Office of Fossil Energy, U.S. Department of Energy • DOE/FE-0519 • Issue No. 75, Spring 2008

CLEAN COAL TODAY

A Newsletter About Innovative Technologies for Coal Utilization

News Bytes

On January 30, 2008, the **Department of Energy (DOE) issued a "Request for Information on the Department of Energy's Plan to Restructure FutureGen."** Comments were due March 3, 2008, and are to be followed by a competitive solicitation. The FutureGen concept announced in 2003 planned the creation of a near-zero emissions, 275-MW power plant that would produce hydrogen and electricity from coal, and serve as a laboratory for commercial development. DOE considers the restructured approach an all-around better investment. Under this strategy, DOE would join industry in its efforts to build commercial-scale power plants utilizing Integrated Gasification Combined Cycle. DOE would provide funding for the addition of carbon capture and

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Inside This Issue

NETL Emphasizes CO_2 Capture from Existing Plants

Over the past two decades, the Department of Energy's (DOE) Innovations for Existing Plants (IEP) Program has played a crucial role in moving advanced emission control technologies from concept to commercial reality. The successes from the program have been many. In recent years, several advanced NO_x control technologies, such as Praxair's oxygen-enhanced combustion and REI's ALTA NO_x technology, have been commercially deployed on the existing fleet of coal-fired power plants. In addition, as a direct result of the IEP program, more than 40 gigawatts of an advanced mercury control technology — activated carbon injection — will be installed on new and existing pulverized coal plants, with more orders anticipated.

SRI's Combustion Research Facility will be retrofitted for oxycombustion operation

The IEP program is now positioned to take on the critical challenge of climate change. In response to Congressional language in the Fiscal Year 2008 budget, the IEP program will shift focus to R&D on CO_2 capture technologies that can be retrofitted to existing pulverized coal-fired power plants. To implement this new program focus, DOE's National Energy Technology Laboratory issued a Funding Opportunity Notice on February 13, 2008, seeking applications for advanced concepts in post-combustion capture (membranes, solvents, and solid sorbents); various aspects of oxycombustion, and chemical looping combustion to be carried out through laboratory, bench-scale, and pilot-scale R&D. Technologies must be capable of achieving at least 90 percent CO_2 capture at less than a 20 percent increase in the cost of electricity. Applications are due April 10, with multiple awards anticipated to be made by the end of September 2008.

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... "CO_2 Capture" continued

The new research will build on a portfolio of advanced CO_2 capture projects that were awarded under a 2005 solicitation directed toward a broader range of capture technologies. A brief description of several projects follows.

SORBENTS FOR POST-COMBUSTION CAPTURE

Post-combustion CO_2 capture technologies deal with the removal of CO_2 from power plant flue gas. Removal can be accomplished through the use of solvents, sorbents, membranes, and other gas removal technologies. *RTI International* is heading a research team tasked with continuing development and scale-up of its innovative process utilizing a dry, regenerable, carbonate-based sorbent. The sorbent captures CO_2 in the presence of water to form bicarbonate. Upon heating, the bicarbonate decomposes into a CO_2/steam mixture that can be converted into a pure CO_2 gas stream suitable for industrial use or for sequestration. RTI has started process engineering work to design a "pre-pilot" system based on the novel process design concept. The design basis is a system that can capture 1–2 tons of CO_2 per day from a coal-fired flue gas stream.

Another CO_2 capture sorbent system is being investigated by *UOP LLC*. The company is developing novel microporous metal organic frameworks (MOFs) and an associated process for the removal of CO_2 from coal-fired power plant flue gas. Significant progress has been made on the synthesis of MOF materials, with more than 20 MOFs prepared to date. The MOF materials have been characterized to ultimately enhance the understanding of relationships among material properties and CO_2 capture performance. Studies to investigate the adsorptive behavior of CO_2 on MOFs have been initiated, while increasingly rigorous testing of thermal and contaminant effects will be applied to optimize the MOF materials. As the three-year project progresses, MOF materials that demonstrate the best performance and stability will be selected for optimization and scale-up to quantities needed for pilot-scale testing.

IONIC SOLVENTS

The *University of Notre Dame* and its partners are working to develop a process using novel ionic liquids (a solvent-based system) for the removal of CO_2 from coal-fired power plant flue gas. Researchers have initiated a synthesis program for ionic liquids having functional groups capable of complexing with CO_2, thereby increasing absorption capacity. To date, 13 new ionic liquids have been synthesized. Nuclear magnetic resonance characterization and measurement of impurities in these ionic liquids has also been completed. In a related effort, researchers have undertaken atomistic-level classical and quantum calculations to engineer ionic liquid structures that maximize CO_2 carrying capacity while minimizing regeneration costs. Also, research efforts have been initiated to measure or accurately estimate all physical properties of the ionic liquids that are essential for detailed engineering and design calculation. During the three-year project, researchers will refine development efforts for the optimal absorbent and use this information to complete a detailed systems and economic analysis study.

MEMBRANE-BASED CAPTURE

Carbozyme is developing membrane-based technologies for CO_2

capture, specifically the contained-liquid membrane (CLM) system that leverages a highly efficient CO_2 catalyst, carbonic anhydrase (CA). The main objective of this project is to demonstrate and evaluate, at pre-pilot scale, the ability of the enzyme-based CLM permeator to capture CO_2 from a variety of combusted coal rank flue gas streams. In order to maintain membrane life, a flue-gas pretreatment system has been installed at the *University of North Dakota Energy and Environmental Research Center's* combustion test furnace (CTF). CLM modules will be evaluated using flue gases produced by the CTF. Enzymes capable of operating in an industrial gas environment have also been produced by *Novozymes* for testing on the CLM. Future work will focus on the scale-up of the hollow fiber CLM permeator and engineering and economic analysis of the technology as it relates to retrofit and greenfield installations.

PROGRESS IN OXYCOMBUSTION

Oxycombustion involves the combustion of coal or another fossil fuel with a mixture of pure oxygen and recycled flue gas. This eliminates the presence of N_2 in the flue gas and results in much higher CO_2 concentrations. The oxycombustion flue gas will then only require a minor purification step prior to sequestration. *The Babcock and Wilcox Company (B&W)* is leading a project team to further develop the oxycombustion technology for commercial retrofit in existing wall-fired and cyclone boilers by 2012. To meet this goal, a two-phase research project is planned that includes pilot-scale testing and a full-scale engineering and economic analysis. Progress has been made in defining the requirements for combustion, purification, transportation and sequestration of CO_2 in the oxycombustion process. In addition, the design, fabrication, and installation activities for oxygen testing at the B&W test facility continue. The new 6 MBtu/h pilot facility is expected to begin start up operations in June 2008. As part of the research effort, Air Liquide has simulated several CO_2 purification techniques that substantially reduce moisture, nitrogen and oxygen, and increase CO_2 concentration.

An oxycombustion retrofit with CO_2 recycle is being evaluated in a project with the *Southern Research Institute (SRI)*. Under this effort, SRI's 6 MBtu/h Combustion Research Facility (CRF) will be retrofitted for oxycombustion operation. An oxycombustion burner has been designed by MAXON specifically for the CRF and coal-based oxycombustion. The initial design of the retrofit system and the construction of the burner have been completed. An existing computational fluid dynamics model of the CRF has been updated to include the effects of oxycombustion with flue gas recycle, and the model will be validated against the results of detailed experiments. Testing will include operation with different coal types, oxygen and recycled flue gas flow configurations, and oxygen purity.

In order to produce the large amounts of oxygen that would be required by a pulverized coal oxycombustion system, cryogenic air separation systems would be necessary. These systems use large amounts of electricity for refrigeration. Thus, the IEP program also is conducting research on technologies that aim to reduce air separation costs in conjunction with the oxycombustion process. *The BOC Group, Inc.* (a member of the Linde Group) is currently developing a process that utilizes the oxygen storage capacity of perovskite materials at high temperatures. The Ceramic Autothermal Recovery (CAR) involves oxygen sorption and oxygen release. Air is passed through one bed to allow sorption and storage of oxygen, followed by a sweep gas (such as flue gas or steam), which is passed through the other bed to release the stored oxygen. The process operation is made continuous by operating two or more beds in a cyclic mode. Current work focuses on the testing of CAR bed material performance in the presence of coal-based flue gas contaminants.

Praxair is also developing oxygen transport membranes (OTM) for integration into coal-based power production systems to reduce the costs

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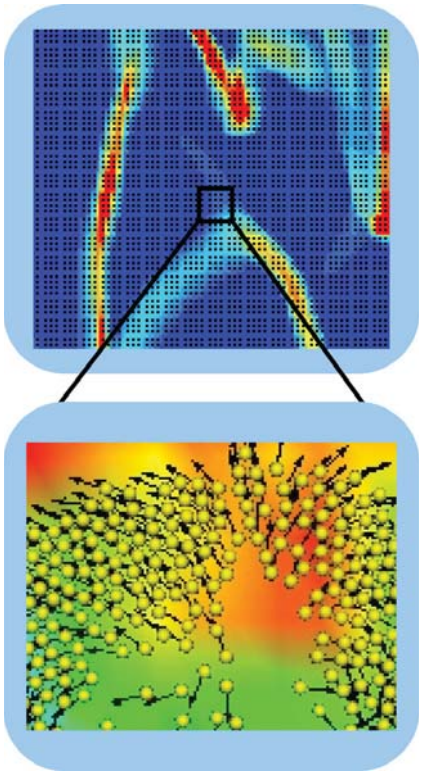
Praxair's high pressure reactor

NETL IN-HOUSE TECHNOLOGIES RECEIVE PRESTIGIOUS AWARD

R&D Magazine has awarded its prestigious 2007 R&D 100 Award for innovation to the Department of Energy's (DOE) National Energy Technology Laboratory (NETL) and its research partners for energy technologies developed in-house at NETL laboratories. The winning technologies were MFIX (Multiphase Flow with Interphase eXchanges) software, which develops physics-based equations to simulate high-solids loading in critical coal-related equipment, and SEQURE™, a helicopter-based well-finding technology with implications for secure carbon dioxide (CO_2) storage in active and abandoned oil and gas fields. MFIX was developed with support from Aeolus Research, Inc., Parsons, Inc., and Oak Ridge National Laboratory. SEQURE™ partners include Apogee Scientific, Inc., Fugro Airborne Surveys, and LaSen, Inc. R&D 100 awards applications are evaluated by an independent panel of experts, and the technology must have demonstrated commercial value.

MFIX SOFTWARE

Researchers developed the MFIX computational fluid dynamics (CFD) software as a physics-based model of multiphase reactors in order to address scale-up problems for advanced power plants. Advanced power plant technologies with multiple phases (i.e., coal, steam, and air) require sophisticated, multiphase models. MFIX allows for modeling of discrete particles, such as individual coal particles in a gasifier, their movement and interaction with other particles. This represents a step above models that consider only one phase in a continuum.



MFIX simulation results illustrating both continuum (top) and discrete (bottom) approaches

Behavior of gas streams changes with scale-up, and actual experimental data is difficult and costly to obtain. Without simulation/visualization models such as MFIX, scale-up of a coal plant from pilot to commercial size is unpredictable. MFIX simulates heavily loaded gas-solids flows, commonly encountered in fossil fuel processes and in other industries such as chemical, petrochemical, pharmaceutical, and mineral. MFIX can predict changes in temperature, pressure, gas and solids velocity and species concentration in the reactor over time. It can calculate the detailed motion of gas and solids in a general process vessel, allowing for the effects of heat transfer and chemical reactions.

The MFIX model has been in use at NETL for over 15 years and has become internationally recognized as one of the premiere two-fluid models available to researchers. It was developed as an open source model in order to allow for continual improvement, spur research at universities, and help transfer models from academia to industry. MFIX is fully optimized to run on high-performance computers, has FORTRAN coding of subroutines, and versatile post-processing tools, all making the software an ideal platform to develop, validate, and test sub-models (e.g., coal combustion and gasification).

NETL and gasifier developers have been successful in using MFIX for advanced gasifier design. MFIX has been used to simulate the transport gasifier at the Power Systems Development Facility, Wilsonville, Alabama, operated by Southern Company and Kellogg Brown & Root. The simulations convincingly showed the gasifier developers that the model does not merely reproduce what is already known, but provides insight into unobserved phenomena, later verified through actual experiments.

The success of MFIX is evident by its widespread use in a number of fossil energy applications (coal gasification, fluid cat cracking, chemical looping combustors) as well as non-fossil applications (black liquor gasification, polyethylene manufacture, ultra-pure polycrystalline silicon production, vulcanology, dust explosions, and nuclear particle coating). More than 100 researchers from over 250 institutions worldwide have registered on the MFIX Web site.

SEQURE's™ magnetic sensors are mounted on boom beneath the helicopter

SEQURE™ Well Finding Technologies

The need to search large areas for abandoned or leaking oil and gas wells was the impetus for the development of SEQURE™ Well Finding Technologies. SEQURE™ uses helicopters fitted with magnetic and methane sensors to locate these wells — a search which can stretch over hundreds of square miles. It is the only such commercially available technology; it is speedy and cost-effective, and eliminates the need for land access in areas of dense vegetation and rugged terrain.

Oil and gas reservoirs have trapped hydrocarbons underground for millions of years. Since 1859, when the first oil well was drilled in the United States, engineers have been drilling into these reservoirs to supply the nation's energy needs. Many wells were abandoned and plugged as reservoirs became depleted. Today, the locations of these wells are often unknown or inaccurate; and some may be totally buried, covered over with houses and parking lots. Engineers now hope to boost oil production by pumping CO_2 into these reservoirs to push out the remaining product. Further, many depleted oil and gas reservoirs could become ideal locations for CO_2 storage, but only if all leaking wells can be found and plugged.

SEQURE's™ magnetic sensors are located on opposite ends of a transversely mounted boom on the underside of a helicopter. SEQURE™ detects wells by sensing disturbances in the earth's magnetic field caused by steel casing. Magnetic sensors can detect up to 97 percent of the wells present in oil and gas fields. Wells with no magnetic signature may have wood casings, corroded casings, or have had casings removed as part of the World War II scrap metal collection campaign. In those cases, though, SEQURE™ may be able to find the wells via escaping methane, detected by its sensitive methane detectors. SEQURE™ uses one of two methane sensor types, depending on the altitude of the helicopter survey. Both sensors detect volatile components from sedimentary strata that have migrated to the earth's surface via the wellbore. The methane sensors can detect a leaking well, regardless of whether a steel casing is present or not.

For survey altitudes of 50 meters or higher, the ALPIS differential absorption lidar (DIAL) sensor, developed by LaSen, Inc., is used to detect methane in the air column between the helicopter and the ground. The ALPIS sensor uses two mid-infrared laser beams — one with a wavelength in the methane absorption band, and one with a wavelength outside that band. Both beams are transmitted from the helicopter to the ground where part of the energy is reflected back to the ALPIS instrument located between the helicopter skids. If the beams pass through a methane plume, the beam at the methane absorption wavelength will be diminished in intensity with respect to the other beam. For survey altitudes less than 30 meters, a cockpit-mounted methane sensor is used with the air sampling hose mounted on one of the skids. The Apogee leak detection system, a high-speed gas analyzer capable of measuring methane, total hydrocarbons, and CO_2 in sub-parts per million (ppm) concentrations was used for low altitude, in-plume surveys. ■

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Comments are welcome and may be submitted to the Editor.

RESEARCHING POWER PLANT WATER RECOVERY

Since 2003, DOE's National Energy Technology Laboratory (NETL) has undertaken a variety of projects aimed at reducing freshwater needed for power plant operations, in order to minimize water supply and water quality impacts, especially in arid regions. Electricity generation is the largest consumer of water in the energy production chain. According to the U.S. Geological Survey, the U.S. withdraws approximately 97.5 billion gallons per day (BGD) of fresh water for fossil fuel power plants and an additional 34.4 BGD for nuclear power plants. Of this water, about 2.5 BGD are consumed (evaporated) at fossil plants and 0.8 BGD at nuclear plants. Once-through cooling systems return most of cooling water to a water body, and cooling tower technology recycles the cooling water. Still, water use in power plants is only slightly less than that used for irrigation.

View from top of Air2Air™ test cell

A range of projects supported by NETL under the Innovations for Existing Plants Program are investigating modifications to power plant cooling systems for reducing water loss, and recovering water from the flue gas and the cooling tower. Two technologies showing particular promise condense water that is typically lost to evaporation. SPX Technologies' Air2Air ™ condenses water from a cooling tower, while Lehigh University's process condenses water and acid in flue gas. Both projects were awarded in November 2005.

In the Air2Air™ process, humidified air from the heat exchanger rises through the cooling tower and is cooled by ambient air from the atmosphere. The bottom of the Air2Air™ cell is a traditional wet cooling tower. The hot, moist air rising from this section goes to the Air2Air™ heat exchanger. Relatively cool ambient air is brought into one side of the heat exchanger and it cools the hot, moist air and condenses some of the water vapor, releasing a warm, drier air. This acts to minimize the plume. The ambient air is warmed but does not change moisture content since it does not come into direct contact with the moist air from the cooling tower. The Air2Air™ design is larger than conventional cooling towers and requires more fan power to operate; however, the water savings and reduced water treatment costs savings make Air2Air™ an appropriate technology for some power plants.

Initial pilot-scale tests undertaken at SPX's test facility indicate about 20 percent of water lost from the tower can be recovered. Larger pilot-scale testing is currently being performed and will continue for the rest of this year at the 550 MW Unit 4 at the San Juan Generating Station in New Mexico. San Juan's Unit 4 evaporates about 5,200 gallons per minute, so if this technology were retrofitted to the entire Unit it would save more than 1,000 gallons per minute. The cell for larger scale pilot testing has been constructed. At full scale, Air2Air™ technology would employ 16 cross-flow cells. Tests at San Juan will validate smaller-scale results, and will demonstrate how the technology stands up to actual power plant operating conditions. Also, the integrity of the cooling system will be evaluated since the Air2Air™ may not remove heat as well as a standard wet cooling tower. This would cause water returning to the condenser to be too hot.

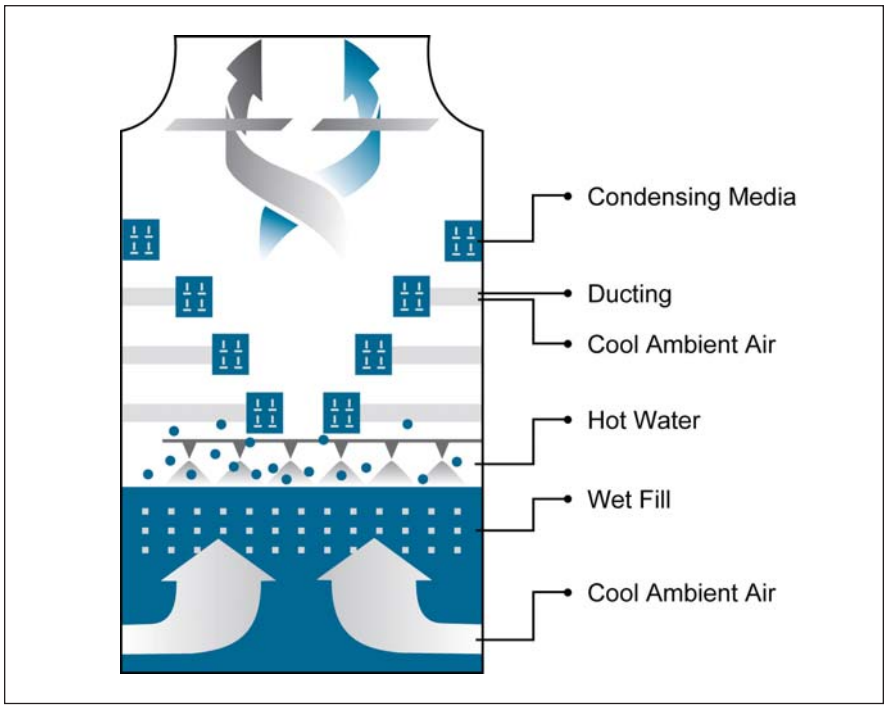
Another source of potentially recoverable water in a power plant is the flue gas. This water comes from the moisture in the coal, water formed from the oxidation of hydrogen in the coal, and water from the combustion air. The amount of water in the coal varies by coal rank, with lower rank coals generally having a higher moisture content. For a 600 MW coal-fired power plant, the flue gas typically emits 400–1,200 gallons of water per minute. However, acid present in the flue gas presents a major barrier to condensing this water. Flue gas from coal-fired boilers typically contains concentrations of sulfuric acid ranging up to 50 ppm, with acid dew points in the range of 230–300 °F. If the flue gas is brought below the dew point, the acid can be condensed and removed.

Lehigh University is working with NETL to condense the water and acid in flue gas in a series of six condensing heat exchangers. The test apparatus consists of a long rectangular duct with both smooth and finned tubes. The hot flue gas enters the duct and cooling water flows through the six sections of tubes in a counterflow direction, from hot to cold. The acids are removed in the upstream heat exchangers, and water in the cooler downstream ones. An oil-fired test was conducted first to test the concept, followed by a test in a coal-fired boiler.

At a large scale, the conducting heat exchangers should improve plant efficiency by recovering latent and sensible heat from the flue gas. In testing last July, the coal-fired boiler was successful in capturing 50–72 percent of water in the flue gas, with capture efficiency highly dependent on the temperature of cooling water used (75–100 °F). The heat exchangers removed 60 percent of the mercury. While the oil-fired test condensed almost all of the acid in the first heat exchanger, the coal-fired test required three heat exchangers to complete condensation. Contributing to this would be the higher soot content of the oil flue gas; much of the soot in the coal flue gas was removed by the ESP upstream of the heat exchanger.

SPX has now begun testing the Air2Air™ in an actual power plant operation. A year of data collection is scheduled to measure performance. Lehigh will begin testing finned tube heat exchangers in a coal-fired flue gas slip stream. The data will be analyzed and potential reductions in heat rate will be calculated. ■

An SPX cooling tower equipped with Air2Air™ technology



Schematic of SPX's Air2Air™ process

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storage technology to multiple plants (at least 300 MW in size) that would be operational by 2015. ◆

DOE's **Office of Fossil Energy (FE) has requested $648 million for coal-related funding** in FY 2009, representing the largest budget request for coal RD&D in over 25 years. When combined with private sector contributions, it leverages the nearly $1 billion investment in Clean Coal Technology. An important area of emphasis will be on full-scale integration of IGCC and carbon capture and storage technologies, resulting in near-zero emissions from coal-fired power plants. For the current fiscal year (FY 2008), FE is operating under a coal budget of $406.5 million. For details see www.fe.doe.gov/aboutus/budget/ ■

Fabricating USC Boiler Components

The Department of Energy's National Energy Technology Laboratory (NETL) is working with two consortia of major U.S. boiler and turbine manufacturers to develop the materials necessary for the construction of highly efficient, coal-fired ultrasupercritical (USC) power plants that operate with steam temperatures up to 760 °C (1,400 °F) and steam pressures up to 35 MPa (5,000 psi). The Boiler Consortium previously identified six advanced high temperature, corrosion-resistant materials — 740, 230, 617, HR6W, SUPER304H, and SAVE12 — for superheaters/reheater tubing and heavy section applications based on creep strength and allowable stress considerations. (See *Clean Coal Today*, Fall 2005). For USC power plant construction, these unique materials will have to be fabricated into high quality boiler components that perform effectively.

The ability to fabricate alloys relates to ease with which they can be formed, machined, joined, heat treated, or otherwise processed to produce a component with the desired shape, properties and characteristics. In fabricating alloys for the construction of fossil-fueled utility boilers, the effects of various metalworking processes on alloy microstructure and properties can have a significant impact on boiler design and configuration, operating service life, total cost, and reliability.

Boiler Consortium participants have been successful in developing metal fabrication processes for selected high temperature alloys to produce advanced USC boiler components. This subtask has now been completed, and a topical report documenting the results was issued by the Electric Power Research Institute in February 2008 (www.epri.com). Completion of this important work is another significant step toward the realization of cleaner, more efficient energy production with USC coal-fired power plants.

Technical Approach

A fundamental objective of the USC Materials Project was to identify any limitations on fabricating the selected USC alloys. The technical approach included obtaining metallurgical and processing information about the alloys, conducting controlled strain/recrystallization/precipitation studies of each one, and performing typical fabrication trials with each in North American boiler manufacturing facilities. Fabrication trials included tube U-bending, tube swaging, machining, cutting, boring, grinding, welding, and thermal treatment. Effects on microstructure and alloy properties were also determined. As part of this effort, processed USC materials were provided to researchers at Oak Ridge National Laboratory who conducted tests to determine the effects of fabrication on the material design properties.

To determine the response of the USC alloys to mechanical deformation and thermal treatment, specimens of USC materials with a known amount of strain were measured for hardness, and then thermally exposed at selected temperatures and times that represent both post-fabrication heat treatment options, as well as boiler operating conditions. Following exposure, the hardness of these specimens was measured, and microstructure characterized.

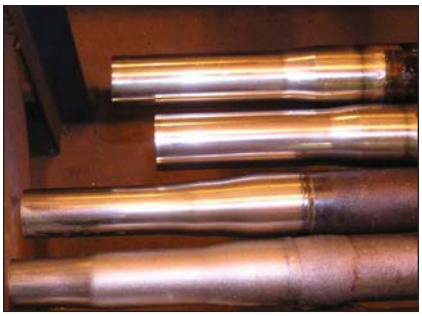
Fabrication Trials

Using 2-inches outer diameter (OD) by 0.400-inch metal width (MW) alloy tubing, cold U-bends were produced successfully for each of the six alloys. The strain levels for the U-bending trials were specifically chosen to "bracket" the cold-forming strain limits typical of boiler superheater design, and to meet ASME Boiler & Pressure Vessel code.

Three cold U-bends on alloy 230 produced at a North American manufacturing facility. These bends correspond to calculated outer fiber strain levels (at the extrados) of 13.3%, 20%, and 33.3%

Because of the high work hardening rate of some of the alloys, tube specimens that had been swaged to 1.75 inches OD were subsequently heat treated before making further reductions. After annealing, the 1.75-inch OD specimens were then easily swaged to 1.5 inches OD.

Other fabrication processes, including machining, cutting, boring, grinding, welding, and thermal treatment, were also investigated. In almost all cases, the USC alloys were found to have satisfactory fabrication processing characteristics. While the machining of such alloys as a group is considered somewhat difficult, it was concluded that they can usually be machined using conventional methods at standard rates.



2-inch OD tube specimens (photo, left) that were sequentially swaged to 1.75-inches OD and to 1.5-inches OD (photo, right)

FABRICATION DEMONSTRATION

Several of the fabrication processes that were developed in the USC Materials Project were successfully demonstrated through construction of boiler components. The header mockup, shown in the photo below, was constructed to demonstrate successful implementation of these fabrication processes. Thick section (2 inches) alloy 617 plate was cold-formed to produce the header body, and submerged arc welding and shielded metal arc welding were used to make the longitudinal and circumferential seams. After bending, alloys 617 and SUPER304H tubes were butt-welded and then joined to the header using both shielded metal arc and gas tungsten arc welding processes. The end of one tube was additionally swaged to illustrate how diameter changes could be accommodated. Drilling, turning, boring, and sawing processes were utilized to fabricate the individual pieces.

BENEFITS

The fabrication of both pressure parts and non-pressure parts for USC boiler systems will involve a variety of manufacturing methods and skills, as well as almost every metal-working and metal-forming process. As part of the USC Materials Project, a technical plan has been successfully executed to assess and characterize the fabricability of the six high-temperature, corrosion-resistant alloys selected for building USC power plants. The information gained in this work will help to understand the behavior of these advanced alloys when subjected to conventional boiler fabrication processes. Using the knowledge gained, fabricators will be able to successfully produce dependable components from the selected materials for advanced USC boiler systems. ■

Demonstration article representing a header assembly and illustrating the fabrication processes that were successfully developed in the USC Materials Project

... "CO_2 Capture" continued

associated with air separation. The OTM system utilizes the combustion reaction on the fuel side of the membrane to create a very low oxygen partial pressure compared to the pressure on the air side of the membrane. This difference in chemical potential drives oxygen through the membrane without the need for additional air compression. The current project is focusing on the development of a robust OTM module that will be able to produce the required oxygen flux while maintaining structural integrity during coal-fired operations. A high pressure reactor is being designed and constructed in order to test the functionality of the OTM materials in the presence of coal-based fuel gas. Another project task is focused on determining the optimum configuration for integration of OTMs in a coal-based power system. ■

UPCOMING EVENTS

May 5 – 8, 2008
Seventh Annual Conference on Carbon Capture and Sequestration
Sponsor: DOE/NETL
Location: Pittsburgh, PA
Phone: 202-296-2814 ext. 109
Toll Free: 877-303-7367
E-mail: carbonsq@exchangemonitor.com
Web site: www.carbonsq.com

September 29 – October 2, 2008
Twenty-fifth Annual International Pittsburgh Coal Conference
Host: University of Pittsburgh Swanson School of Engineering
Location: Pittsburgh, PA
Phone: 412-624-7440
E-mail: pcc@engr.pitt.edu
Web site: www.engr.pitt.edu/pcc

RTI's Warm Gas Cleanup Gives Boost to Gasification

DOE and industry have been partnering since 1999 to develop technologies for warm synthesis gas (syngas) cleanup. While a variety of technologies are showing promise, the most advanced to date — almost ready for pre-commercial demonstration — are two technologies co-sponsored by NETL and the Research Triangle Institute (RTI). The High Temperature Desulfurization System (HTDS) focuses on removing sulfur from the syngas, while the Direct Sulfur Recovery Process (DSRP) is designed to convert the recovered sulfur compounds into a pure sulfur product. Both sets of tests were just completed at the Eastman Chemical plant in Kingsport, TN.

RTI successfully tested the HTDS for more than 3,000 hours on a coal gasifier slipstream this past summer. Testing employed a General Electric quench gasifier fed with high-sulfur Eastern coals. RTI's HTDS unit consists of two integrated transport reactors (a sulfur absorber and a sorbent regenerator) which have achieved stable operation and ease of control that exceeded the most optimistic expectations. RTI used its highly reactive and attrition-resistant RTI-3 sorbent, which won an R&D 100 award in 2004. Use of the RTI-3 sorbent in the HTDS system resulted in syngas sulfur concentrations as low as 0.5 ppmv from a feed stream typically containing about 8,000 ppmv sulfur (H_2S+COS), without requiring a separate COS hydrolysis step. Test conditions ranged from 700–900 °F and from 300–600 psig.

RTI developed the DSRP to operate in concert with the HTDS to treat the SO_2 in the regeneration tail gas, at similar temperatures and pressures. In the DSRP, SO_2 is partially reduced (using a small slipstream of synthesis gas) to elemental sulfur. Testing of the HTDS included over 100 hours of integrated operation with the DSRP; the DSRP successfully converted over 90% of the SO_2 into elemental sulfur.

Based on the Eastman pilot-scale data, a detailed techno-economic evaluation of the HTDS and DSRP technologies was performed by Nexant. The evaluation showed that in comparison to a General Electric reference plant (with Selexol) – for a 600 MW (nominal) IGCC plant – using the HTDS with DSRP could increase the overall thermal efficiency by 3.6 percent points (from 37.6 percent HHV to 41.2 percent HHV) over conventional technologies. It could also reduce the overall capital cost of the entire IGCC system by $269/kW over current technology, while reducing the cost of electricity by 9.6 percent.

The next envisioned development step for the sulfur-related processes at HTDS and DSRP is a 50 MWe demonstration facility. An engineering and design package for a 50 MWe facility has been completed by Mustang Engineering, and RTI is in active negotiations to find a committed industrial partner for this next development step towards bringing this compelling technology to the commercial marketplace. ■

Pilot-scale DSRP system processes about 200 standard liters per minute of regeneration tailgas. The facing section shows the preheating system for the regeneration tailgas and syngas.

INTERNATIONAL INITIATIVES

NETL SIGNS TWO AGREEMENTS WITH BRAZIL

A long-term relationship and common R&D interests have resulted in two Memorandum of Understanding (MOU) between the National Energy Technology Laboratory (NETL) and the Pontifical Catholic University of Rio Grande do Sul (PUC) and the Brazilian Coal Association (BCA).

In 2007, the PUC established the Center of Excellence for Carbon Storage Research (CEPAC) in partnership with Petrobras, Brazil's quasi state-owned energy company. Last October, PUC organized — with Petrobras' sponsorship — a Capacity Building Workshop for Emerging Economies, under the auspices of the Carbon Sequestration Leadership Forum. The inauguration of CEPAC and the signing ceremony for the MOU were conducted on the sidelines of this event. The document was signed by Dr. Anthony Cugini, NETL's Director of the Office of Research and Development, representing Mr. Carl O. Bauer, NETL's Director. Dr. Joaquim Clotet, PUC's President was the signatory on the Brazilian side.

Brazilian coal officials are present during the 2007 signing of the NETL-BCA MOU. Santa Catarina's Governor, Luiz Henrique da Silveira (center) presides over the ceremony while Carl Bauer (second from his right) and Fernando Zancan (on his left) sign the document

The MOU anticipates cooperative work in the development of clean technologies for the use of fossil fuels, coal gasification technologies and related areas. Incomplete data (1982 being the most recent coal survey) shows Brazil has 32 million metric tons of high-sulfur, high-ash, subbituminous coal – 87 percent in Rio Grande do Sul and 13 percent in Santa Catarina. The initial activities under the MOU include short-term assignments of CEPAC researchers at NETL and a project on underground coal gasification. This project will be conducted by NETL and CEPAC in conjunction with Petrobras and the Lawrence Livermore National Laboratory.

A second MOU was signed at the Governor's Palace in Florianopolis – Santa Catarina's capital city – by Carl Bauer; the Honorable Luiz Henrique da Silveira, Governor of the State of Santa Catarina; and Fernando Zancan, President of the Brazilian Coal Association. Cooperation with Santa Catarina has been underway since 1995, when NETL and the Office of Fossil Energy's Office of Coal Import/Export (now the Office of Clean Energy Collaboration) worked with the State Coal Producer's Association to develop a new coal policy and regulatory framework for the Brazilian central government.

The BCA and its partners are planning a R&D laboratory in Santa Catarina focused on coal gasification and carbon sequestration. BCA has invited two NETL scientists to come to Santa Catarina in Spring 2008 to conduct a one-week course on coal gasification. The NETL scientists will also have the opportunity to meet with members of the Brazilian Gasification Network.

Other activities on the horizon include a potential MOU between NETL and Petrobras to encompass R&D in both coal and other fossil energy sources.

NETL AND KIER TO COOPERATE ON COAL TECHNOLOGY R&D

This past September, the Department of Energy's National Energy Technology Laboratory (NETL) signed an Implementing Arrangement with the Korea Institute of Energy Research (KIER). The agreement enables cooperation on a broad range of fossil energy and related environmental technologies and will encompass joint R&D and the exchange of personnel and equipment, joint publications, meetings, and workshops. A joint symposium is to be held every two years alternating between the two countries, with the first one being planned for 2008. Since execution of this agreement, two web seminars between NETL and KIER have been convened to develop work plans and initiate cooperation

Dr. Moon-Hee Han, President of KIER (left) and Dr. Anthony V. Cugini, Director of NETL's Office of Research and Development (right) at the signing ceremony

With limited domestic energy resources, Korea is almost entirely dependent on imports to meet its energy demands. Korea is the fifth-largest net importer of oil in the world, and a significant importer of coal and liquefied natural gas. Oil makes up the greatest share of Korea's total energy consumption, though that share has been declining gradually in recent years. Oil supplied 50 percent of Korea's total energy consumption in 2004, compared with 65 percent in 1994. This decline reflects faster growth in natural gas consumption and increased use of coal. Coal is Korea's second-largest energy source, supplying 24 percent of its primary energy consumption needs in 2004, followed by modest contributions from nuclear power (14 percent) and natural gas (12 percent). Hydropower and other renewable energy sources make up a small fraction of Korea's total energy consumption mix.

KIER – a Korean Ministry of Science and Technology (MOST) organization, and the primary institute in Korea specializing in energy research – celebrated its 30th anniversary by convening a two-day International Energy Forum in September 2007. NETL participated in this Forum, during which the Implementing Arrangement with KIER was signed. KIER is located in Daeduk Science Town, near Daejon. Established in 1972, Daeduk Science Town is a planned research community housing over 50 organizations, including government-supported institutes, and industry and university research laboratories.

KIER boasts one of the most advanced integrated gasification combined-cycle research facilities in the world. Korea is also making headway in carbon sequestration, and is an active member of the Carbon Sequestration Leadership Forum. KIER has been carrying out sequestration projects through MOST's 21st Century Frontier R&D Program, to develop strategic technologies by 2010.

Korea is also an active member of the Asia Pacific Economic Cooperation (APEC) and the Asia Pacific Partnership on Clean Development and Climate (APP), two organizations where DOE's Office of Fossil Energy plays a lead role. The NETL-KIER cooperation has been approved as an official project under the APP Cleaner Fossil Energy Task Force.

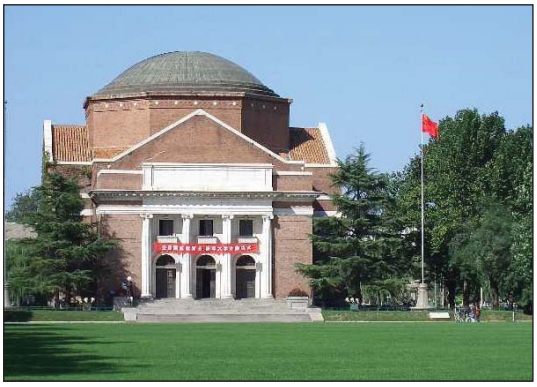
The new Implementing Agreement formally reestablishes the technology transfer cooperative laboratory relationship that existed between NETL (and its predecessor organizations) and KIER from 1982 to 1999.

ESTIMATING MERCURY EMISSIONS IN CHINA

In 2006, scientists at Argonne National Laboratory (ANL) and Tsinghua University in Beijing, China developed a new model for estimating mercury emissions from coal-fired power plants in China. The collaborative effort was funded by the DOE Office of Fossil Energy, U.S. Environmental Protection Agency (EPA), and Chinese government organizations. In 2007, stochastic simulation capability was incorporated into the model to address uncertainties and variability in underlying data sets as to the mercury content in coal analyses, and uncertain emission factors based on limited mercury stack testing in Chinese utility boilers. Total mercury emissions from all manmade sources in China were estimated at 696 tons/year for 2003 – or about 5.8 times that of the United States. Mercury sources in China include: coal-fired power plants; industrial boilers and cogeneration facilities; coke, cement and chlor-alkali plants; municipal and hazardous waste combustors; non-ferrous smelting; artisinal gold mining, and residential stoves. Coal use in Chinese power plants could reach over 1,300 million tons/year by 2010 and over 1,700 million tons/year by 2020, compared to 800 million tons in 2003.

The ANL/Tsinghua modeling study shows that China's mercury emissions from coal-fired power plants exceed those for coal-fired utilities in the United States. ANL/Tsinghua's best estimate for total annual mercury emissions from coal-fired power plants in China in 2003 is 90.5 tons/yr, with an uncertainty range of 57.1–154.6 tons/year within a 90 percent confidence range. U.S. mercury emissions have been comprehensively examined during the last decade – with literally thousands of experimental measurements in relevant datasets. This has resulted in the commonly accepted value of 48 tons/yr annual mercury emissions from U.S. coal-fired utilities for reference year 1999. This level has been established as a regulatory baseline.

Future ANL/Tsinghua research will reduce the uncertainty in China's mercury emissions estimates as more experimental data becomes available to better quantify emissions factors for various configurations of Chinese coals, boiler designs, and control equipment. Future model refinements will also allow for forecasts based on adopting different mercury control strategies, including co-benefit approaches. Researchers will be able to evaluate scenarios whereby installing pollution control equipment for SO_2 and NO_x might result in significant mercury reductions.



The Grand Auditorium at Tsinghua University

Mercury and other emissions in China will also be explored at the planned September 2008 "U.S./China Multipollutant Control Workshop for Stationary Sources in China" scheduled tentatively for Hangzhou. The workshop would support the Energy and Environmental Technologies Annex of an R&D protocol agreement with China first signed in 2000, as well as U.S. participation in the Asia Pacific Partnership (APP) on Clean Development and Climate. The upcoming workshop builds on the success of earlier DOE/EPA-sponsored single pollutant workshops held in China. It will be co-organized and supported by EPA, China Ministry of Science and Technology (MOST), and China State Environmental Protection Administration (SEPA). The workshop will provide an active forum to discuss research findings and needs of both countries, with emphasis on identifying cost-effective solutions. ■

ACTIVE CCT DEMONSTRATION, PPII, AND CCPI PROJECT STATUS

CCT DEMONSTRATION STATUS

Kentucky Pioneer Energy (KPE), LLC – *Kentucky Pioneer Energy Project*. The Cooperative Agreement has expired. The Final Report has been received and accepted. (Trapp, KY and West Terre Haute, IN)

TIAX, LLC (formerly Arthur D. Little, Inc.) – *Clean Coal Diesel Project*. The Post Project Assessment has been completed. (Fairbanks, AK and Beloit, WI)

PPII STATUS

Universal Aggregates, LLC – *Commercial Demonstration of the Manufactured Aggregate Processing Technology Utilizing Spray Dryer Ash*. The Cooperative Agreement for this project expired on December 31, 2006. The Final Report has been approved and posted on the NETL Clean Coal Compendium website. The Post Project Assessment is under review and the project is in close-out. (King George, VA)

CONSOL Energy Inc. – *Greenidge Multi-Pollutant Control Project*. Testing of the emissions control systems installed in Unit 4 of the AES Greenidge plant in Dresden, NY, has verified that the plant meets the guaranteed performance parameters warranted by the technology suppliers. A series of performance tests are being conducted to measure the longer-term effectiveness of the emissions control systems under a variety of operating conditions. The project team is also working to resolve a recurring problem of ash deposits fouling the selective catalytic reduction system, which necessitates premature outages to clean the catalyst. (Dresden, NY)

CCPI STATUS

MEP-I LLC (Excelsior Energy Inc.) – *Mesaba Energy Project*. Excelsior's application for pre-construction site environmental permits is proceeding through the Minnesota Public Utilities Commission (MPUC) approval process. The state-mandated contested case hearings were held January 29–30, 2008, with the administrative law judge report and recommendation to the MPUC due in April 2008. The permit application included requests for a large electric power generating plant site permit and routing permits for a high voltage transmission line and natural gas pipeline. Also included was Excelsior's request for air and water appropriation permits. The public comment period on the Draft Environmental Impact Statement (EIS), prepared jointly by the U.S. DOE and the Minnesota Department of Commerce, ended on January 11, 2008. Minnesota has an EIS-equivalent requirement associated with the site environmental permitting process pursuant to the state Power Plant Siting Act. The MPUC is also considering Excelsior's petition for approval of a Power Purchase Agreement (PPA) with Xcel Energy, per the state Innovative Energy Project and Clean Energy Technology statutes. The MPUC has not issued a final ruling but has directed Excelsior and Xcel to enter into a dialogue with other Minnesota utilities to determine their interest in participating in the PPA. (Itasca & St. Louis Counties, MN)

NeuCo, Inc. – *Integrated Optimization Software*. NeuCo has successfully completed the operational phase of the CCPI Round 1 Project, "Demonstration of Integrated Optimization Software at the Baldwin Energy Complex." Project goals included reducing NO_x and increasing efficiency and availability. NO_x and ammonia consumption have been reduced to a point significantly below the target values. Substantial heat rate and availability benefits were also attained. An analysis is currently being done to determine more precisely the magnitude of those benefits. (Baldwin, IL)

We Energies – *TOXECON™ Retrofit for Mercury and Multi-Pollutant Control*. We Energies is optimizing the ESP in order to determine its effect on mercury removal in the downstream TOXECON baghouse. By adjusting the ESP, additional unburned carbon may be made available to the baghouse for possible mercury capture. In addition, alternative mercury sorbents will be injected as well as co-injection of high Loss-On-Ignition (LOI) ash obtained from Units 5 & 6 of the We Energies Presque Isle Plant. Full-scale re-injection of this ash upstream of the TOXECON™ baghouse will be used to supplement Powdered Activated Carbon (PAC) injection to determine if a lower PAC injection rate can still achieve >90% mercury removal. Milling of both ash and PAC to reduce particle size will also be tested. Smaller particle size would provide better initial contact, but may affect ash handling and/or pressure drop across the baghouse. Another series of tests involving injection of two alternative sources of activated carbon are underway. One source of PAC, provided by ADA-ES, originates from Asia and will be treated, prepared, and shipped from a U.S. facility. The second source is from Europe and will be provided by Norit Americas. Testing should be completed by April 2008. (Marquette, MI)

Western Greenbrier Co-Generation (WGC), LLC – *Western Greenbrier Co-Production Demonstration Project*. The preliminary process design is completed. WGC continues to finalize key project areas including the plant engineering/procurement/construction, and operations and maintenance contracts. Arrangements are in progress for sale of power to support a public tax-exempt bond sale. A National Environmental Policy Act (NEPA) Record of Decision (ROD) is expected this spring, following release of the final EIS in November 2007. (Rainelle, WV)

Great River Energy (GRE) – *Lignite Fuel Enhancement*. GRE has completed the design of the integrated full-scale dryer system. GRE is building eight dryers, four dryers for Unit 2 under the DOE cooperative agreement and four dryers for Unit 1 with its own funds. The three-section outer shells have been fabricated for all eight dryers and delivered to the Coal Creek Station. GRE has initiated assembly of the dryer shells, which will be later installed in the dryer area, and then fitted with dryer internals, such as heating coils, air distributions systems, etc. GRE is also upgrading the front-end coal handling system. A new crusher house is being built. Foundations have been poured for the dryer area and steel structures are being built. Major overhauls of boiler, turbine, and scrubber are planned during the Unit 1 outage from mid-March through May 2008. (Underwood, ND)

Pegasus Technologies – *Mercury Specie and Multi-Pollutant Control*. NETL approved project continuation to Budget Period 2 beginning December 15, 2007 and ending December 31, 2008. Budget Period 1 included successful sensor installation and baseline testing. During Budget Period 2, parametric testing will be performed to enable development of neural network optimization algorithms for plant-wide control. This will minimize mercury and other emissions, and increase efficiency. Longer term operational demonstration of plant-wide optimization will take place during Budget Period 3 beginning in January 2009. The project will result in the host site (NRG Texas Limestone Plant) having the most advanced network of integrated optimization systems ever applied in the industry. The Pegasus NeuCo technology provides plant operators the ability to assess detailed plant operating parameters which affect mercury capture efficiency as well as overall heat rate, and ESP particulate removal and flue gas desulfurization efficiencies. The technology, once demonstrated, should have broad application to existing coal fired boilers and provide positive impact on the quality of saleable by-products such as fly ash. (Jewett, TX)

Southern Company Services, Inc. – *Demonstration of a 285-MW Coal-Based Transport Gasifier*. On November 14, 2007 Southern Company and Orlando Utilities Commission announced cancellation of the Orlando Gasification Project because of uncertainty surrounding potential state regulations relating to greenhouse gas emissions. Southern Company requested that DOE give them the opportunity to evaluate other potential sites at which to demonstrate the Transport Gasifier technology. (Orlando, FL) ■

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