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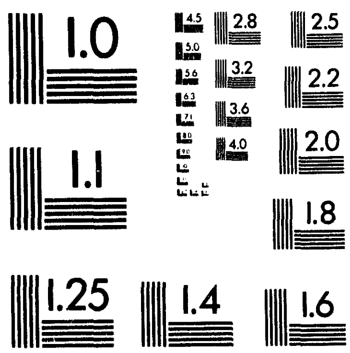

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PARTICLE FILTER TESTING AT THE POWER SYSTEMS DEVELOPMENT FACILITY, WILSONVILLE, ALABAMA

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INTRODUCTION

A part of the U.S. Department of Energy's objective which is carried out through the Morgantown Energy Technology Center (METC) is to do systems and component testing for the development of advanced coal-based power generation systems, including Integrated Gasification Combined Cycle (IGCC), Pressurized Fluidized Bed Combustion (PFBC), and Integrated Gasification/Fuel Cell (IGFC) systems. [1]

Combustion turbines or fuel cells are an integral part of these systems. However, 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, particulate control devices (PCDs) is necessary to achieve high efficiency and extend the lifetime of downstream components to acceptable levels. Demonstration of practical high-temperature PCDs is crucial to the evolution of advanced, high-efficiency coal-base power generation systems.

The intent at the Power Systems Development Facility (PSDF) 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 PSDF will consist of five modules, an Advanced Pressurized Fluidized-Bed Combustion (APFBC) Module, an Advanced Gasifier

Module, a Hot Gas Cleanup Module, a Compressor/Turbine Module, and a Fuel Cell Module. Four separate PCD technologies can be tested at the facility on the two gas-producing modules. The facility will also support the DOE Clean Coal Program.

The PSDF will be located 40 miles southeast of Birmingham, Alabama, at the Southern Company's Clean Coal Research Center in Wilsonville, Alabama.

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 at 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 project team is led by Southern Company Services (SCS) and is comprised of M. W. Kellogg, Foster Wheeler, Westinghouse, Allison, and Southern Research Institute (SRI) and several developers of PCDs. The facility design reflects the Power Systems R&D needs as identified by DOE and the Electric Power Research Institute (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.

PROJECT DESCRIPTION

The advanced gasifier module uses M. W. Kellogg's transport reactor technology, which was selected for the gas generator due to its flexibility to produce gas and particulate under either pressurized combustion (oxidizing) or gasification (reducing) conditions for parametric testing of PCDs over a wide range of operating temperatures, gas velocities, and particulate loadings.[2] The feed to the reactor consists of fine coal particles similar to entrained systems, while the reactor has the outlet gas temperature characteristics of a fluidized bed system. The transport reactor potentially allows the particle size distribution, solids loading, and characteristics of the particulate in the gas stream to be varied in a number of ways. The transport reactor is sized to process nominally 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 PCDs will be tested on the transport reactor, at alternate times. Short term parametric tests will be conducted using the transport reactor.

Plans are being made to integrate a fuel cell module with the transport gasifier. The capacity of the fuel cell to be tested initially is set at 100 kW. This will be accomplished by utilizing EPRI's 100 kW Fuel Cell Test Skid at the facility. Later, using a multi-MW fuel cell, testing can begin to address integration issues and overall plant performance for integrated gasification/fuel cell (IGFC) systems.

The advanced pressurized fluidized-bed combustor (PFBC) consists of Foster Wheeler's technology for second generation PFBC.[3] The advanced PFBC system consists of a high pressure 1172 kPa (170 psia), medium temperature 871-982°C (1600-1800°F) carbonizer to generate .708-.802 actual m^3/s (1500-1700 acfm) of low-Btu fuel gas. This is followed by a circulating pressurized fluidized bed combustor (CPFBC) (operating at 1034 kPa (150 psia), 871°C (1600°F)) generating 2.93 actual m^3/s (6,200 acfm) combustion gas. The design coal for the facility is Illinois No. 6 bituminous coal with a Powder River subbituminous coal as an alternate coal. Longview limestone, which is obtained locally near Wilsonville, has been chosen for initial testing. The coal feed rate to the carbonizer will be 2495 kg/hr (2.75 tons/hr). With the Longview limestone, a Ca/S molar ratio of 1.75 is required to capture 90-percent of the sulfur in the carbonizer/CPFBC. The gases exiting from the carbonizer and the CPFBC will each be filtered hot to remove particulates prior to entering a topping combustor.

The topping combustor will be used to raise the inlet temperature of the gas turbine, which will raise the net plant efficiency of advanced PFBC systems to 45%, while maintaining low levels of NOx. To withstand the expected severe conditions in the topping combustor application, a Multi-Annular Swirl Burner (MASB) developed by Westinghouse has been chosen to combust the gases from the carbonizer and increase the temperature of the CPFBC flue gases to 1288°C (2350°F), consistent with turbine inlet temperatures offered on advanced commercial high-efficiency turbines.[4] At the PSDF, however, the topping combustor flue gas will be cooled to 1077°C (1970°F) in order to meet the temperature limitation on 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 a nominal 4 MW of electric power.

PARTICLE FILTERS

At the PSDF, PCDs will be tested at temperatures, pressures, and other gas conditions characteristic of a number of gasifiers and pressurized fluidized-bed combustors.[5] The critical issues include integration of the PCDs 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 PCDs. The particulate control devices to clean gases from both the Foster Wheeler Carbonizer and Kellogg's transport reactor (2) are the same size, to allow for the possibility of interchanging these three PCDs. One larger PCD will be tested on the combustion gases from the CPFBC.

A total of four PCDs from three developers have been selected for initial testing at the PSDF. The PCDs were selected in response to two requests for proposals, one for the smaller PCDs and one for the larger PCD.

Each of the PCDs is expected to maintain outlet particulate loadings of less than 20 ppmw with no more than one 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 PCDs 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 PCDs 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 PCDs.

The two PCDs 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.

Westinghouse Filter

For one of the transport reactor/carbonizer filters, Westinghouse will use a tiered vessel which can be fitted with ceramic candles, cross flow filters, CeraMem ceramic filters, or 3M ceramic bag filters. 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. Qualification testing is in progress at Westinghouse to decide which type of filter element to test and evaluate first. The number and size of the filters required will vary. For instance, twenty CeraMem filters or 80 candle filters will be needed.

Combustion Power Company Granular Bed Filter

In the CPC granular bed filter 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.

The following two filters will be tested initially on the PFBC.

Industrial Filter and Pump Fibrosic Candle Filter

Initial testing of an IF&P filter will be on the PFBC carbonizer. The filters are ceramic candles made of low density aluminosilicate fiber/silica and 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 thirteen 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]

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.

Westinghouse Ceramic Candle Filter

A larger Westinghouse filter will be tested on the PFBC combustor. This filter will contain six clusters of ceramic candles in a 3.11 m (10.2 foot) outside diameter, refractory-lined pressure vessel. Each array of filters is attached to a common plenum and discharge pipe and is cleaned from a single pulse nozzle source. Several arrays of individual candle filter elements are assembled into a cluster and the 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 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.

CURRENT STATUS

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 has been approved.

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 third quarter of 1994. Phase 3, Construction, began with site clearing in September 1993. Construction of the transport reactor is scheduled for completion in April 1995 and for the APFBC in September of 1995. Phase 4, Operation, will begin as soon as shakedown and commissioning of each part of the facility is completed and will extend until September 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 completely integrated, advanced coal-based power generating systems. PCDs 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.

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