PSDF

Power Systems Development Facility

Technical Progress Report Gasification Test Run TC06

July 4, 2001 - September 24, 2001

DOE Cooperative Agreement Number DE-FC21-90MC25140

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POWER SYSTEMS DEVELOPMENT FACILITY
TECHNICAL PROGRESS REPORT

GASIFICATION TEST RUN TC06

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POWER SYSTEMS DEVELOPMENT FACILITY

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ABSTRACT

This report discusses test campaign TC06 of the Kellogg Brown & Root, Inc. (KBR) Transport Reactor train with a Siemens Westinghouse Power Corporation (Siemens Westinghouse) particle filter system at the Power Systems Development Facility (PSDF) located in Wilsonville, Alabama. The Transport Reactor is an advanced circulating fluidized-bed reactor designed to operate as either a combustor or a gasifier using a particulate control device (PCD). The Transport Reactor was operated as a pressurized gasifier during TC06.

Test run TC06 was started on July 4, 2001, and completed on September 24, 2001, with an interruption in service between July 25, 2001, and August 19, 2001, due to a filter element failure in the PCD caused by abnormal operating conditions while tuning the main air compressor. The reactor temperature was varied between 1,725 and 1,825°F at pressures from 190 to 230 psig. In TC06, 1,214 hours of solid circulation and 1,025 hours of coal feed were attained with 797 hours of coal feed after the filter element failure. Both reactor and PCD operations were stable during the test run with a stable baseline pressure drop. Due to its length and stability, the TC06 test run provided valuable data necessary to analyze long-term reactor operations and to identify necessary modifications to improve equipment and process performance as well as progressing the goal of many thousands of hours of filter element exposure.

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1.0 EXECUTIVE SUMMARY

1.1 SUMMARY

This report discusses test campaign TC06 of the Kellogg Brown & Root, Inc. (KBR) Transport Reactor train with a Siemens Westinghouse Power Corporation (Siemens Westinghouse) particle filter system at the Power Systems Development Facility (PSDF) located in Wilsonville, Alabama. The Transport Reactor is an advanced circulating fluidized-bed reactor designed to operate as either a combustor or a gasifier using a particulate control device (PCD). The Transport Reactor was operated as a pressurized gasifier during TC06.

TC06 was planned as a 1,000-hour test run to perform long-term tests of the Transport Reactor using a blend of several Powder River Basin (PRB) coals and Bucyrus limestone from Ohio. The primary test objectives were as follows:

- Evaluate reactor loop and PCD operations for commercial performance by conducting long-term tests at near-constant coal-feed rate, air/coal ratio, riser velocity, solids-circulation rate, system pressure, and air distribution.
- Continue the evaluation of effects of the reactor modifications on PCD operations, especially regarding controlling PCD pressure drop through maintaining stable baseline and peak pressure drop.
- Test the effects of varying back-pulse parameters upon the particle filter system.
- Continue to test the use of metallic filter elements in the PCD.

Secondary objectives included the continuation of the following reactor characterizations:

- Reactor Operations – Study the devolatilization and tar cracking effects from transient conditions during the transition from start-up burner to coal. Evaluate the effect of process operations on heat release, heat transfer, and accelerated fuel particle heatup rates. Study the effect of changes in reactor conditions on transient temperature profiles, pressure balance, and product gas composition. Observe performance of new reactor temperature and coal-feed rate controllers.
- Effects of Reactor Conditions on Synthesis Gas Composition – Evaluate the effect of air distribution, steam/coal ratio, solids-circulation rate, and reactor temperature on CO/CO_2 ratio, synthesis gas Lower Heating Valve (LHV), carbon conversion, and cold and hot gas efficiencies.
- Recycle Gas Compressor Commissioning in Gasification Mode – Run the recycle gas compressor in bypass mode and evaluate the performance of the new moisture removal systems.

- Loop Seal Operations – Optimize loop seal operations and investigate increases to previously achieved maximum solids-circulation rate.

Test run TC06 was started on July 4, 2001, and completed on September 24, 2001, with an interruption in service between July 25, 2001, and August 19, 2001, due to a filter element failure in the PCD caused by abnormal operating conditions while tuning the main air compressor. The reactor temperature was varied between 1,725 and 1,825°F at pressures from 190 to 230 psig. In TC06, 1,214 hours of solid circulation and 1,025 hours of coal feed were attained with 797 hours of coal feed after the filter element failure. Both reactor and PCD operations were stable during the test run with a stable baseline pressure drop. Due to its length and stability, the TC06 test run provided valuable data necessary to analyze long-term reactor operations and to identify necessary modifications to improve equipment and process performance as well as progressing the goal of many thousands of hours of filter element exposure.

1.2 PSDF ACCOMPLISHMENTS

The PSDF has achieved over 4,985 hours of operation on coal feed and about 6,470 hours of solids circulation in combustion mode, and 2,505 hours of solid circulation and 1,902 hours of coal feed in gasification mode of operation. The major accomplishments in GCT1 through TC06 are summarized below. For combustion-related accomplishments see the technical progress report for the TC05 test campaign.

1.2.1 Transport Reactor Train

The major accomplishments and observations in GCT1 through TC06 include:

Commercial:

- With subbituminous coal, more than 95-percent carbon conversion and 110 Btu/scf nitrogen-corrected syngas heating value can be attained. The nitrogen-corrected syngas characteristics were sufficient to support existing pressurized syngas burners.

- Transport Reactor-generated syngas can be combusted without propane enrichment. The thermal oxidizer (atmospheric syngas burner) operated well using syngas with different heating values and was run for short periods of time without propane addition while maintaining an exit temperature near 2,000°F.

- The corrected cold gas efficiency (syngas latent heat to coal latent heat) and hot gas efficiency (syngas latent + sensible heat to coal latent heat) ranged from 65 to 75 percent and from 90 to 95 percent, respectively. These efficiencies can be obtained with subbituminous coals at coal-feed rates in terms of riser energy flux exceeding 100 MBtu/hr/ft^2.

Process:

- In GCT1, the reactor was operated using two bituminous coals and a PRB coal with different sorbents. Gasifier operations were stable, but carbon conversions were low due to disengager and cyclone inefficiencies.

- During GCT2, the longest continuous run of 184 hours at this point in gasification mode of operation was achieved with PRB coal. Reactor operations were smooth without any incident of oxygen breakthrough, temperature excursions, deposits, clinkers, or any other operational problem. The reactor loop was run consistently at about 50 percent of the design circulation rate. For the most part, the cyclone dipleg operated well with high solids flow due to the inefficiency of the disengager. However, there were brief cyclone dipleg upsets.

- In GCT3, stable gasification reactor operation was achieved at a range of coal-feed rates and solids-circulation rates, with reactor pressures ranging as high as 240 psig on PRB coal. The modification of the Y-type cyclone dipleg to a loop seal performed well, needing little attention and promoted much higher solids-circulation rates and higher coal-feed rates that resulted in lower relative solids loading to the PCD and higher gasification ash (g-ash, formerly referred to as char) retention in the reactor. The level in the disengager standpipe reached its highest levels, attaining heights beyond expectations without difficulties. The coal-feed rate in this run was the highest to date, with much higher carbon conversions achieved. The high coal-feed rate produced the highest syngas heating value to date. Tar generation was also lower, and could be completely eliminated by varying reactor-operating parameters. It was also demonstrated that coal feed can safely be restarted after more than 30 minutes of down time without lighting the reactor start-up burner.

- In GCT4, stable gasification reactor operation was achieved at a range of coal-feed rates, solids-circulation rates, and reactor pressures ranging as high as 240 psig on PRB coal. The coal-feed rate was increased further exceeding 5,500 pph. The reactor experienced some of the highest circulation rates (more than double the design rate) and riser densities ever observed in the Transport Reactor. These characteristics improved the temperature distribution in both the mixing zone and the riser and likely resulted in higher coal particle heat-up rates. Lower coal-feed rates of about 2,500 pph were also tested because of grinding problems in the coal mill. Carbon conversions as high as 98 percent were achieved.

- TC06 consisted of very long, steady-state periods with few changes in operating parameters. The long steady periods provided data for reactor and PCD performance evaluation and general steady-state system parameter calculations.

- During TC06, a new coal grinding and feeding procedure was successfully implemented to prevent particle segregation and improve coal feeder performance. The new technique allowed the coal feeder to run continuously without any problems for over 278 hours, which was now the longest continuous run in gasification mode of operation.

- Using coke breeze as a start-up fuel to increase reactor temperatures to 1,600°F before starting coal feed drastically improved the performance of the gas analyzers and prevented tar from accumulating in the sample lines. Coke breeze was also used as an alternate fuel feed during coal feeder trips, decreasing outage time to address coal feeder problems.

- Steam injection during TC06 was much lower than in previous test runs, often less than 300 pph. Although the steam-feed rate was much lower, the overall syngas quality remained high. Lowering the moisture content in the syngas by reducing steam flow improved sulfur capture by the sorbent.

- The ammonia (NH_3) and hydrogen cyanide (HCN) concentrations in the syngas were measured for the first time. The NH_3 varied from 1,400 to 1,800 ppm and the HCN varied between 40 and 80 ppm depending on the reactor operating conditions. Fuel nitrogen conversion to NH_3 and HCN varied between 55 to 65 percent and 1 to 3 percent, respectively.

- The gas analyzers were online for the majority of TC06, providing the best gas composition data from the Transport Reactor to date.

- Limestone calcination of 60 to 90 percent was achieved in the Transport Gasifier.

- The overall mass and energy balance was excellent with only ±5-percent error. The hydrogen and oxygen element balances illustrated marginal results with ±20-percent error. The hydrogen and oxygen balances were off due to a steam leak in the primary gas cooler. The calcium balance yielded marginal results with ±25 percent, and the silica balance error was very poor at ±100 percent.

- With PRB coal, the corrected fuel gas heating values ranged from 105 to 125 Btu/scf depending on the coal-feed rate. The air-to-coal ratio was between 3.2 and 3.6 lb/lb coal. In the test range, the solids-circulation rates, gas and solids residence times, and reactor temperatures do not show much effect on the fuel gas heating values. The devolatilization products evolution on unit coal feed basis was invariant to increases in PRB coal-feed rate. The observed increase in syngas heating value at high coal-feed rates is mainly due to the reduced effect of added nitrogen (dilution and relatively less energy consumption for heatup).

- Steam plays a major role in the performance of the Transport Gasifier. When the ratio of total steam (steam fed and coal moisture) to feed PRB carbon varied from 0.42 to 0.54, the gas H_2 to feed carbon ratio varied from 0.25 to 0.3. Based on gas analysis, test data show that for each mole of carbon converted about 0.35 moles of steam react. Calculations indicate that about 75 percent (50- to 90- percent range) of the H_2 in the gas originates from gasification reactions and 25 percent from devolatilization reactions. High steam-feed rates enhance H_2 production and reduce CO concentration in the gas phase.

- The mean particle size, in terms of mean mass diameter (mmd), of the PCD fines varied from 15 to 20 μm and the carbon content varied from 10 to 50 percent. The average higher heating value of PCD fines was about 4,200 Btu/lb at about 30-percent carbon content.

- The long test run enabled the displacement of initial start-up bed material with process-derived solids from coal minerals and sorbent. Reactor solids composition reached a steady-state condition in about 500 hours. No significant change in reactor performance was observed after reaching the steady-state.

- The particle-size distributions, in terms of mean mass diameter (mmd), were as follows: standpipe solids – 140 to 180 μm, sand – 122 μm, sorbent – 5 to 20 μm, coal – 200 to 350 μm. The standpipe solids were composed mainly of coal minerals.

Equipment:

- The recycle gas compressor was operated for about 20 hours using syngas with the discharge sent to the atmospheric syngas burner. The recycle gas moisture removal system needs additional modifications to improve its performance.

- The automatic reactor temperature control performed remarkably well, controlling air to maintain a steady reactor temperature at varied coal-feed rates.

- At the end of the test run the primary gas cooler experienced a tube failure, causing water to enter the refractory-lined pipe downstream between the cooler and the filter vessel.

- The HTF system modifications and new reactor shut-down procedure successfully prevented heat transfer fluid from leaking from the standpipe screw cooler into the reactor.

- The PCD and its solids removal system operated well without any major problems. The pressure drop was stable with a mild increase throughout the entire run. The peak pressure drop was well controlled with a 5- to 20-minute back-pulse timer. Due to the coke breeze feeding during on-coal transition, tar formation was significantly reduced, and therefore the PCD operation was much smoother, especially during the start-up phase. The inlet particulate loading averaged at about 15,000 ppmw. The outlet particulate loading was less than the detectable level of the sampling system (<0.1 ppmw) for the entire run. However, g-ash bridging was found after the shutdown.

- The gasifier g-ash removal system (FD0510) operated well without any line plugging during gasification.

- The gas coolers upstream and downstream of the PCD operated well without fouling.

- Since the high carbon conversion in the Transport Gasifier significantly reduced the amount of remaining g-ash the sulfator did not receive enough g-ash to maintain a high temperature. Thus, the sulfator required additional heating from its start-up burner and fuel oil injection system. Overall, the sulfator performed well.

1.2.2 Particulate Control Device

The highlights of PCD operation for TC06 include:

- During TC06, a 1,025-hour run, a relatively stable baseline pressure drop was maintained in the PCD. The baseline pressure drop ranged from about 80 to 120 in H_2O, a much smaller range than that seen in GCT3 or GCT4. An increase in the baseline pressure drop near the end of TC06 was largely attributable to g-ash bridging. Stable PCD inlet temperature and solids loading were maintained.

- Throughout the run SRI samples indicated that the measured PCD outlet solids loading was consistently below the minimum requirements for gas turbine operation, with the exception of one sample taken after a filter failure. There was no indication of leakage through PCD seals.

- SRI also successfully took samples at the PCD inlet, and these samples affirmed the relatively low solids loading resulting from the loop seal modifications completed after GCT2.

- The one filter element failure that occurred was caused by a thermal transient resulting from operating conditions that were well beyond normal, and the consequent leakage precipitated the first major system shutdown. The failure and leakage emphasized the need of a reliable failsafe. Several other less extreme thermal transients occurred during the run, and it was found that back-pulsing during a rapid temperature increase is very effective in stopping the temperature rise.

- As in GCT4, all metal filter elements, both new and previously exposed, were tested during the run and many of these filter elements have accumulated 1,450 hours of on-coal exposure. These filter elements will continue to be tested to assess material properties.

- After the first major shutdown in July there was no g-ash bridging found. However, operational data indicates that g-ash bridging may have been present but combusted during an extended thermal transient. After the final shutdown in September g-ash bridging was found. Addressing the issue of g-ash bridging will continue to be a major focus of PCD operations.

- Four iron aluminide filter elements and one Hastelloy X element were removed after TC06 for property testing, and the results will be presented in a subsequent run report. Property test results for elements removed after GCT3 and GCT4 are presented in this report.

1.3 FUTURE PLANS

During the outage following TC06, the Transport Reactor will be modified by adding a lower mixing zone (LMZ) to enable operations as an oxygen-blown gasifier. A 500-hour air blown test campaign (TC07) will begin in December 2001 to commission the LMZ and test a bituminous coal. A 250-hour test campaign (TC08) to commission the Transport Gasifier in oxygen-blown mode operation is scheduled for June 2002. A 250-hour test campaign (TC09) with bituminous coal in air-blown mode is scheduled for September 2002. Another oxygen-blown mode operation is scheduled for late 2002.

2.0 INTRODUCTION

This report provides an account of test campaign TC06 with the Kellogg Brown & Root, Inc. (KBR) Transport Reactor and the Siemens Westinghouse Power Corporation (Siemens Westinghouse) filter vessel at the Power Systems Development Facility (PSDF) located in Wilsonville, Alabama, 40 miles southeast of Birmingham. The PSDF is sponsored by the U. S. Department of Energy (DOE) and is an engineering-scale demonstration of advanced coal-fired power systems. In addition to DOE, Southern Company Services, Inc., (SCS), Electric Power Research Institute (EPRI), and Peabody Energy are cofunders. Other cofunding participants supplying services or equipment currently include KBR and Siemens Westinghouse. SCS is responsible for constructing, commissioning, and operating the PSDF.

2.1 THE POWER SYSTEMS DEVELOPMENT FACILITY

SCS entered into an agreement with DOE/National Energy Technology Laboratory (NETL) for the design, construction, and operation of a hot-gas, clean-up test facility for pressurized gasification and combustion. The purpose of the PSDF is to provide a flexible test facility that can be used to develop advanced power system components and assess the integration and control issues of these advanced power systems. The facility was designed as a resource for rigorous, long-term testing and performance assessment of hot stream clean-up devices and other components in an integrated environment.

The PSDF now consists of the following modules for systems and component testing:

- A Transport Reactor module.
- A hot-gas, clean-up module.
- A compressor/turbine module.

The Transport Reactor module includes KBR Transport Reactor technology for pressurized combustion and gasification to provide either an oxidizing or reducing gas for parametric testing of hot particulate control devices. The filter system tested to date at the PSDF is the particulate control device (PCD) supplied by Siemens Westinghouse.

2.2 TRANSPORT REACTOR SYSTEM DESCRIPTION

The Transport Reactor is an advanced circulating fluidized-bed reactor operating as either a combustor or as a gasifier, using a hot-gas, clean-up filter technology (particulate control devices or PCDs) at a component size readily scaleable to commercial systems. The Transport Reactor train operating in gasification modes is shown schematically in Figure 2.2-1. A taglist of all major equipment in the process train and associated balance-of-plant is provided in Tables 2.2-1 and -2.

The Transport Reactor consists of a mixing zone, a riser, a disengager, a cyclone, a standpipe, a loopseal, a solids cooler, and J-legs. The fuel, sorbent, and air are mixed together in the mixing zone along with the solids from the standpipe and solids cooler J-legs. The mixing zone, located below the riser, has a slightly larger diameter compared to the riser. Provision is made to inject air at several different points along the riser to control the formation of NO_X during combustion mode of operation. The gas and solids move up the riser together, make two turns and enter the disengager. The disengager removes larger particles by gravity separation. The gas and remaining solids then move to the cyclone, which removes most of the particles not collected by the disengager. The gas then exits the Transport Reactor and goes to the primary gas cooler and the PCD for final particulate clean-up. The solids collected by the disengager and cyclone are recycled back to the reactor mixing zone through the standpipe and a J-leg. In the combustion mode of operation, the solids cooler (not shown) controls the reactor temperature by generating steam and provides solids surge volume. A part of the solids stream from the standpipe flows through the solids cooler. The solids from the solids cooler then return to the bottom of the reactor mixing zone through another J-leg. The solids cooler is not used in gasification. The nominal Transport Reactor operating temperatures are 1,800 and 1,600°F for gasification and combustion modes, respectively. The reactor system is designed to have a maximum operation pressure of 294 psig with a thermal capacity of about 21 MBtu/hr for combustion mode and 41 MBtu/hr for gasification mode.

For start-up purposes, a burner (BR0201) is provided at the reactor mixing zone. Liquefied propane gas (LPG) is used as start-up fuel. The fuel and sorbent are separately fed into the Transport Reactor through lockhoppers. Coal is ground to a nominal average particle diameter between 250 and 400 μm. Sorbent is ground to a nominal average particle diameter of 10 to 30 μm. Limestone or dolomitic sorbents are fed into the reactor for sulfur capture. The gas leaves the Transport Reactor cyclone and goes to the primary gas cooler which cools the gas prior to entering the Siemens Westinghouse PCD barrier filter. The PCD uses ceramic or metal elements to filter out dust from the reactor. The filters remove almost all the dust from the gas stream to prevent erosion of a downstream gas turbine in a commercial plant. The operating temperature of the PCD is controlled both by the reactor temperature and by an upstream gas cooler. For test purposes, 0 to 100 percent of the gas from the Transport Reactor can flow through the gas cooler. The PCD gas temperature can range from 700 to 1,600°F. The filter elements are back-pulsed by high-pressure nitrogen or air in a desired time interval or at a given maximum pressure difference across the elements. There is a secondary gas cooler after the filter vessel to cool the gas before discharging to the stack or thermal oxidizer (atmospheric syngas combustor). In a commercial process the gas from the PCD would be sent to a gas turbine in a combined cycle package. The flue gas or fuel gas is sampled for on-line analysis after traveling through the secondary gas cooler.

After exiting the secondary gas cooler the gas is then let down to about 2 psig through a pressure control valve. In gasification the fuel gas is then sent to the thermal oxidizer to burn the gas and oxidize all reduced sulfur compounds (H_2S, COS, CS_2) and reduced nitrogen compounds (NH_3, HCN). The thermal oxidizer uses propane as a supplemental fuel. In combustion, the thermal oxidizer can be bypassed and fired on propane to make start-up steam. The gas from the thermal oxidizer goes to the baghouse and then to the stack.

The Transport Reactor produces both fine ash collected by the PCD and coarse ash extracted from the Transport Reactor standpipe. The two solid streams are cooled using screw coolers, reduced in pressure in lock hoppers, and then combined together. The combustion solids are suitable for commercial use or landfill as produced. In gasification, any fuel sulfur captured by sorbent should be present as calcium sulfide (CaS). The gasification solids are processed in the sulfator to oxidize the CaS to calcium sulfate ($CaSO_4$) and burn any residual carbon on the ash. The waste solids are then suitable for commercial use or disposal. Neither the sulfator nor the thermal oxidizer would be part of a commercial process. In a commercial process, the gasification solids could be burned in an atmospheric or pressurized fluidized bed combustor to recover the solids heat value.

Table 2.2-1

Major Equipment in the Transport Reactor Train

TAG NAME	DESCRIPTION
BR0201	Reactor Start-Up Burner
BR0401	Thermal Oxidizer
BR0602	Sulfator Start-Up/PCD Preheat Burner
CO0201	Main Air Compressor
CO0401	Recycle Gas Booster Compressor
CO0601	Sulfator Air Compressor
CY0201	Primary Cyclone in the Reactor Loop
CY0207	Disengager in the Reactor Loop
CY0601	Sulfator Cyclone
DR0402	Steam Drum
DY0201	Feeder System Air Dryer
FD0206	Spent Solids Screw Cooler
FD0210	Coal Feeder System
FD0220	Sorbent Feeder System
FD0502	Fines Screw Cooler
FD0510	Spent Solids Transporter System
FD0520	Fines Transporter System
FD0530	Spent Solids Feeder System
FD0602	Sulfator Solids Screw Cooler
FD0610	Sulfator Sorbent Feeder System
FL0301	PCD — Siemens Westinghouse
FL0302	PCD — Combustion Power
FL0401	Compressor Intake Filter
HX0202	Primary Gas Cooler
HX0203	Combustor Heat Exchanger
HX0204	Transport Air Cooler
HX0402	Secondary Gas Cooler
HX0405	Compressor Feed Cooler
HX0601	Sulfator Heat Recovery Exchanger
ME0540	Heat Transfer Fluid System
RX0201	Transport Reactor
SI0602	Spent Solids Silo
SU0601	Sulfator

Table 2.2-2 (Page 1 of 3)

Major Equipment in the Balance-of-Plant

TAG NAME	DESCRIPTION
BO2920	Auxiliary Boiler
BO2921	Auxiliary Boiler – Superheater
CL2100	Cooling Tower
CO2201A-D	Service Air Compressor A-D
CO2202	Air-Cooled Service Air Compressor
CO2203	High-Pressure Air Compressor
CO2601A-C	Reciprocating N_2 Compressor A-C
CR0104	Coal and Sorbent Crusher
CV0100	Crushed Feed Conveyor
CV0101	Crushed Material Conveyor
DP2301	Baghouse Bypass Damper
DP2303	Inlet Damper on Dilution Air Blower
DP2304	Outlet Damper on Dilution Air Blower
DY2201A-D	Service Air Dryer A-D
DY2202	Air-Cooled Service Air Compressor Air Dryer
DY2203	High-Pressure Air Compressor Air Dryer
FD0104	MWK Coal Transport System
FD0111	MWK Coal Mill Feeder
FD0113	Sorbent Mill Feeder
FD0140	Coke Breeze and Bed Material Transport System
FD0154	MWK Limestone Transport System
FD0810	Ash Unloading System
FD0820	Baghouse Ash Transport System
FL0700	Baghouse
FN0700	Dilution Air Blower
HO0100	Reclaim Hopper
HO0105	Crushed Material Surge Hopper
HO0252	Coal Surge Hopper
HO0253	Sorbent Surge Hopper
HT2101	MWK Equipment Cooling Water Head Tank
HT2103	SCS Equipment Cooling Water Head Tank
HT0399	60-Ton Bridge Crane
HX2002	MWK Steam Condenser
HX2003	MWK Feed Water Heater

Table 2.2-2 (Page 2 of 3)

Major Equipment in the Balance-of-Plant

TAG NAME	DESCRIPTION
HX2004	MWK Subcooler
HX2103A	SCS Cooling Water Heat Exchanger
HX2103C	MWK Cooling Water Heat Exchanger
LF0300	Propane Vaporizer
MC3001-3017	MCCs for Various Equipment
ME0700	MWK Stack
ME0701	Flare
ME0814	Dry Ash Unloader for MWK Train
ML0111	Coal Mill for MWK Train
ML0113	Sorbent Mill for Both Trains
PG2600	Nitrogen Plant
PU2000A-B	MWK Feed Water Pump A-B
PU2100A-B	Raw Water Pump A-B
PU2101A-B	Service Water Pump A-B
PU2102A-B	Cooling Tower Make-Up Pump A-B
PU2103A-D	Circulating Water Pump A-D
PU2107	SCS Cooling Water Make-Up Pump
PU2109A-B	SCS Cooling Water Pump A-B
PU2111A-B	MWK Cooling Water Pump A-B
PU2300	Propane Pump
PU2301	Diesel Rolling Stock Pump
PU2302	Diesel Generator Transfer Pump
PU2303	Diesel Tank Sump Pump
PU2400	Fire Protection Jockey Pump
PU2401	Diesel Fire Water Pump #1
PU2402	Diesel Fire Water Pump #2
PU2504A-B	Waste Water Sump Pump A-B
PU2507	Coal and Limestone Storage Sump Pump
PU2700A-B	Demineralizer Forwarding Pump A-B

Table 2.2-2 (Page 3 of 3)

Major Equipment in the Balance-of-Plant

TAG NAME	DESCRIPTION
PU2920A-B	Auxiliary Boiler Feed Water Pump A-B
SB3001	125-V DC Station Battery
SB3002	UPS
SC0700	Baghouse Screw Conveyor
SG3000-3005	4,160-V, 480-V Switchgear Buses
SI0101	MWK Crushed Coal Storage Silo
SI0103	Crushed Sorbent Storage Silo
SI0111	MWK Pulverized Coal Storage Silo
SI0113	MWK Limestone Silo
SI0114	FW Limestone Silo
SI0810	Ash Silo
ST2601	N_2 Storage Tube Bank
TK2000	MWK Condensate Storage Tank
TK2001	FW Condensate Tank
TK2100	Raw Water Storage Tank
TK2300A-D	Propane Storage Tank A-D
TK2301	Diesel Storage Tank
TK2401	Fire Water Tank
XF3000A	230/4.16-kV Main Power Transformer
XF3001B-5B	4,160/480-V Station Service Transformer No. 1-5
XF3001G	480/120-V Miscellaneous Transformer
XF3010G	120/208 Distribution Transformer
XF3012G	UPS Isolation Transformer
VS2203	High-Pressure Air Receiver

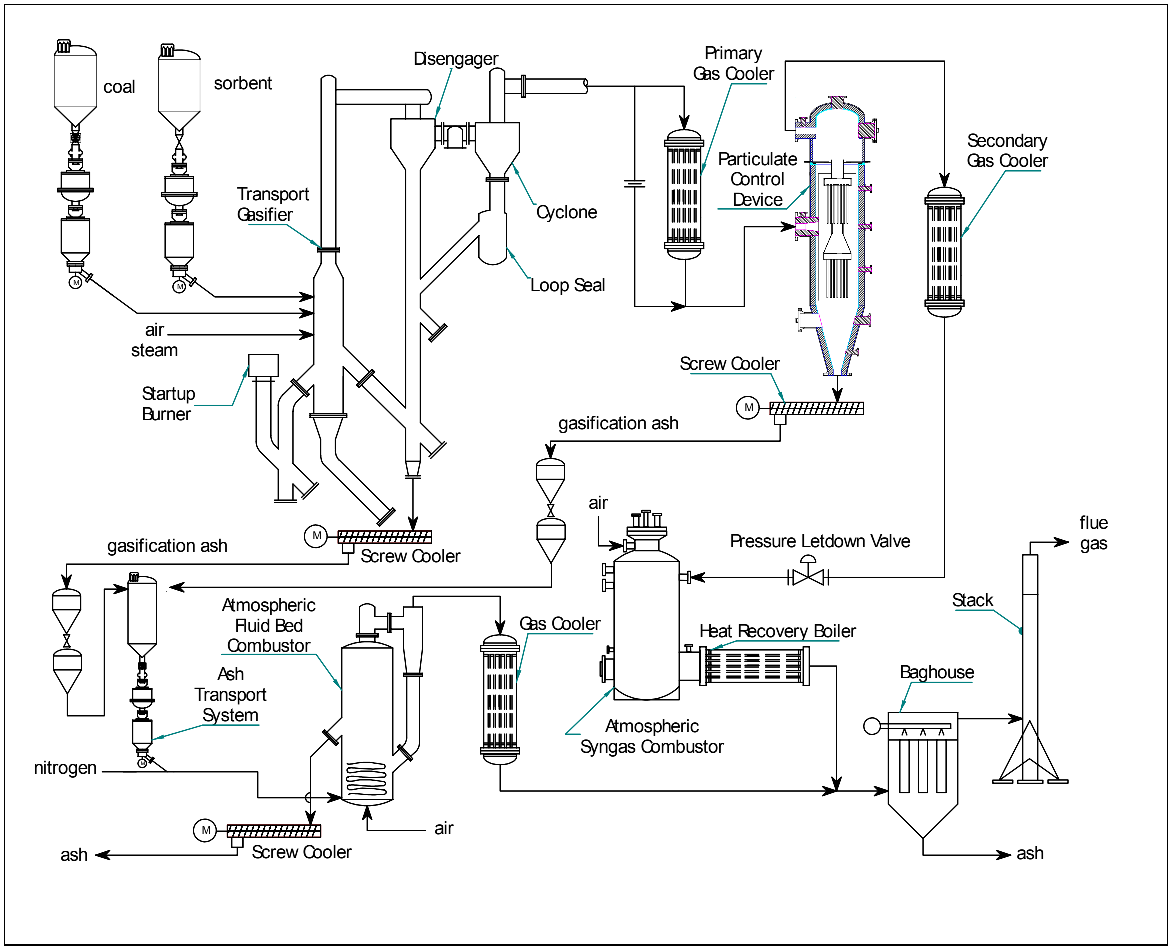

Figure 2.2-1 Flow Diagram of the Transport Reactor Train in Gasification Mode of Operation

2.3 SIEMENS WESTINGHOUSE PARTICULATE CONTROL DEVICE

Different PCDs will be evaluated on the Transport Reactor train. The first PCD that was commissioned in 1996 and has been used in all of the testing to date was the filter system designed by Siemens Westinghouse. The dirty gas enters the PCD below the tubesheet, flows through the filter elements, and the ash collects on the outside of the filter. The clean gas passes from the plenum/filter element assembly through the plenum pipe to the outlet pipe. As the ash collects on the outside surface of the filter elements, the pressure drop across the filter system gradually increases. The filter cake is periodically dislodged by injecting a high-pressure gas pulse to the clean side of the filter elements. The cake then falls to the discharge hopper.

Until the first gasification run in late 1999, the Transport Reactor had been operated only in the combustion mode. Initially, high-pressure air was used as the pulse gas for the PCD; however, the pulse gas was changed to nitrogen early in 1997. The pulse gas was routed individually to the two-plenum/filter element assemblies via injection tubes mounted on the top head of the PCD vessel. The pulse duration was typically 0.1 to 0.5 seconds.

A sketch of the Siemens Westinghouse PCD is shown in Figure 2.3-1.

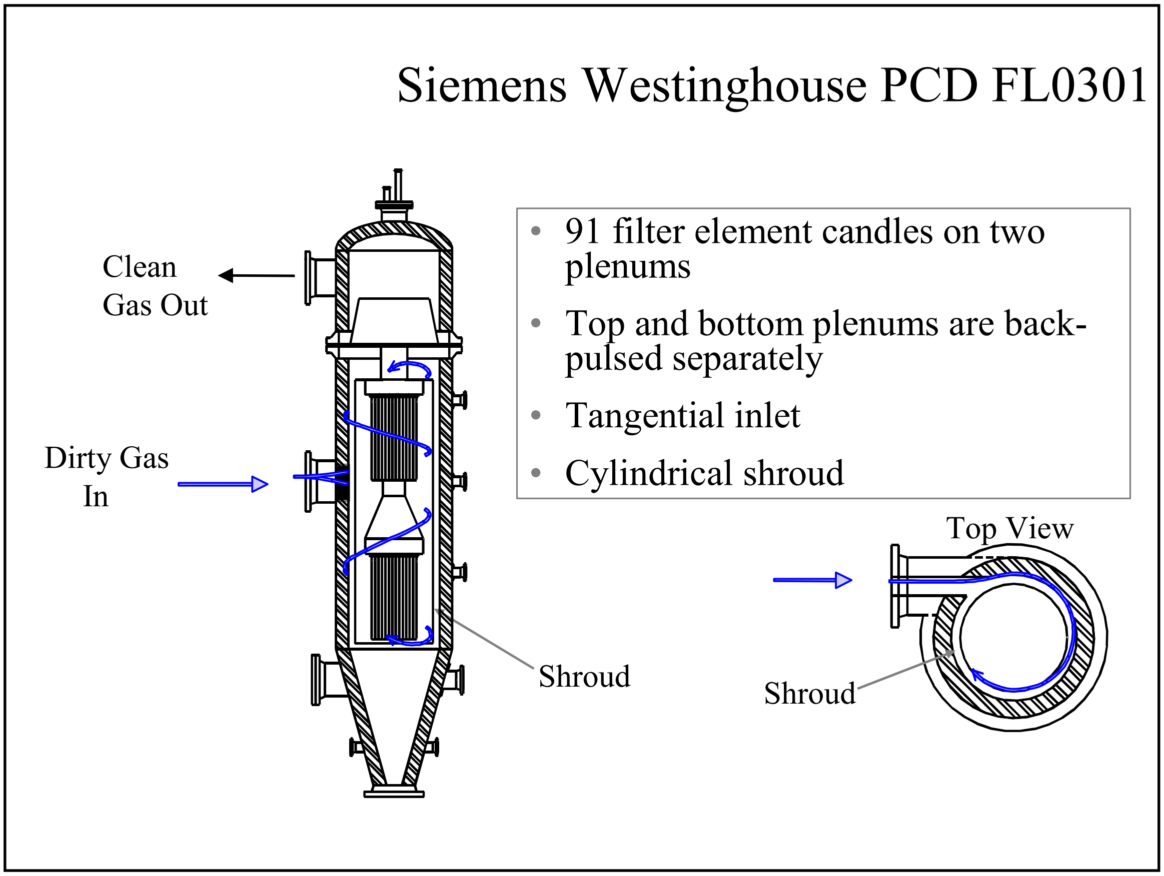

Figure 2.3-1 Siemens Westinghouse PCD

2.4 OPERATION STATUS

Commissioning activities began in September 1995 and proceeded in parallel with construction activities. Design and construction of the Transport Reactor and associated equipment was completed in early summer of 1996. All separate components and subsystems were fully operational by midsummer and commissioning work was focused on integration issues for the entire Transport Reactor train. The first coal fire in combustion mode of operation was achieved on August 18, 1996. A series of characterization tests was initiated to develop an understanding of reactor system operations. Test runs CCT1, CCT2, and CCT3 were completed by December 1996. Solids carryover from the reactor to the PCD was found to be excessive during these test runs. A number of startup and design problems associated with various equipment were successfully addressed.

During 1997, three additional sets of characterization test runs (CCT4, CCT5, and CCT6) and one major test campaign (TC01) were undertaken. TC01 focused on exposing the PCD filter elements to process gas for 1,000 hours at temperatures from 1,350 to 1,400°F and achieving stable reactor operations. An Alabama bituminous coal from the Calumet mine in the Mary Lee seam and Plum Run dolomite were used in these test runs.

Two test campaigns (TC02 and TC03) were successfully completed during 1998. TC02 was planned for reactor parametric testing to better quantify the effect of different variables on reactor and filter element operation. test run TC02 was started on April 5, 1998, and completed on May 11, 1998. Based on TC02 observations, TC03 was planned for additional reactor parametric testing to better quantify the effect of different variables on reactor and PCD operation and to evaluate operation with an Eastern Kentucky bituminous coal and a Gregg Mine limestone from Florida. The third major test campaign, TC03, was performed from May 31, 1998, to August 10, 1998. Stable operations were demonstrated using the Eastern Kentucky coal and Plum Run dolomite, Bucyrus limestone, and Longview limestone during TC03. There were, however, circulation problems using the Eastern Kentucky coal and Florida Gregg Mine limestone because of deposits resulting from excessive fines (segregated) in the Eastern Kentucky feed. One additional test run, TC04, was started on October 14, 1998, but was prematurely ended due to a temperature excursion in the PCD during the initial heat-up of the Transport Reactor system.

The final combustion test campaign was started on January 10, 1999, in combustion mode of operation and was completed May 2, 1999. During TC05 steady-state operations with a variety of fuel and sorbent feed materials was demonstrated (including petroleum coke with two different sorbents) and reactor parametric testing with different feed combinations was performed. Overall, TC05 was a successful test run with 10 different feed combinations tested.

Conversion of the Transport Reactor train to gasification mode of operation was performed from May to September 1999. The first gasification test run, GCT1, was planned as a 250-hour test run to commission the Transport Reactor train in gasification mode of operation and to characterize the limits of operational parameter variations. GCT1 was started on September 9, 1999, with the first part completed on September 15, 1999 (GCT1A). The second part of GCT1 was started on December 7, 1999, and completed on December 15, 1999 (GCT1B-D). This test run provided the data necessary for preliminary analysis of reactor operations and for identification of necessary modifications to improve equipment and process performance. Five different feed combinations of coal and sorbent were tested to gain a better understanding of the reactor solids collection system efficiency.

GCT2, planned as a 250-hour characterization test run, was started on April 10, 2000, and completed on April 27, 2000. Additional data was taken to analyze effect of different operating conditions on reactor performance and operability. A blend of several PRB coals was used with Longview limestone from Alabama. In the outage following GCT2, the Transport Reactor underwent a major modification to improve the operation and performance of the reactor solids collection system. The most fundamental change was the addition of the loop seal underneath the primary cyclone.

GCT3 was planned as a 250-hour characterization test with the primary objective to commission the loop seal. A hot solids-circulation test (GCT3A) was started on December 1, 2000, and completed December 15, 2000. After a 1-month outage to address maintenance issues with the main air compressor, GCT3 was continued. The second part of GCT3 (GCT3B) was started on January 20, 2001, and completed on February 1, 2001. During GCT3B a blend of several PRB coals was used with Bucyrus limestone from Ohio. The loop seal performed well, needing little attention and promoting much higher solids-circulation rates and higher coal-feed rates that resulted in lower relative solids loading to the PCD and higher gasification ash (g-ash) retention in the reactor.

GCT4, planned as a 250-hour characterization test run, was started on March 7, 2001, and completed on March 30, 2001. A blend of several PRB coals with Bucyrus limestone from Ohio was used. More experience was gained with the loop seal operations and additional data was collected to better understand reactor performance. Also during GCT4, RTI began commissioning of the DSRP achieving conversions as high as 80 percent.

TC06, the subject of this report, was planned as a 1,000-hour test campaign. TC06 started on July 4, 2001, and was completed on September 24, 2001. A blend of several PRB coals with Bucyrus limestone from Ohio was used. Both reactor and PCD operations were stable during the test run, with a stable baseline pressure drop. Due to its length and stability, the TC06 test run provided valuable data necessary to analyze long-term reactor operations and to identify necessary modifications to improve equipment and process performance as well as progress toward the goal of many thousands of hours of filter element exposure. Figure 2.4-1 shows a summary of operating test hours achieved with the Transport Reactor at the PSDF.

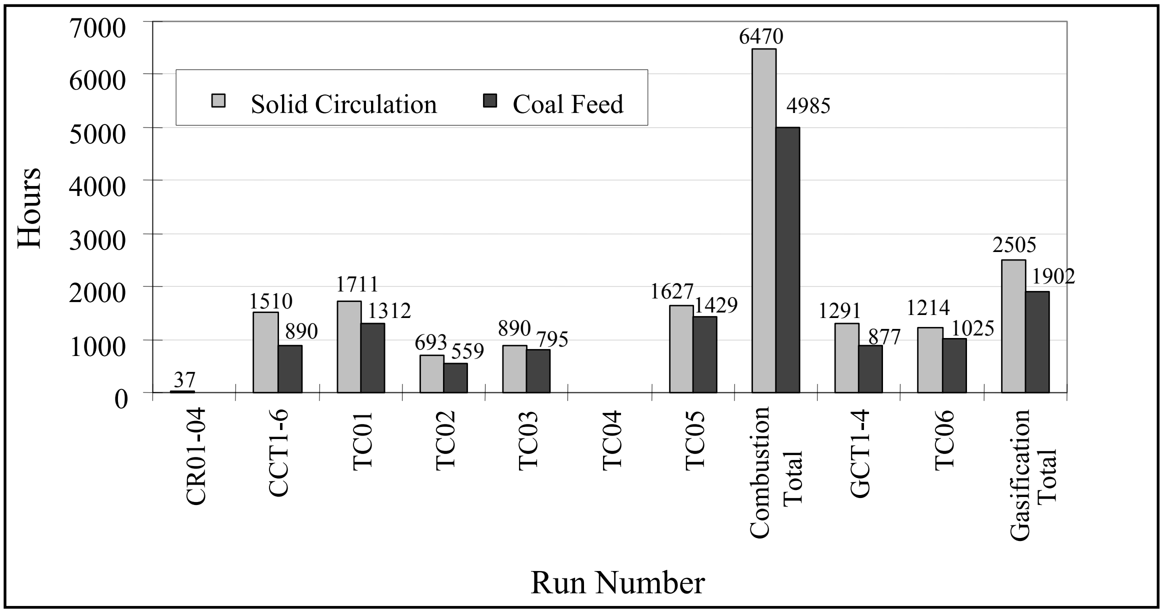

Figure 2.4-1 Operating Hours Summary for the Transport Reactor Train

3.0 PARTICLE FILTER SYSTEM

3.1 TC06 RUN OVERVIEW

TC06 was the first major gasification test campaign following four gasification characterization tests of the Halliburton KBR Transport Reactor train at the PSDF. It was the first gasification run since the reactor loop seal modifications were completed in which a stable baseline pressure drop was maintained in the particulate control device (PCD). Much of the success in attaining stable PCD operation was attributable to the reduction in tar formation during startups and periods of coal feed loss. The addition of a coke breeze feed line to the Transport Reactor allowed reactor heat-up to 1,600°F, the temperature below which excessive tar formation from coal is believed to occur, before coal feed. This change also allowed higher system pressure during the introduction of coal feed, since the start-up burner, which cannot operate at normal system pressure of 200 to 240 psig, was not required after the establishment of coke breeze feed. Because of the higher allowable system pressure at startups the PCD face velocity and subsequently the pressure drop generally did not reach unsustainable levels as it had in startups during previous runs.

TC06 consisted of two major periods of operation, including 228 on-coal hours in July 2001, and 797 on-coal hours during August and September 2001. Baseline pressure drops during both of these periods ranged from about 80 to 120 inH_2O. Only in GCT2, a 217-hour run which occurred before the reactor loop seal modifications, was the baseline pressure drop range smaller, only 50 to 80 inH_2O. The other two coal runs occurring after the reactor modifications, GCT3 and GCT4, consisted of only 183 and 242 on-coal hours, respectively. However, in GCT3 the baseline pressure drop ranged from 50 to 120 inH_2O; in GCT4, the range was 80 to 200 inH_2O. Near the end of TC06, an upward trend in baseline pressure drop occurred which corresponded to an increase in coal-feed rate. This increase may have been largely attributable to the growth of gasification ash (g-ash, formerly called char) bridging which was found during the September inspection.

The major operational concern during TC06 was the occurrence of thermal transients in the PCD caused by oxygen breakthrough. A major thermal transient occurred in July during a period when coal feed was stopped so that tuning of the main air compressor could be performed. During this time the oxygen level in the PCD exceeded 12 percent, and filter element surface thermocouples showed a rapid and sustained temperature increase. This resulted in a broken filter element, particulate leaking through the PCD, and eventually the first system shutdown after stable operation had been achieved.

This was the only time that particulate leaking was detected in TC06; all other PCD outlet samples indicated solids concentration below the sampling system limit of detection (0.1 to 0.4 ppmw). Other than the filter failure that occurred as a result of conditions that were beyond normal operating parameters, PCD operation was successful. The run provided the opportunity to expose filter elements to relatively long-term operation, advancing the goal of accumulating several thousand hours of individual filter element operation. TC06 also demonstrated the need for increased knowledge about the cause of g-ash bridging, as g-ash bridging had previously been attributed mainly to tar deposition on the filter surfaces. In addition, the run emphasized the need for a reliable failsafe device.

This report contains the following information:

- Run Report, Section 3.2—This section describes the main events and operating parameters affecting PCD operation. Operation of the fines removal system is also included in this section.

- Inspection Report, Section 3.3—The two inspections performed during TC06 are discussed in this section, including details of the post-run conditions of various PCD components and of the fines removal system.

- G-ash Characteristics and PCD Performance, Section 3.4—This is a detailed discussion of g-ash physical and chemical properties, as well as the effects of these g-ash characteristics on PCD performance. The results of PCD inlet and outlet solids concentration sampling is presented in this section.

- Filter Material Testing, Section 3.5—This section presents results of ongoing testing of various types of filter element media in an effort to characterize material properties such as corrosion resistance and useful filter life in gasification operation.

3.2 TC06 RUN REPORT

3.2.1 Introduction

For the filter system, TC06 was a demonstration of relatively long-term stable operation. Baseline pressure drop did not show as marked an increase throughout the run as it had in the two previous gasification runs. Although the baseline pressure drop did increase slightly near the end of the run, this increase was likely due to gasification ash (g-ash) bridging and to an increase in the coal-feed rate. Also, the filter system was successful in controlling outlet solids loading below the sampling system limit of detection, except in the one instance of a filter element failure caused by conditions that were well outside normal operations.

The fines removal system operated reliably during the majority of the run, although there were some occasions when the fines removal system interfered with reactor train operation. The major problems associated with the fines removal system were the FD0520 outlet line plugging and a leaking spheri valve on FD0520. Also, although not hindering system operations, the FD0502 screw cooler required almost daily maintenance to control leaking seals. There was concern that eventually seal adjustments would become impossible. After TC06 the FD0502 seals were redesigned, providing improved purge gas distribution and more room for necessary adjustments during future operation.

Run statistics for TC06 are shown in Table 3.2-1 and the two filter element layouts implemented are shown in Figures 3.2-1 and 3.2-2. Filter element layout 20 was used during the first part of TC06 in July. This layout was modified to become layout 21 after the major thermal event in the PCD, which required the removal of and repositioning of several filter elements.

3.2.2 Test Objectives

The primary objectives of TC06 for the filter system were:

- Maintain stable baseline and peak pressure drop. In the previous two gasification runs since the reactor loop seal modifications, controlling PCD pressure drop had been a major operational challenge. The major factor in the increasing baseline pressure drop during these runs is thought to have been excessive tar formation which contributed to a thick residual g-ash cake and to g-ash bridging. TC06 was the first run in which a coke breeze feeder was used during the heat-up period prior to coal feed and during periods of unstable coal feeder operation. The addition of the coke breeze feeder significantly reduced tar formation and tar deposition in the PCD. Also, since the start-up burner was no longer needed during the transition to coal, system pressure at the introduction of coal could be much higher. Therefore, PCD face velocity was lower and the extremely high face velocities previously seen at startups were no longer inevitable.
- Test the effects of varying back-pulse parameters. The back-pulse frequency and back-pulse pressure were changed during steady-state operations so that the effect on baseline pressure drop could be compared.

- Continue to test metal filter elements. As in the GCT3 and GCT4 coal runs, all metallic filter elements were used in TC06 because of the potential for thermal transients on the filter element surfaces, which can damage ceramic filter elements. For TC06, new and previously exposed Pall Iron Aluminide (Fe_3Al) filter elements were installed as well as Pall Hastelloy-X and USF-Schumacher metallic filter elements. Exposing the metallic filter elements to the gasification environment for extended periods of time will help determine material properties such as corrosion resistance and structural integrity.

3.2.3 Observations/Events – July 6, 2001, Through September 25, 2001

Refer to Figures 3.2-3 through -26 for operating data trends corresponding to the following list of events.

A. At 07:50 on July 6, 2001, after a final pressure test, the system was pressurized to 60 psig.

B. At 15:20 on July 6, 2001, back-pulsing began with a pressure of 250 psid (250 psi above system pressure) and the frequency was set at 30 minutes. At 15:35, the main air compressor was started and at 15:50, the start-up burner was lit. The start-up burner tripped at 16:30.

C. At 14:40 on July 7, 2001, the start-up burner was again lit. Beginning at 18:30, multiple burner trips occurred, and the burner operation was unstable over the next 2 days.

D. At 08:45 on July 9, 2001, the main air compressor control response was tested and caused a momentary surge in flow to the PCD. At 09:20, back-pulsing was stopped and the system was depressurized so that repairs could be made to the start-up burner.

E. Back-pulsing began again at 17:12 on July 9, 2001, with pressure set at 250 psid and timer set at 30 minutes. The system was pressurized to 60 psig. At 17:50, the main air compressor was started. At 20:30, lighting of the start-up burner was attempted. The start-up burner tripped several times over the next day and at 00:08 on July 10, 2001, the system pressure was reduced to 40 psig to improve burner performance. At 03:38, system pressure was increased to 60 psig but was reduced again to 40 psig at 04:13 after the burner tripped. After difficulty relighting the burner, system pressure was reduced to 24 psig at 08:45, and the burner was lit successfully at this time.

F. At 08:53 on July 10, 2001, system pressure was increased to 60 psig. At 13:35, the main air compressor tripped, and was restarted at 14:45. The start-up burner was relit at 14:50. Also on July 10, 2001, at 15:20, system pressure was incrementally increased to 120 psig.

G. At 16:53 on July 10, 2001, coke breeze feed started and at 17:00 back-pulse pressure was increased to 400 psid and the back-pulse frequency was increased to 5 minutes.

H. At 01:10 on July 11, 2001, coal feed began and at 01:40, system pressure was increased to 110 psig. Propane flow to the start-up burner was reduced. At 01:45, the FD0502 screw cooler tripped because of high outlet temperature and was restarted at 01:48. At 01:55, system pressure was increased to 135 psig and coke breeze feeding stopped. During this period of coal feed PCD pressure drop was the highest of the run, exceeding 500 inH_2O at one point. For most of this period the pressure drop exceeded the back-pulsing trigger point of 275 inH_2O before the time required by logic for a back-pulse cycle (about 3 minutes, 14 seconds).

I. At 01:57 on July 11, 2001, FD0520 system plugged and the coal-feed rate was reduced. At 02:40, coal feed was stopped because FD0520 could not be cleared. At 05:20, FD0520 was cleared, cycled, and immediately plugged again. Back-pulse pressure was reduced to 250 psid and frequency was reduced at 06:20 to 30 minutes. At 08:30, coke breeze feed was discontinued until the fines removal system could be restored.

J. At 08:45 on July 11, 2001, system pressure was reduced to 110 psig because of operating problems with the start-up burner. At 18:40 back-pulse pressure was increased to 360 psid. System pressure was increased to 120 psig at 06:50 on July 12, 2001.

K. At 09:25 on July 12, 2001, back-pulse pressure was increased to 400 psid and the timer was reduced to 5 minutes. At 09:30, coal feed started and at 09:33, system pressure was increased to 212 psig. A surge in the main air compressor occurred at 10:25, which caused it to unload, so coal feed was stopped and coke breeze feed was attempted. Coke breeze feed could not be started because the system pressure was too high for the feeder operation. At 10:40, the system pressure was reduced to 190 psig and coke breeze was successfully fed.

L. At 12:30 on July 12, 2001, coal feed was attempted. The feeder motor would not operate and the feeder was taken off-line for repairs. Back-pulse pressure was decreased to 250 psid and at 12:36 the timer was increased to 30 minutes. After unsuccessfully attempting coke breeze feed, system pressure was reduced to 110 psig at 18:30 so the start-up burner could be lit. Because of problems with start-up burner operation, system pressure was reduced to 40 psig so that repairs could be made on the burner. Back-pulsing was stopped at 01:00 and the system was depressurized at 07:10 on July 13, 2001.

M. After repairs were made on the start-up burner, back-pulsing was resumed at 14:45 on July 13, 2001, with back-pulse pressure set to 250 psid and timer set to 30 minutes. The system was pressurized and reached 60 psig at 16:05. After several unsuccessful attempts to light the start-up burner, the system was depressurized at 19:26 and back-pulsing ended at 20:27 on July 13, 2001.

N. At 00:00 on July 14, 2001, the system was pressurized and reached 100 psig at 05:50. Back-pulsing was resumed with the pressure set to 250 psid and timer set to 30 minutes. The start-up burner was lit at 01:25. Coke breeze feed began at 10:15 and was fed intermittently over the next few hours. System pressure was slowly increased to 130 psig.

O. At 15:58 on July 14, 2001, back-pulse pressure was increased to 400 psid and the timer was decreased to 5 minutes. Coal feed began at 16:00 and system pressure was slowly increased over the next few hours and held at 210 psig.

P. At 16:40 on July 14, 2001, the main air compressor unloaded and tripped the coal feeder. The thermal oxidizer also tripped at this time. Coal feed was resumed at 17:18.

Q. Multiple coal feeder trips occurred from 18:43 through 19:15 on July 14, 2001. A coal feeder trip occurred at 19:59 and coke breeze feed began until coal feed could be stabilized. The coal feeder was taken off-line so that the feed line could be cleared of obstructions which were blocking coal flow. Back-pulse pressure was reduced to 250 psid and back-pulse frequency was reduced to 30 minutes at 20:12 on July 14, 2001.

R. After the coal-feed line was cleared, coal feed began at 00:44 on July 15. Back-pulse pressure was increased to 400 psid and the frequency increased to 5 minutes. Coal feed was unsteady until about 01:00 when adjustments were made on the coal feeder fluidization nozzles and gate valve.

S. At 23:06 on July 18, 2001, after about an hour of coal feeding difficulty, the coal feeder tripped. At 23:08, a thermal excursion occurred in the PCD. As filter element surface temperatures began rapidly increasing, back-pulsing was manually initiated, and as each plenum received a back-pulse, filter element surface temperatures immediately dropped. The top plenum filter element surface temperatures rose about 70°F in 1 minute, and the bottom plenum, which was back-pulsed 1 minute after the top plenum, showed a rise in filter element surface temperature of about 170°F in 2 minutes.

   Coke breeze feed was started at 23:11 on July 18, 2001. After a few more minutes of coal feeding difficulty, coal feed was restored and coke breeze feed was discontinued.

T. At 13:05 on July 19, 2001, coke breeze feed was started after another period of coal feeding difficulty. The coal feeder tripped at 13:15 but was quickly restored. At 18:18, the back-pulse timer was increased from 5 to 10 minutes, but was reduced back to 5 minutes at 19:04 because back-pulsing was being triggered by high peak pressure drop.

U. At 14:34 on July 20, 2001, back-pulse pressure was reduced to 200 psid to observe the effect of back-pulse pressure on baseline pressure drop for a few hours. Back-pulse pressure was increased back to 400 psid at 20:53.

V. At 07:13 on July 21, 2001, the back-pulse timer was increased to 7.5 minutes.

W. At 14:34 on July 21, 2001, back-pulse pressure was increased to 400 psid to observe the effect of back-pulse pressure on baseline pressure drop.

X. At 18:00 on July 21, 2001, system pressure was gradually reduced from 210 to 180 psig because of coal feeding difficulty. At 18:38, back-pulse pressure was decreased to 400 psid to end the testing of back-pulse effect, and at 18:59 the back-pulse timer was reduced to 5 minutes. Coal feed stabilized and system pressure of 210 psig was resumed at 20:10.

Y. At 00:00 on July 22, 2001, after coal feeding difficulty began again, system pressure was gradually reduced to 175 psig, and at 00:10 coke breeze feed was started. As coal feed became steadier, coke breeze feed was stopped at 02:12 and system pressure was increased to 210 psig. Coal feeding became unsteady again, and after a coal feed trip at 03:40, system pressure was reduced to 194 psig and coke breeze feed resumed.

Z. At 06:41 on July 22, 2001, coal feed was started and coke breeze feed was discontinued at 07:03. At 08:06, system pressure was slowly increased to 210 psig.

AA. At 21:15 on July 23, 2001, coal feeder problems reoccurred. At 21:26, system pressure was reduced to 197 psig and coke breeze feed started. Coal feeding improved and system pressure was increased to 210 psig on July 24, 2001, at 00:27. Coke breeze feed stopped at 00:49.

BB. At 11:50 on July 24, 2001, coal feed was discontinued so that the main air compressor could be tuned. System pressure was reduced to 190 psig and coke breeze was attempted. Coke breeze would not convey, so system temperature dropped. At 14:25, back-pulse pressure was reduced to 250 psid (differential, that is, 250 psi above reactor pressure), and the timer was increased to 30 minutes.

At 16:12 on July 24, 2001, as the air compressor was being tuned, oxygen levels in the PCD increased to about 12 percent, and two filter element surface thermocouples indicated combustion on the bottom plenum. One thermocouple reading increased from about 480 to 800ºF in less than 5 minutes. Back-pulsing frequency was increased to 5 minutes at this time. The temperatures did not return to their previous values for about 20 minutes. At 16:25, the on-line particulate monitor on the PCD outlet duct detected particle leakage.

The back-pulse timer was increased to 30 minutes at 20:00 on July 24, 2001, and at 20:20 system pressure was reduced to 60 psig.

CC. At 06:36 on July 25, 2001, the start-up burner was lit and circulation was reestablished. A Southern Research Institute (SRI) sample taken at 09:55 showed a PCD outlet solids concentration of 23 ppmw, indicating a possible filter element failure. The system was therefore shut down. The start-up burner was shut off at 13:23 and the system was depressurized at 15:05. During this outage the PCD was inspected, a crack was found in one filter, and several filter elements were removed.

DD. After a final pressure test the system was pressurized to 60 psig on August 18, 2001, at 21:20. At 13:50 on August 19, 2001, the start-up burner was lit, and at 15:50 the back-pulsing sequence was started with back-pulse pressure set to 250 psid and timer set at 30 minutes. At 21:47 on August 19, 2001, system pressure was slowly increased to 100 psig. The start-up burner tripped a few times beginning at 03:30 on August 20, but operation continued. Coke breeze feed started at 08:40. At 08:55, back-pulse pressure was increased to 400 psid.

EE. Coal feed was started at 15:55 on August 20, 2001. The back-pulse timer was decreased to 5 minutes. Coke breeze feed was discontinued at 16:10 on August 20.

FF. At 01:22 on August 21, 2001, the back-pulse timer was increased from 5 to 10 minutes.

GG. At 21:43 on August 21, 2001, the back-pulse timer was decreased to 7.5 minutes because back-pulsing was being triggered by high peak pressure drop.

HH. At 22:30 on August 21, 2001, the coal feeder operation became unsteady. Coke breeze feed was started at 22:50 and the coal feeder tripped at 22:56. Coke breeze would not feed, apparently because of a plugged feed line. At 23:35 on August 21, system pressure was reduced gradually to 70 psig so that the start-up burner could be lit. The start-up burner was successfully lit at 01:30 on August 22.

II. At 02:26 on August 22, 2001, the back-pulse timer was increased to 10 minutes. At 04:48, FD0520 tripped, apparently due to a plugged line resulting from a large amount of solids carryover from the reactor. Operations personnel cleared the line and FD0520 operation resumed at 05:34 on August 22. Coke breeze was successfully fed beginning at 10:35 on August 22.

JJ. At 16:37 on August 22, 2001, coal feed was resumed and system pressure was incrementally increased to 190 psig.

KK. At 02:38 on August 23, 2001, the back-pulse timer was decreased to 7.5 minutes.

LL. At 09:12 on August 23, 2001, the coal feeder tripped, coke breeze feed was started, and FD0520 also tripped due to a momentary drop in control nitrogen pressure. FD0520 operation resumed at 09:38 and coal feed was resumed at 10:02.

MM. At 23:21 on August 23, 2001, the coal feeder tripped and coke breeze feed was started. Adequate air flow could not be maintained due to a logic problem, so system pressure was reduced to 60 psig at 23:37. The start-up burner was lit at 01:12 on August 24, 2001. System pressure was then increased to 80 psig. The back-pulse timer was increased to 10 minutes at 04:25 on August 24.

At 08:10 on August 24, 2001, coke breeze feed began and at 10:55 system pressure was increased to 115 psig.

NN. At 11:30 on August 24, 2001, the back-pulse timer was reduced to 5 minutes, coal feed resumed at 12:32, and system pressure was gradually increased to 200 psig.

OO. At 17:10 on August 24, the back-pulse timer was increased to 10 minutes. At 22:50, system pressure was reduced to 190 psig because the coal feeder operation was unsteady. System pressure was increased to 195 psig at 23:15 on August 25.

PP. At 11:50 on August 27, 2001, the fines removal system (including FD0502, FD0520, and FD0530) was taken off-line so that a g-ash leak on the FD0530 spheri valve could be repaired. The coal- and sorbent-feed rates were reduced to minimize solids carryover to the PCD. As the PCD cone thermocouples indicated that the cone was filling up; coke breeze was started at 13:32 and coal feed was discontinued at 13:47. Operation of the fines removal system resumed at 14:40 after the leak was repaired.

QQ. At 17:15 on August 27, 2001, the back-pulse timer was increased to 15 minutes.

RR. After the PCD cone was cleared of all solids, coal feed was resumed at 17:45. The back-pulse timer was decreased to 5 minutes. At 00:55 on August 28, 2001, system pressure was increased to 200 psig.

SS. Coal feeding became unsteady, so coke breeze feed was started and system pressure was reduced to 190 psig at 21:05 on September 2, 2001. The coal feeder tripped at 21:17. Coal feed quickly resumed at 21:22 and coke breeze feed was discontinued at 21:30. System pressure was increased to 200 psig at 21:42 on September 2, 2001.

TT. The coal feeder tripped at 12:43 on September 3, 2001, due to low control nitrogen pressure. Coke breeze feed started at 12:45, and system pressure was lowered to 190 psig. Coal feed was resumed at 13:21 and coke breeze feed was stopped at 14:43. At 15:07 on September 3, 2001, system pressure was increased to 200 psig.

UU. At 01:10 on September 4, 2001, the coal feeder tripped and coke breeze feed was started at 01:12. Coal feed was resumed at 01:14 and coke breeze feed was discontinued at 01:17.

VV. At 06:40 on September 5, 2001, the bottom plenum back-pulse pressure was increased to 600 psid while the top plenum back-pulse pressure was kept at 400 psid. Earlier, on September 4, at 17:00, one of the seven filter element surface thermocouples on the bottom plenum began reading a higher temperature than the other six thermocouples. Based on operational experience, such a deviation in temperature is caused by g-ash bridging. The bottom plenum back-pulse pressure was increased in an effort to dislodge the bridging. There was no effect on the thermocouple readings and the back-pulse pressure was set back to 400 psid at 12:50 on September 5, 2001.

WW. At 11:30 on September 6, 2001, the back-pulse valve open time was increased from 0.2 to 0.5 seconds in an effort to dislodge the apparent g-ash bridging. The valve-open time was then increased to 0.8 seconds and then to 1.2 seconds before eventually changing the timer back to 0.2 seconds on September 8, 2001.

XX. At 12:58 on September 6, 2001, the back-pulse timer was decreased to 5 minutes.

YY. At 14:25 on September 6, 2001, the bottom plenum back-pulse pressure was again increased to 600 psid. Despite this change and the longer back-pulse valve-open time, the deviating thermocouple remained at a higher reading than the other thermocouples, although it did show an increased response to back-pulsing while the valve-open time was increased. The bottom plenum back-pulse pressure was decreased to 400 psid at 21:55 on September 7, 2001.

ZZ. At 08:00 on September 7, 2001, the coal feeder tripped due to a high-oxygen-level alarm, which had been set off during gas analyzer calibrations. Coke breeze feed was started at 08:03, coal feed was reestablished at 08:07, and coke breeze feed was discontinued at 08:14.

AAA. At 18:13 on September 7, 2001, the back-pulse timer was increased from 5 to 10 minutes.

BBB. At 22:59 on September 7, 2001, coke breeze feed was started after coal feeding became unsteady. The coal feeder tripped at 23:38, and coal feed was resumed at 01:43 on September 8.

CCC. At 03:03 on September 10, 2001, coke breeze feed was started after coal feeding became unsteady. The coal feeder tripped at 03:05 and resumed operation at 03:17. Coke breeze feed was discontinued at 04:31 on September 10.

DDD. The next coal feeder trip occurred on September 10, at 23:00, and coal feed was quickly reestablished at 23:19.

EEE. There were several times over the next few days when the coal feed tripped but was quickly back on-line. This occurred on September 11, 2001, at 10:18; on September 11, at 19:01; on September 12, at 01:02; and on September 12, at 23:21. The coal feeding problems were attributed to coal particle-size segregation in the coal silos. Changing the coal grinding schedule from grinding coal 12 hours per day to continuous coal grinding seemed to negate the size segregation and solve the coal feeding problem.

FFF. At 18:57 on September 16, 2001, system pressure was increased to 220 psig.

GGG. At 13:48 on September 17, 2001, air- and coal-feed rates were increased.

HHH. At 12:48 on September 18, 2001, air- and coal-feed rates were again increased. At 13:46, the back-pulse timer was reduced from 20 to 10 minutes.

III. At 18:47 on September 19, 2001, system pressure was increased to 230 psig.

JJJ. At 00:10 on September 21, 2001, air- and coal-feed rates were increased.

KKK. At 00:05 on September 22, 2001, the back-pulse timer was decreased to 7.5 from 10 minutes.

LLL. At 13:38 on September 22, 2001, the coal feeder tripped and coke breeze feed was started. Coal feed resumed at 13:47, and coke breeze feed was stopped at that time.

MMM. At 11:26 on September 24, 2001, system pressure was increased to 240 psig.

NNN. At 14:27 on September 24, 2001, the back-pulse sequence was disabled for a dirty shutdown. Coal feed was stopped at 14:33 on September 24, 2001.

3.2.4 Run Summary and Analysis

For the PCD, TC06 began as the system was pressurized and the back-pulsing sequence was first started on July 6, 2001. After solving some initial operational problems (primarily involving the start-up burner) coal feed first began on July 11, 2001, at 01:10 but was discontinued at 02:40. During this period of coal feed, the PCD pressure drop was the highest of the run. Back-pulsing exceeded the trigger point of 275 inH_2O before back-pulsing could be initiated by the logic sequence, and the peak pressure drop reached 515 inH_2O at one point. Coke breeze had been fed to bring the reactor temperature above 1,500°F and both coke breeze feed and start-up burner operation were continued over the duration of coal feed. Apparently, there was a tremendous amount of solids entering the PCD when coal feed was introduced, because the screw cooler FD0502 outlet temperature quickly reached 400°F (the high-high alarm set point). The face velocity in the PCD was also extremely high, exceeding 8 ft/min several times. One reason for the high face velocity was that system pressure was kept low, between 119 and 134 psig, during this time so that the start-up burner could operate. Coal feed was ended after FD0502 tripped on high outlet temperature and the FD0520 outlet line plugged and could not be cleared. This was the first time coke breeze had been used in the transition to coal feed and it was a learning experience. After this experience, the start-up burner was no longer used during the transition to coal and coke breeze feed was discontinued quickly after coal feed was established.

The next time coal feed was introduced was on July 12, 2001. However, this period of coal feed lasted less than one hour due to operational problems with the main air compressor. Over the next few days, coal feed was attempted several times, but due to various problems coal feed was not established again until 00:44 on July 15, 2001. At 23:08 on July 18, 2001, after a coal feeder trip, oxygen breakthrough caused a thermal excursion in the PCD. As filter element surface temperatures began rapidly increasing, back-pulsing was manually initiated, and as each plenum received a back-pulse, filter element surface temperatures immediately dropped. The top plenum filter element surface temperatures rose about 70ºF in 1 minute, and the bottom plenum, which was back-pulsed 1 minute after the top plenum, showed a filter element surface temperature increase of about 170ºF in 2 minutes. This was useful operational experience, supporting the action of back-pulsing during a thermal excursion as an effective method of stopping combustion on the filter element surfaces.

Coal feed was quickly reestablished at 23:42 on July 18, 2001, and coal feed was maintained except for short periods of coal-feed loss occurring over the next few days. During these periods of coal-feed loss, reactor temperatures were kept fairly stable with coke breeze feed, and system pressure was also fairly constant. There were other minor thermal excursions occurring during unstable coal feeder operation causing oxygen breakthrough.

At 11:50 on July 24, 2001, coal feed was stopped so that the main air compressor could be tuned. At 16:12, during the compressor tuning, oxygen levels in the PCD exceeded 12 percent, and two filter element surface thermocouples indicated combustion in the PCD. The temperature of the filter element surfaces had been about 480ºF, but during this thermal excursion one thermocouple increased to about 800ºF. The air compressor tuning continued and the PCD oxygen level remained elevated. The filter element surface thermocouple readings did not return to their previous temperatures until about 16:47 on July 24, 2001. At this time, no coal or coke breeze had been fed for over 4 hours, although back-pulsing had continued. Therefore, most g-ash in the form of a transient filter cake should have been removed, and the extended thermal transient was likely caused by the combustion of g-ash bridging. The two thermocouples that showed significant response during the thermal excursion had previously begun deviating a few degrees from the nearby thermocouples, indicating that they were covered with g-ash bridging. The on-line PCME PCD outlet particulate monitor began indicating particle leakage at 16:23, showing a peak reading of 100 percent at 16:30 on July 24, 2001. On July 25, 2001, at 10:45, an SRI outlet sample affirmed particulate leakage through the PCD with a solids concentration of 23 ppmw. Therefore, the system was shut down so that the PCD could be opened for inspection. When the PCD was inspected, one broken filter element was found. This filter element was removed (as well as several nearby filter elements) because of the potential damage incurred by the thermal excursion.

System operation resumed in August. The system was pressurized on August 18, 2001, and back-pulsing and system heat-up started on August 19, 2001. Coal feed began on August 20, 2001, at 15:55, and this period of coal feed lasted until August 21, 2001, at 22:56, when the coal feeder tripped. At this time, the coke breeze feeding system would not convey solids, so the system pressure was reduced so that the start-up burner could be lit to reheat the reactor. On August 22, 2001, at 16:37, coal feed began again, but after a coal feeder trip on August 23, 2001, at 23:21, a logic problem caused inadequate air flow to the reactor, and system pressure had to be reduced again to light the start-up burner. The next time coal feed began was on August 24, 2001, at 11:30. This period of coal feed lasted until the end of the run on September 24, 2001, and was interrupted by only short periods of coal-feed loss. During unsteady coal feeder operation, coke breeze was successfully fed, so system temperature and pressure were generally kept constant. Unsteady coal feeder operation was attributed to particle-size segregation in the silos which could result in periods of coal feeding with finer particles that are more difficult to convey. This problem was apparently alleviated by constantly filling the silos with coal instead of only grinding coal and filling the silos 12 hours per day as had been previously done. The run ended in a controlled dirty shutdown on September 24, 2001. The back-pulsing sequence was disabled at 14:27 at the end of a back-pulsing cycle, and coal feed was discontinued at 14:33 on September 24, 2001.

The baseline pressure drop was much more stable in TC06 than it was in the two preceding gasification runs (GCT3 and GCT4). As discussed in Section 3.4, the fairly stable baseline was largely attributable to the reduction in tar deposition on the filter element surfaces. Near the end of the run, the baseline did show a noticeable increase. This increase corresponded to an increase in the coal-feed rate and the apparent presence of g-ash bridging. Because baseline pressure drop is only a small function of coal-feed rate, g-ash bridging growth likely contributed most to the increasing baseline.

Figure 3.2-27 shows the normalized baseline pressure drop throughout TC06, a filter surface temperature difference indicating g-ash bridging, and the coal feeder speed. The normalized baseline pressure drop is the baseline pressure drop corrected for constant face velocity and temperature. The filter surface temperature difference is the difference between one thermocouple reading (TI3025J), which began reading higher than the other nearby thermocouples on the bottom plenum, and another thermocouple (TI3025H), which showed no such deviation throughout the run. In addition, on inspection, g-ash bridging was extensive in the area where TI3025J was located and was not found near TI3025H. Also seen in Figure 3.2-27 is the coal feeder speed, which gives an estimate of the relative coal-feed rate. As seen in the figure, the baseline pressure drop changes correspond well to the indications of g-ash bridging. PCD operations will continue to focus on maintaining a stable baseline; therefore, eliminating g-ash bridging will remain a priority.

Table 3.2-1

TC06 Run Statistics and Steady-State PCD Operating Parameters
July 6, 2001 Through September 24, 2001

Start Time:	07/06/00 15:20 (for back-pulse system)
End Time:	09/24/00 14:27
Coal Type:	Powder River Basin
Hours on Coal:	Approximately 1,025 hr
Sorbent Type:	Ohio limestone
Number of Filter Elements:	90
Filter Element Layout No.:	20 and 21 (Figure 3.2-1 and 3.2-2)
Filtration Area:	261.3 ft^2 (24.3 m^2)
Pulse-Valve-Open Time:	0.2 sec
Pulse-Time Trigger:	5 to 20 min
Pulse Pressure, Top Plenum	250 to 400 psi above System Pressure
Pulse Pressure, Bottom Plenum:	250 to 600 psi above System Pressure
Pulse-dP Trigger:	275 inH_2O
Inlet Gas Temperature:	675 to 750°F
Face Velocity:	3 to 4 ft/min
Inlet Loading Concentration:	9,200 to 18,800 ppmw
Outlet Loading Concentration:	Below 0.4 ppmw*
Baseline Pressure Drop:	80 to 120 inH_2O
Peak Pressure Drop:	150 to 250 inH_2O

* Except for outlet loading concentration of 22.9 ppmw detected on July 25, 2001, during an off-coal period resulting from a broken filter element.

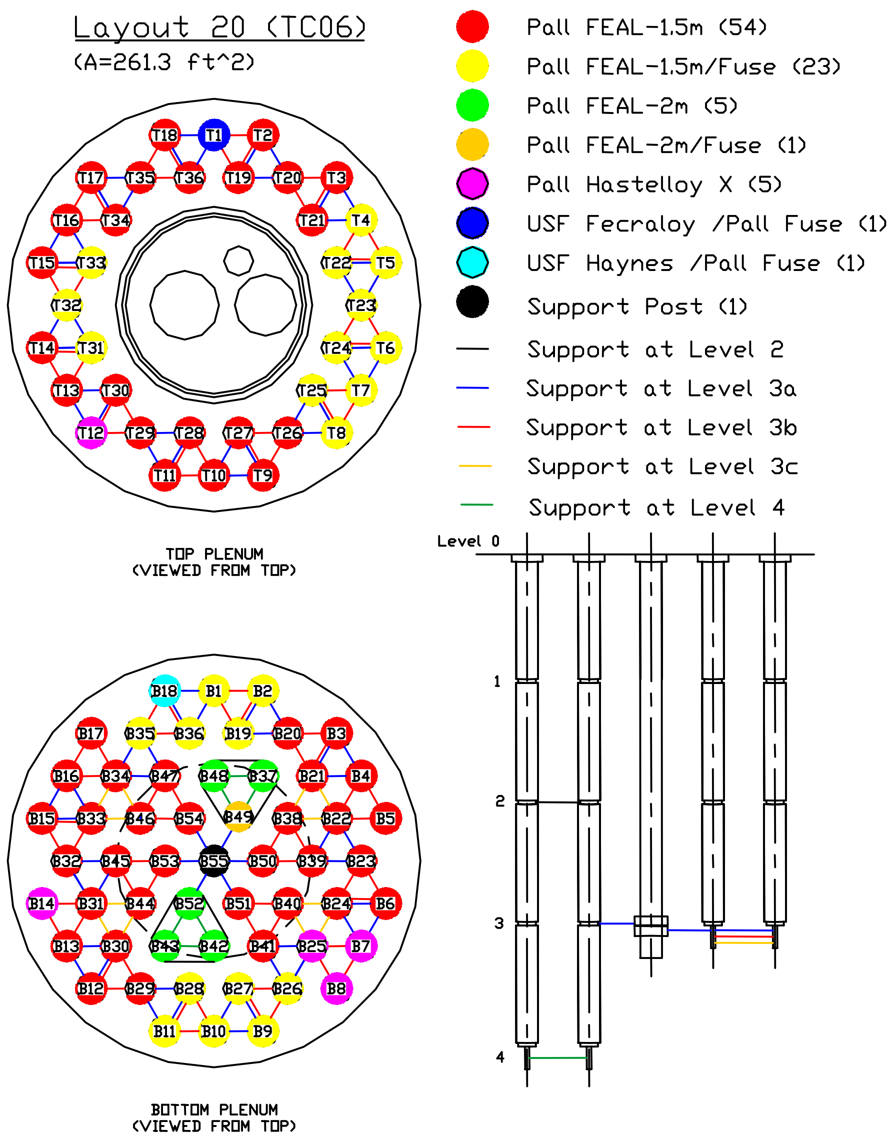

Figure 3.2-1 Filter Element Layout for TC06, July 2001

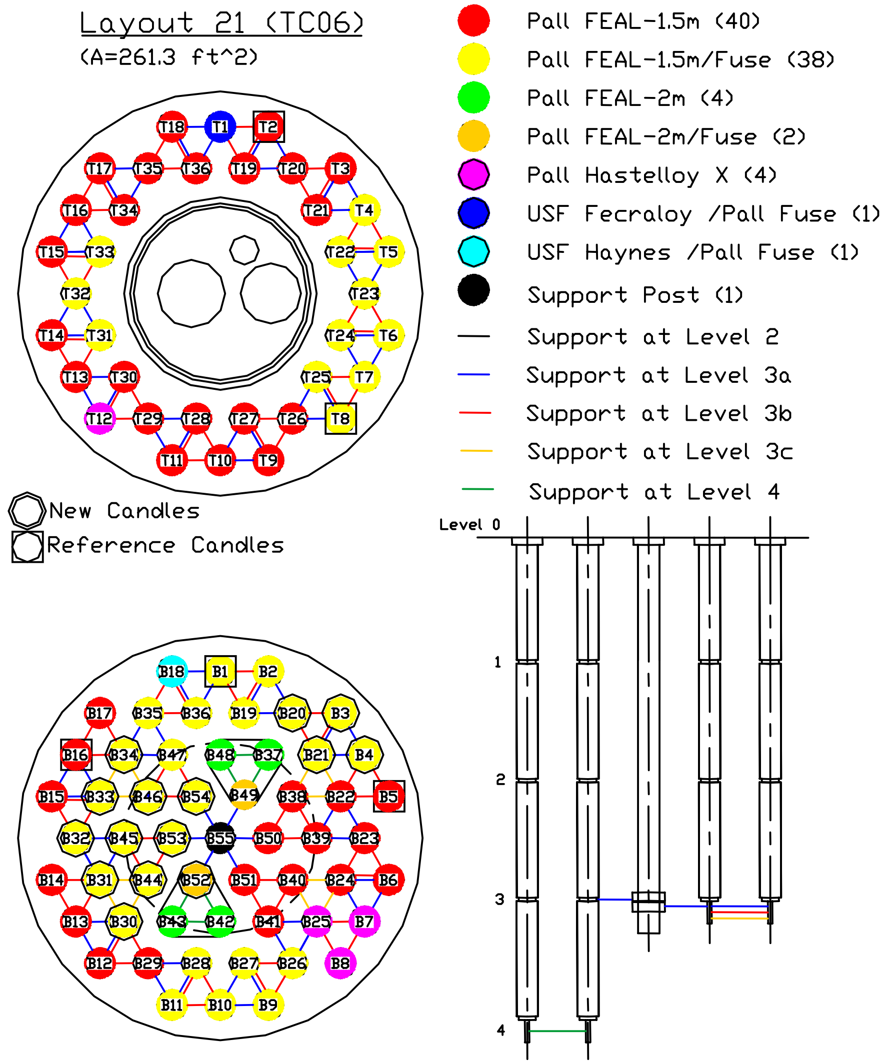

Figure 3.2-2 Filter Element Layout for TC06, August and September 2001

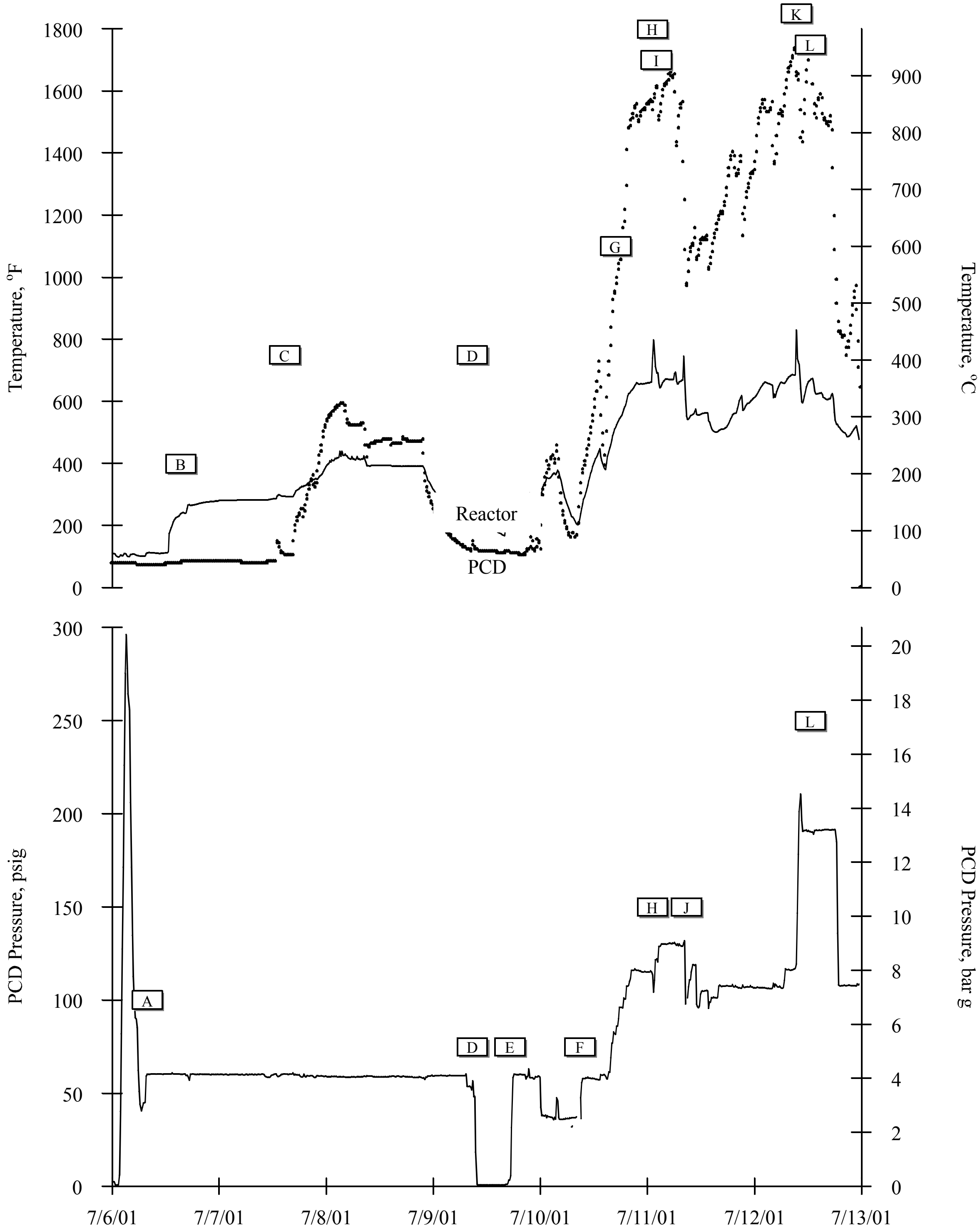

Figure 3.2-3 Reactor and PCD Temperatures and PCD Pressure, July 6, 2001 Through July 13, 2001

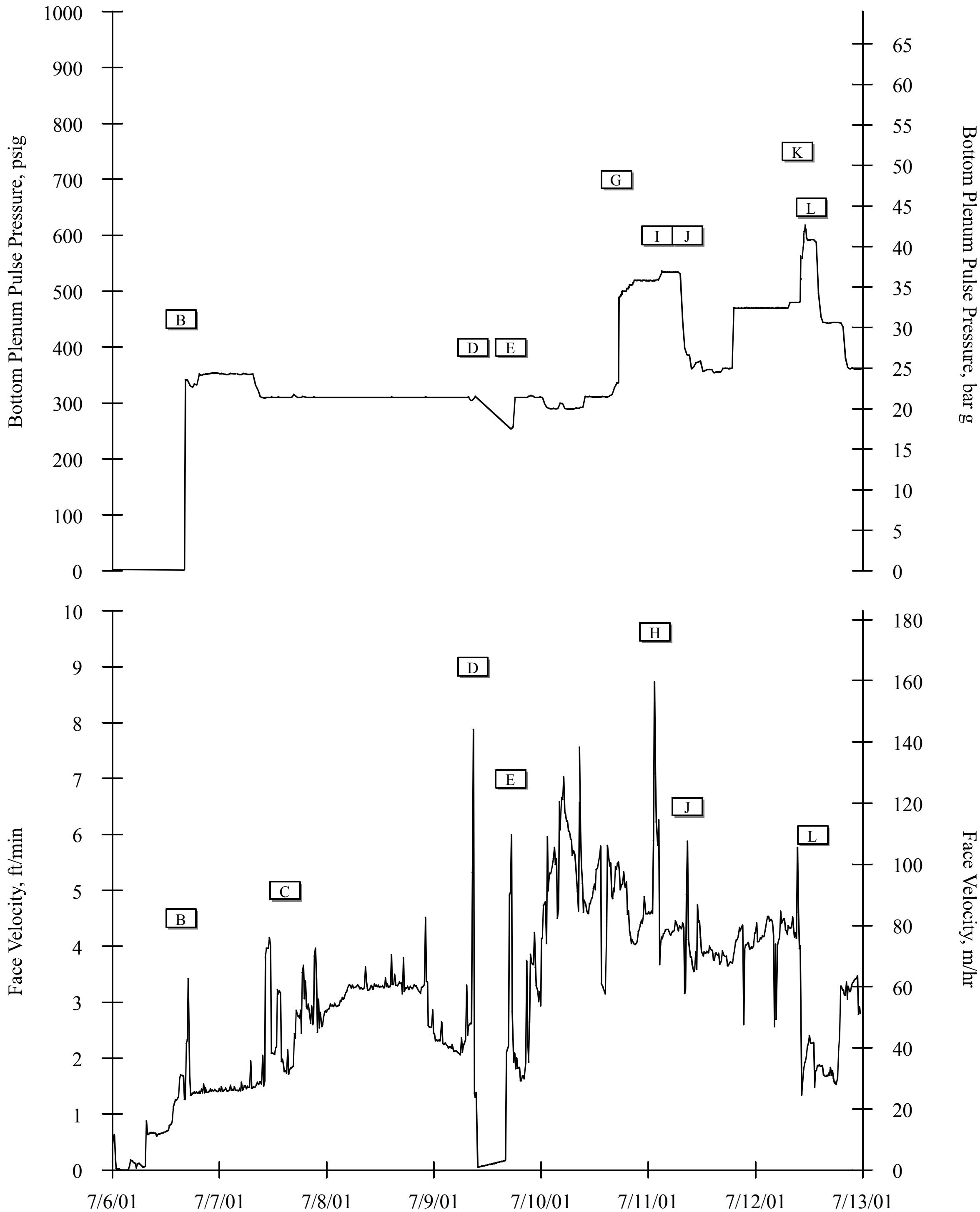

Figure 3.2-4 PCD Pulse Pressure and Face Velocity, July 6, 2001 Through July 13, 2001

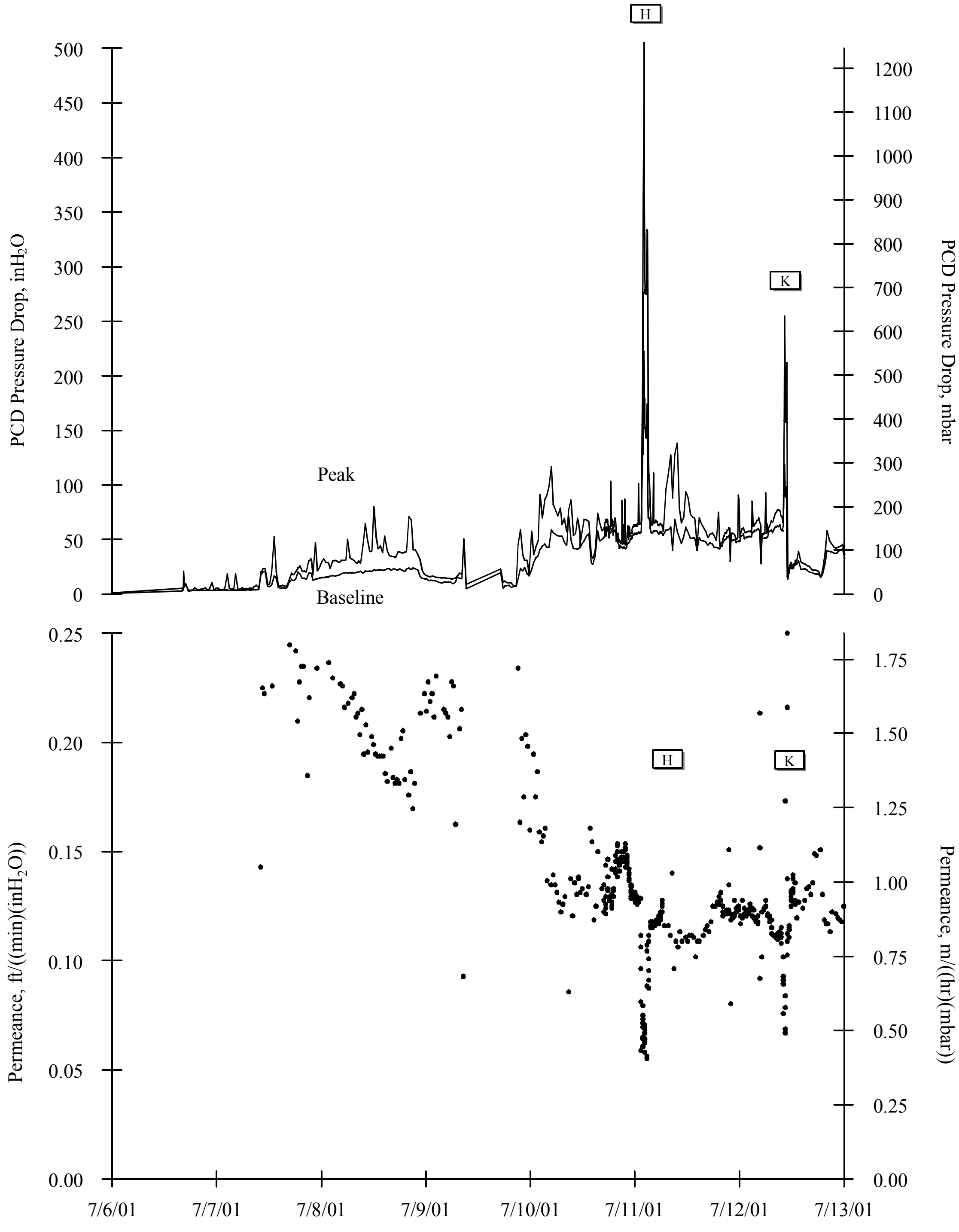

Figure 3.2-5 PCD Pressure Drop and Permeance, July 6, 2001 Through July 13, 2001

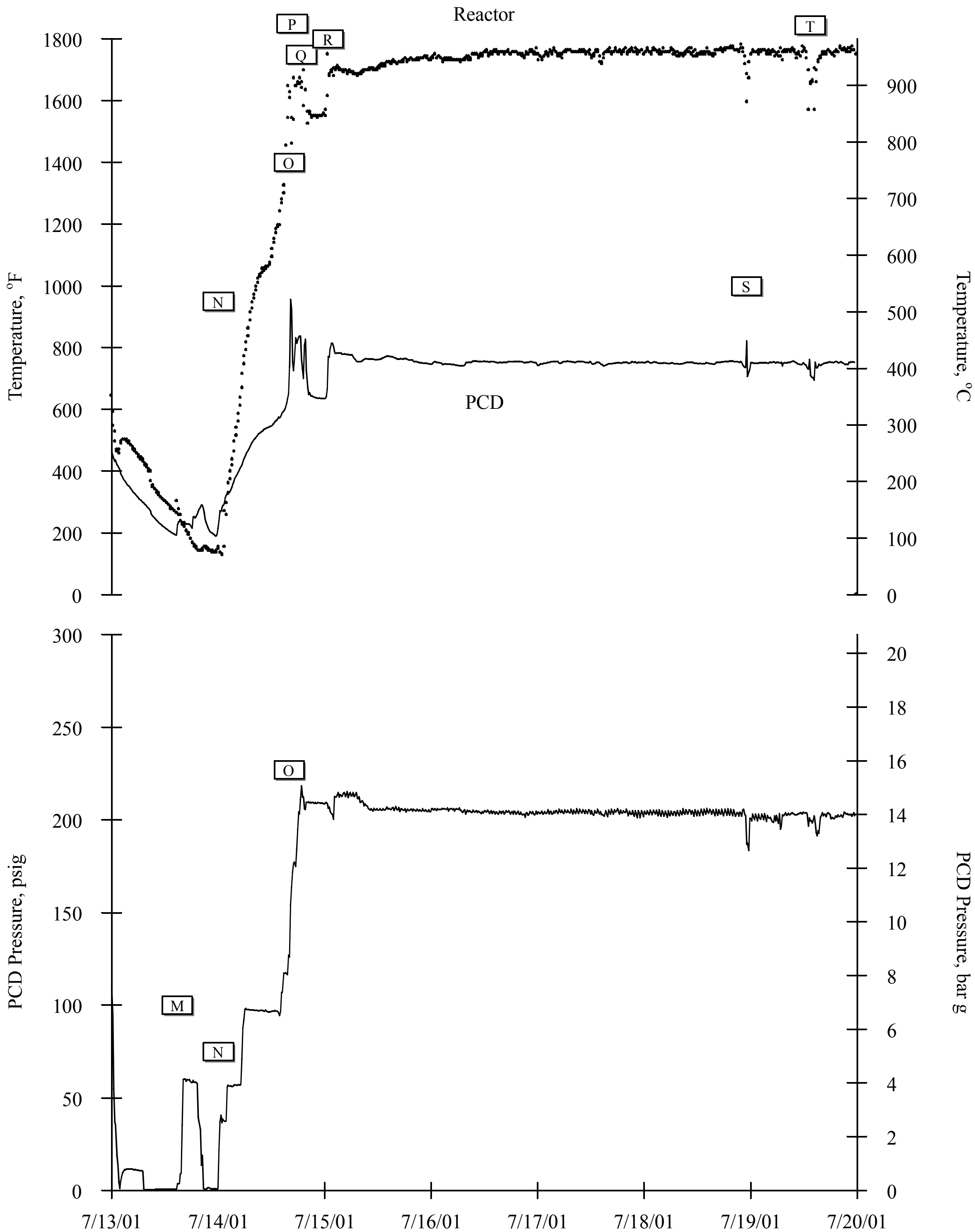

Figure 3.2-6 Reactor and PCD Temperatures and PCD Pressure, July 13, 2001 Through July 20, 2001

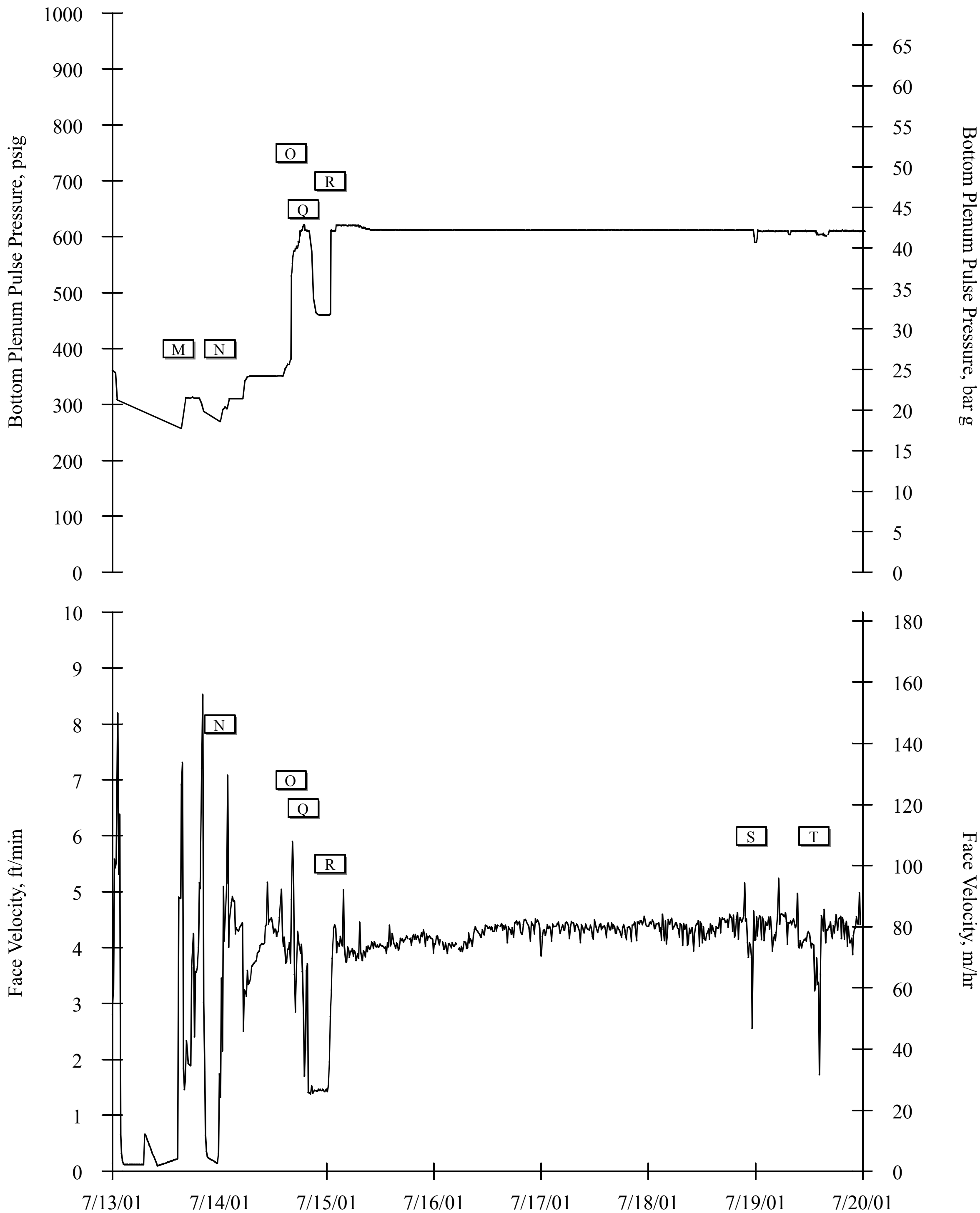

Figure 3.2-7 PCD Pulse Pressure and Face Velocity, July 13, 2001 Through July 20, 2001

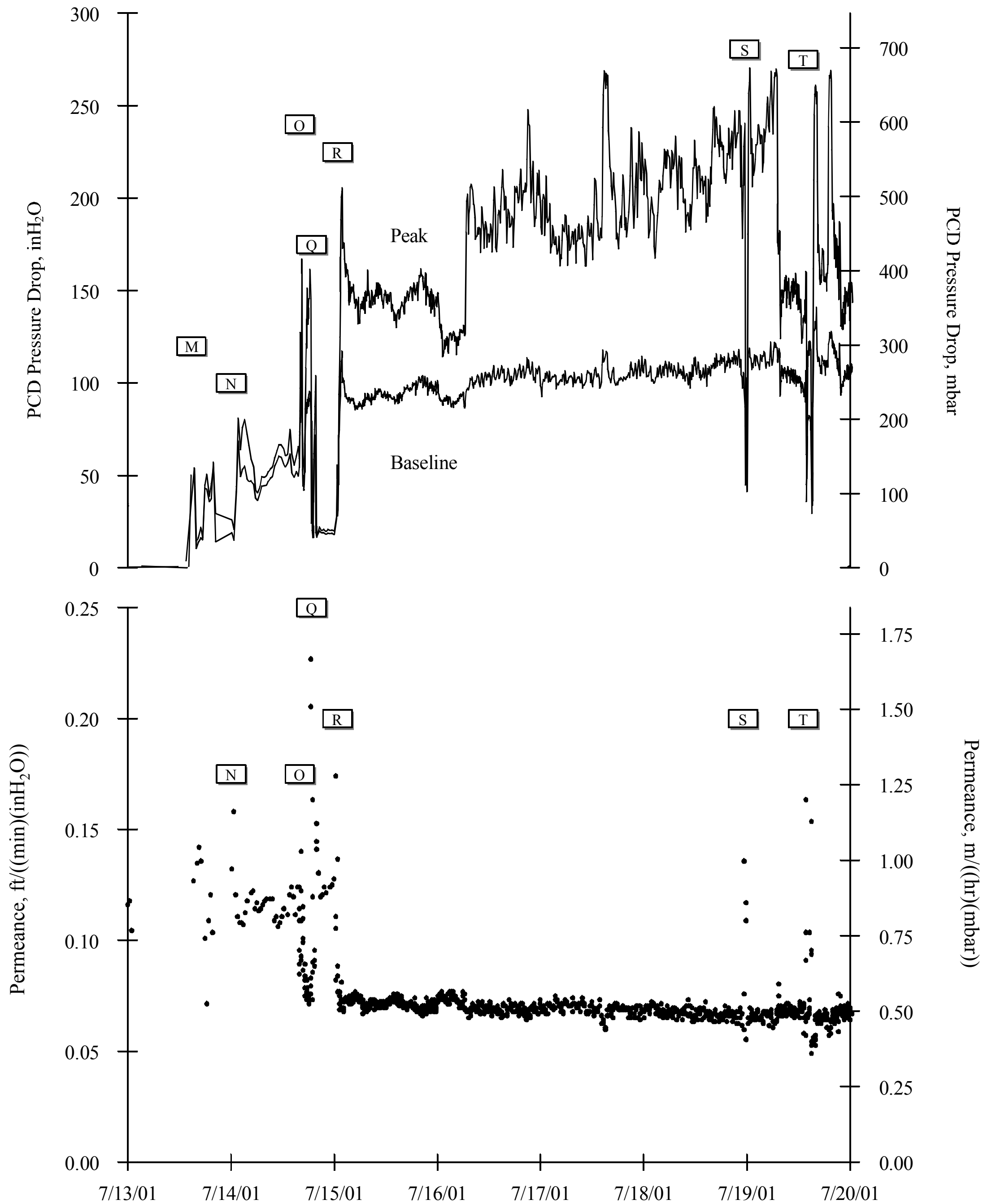

Figure 3.2-8 PCD Pressure Drop and Permeance, July 13, 2001 Through July 20, 2001

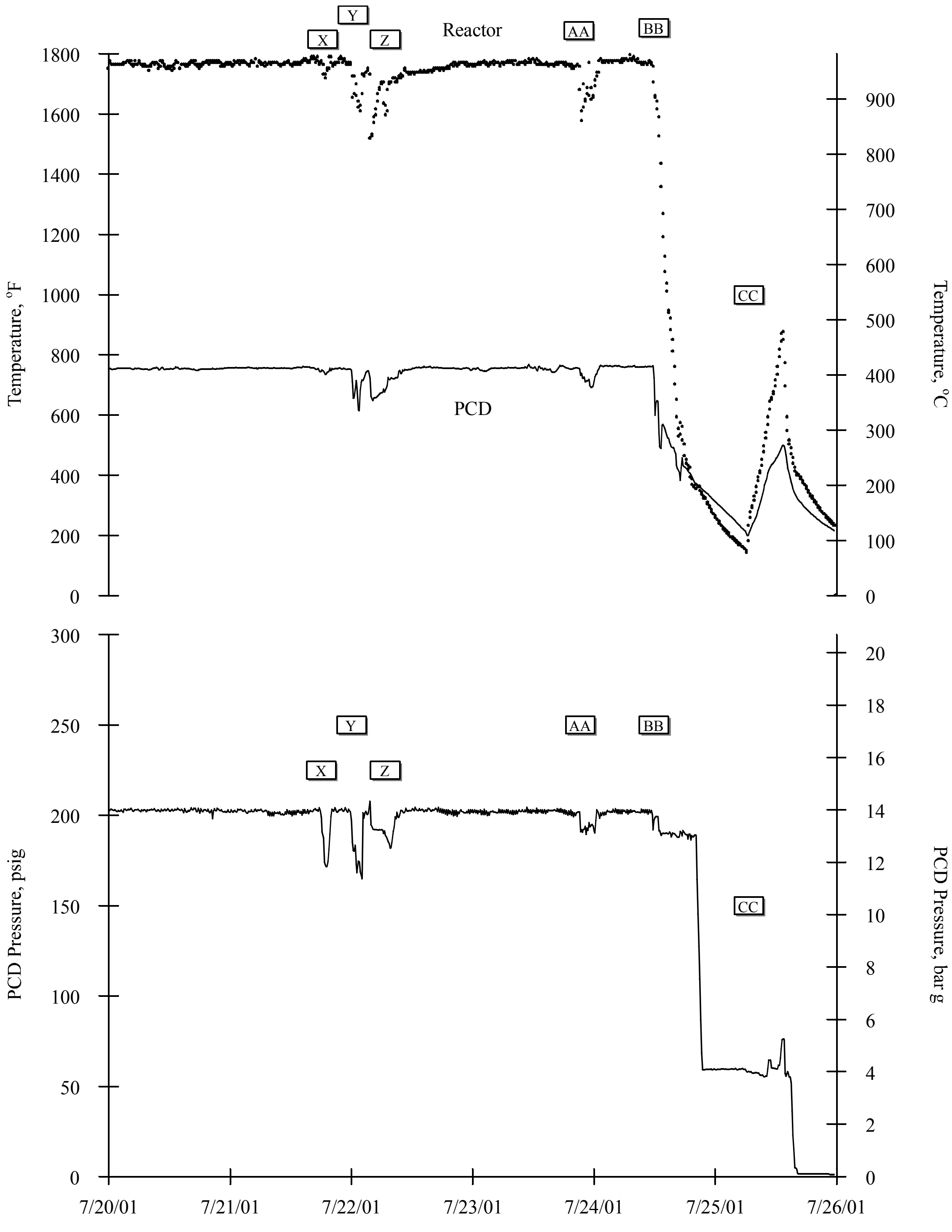

Figure 3.2-9 Reactor and PCD Temperatures and PCD Pressure, July 20, 2001 Through July 26, 2001

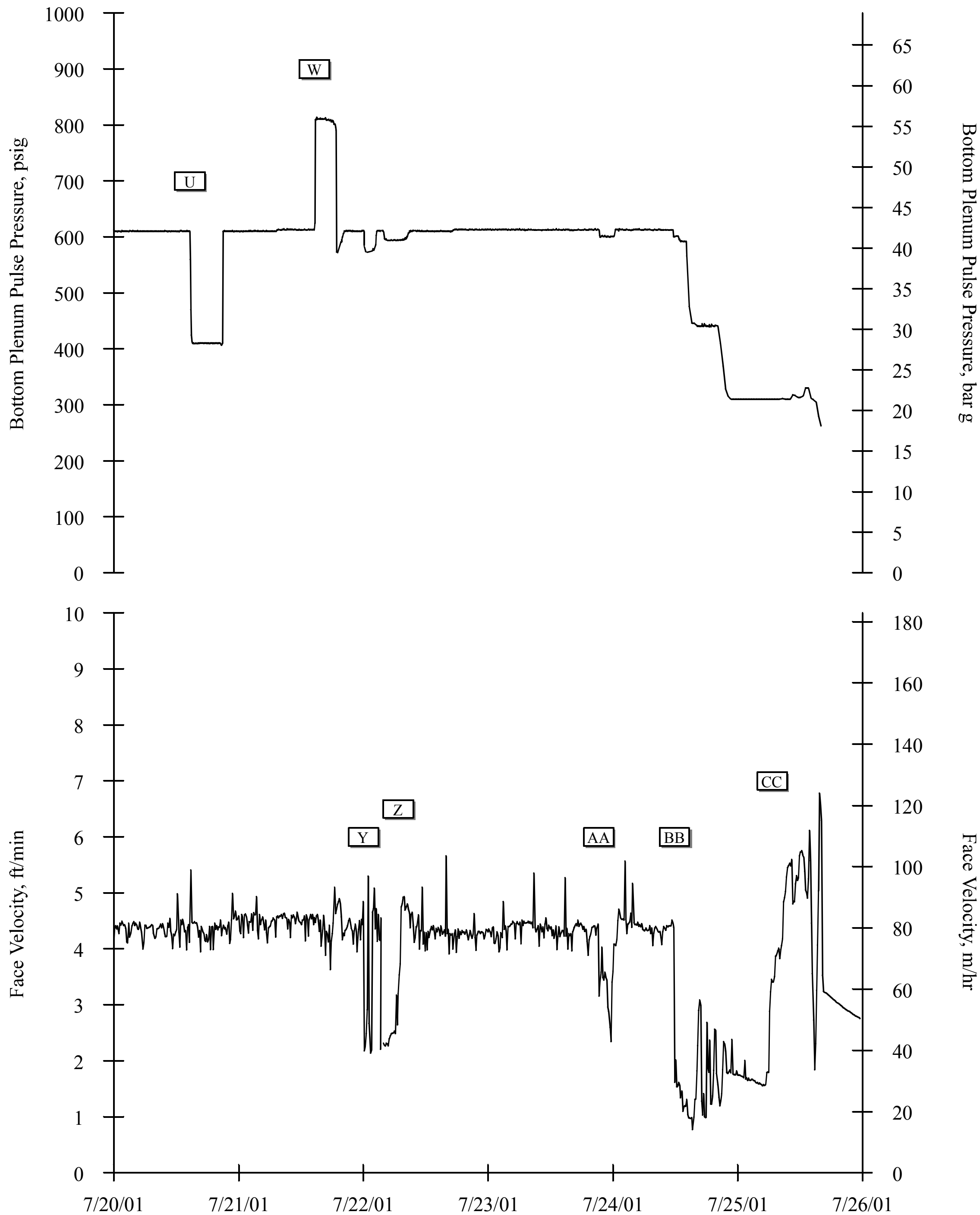

Figure 3.2-10 PCD Pulse Pressure and Face Velocity, July 20, 2001 Through July 26, 2001

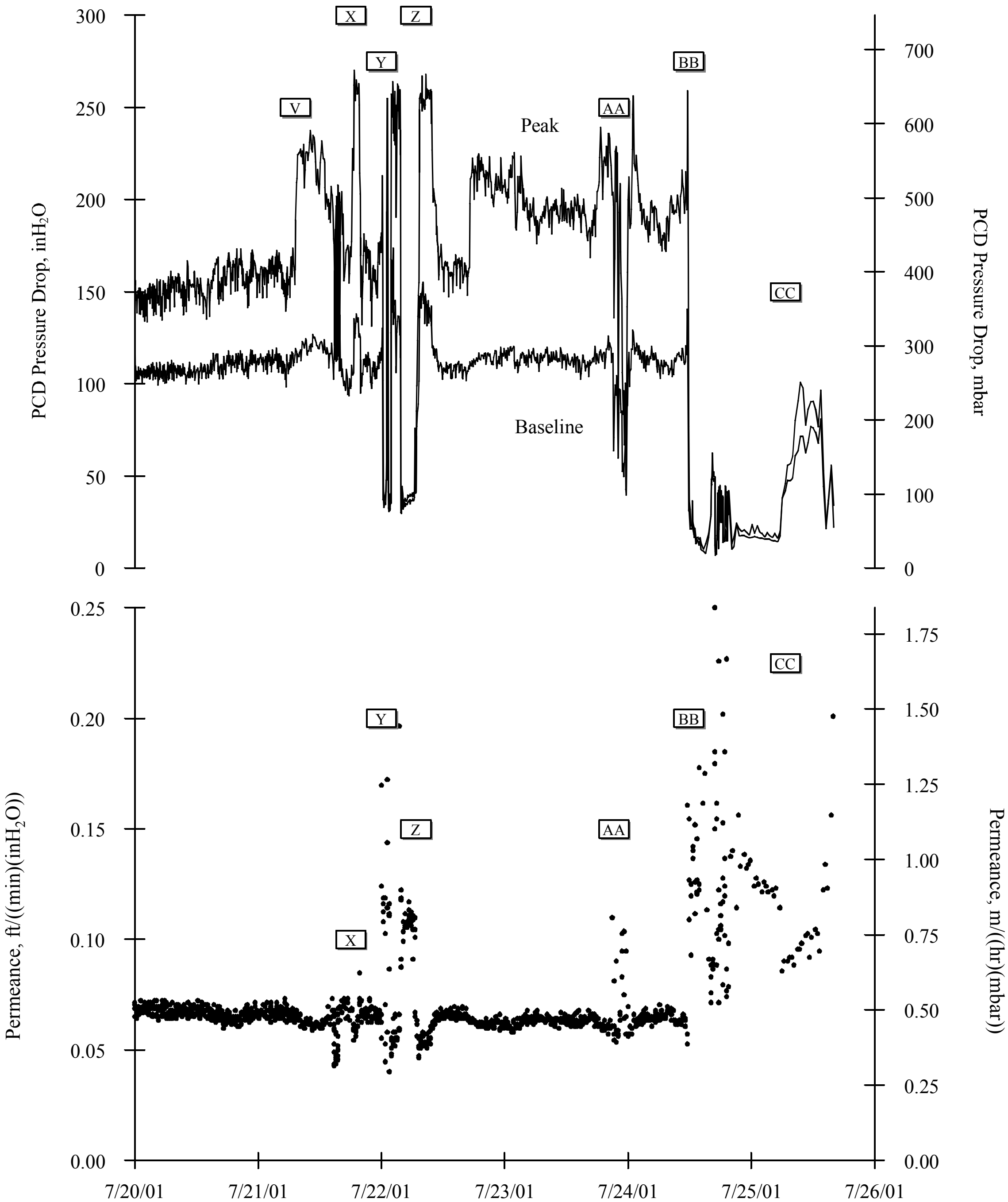

Figure 3.2-11 PCD Pressure Drop and Permeance, July 20, 2001 Through July 26, 2001

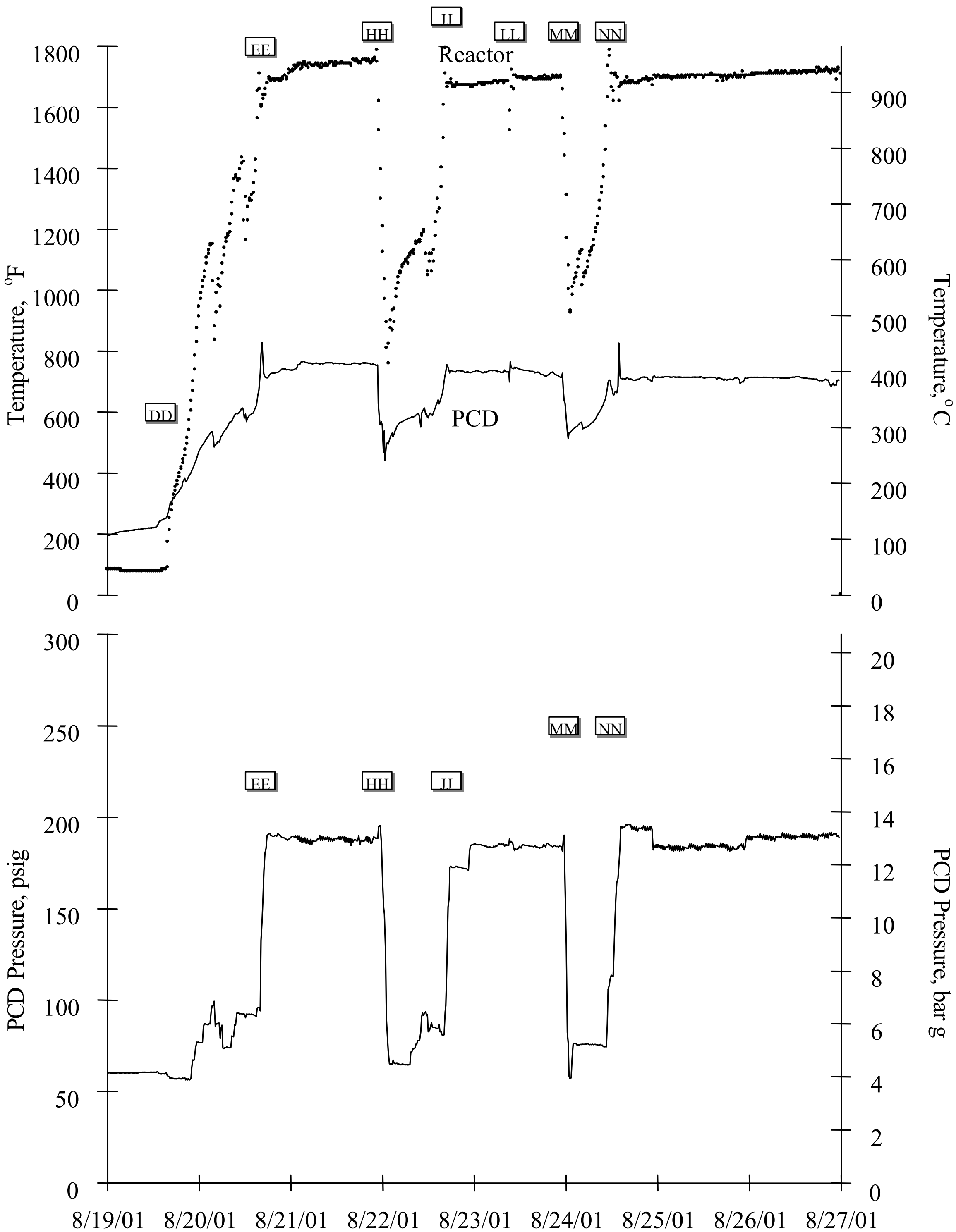

Figure 3.2-12 Reactor and PCD Temperatures and PCD Pressure, August 19, 2001 Through August 27, 2001

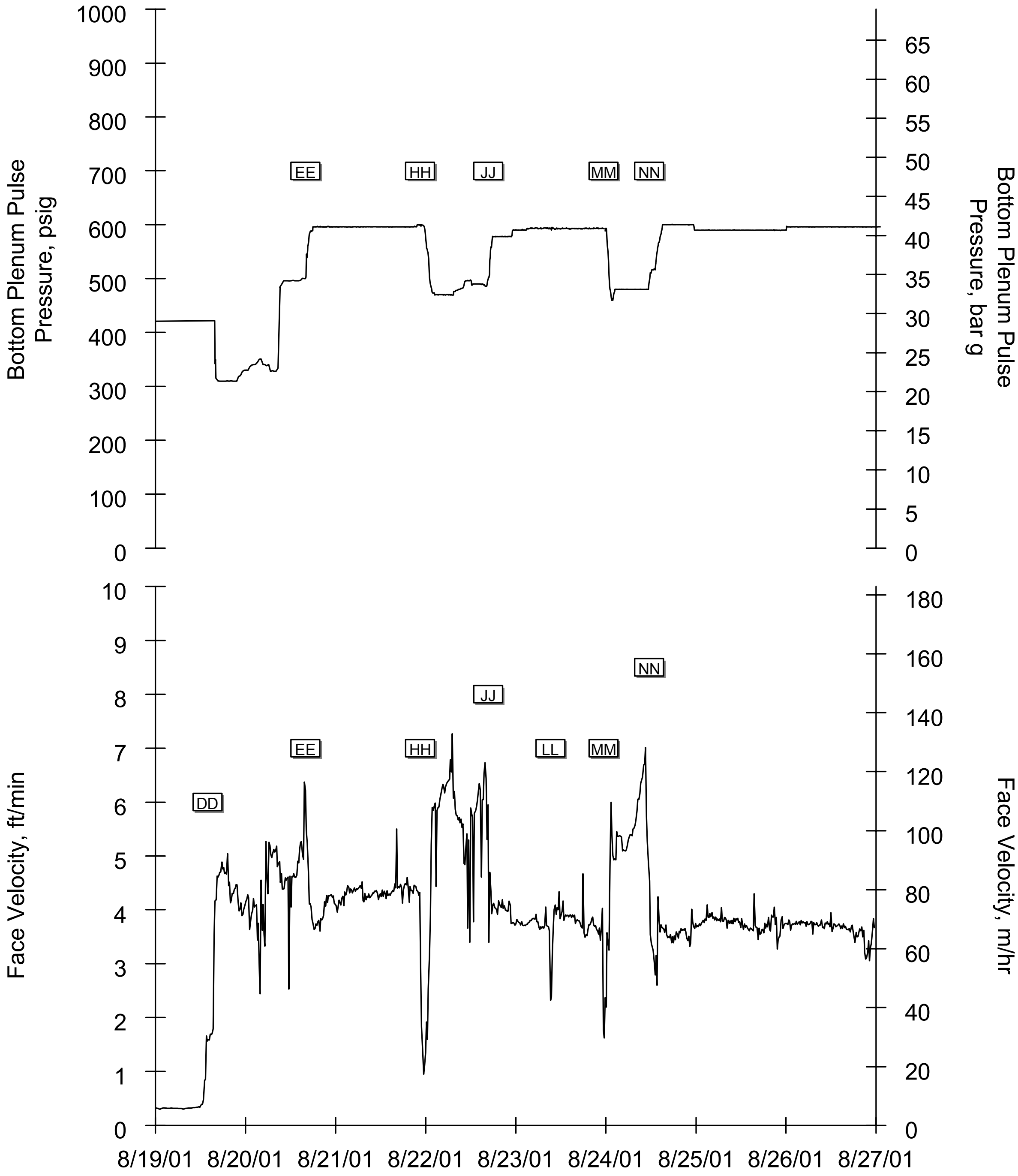

Figure 3.2-13 PCD Pulse Pressure and Face Velocity, August 19, 2001 Through August 27, 2001

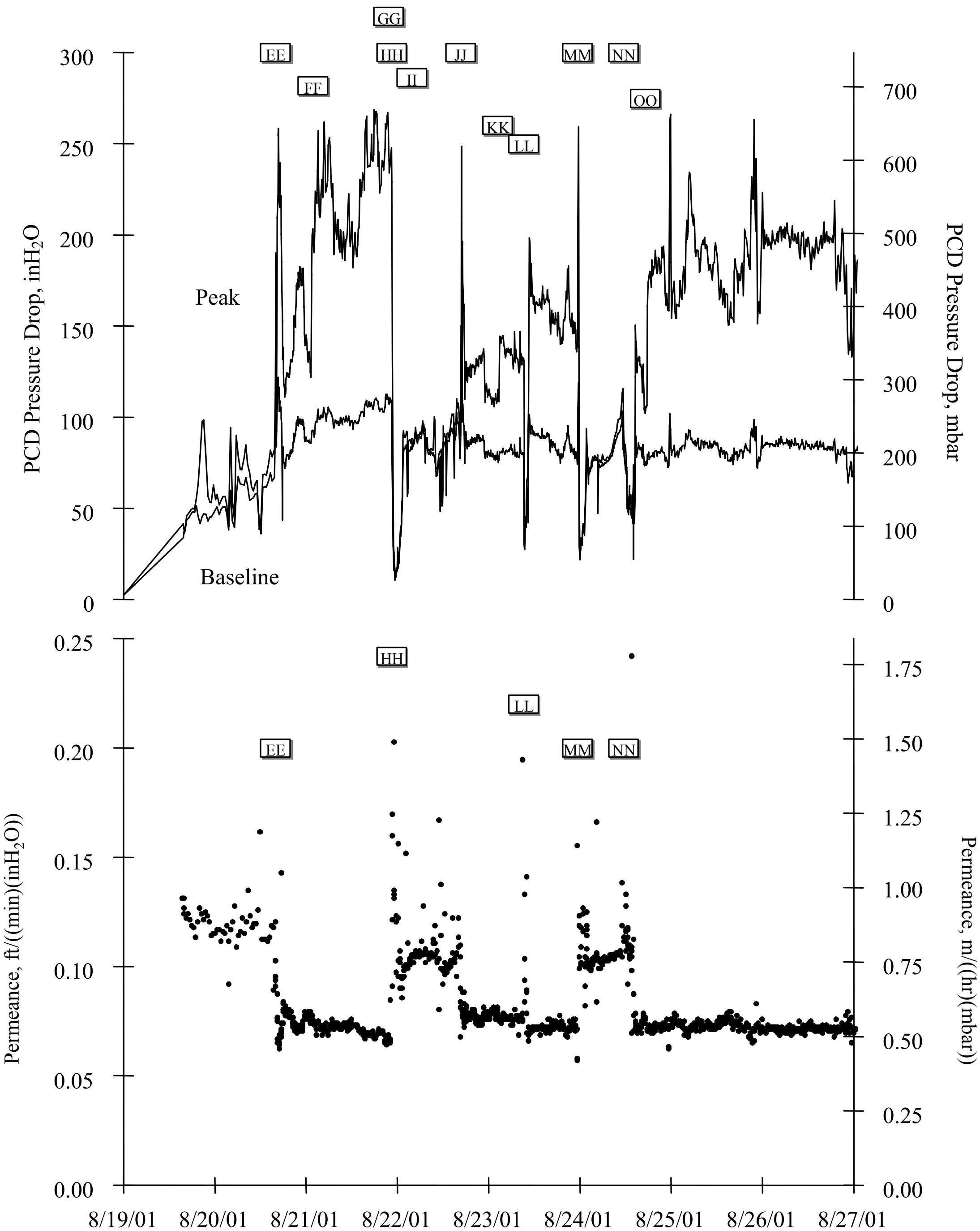

Figure 3.2-14 PCD Pressure Drop and Permeance, August 19, 2001 Through August 27, 2001

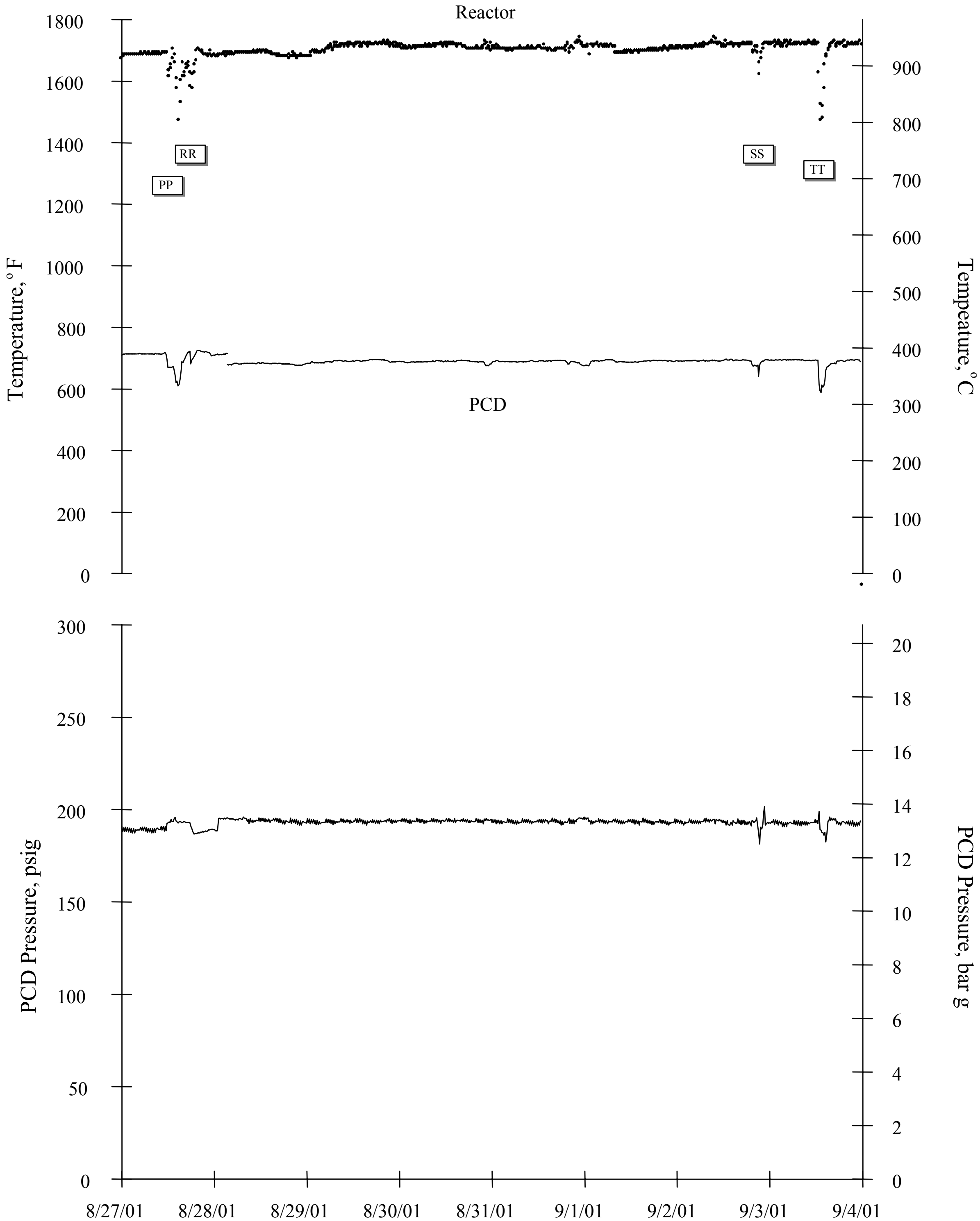

Figure 3.2-15 Reactor and PCD Temperatures and PCD Pressure, August 27, 2001 Through September 4, 2001

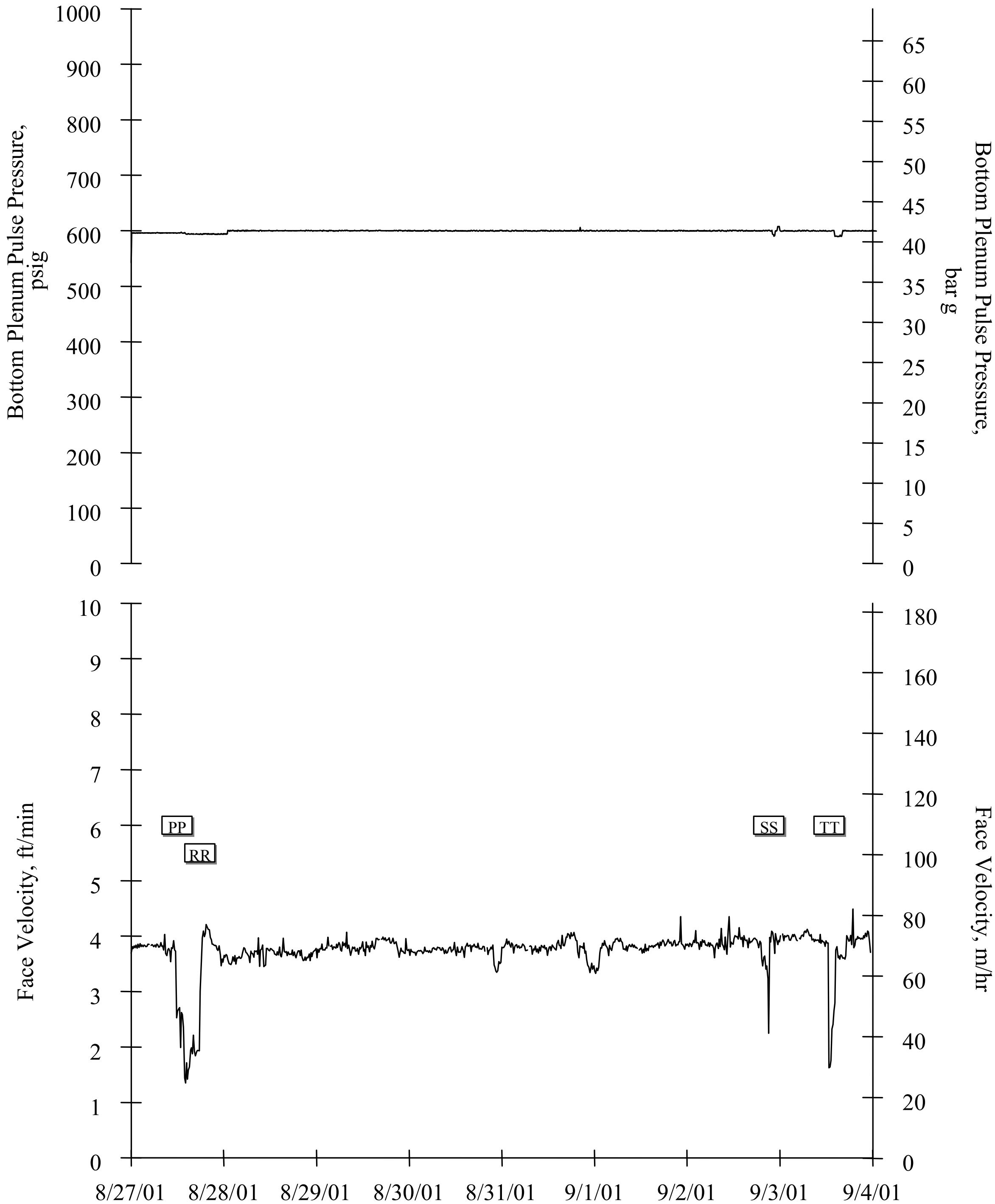

Figure 3.2-16 PCD Pulse Pressure and Face Velocity, August 27, 2001 Through September 4, 2001

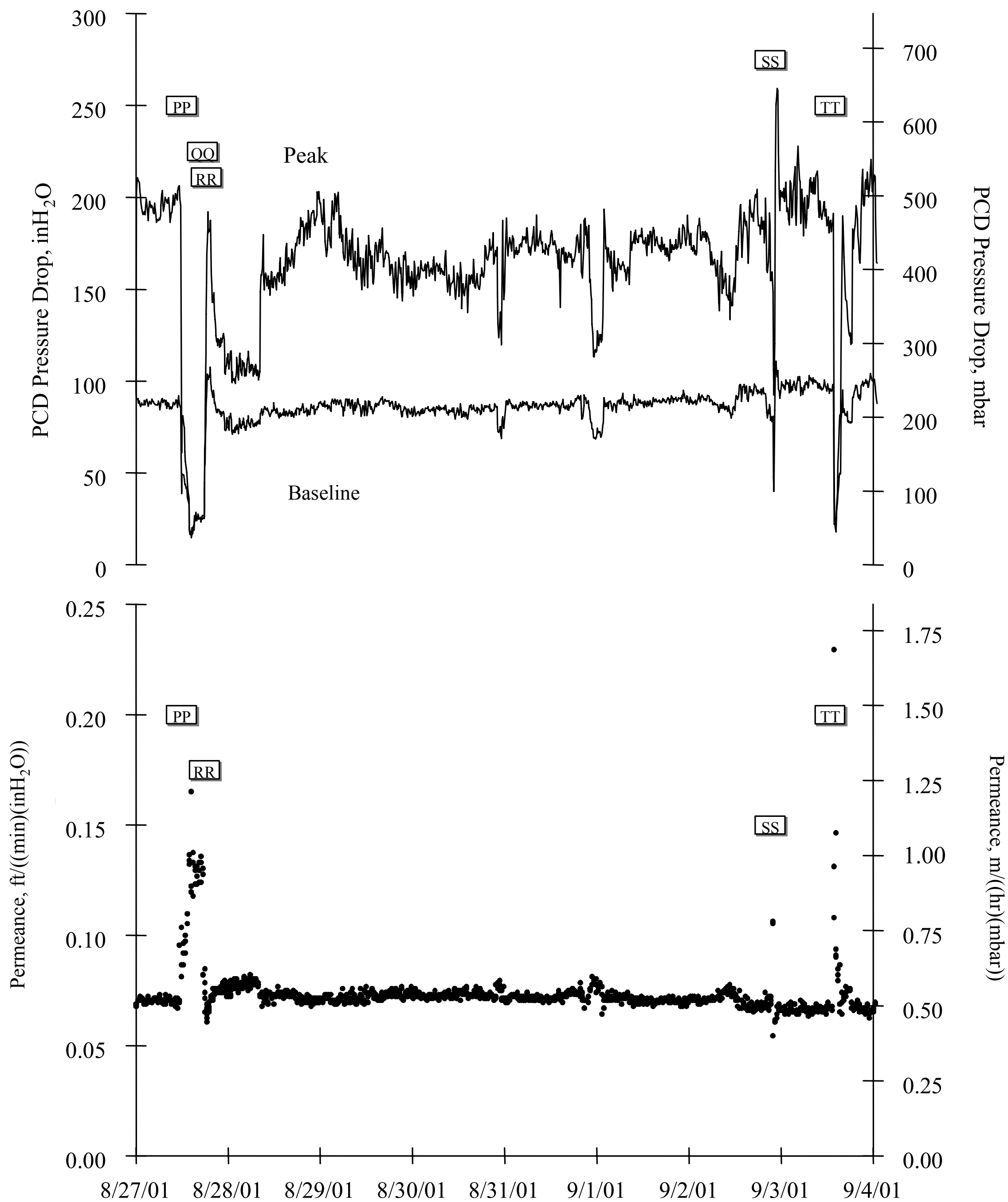

Figure 3.2-17 PCD Pressure Drop and Permeance, August 27, 2001 Through September 4, 2001

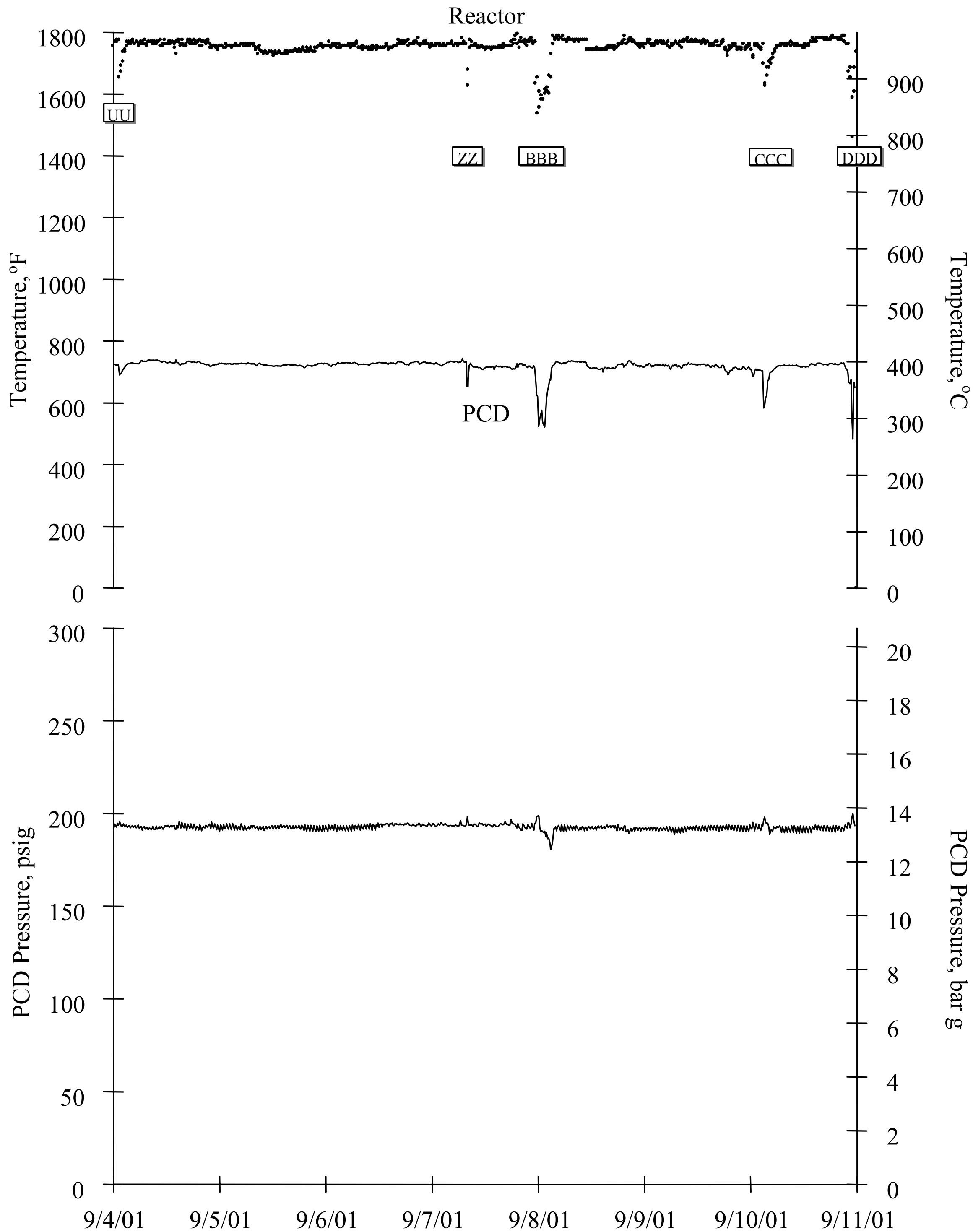

Figure 3.2-18 Reactor and PCD Temperatures and PCD Pressure, September 4, 2001 Through September 11, 2001

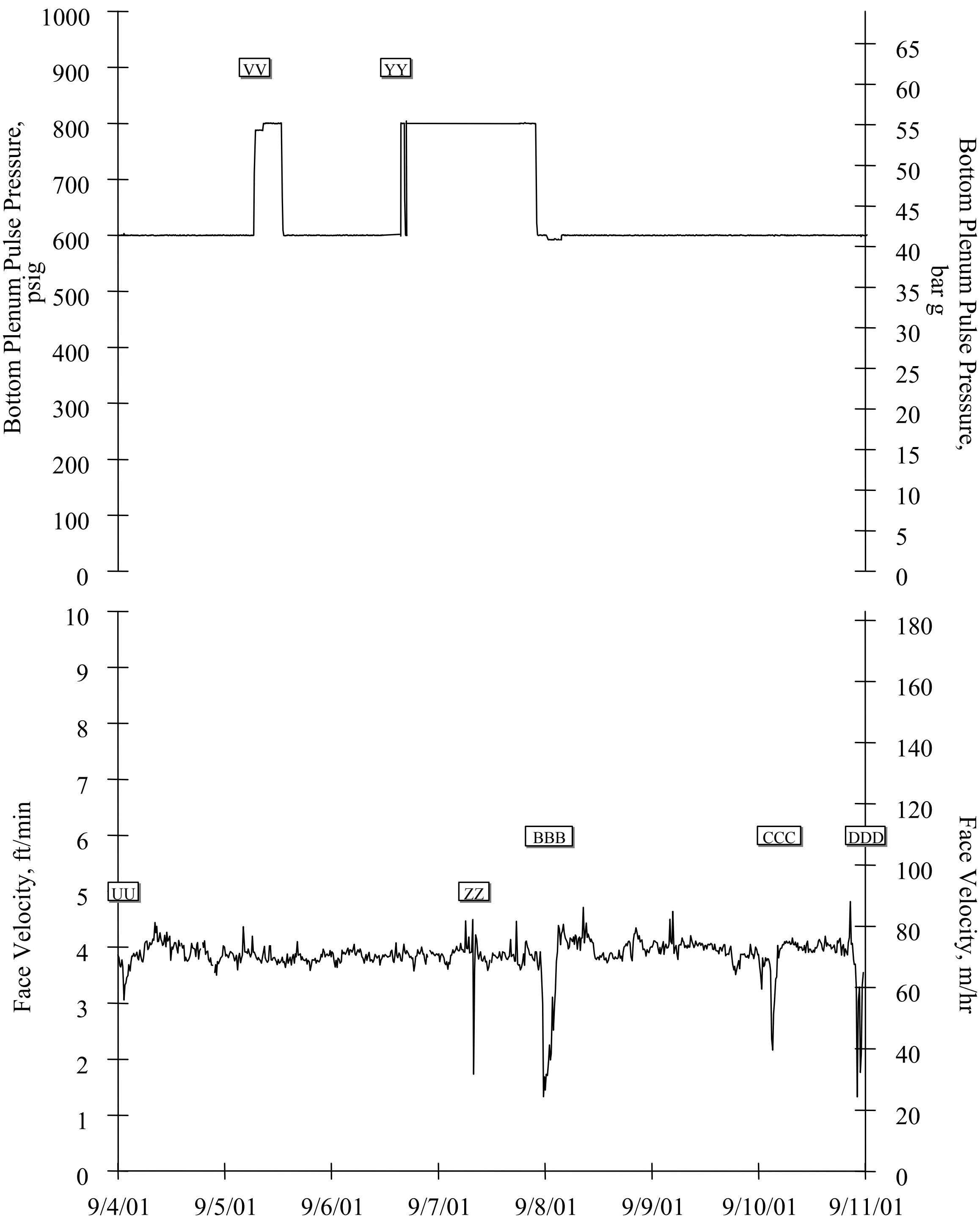

Figure 3.2-19 PCD Pulse Pressure and Face Velocity, September 4, 2001 Through September 11, 2001

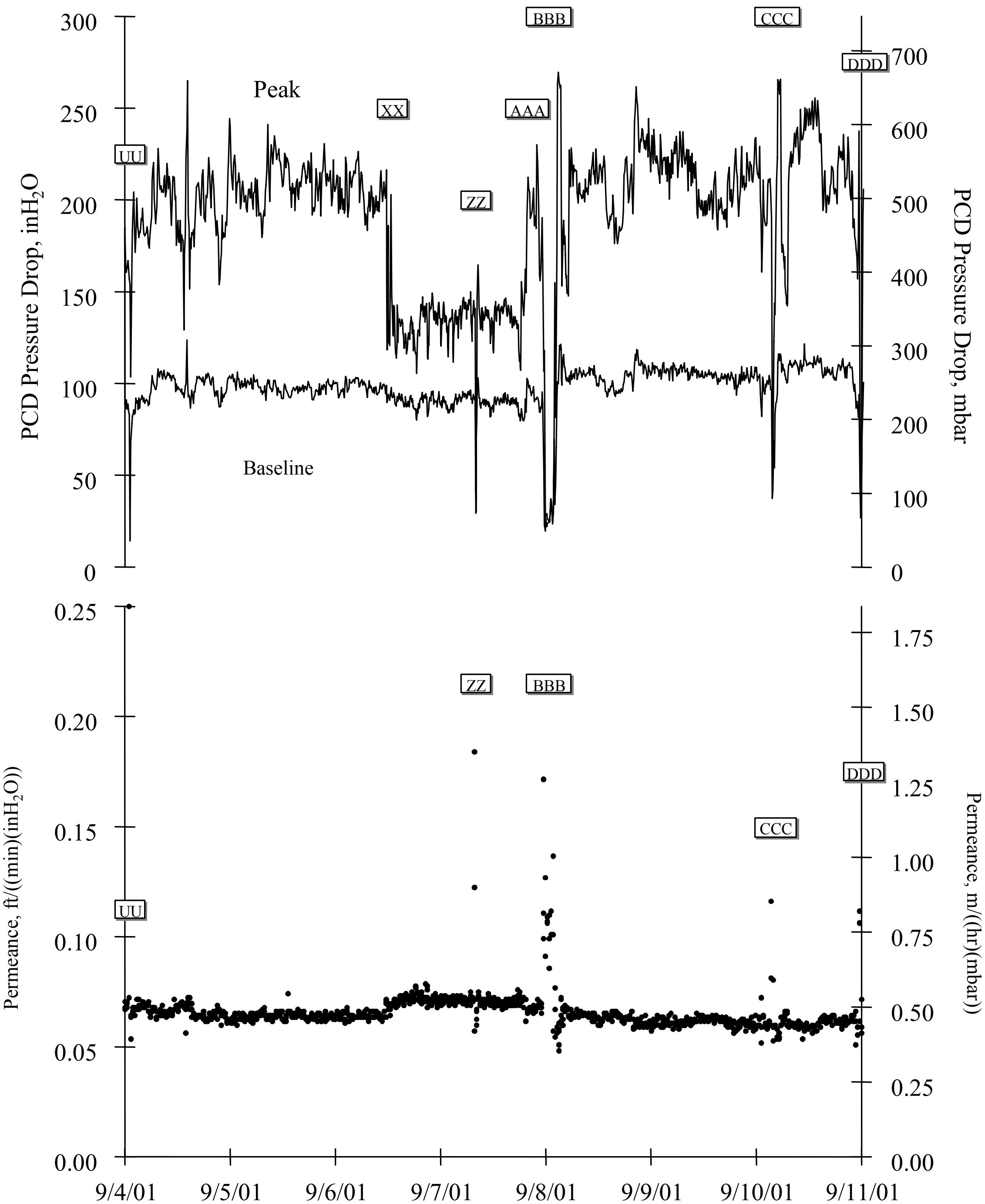

Figure 3.2-20 PCD Pressure Drop and Permeance, September 4, 2001 Through September 11, 2001

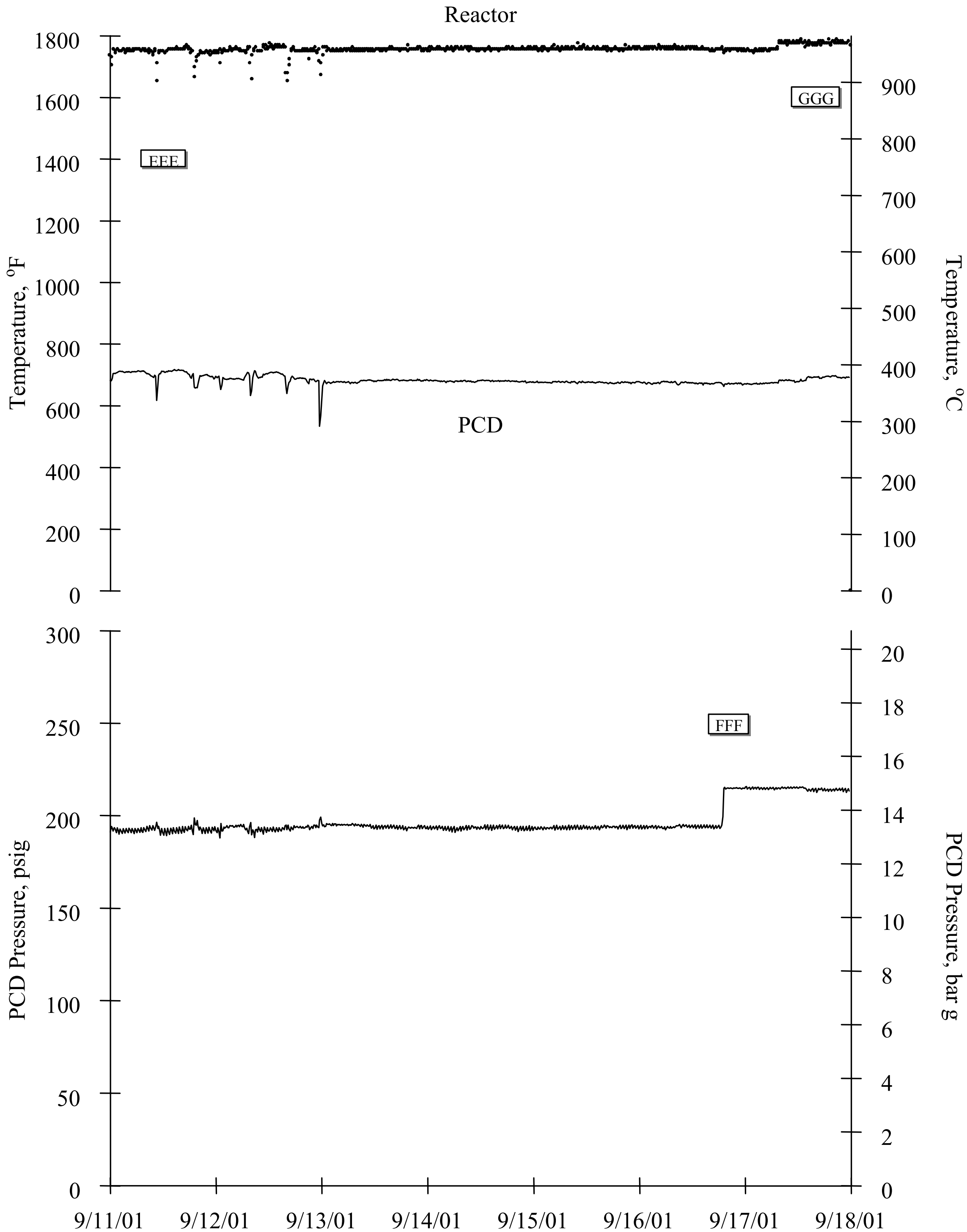

Figure 3.2-21 Reactor and PCD Temperatures and PCD Pressure, September 11, 2001 Through September 18, 2001