters were extensively tested during the long-term tests, with the longest exposure time (1,700 hours) being in the 700–900 °F temperature range. PCD performance was within design parameters of stable baseline and peak differential pressures. Char removal efficiencies were excellent, with outlet dust measurements consistently less than 1.0 part per million by weight. In preparation for oxygen-blown operation, tests were conducted that focused on modifications made to the transport gasifier. These tests were performed from December 2001 to April 2002. One successful 157 hour test has been completed on oxygen-blown gasification of PRB coal. Oxygen-blown operation can result in nitrogen-free syngas, which facilitates CO_2 capture and sequesteration. In addition, the smaller volume of gas without nitrogen leads to lower costs for gas cleanup. Both CO_2 capture and nearly 100 percent gas cleanup are important features in a future Vision 21 process in which coal would be used to produce electricity, fuels, or chemicals with virtually no emissions from the process.

COSTS

SCS developed a conceptual commercial plant design and cost estimate for an air-blown Transport Reactor-based integrated gasification (TRIG) combined-cycle power plant. The design features General Electric (GE) 7FA combustion turbines and PRB coal. The cost estimate is based on a typical greenfield site in the southeast United states. Cost estimates were developed using commercial power plant costing software, process plant costing software, vendor quotes, and historical SCS cost information. SCS presented the conceptual commercial plant design and cost estimate at the DOE Clean Coal and Power Conference in Washington, D.C. on November 19–20, 2001. The conceptual TRIG™ plant design is 298.4 MW (net) with a lower heating value (LHV) heat rate of 7,830 Btu/kWh (43.6 percent efficiency) at average annual ambient conditions. Projected sulfur dioxide (SO_2) emissions are 0.10 lb/10^6 Btu, and NO_x emissions are 0.07 lb/10^6 Btu. The estimated total plant cost for a first-of-a-kind greenfield plant is $1,290/kW (excluding the cost of capital during construction and startup costs). The total second plant cost for a 600-MW plant was projected to be $1,040/kW, and the LHV heat rate was projected to be 7,420 Btu/kWh (46.0 percent efficiency). All capital costs are given in January 2001 dollars.

FUTURE PLANS

Initial gasification tests concentrated on PRB sub-bituminous coals because their high reactivity and volatiles content enhance gasification. Future gasification tests are planned with bituminous coal to verify commercial suitability. Sulfur emissions are expected to be lower with bituminous coals, despite typically higher sulfur content.

DOE's National Energy Technology Laboratory (NETL), SCS, and other participants currently are planning the next five years of research at the PSDF. The main goals are to support DOE's Vision 21 program for developing oxygen-blown synthesis gas-based processes and to support commercialization of the air-blown TRIG™. A five-year renewal plan has been proposed for the PSDF, but has not yet been signed.

Major proposed activities for 2002 through 2006 include the following:

- Continue air-blown and oxygen-blown gasification development
- Integrate oxygen-blown gasifier with advanced air separation technology
- Integrate gasifier with existing combustion turbine at the PSDF
- Evaluate multi-contaminate (sulfur, mercury, acid gases, and alkalis) control systems
- Evaluate novel carbon dioxide and hydrogen separation systems
- Test advanced materials in gasifier and combustion turbine environments
- Evaluate high temperature gas and particle sensors
- Improve system integration and controls
- Improve gas cooling technology
- Improve coal and limestone feed systems and ash removal and cooling systems

The Transport Reactor has proven to be both an excellent test bed for advancing combustion and gasification system development as well as a promising technology platform for near-term commercialization as a gasifier. Future activities will leverage both aspects.

FE HOSTS SPECIALTY CONFERENCES

On May 14–16, 2002, the U.S. Department of Energy, National Energy Technology Laboratory (NETL) sponsored two "Specialty Conferences" focusing on reducing air pollution generated by electric power plants. The conferences, held sequentially in Pittsburgh, Pennsylvania, featured "Unburned Carbon (UBC) on Utility Fly Ash," followed by "Selective Catalytic Reduction (SCR) and Selective Non-Catalytic Reduction (SNCR) for NO_x Control." This year marked the eighth year for the UBC Conference and the sixth year for the SCR/SNCR Conference. As in past years, these events were very successful, bringing together a wide range of representatives from industry research institutions, and government. The UBC Conference drew 155 registrants, 371 registered for the SCR/SNCR Conference, and 82 attended both conferences. Combined, the conferences drew 60 international attendees, representing 14 countries.

NO_x reduction required to meet Title IV requirements of the Clean Air Act Amendments (CAAA) of 1990 is being achieved through widespread use of low-NO_x burners (LNBs). However, use of these burners results in the production of excess UBC, which is also referred to as loss-on-ignition (LOI). This high level of UBC reduces boiler efficiency and can render fly ash unsalable. The issue of UBC mitigation continues to be an issue addressed by the annual conferences. More stringent reductions in NO_x emissions, required by Title I of the CAAA, now are being met by the two major post-combustion technologies, SCR and SNCR, which are the primary focus of the ongoing SCR/SNCR Conference. Many power plants use or are planning to use post-combustion controls in conjunction with LNBs.

Henry (Hank) Courtright, Vice-President, Power Generation and Distributed Resources for EPRI, opened the UBC Conference with his keynote address, "Achieving the Difficult Challenges." He discussed five basic issues facing the electric power generating industry: enhancing the basic power infrastructure; building a robust generation portfolio; capturing and utilizing or sequestering carbon dioxide; improving the customer-managed service network; and developing a global energy strategy. Courtright drew attention to the fact that the significance of new approaches is often underestimated, and he encouraged the audience to carefully consider new technologies and new options.

The UBC Conference also included 13 oral presentations and 10 poster presentations addressing experiences and observations, predictive performance tools, measurement techniques for UBC, and new uses for high-carbon fly ash. After the keynote address, a review of the seven previous UBC Conferences (1995-2001) was presented. Of 103 technical presentations given, 12 cited laboratory, pilot plant or commercial operating values of UBC on fly ash before and after application of a variety of combustion modification technologies. While site specific, these results indicate that, on average, reduction in UBC levels of approximately 50 percent (for a reduction from 8.8 to 4.1 percent) can be achieved by combustion modification.

Other highlights of the UBC Conference included the results of studies of multi-pollutant controls at coal-fired power plants through process modeling; an analysis of carbon burnout for specific coals through computational fluid dynamics (CFD); use of high-LOI fly ash (>20% UBC) to replace shale in cement manufacture to increase clinker (raw cement) production and reduce fuel consumption; use of CFD to study detailed

Hank Courtright of EPRI opened the UBC conference with a keynote address

Speaker fields questions from a lively audience

Brian Schimmoller, managing editor of Power Engineering magazine, delivers keynote speech at the SCR/SNCR conference

mechanisms of coal combustion; and the effects of high-LOI fly ash on electrostatic precipitators. A commercial carbon burnout process is producing 18,000 tons of salable fly ash per month while recovering heating value of the UBC equivalent to 1.5 tons of coal per hour. Power plant application of a combination of high velocity overfire air and SNCR has reduced NO_x by 45 percent while having minimal effect on carbon monoxide and LOI. It was also shown that high-LOI fly ash performs well as a binder for iron ore pelletization, steel mill desulfurization slag, and foundry molds.

Brian Schimmoller, managing editor of *Power Engineering* magazine, set the tone for the SCR/SNCR Conference with his keynote presentation, "After the Bubble: Life in a Post 9/11 World." He discussed uncertainties in the economy, electricity generation and supply, financial, environmental, and energy policy. There is now a synchronous, interconnected global economy. Following the introduction of examples of each component of these global issues, Schimmoller concluded with a plea to develop multiple technologies and multiple generation resources.

The SCR/SNCR Conference included 40 oral presentations and 17 poster presentations, addressing emissions regulations, economics of NO_x emissions reduction, emissions trading, risk issues in commercial applications of NO_x reduction technologies, non-coal applications, commercial implementation of SCR and SNCR processes, and chemical reagent considerations. Also discussed were alternative NO_x control technologies, including selective autocatalytic reduction, integration of coal gasification and reburning, and oxygen enhanced combustion for NO_x control.

A large audience fills the conference room

Tom Ruppel of Parsons Corporation presents a review of the UBC conferences since their inception

Of great interest to power generators is the potential of multi-pollutant emission controls, including not only NO_x and sulfur dioxide (SO_2), but also mercury and carbon dioxide. One speaker outlined the current status of this issue, including regulations proposed by several New England states, and others being considered at the federal level. It was noted that in the midst of the ongoing controversial debate, an integrated approach is needed to help generating companies plan for the future. There also were three presentations on the dynamics of existing NO_x trading markets, another major factor in industry's response to current and future regulations.

Several power generating companies reported successful operation of SCR and SNCR units, including meeting performance targets for at least one year's service. These reports

Tom Sarkus, Chair of both conferences, gives opening remarks

emphasized that special attention to design details is required to insure proper mixing of chemical reagents with the flue gas. Of particular concern is maintaining the correct balance of reagent to NO_x in the flue gas to minimize formation of ammonium bisulfate, a sticky substance that can plug downstream heat exchangers. It has also been found that traces of sulfur trioxide, formed by oxidation of SO_2 in the flue gas, can lead to visible plumes from the stacks. In some cases, this problem is alleviated by injection of magnesium oxide into the flue gas. Several speakers reported that certain components in coal feeds, especially calcium, arsenic and mercury, have significant effects on SCR catalyst performance, requiring careful testing and selection of catalysts for particular coals. A number of companies have developed sophisticated strategies for catalyst regeneration and replacement to minimize overall operating costs.

With increasingly stringent NO_x reductions being implemented on an industry-wide basis, these specialty conferences are expected to continue to be popular. Conference proceedings are available on NETL's web site (http://www.netl.doe.gov) under Events.

CLEAN COAL FORUM

A Capitol Hill workshop entitled *Clean Coal Technology Forum: Roadmap to the Future* was held on May 20, 2002, to provide up-to-the-minute information regarding congressional and U.S. Department of Energy (DOE) support of the Federal clean coal programs. The workshop coincided with the release of the Coal Utilization Research Council's (CURC) Clean Coal Technology Roadmap. The roadmap provides a basis for discussion of coal-fired power generation research and development needs — both technological and financial.

Along with CURC, the workshop was co-hosted by some of the coal and power industry's strongest voices including the Electric Power Research Institute, National Rural Electric Cooperative Association, American Public Power Association, Edison Electric Institute, United Mine Workers of America, and the National Mining Association. Attendance was near 150 with representatives from the rail, mining and electric power industries, state and Federal government, academia, and research institutions.

Enthusiasm for the future of clean coal technology was evident in all of the speakers' presentations, including those of Senator Byron Dorgan (D-ND) and John McCutcheon, Senior Policy Advisor for DOE's Office of Fossil Energy. A highlight of the Workshop was the keynote address given by Senator Robert Byrd (D-WV), who has drawn national attention toward the use of clean coal technology over the past five decades.

Senator Byrd has spent nearly a half century advocating the use of coal, calling attention to its vital importance to the nation's economy and security. The Clean Coal Technology Demonstration Program that Senator Byrd helped launch in 1985 has earned the reputation as one of the most successful government/industry R&D partnerships ever implemented. Senator Byrd remarked that the comprehensive national energy package that recently passed through the Senate includes a number of difficult provisions and produced some contentious debate. "But coal — the area where I focused the lion's share of my efforts — was one issue on which the Senate was strongly in agreement from the beginning," said Byrd.

Both the House and Senate versions of the energy legislation contain the $2 billion, 10-year clean coal technology demonstration program (the Clean Coal Power Initiative), and both versions call for significant clean coal tax incentives. Having passed through the House and Senate, the energy legislation will be handled by a conference committee to resolve differences between the two versions. Senate and House members are considering making the conference open to the public and allowing it to be televised on C-SPAN.

While a pledge of monies and incentives for clean coal technology is critical to provide industry with targeted assistance, the way in which it is appropriated may compromise the program's success, according to workshop attendees. Staff of the Department of Interior Appropriations Subcommittee, where funding for these programs is controlled, attended the workshop to discuss the realities of the appropriations cycle and its impact on the clean coal R&D programs. The need to secure advance appropriations for DOE's Clean Coal Power Initiative was cited as a critical step. Yet, CURC and other industry representatives noted that the Administration and Congress do not currently support advance appropriations of clean coal dollars, as they had done in the past for the Clean Coal Technology Demonstration Program.

Industry representatives consistently cite the uncertainty surrounding the availability of future demonstration funds as a central reason for industry's reluctance to put forward ambitious demonstration projects representing a federal/private partnership. Accordingly, the workshop provided the perfect environment to educate industry about the complexities surrounding Federal funding of clean coal technology. While the government's long-term commitment to coal-based technology development must be assured and funding of programs should be substantial, industry must also do its part in educating and advocating coal-based technology — keeping coal in the national energy spotlight.

COALBED METHANE — ENHANCING PRODUCTION AND SEQUESTERING CO_2

While methane (CH_4) from coal mines (CBM) has long been considered a viable energy source, recent U.S. Department of Energy (DOE) efforts that couple methane recovery technology with CO_2 sequestration provide a new twist. While site specifics vary, unmineable, gassy coal beds can often store CO_2 indefinitely. Economics can be favorable when a CO_2 source is located near a coal-powered plant, and the extracted methane can be returned to the CO_2 source plant for either co-firing or reburning. Since 90 percent of estimated U.S. coal resources are unminable — due to extreme depth, insufficient quantity, or high sulfur and ash content. These coal depostis represent a potentially large CO_2 repository and CBM resource base.

The methane/CO_2 combination is efficient as a sequestration method, due to a 2:1 coal-sorption "selectivity" for CO_2 over methane. In the application of this concept, the CO_2 is captured from powerplant flue gas, pressurized, and transported to an injection site. There, it is injected into deep reservoir rocks capped by low-permeability seals such as shales or claystones. The CO_2 displaces CH_4 from the coal surface, where two molecules of CO_2 are trapped for every molecule of CH_4 released. High CBM production efficiencies can help recover costs of separating CO_2 from flue gas (a range of $27/ton to $65/ton of CO_2 avoided) and the associated costs of the pipeline infrastructure. Additionally, the sequestered CO_2 does not escape as it can in industrial recycling for enhanced oil recovery operations.

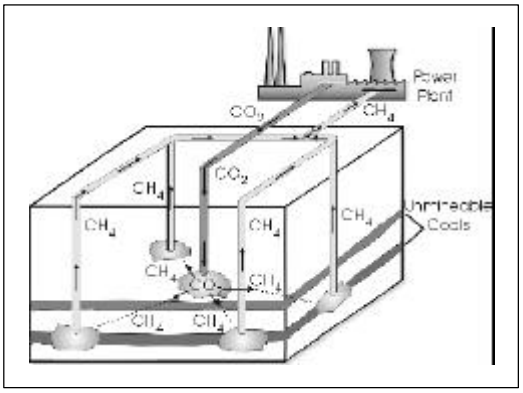
Significant exploration for and production of coalbed gas in the United States began in the mid-1980s mainly due to Federal tax credits given for the production of coalbed gas. In the United States, more than one trillion cubic feet of coalbed methane is now being produced and meets about seven percent of the total natural gas demand. In enhanced coalbed methane recovery, industry mostly uses nitrogen instead of CO_2 as a sweep gas for economic reasons — among them, being that nitrogen can be recycled.

The DOE began extensive coalbed methane research, development, and demonstration efforts in 1977. Today's coalbed methane R&D is part of the geological carbon sequestration R&D program which investigates long term CO_2 storage in such formations as depleted oil reservoirs or saline formations (see article on brine data base). The DOE Office of Fossil Energy and Office of Science have released a roadmapping report entitled *Carbon Sequestration — Research and Development*, which identifies key R&D areas. The goals of the DOE sequestration program are to provide economically competitive and environmentally safe options to offset all projected growth in baseline emissions of greenhouse gases by the United States after 2010. The long-term cost goal for this effort is to reduce the cost to $10/ton of carbon avoided (net costs).

FIELD TESTING WITH INDUSTRY

Field tests coupling sequestration with methane extraction are taking place in areas where methane is already produced, as well as new areas where production could be economic if coupled with CO_2 sequestration.

The DOE is providing 25 percent of the costs of a project with industrial partners Advanced Resources International, B-P America, and Shell, in the San Juan Basin, New Mexico. The project integrates research- and commercial-scale field demonstration. Field data collected during this project will help validate results of reservoir modeling efforts. These data should lead to a better understanding of the mechanisms and dynamics of coal, gas, and water in reservoirs. Most importantly, the project will assess the technical and economic recovery of enhanced quantities of coalbed methane, using CO_2 as the sweep gas. The data will help determine the sorptive behavior of CO_2 on various coal types. The results of this effort are expected to be applicable to coalbeds in other basins.



CH_4 production/CO_2 storage concept

In another effort, DOE, the Geological Survey Office of Alabama, and industry are focusing on the sequestration potential of Alabama's Warrior Coal Basin "fairway." One goal is to develop a broad based geological screening model that is transferable to highly industrialized coal basins in North America, Europe, and Asia. The screening model looks at geologic variables such as stratigraphic architecture, structural geometry, permeability, and hydro

See "CBM" on page 8 ...

...CBM continued

geology, as well as coal quality, gas content, and sorption capacity. Proximity to power plants, pipeline systems, and other infrastructure are also part of the model. This model would be able to identify sites of high CO_2 storage potential. In the Warrior Basin, two large coal-fired plants emitting 31 megatons of CO_2 annually operate adjacent to a thriving coalbed methane industry.

CO_2 sequestration can prolong the life of more than 3,000 wells in Alabama, including one shown above, and increase CBM reserves

The DOE and its partners also are focusing on increasing the methane recovery rate of marginally economic Appalachian coal beds. There are approximately 115 coal beds in West Virginia alone, and only 10–15 percent of them are classified as mineable. These potential sources of methane are near eastern markets and could make use of the existing pipeline infrastructure to deliver the CBM. Many of the unmineable deposits are close to existing coal-fired powerplants and could be potential reservoirs for CO_2 in addition to providing methane for co-firing at those facilities.

Industry acceptance of these applied and evolving technological efforts may require pilot testing and demonstrations of many phases of energy production/utilization. More applied scientific R&D for system characterization will be necessary. DOE's coalbed methane program with industry is an opportunity to instill further confidence in these evolving technologies that have worldwide application.

CLEAR SKIES INITIATIVE

The Clear Skies Initiative, announced by the President on February 14, 2002, represents a market-based, multi-pollutant approach to reduce emissions of SO_2, NO_x, and mercury further, faster, and cheaper than the current "piecemeal" approach. According to President George W. Bush's remarks delivered at the National Oceanic and Atmospheric Administration (NOAA), the initiative "...will harness the power of markets, the creativity of entrepreneurs, and draw upon the best scientific research." Some elements of Clear Skies will require legislation, while others can be implemented through the regulatory process. Also at NOAA, the President announced a new approach on global climate change, designed to cut greenhouse gas intensity 18 percent over the next 10 years, while supporting vital climate change research.

The Clear Skies Initiative is modeled on the 1990 Clean Air Act (CAA) Acid Rain program's cap and trade system of permits and allowances, which is credited with reducing more pollution than all other "command and control" CAA programs combined, and at two-thirds of the cost. Utilities will have to reduce emissions by a set deadline, without a prescribed method. This is expected to save $1 billion in costs, while encouraging newer and cleaner innovative pollution control technologies. Fuel diversity is another expected outcome and, according to U.S. Environmental Protection Agency (EPA) projections, would make coal a larger part of the future fuel mix than would otherwise be the case.

Under the system, allowances good for one ton of pollutant emitted could be bought and sold. The program would apply to both old and new sources. According to EPA, SO_2 trading would be built upon the current Title IV Clean Air Act structure. Furthermore, NO_x trading would expand the current seasonal program in the northeast to a national program annual program with two (geographic) trading zones. The mercury trading program would be entirely new.

Clear Skies goals are: 73 percent cut in SO_2 emissions, from current emissions of 11 million tons/year to a cap of 4.5 million tons in 2010, and 3 million tons in 2018; and a 67 percent cut in NO_x emissions, from current emissions of 5 million tons to a cap of 2.1 million in 2008, and 1.7 million in 2018. Mercury would be capped for the first time, reducing emissions from 48 tons/year to a cap of 26 tons in 2010, and 15 tons in 2018. For details seehttp://www.whitehouse.gov or http://www.epa.gov/clearskies

NETL CONFERENCE ON PM 2.5 AND ELECTRIC POWER

In anticipation of regulatory actions by the U.S. Environmental Protection Agency (EPA), the U.S. Department of Energy's National Energy Technology Laboratory (NETL), hosted a conference on April 9–10, 2002, in Pittsburgh, Pennsylvania entitled *PM2.5 and Electric Power Generation: Recent Findings and Implications*. A major goal of the conference was to highlight remaining scientific questions and discuss policy options relating to regulation of PM2.5. The conference was attended by almost 200 technical, regulatory, and managerial personnel in the utility air pollution control area.

Two key documents are being prepared by EPA to provide a basis for determining whether to maintain or revise the National Ambient Air Quality Standards (NAAQS) for PM2.5. Both documents are scheduled for public comment. The "criteria document," recently released in third draft, will summarize the most recent science on health and welfare effects. The "staff paper" will address policy options in light of the science, and is expected to be issued later this year. EPA is scheduled to designate areas of the United States as being in attainment or nonattainment with the PM2.5 NAAQS in the 2004–2005 timeframe. State Implementation Plans for attaining the PM2.5 NAAQS and for complying with the 1999 Regional Haze rule are scheduled for completion in 2007–2008. Because very small particles in the atmosphere act to either absorb or scatter light, and thus impair visibility, the regulatory debate has closely connected the PM2.5 and regional haze issues.

The conference keynote session highlighted the remaining scientific questions surrounding PM2.5 and discussed how policy options may be implemented through the legislative/regulatory framework. The four plenary session speakers are at the forefront of current effort to integrate PM2.5 science and policy. James Vickery of EPA provided an overview of the NARSTO PM Assessment, a two-year effort to produce a document that describes the "state of the science" for use by policy makers and their advisors. In addition, EPA representatives at the conference indicated that NAAQS for PM2.5 will probably continue to be based on massconcentrations.

Ronald Wyzga of the Electric Power Research Institute described the results of a recent study examining the effects of PM2.5 and co-pollutants on health in Atlanta, Georgia. This study showed that whenever PM2.5 is associated with adverse health effects, some form of carbon is also implicated, whereas sulfates and nitrates (the components of PM2.5 most closely associated with power plants) were not significantly associated with adverse health effects. John Bachmann of EPA described the status and likely course of implementation for PM2.5 standards, and the potential role of the Bush Administration's new Clear Skies Initiative to provide a new regulatory baseline for power generation (see page 8). Bachman claimed that the multi-pollutant approach embodied in the Clear Skies Initiative can result in lower overall costs to industry and consumers, and can provide faster protection to human health and ecosystems than under the current Clean Air Act requirements. EPA studies suggest that implementation of the Clear Skies Initiative will result in greater nationwide attainment of the PM2.5 NAAQS and/or reduced residual non-attainment costs for local areas.

Lucinda Langworthy of Hunton & Williams, representing the Utility Air Regulatory Group, provided an overview of the electric utilities' perspective on the regulations and the current scientific uncertainties surrounding PM2.5. She noted concerns over inconsistent study results in the EPA's draft criteria document (in circulation at the time of her talk), as well as the need to better define toxicity of different particle types. The role of co-pollutants (gases) in influencing particle effects was another uncertainty cited.

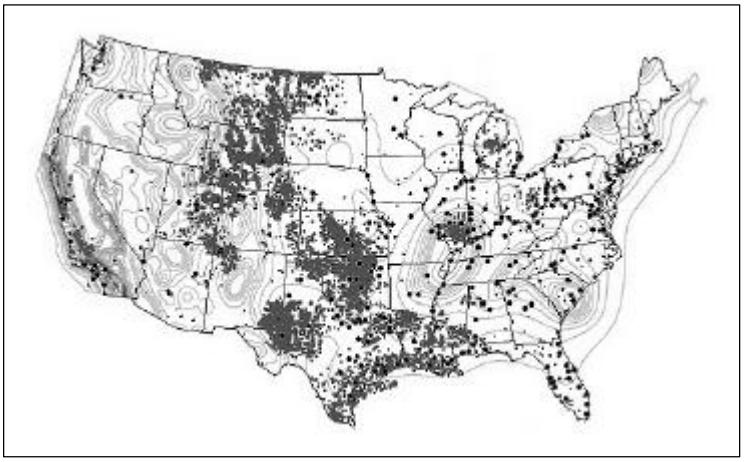
Lucinda Langworthy of Hunton & Williams, representing UARG

In the conference technical sessions, over 40 oral presentations and 15 posters examined the relationship between power plant emissions and the concentrations and composition of ambient fine particles. Technical session topics included analysis of ambient monitoring data, emissions characterization, atmospheric chemistry, and air quality modeling. Research findings presented at the conference gave important insights on the relationship between power plant emissions and PM2.5 chemical composition and concentrations. Copies and summaries of the presentations are available on the conference web site (http://www.netl.doe.gov/publications/proceedings/02/PM25/).

BRINE AQUIFERS FOR CO_2 SEQUESTRATION

Geological disposal of CO_2 can involve injection into deep underground formations such as coal seams, oil and gas fields, large voids and cavities, or into deep saline aquifers. Disposal of CO_2 in brine aquifers appears to be an appealing option for sequestration. According to the U.S. Geological Survey (USGS), some two-thirds of the contiguous 48 states are underlaid by brine aquifers. Brine aquifers contain high concentrations of Group I and II metals and metal carbonate rocks, such as $CaCO_3$ and $MgCO_3$, which are among the few proven long-term storage sites for CO_2. However, chemical characteristics of deep brines vary considerably both laterally and stratigraphically. As a consequence, detailed characterization of each brine field is necessary if they are going to have potential as sites for CO_2 sequestration.

The U.S. Department of Energy's National Energy Technology Laboratory (NETL) is developing a brine database which includes temperature, depth, pressure and a variety of chemical variables (pH, sodium, iron, chloride, bicarbonate, calcium, magnesium, sulfate, and total dissolved solids) on some 64,000 brines taken from promising locations in the contiguous United States. Sources of these data include those provided by the USGS, searches of the geoscience literature, State Geological Surveys and oil and gas producing companies. Additionally, NETL has instituted a limited field program of brine collection throughout the United States. This brine sampling is being done in conjunction with other government agencies and oil and gas companies.



A map of the Unites States has also been constructed using ArcView which includes the geographic location of more than 64,000 brine wells, the location of fossil fuel-fired electric power generating stations (100 megawatt capacity and larger), and past seismic activity and/or potential. An example of a map constructed using the information currently in the database is shown in the map (above right). The black dots on the map indicate the location of the fossil fuel-fired power plants. The shaded areas show locations with high concentrations of brine wells, while the contour lines indicate seismic potential. Such maps display the possible locations where sequestration of CO_2 in brines may be most appropriate by indicating the relative position of the various sources and sinks. Information concerning the chemical nature of brines, which also will be part of the database, provides insight into the possible chemical and mineralogical changes that may occur as a result of pumping large volumes of CO_2 into brines. The brines vary greatly from one field to another and even within the same field. Seismic potential is particularly important because it affects stability of the storage site. The programs, database tabulation, and field collection of brines allow NETL to perform statistical evaluation of the tabulated brine database on a formational and basinal level, and provide brine samples for experimental study of CO_2 sequestration within the laboratory. Statistical methods that have been used to test relationships between the tabulated brine variables on basinal and formational levels include a variety of parametric and non-parametric tests. Carbonation of naturally occurring acidic brines has shown that it is necessary to increase the alkalinity of the brines before carbonate precipitation occurs.

The brine database will be available in a format that can be used as input for a variety of other computer programs. Statistical evaluations of much of the database have been completed. These data evaluations can provide a framework for future direction of CO_2 sequestration within brine environments. In addition, the NETL brine carbonation test facility, a lab apparatus to react CO_2 with brine, can be used to test different brines under various conditions.

CLEAN COAL TODAY

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

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INTERNATIONAL INITIATIVES

FE AND PARTNERS EXPLORE OPPORTUNITIES FOR CCTS IN THAILAND

The Eco-Industrial group in front of the CoCo3 facility, a Thai cogeneration company

The U.S. Department of Energy (DOE) Office of Fossil Energy (FE), in cooperation with the Southern States Energy Board and the US-Asia Environmental Partnership, is working with the Industrial Estates Authority of Thailand (IEAT) to include the unique environmental capabilities of American clean coal technologies (CCTs) in the IEAT "Eco-Industrial" program. The IEAT operates 29 industrial estate complexes and five of these are involved in the IEAT pilot Eco-Industrial program. The complexes, which house a variety of tenant industries, are envisioned as a somewhat "closed loop" system, with wastes from one process used as input to another process. Some of these wastes, generated from refining and petrochemical operations, can be used a supplemental fuel in CCTs, eliminating environmental liabilities associated with these materials. Co-firing some of these wastes with coal is clearly advantageous, and could provide a market for CCTs as well as other environmental goods and services. Thailand has expressed interest in maintaining fuel diversity through coal use, and the use of CCTs can assist in this arena while creating unique opportunities in the IEAT Eco-Industrial program.

There are several areas where U.S. practice can be adapted to the Thai situation. In the United States, both circulating fluidized-bed (CFB) and integrated gasification combined-cycle (IGCC) technologies have provided a low-cost method of recovering environmentally benign energy from refinery wastes. One particular opportunity could be offered by co-firing refinery waste gases with coal in a CFB combustor. Refinery waste gases typically are flared, which results in both significant emissions and lost energy value. In the United States, fluidized-bed combustion systems have been installed to use refinery waste gases, recovering their energy while reducing emissions associated with this recovery. In addition to waste gases, the CFB process is capable of using several other refinery by-products, including petroleum coke. Additionally, the IGCC process can co-fire refinery wastes, including some that would be subject to land disposal restrictions (i.e., classified as hazardous) in the United States.

The Map Ta Phut refinery and petrochemical complex in Thailand is designated for "eco" conversion, and produces a variety of by-products that might be candidates for CCT co-firing. Also at the Map Ta Phut site, construction of 1,400 MW of coal-fired power capacity is currently stalled due to the new regulatory emphasis on environmental concerns. FE has visited the Map Ta Phut complex as well as other sites to explore CCT opportunities, and has met with engineering and environmental specialists in the tenant industries.

While coal-fired power plants using older technologies are subject to significant environmental opposition (and are difficult to permit), CFB technologies purchased from American vendors have been installed at the Thai industrial complexes. The 300-MW CoCo3 plant at Map Ta Phut is fired by coal and gas, and includes two coal-fired CFB boilers. A paper complex in Tha Toom also has two coal-fired CFBs.

MEETING OF COAL ADVISORY GROUP IN KOLKATA, INDIA

The first Meeting of Coal Advisory Group (CAG), established under the Indo-US Bilateral Energy Consultations, was held in Kolkata, India, April 2–5, 2002. The Advisory Group wasestablished to serve as a forum for identifying and carrying out collaborative projects of mutual benefit in the coal sector. India has vast reserves of high-ash coal and seeks foreign R&D as well as foreign investment to promote cleaner use of coal.

The open round table discussion brought together 45 experts including representatives from India's Ministry of Coal, Ministry of Power, National Thermal Power Corporation, the Confederation of Indian Industries, Bharat Heavy Electric, Ltd, as well as other corporate and government participants. The U.S. delegation was represented by industrial associations, government and academia who were selected to address issues earlier identified by the Indian side as being of near-term importance. These areas of interest included coal washing and cleaning, fly ash utilization and disposal, coal mining and associated environmental issues, and ways to facilitate investment decisions by the private sector.

In order to give the U.S. team a realistic view of the Indian coal chain and related, real-life problems, the meeting included site visits to the Singrauli and Piparwar coal regions to look at an opencast mine, a coal beneficiation plant, and a thermal power plant with an associated fly ash disposal system.

As one meeting outcome, the U.S. Department of Energy, Office of Fossil Energy agreed to provide a model business plan for developing a coal washery project using inputs from their Indian counterparts. This would be an example of a "bankable" document to support "build-own-operate" decisions, and attract financing.

Meeting participants were interested in storage of fly ash in mines (both surface and underground) and utilization of mine and washery wastes. The group agreed to continue discussions of available technology for large-volume storage of fly ash, looking at areas for potential cooperation. Preparations will also be made for a study tour of U.S. facilities that use mine and washery wastes in CFB combustion both to produce power and to alleviate environmental problems.

A second CAG meeting has tentatively been scheduled in the United States in about six months, at which time the issues of coal combustion efficiency and emissions reduction will be the principal focus of the agenda.

IEA GROUP DRAFTS FOSSIL FUELS ZERO EMISSIONS STRATEGY

The IEA Working Party on Fossil Fuels' technology status report

The International Energy Agency (IEA) Working Party on Fossil Fuels (WPFF) met in Paris on May 6–7, 2002, under the leadership of the newly elected Chair, Barbara McKee, Director of the U.S. Department of Energy (DOE), Office of Fossil Energy (FE), Coal and Power Import and Export. A major objective of the WPFF is to implement a new strategic plan — *Vision for the 21st Century: Zero Emissions Technologies for Energy Security, Environmental Protection, and Economic Development*, which was designed to raise the profile of this important R&D area.

FE has been an active member of WPFF since it was founded in 1974, chaired from 1995 to 1997 by a former FE Assistant Secretary. The WPFF advises the IEA Committee on Energy Research and Technology on technology issues, trends, and R&D programs in fossil fuels and electricity system issues, and has grown to amembership of 25 industrialized countries. The WPFF administers seven implementing agreements, which facilitate cooperation among IEA members in specific fossil energy RD&D areas.

The zero emissions strategy was developed in response to a recommendation of the Conference on Zero Emissions Technologies for Power Generation that took place in New Orleans in October 2001, and which was sponsored by WPFF, DOE, and the U.K. Department of Trade and Industry. That conference saw as a critical global task, the development of zero emission technologies such as FE's Vision 21 concept. Vision 21 would provide the technology basis for integrated ultra-clean plants for producing electricity and opportunity products including

clean transportation fuels, high-value chemicals, syngas, and hydrogen. The conference also led to selection of the WPFF as the effective conduit for Vision 21 into the international market. Speakers indicated that "out of the box" thinking could bring about zero emissions technologies over the next two decades. Zero emissions technologies, which apply to all fossil fuels, could range from industrial clusters that strive to use outputs from one system as inputs to other systems (see related article on Thailand eco industrial parks) to such advanced clean coal processes as integrated gasification combined-cycle and hybrids, and enhanced oil recovery using CO_2 from energy conversion processes. The WPFF completed a *Technology Status Report* on zero emissions technologies in May 2002.

The strategic plan emphasizes the stake that countries throughout the world have in advanced technologies, and lays out a concrete basis for working together. The WPFF zero emissions strategy focuses on four elements: communications, collaboration in development and deployment, cooperation to improve existing power plants, and energy safety/security. Communication of the zero emissions opportunity is seen as a vital component of the strategic plan. Given the increasing energy use and emissions in developing countries, the strategy also incorporates cooperation with non-member nations such as China and India that have an extensive base of low performing fossil fuel plants. A conference is planned for 2003 in the Asia Pacific region to focus on economic development and environmental protection. A roundtable on energy safety and security is also envisioned.

UPCOMING EVENTS

— September 9–12, 2002 —
Air Quality III: Mercury, Trace Elements and Particulate Matter Conference
Sponsor: Energy & Environmental Research Center, University of North Dakota with DOE, EPRI, and others
Location: Arlington, VA
Contact: for online registration http://www.undeerc.org

— September 17–20, 2002 —
5th International Symposium on Gas Cleaning at High Temperature
Sponsor: NETL
Location: Morgantown, WV
Contact: Kimberly Yavorsky
Phone: (412) 386-6044
E-mail: kimberly.yavorsky@netl.doe.gov

— September 23–27, 2002 —
19th Annual International Pittsburgh Coal Conference
Sponsor: University of Pittsburgh, with participation of DOE among others
Location: Pittsburgh, PA
Contact: University of Pittsburgh
Phone: (412) 624-7440
E-mail: pcc@engrng.pitt.edu

— October 21–23, 2002 —
International Conference on Clean Coal Technologies for Our Future
Sponsor: U.S. DOE, Assessorato all'Industria Regione Autonoma della Sardegna, and Enel Produzione
Location: Sardinia, Italy
Contact: Conference Secretariat
Phone: +39 070 499242-43
Website: www.iea-coal.org.uk/cct2002

— November 18–21, 2002 —
I2002 Fuel Cell Seminar
Sponsor:NETL
Location: Palm Springs, CA
Contact: Kimberly Yavorsky
Phone: (412) 386-6044
E-mail: kimberly.yavorsky@netl.doe.gov

..."News Bytes" continued

In May 2002, **JEA** Unit 2, the world's largest circulating fluidized-bed boiler, performed at full load (300 MWe). Unit 2 has fired 26 tons of coal during startup and checkout activities since February. A two-year series of demonstration tests are planned to begin in August using coal and fuel blends (coal/petroleum coke).

Aerial views of JEA plant

STATUS OF ACTIVE CCT DEMONSTRATION PROJECTS

ENVIRONMENTAL CONTROL DEVICES

Southern Company, Inc. –*Demonstration of Advanced Combustion Techniques for a Wall-Fired Boiler*. All testing on the original project has been completed and reported. Phase 4 has been extended until December 31, 2002, 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.* Construction of Unit 2 at the Northside Station was completed in December 2001. Overall startup completion for the DOE project was at 86 percent at the end of June 2002. Commercial operations are planned for August 2002 followed by a two-year demonstration period, testing coal-fuel blends. (Jacksonville, FL)

Kentucky Pioneer Energy, L.L.C. – *Kentucky Pioneer Energy Project.* The Draft Environmental Impact Statement (EIS) was issued in early November 2001 and the public meetings were held in December 2001. The public comment period ended January 25, 2002. The final EIS is in preparation and scheduled to be issued before the end of the summer of 2002. (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. DOE is preparing a post-project assessment report. (Reno, NV)

Tampa Electric Co. – *Tampa Electric Integrated Gasification Combined-Cycle Project.* Tampa's Polk Power Station completed its operational period at the end of October 2001 with over four and one-half years of successful commercial operation. The final report is in preparation and review, and should be released in late summer 2002. (Polk County, FL)

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*. Due to Author D. Little's reorganization, testing on the hardened engine parts has been delayed. However, problems associated with oil leakage and cooling cycle of the large diesel at University of Alaska Fairbanks has been solved. Hardened engine component testing should resume by early fall 2002. (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. The Final Report for the project is due in December 2002. (Colstrip, MT)

Air Products Liquid Phase Conversion Company, L.P. - *Liquid Phase Methanol Process Demonstration Project*. The Liquid Phase Methanol (LPMEOH™) Process Demonstration Facility continues to experience stable operation on coal-derived synthesis gas. An assessment of the performance of the methanol synthesis catalyst activated *in-situ* in August 2001 found that storage of the fresh catalyst in the presence of mineral oil at elevated temperatures prior to reduction was the cause of the lower than expected initial catalyst activity. Based on the results of this assessment, the *in-situ* activation procedure was modified so that the fresh methanol catalyst would not be exposed to temperatures that exceed 100°C prior to activation with a mixture of dilute synthesis gas in nitrogen. A second *in-situ* activation of methanol synthesis catalyst was successfully completed in late June 2002. A preliminary synthesis gas uptake of 98 percent of the theoretical value was attained, indicating that the methanol synthesis catalyst was properly activated during the in-situ activation procedure. Demonstration operations in a temperature-programming mode are currently underway. Since startup in April 1997, the demonstration facility has operated at an availability approaching 98 percent, and has produced more than 94 million gallons of methanol, all of which was accepted by Eastman Chemical Company for use in downstream chemical processes. Monitoring all potential catalyst poisons, and methods for their removal and control, continues to be important. (Kingsport, TN)

Industrial Applications

CPICOR Management Company, L.L.C. – *Clean Power From Integrated Coal/Ore Reduction.* DOE has continued its work toward completing an Environmental Impact Statement for this project, a draft of which is expected later in 2002. 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. (Vineyard, UT)

ThermoChem, Inc. –*Pulse Combustor Design Qualification Test.* The Final Report has been submitted and accepted by DOE. The preparation of the Post Project Assessment is now underway and the Cooperative Agreement is in the close-out process. (Baltimore, MD)

U.S. Department of Energy
19901 Germantown Road
Germantown, MD 20874

FE-24

Printed with soy ink
on recycled paper