CONF-9506162--9

DOE/MC/25140-96/C0500

Power Systems Development Facility Progress Report

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Contract Number:

DE-FC21-90MC25140

Conference Title:

Advanced Coal-Fired Power Systems '95 Review Meeting

Conference Location:

Morgantown, West Virginia

Conference Dates:

June 27-29, 1995

Conference Sponsor:

U.S. Department of Energy, Morgantown Energy Technology Center (METC)

DISCLAIMER

2.1 Power Systems Development Facility Progress Report

CONTRACT INFORMATION

Cooperative Agreement DE-FC21-90MC25140

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Other Funding Sources Electric Power Research Institute
Southern Company Services, Inc.
The M. W. Kellogg Company
Foster Wheeler
Westinghouse Electric Corporation
Industrial Filter and Pump Manufacturing Co.
Combustion Power Company
Nolan Multimedia

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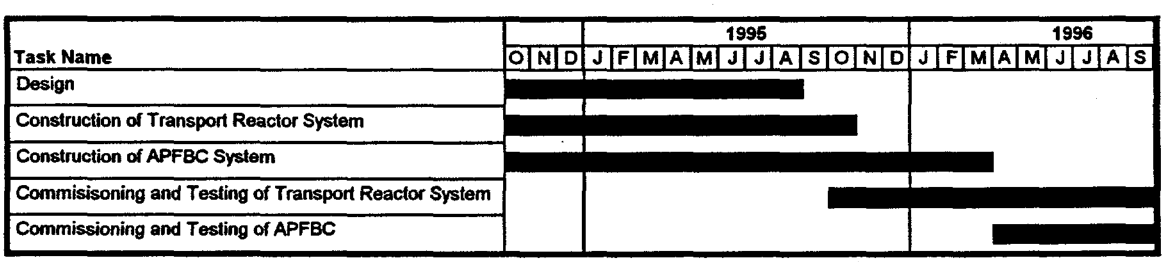
Period of Performance June 7, 1994 to June 12, 1995

Schedule and Milestones

FY95 and FY96 Program Schedule



OBJECTIVES

The objectives of the Power Systems Development Facility (PSDF) are to develop advanced coal-fired power generation technologies through the testing and evaluation of hot gas cleanup systems and other major components at the pilot scale and to assess and demonstrate the performance of the components in an integrated mode of operation and at a component size readily scaleable to commercial systems.

The primary focus of the PSDF project is to demonstrate and evaluate high temperature Particulate Control Devices (PCDs) which are the single most important component required for successful development of advanced power generation systems. High temperature PCDs are a common component of advanced gasification and Advanced Pressurized Fluidized Bed Combustion (APFBC) technologies, both of which will be evaluated at the facility. Successful high temperature gas cleanup will increase the efficiency and reduce the capital and operating costs of coal gasification processes by avoiding cooling and reheating of the syngas as is required in current technology. APFBC processes also benefit from the use of high-temperature PCDs which allow the use of modern high efficiency gas turbines instead of ruggedized expander turbines. A recent engineering and economic evaluation by the Electric Power Research Institute indicates that the capital cost of ABB-Carbon's bubbling PFBC can be reduced by as much as 9% when a PCD is used in conjunction with a non-ruggedized gas turbine.[1]

BACKGROUND INFORMATION

The PSDF located at Wilsonville, Alabama will be the focal point for much of the Nation's advanced coal-fired electric power technology development in the latter 1990s and into the 21st century. Coal will supply at least half the Nation's electricity well into the 21st century (it currently accounts for 56%). Yet, future coal systems will have to be increasingly cleaner and more efficient if the United States is to use its most abundant fossil fuel to sustain economic growth.

Jointly sponsored by the Department of Energy and many of the Nation's most forward-looking power equipment developers, the PSDF will be a highly flexible modular test center. Equipment developers will be able to test innovative electric power system components--new combustors, improved cleanup systems, and advanced turbines and fuel cells--at a central location, saving the time and expense of building separate test facilities.

Plans call for the facility to contain five modules initially: (1) an advanced pressurized fluidized-bed combustion system, (2) a transport reactor gasifier and combustor, (3) a particulate control module, (4) an advanced burner-gas turbine module, and (5) a fuel cell. Combining these modules into a single structure has saved more than $32 million when compared to the cost of building stand-alone facilities.

Hardware systems can first be evaluated separately, then linked together in an integrated power system. Filters can be tested with a pressurized fluidized-bed combustor or with a coal gasifier. Advanced turbines and fuel cells can be tied into the process path in a variety of ways. The facility will be capable of operating at pilot to near-demonstration scales, large enough to give industry real-life data for scaleup to commercial size, yet small enough to be cost-effective and adaptable to a variety of industry needs.

PROJECT DESCRIPTION

Initially, the five modules at the PSDF will be configured into two separate test trains as shown in the process schematic in Figure 1. The transport reactor train will be used to produce a particle-laden gas for testing of two of the PCDs. The APFBC module will be integrated with the topping combustor and gas turbine for long term testing of the PCDs in an integrated system and assessment of the control and integration issues associated with the APFBC system.

Advanced Gasifier

The M.W. Kellogg transport reactor technology under development at the PSDF at a scale of 2 tons/ hour of coal can operate either as a gasifier or as a PFBC unit. A simplified process flow diagram for the transport reactor system is shown in Figure 2. Tests will be conducted in both configurations. In the gasifier mode, coal is introduced and fired substoichiometrically. The coal devolatilizes, the volatiles pyrolize and the residual char is steam gasified. This staging of the gasification reaction forces oxygen to react with char rather than volatiles, as is characteristic in fluid bed gasifiers. As a result, the size of the gasifier (and the capital cost) is reduced because the amount of char to be gasified by reaction with steam (which is quite slow) is reduced substantially. Operation in the circulating PFBC mode is similar, but the reactor is fired with excess air.[2]

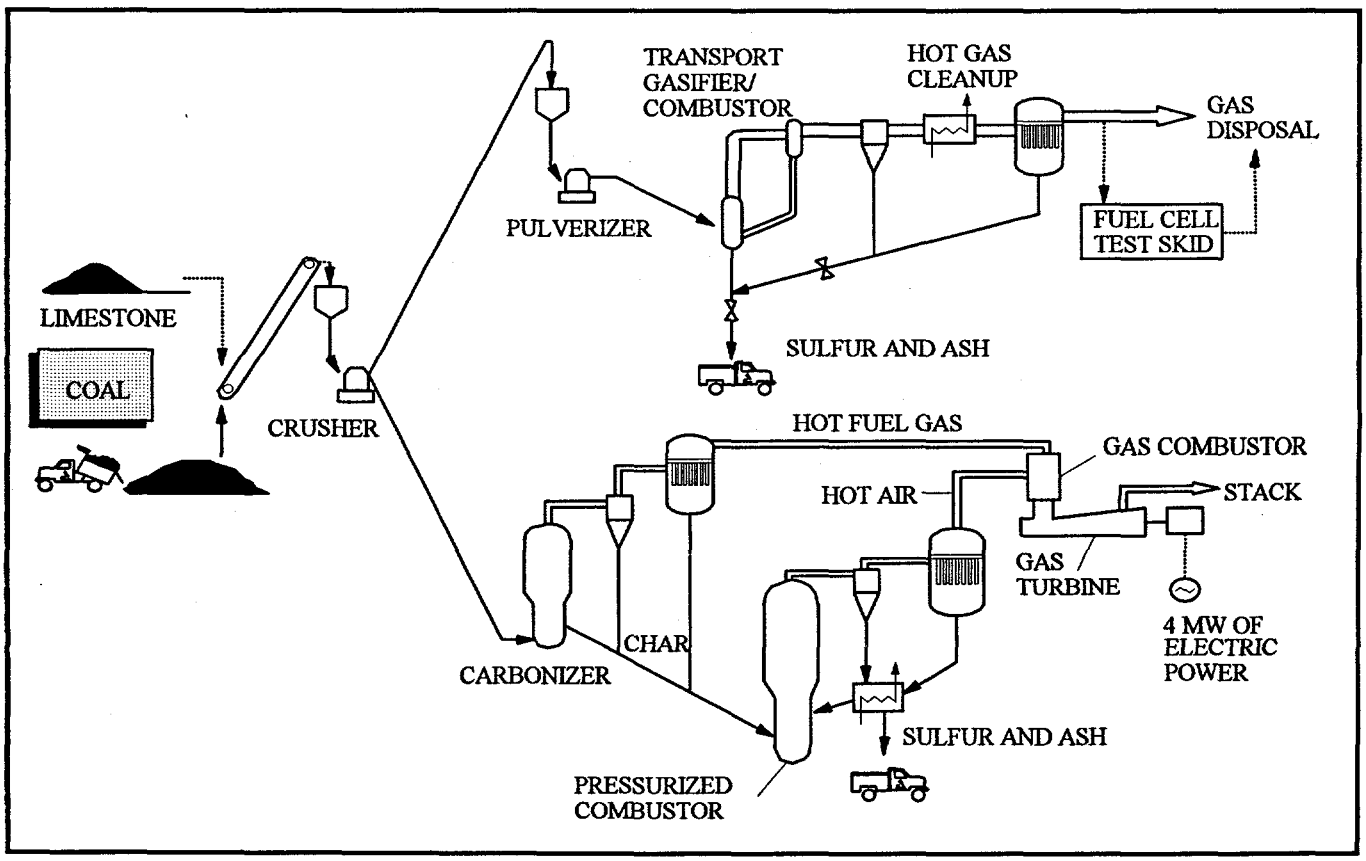


Figure 1. Simplified Process Diagram of the PSDF

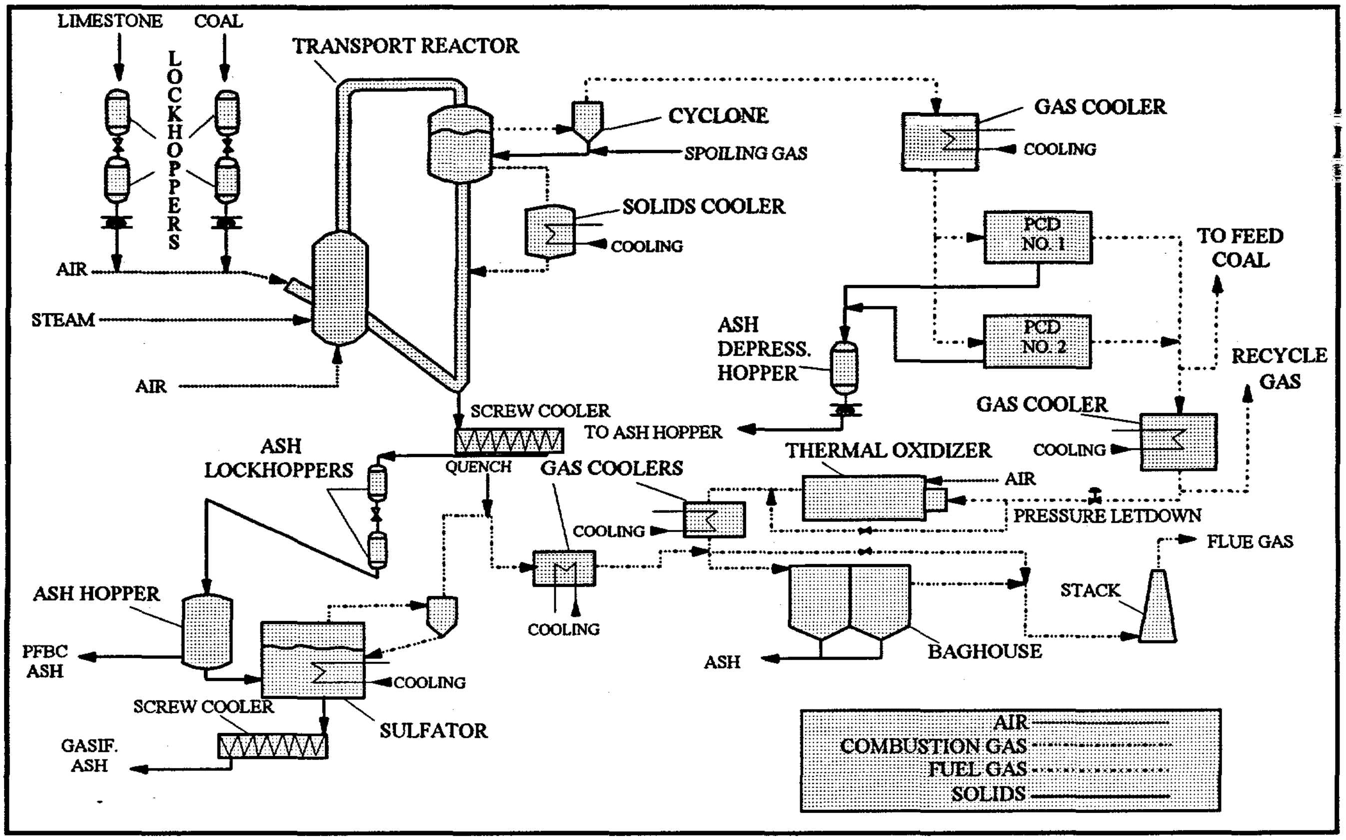


Figure 2. M.W. Kellogg Advanced Gasifier Train

Advanced PFBC

APFBC continues to emerge as a viable coal-based advanced power generation technology in the utility industry for both repowering and new plants. First generation PFBC technology offers the advantages of being more compact and efficient, compared to pulverized coal units, and has a simpler design than most advanced power generation systems. However, first generation PFBC systems have limited efficiency due to low temperature operation and the use of ruggedized turbines. To improve efficiency, PFBC systems must employ hot particulate removal and a topping cycle in order to use advanced turbine designs. These second-generation APFBC designs are expected to be capable of achieving 45% net plant efficiency. Advancing the development of APFBC systems is one of the primary goals of the PSDF.

The Foster Wheeler APFBC system under development at the PSDF (see Figure 3) at a scale of 3 tons/hour utilizes a topping cycle. It is a hybrid system that combines partial gasification with PFBC. Coal is first fed to a pressurized carbonizer, where it is converted to a low-Btu fuel gas and char. The char produced in the carbonizer is transferred to a circulating PFBC (CPFBC) where it is subsequently burned. Sulfur is removed in the process by the addition of limestone into the carbonizer and CPFBC. The carbonizer fuel gas and CPFBC flue gas are cleaned of particulates in separate ceramic filters, after which the fuel gas is fired in a specially designed topping combustor outside a high-

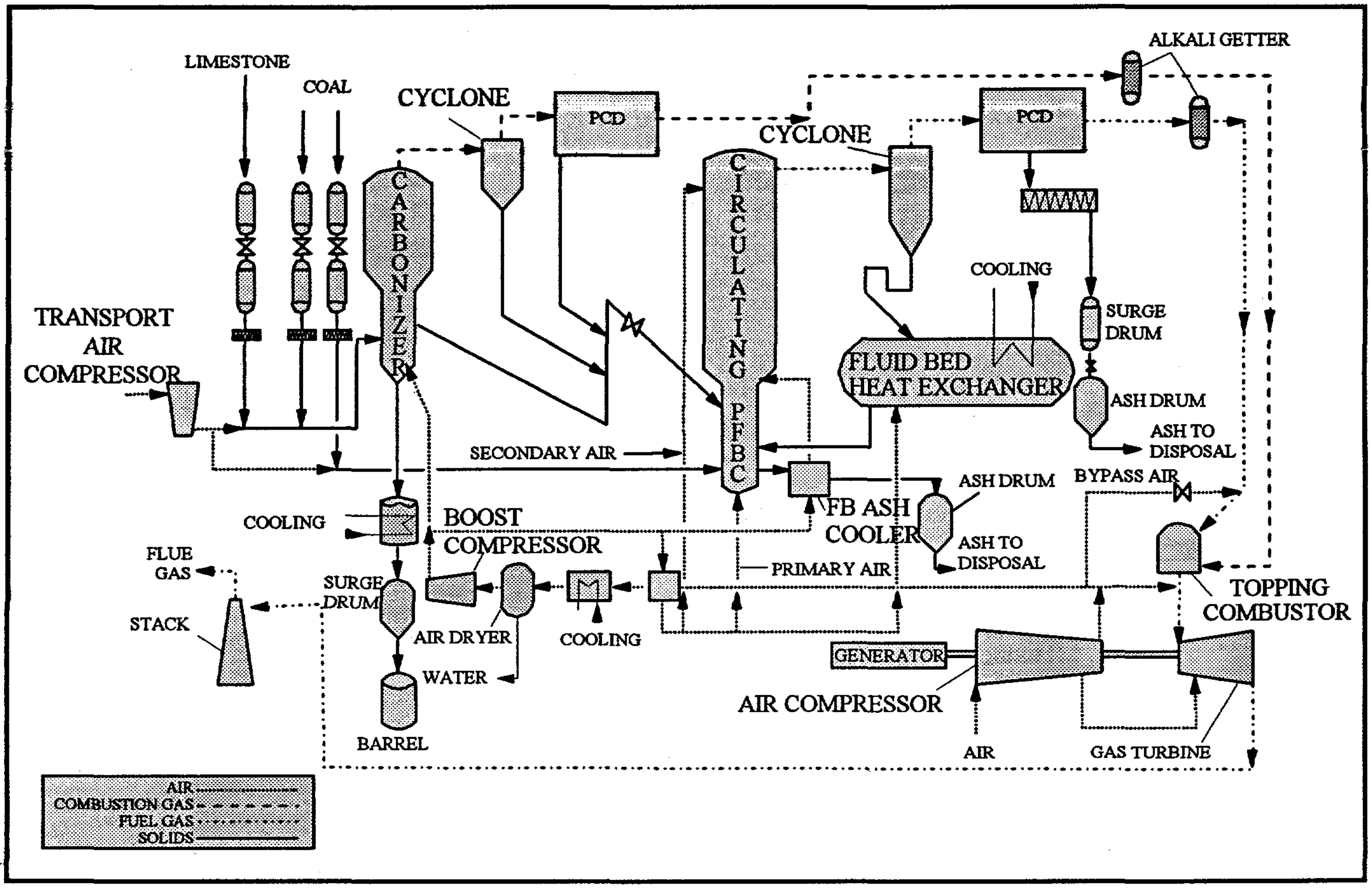


Figure 3. Foster Wheeler APFBC Train

temperature gas turbine using the CPFBC flue gas as the oxidant.

The APFBC plant at the PSDF will provide the first operation of a gas turbine and topping combustor with hot pressurized fuel gas from the carbonizer and hot pressurized flue gas from the APFBC. Periodic examination of the gas turbine will allow the merits of hot gas cleanup for APFBC systems to be evaluated.

Particulate Control Devices

At the PSDF, four different PCDs will be evaluated initially. Industrial Filter & Pump Mfg. Co. (IF&P) will supply one PCD that will be tested initially on the Carbonizer fuel gas from the Foster Wheeler APFBC train. The IF&P device will contain ceramic (Fibrosic) candles and a ceramic tubesheet, but the design is flexible to allow the use of alternate elements as backup. The IF&P PCD is sized to match the gas flow requirements from the M.W. Kellogg transport reactor and can be moved to the transport reactor for testing at a later date.

Westinghouse will provide two PCDs. One will initially be tested on the M.W. Kellogg transport reactor and is interchangeable with the IF&P device on the Foster Wheeler APFBC process. This Westinghouse PCD will be capable of operating with several types of filter elements, but the initial configuration will use candle filters.

The Foster Wheeler APFBC system requires two PCDs. The second Westinghouse PCD for the combustor in the APFBC system will use mullite candle filter elements, but will not be interchangeable with other PCDs at the facility.

The fourth PCD is a moving, granular bed filter to be supplied by Combustion Power Company. This PCD is sized to be interchangeable with the IF&P PCD installed on the APFBC system, but because of its substantially different configuration, is not expected to be tested on the Foster Wheeler unit.

Fuel Cell

A fuel cell is scheduled for integration with the advanced gasifier during the second year of operation after stable operation of the system is assured. The fuel cell will be connected to the advanced gasifier downstream of the PCD and the secondary gas cooler. This Integrated Gasification/Fuel Cell (IG/FC) system will be the first to operate with a hot gas cleanup system. IG/FC systems have the potential of achieving system efficiencies above 55% with extremely low emissions.

RESULTS

The major activities during the past year have been the final stages of design, procurement of major equipment and bulk items, construction of the facility, and the preparation by the O&M staff for operation of the facility in late 1995.

Design

The process design was predominantly completed in the previous reporting period and the design activities for the current period had little impact on the process flow sheets. A detailed description of the process design was presented in two previous papers at the Advanced Coal-Fired Power Systems Conference[3 4] and a detailed description of the PCDs also appears elsewhere[5]. M.W. Kellogg completed the design for the transport reactor system in December 1994 and Foster Wheeler is scheduled to complete the design of the Advanced PFBC system in July of 1995. The balance-of-plant (BOP) design is scheduled for completion by Southern Company Services in August of 1995.

One design item of note for the reporting period was the completion of a Design Hazard Review (DHR) for the APFBC and PCDs. A DHR was completed for the transport reactor system in May of 1994. The DHR for the BOP has been completed for that portion of the design prepared by Southern Company Services. The remainder of the BOP DHR will be completed in July after all final equipment vendor drawings are received.

The objective of the DHR was a qualitative assessment of the design using a structured format and methodology. The specific methodology for the reviews conducted used the "What-if" technique augmented by a guide-word checklist and was performed in accordance with the guidelines published by the American Institute of Chemical Engineers Center for Chemical Plant Safety. The review systematically examined design documentation in order to identify potential hazards and major operability problems in the facility which could compromise the ability of the systems and equipment to safely handle start-up and credible operating deviations from the design intent. The findings of the DHR were reviewed in detail and incorporated into the design as necessary.

Construction

Site preparation was completed in the last reporting period. Installation of underground pipes and conduits began in July 1994 and was complete except for some miscellaneous connections by November 1994.

Erection of structural steel began in November of 1994 when work began on the structure to house the coal and limestone storage bins and mills for sizing the coal and limestone. Erection of the main process structure began in December 1994. The main process structure is five bays wide by three bays deep with the two outside bays on one side housing the APFBC system and the two outside bays on the other side housing the transport reactor system; the center bays between the two systems provide a buffer and access for maintenance. Erection of the steel for the transport reactor bays and the center bays has been completed to the top elevation of 190 feet above grade and the two bays for the APFBC system have been erected to 52 feet with equipment placement as the structure is built.

All of the major equipment for the transport reactor system has been placed in the structure and installation of all the large refractory-lined pipe is scheduled to be completed by the end of July. Installation of smaller diameter pipe has begun within the transport reactor process area and installation of instrument and power cables will begin soon with mechanical completion of the system expected in November 1995. Commissioning will begin in October and these activities will proceed in parallel with the final construction activities. The first coal feed is targeted for December 1995.

The erection of steel and installation of the major equipment and refractory-lined pipe for the AFPBC system is scheduled for completion in October. Installation of smaller diameter pipe and instrument and power cables will continue through March of 1996. Commissioning activities for the gas island will continue from March until the arrival of the Westinghouse topping combustor in June of 1996. After commissioning the topping combustor, the first coal feed to the APFBC system will occur.

Buildings housing the warehouse, maintenance shop, on-site laboratory, offices and control room are complete, and the O&M and the research staff moved to the site in April.

Preparation for Operation

Southern Company Services personnel will be responsible for operation of the PSDF. The operations manager and maintenance supervisor were assigned to the project in the last quarter of 1994. Operations shift coordinators and the remainder of O&M supervisory personnel were assigned to the project beginning in March. The O&M staff is currently developing detailed operating manuals and maintenance procedures, setting up the maintenance shop, and preparing training materials in preparation for assignment of the first operators to the project in July of 1995. Alabama Power Company, a subsidiary of the Southern Company, will provide the PSDF well-trained and experienced operators and mechanics. Once trained on the specifics of the PSDF technologies, the operators and maintenance technicians will assist in final preparation of the operating and maintenance manuals and begin commissioning activities on the transport reactor system and balance-of-plant equipment.

Work started in the Fall of 1994 on developing a commissioning sequence that would logically order the equipment start-up testing and commissioning to allow significant pre-operational milestone tests and activities to occur before construction was complete on the entire process train and balance-of-plant equipment. The commissioning schedule identified required components that need to be operational to complete each milestone activity. The commissioning schedule was integrated with the existing project engineering and construction schedule.

Electrical equipment (breakers, relays, motor starters) is being tested by construction and engineering personnel as it is installed and this process has already identified several bad relays that have been replaced by the vendor. All testing is being completed as early as possible to identify and correct any problem associated with equipment, before it could impact the process start-up date. Commissioning of the fire water system has also been completed.

PSDF Experimental Test Program

The critical issues to be addressed include the integration of PCDs into coal utilization systems, on-line cleaning techniques, chemical and thermal degradation of components, fatigue or structural failures, blinding, collection efficiency as a function of particle size, and scale-up to commercial-size systems. To facilitate the assessment of the PCDs, it is critical that the test conditions, such as gas temperature and particle loading, be variable over a range of values. Long-term endurance tests will involve about 1000 hours of continuous PCD operation at nominally constant operating conditions. The goals of these tests are to demonstrate integration of the PCDs into advanced power generation systems, assess the long-term durability of the PCDs, demonstrate durable candle materials, and evaluate load cycling effects on the PCDs.

In addition to being a resource for performance assessment of hot stream cleanup devices, the PSDF has been designed as a flexible test facility that will be used to test and optimize the operation of advanced power system components, such as the transport gasifier/combustor, and advanced topping combustor and turbine as well as fuel cell system configurations. Testing plan for PSDF will also focus on issues related to integration of several advanced power system components as part of an entire power generation train. The M.W. Kellogg transport reactor for the PSDF represents a novel design for a gas source, and the test plan will address the operation and characterization of the reactor as well as the behavior of the PCDs selected for testing with the transport reactor. Similarly, the test plan will also address the control issues associated with the operation of the Foster Wheeler APFBC train with PCDs integrated into the system.

An outline of the test plan for the transport reactor system has been developed and a detailed test plan and schedule will be completed in July. Most of the parametric testing will be done using the transport reactor system, since the APFBC system is integrated with a gas turbine and is less flexible in terms of the PCD operating conditions. The transport reactor will be operated as both a combustor and a gasifier to allow PCD testing in both modes of operation. Shakedown of the transport reactor system and the PCDs will begin in October 1995, and the test program will begin in January 1996. The transport reactor will be operated in the combustion mode first before proceeding with the gasification tests.

The initial operation, shakedown, characterization testing, and the first three months of performance testing, will be in the combustion mode. The temperature of the gases leaving the transport reactor can be lowered using a gas cooler, allowing for a range of PCD inlet temperatures. In view of reported problems with the thermal shock of the ceramic filter elements, the initial PCD testing will be done at 1,000-1,200°F, and then gradually increased as experienced is gained in operating the PCDs.

The design of the transport reactor was based on Illinois #6 high sulfur, bituminous coal, but locally available bituminous coal will be used during initial operation. This will be followed by Illinois #6 and a Powder River Basin subbituminous coal. In the design specification limestone was specified as the sulfur sorbent. Both dolomite and limestone will be used, but the primary sorbent will depend on its effectiveness in lessening candle-cleaning difficulties.

The granular bed filter performance will be assessed by gathering inlet and outlet dust loading data at full- and part-load test conditions to determine the effect of reactor process variables (filtration gas velocity, inlet dust loading and size distribution, depth of filter media, media circulation rates, and media sizes) upon dust collection efficiency. The performance data will be compared with tests conducted previously at New York University to assess the effect of scale-up. The Westinghouse filter performance will similarly be assessed by determining how dust collection efficiency and filter cake removal is influenced by filtration gas velocity, inlet dust loading, inlet dust size distribution, load change and pulse parameters including pulse gas pressure and pulse frequency.

As tests with the filters are being performed, the transport reactor performance will be determined as a function of process variables and at full- and part-load conditions. The reactor performance indicators to be monitored include combustion and sulfur retention efficiencies, heat transfer rates to all cooling surfaces, alkali emissions before and after the flue gas cooler, NO_x emissions, CO emissions, flue gas dust loadings leaving the cyclone, and the dynamic response rate of the reactor to changes in temperature, Ca/S molar ratio, and to simulated load changes. The combustion test program with the transport reactor and the filters will be followed by operating the reactor as a gasifier and subjecting the filters to tests with fuel gas. The range of operating conditions for parametric and long-term testing of the PCDs for both the M.W. Kellogg transport reactor and Foster Wheeler APFBC trains is given in Table 1.

An outline of the test plan for the APFBC will be completed in July and the detailed test plan and schedule will be completed in September of 1995.

FUTURE WORK

Construction of the transport reactor system will be completed in November of 1995 at which time commissioning and testing activities will follow. The first coal feed to the system is targeted for December of 1995.

Construction of the APFBC system will be completed in March 1995 except for the topping combustor which is expected to be delivered in June 1996.

Table 1. Test Parameter

Test Parameter	M.W. Kellogg Combustor	M.W. Kellogg Gasifier	Foster Wheeler Carbonizer	Foster Wheeler Combustor
Gas flow rate, acfm	1,000	1,000	1,475 to 1,700	6,200
Pressure, psia	216 to 305	197 to 305	170	150
Temperature, °F	1,000 to 1,600	1,000 to 1,800	1,500 to 1,800	1,600
Particulate load, ppmw	4,000 to 10,000	4,000 to 16,000	11,000	8,000
Mean particle size, µm	3 to 16	3 to 16	15	5