Power Systems Development Facility: High Temperature, High Pressure Filter System Operations in a Combustion Gas[•]

Matthew D. Davidson (mddavids@southernco.com; 205-670-5872)
Edwin N. Galloway (engallow@southernco.com; 205-670-5961)
Xiaofeng Guan (xguan@southernco.com; 205-670-5891)
Howard L. Hendrix (hlhendri@southernco.com; 205-670-5876)
Patrick T. Scarborough (ptscarbo@southernco.com; 205-670-5926)
Southern Company Services, Inc.
P.O. Box 1069
Wilsonville, AL 35186

Robert S. Dahlin (rsdahlin@southernco.com; 205-670-5068)
E. Carl Landham (eclandha@southernco.com; 205-670-5990)
Southern Research Institute
P.O. Box 1069
Wilsonville, AL 35186

Jack D. Spain (spain@sri.org; 205-581-2323)
Southern Research Institute
757 Tom Martin Drive
Birmingham, AL 35211

Introduction

The Power Systems Development Facility (PSDF) is a Department of Energy (DOE) sponsored engineering scale demonstration of two advanced coal-fired power systems and several High Temperature, High Pressure (HTHP) gas filtration systems. The PSDF was designed at sufficient scale so that advanced power systems and components could be tested in an integrated fashion to provide confidence and data for commercial scale-up. This paper provides an operation summary of a Seimens-Westinghouse Particulate Control Device (PCD) filtering combustion gas from a Kellogg Brown & Root (KBR) transport reactor located at the PSDF.

The transport reactor is an advanced circulating fluidized bed reactor designed to operate as either a combustor or a gasifier. Particulate cleanup is achieved by using one of two PCDs,

---

[•] The PSDF is supported by the U.S. Department of Energy's Federal Energy Technology Center (FETC), under Contract DE-FC21-90MC25140 with Southern Company Services, Inc., P.O. Box 1069, Wilsonville, AL 35186-1069, fax: 205-670-5843. The FETC Contracting Officer's Representative is James Longanbach.

located downstream of the transport reactor. Since start-up, the transport reactor and Seimens-Westinghouse PCD have operated on coal for over 3500 hours in combustion. The particulate loading and size to the PCD were much larger than designed during the initial testing because of cyclone problems. However, both the loading and particulate size have substantially decreased and design values are now being achieved. Operationally, the PCD has worked well, with few mechanical problems.

As of the end of 1998, the following PCD achievements have been made:

- The PCD has operated successfully on coal for over 3500 hours. Over 3000 hours of this operation has been at a PCD inlet temperature of ~1400°F (760°C).
- There have been no incidents of ash bridging.
- There have been no incidents of candle bowing.
- No measurable elongation of silicon carbide filter elements has occurred after 1000 hours exposure at 1350-1400°F (730-760°C).
- Filter elements from 3M, Blasch, Coors, Allied Signal (DuPont), IF&P, McDermott, Pall, Schumacher and Specific Surface have been tested.
- Exposure of several clay bonded silicon carbide filter elements has exceeded 3200 hours.
- The PCD operated on coal for over 800 hours with two broken filter elements to monitor failsafe performance. At no time was the outlet loading measured at greater than 15 ppm. The PSDF is working with Seimens-Westinghouse and others to improve the failsafe performance.
- The originally supplied pulse valves had a design flaw that limited their performance. This flaw was identified and has been corrected.
- The collection efficiency of the Seimens-Westinghouse PCD has been demonstrated to be greater than 99.99%.
- Southern Research Institute (SRI) has continued to reliably, safely and routinely take isokinetic ash samples both at the PCD inlet and outlet which have been used to evaluate the performance of both the transport reactor and the PCD.

Project Description

The PSDF is configured into two separate trains. The transport reactor train is used to produce a particulate-laden gas for testing two of the PCDs. The Advanced Pressurized Fluidized Bed Combustor (APFBC) train will be integrated with a topping combustor and gas turbine for long term testing of two additional PCDs in an integrated system and assessment of the control and integration issues associated with the APFBC system.

Transport Reactor: The KBR transport reactor, under development at the PSDF at a scale of about 2 tons/hour (1800 kg/hr) of coal feed, can operate either as a gasifier or combustor. Tests will be conducted in both configurations. In the gasifier mode, coal is introduced and fired sub-stoichiometrically. 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 is reduced because the amount of char to be gasified by reaction with steam is reduced substantially. Operation in the combustion mode is similar, but the reactor is fired with excess air and a fluidized bed heat exchanger is included in the reactor loop to remove heat.

Advanced PFBC: First generation PFBC technology offers the advantages of being more compact and efficient than pulverized coal units, and the design is simplier 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 50% net plant efficiency. Advancing the development of APFBC systems is one of the primary goals of the PSDF.

At a scale of 3 tons/hr (2700 kg/hr), the Foster Wheeler APFBC system under development at the PSDF utilizes a topping cycle. The process 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 before entering a high-temperature gas turbine using the CPFBC flue gas as the oxidant.

Multi-Annular Swirl Burner (MASB)/Turbine: To withstand the expected severe conditions in the combustor in a topping application, a Multi-Annular Swirl Burner (MASB) is chosen to combust the fuel gas from the carbonizer and increase the temperature of the CPFBC vitiated air to 2350^{o}F (1290^{o}C). The wall cooling challenge in the MASB is met by utilizing the 1400^{o}F (760^{o}C) vitiated air from the CPFBC and maintaining a cooling air layer of substantial thickness through concentric annular passages in the MASB. At Wilsonville, the hot gas is expanded through a gas turbine (Allison Model 501-KM), powering both the electric generator and air compressor.

Particulate Control Devices: At the PSDF three PCDs have been installed in the process structure. Seimens-Westinghouse has provided two of the PCDs. The smaller Seimens-Westinghouse PCD can test up to 91 candle filter elements and is installed on the KBR transport reactor process. The larger Seimens-Westinghouse PCD contains up to 273 candle filter elements and will be used to remove particulate from the vitiated air leaving the combustor in the Foster Wheeler APFBC system. In addition to the Seimens-Westinghouse systems, a Combustion Power Company (CPC) moving granular bed filter is installed and will be tested on the KBR transport reactor.

Results

System Operations

Seimens-Westinghouse PCD Design

Dirty gas from the transport reactor enters the PCD through a tangential inlet nozzle, then flows in an annulus between the vessel wall and a shroud. The gas flows both over the top and bottom of the shroud into the central filtration zone of the vessel. Dirty gas flows through the filter elements, depositing the particulate on the filter surface.

The filter elements are attached to one of two plenums, or levels, which support filter elements, collect the clean gas, and distribute the pulse flow. There are 55 filter elements attached to the lower plenum and 36 filter elements attached to the upper plenum. Each filter element has a series of gaskets to provide a dust tight seal, and there is a Seimens-Westinghouse "failsafe" device located above each filter element. The failsafe is designed to restrict ash flow in the event of a filter element failure.

The clean gas flows from the plenum to the outlet of the filter vessel through the support tube, which is attached to the vessel tubesheet. The tubesheet provides a physical barrier separating the "dirty" and "clean" sides of the PCD. The Seimens-Westinghouse tubesheet is designed with a double cone expansion joint, to provide a positive seal at a variety of operating temperatures.

As the particulate accumulates on the outside of the filter surface, the differential pressure will continually rise. Periodically, a pulse of high pressure gas generated by the back-pulse skid removes the filter cake. This gas flows into the filter vessel through the pulse piping and is channeled to the individual plenums via the support tube. The filter cake removed from the filter elements falls to the bottom of the vessel where it is removed and cooled by a screw cooler and lockhopper system.

Operating Conditions

Typical operating conditions of the Seimens-Westinghouse PCD for the KBR process are summarized in Table 1:

Table 1. Typical Operating Conditions in the Seimens-Westinghouse PCD

Temperature	1350-1400°F (732-760°C)
Pressure	200 psig (13.8 bar, g)
Face Velocity	5.0 ft/min (91 m/hr)
Baseline Pressure Drop	80 INWG (200 mbar, g)
Baseline Permeance	0.154 ft/(min*INWG) (1.13 m/(hr*mbar))
Back-pulse Pressure	400-500 psig (27.6-34.5 bar, g)
Back-pulse Duration	0.2 seconds
Back-pulse Interval	40 minutes
Particulate Loading	11,000 ppm
Particle MMD	18-25 micron

To date, the PCD has been exposed to coal combustion particulate-laden gas from the KBR transport reactor for over 3500 hours (See Figure 1). Initial operations were conducted at ~600°F (320°C) by flowing all of the gas from the transport reactor through a gas cooler. The primary reason for this approach was to operate the PCD as conservatively as possible while gaining familiarity with the transport reactor. As operation of both the reactor and the PCD were better understood, the temperature in the PCD was increased to ~1000°F (540°C) by partially bypassing the gas cooler. Operation at this temperature went quite well, so shortly afterwards the PCD inlet temperature was increased to its present operating temperature of ~1400°F (760°C).

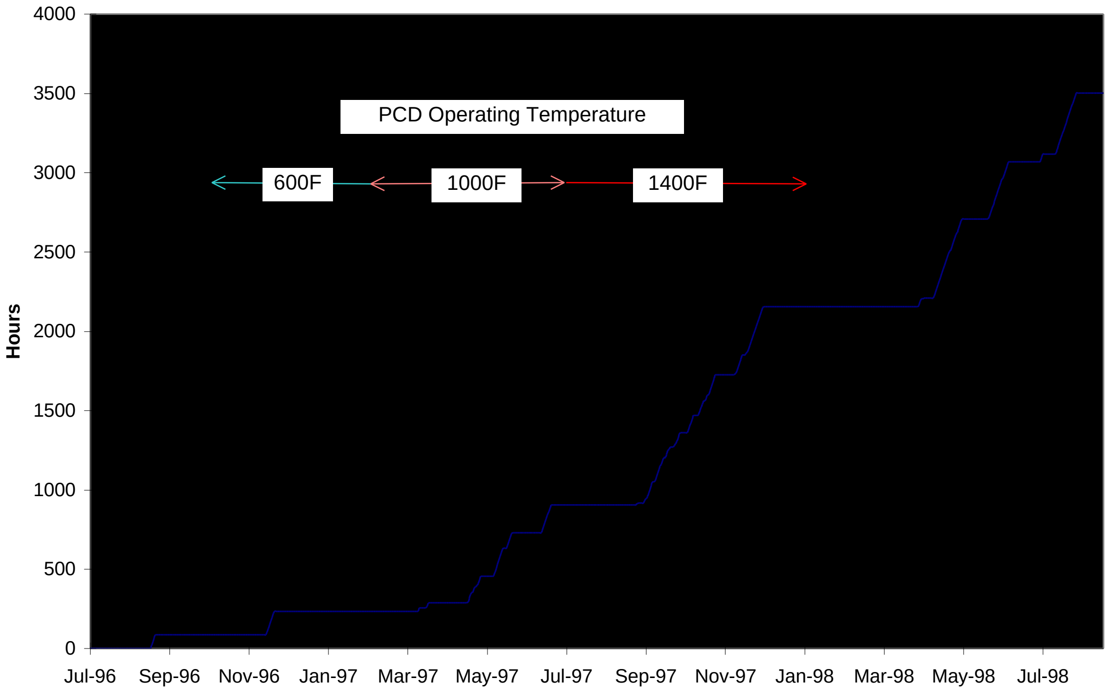

Figure 1 – KBR Cumulative Hours On Coal

Permeance

For a given face velocity the baseline pressure drop changes with time as a residual cake forms on the filter surface. If the face velocity remains constant, the rate of change in pressure drop should approach zero as the filter system reaches steady state. Since face velocity is changed fairly often in test facilities such as the PSDF, the change in pressure drop is monitored by plotting the system *permeance* vs. time. Permeance is defined as the face velocity, divided by the pressure drop and corrected for gas temperature. The equation for permeance is:

$$Permeance = \frac{Face\,Velocity * \mu}{\Delta P * \mu_{20}}$$

Where:

Face Velocity = Volumetric Flow/Filtration Area , ft/min
μ = Gas Viscosity At Operating Conditions, cP
ΔP = Filter Pressure Drop Immediately After The Backpulse, INWG
μ_{20} = Gas Viscosity At 20^{o}C And 1 atm, cP

Under ideal conditions, the permeance will decrease as the residual cake forms until a steady-state value is reached. If the permeance fails to reach a steady state, operations may eventually be affected due to higher than acceptable pressure drops. Eventually, the plant may have to shut down to avoid compromising the mechanical integrity of the PCD.

The permeance of the Seimens-Westinghouse PCD for the nearly 2000 hours of testing in 1997 is shown in Figure 2. There are several items of interest shown on the graph.

1. During the first ~700 hours of on-coal operation in 1997, the particulate size to the PCD was fairly large (MMD >100 microns) due to problems with the transport reactor Primary Cyclone. Understanding of the cyclone's operation improved substantially in June. From then until the end of the year, the particle size was much smaller (MMD 15-20 microns). The decrease in permeance from 700 to 800 hours on coal was primarily due to the change in particle size.
2. The last ~1300 hours on coal in 1997 was during a 1000 hour run at ~1400^{o}F (760^{o}C). At the beginning of the run two Coors filter elements broke but it was decided to continue operation to monitor failsafe performance. For the next ~800 hours, the outlet loading of the PCD varied between 0 and 15 ppm due to leakage through the failsafes, leakage associated with installed blanks and leakage through some filter element gaskets. Some of the entrained particulate on the clean side of the PCD was blown into the inner bore of the filter elements during pulse cleaning causing "backside blinding." The downward trend from ~900 hours on coal until ~1500 hours may have been due to this phenomenon.

3. On November 2, several filter elements failed due to an upset in the coal feed system. At that time the presence of ash on the inner bore of several filter elements was observed. A significant number of filter elements were cleaned and/or replaced with new filter elements. This caused a “step change” in the permeance curve until the system reached an equilibrium ~200 hours later.
4. After the maintenance period related to the November 2nd incident and until the end of the run, the PCD outlet loading was a constant 4-5 ppm. The decrease in permeance from this event until the end of the year may have also been due to “backside blinding”.
5. Several “breaks” are shown in the curve. These are primarily due to fairly rapid changes in gas flow, temperature, pressure, etc. on start-up and shut-down.

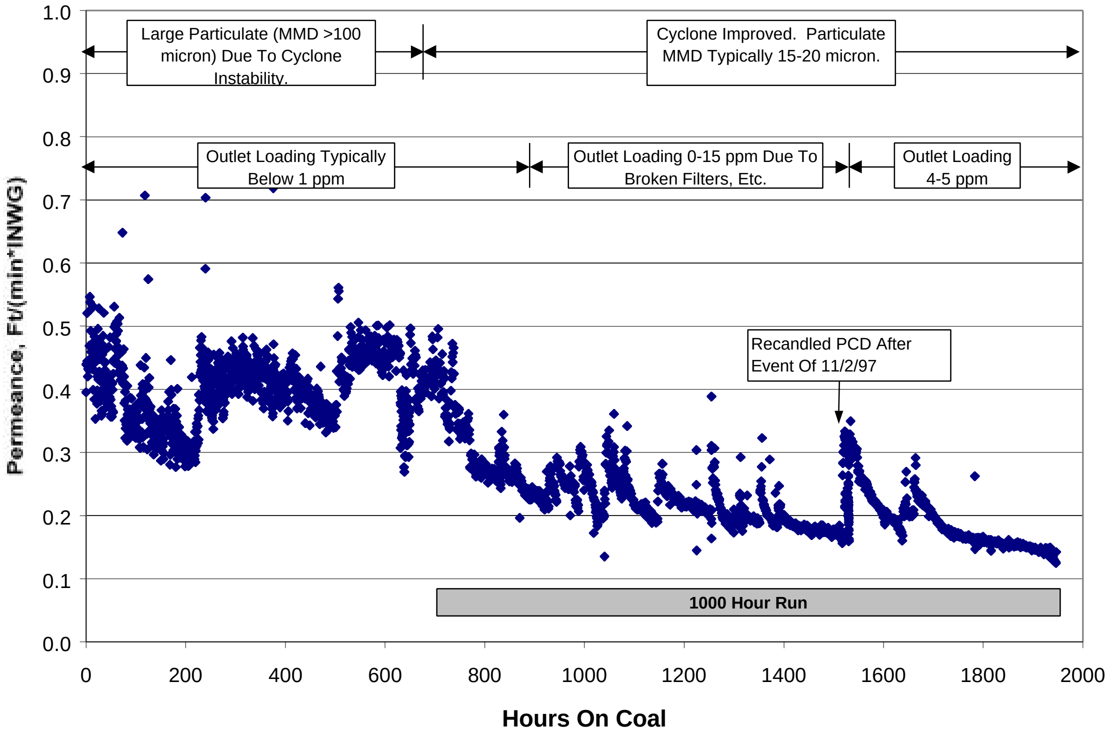

Figure 2 – 1997 PCD Permeance vs. Hours on Coal

Filter Element Losses

During the 3500 hours of combustion testing on the KBR transport reactor, there have been several incidents where filter elements have broken during operation. These incidents can be broadly categorized into two groups: initial operation of a developmental reactor and transition from propane to coal during start-up.

Initial Operation

As with most new facilities, there were start-up challenges with various pieces of equipment throughout the plant and the PCD was no exception. During the initial coal firing in August 1996, the PCD filled to an ash level high enough to break a significant number of filter elements.

Additionally, in April 1997 due to an operational error, a significant amount of coal was fed into the transport reactor while the system was being heated. The transport reactor was at a temperature just hot enough to cause the initial combustion of the coal and the PCD was at a temperature of about 400^{o}F (200^{o}C). It is believed that when the smoldering coal reached the filter elements it ignited, causing a rapid increase in the filter element temperature and failure of many of the filter elements.

Transition To Coal

Understanding why the events during start-up occurred was relatively simple and through changes in operating procedures, additional training and increased experience the events were not repeated. However, beginning in September 1997 several monolithic oxide filter elements failed during the transition from the start-up burner to coal feed. In total, from September to April 1998, 23 of the 28 monolithic oxide filters installed failed during operation (17 Coors, 6 Blasch Precision Ceramic). All but one of these failures occurred during the transition to coal or when there was an upset in the coal feeder. Concurrently, there were monolithic silicon carbide and composite oxide and silicon carbide filter elements installed from a variety of manufacturers that did not fail during these thermal transients.

Based on past successes with monolithic oxide elements at other facilities, the failures at the PSDF were unexpected and initially not understood. After in-depth analysis, the cause of the failures was not readily evident from the existing plant instrumentation. Therefore, it was decided to instrument two filter elements (one Pall 326 and one Coors) with thermocouples to see what thermal gradients were present during a normal start-up and during upsets. Each filter element had six 0.060 inch diameter (1.5 mm) thermocouples installed: three on the ID and three on the OD. The thermocouples were arranged in pairs so that the thermal gradient across the wall could be determined.

During the transition to coal on April 9, 1998, several “spikes” in temperature on the Pall filter element OD were measured (Figure 3). When coal feed was started, the temperature in the reactor was about 950^{o}F (510^{o}C). It is currently believed that this temperature was too cool to fully combust the coal prior to the solids entering the PCD, and the “spikes” in temperature on the filter are evidence of coal burning on the surface of the elements.

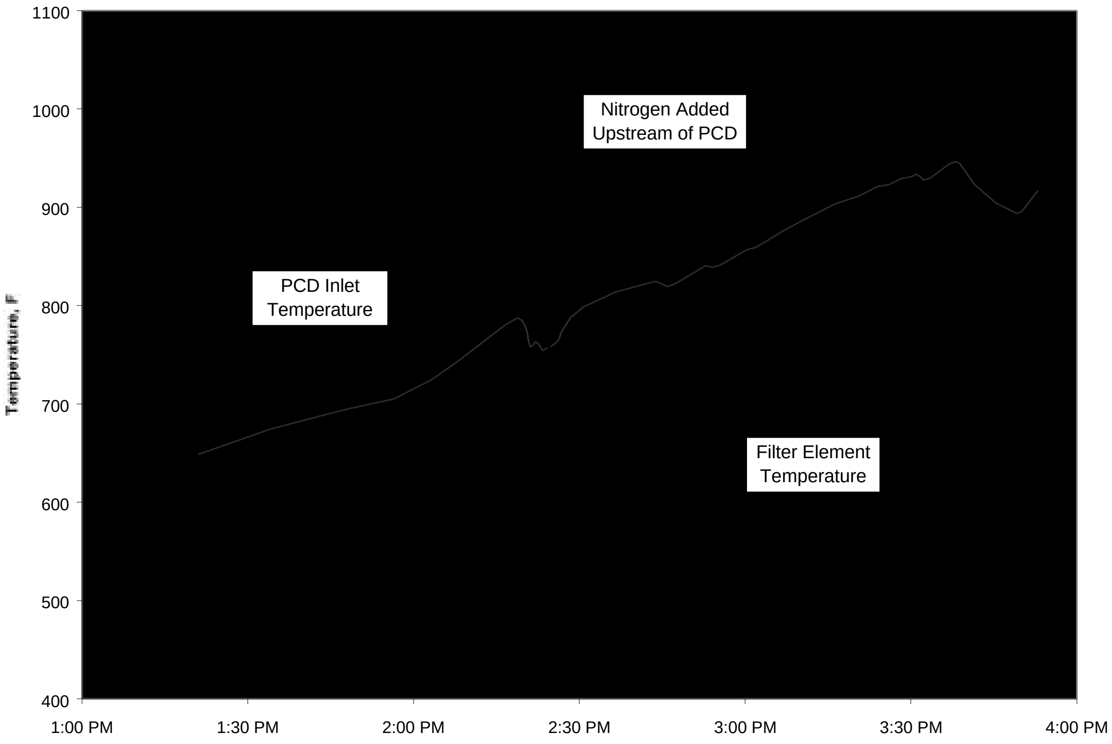

Figure 3 – Temperature Transients On Filter Element

As previously mentioned, thermocouples were installed in pairs on the OD and ID surface of the filter element. Figure 4 shows the measured thermal gradient across the wall. Based on the material properties of the Coors filter material, a thermal gradient of this magnitude could cause the filter elements to crack and possibly fail.[1]

This test segment ended when several pieces of Coors, Blasch Precision Ceramic, and Specific Surface filter elements were found in the ash removal system. Upon disassembly and inspection of the filter system it was found that 2 of 2 Coors elements, 6 of 8 Blasch Precision Ceramic elements and 1 of 2 Specific Surface elements had failed. The Coors and Blasch materials are monolithic oxide materials with similar microstructure. The Specific Surface element was made of cordierite. None of the silicon carbide or composite oxide materials failed due to this transient. The Coors, Blasch and Specific Surface elements were replaced and the instrumented Pall 326 element was left in the PCD to monitor any additional transients during start-up. The start-up burner was modified to allow higher temperatures prior to firing coal and the start-up procedure was modified to require the transport reactor temperature to exceed 1200°F (650°C) before coal feed can begin. This procedure was followed during the next start-up and no similar transients were detected.

---

[1] Spain, J.D. and Starrett, H.S, "Physical, Mechanical, and Thermal Properties of Coors Alumina Mullite Filter Material - Final Report", DOE/METC Contract Number: DE-AC21-89MC26233, August 1997, pg 96.

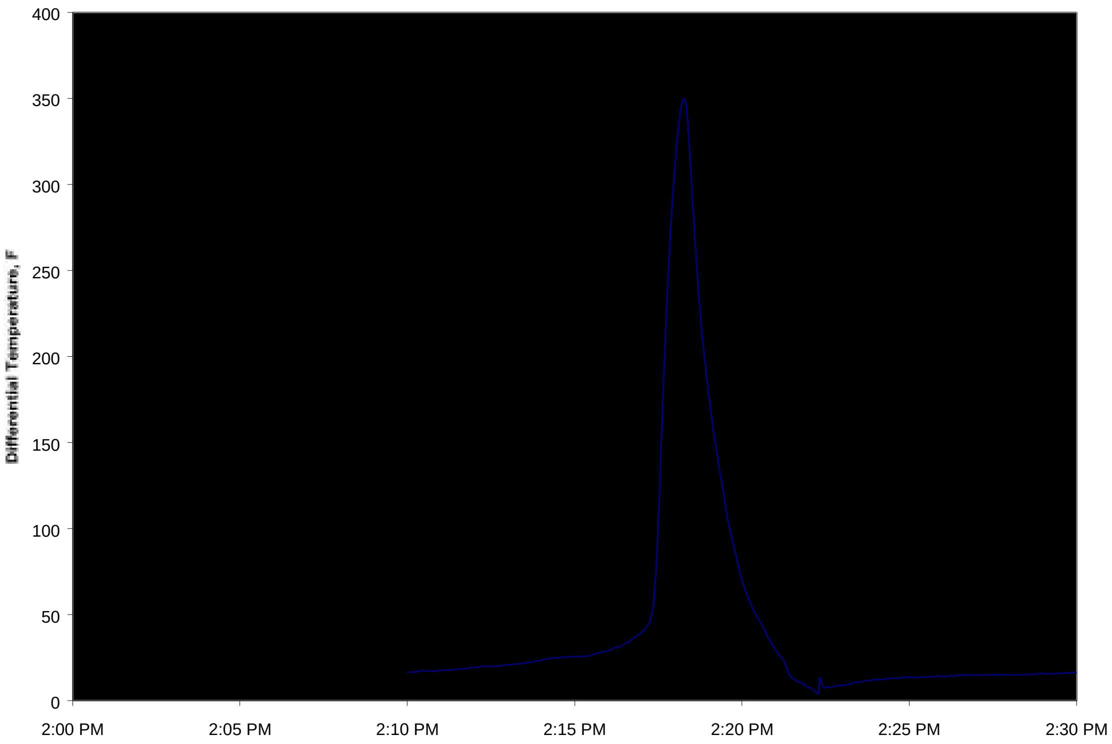

Figure 4 – Thermal Gradient Across Filter Wall

It is important to point out that the monolithic oxide filter elements probably failed due to an operational upset. It is also believed that all of the monolithic oxide failures occurring between September 1997 and April 1998 were caused by similar phenomena. If the reactor had been at a higher temperature before starting coal feed, it is unlikely that these failures would have occurred. However, these experiences have shown that the thermal properties of the monolithic silicon carbide elements make them much less susceptible to these types of thermal transients than the monolithic oxide materials.

To evaluate the performances of differential filter elements under the severe thermal transient, a finite element analysis (FEA) has been conducted for Coors P-100A, Pall 326 and Schumacher TF20 filter elements subject to the same temperature increase on the OD surface indicated in Figure 3. The results showed that the Coors element had the greatest temperature gradient as shown in Figure 5. This might answer why Coors elements failed but the silicon carbide elements survived. Currently, further FEA simulations and failure analysis are being carried out to identify the cause of the filter element failure. In the future, these analysis results could also be used to evaluate the performance of exposed filter elements and predict the performance of newly developed filter elements.

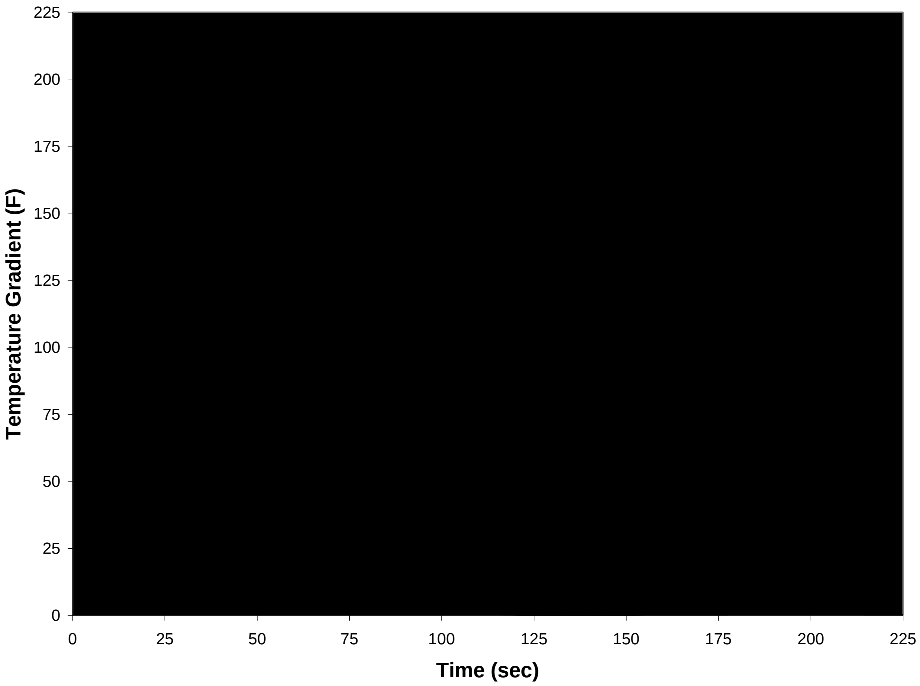

Figure 5 – Temperature Gradient on Filter Elements

Operational Developments

In addition to the experience gained with the filter elements, other operational challenges have been successfully accomplished during the last twelve months of operation. The most significant of these are listed below:

- The operational staff has successfully monitored the level of ash in the PCD cone using thermocouples. This technique has a much lower cost than measurement of ash using nuclear level devices.
- During testing, it was realized that the Müller Co-axial back-pulse valves were not operating properly at high valve differential pressures. Using high-speed data acquisition equipment, the PSDF staff was able to characterize the problem. Working with the valve manufacturer, the valves have been modified and the problem resolved. Figure 6 shows the mass discharge per back-pulse in a typical testing condition. The dotted curves are the data obtained before the valve modification and the solid lines are the data obtained after the modification. In the region of high valve differential pressure, the mass discharge is no longer reduced.
- PSDF has successfully demonstrated the operation of the transport reactor and PCD with the design coal and sorbent for the Lakeland CCT project.

- The installation of the Seimens-Westinghouse PCD on the Foster Wheeler combustor has been completed.
- The Foster Wheeler APFBC has been pressure tested and solid circulation performed.

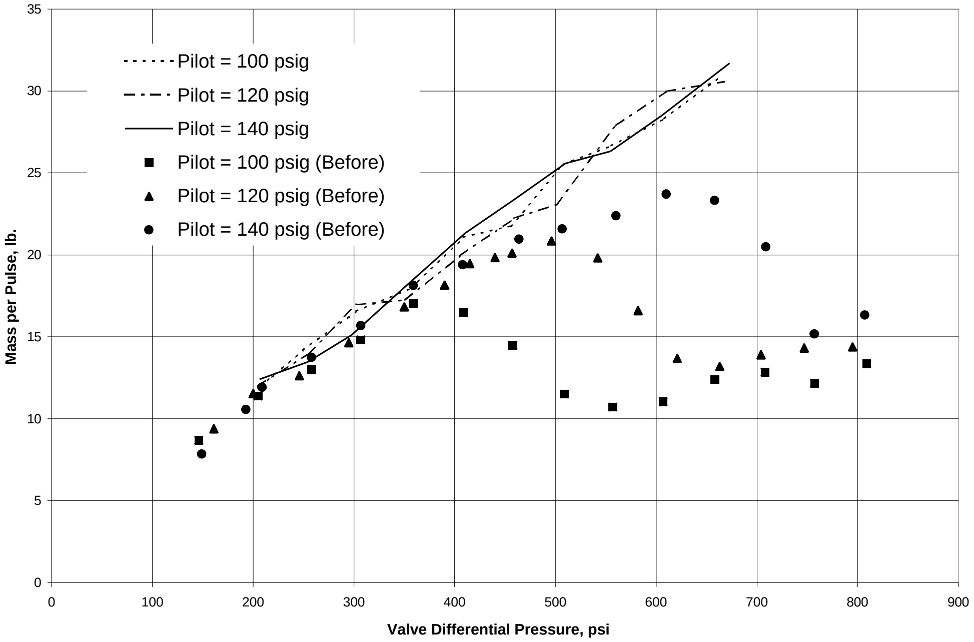

Figure 6 – Back-Pulse Performance before and after the Modification

Filter Element Materials

Materials Exposed

In light of the experience gained with the monolithic oxide elements, the PSDF continues to work with many filter element suppliers to evaluate materials suitable for HTHP gas filtration applications. Table 2 below shows the filter elements that have been tested and the maximum number of exposure hours for each type of filter element.

Table 2. Filter Elements Tested at the PSDF (As of 8/10/98)

Manufacturer	**Type**	**Material**	**Exposure Hours on Coal**
3M	Oxide	Composite	790
	Type 203	Composite	1250*
Blasch		Alumina/mullite	50
Coors	P-100A-1	Alumina/mullite	810
Allied Signal (Dupont)	PRD66C	Composite	1350
IF&P	REECER	Recrystallized silicon carbide	1350
McDermott		Composite	1350
Pall	326	SiC	3210
	442T	SiC	3210
	FeAl	Iron Aluminide	1350
Schumacher	F40	SiC	620
	TF20	SiC	1350
	T10-20	SiC	2590
Specific Surface	CC-4001	Cordierite	50

* The 3M SiC filter elements with 1250 hours have been removed from the PCD.

Filter Element Growth Testing

It had been previously reported by Seimens-Westinghouse[2] that clay bonded silicon carbide filters from Pall and Schumacher had significantly elongated with exposure at an operating temperature of 1530-1560°F (830-850°C) during testing at the Karhula R&D Center. The elongation had been measured on the Pall 326 and 442T and the Schumacher TF20 elements. In June 1997, Seimens-Westinghouse requested that the PSDF perform a 1000 hour test with these materials, limiting their exposure temperature to 1350-1400°F (730-760°C). The specific purpose of this request was to determine if elongation of these materials would occur in this temperature range. The test occurred between September and December 1997.

The twenty-six filter elements to be monitored for elongation were installed at the beginning of the 1000-hour run. These consisted of eight Pall 326 elements, ten Pall 442T elements, and eight Schumacher TF20 elements. The length of each of the elements was measured prior to installation. After 650 hours into the run, an operational upset occurred that caused failure of several monolithic oxide filter elements. Since the

---

[2] Alvin, M.A. et. al., "Filter Component Assessment," *Proceedings of the Advanced Coal-Based Power And Environmental Systems '97 Conference,"* DOE/FETC-97

cause of the failures was not fully understood, all 26 test filter elements were removed for measurement.

Two TF20 elements broke after they were removed. It was not known if the failures had occurred due to handling or due to damage of the filter matrix because of the upset, so none of the remaining six TF20 elements were re-installed. Additionally, three Pall 326 and three Pall 442T filters were removed in case future material testing was desired. Therefore, out of the 26 filter elements removed, only 12 elements were put back into the filter vessel for further testing.

Figure 7 shows the results of the measurements taken at both 650 hours and 1000 hours of exposure. As shown in the figure, the measured length of the filter elements after exposure was within ±1.5 mm of the original length. This indicates that little, if any, elongation is occurring under these conditions. It is important to mention that an "elongation" of ±1.5 mm is within the accuracy of the measurement. The filter elements are not smooth and flat at the surface being measured, and there are also errors related to the measurement technique. However, the elongation reported by Seimens-Westinghouse was between 5 and 25 mm over 1000 hours exposure. It is safe to say that elongation of this magnitude is not occurring under the operating conditions at the PSDF. Additionally, the Karhula R&D Center performed a similar test in the Fall of 1997 after ~500 hours. In conversations with their staff, there was little to no elongation of the filter elements exposed for this duration at 1350-1400^{o}F (730-760^{o}C), which confirms the results observed at the PSDF.

The clay bonded silicon carbide elements will continue to be measured at various exposure times so that as much data as possible can be collected to confirm the results from this first 1000 hours of exposure.

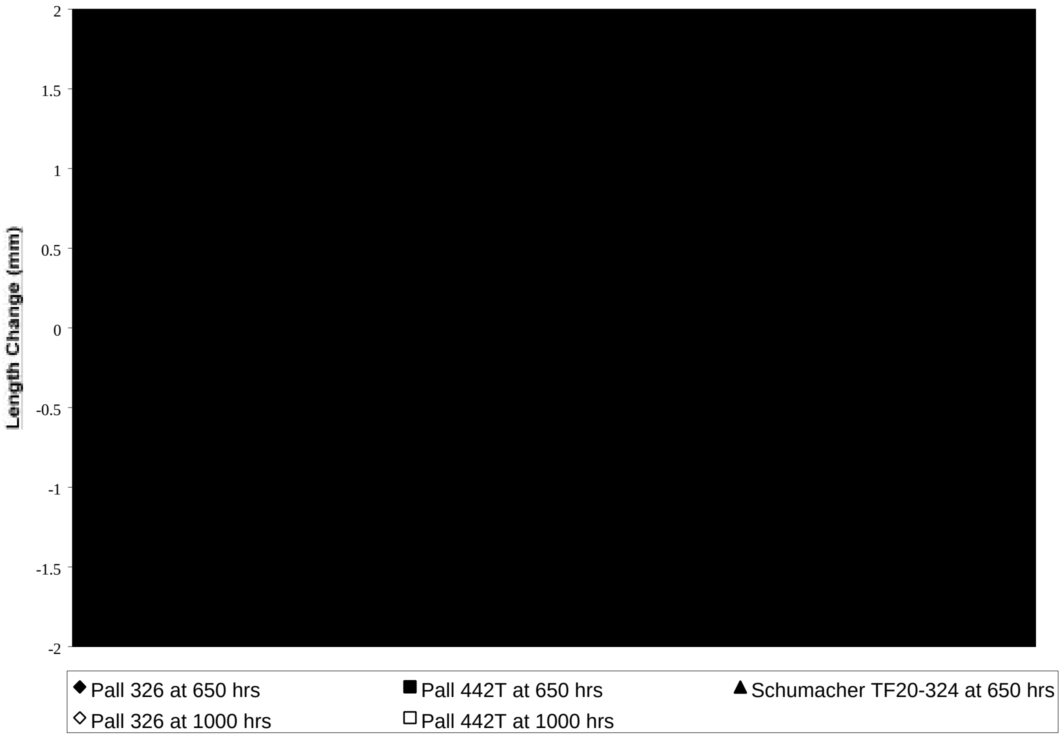

Figure 7. Silicon Carbide Filter Element Growth at 1350-1400°F

Destructive Filter Element Strength Testing

To date, extensive destructive filter element testing has focused on all of the filter materials in an attempt to understand the failures. In July 1997, eleven of nineteen Coors elements were removed intact after 616 hours of testing. At this time, there had been no failure of any Coors elements. Using a hydrostatic O-ring test, SRI has evaluated the ultimate strength of three of the exposed elements, as well as two virgin elements. The results of this testing are shown in Figure 8. The gray region encompasses all of the data from the testing and shows about a 10% loss of strength, on average, during the 616 hours of exposure.

During the next start-up on September 1st, three Coors elements failed. Two elements were removed intact, and one of these elements was sent to SRI for evaluation. Typically, SRI cuts nine O-rings per element, three near the flanged end of the element, three in the middle of the element and three near the bottom. The results of these tests are also shown in Figure 8 at about 625 hours exposure. As indicated by the graph, three of these samples exhibited very low strength, on the order of 150-450 psi. All of the samples exhibiting low strength were from the flanged end of the filter element. When the specimens were reassembled after testing, it was evident that they had failed at a crack that was not apparent prior to the O-ring testing. It is believed that a thermal transient similar to the one measured in April 1998 may have caused the crack.

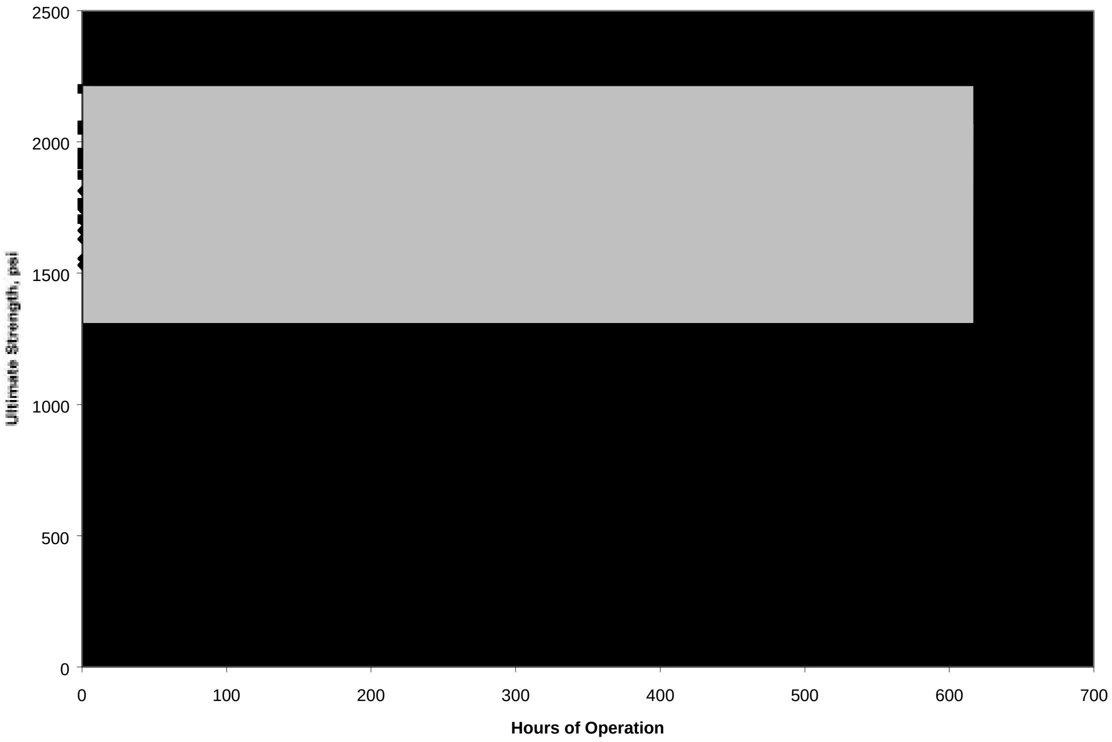

Figure 8 – Ultimate Strength of Coors P-100A-1 vs. Hours of Exposure

Non-Destructive Filter Testing

The PSDF is working closely with Dr. Roger Chen at West Virginia University (WVU) to evaluate his acoustic technique for non-destructively determining the mechanical properties of filter elements. Under a separate DOE contract[3], Dr. Chen has evaluated 36 filter elements that are undergoing testing at the PSDF. He obtained a baseline Young's Modulus for each of the filter elements tested and his values closely agree with the values obtained through literature or from the manufacturer.

The 36 filter elements tested have included twelve Coors P-100A-1, twelve Pall type 326, and twelve Schumacher TF20. Unfortunately, all of the Coors elements have failed during testing in the PCD. The Schumacher elements are being tested on the transport reactor train and have been measured after ~500 hours exposure. The results showed a general decrease in Young's Modulus over time. The Pall filters will be installed in the Combustor PCD on the Foster Wheeler APFBC. Exposure of these elements will continue and the changes in the materials will be monitored over time. Ultimately, the elements will be destructively tested to confirm the results from Dr. Chen's analysis.

---

[3] Research sponsored by the U.S. Department of Energy's Morgantown Energy Technology Center, under contract DE-AP21-95MC05134.

Future Activities

1999 will be a very busy year at the PSDF. The current plans call for the operation of the transport reactor with the Seimens-Westinghouse PCD in combustion and transition to gasification. Also, the start-up of the Foster Wheeler APFBC Pressurized Combustor will be resumed. During that time there are many objectives related to the filter system:

- Operate for a minimum of 1000 additional hours at a temperature of 1350-1400°F (730-760°C).
- Raise the face velocity for the PCD on the transport reactor train.
- Start-up the Foster Wheeler APFBC in a “first-generation” PFBC mode.
- Continue to develop a better understanding of what is happening inside the PCD during operation. This will be through many avenues: on-going FLUENT modeling which is a cooperative effort between the DOE and PSDF, sampling to determine what fraction of the particulate is being separated *prior* to reaching the filter elements, and pulse system modeling and optimization.
- Through the sampling and evaluation of the ash entering the PCD, develop a better understanding of how to predict PCD performance.
- Work with the filter element manufacturers to evaluate new materials and long filter elements, as they become available.
- Continue destructive testing of the exposed silicon carbide filter elements to evaluate their property changes with exposure.
- Continue supporting the research of Dr. Chen and others on non-destructive testing techniques for filter elements.

Acknowledgments

The authors wish to acknowledge the contributions and support provided by various project managers: Jim Longanbach (DOE), Mike Epstein (EPRI), Marty Fankhanel (KBR), Zal Sanjana (Seimens-Westinghouse) and Duane Pontius (SRI). The U.S. Department of Energy’s Federal Energy Technology Center, under contract DE-FC21-90MC25140 sponsored the project.

The authors would also like to especially thank Rich Dennis, Ted McMahon and everyone who has been involved in supporting the PCD testing over the last year. There are well over 100 people who have provided their expertise, support and encouragement to this part of the project. The success of the PCD program at the PSDF is largely due to your input.