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CLEAN COAL TODAY

A NEWSLETTER ABOUT INNOVATIVE TECHNOLOGIES FOR COAL UTILIZATION

NEWS BYTES

In February 2002, JEA Unit 2, the world's largest circulating fluidized-bed boiler, was fired exclusively with coal. The unit is a 300-MWe circulating fluidized-bed boiler designed and constructed by Foster Wheeler as part of a Clean Coal Technology demonstration project located in Jacksonville, Florida. Proceeding through several months of startup, the unit has been fired with natural gas since early December 2001. Unit 2 is scheduled to be fully operational this August, after which a 2-year series of tests will demonstrate commercial operation with both single fuel (coal) and fuel blends (coal/pet coke).

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DOE ISSUED SOLICITATION FOR CLEAN COAL POWER INITIATIVE

The final solicitation for bids under the Clean Coal Power Initiative (CCPI) was issued March 4, 2002, following a public input process that included several public meetings held over a six-month period. The $330 million allocated for this Round I solicitation is part of the 10-year, $2 billion effort in clean coal technology development and demonstration pledged by President George W. Bush and recommended in his National Energy Policy.

NETL Director, Rita Bajura, speaking at the September 28, 2001, CCPI Workshop in Pittsburgh, Pennsylvania

Congress provided the initial installment of CCPI funding by including $150 million for the CCPI in its FY 2002 appropriations. Congress directed the DOE to seek "demonstrations of commercial scale technology to reduce the barriers to continued and expanded coal use" and to "demonstrate technologies that can strengthen electricity reliability...in an environmentally acceptable manner." According to the solicitation just issued, technologies selected must be applicable to a significant portion of the coal-fired generation industry. Projects that mix coal with other fuels are acceptable if coal represents at least 75 percent of the energy input. Technologies also must not have previously been proven in commercial settings or broadly used. Projects must offer environmental, efficiency, and economic improvements over current state-of-the-art. Selected projects might include advanced IGCC and supercritical steam systems, and innovative concepts for reduction in smog, NO_x, SO_2, $PM_{2.5}$, mercury, as well as CO_2 reduction/management. All projects should show potential to move rapidly into the marketplace following demonstration.

In order to gather stakeholder views for the CCPI solicitation, DOE held public meetings on September 28 and November 20, 2001. The draft solicitation was issued December 20, 2001, and a final public meeting was held January 17, 2002. Additionally, over 100 written comments were received.

A number of stakeholder concerns were addressed in the text of the final solicitation. The $330 million federal share would make possible both large

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and small demonstrations. Plans for repayment of the DOE cost share also have become more flexible. Instead of following a DOE-prescribed repayment method, proposers are now free to develop their own plan that will be scored by DOE as part of the evaluation process. Also as part of the evaluation process, DOE has increased the importance of the ability of demonstration projects to make an impact on the coal power generation market and achieve commercialization. In order to allow sufficient time to resolve project team/host site, financial, and National Environmental Policy Act-related issues, a new ìProject Definitionî phase has been added to project activity. DOE also plans to enlist the support of outside experts to help ensure that the advanced technology demonstrations selected will be technically superior and commercially viable.

The final CCPI solicitation provides 150 days for proposal preparation time ó bids are due August 1, 2002. Project selection is expected in January 2003. As part of a separate effort, DOE is negotiating advanced clean coal technology projects awarded last October under the Power Plant Improvement Initiative (PPII). For further information on the CCPI and the solicitation text, visit the web site at: www.netl.doe.gov/coalpower/ccpi.

MIKE SMITH APPOINTED AS NEW FOSSIL ENERGY ASSISTANT SECRETARY

Shown with new Assistant Secretary, Carl Michael Smith at swearing in ceremony on February 5, 2002, is Secretary Spencer Abraham and Anna Bell of DOEís Office of Human Resources Management

As of February 5, 2002, the U.S. Department of Energy, Office of Fossil Energy has a new Assistant Secretary ó Carl Michael Smith. The highly qualified Smith breezed through a Senate confirmation hearing in October 2001. The new Assistant Secretary most recently was the Oklahoma Secretary of Energy, and is an oil and gas lawyer who once operated an independent oil and gas exploration company. He has served as President of the Oklahoma Independent Petroleum Association, Vice Chairman of the Interstate Oil and Gas Compact Commission, and has been a member of the Stateís Energy Resources Board.

Smith also has experience in the coal area, and noted in his Senate testimony that Oklahomaís coal industry predates the discovery of oil and gas in that state. He has served as Chairman of the Coal and Advanced Power Systems Committee of the Southern States Energy Board and has worked closely with the Oklahoma Department of Mines, as well as with various environmental and coal committees of the Interstate Mining Compact Commission.

Smith is a native of Oklahoma and holds an undergraduate as well as a law degree from the University of Oklahoma. As the Assistant Secretary for Fossil Energy, he will oversee an organization of nearly 1,000. Smith will be responsible for several high priority Administration initiatives, such as the $2 billion effort to develop environmentally sound clean coal technologies.

Materials Technology for Ultra-Supercritical Plants

A consortium led by Energy Industries of Ohio met in Pittsburgh, Pennsylvania on March 7ñ8, 2002, to formulate a plan for the first year of a joint research activity to develop advanced materials for ultra-supercritical steam cycles in coal-based power plants. The Consortium includes the Electric Power Research Institute (EPRI), the major domestic boiler manufacturers (Alstom Power, Babcock and Wilcox, Foster Wheeler and Babcock Borsig Power), as well as Oak Ridge National Laboratory.

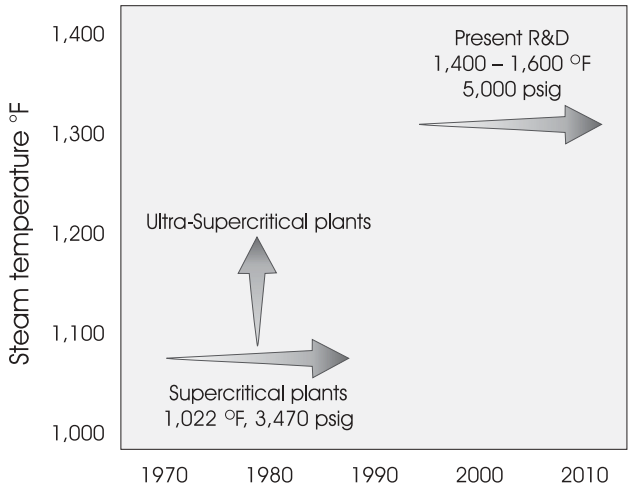
Ultra-supercritical plants operate at conditions well above the critical point of steam, 3,208.2 psia and 705.5 ∞F. Under these conditions, additional heat produces a continuous rise in temperature. Steam above the critical point serves as a superior working medium, releasing more of its heat content into usable energy. The U.S. Department of Energy (DOE), National Energy Technology Laboratory (NETL) is managing the project. This effort builds on work initiated in Europe and Japan over the past 15 years, where high coal prices have spurred development of high-efficiency plants. Ultra-supercritical cycles will raise the efficiency of coal-fired boilers from an average of 35 to over 45 percent (lower heating value basis), enabling coal-fired power plants to generate electricity at competitive rates while reducing CO_2 and other fuel-related emissions substantially. Over a 5-year period, total funding is expected to be $21.6 million. DOE will provide $16.1 million and the Ohio Coal Development Office and the Consortium will provide the remainder. Technical coordination of the research effort is carried out by EPRI, with guidance from NETL specialists.

The consortium has already completed a state-of-the-art assessment. Preliminary analysis has identified several nickel-base alloys as suitable for use at the highest temperatures, both for superheater tubing as well as for headers and piping for the main steam. The range of candidate alloys becomes larger for reheat steam components, since the pressure in this circuit will be much lower compared to the main steam circuit. Austenitic stainless steels for use at intermediate temperatures and ferritic steels for temperatures below 1,150 ∞F were also identified, since actual boiler components will experience a range of temperatures. Advanced ferritic steel alloys are expected to be suitable materials for furnace walls, which typically experience temperatures up to 1,000 ∞F.

Activities planned for the coming year will identify improved alloys, fabrication processes, and coating methods that will permit boiler operation in utility service at steam temperatures of up to 1,400 ∞F. Materials evaluation will be conducted at a range of temperatures, below *and* above 1,400 ∞F. Since the actual metal temperatures vary throughout the tube bundle of an operating steam generator, this approach provides a more complete assessment of materials performance and any corrosion issues that may be encountered in actual practice.

Plans were also made for implementing the groundwork needed to secure ASME Code approval for the new alloys and processes through generating relevant data and participating in the activities of cognizant ASME committees. Simultaneously, the issues impacting the design and operation of utility power generation systems at temperatures as high as 1,600 ∞F also will be developed. In the current scope of work, existing alloys and their capabilities will be first examined with the understanding that if existing alloys do not suffice, new alloy development may become necessary. With the cooperation of alloy developers and fabricators, equipment vendors, and power generating companies, cost targets will be addressed and efforts made to promote the commercial deployment of the alloys and processes developed in this project.

History of Ultra-Supercritical Research



Increase in steam temperature and pressure in coal-fired power plants

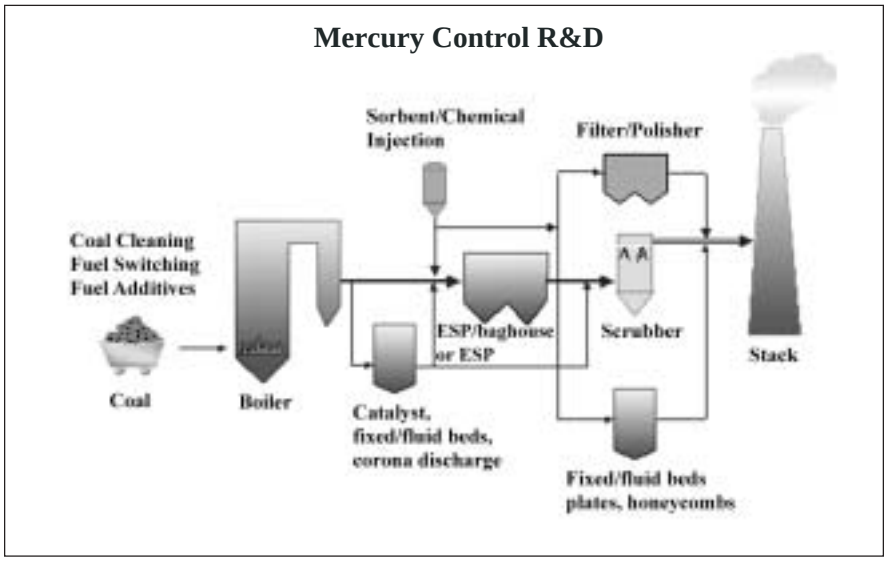
EPRI — BRINGING ADVANCED CLEAN COAL TECHNOLOGY TO MARKET

The U.S. Department of Energy (DOE), Electric Power Research Institute (EPRI), Coal Utilization Research Council, National Coal Council, and other public and private interests have long worked to bring clean coal technology to commercial fruition ó with EPRIís Cool Water project and DOEís CCT demonstrations representing major milestones.

Now with security and economic stability topping the public agenda, the ability to cleanly generate power from low-cost, domestic coal reserves is of paramount national interest. In addition, a viable coal power sector provides a hedge against price spikes in other fuels such as natural gas. Thus, power industry executives and the Bush Administration have renewed their commitment to clean coal in tomorrowís generation portfolio.

EPRI continues to bring its nearly 30 years of R&D experience to bear on clean coal technology development needs. It is particularly well poised to bridge the gap between public-good R&D and the technical and business practicalities of introducing new technologies in deregulated power markets. Current, representative research efforts address mercury controls compatible with evolving criteria pollutant regulations (such as the Bush Administrationís new Clear Skies Initiative); carbon capture, transport, and storage; state-of-the-art ultra-supercritical steam cycles; and resource-efficient, gasification-based ìpowerplexes.î

EPRIís mercury control R&D program is particularly far-reaching. One major thrust consists of pilot and full-scale tests of various techniques for injecting sorbents into the exhaust gas stream ahead of various types of particulate and SO_2 control devices. DOEís National Energy Technology Laboratory has partnered with EPRI in many of these field tests. Other work focuses on refining those devices as well as upstream NO_x controls to create effective ìmulti-pollutantî removal systems; supporting work assures that captured mercury does not inadvertently escape in the course of ash handling, storage, and re-use. In addition, EPRI is exploring novel mercury control solutions, such as those that eliminate the need for costly sorbents.



EPRI is testing mercury control techniques including sorbent injection

Many analysts believe that CO_2 will be an important issue for coal power in the 21st century. Technically, CO_2 removal technologies for coal power systems are in their infancy, as is the assessment and testing of carbon sequestration methods. As a first step toward accelerating the pace of carbon control technology development, EPRI and its new affiliate that spearheads much of its public-good R&D ó the Electricity Innovation Institute (E2I) ó are proposing a program for pilot-scale test centers. To be located regionally throughout the United States, these centers will greatly improve researchersí ability to evaluate CO_2 control options under realistic operating conditions.

Because of competitive pressures resulting from deregulation, coal power must become more efficient and cost-effective at the same time it becomes cleaner. DOE is helping power producers meet this goal through funding of a major strategic initiative on materials development for advanced power systems. As part of this effort, EPRI has teamed with steelmakers, equipment manufacturers, economic development agencies, and others to test new materials, components, and designs for ultra-supercritical (USC) steam cycles (applicable to Rankine and combined-cycle plants). Current initiatives focus on creep- and fatigue-resistant steam lines, headers, and turbines, and also on corrosion-resistant tubing. The goal is to produce more robust components and designs that will enable next-generation USC plants to reliably accommodate steam temperatures of up to 1,200∞F, which would improve thermal efficiency from about 37

percent to 41 percent (HHV basis). Ultimately increasing main steam conditions to 1,400 ∞F and 5,000 psig will boost thermal efficiency to over 50 percent.

Over the long term, power producers using coal will need to maximize resource utilization to stay competitive. EPRI is evaluating designs and implementation plans for a state-of-the-art ìpowerplexî that could make productive use of all coal constituents while dramatically lowering CO_2 output. EPRI studies indicate that a coal-fired powerplex could compete with advanced natural gas-fired plants ó even with gas prices as low as $4/10^6$ Btu and stringent CO_2 reduction requirements.

Recent EPRI analysis suggests that the most practical way to develop a powerplex is to build it in three distinct phases. The object of such ìphasedî construction is to limit initial capital outlay while allowing power producers to respond effectively to subsequent emission rules and economic co-production opportunities. Phase 1 covers the construction of a full-scale, state-of-the-art coal gasification combined-cycle unit with superior criteria pollutant and trace substance controls. Phase 2 encompasses the implementation of CO_2 removal and transportation equipment, and Phase 3 introduces H_2 or clean transportation fuel coproduction and purification systems.

Clearly, this is a vital time for clean coal technology. The EPRI family of companies is committed to advancing clean coal R&D through collaboration with all types of public interest and private sector organizations. EPRIís broad array of coal power and environmental assets includes a highly experienced staff, patents and intellectual property rights, numerous industry advisory and user groups, and the independent affiliate, E2I. By providing practical opportunities for diverse organizations to work together, EPRI offers an effective vehicle for moving clean coal concepts into commercial applications.

Guest article was submitted by: Hank Courtright, Vice President, Power Generation & Distributed Resources, EPRI. For further information about EPRI technical programs, contact: EPRI Customer Assistance Center, 800-313-3774 (phone); by e-mail, askepri@epri.com; or on the Internet at www.EPRI.com.

...News Bytes continued

April 2, 2001, marked the fifth anniversary of demonstration operations at **Air Products Liquid Phase Conversion Companyís Liquid Phase Methanol (LPMEOHô) Demonstration Project** in Kingsport, Tennessee. A second *in situ* catalyst activation is planned for May. The first activation took place last August. A new mode of operation ñ temperature programming ñ was initiated at that time. The reactor temperature was increased from 216ñ250 ∞C, as necessary, to maintain the production of methanol as the catalyst aged. Results showed that the catalyst activity following the *in-situ* activation was lower than expected, thus the second activation is planned to improve upon these results. The Department and the Partnership recently agreed to a six-month extension of demonstration operations which will allow for the additional testing. The LPMEOHô Demonstration 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 91 million gallons of methanol, all of which was accepted by Eastman Chemical Company for use in downstream chemical processes.

DOE DEVELOPING TRAPPED VORTEX COMBUSTOR CONCEPT

New combustion concepts are being pursued to extend efficient, low emissions combustion capabilities of gas turbines beyond natural gas fuels to synthesis gas fuels derived from gasification of coal, biomass, and wastes. Achieving this fuel flexibility is key to the U.S. Department of Energy (DOE) High Efficiency Engines and Turbines Program. This program seeks to expand usage of inherently clean, efficient gas turbines to applications using our nationís more abundant fuel resources.

The current state-of-the-art Dry Low-NO_x (DLN) gas turbine combustion systems are effective for minimizing pollutant emissions ó NO_x and carbon monoxide (CO) ó in natural gas applications. However, the composition of gasification-derived fuels requires both a different fuel-injection strategy *and* combustion approach to achieve efficient, sustainable, low-NO_x combustion. Gasification-derived fuels contain fuel-bound nitrogen components that can result in excessive nitrogen-oxide emissions, and contain concentrations of hydrogen that can significantly affect the flame behavior.

As a result, researchers at DOEís National Energy Technology Laboratory (NETL) have been collaborating with other government agencies to develop a revolutionary combustion approach called the Trapped Vortex Combustor (TVC). The TVC concept, originally conceived at the Air Force Research Laboratory (AFRL), is being investigated at NETL as a potential fuel-flexible combustor concept. Theoretically, this concept can be used for both low-Btu and medium-Btu fuels produced from air- and oxygen-blown gasification processes. In addition, there is commercial interest in pursuing this combustor concept for natural gas applications. In the future, this technology could be enhanced to burn syngas derived from coal ó an important goal of NETL Vision 21, Hybrid, and High Efficiency Engines and Turbines programs. The TVC effort is a good example of transferring technology from potential military applications to commercial applications.

The TVC uses a basic rich-burn, quick-quench, lean-burn (RQL) staged combustion approach to deal with the fuel-bound nitrogen and usual thermal NO_x formation issue. But, the TVC is significantly different from other more conventional RQL combustors.

The RQL principles offer insight as to the challenges. In the rich-burn, only enough oxygen is injected to partially oxidize and heat the fuel mixture to break the nitrogen compounds down, and not enough to oxidize the nitrogen. This process primarily results in pure nitrogen, hydrogen and CO. The quench process involves rapid injection of air in an attempt to achieve a homogeneous, lean (high air to fuel ratio) mixture prior to combustion. The importance of a homogeneous lean mixture lies in avoiding stratified air and fuel layers leading to localized combustion at the boundaries, which results in hot spots and thermal NO_x formation. Premixing to achieve a homogeneous air/fuel mixture provides for uniform temperatures in combustion and the high air/fuel ratio reduces the combustion temperature by limiting the amount of fuel. Lean combustion occurs almost immediately upon air injection, hence the need for rapid mixing. The challenge in lean mix combustion is sustaining a stable flame under the lean fuel conditions. Hot products of combustion must be recirculated to the fresh mix of reactants to ignite them and establish a flame anchor.

In a conventional RQL combustor, the products of the rich-burn move axially into a reduced volume quench section (*see Figure 1*). In this quench section, jets peripherally inject air through holes along the section length. The difficulty is in distributing the amount of air needed for a lean mix evenly into the cross-sectional area of the axially moving fuel. To address this issue, the TVC introduces the rich-burn products radially into the quick quench air stream, which pulls the rich-burn products into it through momentum (*see Figure 2*). This use

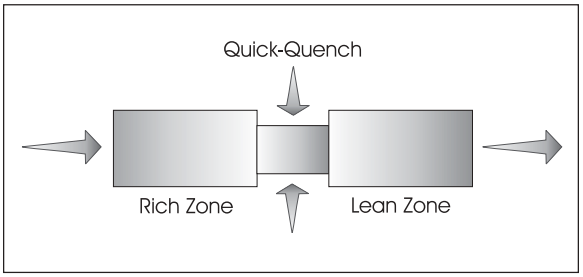


Figure 1: Standard axial-staged approach

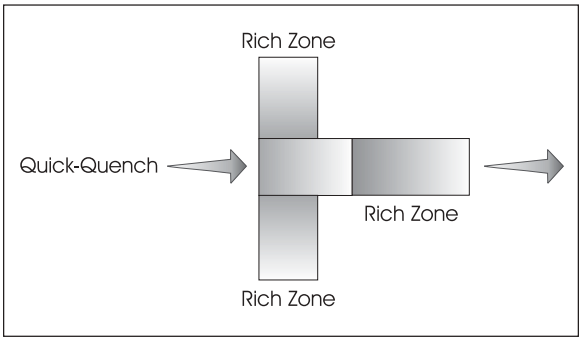


Figure 2: Radial-staged TVC approach

of momentum to engage the rich-burn products, called entrainment, is faster than jet mixing processes.

Sustaining combustion of the lean mix in a conventional combustor depends upon creating a cyclonic movement of the mix to form a low pressure in the center, causing hot products of combustion to recirculate to the fresh fuel mix and anchor the flame (*see Figure 3*). However, changes in velocities and operating conditions can lead to flame instability and blow-out. In the TVC, the flame anchor is not dependent on the dynamics of swirling flow. Instead, the flame anchor is produced by the unique geometry of the combustion chamber itself, which sustains the flame anchor over a greater range of operating conditions than does the conventional approach.

In the TVC, a notch around the circumference of a circular combustion chamber creates a vortex, which recirculates hot products of combustion and establishes a flame anchor (*see Figure 4*). The AFRL at Wright-Patterson Air Force Base found that with the proper notch design, the vortex does not jump out of the cavity, becoming a ìtrapped vortexî and stable flame anchor.

NETL has performed a series of preliminary tests on the TVC to assess the performance potential. Preliminary results show that the TVC has promise for providing the necessary fuel flexibility and low emissions performance required for gasification-based power plants. Initial tests of the TVC approach at AFRL confirmed fuel-bound nitrogen control. Subsequently, NETL applied computational fluid dynamic simulations to design a prototype TVC (*see Figure 5*). Prototype TVC tests showed good fuel mixing characteristics (with potential for improvement), and demonstrated an operational stability and robustness seemingly superior to conventional combustor designs. To explore other avenues for performance improvement, NETL evaluated adding steam by premixing the steam with the quick-quench air, as opposed to conventional injection into the fuel/air mix. The steam addition resulted in a significant reduction of NO_x emissions.

The results to date for the ìfirst-of-a-kindî TVC/RQL combustor are encouraging. Tests to date have been on doped fuel and natural gas to verify performance potential. NETL plans to extend TVC testing to further evaluate its ability to handle gasification-based fuels, including the effects of fuel-bound nitrogen control. These tests are designed to determine if the TVC approach can play a role in the next generation of gas turbines as a fuel-flexible combustor.

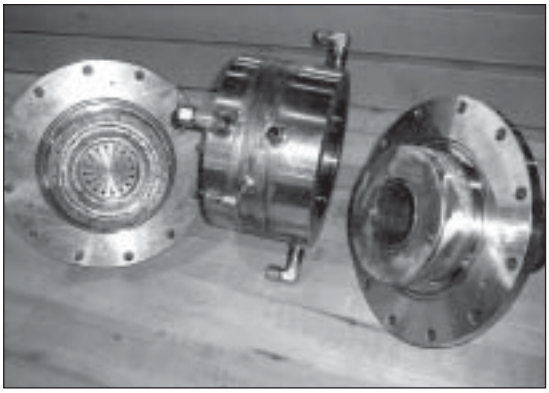


Figure 5: NETL trapped vortex combustor for RQL applications

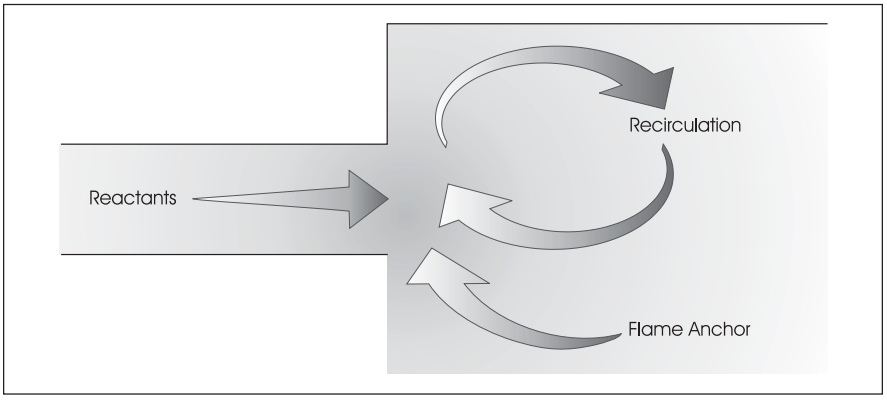


Figure 3: Conventional flame anchor

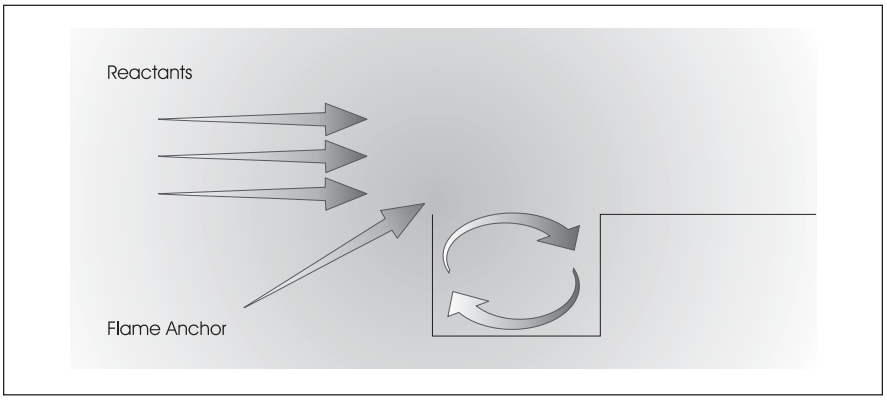


Figure 4: TVC flame anchor

INTERNATIONAL INITIATIVES

ENGINEERS FROM INDIA TRAINED IN UTILITY OVERHAUL AND MAINTENANCE

Indian engineers receiving training at a coal-fired power plant in Kentucky

Since 1995, the U.S. Department of Energyís National Energy Technology Laboratory (NETL) has been providing technical assistance to utilities in India under the Greenhouse Gas Pollution Prevention project, a U.S. Agency for International Development (USAID) initiative. A number of training programs have been held to help the utilities to generate electricity more efficiently utilizing coal.

In Fall 2001, NETL arranged a training program, held at the NETL-Pittsburgh campus and various southeastern power plants, on overhauling and maintaining critical components in coal-fired power generation. Nine engineers from Indian power plants learned best practices used in the U.S. for the design, operation, maintenance, overhaul, and instrumentation of steam turbines, boilers, and generators. Indian power plants periodically shut down to overhaul these three components. Typical shut-downs require a two-month maintenance period, resulting in a significant loss of electricity generation. The engineers studied plant shutdown procedures, performance recovery measures, outage optimization techniques, and on-line environmental monitoring systems during their visits to fossil fuel power plants in Tennessee, Alabama, and Kentucky.

U.S. power plants not only carry out scheduled plant outages over a short period of time, but also implement advanced approaches for efficiency improvements during the shutdown. The Indian visitors were able to observe: installation of specialty seals in critical locations to minimize steam leaks from the interstage packing of steam turbines; non-destructive testing for life improvement of boiler components; and technical specifications and design considerations for improved auxiliaries. In addition to in-plant training, NETL also arranged visits to U.S. service providers and manufacturing companies in the electric power generation industry.

Last Fall, NETL also supported a study tour for senior executives from the Indian power industry and USAID to familiarize them with the latest technologies being developed by NETL and the best practices in U.S. utilities. NETL arranged meetings with EPRI, Southern Research Institute, National Mine Land Reclamation Center, and others. At NETL, tour participants learned the status of technology development in integrated gasification combined-cycle systems, fuel cells, advanced turbines, mine-backfilling with power plant ash, and advanced coal cleaning.

The senior executives also visited supercritical power plants to identify critical operating issues. Coal-fired supercritical power plants, which operate at higher temperatures and pressures than conventional subcritical plants, offer much higher thermal efficiencies and lower environmental emissions. In January 2002, Indiaís Prime Minister laid the foundation stone for the first supercritical power plant in India. This 1,980 MW coal-fired power plant, which cost some $1.85 billion, will be commissioned by the National Thermal Power Corporation (NPTC) in the town of Sipat, Bilaspur district, Chattisgarh State, India. NTPC, a public sector company wholly owned by the government of India, is the largest thermal power generating company of India and sixth largest utility in the world. NTPC operates a total of about 20,000 MW of capacity, of which 16,000 MW is coal-fired capacity.

EETC Efforts for "Green" 2008 Beijing Olympics

Since its creation in 1997, Chinaís Energy and Environmental Research Institute (EETC) has undertaken a variety of project development and training activities to carry out its mission of enhancing competitiveness of U.S. clean coal technology, equipment and services. China is the largest coal producer in the world with an annual production capacity of more than one billion tons, now mostly burned in antiquated systems, and is a large potential market for U.S. clean coal technologies. EETC, which is run jointly by Tsinghua and Tulane Universities with funding from DOE, is participating in several efforts geared towards reducing air pollution in the Beijing area in preparation for the Olympics, with the object of later penetrating a larger Chinese market.

Last August, EETC coordinated the first meeting between a DOE energy delegation and the Beijing Municipal Government to discuss a ìGreenî Olympics. Beijing plans to adopt various coal preparation and clean combustion technologies and switch larger boiler installations from coal to oil or natural gas. It also plans to build a number of gas turbine-based combined heat and power plants. In one activity, EETC is coordinating a pilot project in boiler tuning near Beijing. The project introduces low-cost American technology for fine tuning boiler performance with operation and maintenance optimization techniques that would have the effect of reducing emissions while reducing operating costs. In January 2002, EETC co-hosted, with the China Coal Research Institute, a Workshop on Improving and Retrofitting Industrial Boilers that was attended by some 50 U.S. and Chinese representatives. Staff from Lehigh University, EETC, explained the boiler tuning process used in the U.S. The ultimate goal is to establish a U.S.-China joint venture to service the China boiler maintenance market.

In February, EETC facilitated DOEís participation at the Beijing Energy and Environment International Symposium 2002, to which five nations sent experts on clean energy and environment, with more than 150 representatives in attendance. EETC managed an executive session for DOE representatives and senior Beijing officials to exchange views on the specific potential of clean coal technology in the Beijing area.

In addition to the Olympic activity, EETC also has recently been successful in promoting two major projects where U.S. companies have been invited to bid. On January 28, 2002, a solicitation was issued for the city of Yantaiís coal-fired IGCC project in the State of Shandong, a 300- to 400-MW power project valued from $300ñ400 million. That project would be owned as a research project by the Chinese government. Two U.S. companies were invited to submit bids for equipment and engineering services. EETC is working with the World Bank to obtain a $20 million Global Environmental Facility grant. With help from EETC, HTI (Hydrocarbon Technology Inc.) is under contract to provide process design for a direct liquefaction project with Chinaís Shenhua Group, to be sited in inner Mongolia. The project, the largest of its type in the world, is valued at $3 billion with a capacity of 50,000 barrels per day of clean transportation fuel.

Other efforts of EETC involve coordinating activities in support of the R&D protocol between DOE and Chinaís Ministry of Science and Technology signed in 2000. As part of the Oil and Gas Annex, signed last August, EETC will assist in training for Chinese audiences in the areas of natural gas and coalbed methane. Chinaís coalbed methane resource is rich and comparable in size to its natural gas reserves. The proven reserves of coalbed methane in the Qinshui Basin alone are over 75 billion cubic meters.

HIGH-TEMPERATURE MATERIALS TESTING RECORD AT CERF

After completing a 350-hr continuous high-temperature materials test in October 2001, another major milestone was recently achieved at the Combustion and Environmental Research Facility (CERF) at NETL-Pittsburgh where steady-state operation was maintained while firing a low-sulfur Prater Creek Kentucky eastern bituminous coal for 658 hours. The recently completed CERF tests represent a new NETL record for extended 24-hr/day, round-the-clock pilot-scale coal-fired test operations with firing availability exceeding 98 percent over sustained periods. High-temperature metal alloy and ceramic materials were exposed to flue gas (containing SO_2, NO/NO_x, CO, fly ash and trace hydrocarbons) at various locations in the CERFís convection section (1,400ñ1,800 ∞F) and CERFís radiant furnace (1,900ñ2450 ∞F) in a first-of-a-kind systematic pilot-scale study of advanced materials in actual coal combustion environments. Partnering in the research effort, with support of the Office of Fossil Energyís Vision 21 and Materials programs, are DOEís Oak Ridge and Argonne National Laboratories, and its Energy and Environmental Research Center-North Dakota, SRI International, Honeywell, Composite Optics, Specialty Metals, and NCC Engineering.

The conventional metals used in most of todayís utility boiler tubes are limited to surface temperatures of only about 1,100 ∞F based on steam cycles, representing a key barrier for improving power plant efficiency. Because efficiencies are largely determined by temperature, a key objective is to develop advanced materials that can withstand much higher temperatures for heat transfer applications in coal-based environments. Advanced materials are also needed for related components, such as high-temperature membranes, filters, or slag screens that would serve to reduce ash impacts on heat transfer efficiency. Such advanced materials could push the envelope on steam-based cycles to significantly improve plant efficiency and reduce emissions, or enable the development of new, more efficient plant designs that might incorporate new air-based turbines, variations on combined cycles, or other novel approaches.

The CERF tests enable researchers to examine how surfaces and specialty thin-layer coatings are initially attacked by combustion gases and ash deposits, and subsequent transformations of bulk materials after surfaces are compromised. Using a wide variety of physical and chemical characterization techniques, researchers study how properties of surfaces, coatings, and bulk materials have been altered, such as corrosion induced by alkali, chlorine, sulfur, and other mechanisms that would impact long-term reliability.

The CERF furnace locations used in the study enabled materials to be simultaneously evaluated in 100 ∞F increments to help define practical upper limits. For example, the CERF tests allowed variable duration corrosion comparisons of novel Thermie and Haynes 230 alloys at different temperatures while at the same time comparing them to 9 other alloys at the same temperature.

Other alloy samples tested in the CERF included 310TAN, 310HCBN stainless steel, standard 803, modified 803 (Fe-25Cr-35Ni), INC-625, NF-709 (0.04 annealed), RA253MA, as well as several ODS and chrome alloys, including (Cr-6MgO-0.75Ti) and (Cr-9Ta-5Mo-2Si-0.15La-0.1Ti). Ceramic samples included specimens of CVD mullite-coated SiC, as well as mullite foam, alumina/laminate, alumino-silicate laminate, plasma spray TaO-coated SiC, and various SiC/SiC rings.

As part of the study, NETL developed new probe fabrication techniques. Probes are used to take samples and place them in the furnace. One new technique uses Hastelloy X and high-temperature ceramic cloth to minimize potential corrosion artifacts. NETL researchers successfully developed and tested new probe designs before the final construction of 15 probes with multiple sample holder configurations to securely mount 155 sample coupons, rings, and cubes of advanced alloys and ceramics of varying dimensions.

Since the mid-1990s, the CERF has served as a host site for exposure of ceramic and alloy samples. The latest CERF tests represent a significant expansion of NETL in-house capabilities with a record number of samples tested. The goal is to bring testing costs down from $2,000 to $1,000 per sample.

At NETLís CERF, materials were inserted at 1,900ñ2,400 ∞F in the radiant furnace, the vertical section shown here

Combustion Workshop Solicits Stakeholder Input

On January 14ñ16, 2002, in Orlando, Florida, the U.S. Department of Energyís National Energy Technology Laboratory (NETL) organized a workshop, ìEvolution of Combustion Technology to Support National Energy Needs.î The workshop built a consensus on the engineering R&D needs to overcome various barriers to combustion technologies that can provide the nation with an environmentally superior, affordable, and dependable supply of coal-based electric power. Coal combustion accounts for nearly 54 percent of the nationís fuel mix for generating electricity, and has a 70-year history of successful use.

The workshop was attended by a diverse group of participants. Equipment suppliers and A&E firms constituted the largest group, followed by utilities, universities, and oxygen system suppliers. Facilitated group discussions solicited stakeholder input to NETLís planning process for the Advanced Combustion Technologies program. The workshop format consisted of presentations by industry and DOE representatives on a variety of issues such as cost, efficiency, environment, and materials.

HIGH

Kentucky Workshop, August 1992	**Orlando Workshop, January 2002**
- Capital Cost	- Capital Cost
- Recent Oil and Gas Prices	- Possibility of More Stringent Regulation
- Operating Costs	- Financial Risk (new)
- Possibility of More Stringent Regulation	- Time for Environmental Permitting
- Space Limitations	- Recent Oil and Gas Prices
- Gas Cleanup Equipment Costs	- Cost of Obtaining Environmental Permits
- Solid Waster Disposal	- Gas Cleanup Equipment Costs
- Flexibility (fuel, operational)	- Operating Costs
- Automation & Controls Cost	- Solid Waste Disposal
- Time for Environmental Permitting	- Flexibility (fuel, operational)
- Lack of Experienced Operators	- Transportation Costs

LOW

Perceptions of barriers to coal combustion have changed, ranked from high to low

The first exercise was to survey the group about overall barriers to coal combustion today. The questions used were the same as questions asked of a similar group at a 1992 conference held in Kentucky. As shown in the table above, environmental issues are seen to be more critical barriers today than they were 10 years ago. The possibility of more stringent regulation was only one vote short of being voted the most significant barrier of all.

Following the survey, breakout sessions were organized to address:

- R&D needs for advanced combustion systems including circulating fluidized-bed, cyclones, and other slagging furnaces and oxygen-enhanced combustion modes.
- R&D needs to meet the DOE Vision 21 goals of 60 percent efficiency of coal-fired power plants and near-zero emissions of stack gas pollutants; and specific R&D needs to support the next 10 years of the Clean Coal Power Initiative (CCPI) program.
- R&D needs for pressurized hot gas clean-up, materials issues and risks for supercritical and ultra-supercritical steam cycles, and design improvements needed for the balance-of-plant of advanced combustion systems.

Workshop participants were supportive of the current NETL combustion program, citing Vision 21 as a laudable goal and encouraging a Vision 21 solicitation targeted specifically to combustion technologies. Attendees further agreed on the importance of the planned CCPI demonstrations, and hoped that projects would be funded for supercritical and ultra-supercritical cycles for atmospheric and circulating fluidized-bed combustion, pressurized and hybrid systems, and pulverized coal combustion systems.

Participants suggested expanding the scope of repowering studies. Repowering is upgrading the performance of aging coal-fired plants through replacement with newer, high-performance equipment. Repowering would extend the engineering life of the existing combustion fleet with superior environmental performance and would minimize major capital investment, while allowing gradual diffusion of advanced concepts and components in coal combustion systems.

Attendees also stressed the importance of R&D in oxygen and oxygen-enhanced combustion, and the development of a multi-pollutant collection device for hot gas filtration and cleanup. They also recommended investigating various system options and assessing the economic and market opportunities for coal-fired peaking units.

In all, workshop participants felt that improvements in the economics of coal combustion systems have occurred over the last decade in response to the deregulated power generation market. Future growth requires superior environmental performance, reliability and efficiency improvements, cost reductions, shorter construction schedules, improved performance, and fuel flexibility.

DOE Examines Environmental Issues in By-Product Use

The Office of Fossil Energyís National Energy Technology Laboratory (NETL) is cooperating with industry and academia in an important program of pilot projects focused on environmental research for the safe use of coal utilization by-products (CUBs) ó fly ash, bottom ash, boiler slag, and flue gas desulfurization residues. These by-products have applications ranging from wallboard to roadbed materials to synthetic countertops, and can offer an important pollution prevention benefit in reducing the amount of by-products that must be landfilled. With landfill costs rising, the choice to recycle CUBs into useful products can be economic, especially if markets are relatively close. Over 1 million tons of CUBs are generated annually in the United States, of which just over 30 percent is reused.

A buffalo stands on ash-stablized soil, which helps overcome wet, muddy conditions in animal pens

The Changing CUB Product

The largest CUB market has traditionally been concrete additives. However, pollution control devices over the last decade have changed the characteristics of CUBs so that the product contains more carbon and ammonia and is less suitable for use in manufacturing cement. Low-NO_x burners fire coal at lower temperatures which produce less NO_x but leave more carbon in the by-product. High carbon ash is not suitable for use in Portland cement. Other low-NO_x techniques, Selective Catalytic Reduction and Selective Non-Catalytic Reduction, use a reagent, ammonia or urea, to reduce NO_x to nitrogen and water. The residual reagent may be absorbed by the by-product, causing off-gassing of ammonia compounds. Thus, cement manufacturers have set limits for ammonia in CUBs. Mercury removal techniques being developed to prepare for upcoming EPA regulations may also change CUB characteristics in ways still uncertain.

Regulatory Impacts

NETLís projects are providing important data to the U.S. Environmental Protection Agency to aid in regulatory decision making. In December 2000, EPA announced its intention to regulate mercury from coal-fired powerplants. Draft regulations will be published in 2003 with final regulations in 2004 and implementation beginning in 2007. EPA considers mercury emissions from power plants to be the largest anthropogenic source of mercury. Past research indicates that mercury in CUBs is usually below analytical detection limits of standard measuring systems, and mercury also is not easily leachable to groundwater. However, EPA is concerned about mercury transfer from the air to the solid waste by-product. Current mercury removal technologies remove the mercury from the flue gas while placing a larger concentration in the solid by-product. Uncertainties exist as to how much of the mercury will volatize or leach into the environment. EPA, in its regulatory determination of May 2000, stated that CUBs will continue to be exempt from hazardous waste regulation under Subtitle C of RCRA. However, in March 2003, EPA intends to issue regulations or guidance on CUB disposal at surface impoundments and minefilling.

Combustion By-Product Recycling Consortium

Much of the NETL work is accomplished via the Combustion By-Product Recycling Consortium composed of researchers from state and federal governments, as well as the utility and mining industries. Organized in 1998, the Consortium has since produced annual Requests for Proposals. To date, 31 projects located in 17 states have been funded with $2.6 million from NETL and $3.3 million from industry. In the Consortium structure, NETL performs program management activities while the National Mine Land Reclamation Center at West Virginia University is in charge of project management.

One project funded in the 2002 round of awards, investigates the environmental effects of flue gas desulfurization material used for structural fill. The project teams together the Federal Aviation Administration (FAA), the Pennsylvania Department of Environmental Protection, Orion Power Midwest, and GAI Consultants, in a project to utilize 472,000 tons of fixated flue-gas desulfurization material in the construction of an embankment at the Rostraver Airport near Pittsburgh, Pennsylvania. This embankment is needed in order to meet FAA requirements for a 300-ft runway safety area. The effects of this CUB utilization on groundwater, surface water, and fugitive dust emissions will be monitored.

In another noteworthy Consortium project, begun in 2000, Southern Illinois University at Carbondale, and

Rostraver Airport near Pittsburgh, Pennsylvania, with CUB project safety area in the foreground

partners Ashland Chemicals and Trinity Marine Products, are examining the use of CUBs instead of wood for transmission poles. Ashland Chemicals is developing polymer casing for the poles and Trinity Marine Products is conducting the economic analysis. The novel poles will avoid the issue of water pollution caused by chemical impregnation of wooden poles and also insect or animal degradation of the wood.

Other Consortium projects include research in such areas as: fly ash-derived sorbents for mercury control, fly ash to increase soil fertility, CUBs to neutralize acid drainage and prevent mine subsidence, and CUBs as fill materials for artificial marine reefs.

In-House Research

Teams at the NETL campuses located in Pittsburgh, Pennsylvania and Morgantown, West Virginia are conducting research in several important CUB areas. Ammonia leaching to surface waters from nitrate compounds has been linked to water eutrophication. NETL researchers are evaluating the potential of the ammonia to leach from CUB collected from plants that use SCR or SNCR. In the mercury area, teams are examining fly ash from a 500-pound/hour combustion unit at NETL for mercury mobility. The team is using five lixiviants (e.g., sulfuric acid, acetic acid, distilled water) that mimic solutions present in the natural environment that can be used to assess the likelihood that mercury will leach from this by-product material.

Still another important way in which the CUB program does business is through broad-based solicitations. These solicitations are open to projects of many types. In one such project showing innovative uses of CUBs, the University of North Dakota Energy and Environmental Research Center and the North Dakota State University Carrington Research Extension Center are demonstrating the placement, engineering and environmental performance of by-products for feedlot surfaces in order to promote feedlot surface stability. Mud and poor drainage can adversely affect animal health and weight gain, increase odor, and make it harder to maintain the pen and remove manure. Earthen pens cannot withstand high use when wet, or during spring thaw. Once this application is approved for general use, it is estimated that more than 2 million tons of ash could be used annually for this purpose in the northern Great Plains. Currently, only about 8 percent of coal ash produced each year in the northern Great Plains is used for a variety of purposes, leaving nearly 3 million tons of ash to be landfilled annually.

NETLís program to study and resolve environmental concerns in CUB use opens the way for using this resource in a variety of innovative ways.

Upcoming Events

ó May 14, 2002 ó
2002 Conference on Unburned Carbon on Utility Fly Ash
Sponsor: NETL
Location: Pittsburgh, PA
Contact: Kimberly Yavorsky
Phone: 412-386-6044
E-mail:
kimberly.yavorsky@netl.doe.gov

ó May 15-16, 2002 ó
2002 Conference on Selective Catalytic Reduction (SCR) and Selective Non-Catalytic Reduction (SNCR) for NO_x Control
Sponsor: NETL
Location: Pittsburgh, PA
Contact: Kimberly Yavorsky
Phone: 412-386-6044
E-mail:
kimberly.yavorsky@netl.doe.gov

ó May 19-22, 2002 ó
3rd Annual Small Business Conference
Sponsor: NETL
Location: Orlando, FL
Contact: Kimberly Yavorsky
Phone: 412-386-6044
E-mail:
kimberly.yavorsky@netl.doe.gov

ó June 4-5, 2002 ó
University Coal Research/Historically Black Colleges and Universities & Other Minority Institutions Program Review Meeting
Sponsor: NETL
Location: Pittsburgh, PA
Contact: Kimberly Yavorsky
Phone: 412-386-6044
E-mail:
kimberly.yavorsky@netl.doe.gov

ó September 9-12, 2002 ó
Air Quality III: Mercury, Trace Elements and Particulate Matter Conference
Sponsor: EERE with DOE, EPRI and others as collaborating sponsors
Location: Arlington, VA
Contact: http://www.undeerc.org for online registration

STATUS OF ACTIVE CCT DEMONSTRATION PROJECTS

ENVIRONMENTAL CONTROL DEVICES

Southern Company Services, Inc. ñ *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 June 30, 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 ñ *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 ñ *ACFB Demonstration Project.* Construction of Unit 2 at the Northside Station was completed in December 2001. On February 14, 2002, Unit 2 achieved 100% unsupported coal firing. The steam turbine generator was in startup, vibration was acceptable, and power production was at approximately half load (150 MWe). 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. ñ *Kentucky Pioneer Energy Project.* The Draft 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 should be issued in the summer of 2002. (Trapp, KY)

Sierra Pacific Power Co. ñ *PiÒon 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 Sierraís Tracy Station (which includes the PiÒon 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. DOE is preparing a post-project assessment. (Reno, NV)

Tampa Electric Co. ñ *Tampa Electric Integrated Gasification Combined-Cycle Project.* Tampaís 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 should be published in the second quarter of 2002. (Mulberry, FL)

Alaska Industrial Development and Export Authority (AIDEA) ñ *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 projectís 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 ìfull retrofitî 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 ìfull retrofitî 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. ñ *Clean Coal Diesel Project*. A fuel mixture (solid loadings and additives) has been determined. Combustion testing of the fuel will commence this quarter. Hardened parts have been manufactured and will be installed after combustion tests have been accomplished. Only minor problems have been encountered. (Fairbanks, AK)

Coal Processing for Clean Fuels

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

Air Products Liquid Phase Conversion Company, L.P. ñ *Liquid Phase Methanol Process Demonstration Project.* The Liquid Phase Methanol (LPMEOHô) Process Demonstration Facility continues to experience stable operation on coal-derived synthesis gas. Since restarting the facility following the *in-situ* activation of methanol synthesis catalyst in August 2001, the LPMEOHô reactor has been operated in a temperature-programming mode; the reactor temperature has been increased over time to maintain methanol production rates. In order to address the rapid loss of the adsorption capacity for arsenic of the catalyst guard bed, a procedure for restoring the adsorbent capacity for arsenic was developed and used successfully on two occasions. The adsorbent, however, was replaced with fresh material in February 2002 to fully restore the adsorbent capacity of the catalyst guard bed. 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. ñ *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 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. CMC is discussing teaming arrangements with several engineering and independent power producers. (Vineyard, UT)

ThermoChem, Inc. ñ *Pulse Combustor Design Qualification Test.* The public Design Report for the Pulse Combustor Design Qualification Test has been accepted by DOE. The Final Report was submitted after revision as per DOE review and accepted by DOE before the expiration of the Cooperative Agreement on March 31, 2002. The Cooperative Agreement is now in the close-out process. (Baltimore, MD)

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