THE POWER SYSTEMS DEVELOPMENT FACILITY AT WILSONVILLE, ALABAMA

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INTRODUCTION

One of the Morgantown Energy Technology Center's (METC's) goals is to: "Commercialize Advanced Power Systems with improved environmental performance, higher efficiency, and lower cost." Advanced coal-based power generation systems include Integrated Gasification Combined Cycle (IGCC), Pressurized Fluidized-Bed Combustion (PFBC), and Integrated Gasification/Fuel Cell systems. The strategy for achieving this goal includes: (1) Show the improved performance and lower cost of Advanced Power Systems through successful Clean Coal Technology demonstration projects, (2) Build and operate Technology Integration Sites in partnership with U.S. Industry (these sites will resolve key technology issues and effect continuous product improvement, and these partnerships result in leveraging of research and development (R&D) funds), and (3) Set up partnerships with other agencies and organizations such as Electric Power Research Institute (EPRI) to leverage R&D funds and skills.[1]

Demonstration of practical high-temperature particulate control devices (PCD's) is crucial to the evolution of advanced, high-efficiency coal-based power generation systems. There are stringent particulate requirements for the fuel gas for both turbines and fuel cells. In turbines, the particulates cause erosion and chemical attack of the blade surfaces. In fuel cells, the particulates cause blinding of the electrodes. Filtration of the incoming, hot, pressurized gas is required to protect these units. Although filtration can presently be performed by first cooling the gas, the system efficiency is reduced. Development of high temperature, high pressure, is necessary to achieve high efficiency and extend the lifetime of downstream components to acceptable levels.

THE POWER SYSTEMS DEVELOPMENT FACILITY - A TECHNOLOGY INTEGRATION SITE

The Power Systems Development Facility (PSDF) combines a number of pilot-scale test facilities at a single site to reduce the overall capital and operating cost compared to individual stand-alone facilities. Combining all of these pilot-scale facilities in a new 60x100 foot structure and sharing resources common to different modules, such as coal preparation, are estimated to save nominally $32 million over the cost of separate facilities. The PSDF will be located 40 miles southeast of Birmingham, Alabama, at Southern Company's Clean Coal Research Center in Wilsonville, Alabama.

The objective is to establish a flexible test facility that can be used to develop advanced power system components such as high-temperature, high-pressure particle control devices, evaluate advanced power system configurations, and assess the integration and control issues of these advanced power systems. The facility will also support the Department of Energy (DOE) Clean Coal Program.

The PSDF will consist of five modules. Two of the modules will produce particulate-laden gas, an Advanced Pressurized Fluidized-Bed Combustion (APFBC) module and an Advanced Gasifier module. The PCD's will be in a Hot-Gas Cleanup module, and there will also be a Compressor/Turbine module, and a Fuel Cell module. Four separate PCD technologies will be tested at the facility using the gas from the two gas-producing modules.

The PSDF project team is led by Southern Company Services (SCS) and is comprised of M. W. Kellogg, Foster Wheeler, Westinghouse, Allison, Southern Research Institute (SRI), and several developers of PCD's. The facility design reflects the Power System's R&D needs as identified by DOE and EPRI. The involvement of these diverse private sector organizations will ensure that the duration, scale, and results of the PSDF test program will be sufficient to gain private sector acceptance.

THE ADVANCED GASIFIER

The advanced gasifier module uses M. W. Kellogg's transport reactor technology (Figure 1). The transport reactor was selected for the gas generator due to its flexibility to produce gas and particulates under either pressurized combustion (oxidizing) or gasification (reducing) conditions for parametric testing of PCD's over a wide range of operating temperatures, gas velocities, and particulate loadings.[2] The transport reactor is sized to process 1814 kg/hr (2 tons/hr) of coal to deliver .472 actual m^3/s (1,000 acfm) of particulate laden gas to the PCD inlet over the temperature range of 538 to 982°C (1,000-1,800°F) at 1269-1951 kPa (184-283 psia). Two PCD's will be tested on the transport reactor, at alternate times. Short term (500 hour) parametric tests will be conducted using the transport reactor.

THE ADVANCED PRESSURIZED FLUIDIZED-BED COMBUSTION SYSTEM (PFBC)

The PFBC uses Foster Wheeler's second-generation PFBC technology (Figure 2).[3] The advanced PFBC system consists of a pressurized 1172 kPa (170 psia) carbonizer at 871-982°C (1600-1800°F) to generate .708-.802 actual m^3/s (1500-1700 acfm) of low-Btu fuel gas and a circulating pressurized fluidized-bed combustor (CPFBC), operating at 1034 kPa (150 psia) and 871°C (1600°F), which generates 2.93 actual m^3/s (6,200 acfm) of combustion gas. The coal feed rate to the carbonizer will be 2495 kg/hr (2.75 tons/hr). A Ca/S molar ratio of 1.75 is required to capture 90 percent of the sulfur in the carbonizer/CPFBC. Char which is not converted to gas in the carbonizer is transferred hot to the CPFBC. The gases exiting from the carbonizer and the CPFBC will each be filtered hot in separate PCD's to remove particulates prior to entering the topping combustor.

THE TOPPING COMBUSTOR/GAS TURBINE

A topping combustor will be used to raise the inlet temperature of the gas turbine to 1288°C (2350°F) (Figure 3). The higher turbine inlet temperature will raise the net plant efficiency of advanced PFBC systems to 45 percent, while maintaining low levels of NOx. To withstand the expected severe conditions in the topping combustor application, a Multi-Annular Swirl Burner developed by Westinghouse has been chosen to combust the gases from the carbonizer and increase the temperature of the CPFBC flue gases, consistent with turbine inlet temperatures offered on advanced commercial high-efficiency turbines.[4] At the PSDF, however, the topping combustor flue gas must then be cooled to 1077°C (1970°F) in order to meet the temperature limitation of the small, standard gas turbine (Allison Model 501-KM) which will be used to power both the air compressor and an electric generator to produce about 4 MW of electric power.

PARTICLE FILTERS

At the PSDF, PCD's will be tested at temperatures, pressures, and other gas conditions characteristic of a number of gasifiers and PFBC's.[5] The critical issues include integration of the PCD's into the advanced power systems, on-line cleaning, chemical and thermal degradation of components, fatigue and other modes of physical failure, blinding, collection efficiency as a function of particle size, and scale-up issues.

The hot gases coming off the transport reactor, carbonizer, and CPFBC will be cleaned by different PCD's. The particulate control devices to clean gases from both the Foster Wheeler Carbonizer and Kellogg's transport reactor are the same size, to allow for the possibility of interchanging these three PCD's. One larger PCD will be tested on the combustion gases from the CPFBC.

A total of four PCD's from three developers have been selected for initial testing at the PSDF. Each of the PCD's is expected to maintain outlet particulate loadings of less than 20 ppmw with no more than 1 percent of the particles larger than 10 microns and no more than 10 percent of the particles larger than 5 microns to protect the gas turbine from erosion. The baseline pressure drop of the PCD's is expected to be less than 24.9 kPa (100 inches of water) with the maximum pressure drop less than 49.8 kPa (200 inches of water). The commercial version of the PCD's should have a temperature drop of less than 5.6°C (10°F) but in the PSDF a target of 33°C (60°F) has been set because of the smaller size of the PCD's.

The two PCD's which will be tested initially on the transport reactor are described below. They will operate at .472 actual m^3/s (1000 acfm) gas flow rates at 538-982°C (1000-1800°F), 1379-2068 kPa (200-300 psia), and 4000-16000 ppmw particle loading under both oxidizing and reducing conditions.

For one of the transport reactor/carbonizer filters, Westinghouse will use a vessel which can be fitted with ceramic candles, cross flow filters, CeraMem ceramic filters, or 3M ceramic bag filters in a tiered arrangement (Figure 4). The filter vessel will be a refractory-lined, coded, pressure vessel. The filters will be individual filter elements attached to a common plenum and discharge pipe to form clusters. Clusters of filters will be supported from a common high-alloy, uncooled, tubesheet. Each plenum of the filter will be cleaned from a single pulse nozzle. The number and size of the filters required will vary. For instance, 20 CeraMem filters or 80 candle filters would be needed.

The other filter on the transport reactor will be the Combustion Power Company granular-bed filter (Figure 5). The gas is introduced into the center of a downward moving-bed of granules, 6 mm spheres mostly made of aluminum oxide and mullite, which serve as the filter media to remove the particles from the gas. The gas reverses direction and moves counter current to the direction of the filter media to leave the pressure vessel. Clean media is constantly introduced from the top of the vessel. The particulate-containing media is removed from the bottom of the filter vessel and pneumatically conveyed and cleaned in a lift pipe. At the top of the lift pipe the particulate and clean media are separated in a disengagement vessel and the clean media is returned to the filter vessel. The transport gas and dust are cooled in a regenerative heat exchanger and the dust is removed in a baghouse. The transport gas is cooled in a water cooled heat exchanger and a mist eliminator, and then a boost blower is used to overcome the pressure drop in the system and the gas is reheated in the regenerative heat exchanger and recycled to the lift pipe.

Initial testing of a filter manufactured by Industrial Filter and Pump (IF&P) will be done on the PFBC carbonizer. The IF&P PCD will operate at .708-.802 actual m^3/s (1500 - 1700 acfm) gas flow rates at 871-982°C (1600 - 1800°F), 1172 kPa (170 psia), and 11,000 ppmw particle loading. The IF&P filters are ceramic candles made of low density aluminosilicate fiber and silica with an alumina binder and have densified monolithic end caps and flanges. The tubesheet is made of the same densified material. The 152.4 cm (60 inch) diameter, refractory-lined filter vessel will contain 78 candles arranged in 6 groups of 13 each for pulse cleaning. Individual jet pulse nozzles are provided to each candle. An Enhancer™ consisting of an orifice-type device at the outlet of the candle increases the pulse intensity and also serves as a fail-safe plug in case of a candle failure.[6]

A larger Westinghouse filter will be tested on the PFBC combustor.[7] The Westinghouse PCD will operate at 2.93 actual m^3/s (6200 acfm) gas flow rate at 871°C (1600°F), 1034 kPa (150 psia), and 15,000 ppmw particle loading. This filter will contain six clusters of ceramic candles in a 3.11 m (10.2 foot) outside diameter, refractory-lined pressure vessel. Two clusters of filters are attached to a common plenum and discharge pipe and each cluster is cleaned from a single pulse nozzle source. The three plenums of filter clusters are arranged vertically in the filter vessel. The cluster concept allows replacement of individual filters and provides a modular approach to scale-up.

THE FUEL CELL

Plans are being made to eventually integrate a Fuel Cell module with the transport gasifier. Molten carbonate fuel cell and solid-oxide fuel cell concepts are under consideration for use at the PSDF. The capacity of the fuel cell to be tested initially is 100 kW. This will be accomplished by utilizing EPRI's 100 kW Fuel Cell Test Skid at the facility. Provision has been made in the site layout of the PSDF to phase in a multi-MW fuel cell module with commercial stacks utilizing more than 80 percent of gases from the transport gasifier. At a multi-MW scale, testing can begin to address integration issues and overall plant performance for integrated gasification/fuel cell systems.

CURRENT STATUS OF THE PSDF

Environmental approvals for the PSDF were received in August 1993. Site preparation was completed in December 1993. All of the technologies have been selected and contracts have been signed. Detailed design is nearing completion and equipment fabrication is underway. Construction of the process tower began in mid November 1994.

SCHEDULE

The project will be completed in four Phases. Phase I, Conceptual Design, was completed in June 1992. Phase 2, Detailed Design, will be completed in the first quarter of 1995. Phase 3, Construction, began with site clearing in September 1993 after National Environmental Policy Act (NEPA) approval was obtained for the site. Construction of the transport reactor is scheduled for completion in September 1995 and for the APFBC in March of 1996. Phase 4, Operation, will begin as soon as shakedown and commissioning of each part of the facility is completed and will extend until December 1997 under the present agreement. A detailed test plan is being developed for the first operating phase. It is expected that additional operating phases will be funded, with the addition and/or substitution of other equipment and processes.

SUMMARY

The PSDF design incorporates advanced power system technology modules into integrated process paths. The size of the PSDF allows key component and system integration issues to be addressed at a reasonable engineering scale. Besides individual components testing, this design scheme allows testing and demonstration of integrated, advanced coal-based power generating systems. PCD's and components may be tested under long-term, realistic IGCC and advanced PFBC conditions.

Testing and development of components and systems under long-term, realistic conditions, are critical to the development of cleaner, more efficient, coal-fired power generating systems. The Power Systems Development Facility will play an important role in achieving these tests to support scale-up to demonstration plant sizes. This should have a significant impact on the design and cost of demonstration plants for the development of new technology in the future.

The result of this project will be a reduction or stabilization in the cost-of-electricity and a reduction in environmental emissions for new coal-based power plants.

REFERENCES

1. "METC Strategic Plan 1994," Morgantown Energy Technology Center, August 24, 1994.

2. Gbordzoe, E.A., Henningsen, G. B., and Campbell, W. M., "Development of a Pressurized Transport Gasifier by the M. W. Kellogg Company," Presented at the Ninth Annual Pittsburgh Coal Conference, Pittsburgh, PA, October 12-16, 1992.

3. McClung, James D., Froehlich, Robert E., Quandt, Michael T., "Design Update for an Advanced PFBC Facility at Wilsonville," Presented at the 1993 International Joint Power Generation Conference and Exposition, Kansas City, MO, October 17-22, 1993.

4. McClung, J. D., Kastner, C., Dellefield, R., and Sears, R., "Design and Operating Philosophy for an Advanced PFBC Facility at Wilsonville," Presented at the 12th International Conference on Fluidized-Bed Combustion, San Diego, CA, May 9-13, 1993.

5. Haq, Z. U., Pinkston, T. E., Sears, R. E., and Vimalchand, P., "The DOE/SCS Power Systems Development Facility," Presented at the Twelfth Electric Power Research Institute Annual Conference

on Gasification Power Plants, San Francisco, CA, October 27-29, 1993.

6. Moore, D. L., Vimalchand, P., Haq, Z. U., McClung, J. D., and Quandt, M. T., "PFBC Perspectives at the Power Systems Development Facility," Presented at the Electric Power Research Institute's Conference on Fluidized-Bed Combustion for Power Generation, Atlanta, GA, May 17-19, 1994.

FIGURE 1. TRANSPORT REACTOR

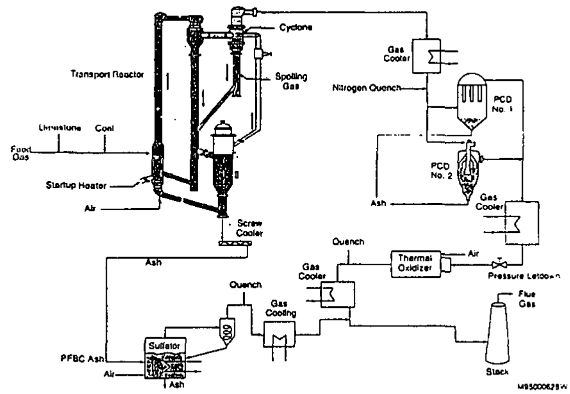

FIGURE 2. SECOND GENERATION PRESSURIZED FLUIDIZED BED COMBUSTION

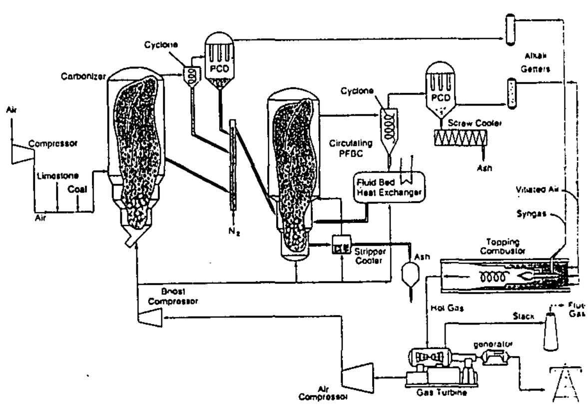

FIGURE 3. TOPPING COMBUSTOR

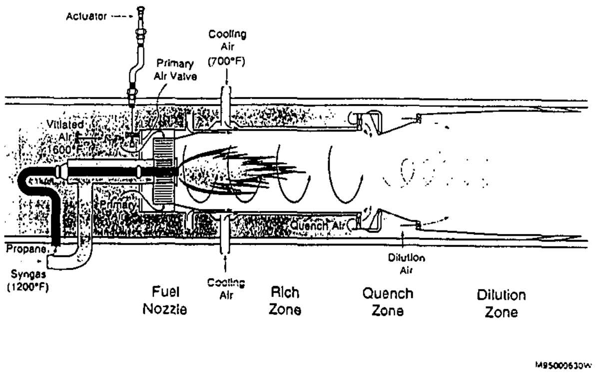

FIGURE 4. CANDLE FILTER

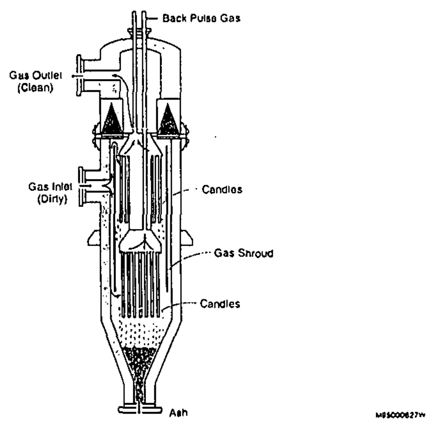

FIGURE 5. GRANULAR BED FILTER