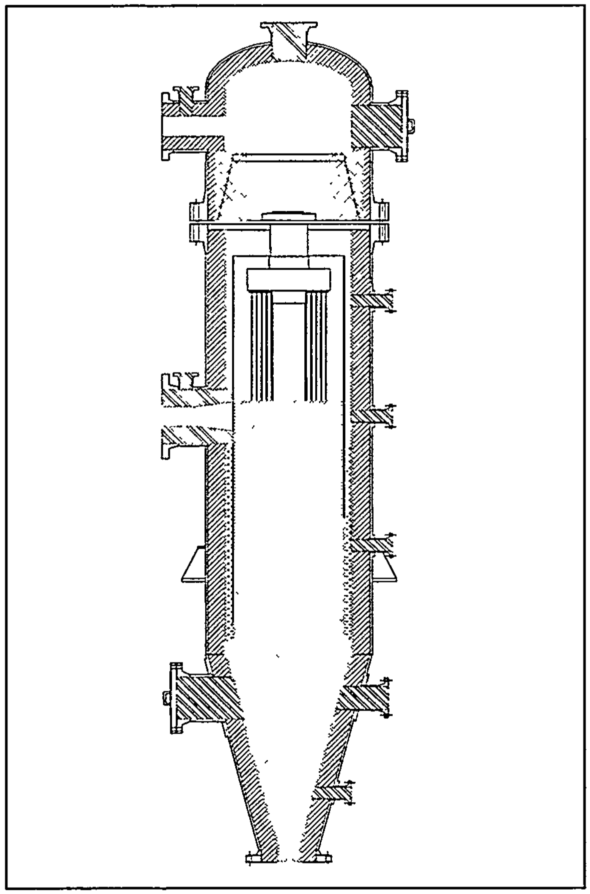


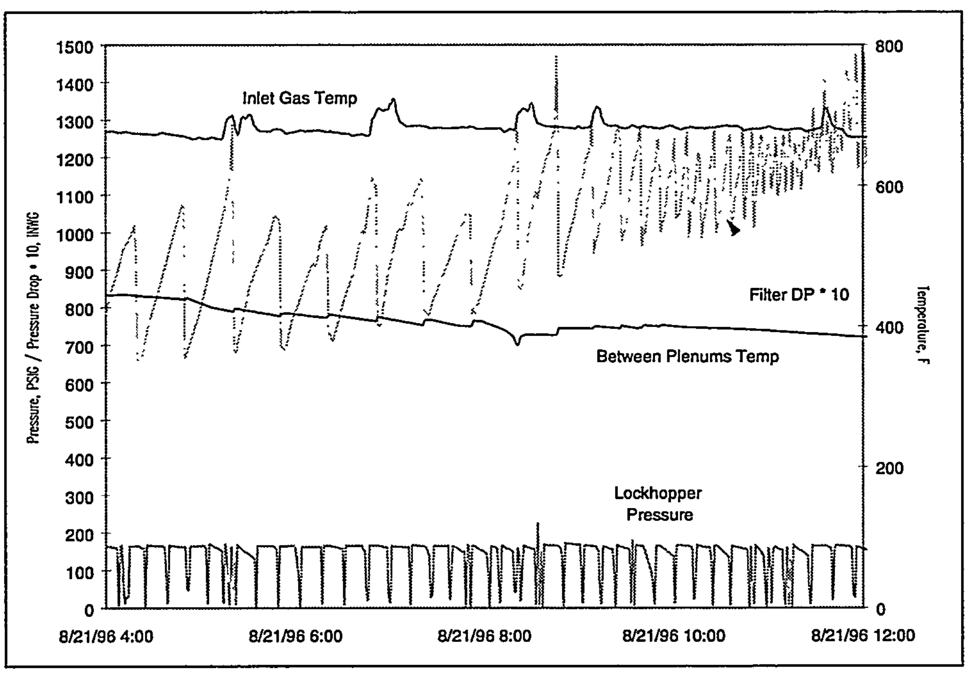


Figure 6.1.15-11 Beginning to Cover Upper Level With Ash

PSDF\1996\6.1.16

6.2 HIGH-PRESSURE AIR AND HIGH-PRESSURE NITROGEN SYSTEM

6.2.1 High-Pressure Air System

The high pressure air compressor (CO2203) is used for on-line back-pulse cleaning of the Westinghouse PCD(s) on the MWK transport reactor and the FW combustor. The unit is a dual-cylinder, double-throw reciprocating compressor manufactured by the Norwalk Co. designed to produce ca. 1,450 lb/h of air at a maximum pressure of 1,500 psig. The compressor receives air from the service/instrument air system during combustion operation or nitrogen from the low pressure nitrogen system in the event that the high pressure nitrogen (RIX) compressors are not functional during MWK gasification operation. The gas is stored in a primary accumulator near the compressor and is then delivered to secondary accumulator tanks located on the Westinghouse back-pulse skid before entering the PCD.

6.2.1.1 Commissioning

The compressor was commissioned during May and June of 1996 by Norwalk, Hydromatics, and PSDF personnel. Two vendor visits were required due to miscellaneous problems described below.

6.2.1.2 Problems and Solutions

The following briefly summarizes the problems that were encountered, reason(s) for the problems, and the corresponding resolution(s):

PROBLEMS	SOLUTIONS
• Low discharge pressure (combination of three leaking valves and poor sealing surface of number 1 cylinder).	• Rebuilt the valves and remachined sealing surface.
• Overheating of number 1 cylinder and lifting of intercooler PRV.	• Solutions above also corrected this problem.
• Rain water in oil reservoir.	• Removed and cleaned reservoir and redesigned cover of oil reservoir.

6.2.1.3 Performance

The compressor was successfully functionally checked and commissioned. The unit performed as expected for back-pulsing the Westinghouse PCD during the MWK runs with no major complications. The compressor has been run a total of 72 hours from commissioning through

MWK test run operation. The low-run time is due to the noncontinuous mode of operation of the system. Operation of the compressor consisted of running it only long enough to build maximum pressure in the primary accumulator tank and then shutting it down. As the pressure in the accumulator tank approached the PCD pulse pressure setting, the compressor was restarted to build the accumulator tank supply. There are plans to modify the system for automatic unloading operation prior to the need for higher pressures and larger volumes of pulse gas needed for future tests. Figure 6.2.1-1 shows a plot of accumulator pressure variation during MWK test run CCT1 in July 1996. This plot is typical of system operation during all MWK commissioning activities and test runs.

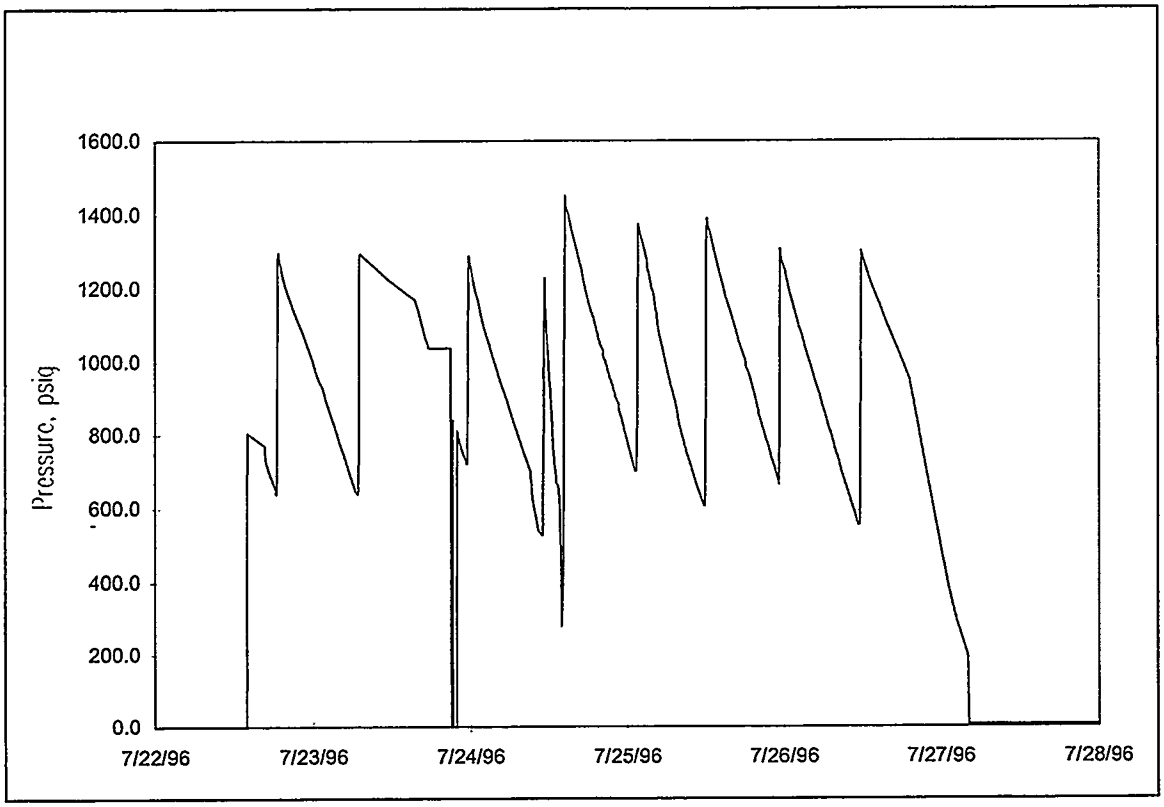


Figure 6.2.1-1 High-Pressure Air Accumulator Tank Pressure

6.2.2 High-Pressure Nitrogen System

The high pressure nitrogen system consists of 3, 3-stage reciprocating compressors, each capable of producing 115 SCFM of oil-free nitrogen at 2,030 psig and ca. 280°F. The units are manufactured by the RIX Co., but assembled and programmed by Compressed Air Products (CAP). These units are used for gasification mode back-pulsing of the PCD(s) on the MWK train and/or the carbonizer PCD on the FW train. Nitrogen is supplied at 30 psig by the on-site BOC Nitrogen plant, either from the plant's generation or the liquid back-up system, to the compressors and then delivered to an accumulator assembly (6 tanks in parallel) with a capacity of 62.9 ft^3. The gas is then delivered to the PCD skid-mounted accumulators on an as-needed basis.

6.2.2.1 Commissioning

Commissioning of these compressors occurred in two phases due to PLC programming changes and personnel availability. CAP, Hydromatics, and RIX initially came to the site during September 1996. Due to a host of problems discussed below, CAP came back in mid-October to complete the installation and finalize commissioning.

6.2.2.2 Problems and Solutions

PROBLEMS	SOLUTIONS
• On skid water leaks.	• Tightened fittings.
• Poor welds on accumulators.	• Cut heads off and rewelded.
• Melted discharge valves.	• Wrong valve material: replaced valve.
• Motor shaft rubbed housing.	• Adjusted housing.
• Exposure to hot (>300°F) lines.	• Insulated lines.
• Inoperable.	• Miscellaneous PLC changes.

6.2.2.3 Performance

During commissioning in late October 1996, the compressors ran according to the design specifications after several days of effort and numerous PLC changes. The compressors have not been run since this time since they are required for gasification operation and only combustion operation has been attempted through the end of 1996.

6.3 PCD FINES REMOVAL SYSTEM COMMISSIONING

6.3.1 PCD Fines Screw Cooler

The purpose of PCD fines screw cooler FD0502 is to convey material from the MWK PCD solids outlet to the fines transport system (FD0520) and to simultaneously cool the material to an acceptable temperature prior to depressurization. It consists of a motor-operated screw conveyor with heat transfer fluid both within the screw shaft and in the jacket of the metal casing which encloses the screw shaft.

For the most part, the FD0502 screw cooler was commissioned and operated in conjunction with the PCD fines transporter system that is described below. There were, however, some operational issues associated only with the screw cooler. The screw cooler mechanical operation was essentially flawless. The only mechanical problems associated with the screw cooler involved heat transfer fluid leaks, which were repaired. Functional checks in March and April of 1996 revealed some control logic problems that were easily solved.

Operation of the screw cooler was crucial to MWK operation since solids had to be removed from the PCD to avoid failure of the filter elements and subsequent shutdown of the transport reactor from solids build-up in the PCD. For this reason, the screw cooler was run constantly throughout all MWK reactor commissioning activities and operation. Its total run time in 1996 is comparable to that of the FD0520 system, which ran for close to 900 hours, because the two systems were almost always run simultaneously for PCD solids removal. Prior to the coal combustion run CCT1C in August the screw cooler was operated at 3 rpm because it was not known that a higher removal rate was necessary. This rate was increased by increasing the screw speed to the maximum value of 8 rpm for subsequent runs. The maximum value was increased to 12 rpm for test run CCT2C, and the rate is to be maintained at this maximum value for all subsequent operation. Figure 6.3.1-1 shows the screw cooler speed during CCT2C on November 20. Also shown in figure 6.3.1-1 are the inlet and outlet temperature of the screw cooler, which show the amount of solids cooling provided by the screw to be approximately 275°F ΔT. The spikes in inlet temperature occur approximately every 30 minutes and are due to the influx of hot solids from the PCD immediately following pulse cleaning of the candle filters which is on a 30-minute cycle.

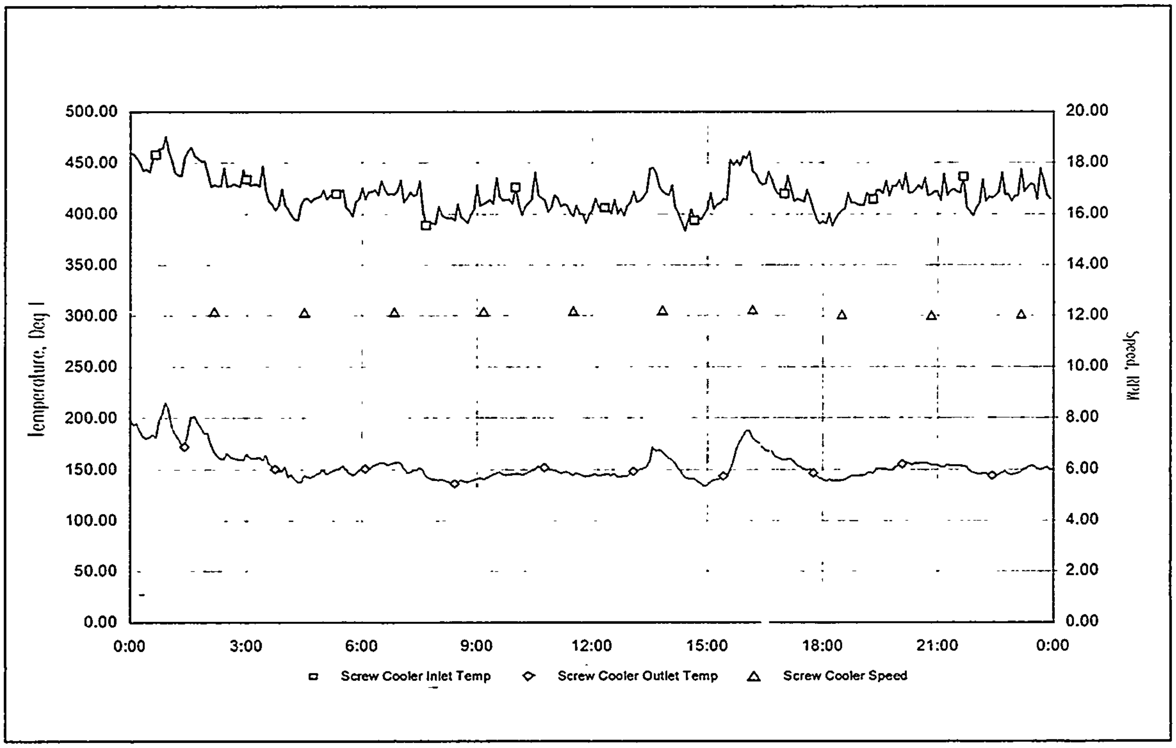


Figure 6.3.1-1 Fines Removal Screw Cooler Operation November 20, 1996

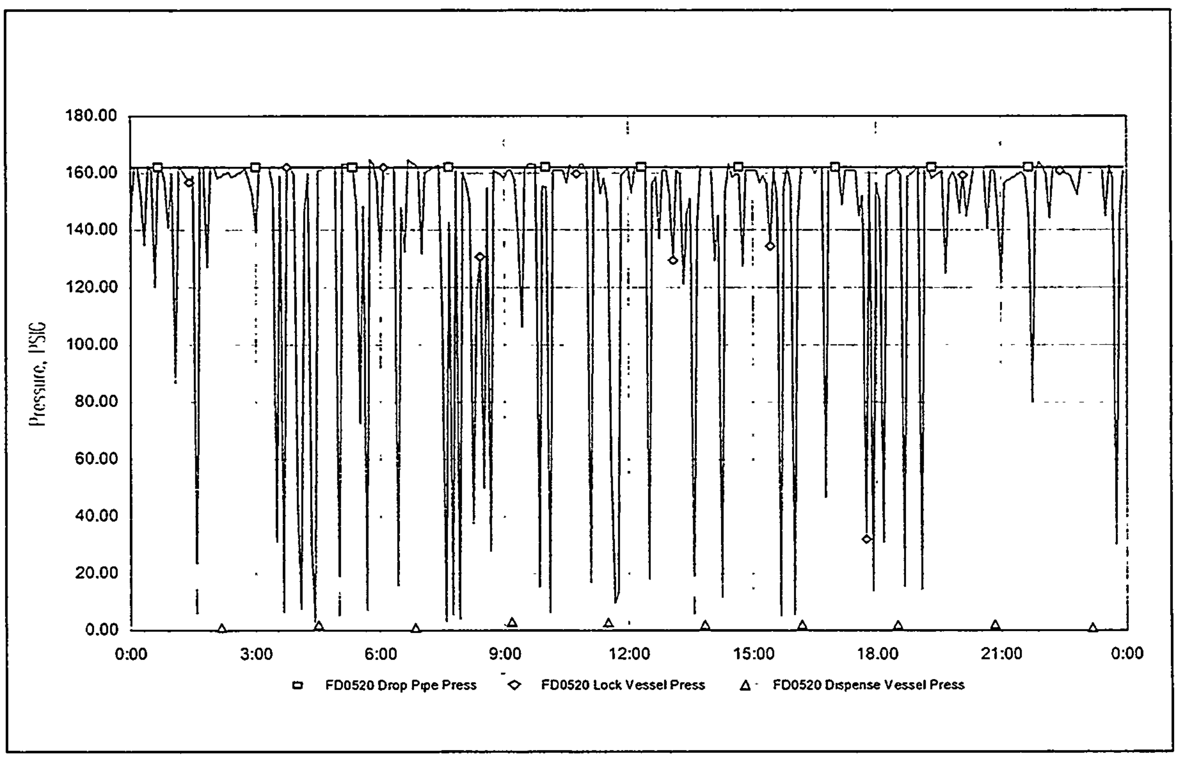


Figure 6.3.1-2 Fines Transporter System Cycles November 20, 1996

6.3.2 PCD Fines Transporter

The PCD fines transporter (FD0520) functions to depressurize solids from the fines screw cooler (FD0502) and pneumatically convey the solids to a common collection bin for both PCD and transport reactor spent solids (part of the FD0530 system). The system consists of two vessels, the lock vessel and the dispense vessel, in series separated by Spheri valves. Solids from FD0502 enter a drop pipe above the lock vessel, at which time the lock vessel Spheri valve is open to accept the solids at system pressure. A level probe in the lock vessel determines when the vessel is full (approximately 1.4 ft^3 capacity) and then closes the Spheri valve. The lock vessel is then vented to atmospheric pressure and the dispense vessel Spheri valve opens to accept the depressurized solids. After a set time to allow the solids to fall by gravity from one vessel to the other, the dispense vessel Spheri valve closes and the solids are blown, using air in combustion mode operation and nitrogen in gasification mode operation, into the common collection bin. The lock vessel is then repressurized with nitrogen and the lock vessel Spheri valve is opened to receive more solids. This completes one cycle of the system.

In March 1996 Clyde Pneumatic Conveying (CPC, formerly Simons Air Systems) personnel were on site to functionally check the systems supplied by them, one of which was the PCD fines removal transporter (FD0520). They completed checks and necessary modifications to the system in early April and reported no existing problems. When MWK transport reactor commissioning activities were to begin in late April, it was assumed that the FD0520 system would be ready for operation. Attempts to perform checks of the system by conveying material that had been placed in the bottom of the PCD to the FD0530 system revealed that, in actuality, the system had some remaining control logic and mechanical problems that needed to be addressed prior to integration into the MWK process. After these problems were addressed by PSDF personnel the FD0520 system was placed into operation for the MWK transport reactor commissioning activities. The FD0520 system was the most active of the CPC systems, which include all MWK reactor feed and ash removal systems, running for a total of 891 hours during commissioning and operation. The system was crucial in maintaining operation of the transport reactor since the reactor had to be shutdown if solids could not be removed from the PCD. The FD0520 system was also crucial in monitoring solids loading to the PCD since the SRI on-line PCD inlet sampling system had only started commissioning activities at the end of 1996 and could not provide accurate loading measurements. This solids loading monitoring will be further discussed below.

There were various mechanical problems experienced with the FD0520 system during commissioning as it adjusted to steady state operation. The main problem was with the Spheri valves, the valves that control the transfer of material through the system as the material is being depressurized from transport reactor pressure to atmospheric pressure. The valves tended to bind, and the spherical metal surfaces had to be polished to allow the valve bodies to rotate. Also, to aid in rotation and to prevent damage to the seals, the clearances between the valve bodies and their respective rubber seals had to be increased.

Problems were also experienced with false level indications from the level probe that controls the conveying cycle of the system. However, these problems cleared up after further conditioning of the system. Additionally, the vent valve became eroded from solids venting through it. The valve was replaced but this problem has not been solved for the long term. Also, it was discovered the pilot valves used for pressurizing the Spheri valve seals were not adequately greased, causing slow seal pressurization resulting in periodic system trips. Another problem which still awaits solution is that of ash agglomeration on the sides of the lock vessel. This was most acutely experienced during the November coal run (CCT2C) as more ash accumulated in the MWK system than had accumulated in any previous run. The ash agglomeration provided a false level indication and caused insufficiently sized solids transfer volumes.

There were also various problems associated with the PLC control logic for the system. There was no flexibility in the logic for operating the system below maximum reactor operating pressure, and this flexibility had to be written into the logic. The pressurization and depressurization of the vessels was not accurate enough resulting in over pressurization of the lock vessel. This also was corrected with PLC logic changes. Additionally, various timers had to be adjusted for different materials that took varying amounts of time to convey. Nuisance alarms were also a problem causing unnecessary system trips at crucial times and had to be removed from permissive control.

Figure 6.3.1-2 shows typical operation of the FD0520 system. The downward spikes in lock vessel pressure are the clearest indicators of the individual cycles of the system as the lock vessel depressurizes and then repressurizes during each cycle. The drop pipe pressure essentially tracks system pressure. The spikes of the dispense vessel pressure show the initial rise in pressure as conveying gas enters the dispense vessel containing the solids to be conveyed and then the decrease in pressure back to atmospheric pressure as the solids are removed from the vessel. Figure 6.3.1-2 is an example of a plot that is constantly watched during operation to monitor solids carryover to the PCD from the transport reactor. Each conveying cycle transfers approximately 1.4 ft^3 of material, so an estimation can be made of solids loading to the PCD by counting the number of conveying cycles during a given time period.

7.0 SOUTHERN RESEARCH INSTITUTE (SRI) PARTICULATE SAMPLING SYSTEM

This report describes the commissioning of the particulate sampling system installed at the inlet of the PCD on the transport reactor train. Commissioning of this system included cold shakedown tests performed in October 1996 and hot shakedown tests performed in November 1996. No major problems were encountered during the shakedown tests, but the need for several modifications to address operational problems and make the system easier to operate was identified. The problems encountered and the modifications made to address these problems are discussed below.

7.1 DESCRIPTION OF PARTICULATE SAMPLING SYSTEM

Sampling systems are provided at the PCD inlet and at the PCD outlet to collect representative particulate samples from the process gas streams entering and leaving the PCD. (See figure 7.1-1 on the following page.) The sampling systems make it possible to isokinetically collect bulk samples as well as size-segregated samples using a filter sampler (mass train), a five-stage cyclone assembly, and a cascade impactor. Throughout each sampling run, the sample gas flow is monitored and controlled to maintain isokinetic sampling conditions and to allow accurate determination of the total quantity of gas sampled. In combination with the sample weights, this information is used to determine the mass loadings and size distributions of particles entering and leaving the PCD and the overall and size-dependent collection efficiencies of the PCD. Particulate samples may also be used in laboratory studies of ash permeability, cohesivity, chemistry, and morphology.

To ensure the collected samples are representative, the sampling systems are designed to allow in situ sampling in the process gas stream at process conditions. This approach minimizes any alteration of particle properties caused by particle deposition and reentrainment in sampling lines and by condensation of alkali vapor or other condensibles on the particles. On-line access to the process gas stream is provided by a set of double block-and-bleed valves. The outer block-and-bleed valve is connected to a flanged spool piece with a packing gland assembly through which the sampling probe is inserted. Accurate positioning of the sampler is ensured through the use of a screw insertion mechanism operated by a stepper motor with a built-in encoder. Insertion and retraction sequences are controlled remotely with a specially designed computer program, and software and hardware interlocks are provided to ensure that the system operates safely.

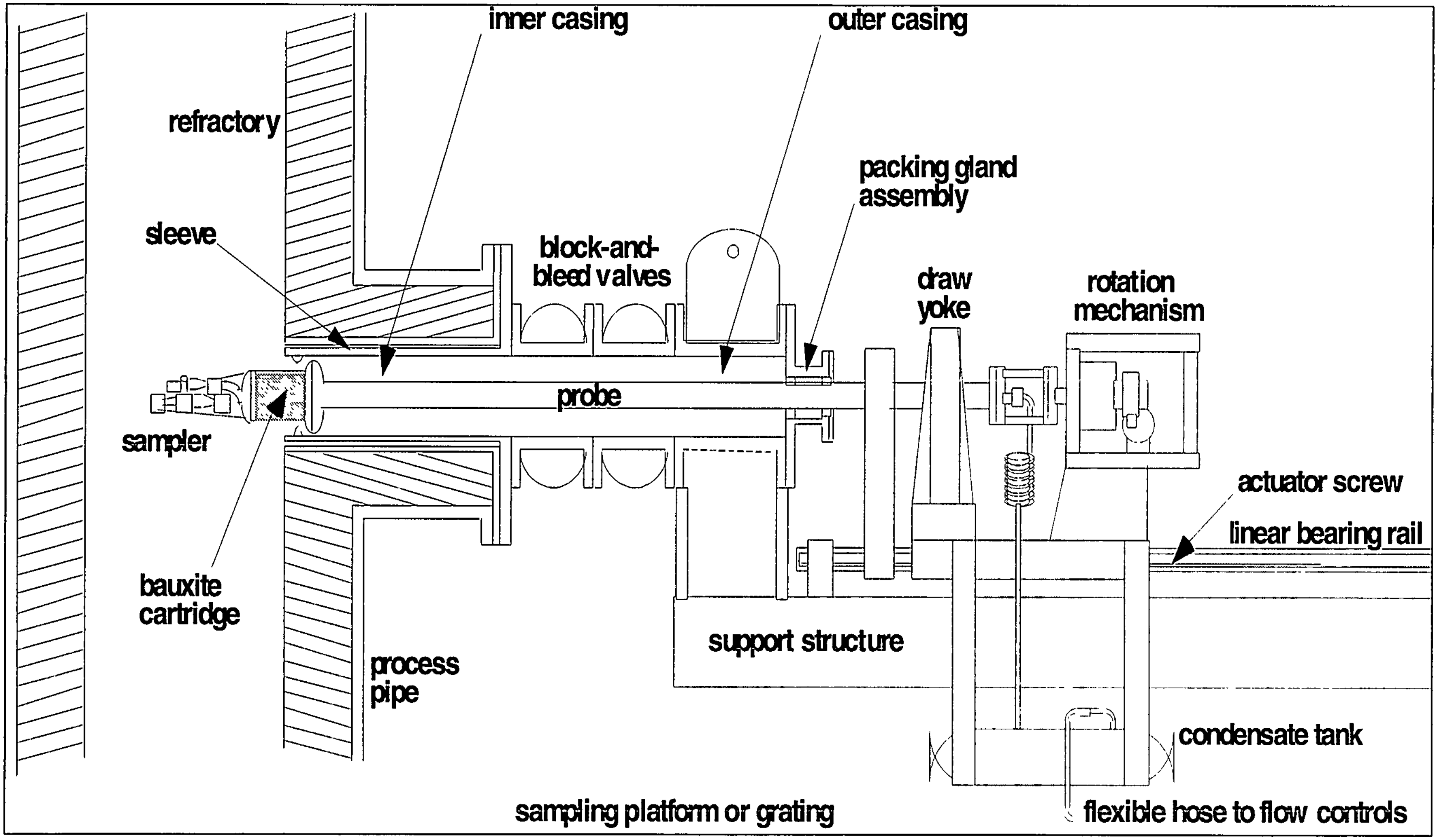


Figure 7.1-1 Particulate Sampling System

7.2 COLD SHAKEDOWN

The cold shakedown testing was comprised the following major elements:

A. Debug the computer control system and instrumentation.

B. Check for leaks and set flows in the cooling water, nitrogen purge, and instrument air systems.

C. Conduct operational checks on all solenoid-operated purge and vent valves and all local push-button controls and indicator lights.

D. Test the cycling of the block-and-bleed valves and gas sampling valve.

E. Conduct leak checks on the outer casing and packing gland.

F. Calibrate the probe positioning system and sample flow orifice.

The debugging of the computer control system included checking the control software, aligning position sensors, checking the operation of the Compumotor AT6400 controllers, stepper motors, analog and digital I/O, and interface between the control system and the DCS. The instrument loop checks revealed a number of wiring problems that were corrected prior to continuing through the cold shakedown tests. Noise in the signals from the temperature transmitters (which was affecting the accuracy of the analog inputs to the computer control system) was eliminated by digitally filtering the signal. Several of the stepper motors were returned to the manufacturer to correct a wiring problem that caused the position encoders to malfunction.

The leak checks revealed some minor leaks that were corrected. Several of the solenoid valves (which were pilot-assisted valves) failed to operate because of inadequate pressure differential across the valve. These valves were later replaced with zero-differential valves.

The sampling flow orifice was calibrated using a laminar flow element installed immediately downstream from the orifice. Four calibration runs were performed over a range of flows from 0.430 to 1.612 scfm, as determined from the flow curve for the laminar flow element. The corresponding orifice flows were calculated using rigorous equations supplied by Rosemount and used to determine the calibration constant for the orifice (i.e., the ratio of the measured flow to the actual flow). Calibration constants determined in this manner varied from 0.937 to 1.016. For the four initial sampling runs discussed later, the calibration factor amounted to a correction of 1.4 to 2.0 percent.

7.3 HOT SHAKEDOWN

Hot shakedown testing was begun in November and was comprised the following major elements:

A. Conduct operation check of the block-and-bleed system with hot process gas.

B. Insert the sampling probe into the hot process gas stream and the retraction back into the outer casing.

C. Conduct leak checks on the outer casing and packing gland.

D. Monitor gas temperature at inboard block-and-bleed valve and adjustment of nitrogen purge flow.

E. Perform initial sample runs to test performance of sampler.

F. Inspect filter material and gaskets after sample runs.

The hot shakedown testing was done with process gas at temperatures of 500 to 600°F and at pressures of 60 to 160 psig. Under these conditions, any change in the alignment of the casing or the probe as a result of the increased temperature was not able to be detected. There did not appear to be any warpage of components exposed to the hot gas. The probe moved smoothly through the packing gland and casing and no leaks were detected in either one. Gas temperatures at the inboard valve remained below 200°F throughout the hot shakedown testing, suggesting the nitrogen purge was more than adequate to protect the block-and-bleed valves. This will also need to hold true with higher process temperatures.

During the hot shakedown testing, one of the solenoid valves in the vent lines failed. Examination of the valve revealed ash had entered the valve through the vent line. To address this problem, filters were added to the vent lines upstream of the solenoid valves, and the vent line connections were moved from the bottom of the casing to the top.

In addition to the problem with the solenoid valves in the vent lines, several other problems were identified and addressed to make the system easier to operate. The absence of a remote pressure indication made it difficult to match the outer casing pressure to the process pressure before opening the block-and-bleed valves. The location of the sample flow-control valve allowed flow surges through the sampler during pressurization and depressurization. Accurate measurement of the nitrogen purge rate was difficult because the flow indicator on the main nitrogen purge line was scaled too high for the required flow rate.

7.4 SYSTEM MODIFICATIONS

The following system modifications were made to address the problems mentioned above and to make the sampling system easier to operate.

A. Added filters ahead of the solenoid valves in the vent lines and changed the vent connections from the bottom to the top of the casing.

B. Replaced pilot-assisted solenoid valves with zero-differential valves.

C. Added manual ball valves for isolation of the vent system and on-line servicing of the solenoid valves.

D. Installed pressure equalization lines to balance the outer-casing pressure with the process pressure before opening the block-and-bleed valves.

E. Added a metering valve at the back end of the probe to act as a surge limiter during pressurization and depressurization.

F. Added a pressure transmitter to allow remote monitoring of the outer casing pressure and pressure gauges to check the pressures in other portions of the casing.

G. Replaced the flow indicator on the main nitrogen purge line with one scaled for lower flow rates.

The above changes were implemented in the outlet sampling system as well as the inlet system.

7.5 INITIAL SAMPLING RUNS

Four sampling runs were performed at the PCD inlet in support of characterization test CCT2C. In general, the measured particulate loadings tracked the changes in solids carryover as expected. Particle-size analyses performed on the in situ samples and samples taken from the PCD hopper suggested the hopper samples were not appropriate for use in determination of particle size entering the PCD. The results of the initial sampling runs and particle-size analyses are discussed in detail in the CCT2C run report.

7.6 PORT INSPECTION

Following the four initial sampling runs, the port cover opposite the sampling probe was removed to inspect the area for deposits. There was concern the cold nitrogen purge gas introduced through the port could cause localized condensation and deposit buildup in this area. The inspection revealed no evidence of deposits or buildups.

7.7 SUMMARY

The particulate sampling system functioned as intended and successfully collected particulate samples from the process gas stream. Samples were collected in situ at process temperature and pressure to ensure they were representative of the ash entering the PCD. Isokinetic sampling conditions were maintained using the calibrated sample flow orifice. Operational problems identified during the shakedown tests were addressed with appropriate system modifications completed.

7.8 MAJOR EVENTS (CHRONOLOGY)

On November 15, 1996, the inlet particulate sampling system was commissioned. Shakedown testing was completed and sample collection with the particulate sampling system installed at the PCD inlet was started.

8.0 BALANCE-OF-PLANT

8.1 Feedstock Preparation

8.1.1 Coal and Sorbent (Feedstock) Reclaim System Description

Feedstock is loaded into the reclaim hopper (HO0100) from the feedstock storage shed via rolling stock (front end loader). From the reclaim hopper the feedstock travels via conveyor (CV0100) through a magnetic separator (MG0102) to the crusher (CR0104). The magnetic separator removes any metal debris from the feedstock before it enters the crusher. The crusher reduces the size of the feedstock to three-fourths of an inch or smaller. From the crusher, the feedstock travels up the trifold conveyor (CV0101) and through the crushed material surge bin (CU0106). If the feedstock is coal it is diverted past the sorbent flop gate (ME0100) through the coal flop gate (ME0101) and on to the drag-chain conveyor (CV0103). If the feedstock is sorbent it is diverted past the coal flop gate (ME0101) through the sorbent flop gate (ME0100) and on to the drag-chain conveyor (CV0102). The drag-chain conveyor deposits crushed coal into the MWK crushed coal silo (SI0101) or the crushed sorbent in the crushed sorbent silo (SI0103). Both crushed material silos are equipped with a baghouse to remove any dust displaced from the storage silo.

8.1.1.1 Coal and Sorbent Reclaim System Commissioning

Commissioning of the reclaim system went as expected. No major problems were encountered.

8.1.1.2 Reclaim System Control

The reclaim system is controlled by an Imperial Technologies PLC. The system runs at two speeds—one for coal and a (slower) speed for the heavier sorbent.

8.1.1.3 Normal Operation

The reclaim system has operated as expected.

8.1.2 MWK Coal Mill Process Description

Crushed coal (zero to three-fourths of an inch) from silo SI0101 moves through an isolation slide gate and is fed by a rotary valve (FD0111) to a William's Patent Crusher (WPC) 30-inch diameter roller mill (ML0111) where the coal is pulverized. A spinner separator (SP0111) returns a certain amount of oversize coal particles to the mill. Air heated by a 3-MBtu/hr air heater (HR0111) transports the pulverized coal to a cyclone collector (CY0111). The main fan (FN0111) and a combustion blower (BL0111) are used to move the transport air. The pulverized coal from the mill travels to the cyclone collector where it is separated from the transport gas. Part of the gas is reused and part is vented to the atmosphere through a baghouse (FL0111). Any additional gas that passes through the baghouse is recycled to the air heater. The baghouse collects the coal dust and deposits it into the pulverized coal silo (SI0111) through a discharge rotary valve (VL0121). An exhaust fan (FN0114) moves the transport gas through the baghouse. The pulverized coal collected by the cyclone is fed by a discharge rotary valve (VL0114) to a vibrating screen (SC0111). The screen separates the oversize coal particles (presently any over 1,000 microns) and returns them to the crushed coal silo by the use of a 12-inch pipe. The correct size coal passes through the vibrating screen to the MWK pulverized coal silo (SI0111). A level transmitter (LT4891A) indicates the coal level in the silo. A low-level alarm will notify the control room when the silo needs to be refilled. A high-level setting stops the rotary feed valve (FD0111) and allows the feed handling equipment to empty. The lubrication requirement of the mill is controlled by the automatic lubrication system. The mill is sealed with nitrogen.

8.1.2.1 MKW Coal Mill System Commissioning

Three basic goals guided commissioning of the coal mill system. First, the mill must operate smoothly and steadily with minimal vibration of the mill and without drastic oscillations of controlling parameters while in the automatic mode. Secondly, the mill must operate below the NFPA O_2 concentration limit of 13.8 percent. Finally, the mill must produce the desired particle size distribution.

8.1.2.2 Mill Control

The mill speed and other parameters are controlled by the WPC PLC to obtain a desired coal particle size distribution and steady mill operation. Along with mill speed, the other controlling parameters are spinner separator speed (SP0111), transport air flow rate, and feeder speed (FD0111). The parameters' setpoints and ranges are adjusted based on experience to vary particle size output. To obtain steady mill operation, the WPC PLC attempts to reach a pressure drop setpoint across the mill by varying the control parameters.

WPC performed the initial system tuning on-site. During a subsequent production run WPC tuned the system via a modem link to the PLC. Because mill tuning relies heavily on experience, WPC will be called periodically for tuning help. Also, if major changes (i.e., coal type change) are made WPC will be needed for tuning help.

8.1.2.3 Limiting Oxygen Concentration Requirements

Section 2.7.2.1 of NFPA 69 states for a continuously monitored process the oxygen concentration must be kept at least 2.0 percent below a limiting oxygen concentration (LOC). For bituminous coal the standard lists the LOC as 15.8 percent, making the maximum allowable O_2 concentration 13.8 percent (for subbituminous coal 11.8 percent). Mill combustion products are recycled to reduce O_2 levels. Hence the need as mentioned in the introduction for recycling the transport gas after the baghouse back to the air heater. (Instead of drawing in excess cooling air from the atmosphere for the heater recycle transport gases are used.) An Ametek Series 2000/WDG in situ measuring system is used to monitor O_2 concentration.

The major problem encountered during commissioning was achieving the NFPA O_2 concentration requirement. Because the system was designed for coals with higher moisture content than the coal used for commissioning more conveying gas must be exhausted to cool the air heater. As more conveying gas is exhausted, more fresh air is introduced, driving up the O_2 concentration. Even with the air heater at its minimum setting, too much conveying gas must be exhausted for cooling the air heater to keep the O_2 concentrations below required levels. Therefore, a method for reducing the O_2 had to be found.

Consultations between PSDF and WPC engineers resulted in an eventual solution of water injection into the mill windbox because the air heaters were sized to remove more water than was present. The water is carried from the windbox into the mill by hot conveying gas. With the coal currently in use about 0.75 g/m of water is added to drive down the O_2 concentration. Once the mill is operating steadily, an O_2 concentration of approximately 12.8 percent is achieved and maintained.

8.1.2.4 Particle Size Distribution

The WPC roller mill system is capable of producing a range of particle size distributions. During commissioning, the mill system was tuned over a range of distributions until the required particle size distribution was acquired (figure 8.1.2-1). The nature of the commissioning process is to gain a certain amount of experience with this particular setup for future changes and troubleshooting by both the PSDF staff and WPC. For this reason one of the results of the commissioning process is a table of particle size distributions along with corresponding setpoints for the various control parameters. This table allows for easier change over to different particle size distributions for future test runs.

8.1.2.5 Normal Operation

The MWK coal mill system operated very well during normal operation. Getting coal flow started from the crushed coal silo was the only real problem encountered. This problem resulted from a water leak in the silo which caused a coal-mud buildup at the silo exit. The leak was repaired and the problem seems to have been corrected.

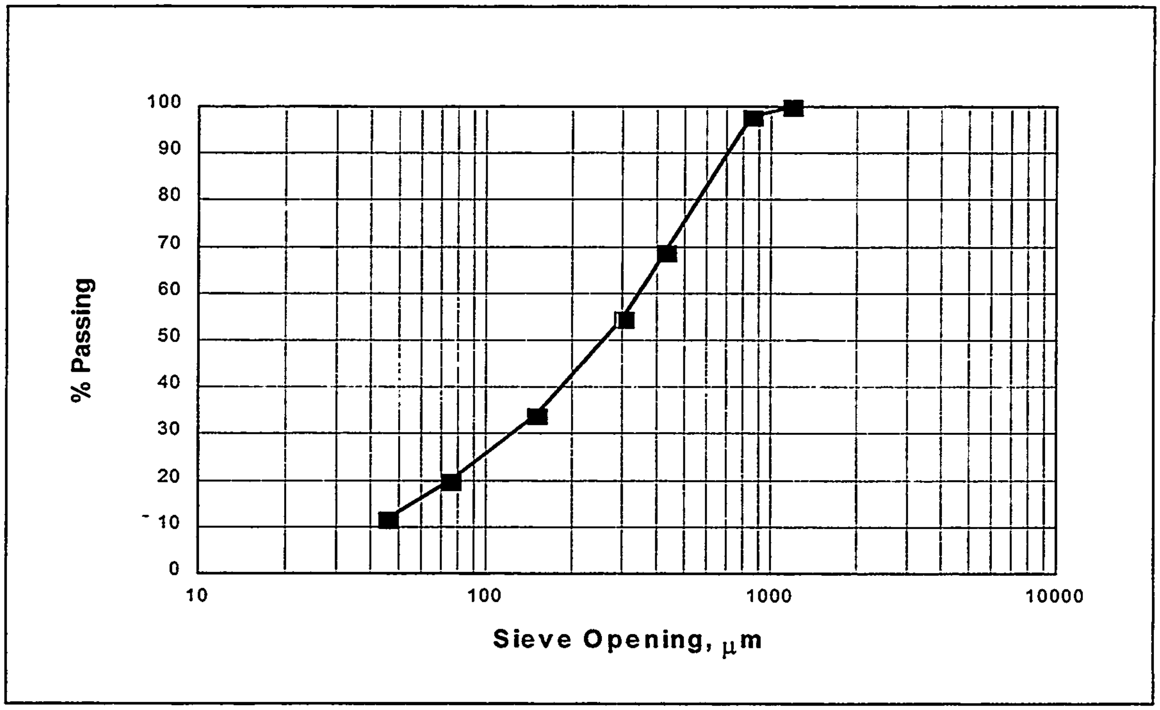


Figure 8.1.2-1 Coal Particle Size Distribution

8.1.3 MKW Sorbent Mill Process Description

Crushed sorbent (zero to three-fourths of 1.0 inch) from silo SI0103 moves through an isolation slide gate and is fed by rotary valve (FD0113) to the William's Patent Crusher (WPC) 30-inch diameter roller mill (ML0113) where the sorbent is pulverized. The spinner separator (SP0113) returns a certain amount of oversize sorbent particles to the mill. Air heated by a 1-MBtu air heater (HR0113) transports the pulverized sorbent to the cyclone collector (CY0113). The main fan (FN0113) and combustion blower (BL0113) are used to move the transport air. The pulverized sorbent from the mill travels through the cyclone diverter slide gate (VL0136) to the cyclone collector where it is separated from the transport air. Part of the air is reused and the rest is vented to the atmosphere through a baghouse (FL0113). The baghouse collects the sorbent dust and deposits it into the MWK pulverized sorbent silo (SI0113) through a discharge rotary valve (VL0123). An exhaust fan (FN0116) moves the air through the baghouse. The pulverized sorbent collected by the cyclone is fed by the discharge rotary valve (VL0116) to the vibrating screen (SC0113). The screen separates the oversize particles (currently any over 500 microns) and returns them to the crushed sorbent silo by the use of a screw feeder (FD0118). The correct size limestone passes through the vibrating screen to the MWK pulverized sorbent silo (SI0113). The level transmitter (LT4892A) indicates the sorbent level in the silo. A low-level alarm notifies the control room when the silo needs to be refilled. A high-level setting will stop the rotary feed valve (FD0113) and allows the feed handling equipment to empty. The lubrication requirement of the mill is controlled by the automatic lubrication system. The mill is sealed with air.

8.1.3.1 MKW Sorbent Mill System Commissioning

The sorbent mill system commissioning was guided by the requirement for the system to operate smoothly and steadily and by the particle size requirement. Dolomite was used during commissioning and for the following two combustion test runs.

With the exception of the NFPA O_2 concentration requirement the sorbent mill system operates identically to the coal mill system. Mill control is achieved in the same fashion. Particle size distribution is likewise achieved in the same fashion as with the coal mill system. A graph of the resulting particle size distribution is shown in figure 8.1.3-1. The commissioning procedure moved along in the same manner as the coal mill commissioning.

8.1.3.2 Normal Operation

The sorbent mill operated very well during normal operation. The mill-feed rotary valve caused the only recurring problem. Because the dolomite is so hard, it caused the rotary vanes to bind against the housing of the valve. The valve housing was changed to relieve this binding.

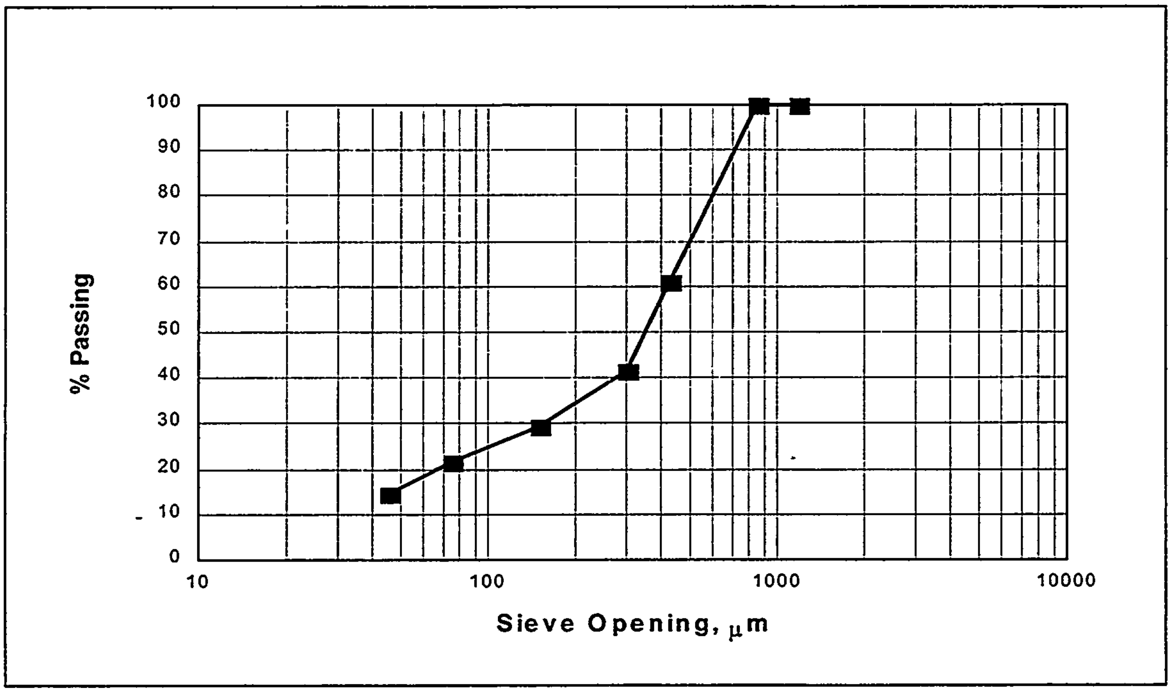


Figure 8.1.3-1 Dolomite Particle Size Distribution

8.2 MAIN AIR COMPRESSOR

8.2.1 Description

The main air compressor (CO0210) was designed to supply 18,000 lb/hr of air at 365 psia and 400°F for gasification, combustion, solids conveying, standpipe aeration, and start-up burner operation. It is a four-stage, integrally geared centrifugal constant speed compressor, with interstage cooling driven by a 1,750-hp Siemens induction motor. The main air compressor takes suction from the atmosphere through an inlet filter. Depending on the process requirements, an Allen Bradley PLC controls the compressor via adjustment to the inlet guide vanes and the blowoff valve.

8.2.2 Commissioning Tests/Runs

Commissioning activities started with a vendor visit at the end of 1995. Since the reactor system was not ready for air flow, all checks were done with the air going through the blowoff valve. Once the system was ready for air in the spring of 1996, the vendor again came to the site to tune the control. It was determined during this 2-day check out that the tuning parameters were incorrect, causing the compressor to frequently, and erroneously, unload since the PLC "thought" a surge condition was imminent. During commissioning by on-site personnel, it was identified that there was a potential for water carryover into stages 2 and 3 without any preventive alarms. Level switches were installed in intercoolers 1 and 2 to activate alarms at the DCS in the event of a high water level in either, or both, intercoolers. DCS-related functional checks were satisfactorily completed April 30.

8.2.3 Highlights of Problems and Solutions

As discussed, there were some initial tuning problems which the vendor was able to address in the spring of 1996. An additional control problem encountered during late 1996 was apparently due to the variation in atmospheric conditions. An inlet temperature compensation will be installed during February of 1997 to address this problem.

8.2.4 Performance During Normal Operation

After some initial tuning problems, the compressor ran well in automatic and responded quickly to changes in downstream conditions. For example, when the positioner arm on the pressure letdown valve broke and the reactor pressure increased from 150 to 260 psig in 30 seconds, the compressor was able to make the necessary adjustments without surging or unloading, figure 8.2.4-1 shows the compressor discharge pressure and the reactor pressure during this event.

However, late in the year during test run CCT2C and CCT3A the compressor experienced some additional control problems. On two consecutive nights during CCT2C, the compressor began to surge and then automatically unload and tripped several other systems. At this time, problems were also experienced with the transport air dryer which was causing some pressure swings (~60 psig) in the compressor downstream pressure. However, the compressor continued to have control problems during CCT3A after the dryer had been repaired. The problems (according to Atlas Copco) are believed to have been caused by the variations in atmospheric conditions operating with "winter air" while the compressor tuning parameters were set in the summer position for "summer air" (humidity ~90 percent and temperature ~90°F). To address this problem, an inlet temperature compensation will be installed during February 1997. Figure 8.2.4-2 is a graph of discharge pressure, inlet guide vane position, and blowoff valve position showing a compressor unload during CCT2C. The compressor ran for a total of 1,570 hours during 1996.

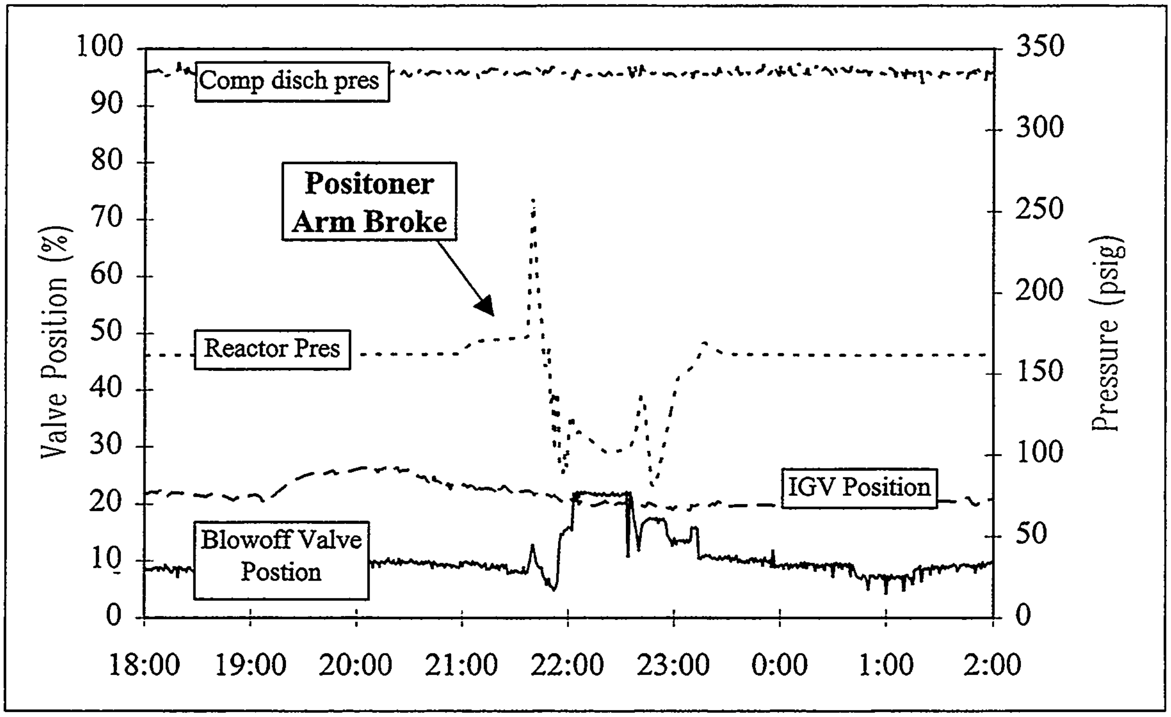


Figure 8.2.4-1 Main Air Compressor Operations August 20 to 21, 1996

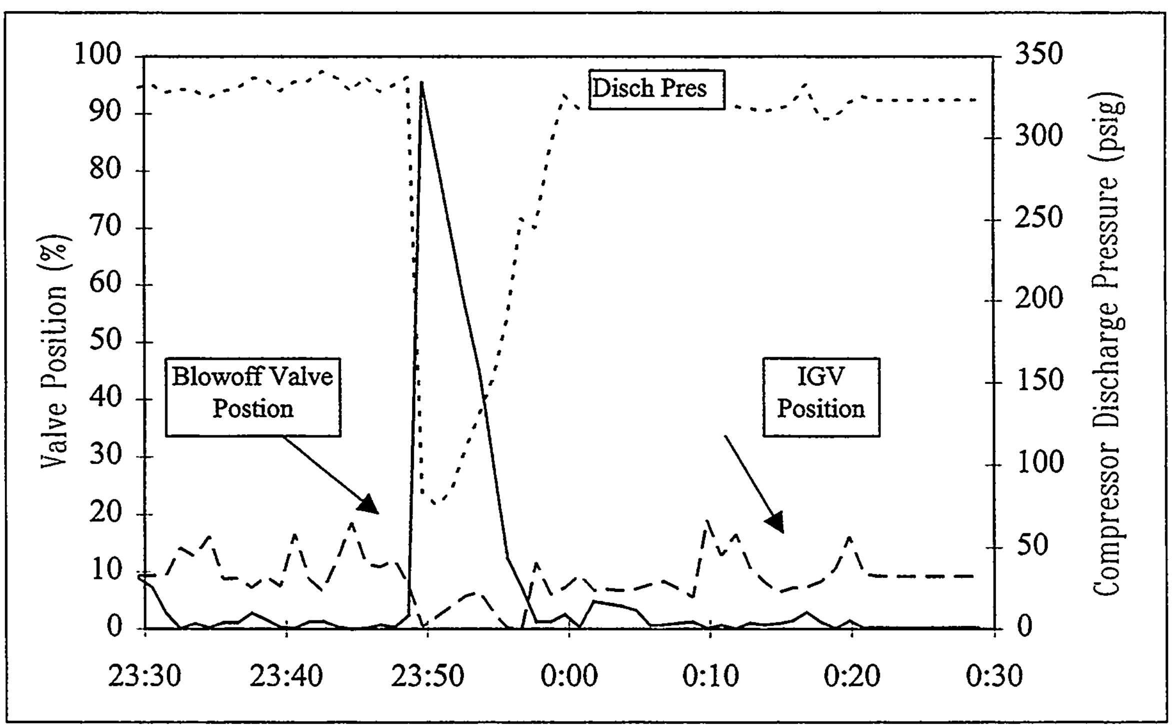


Figure 8.2.4-2 Main Air Compressor Operations November 15 to 16, 1996

8.3 Transport Air System

8.3.1 Description

The transport air system is designed to supply transport air for the coal and limestone feed streams. Air from the main air compressor is cooled to approximately 95°F in the transport air cooler (HX0204) and then dried to a dewpoint of -10°F by the transport air dryer (DY0210). The transport air dryer consists of two unheated drying towers, only one of which is in service at a time. The transport air flows through one desiccant tower where water vapor is adsorbed from the process air stream. At the same time, the other desiccant bed is being regenerated by a flow of dry gas. A coalescing prefilter and trap upstream of the dryer inlet protects the desiccant from liquid condensate and oil carryover from the compressor and a particulate afterfilter is installed downstream of the dryer to remove any desiccant fines from the outlet stream.

8.3.2 Commissioning Tests/Runs

The dryer functional checks were successfully completed during April and the dryer was commissioned in June with essentially no problems.

8.3.3 Highlights of Problems and Solutions

Performance During Normal Operations

On November 16, 1996 (during CCT2C), tower 1 of the transport air dryer was repressurizing rapidly because the regeneration blowoff valve (XV8116) was not closing and the purge flow meter was not maintaining its set point. The dryer was taken out of service and all the valves (XV8116, XV8117, XV8118, and XV8119) were taken apart and cleaned. Since the tower had been repressurizing so rapidly there was a chance some of the desiccant could have been blown out. The afterfilter was inspected and the filter cartridge was found relatively clean. The afterfilter cartridge and the orifice purge flow meter were blown clean. When the dryer was placed back in service, tower 1 repressurized slowly and the purge rate flow maintained its set point, i.e., the dryer was successfully repaired.

Also during this run, the prefilter was draining much more water than in the previous runs indicating that there could be a problem with the upstream separator.

During the following outage, the separator, the drain trap, and the prefilter were inspected. The separator inspection revealed no problems. The drain trap was inspected and the outlet orifice was cleaned. The prefilter coalescing cartridge was damaged due to the excessive water carryover and had to be replaced.

8.4 RECYCLE GAS BOOSTER COMPRESSOR

8.4.1 Description

The recycle gas system supplies an oxygen deficient gas stream at 350 psig for aeration of the combustor heat exchanger, for aeration of the transport reactor mixing zone, standpipe, and J-leg, for spent solids transport, and for spoiling gas to the primary cyclone. The system consists of the compressor feed cooler (HX0405), a separator (SP414), the recycle gas booster compressor intake filter (FL0401), and the recycle gas booster compressor (CO0401). A slipstream of gas leaving the secondary gas cooler (HX0402) feeds the recycle gas system. A portion of this gas flows through the compressor feed cooler to control the compressor discharge temperature at 300°F. Any liquid condensed in the cooler is knocked out by the separator and is injected into the flue gas feed stream that is flowing to the thermal oxidizer. Particulate matter that may be in the gas is filtered out by the intake filter before the gas enters the compressor. The compressor is a 200-hp, 2-cycle, reciprocating compressor driven by a Siemens motor and controlled by an Allen Bradley PLC.

8.4.2 Commissioning Tests/Runs

The functional checks were completed May 17, 1996, with only minor problems encountered and addressed. On May 20 and 21, a vendor representative verified the compressor piston striking distance, crosshead distances, proper installation of the compressor valves, motor and compressor-side thrust, and coupling alignment. After these checks, the compressor was successfully started and run using instrument air with an intake pressure of 50 psig and discharge around 100 psig. During operations the motor amps were checked and found acceptable. On June 29 the compressor was run again so that it could be tested under normal operating conditions. The compressor was started with a suction pressure of 130 psig, and the suction pressure was gradually increased to 250 psig while the discharge pressure was controlled at 325 psig via pressure controller, PIC478. Only minor problems were encountered which were solved by changing a switch point setting and a few PLC rungs. During the operating period various controllers were tuned and it was demonstrated that a smooth transition could be made from air to recycle gas for fluidization of the combustor heat exchanger. Also, vibration readings were taken and found acceptable. The compressor tripped (as programmed) once during this period due to a high suction pressure. Figure 8.4.2-1 shows a graph of this operating period.

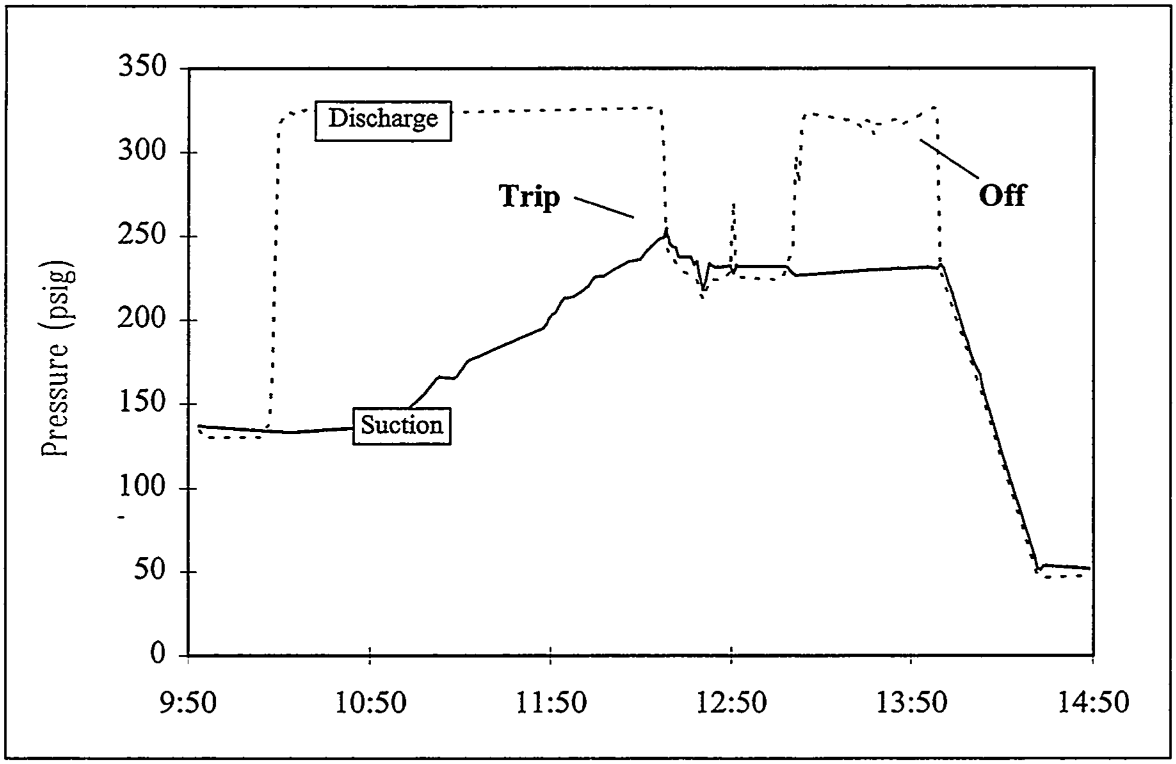


Figure 8.4.2-1 Recycle Gas Booster Compressor Commissioning June 29,1996

8.4.3 Performance During Normal Operation

Since an air line was installed to fluidize the combustor heat exchanger, the compressor was not operated during any of the 1996 reactor test runs.

8.5 PROCESS GAS SAMPLING SYSTEM

8.5.1 System Description

The process gas sampling system extracts gas from two points in the M. W. Kellogg process. One sample stream (designated AE464) is extracted from the transport reactor port S4, located just downstream of the secondary gas cooler (HX0402), and is transported to all gas analyzers in the process gas sampling system. The other sample stream (designated AE610) is extracted from the sulfator system just downstream of the sulfator heat recovery exchanger (HX0601), and is transported solely to the Rosemount Model 890 SO_2 analyzer. The Rosemount SO_2 analyzer is the only analyzer that is switchable between the sample stream AE464 and sample stream AE610.

The process gas sampling system is composed of the instruments shown in table 8.5.1-1. The table also shows the components that are measured by the process gas sampling system along with the detection methodology used.

The Rosemount NGA 2000 analyzer system consists of a common platform controller and three analysis modules: the modules measure CO, NO_x, and O_2. The detection methodology is NDIR for CO, Chemiluminescence for NO_x, and Paramagnetism for O_2. Software loaded into the NGA platform controller allows the O_2 analyzer range to be changed from 0 to 25 percent for combustion mode operations and to the 0 to 5000 ppm for gasification mode operations. Each module is a continuous analyzer with local or remote zero and autospan calibration. The calibration can be programmed to occur daily at a user-specified time.

The Rosemount 890 SO_2 analyzer utilizes an ultraviolet (UV) detection methodology and provides continuous sampling, and local or remote zero and auto-span calibration. The calibration can be programmed to occur daily at a user-specified time.

The ABB model 3501 moisture analyzer utilizes an IR detection methodology. Both manual and automatic zero and calibration are available by menu selection.

The gas chromatograph (GC) is an applied automation GC. The GC is set up for dual sample injections during each cycle with the components routed to two thermal conductivity detectors. The GC is not a continuous analyzer; it operates on a 330 second sample cycle. Table 8.5.1-2 depicts the components measured by the GC and the corresponding calibration ranges.

Owing to possible reaction among some of the components of interest, two calibration streams are required. One of the calibration streams has H_2, CO, CO_2, CH4, and C_2+ with a balance of helium. The other stream is comprised of O_2 and N_2 with a balance of argon.

All of the analyzers transmit a 4- to 20-mA DC signal to the DCS. Also, common trouble alarms from each analyzer are transmitted to the DCS.

The analyzer house (located on the eighth floor of the structure) in the location of all of the process gas sampling system analyzers. The analyzer house is a totally enclosed walk-in shelter which is air-conditioned, heated and ventilated to provide a safe environment for the analytical equipment and personnel. For the protection of the personnel inside the analyzer house, an ambient monitoring system with associated alarms and flashing beacons, is provided to detect unsafe concentrations of CO, H_2S, combustibles, and O_2 deficiency.

Table 8.5.1-1

Process Gas Sampling System Instruments

Instrument	Calibration Range	Sample Stream	Component	Detection Methodology
Rosemount NGA 2000	0-25%	AE464	CO	NDIR
Rosemount NGA 2000	0-1000 ppm	AE464	NO_x	Chemiluminescence
Rosemount NGA 2000	0-25% (comb.)	AE464	O_2	Paramagnetic
Rosemount NGA 2000	0-5000 ppm (gas.)	AE464	O_2	Paramagnetic
ABB Model 3501	0-20%	AE464	Moisture	IR
Rosemount Model 890	0-5000 ppm	AE464/AE610	SO_2	UV

Table 8.5.1-2

Calibration Ranges for the Gas Chromatograph

Component	Calibration Range Percent
CO	0-25
N_2	0-100
O_2	0-25
CO_2	0-25
H_2	0-25
C_2+	0-10
CH4	0-10

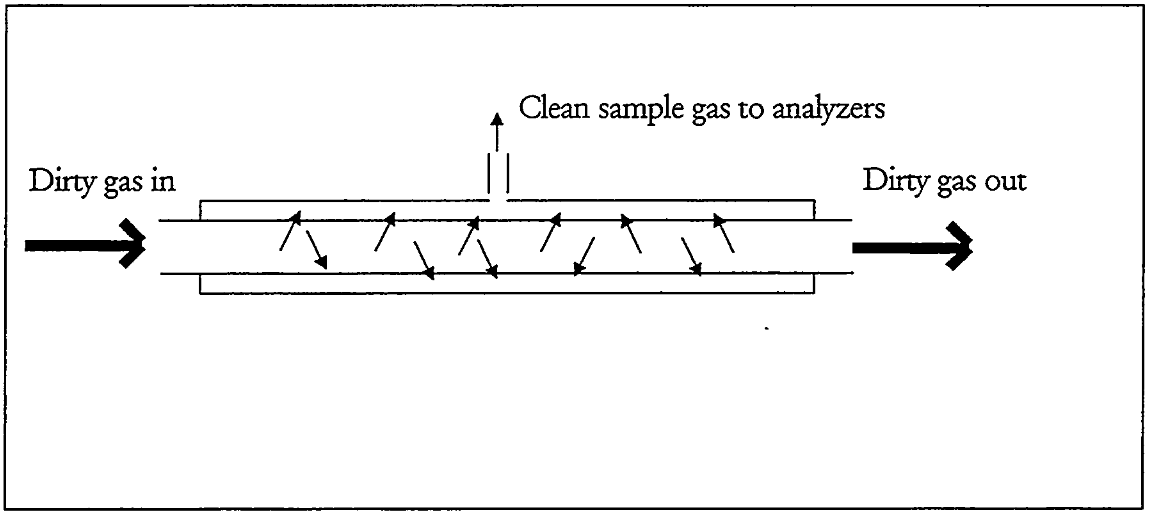


Figure 8.5.1-1 Porous Metal Cross-Flow Filter

8.5.2 Alternative Conceptual Designs Considered for Sample Extraction and Transport

The original design of the AE464 sample stream called for extracting the sample from a point just above the primary heat exchanger (HX0202). However, this sample point would be located in a dead leg if HX0202 were to be bypassed. Therefore, another sample extraction point was considered necessary. An acoustic detector port, located between HX0202 and the particulate control device (PCD), was investigated as a first alternate sample extraction point. However, the process gas at this point had a high-solids loading at an elevated temperature (1,000 to 1,600°F) and was considered too severe for sample extraction. A second alternate sample extraction point located downstream of the secondary gas cooler (HX0402), was considered and selected because of the less severe process conditions (600°F).

The original and the first alternate designs included the use of a porous metal cross-flow filter manufactured by the Mott Metallurgical Corporation. This filter consists of a porous metal filter housed in a solid metal tube with connections for a flow inlet, a flow outlet and a clean sample port. (See figure 8.5.1-1.) A relatively large quantity of flow would have been drawn off the main process and passed through the inside diameter of the porous metal filter. The gas velocity along the inside filter wall had to be between 75 and 100 feet per second in order to clean the dust cake buildup. The bulk of the process gas would have passed through the inside diameter of the filter, then been dropped in pressure by an orifice or pressure control valve, and returned to the process just downstream of the back pressure regulator valve, PV287. The small stream of filtered gas would have been transported to the analyzer house.

The designs utilizing the porous metal cross-flow filter would have required about 180 lb/hr of gas to be drawn from the process. With the high concentration of solids in the process gas, erosion would likely have been severe. Thus, the designs that utilized the porous metal cross-flow filter were rejected and the sample point downstream of HX0402 was considered and selected. Considering the operation of the process sampling system was an absolute necessity for transport reactor operation, the decision to move the sample extraction point was appropriate.

With the original sample extraction designs, the process sample would have been transported 30 feet before reaching the analyzer house. With the current design, the sample must be transported 200 feet. The longer sample transport distance certainly adds time lag in the sampling process; however, during operations a process change was detected within a few seconds by the analyzers. The first 110 feet of the installed sample transport line is a fast loop design which decreases the analyzers detection time of a process change. With a fast loop design, a majority of the sample extracted is bypassed to the flare and a smaller quantity filtered and transported to the analyzers.

The sample transport tubing for sample stream AE610 was installed as designed but was not commissioned. Commissioning of sample stream AE610 will occur in 1997.

8.5.3 Sample Conditions at Extraction

At the extraction point, the temperature of stream AE464 is 600°F and the pressure is at the transport reactor operating pressure (121 to 283 psig). The tube-in-tube cooler located in the AX464 preconditioner box was bypassed since the process temperature is much lower at the selected sample extraction point. The sample stream AE610 is extracted at 490°F and atmospheric pressure.

8.5.4 Checkout and Commissioning Experience

The overall quality of the analyzer house assembly was excellent. However,some aspects such as component selection providing documentation to complete the checkout and commissioning of the process gas sampling system, were less than optimum.

A representative from Cegelee, the analyzer house vendor, and an M. W. Kellogg Company engineer visited the PSDF site in early May to oversee the repair of the heat damaged components, calibrate the analyzers, complete the functional checkout of the analyzer systems, and provide a general overview on the operation of the process gas sampling system. At that time the analyzer house vendor announced they would no longer be building analyzer systems for the petrochemical process industry.

Most of the wiring and other plastic components in the moisture analyzer box were damaged by heat and had to be replaced by the vendor. The heat damage was a result of the installation of an incorrect temperature switch. The temperature switch was replaced and the damaged wires were replaced with high temperature wire.

A service representative from Applied Automation visited the site in early September to check out and calibrate the Gas Chromatograph (GC). Several unsuccessful attempts were made to calibrate the GC. During the troubleshooting, the Applied Automation representative found that an incorrect application program was loaded into the GC and that one of the seven GC columns was bad. The correct program and a replacement column were ordered and installed. Also, the auto-calibration setup was tested and a few wiring problems were corrected.

All of the analyzers except for the NO_x and the GC were brought on-line in August. During the checkout of the analyzers, the communication card in the NGA2000 control platform assigned to the NO_x analyzer failed to function and had to be sent out for repair. The pressure regulator located in AX464 preconditioner box had to be cleaned and reinstalled. The GC was brought on-line in October after the CEM technician attended specialized training required to operate and maintain the GC.

8.5.5 Operational Experience

The process gas sampling system O_2, NO_x, CO, and SO_2 analyzers were on-line for all but 4 hours of the 84-hour August run on coal. The only significant problem was that a pressure regulator located in the AX464 preconditioner box became plugged after being on-line for 72 hours. Most of the material that plugged the regulator appeared to be rust from the secondary heat exchanger (HX0402). To avoid additional pluggage problems, the regulator was moved downstream of the filters located in box AX464.

The Cegelec Automation Artic VI refrigeration sample gas dryer leaked refrigerant and had to be sent back to Cegelec Automation for repair. The refrigeration gas dryer was insufficiently cooling the sample gas and moisture was being carried downstream. A coalescer filter (located downstream) collected most of the carryover.

In early October the range of the Rosemount NGA 2000 CO analyzer module was changed from 0 to 25 percent to 0 to 50,000 ppm. However, when instrument air was fed through the CO analyzer, a lot of noise was present in the output. Thus, the CO analyzer data should only be used when the CO concentration is greater than 10,000 ppm (1 percent). Even though the CO analyzer can be ranged from 0 to 50,000 ppm, the analyzer module cell is too short for accurate readings at low ranges. The range of this analyzer module will be changed back to 0 to 25 percent for 1997 operations.

8.6 THERMAL OXIDIZER

8.6.1 Description

The thermal oxidizer (BR0401) is a downfired, vertical combustion chambered vessel. Other major components are the combustion air blower (BL0401) and a horizontal waste heat recovery section. The thermal oxidizer was designed to function as an incinerator for the syngas and as a steam producer for the steam needed for the gasification reactions. However, during 1996 it was used as a heat source to generate steam to start-up the steam system, to provide steam to indirectly preheat the PCDs, and to supply steam to the propane vaporizer since the auxiliary boiler was not in service. A 125-hp combustion air blower takes suction from the atmosphere and supplies air required for combustion and quench. The blower can deliver a maximum of 10,000 scfm of air and is capable of being turned down to 2,200 scfm. Burner ignition is attained with an Allen Bradley PLC that is dedicated to sequencing the burner management system, and firing of the burner is controlled by a DCS temperature set point.

8.6.2 Commissioning Tests/Runs

Functional checks were performed on the thermal oxidizer burner management system (BMS) on April 25 and 26. The initial checks were performed in a sequence that followed the ladder logic start-up procedure. Trip scenarios were also simulated. The thermal oxidizer blower functional checks including blower discharge pressure, thermal oxidizer temperature, and excess oxygen controls were completed on May 6. All checks were satisfactory with only a few minor problems being detected.

On May 6 and 7 the initial attempts to light the thermal oxidizer pilot were unsuccessful. The combustion air valve at its minimum position allowed too much air flow into the thermal oxidizer causing the pilot to be blown out. The air flow was reduced by using the instrument air purges for the sightglass and flame scanners as the only sources of air. The pilot was successfully lit but when the combustion air valve was opened slightly, the additional air blew out the pilot flame. In addition, the positioner on the combustion air valve was of poor quality and was unable to hold the air flow constant at low flow rates. Since the waste air enters at about the same elevation as the main burner tip, it could be increased without blowing the pilot out. So, the pilot was relit and the waste air flow was increased to provide combustion air in preparation to light the main burner. As soon as the main burner start was pressed, the primary combustion air was increased. The main burner ignited and maintained a stable flame.

The thermal oxidizer refractory was cured to 1,600°F from May 12 to 17. During the cureout, the thermal oxidizer generated steam at approximately 100 psig drum pressure, commissioning the steam and condensate system, providing steam to commission the high pressure propane system and demonstrating that the thermal oxidizer was an efficient way to heat up the steam drum. Figure 8.6.2-1 shows a plot of the thermal oxidizer outlet temperature and steam drum pressure for this operating period. While in operation, the thermal oxidizer was checked for "hot spots" indicating gaps/failure of the refractory but none were found.

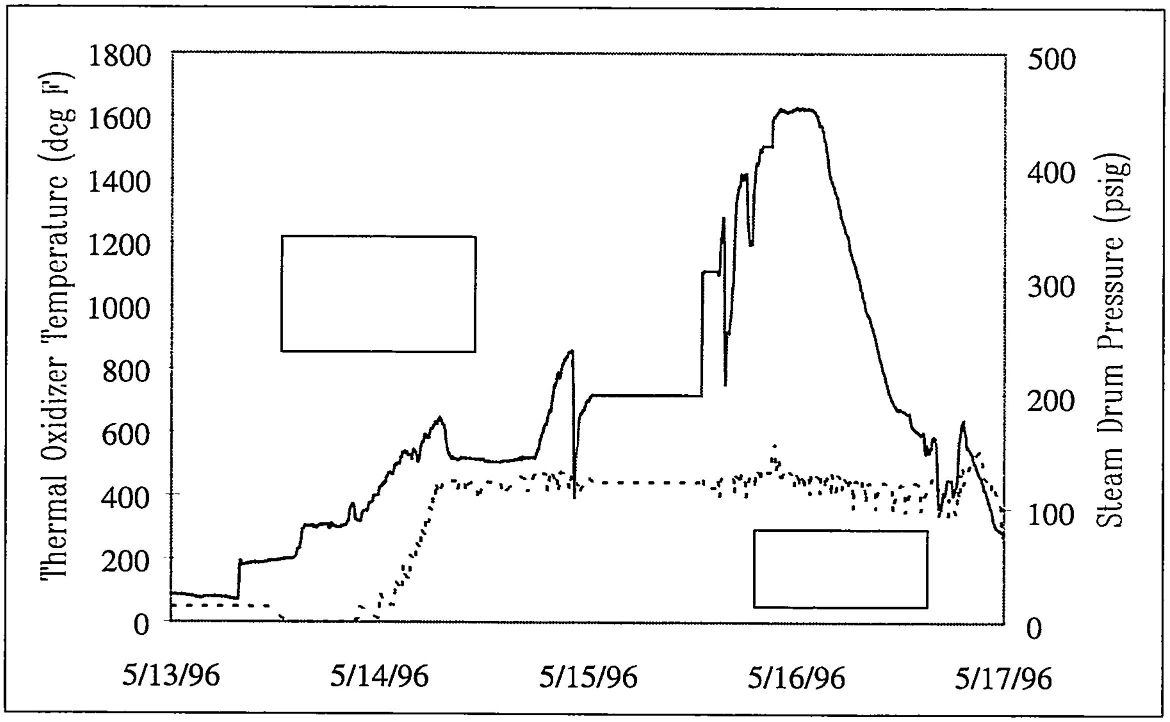


Figure 8.6.2-1 Thermal Oxidizer Refractory Cureout

8.6.3 Highlights of Problems and Solutions

Control problems with the combustion air valve continued, so a 3-inch bypass line with a manual valve was installed around the combustion air valve. The positioner on the combustion air valve was also replaced. During subsequent runs, the bypass around the combustion air valve was used for starting the pilot. The other problem during commissioning dealt with questionable oxygen analyzer readings. At higher firing rates the oxygen analyzer reading was much lower than calculated based on the propane/air flow rates. The oxygen concentration of the gas downstream of the waste heat recovery section was checked, and the reading at that location reflected the calculated oxygen concentration. The above differences could be explained if the oxygen analyzer was reading an unmixed portion of the flame zone, giving unreliable results. The analyzer was moved downstream of the waste heat recovery section to provide more accurate readings.

8.6.4 Performance During Normal Operation

The thermal oxidizer has run for a total of 2,700 hours and has been fired as high as 14 MBtu/hr. The thermal oxidizer has operated well during all test runs of 1996 with only a few instrumentation problems. It has met the steam demands for both the PCD preheat and the propane vaporizer.

During July 1996 the refractory was inspected. There were several small cracks which were all less than one-eighth of an inch in width, probably caused by differential expansion of the metal shell and the refractory. On December 4, following test run CCT2C, another inspection of the thermal oxidizer refractory was completed. The cracks in the refractory were not noticeably larger than they were during the previous inspection. However, there were a few small areas of spalling about 1-inch long and 0.25 inches deep. Some larger refractory pieces were found in the bottom of the vessel which possibly came from the upper part of the vessel, located some 25 feet above grade. Therefore, an inspection of the top section of the thermal oxidizer was conducted on December 19 (after CCT3A) when the appropriate equipment had been gathered for the inspection. This inspection revealed that there was some flaking and minor cracks less than one-eighth of an inch deep in the upper section, but overall the refractory was in good condition. Figure 8.6.4-1 shows two photographs taken during the inspection of the top area of the thermal oxidizer.

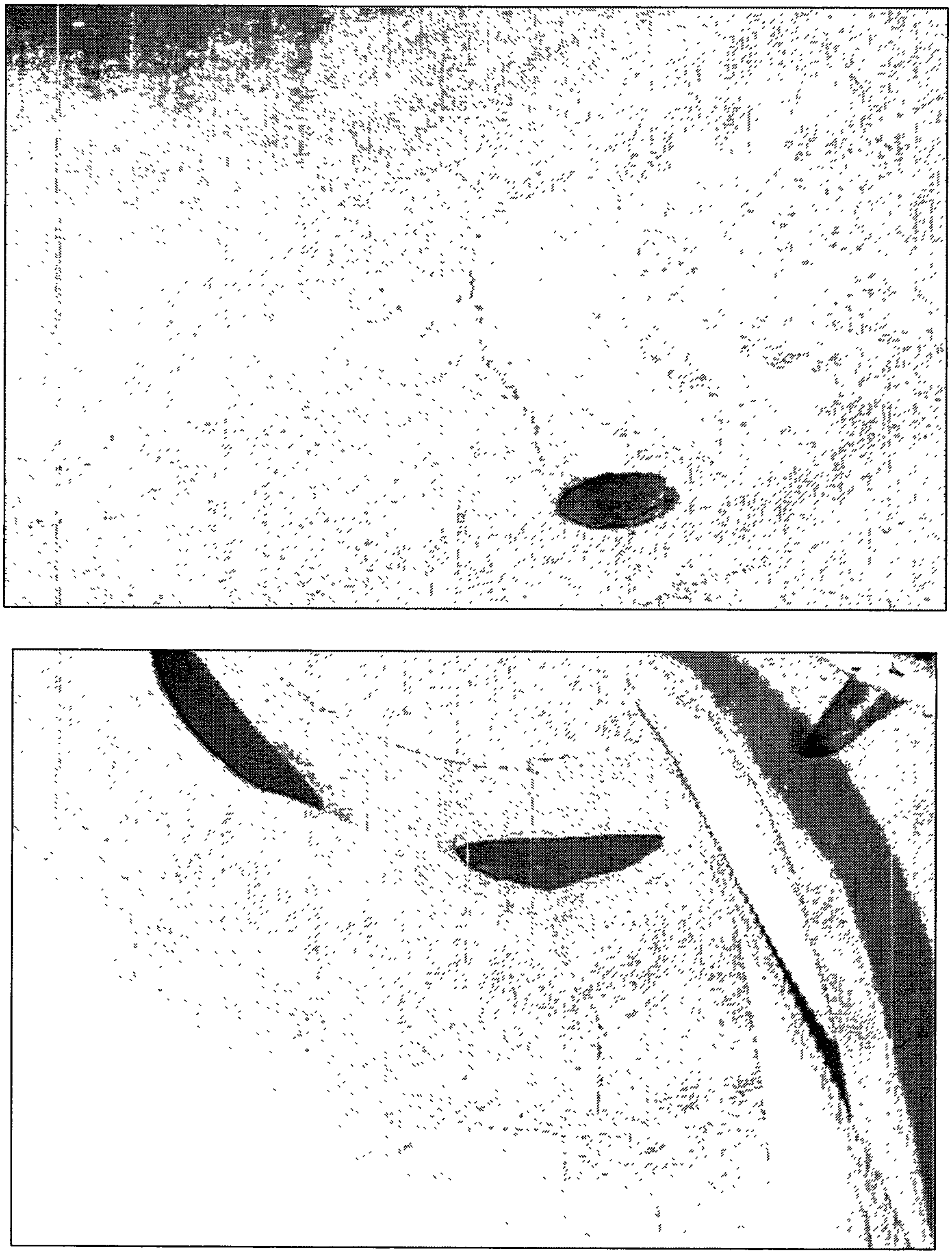


Figure 8.6.4-1 Two Views of Top Areas of Thermal Oxidizer December 19, 1996

PSDF\1996\8.6

8.7 STEAM SYSTEM

8.7.1 Description

Boiler feed water (BFW) flows by natural circulation from the steam drum to the primary gas cooler, the secondary gas cooler, the combustor heat exchanger, the thermal oxidizer, and the sulfator heat recovery exchanger for cooling purposes. The steam produced flows back to the steam drum where the pressure is regulated by pressure controller, PIC405. Excess steam flows from the steam drum to the MWK steam condenser, then to either the MWK feed water heater or the condensate subcooler based on the BFW inlet temperature controller. Depending on the mode of operation, saturated steam may also flow to the thermal oxidizer and the CPC PCD. The steam drum is equipped with continuous and intermittent blowdowns and a chemical injection system to maintain boiler feed water chemistry in a condition to prevent scale, sludge, and alkalinity from becoming a serious problem. Blowdown water is sent to a blowdown tank and then disposed. Each exchanger and/or coil that is generating steam is also equipped with an intermittent blowdown to control solids buildup.

8.7.2 Commissioning Tests/Runs

The demin pump logic (I4700) was checked on April 5, 1996, when the pumps were run to fill the steam and condensate tank. On April 12 the boiler feed pumps were checked while filling the MWK closed-loop cooling water system to ensure that the pumps could be run from the DCS and to set the recirculation valve (CV4003) position. The remaining functional checks, including all alarm points and control loops, were satisfactorily checked by the end of April. On April 19 the steam drum was filled and blanketed with nitrogen.

8.7.3 Highlights of Problems and Solutions

Performance During Normal Operation

Due to low coal feed rates during all commissioning runs, the steam and condensate system has operated below design conditions causing some control problems and a persistent water hammer in the BFW line. The water hammer problem may have resulted from the low BFW temperature and the low BFW flow combined with the fact that the BFW is introduced into the vapor space of the drum. To address this problem and the drum level control problems, a line is being installed which will introduce the BFW into the drum via a chemical injection line below the water level. Low steam production has also caused problems with supplying sufficient steam to the propane vaporizer. A different operating philosophy concerning the drum pressure was implemented to address this issue. The drum operating pressure was reduced and the thermal oxidizer was fired higher so the drum pressure could be maintained with the steam pressure control valve operating around 40-percent open. Figures 8.7.3-1 and -2 show two graphs which illustrate the operations.

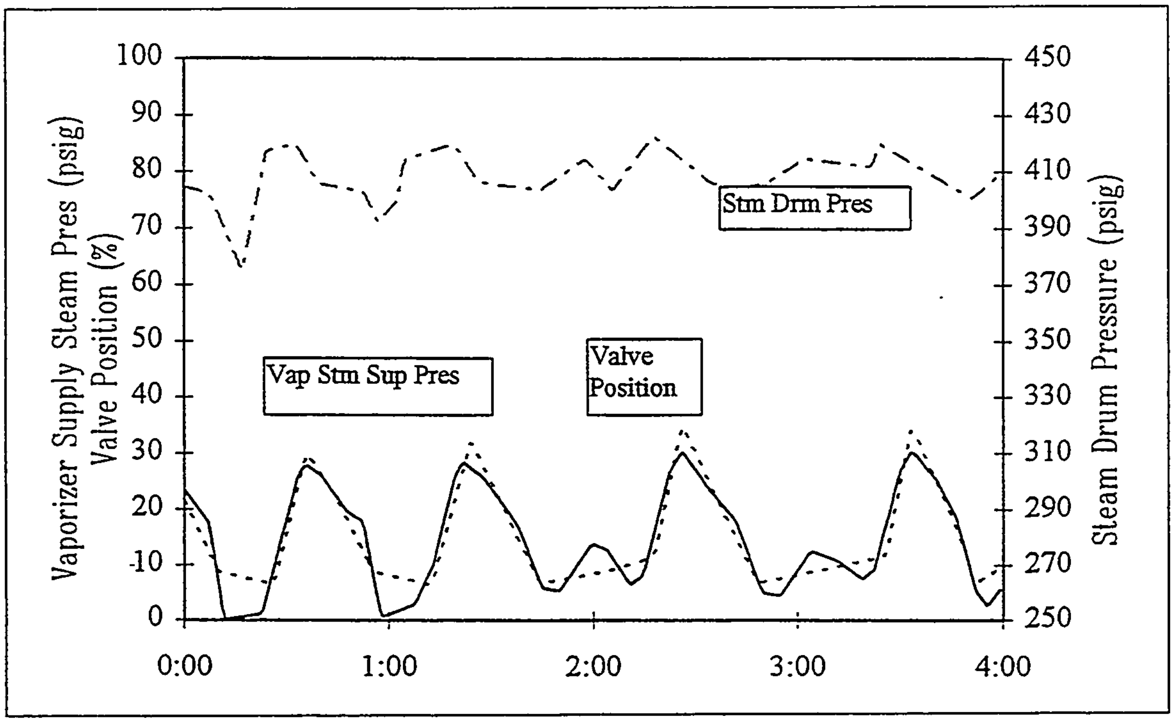


Figure 8.7.3-1 Steam System Operations August 5, 1996

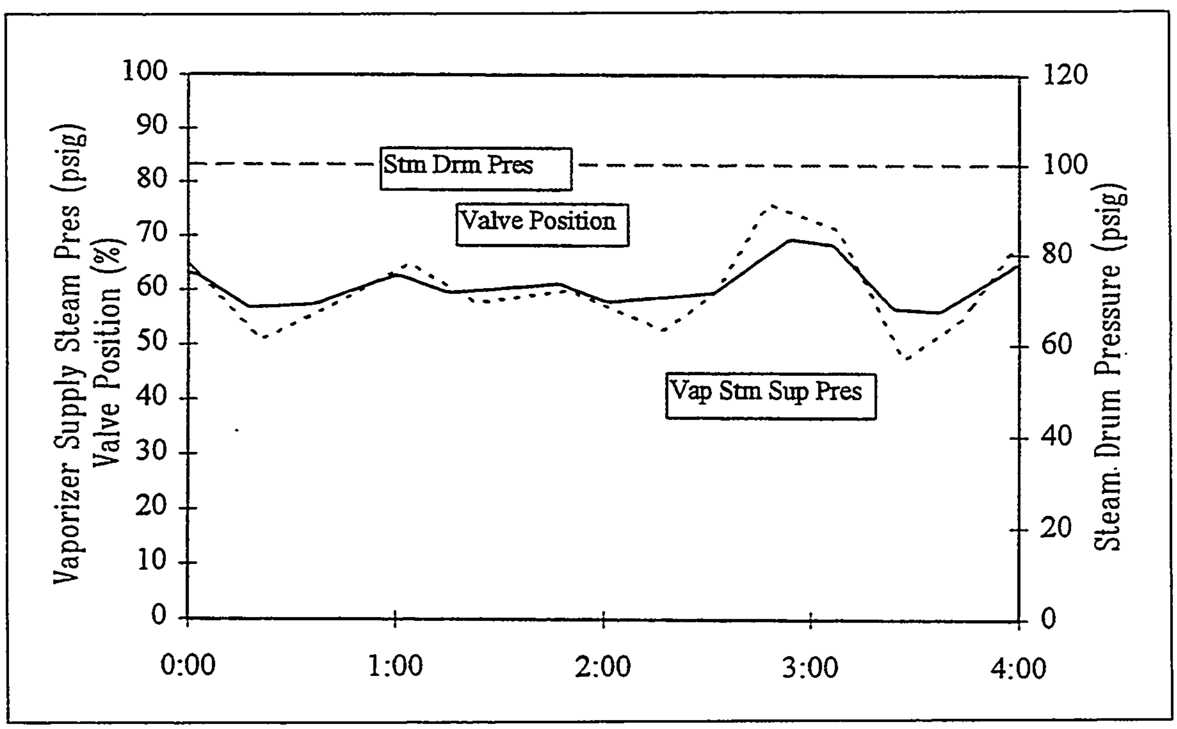


Figure 8.7.3-2 Steam System Operations November 21, 1996

8.8 SULFATOR SYSTEM

8.8.1 System Description

When the transport reactor operates in the gasification mode, the solids removed will be a mixture of carbon, CaS, CaO, and coal ash that must be rendered environmentally safe before disposal. Solids from the transport reactor will be pneumatically transported to the atmospheric fluidized bed sulfator (SU0601) where carbon will be oxidized to CO_2 and CaS will be converted to $CaSO_4$. To control SO_2 emissions, limestone will be introduced by the limestone feeder system (FD0610).

The reaction temperature in the sulfator vessel will be controlled to 1,650°F by superheating saturated steam. The sulfator air compressor (CO0601) will supply the process air required for combustion in SU0601. To preheat SU0601, the process air will be heated by the sulfator start-up heater (BR0602). Flue gases leaving the sulfator will flow through the sulfator cyclone (CY0601) and travel to the sulfator heat recovery exchanger (HX0601). The solids removed by CY0601 will be returned to SU0601. The flue gas exiting CY0601 will be cooled in HX0601 by generating steam. The SU0601 spent solids will be removed and cooled by the sulfator solids screw cooler (FD0602), transported to the spent solids silo (SI0602), and then transferred to the SCS sulfator spent solids removal system (FD0810) for transport to the SCS ash silo.

8.8.2 Commissioning Status

Since the transport reactor has not operated in the gasification mode, the sulfator system has not been fully commissioned. BR0602 and CO0601 were the only parts of the sulfator system fully commissioned. The loop and functional checks were completed on FD0610, FD0602, and FD0810. Only the loop checks were completed on the SI0602 and the spent solids silo vent filter (SI0602-FL01).

8.8.3 Commissioning Experience

8.8.3.1 Commissioning of the Sulfator Start-Up Heater

During the checkout of BR0602, numerous small problems were found and corrected. The internals of the pressure switches on the BR0602 burner management skid were corroded beyond repair. Apparently, this occurred while the skid sat outdoors for over a year. Also, the solenoid valve vents for the air operated valves were plugged with mud deposited by wasps.

Instructions from the BR0602 manufacturer, Tulsa Heater, Inc., stated no flow should pass through the process coils during BR0602 refractory dry out. In order to commission BR0602, the low process flow switch had to be jumped. Also the permissive to operate (HS619) had to be manually forced from the DCS. This DCS manual forcing was not used for subsequent BR0602 operations because it removed the operator's ability to remotely shutdown BR0602 from the DCS. Instead a few temporary changes were made to the DCS logic to permit the BR0602 to operate without steam flowing through the sulfator vessel.

After completing the BR0602 checkout, the burner was lit for the first time on May 14, 1996, and the refractory dry out soon followed.

8.8.3.2 Sulfator Start-Up Heater Dry Out

In late May the dry out of BR0602 was started. A trend of the stack temperature during the dry out is shown in figure 8.8.3-1. Controlling the rise in the BR0602 stack temperature (TI8840) was a major problem. The burner operating manual from John Zinc, Inc., stated the burner should not be operated below a firing rate of 1 MBtu/hr. This firing rate required the propane flow valve (FV688) to be 48-percent open which resulted in a rapid increase in the stack temperature (TI8840) when the burner was lit. The main burner was shut off and propane gas pressure to the pilot was increased from 10 to 15 psig in an attempt to raise the stack temperature to 300°F. After an hour and a half, the stack temperature only increased to 160°F, therefore the burner had to be used to reach the desired temperature.

After consulting with the manufacture, the BR0602 burner was fired at a lower rate. (The only risk was potential carbon buildup on the burner tip - which did happen.) BR0602 was lit and the propane flow valve (FV688) was set to 10-percent open. This allowed better control of the heat-up rate.

With the pilot and the main burner burning, TI8840 indicated 370°F. The pilot valve was closed and the stack temperature dropped to 340°F. The stack temperature was then raised per the dry out schedule. The dry out of BR0602 was successful and BR0602 was not operated again until the end of September. A trend of the stack temperature (TI8840) for the refractory dry out is shown in figure 8.8.3-1.

8.8.3.3 Sulfator Air Compressor Commissioning and Operation

As part of the system checkout, the sulfator air compressor motor was bump started in early September 1996 and was found to have bad bearings. The bearing problem was likely a result of long-term storage. The sulfator air compressor (CO0601) was started for the first time on September 27 and test run for 4 hours. Two cross members were added to stiffen the compressor frame. After a few days of operation, a strap holding the inlet silencer broke and had to be repaired.

A positioner was added to the process air flow control valve (FV620) in order to improve air flow control to the sulfator. Also a flow element (FE620) had to be reinstalled because the guidevanes were not lined up with the flow path.

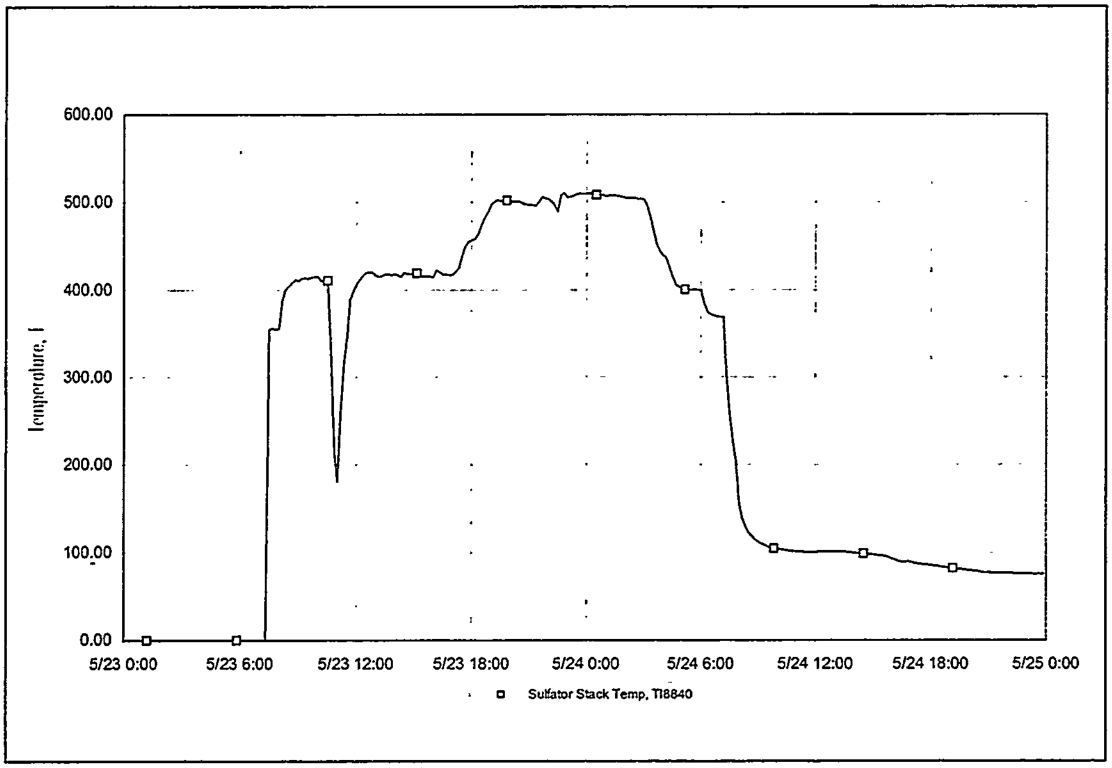


Figure 8.8.3-1 Sulfator Start-Up Heater Refractory Dry Out May 23 to 25, 1996

8.8.4 Sulfator Start-Up Heater Performance Test

The initial plan was to cure the joint refractory in the sulfator system. However, experience from the transport reactor proved that solids would first have to be introduced into the sulfator vessel. Therefore, only a performance test of the sulfator start-up heater was run. The purpose was to evaluate how well BR0602 could preheat SU0601.

The first performance test began on September 27. CO0601 was operated for 48 hours to air dry the sulfator system and then, the BR0602 pilot was lit and burned for 24 hours as part of the initial heatup.

On September 30 the BR0602 burner was lit and the pilot was shut off. The propane flow valve (FV688) was set at 10-percent open. For the next couple of days BR0602 had to be restarted for various reasons. On one occasion, when the sulfator heat recovery exchanger (HX0601) was opened to the steam system, the steam system pressure dropped and steam flow to the propane vaporizer was lost and the propane vaporizer shut down. Similarly, BR0602 tripped once again when the thermal oxidizer was taken off line to fix control problems.

On October 2 when FV688 (propane to BR0602) was opened from 20-to 28-percent open, the flow to BR0602 started to decrease. The propane vaporizer was found to be full of condensate. The condensate was drained and the steam bypass valve was opened.

On October 3 the propane flow valve (FV688) to BR0602 was opened from 10-to 18-percent open and the flow stayed at 1 lb/hr. Then suddenly the flow jumped to 28 lb/hr and the flame was blown out. The restart of BR0602 was attempted to four times but it would not stay lit. The propane pressure regulator (PCV8810) located on the BR0602 burner management skid was fouled. The regulator was cleaned and BR0602 was relit.

On October 5 when FV688 was opened from 69 to 70 percent, BR0602 tripped on high pressure (PSH8816). The drop across the burner (PI8817) was 22 psig when FV688 was 69-percent open and 23 psig when the FV688 was increased to 70-percent open. The design propane flow rate for BR0602 is 120 lb/hr. At the time of the high pressure trip, the flow rate was 140 lb/hr, the stack temperature was 1,360°F, and yet the process outlet temperature (TI617) was only 830°F, well below the design of 1,200°F. The problem was too much excess air was being drawn into the naturally drafted BR0602, cooling the flame and thereby reducing the radiant heat transfer to the process air. A hand-held O_2 sensor was used to measure the stack O_2 levels while the stack damper and bottom register were adjusted to obtain 3 percent oxygen in the stack (~15 percent excess air). With the reduced excess air level, the flame temperature increased and the quantity of propane required was reduced. Shutdowns due to high pressure drop across the burner did not occur again.

Because of the problems with the transport reactor start-up burner (BR0201) and the propane vaporizer, the performance test was suspended on October 6. The trend for TI8840 and TI617 during this period is shown in figure 8.8.4-1.

The performance test was restarted on October 14. The goal was to achieve a process outlet temperature of 1,200°F while keeping the stack temperature below the design of 1,360°F with an excess air level of 15 percent. On October 16 the BR0602 process outlet temperature (TI617) had only reached 850°F, even after the top damper and bottom register were set to get 3-percent O_2 in the flue gas and while maintaining 1,360°F in the stack.

After checking on the temperature limitations of the stack, the propane flow was increased until the stack temperature was 1,450°F. After increasing the propane flow, BR0602 tripped four times with each trip about 4 hours apart. It was discovered the trips occurred because of an accidental removal of a manually set steam flow (FI602) in the DCS. Since these tests were being performed with the SU0601 steam piping dry, FI602 output was manually set to 19,000 lb/hr on September 27. However, on October 15 this manually inserted valve was accidentally removed. With the manually inserted flow rate removed, the permissive to run was lost when a temperature indication in the sulfator (TI568) exceeded 550°F. In the DCS interlock logic during normal operations, BR0602 can only be operated when less than 18,500 lb/hr steam is flowing through the sulfator and TI568 is below 550°F. The inserted steam flow rate was restored.

The trend for this performance period is shown in figure 8.8.4-2. The process outlet temperature (TI617) reached 945°F. BR0602 was shutdown on October 18 to evaluate the performance problem, and the draft in BR0602 was observed to be too high. A Magnehelic gauge was installed, and it was determined that SU0601 temperature (TI567) had reached only 590°F.

The performance test was restarted on November 3. Two days into the test, flame was seen below the burner gas tip. The test was suspended and the burner was removed for inspection. The burner gas tip was covered with carbon which was a result of extended firing of the burner at low propane flows. Flame was seen below the burner gas tip because the threaded connection was leaking. The trend for this period is shown in figure 8.8.4-3.

On November 8 the performance test was restarted. The trend for this period is shown in figure 8.8.4-4. The design process outlet temperature (TI617) of 1,200°F was reached. The process air flow indication (FI620) was 6,283 lb/hr, however, that flow reading is believed to be in error. The process air flow was calculated to be 5,450 lb/hr which is 14 percent below the design flow rate of 6,200 lb/hr. Flow element FE620 is scheduled to be sent off for calibration in early 1997.

One factor that affected the performance of BR0602 was the process air temperature (TI624) entering BR0602 at 50°F below design. The inlet air temperature to BR0602 was 150°F because of the relatively low ambient temperature. The design temperature is 200°F. The temperature of the process air entering BR0602 was affected by the ambient conditions. During previous runs, TI624 had normally reached 215°F. If the process air inlet was at the design temperature, calculations indicated 5,700 lb/hr could have been heated to 1,200°F.

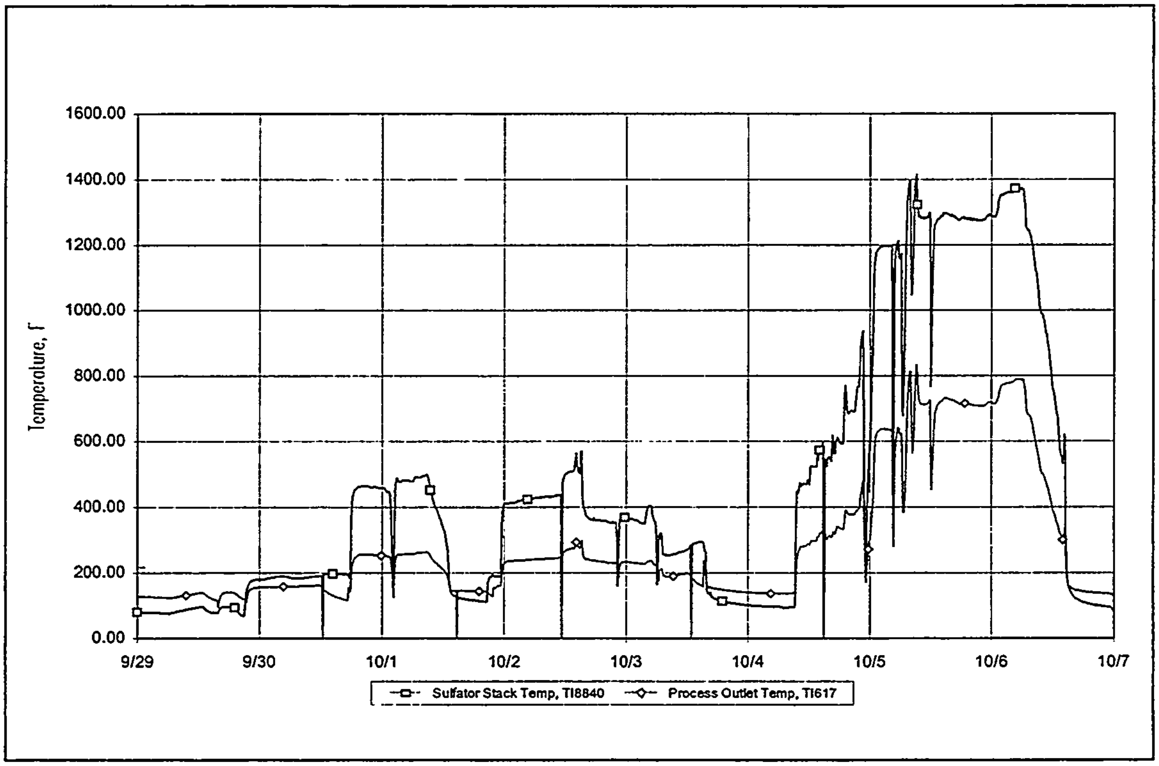


Figure 8.8.4-1 Sulfator Performance Test September 9 to October 7, 1996

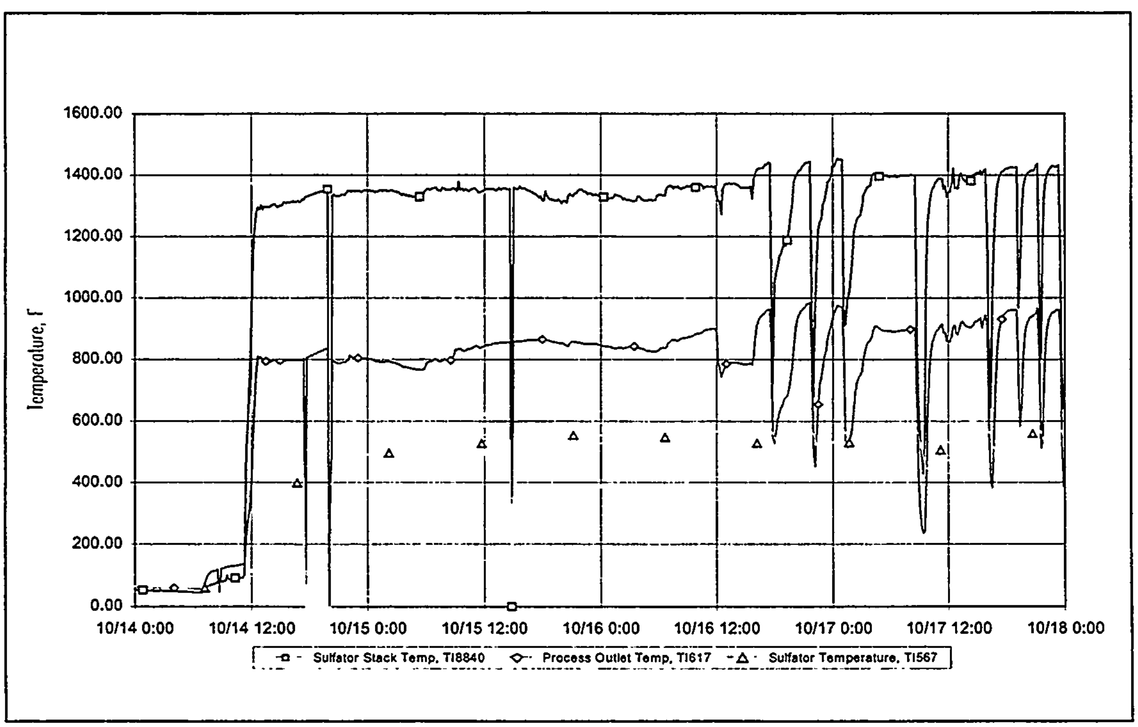


Figure 8.8.4-2 Sulfator Performance Test October 14 to 18, 1996

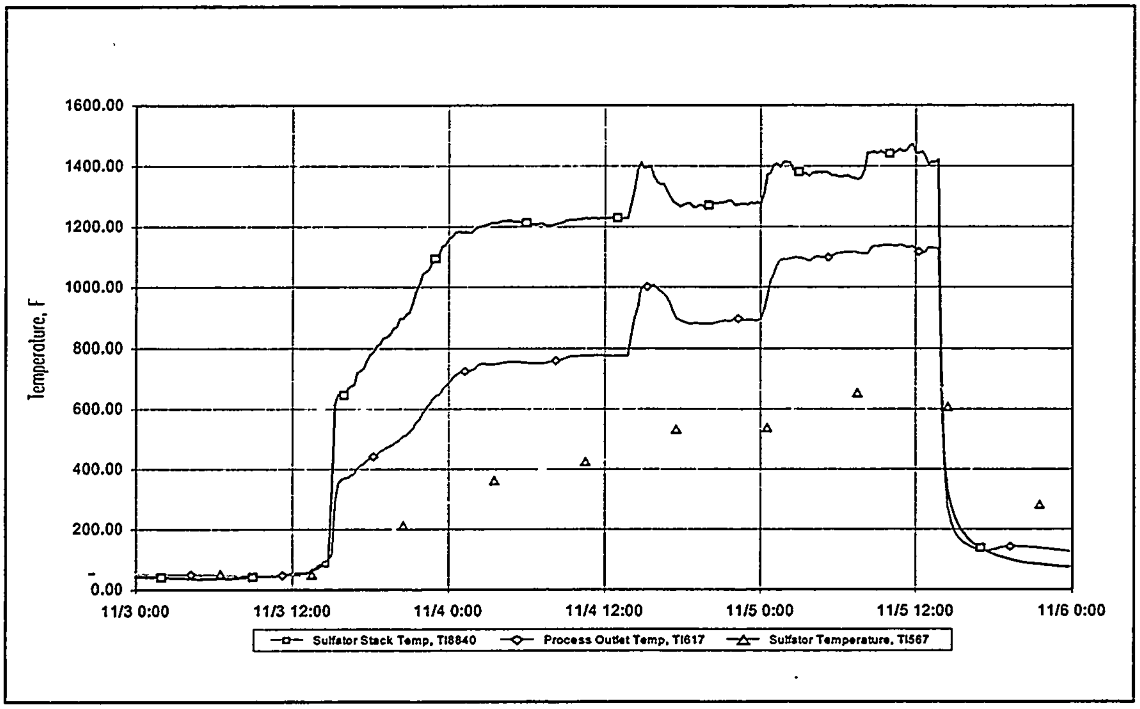


Figure 8.8.4-3 Sulfator Performance Test November 3 to 6, 1996

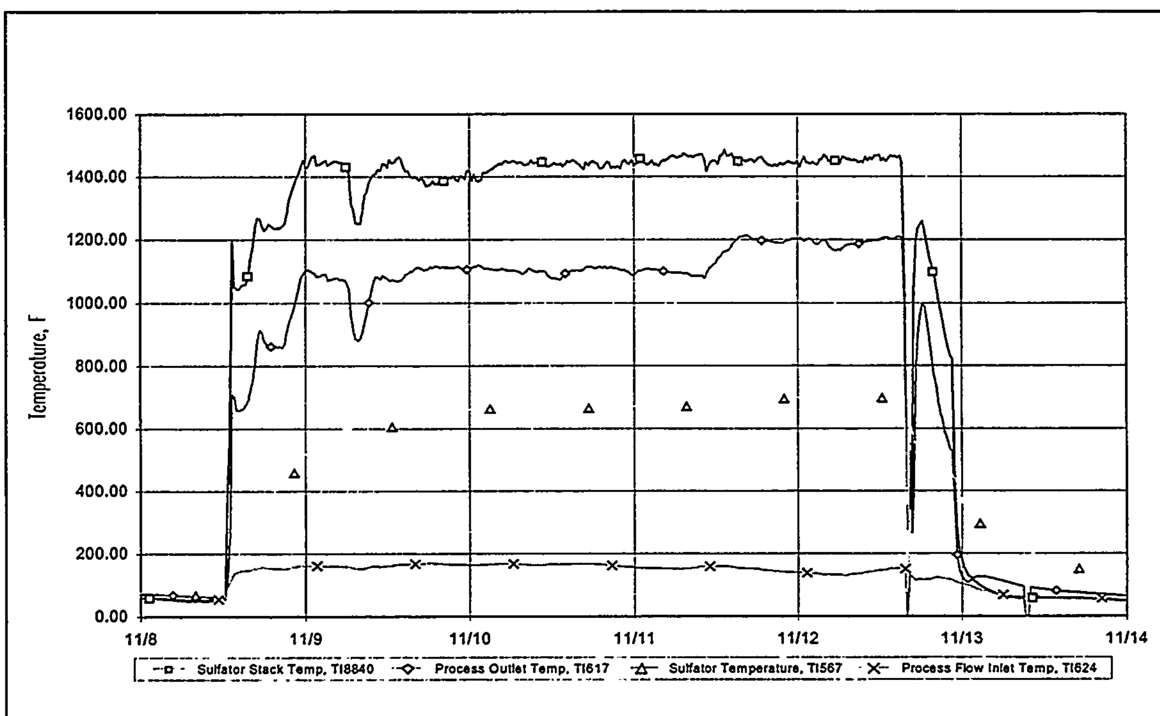


Figure 8.8.4-4 Sulfator Performance Test November 8 to 14, 1996

8.8.5 Other General Problems

When the propane pressure in the structure piping going to the transport reactor start-up burner (BR0201) was increased from the design of 110 to 175 psig, the propane supply pressure to BR0602 increased. Therefore, a new pressure regulator was installed in the piping branch going to BR0602 and set to the design of 85 psig. However, this created a problem with the DCS flow calculation. The flow calculation block was using the pressure indication from PI622 which is located on the Kellogg structure propane header and before the newly installed regulator. As a result, when the propane header pressure was above 85 psig the calculation was in error. The DCS calculation block was changed to use the PI622 input when the Kellogg structure header pressure is less than 85 psig. When the header pressure is above 85 psig, the flow calculation block uses a set 85 psig input.

The flame scanner was tested and worked without any problems during the first few months of operation. However, later in the year the scanner had to be removed and cleaned. The eye of the scanner points up toward the flame which allows debris from the heater to settle on the eye.

8.9 BAGHOUSE, BAGHOUSE ASH REMOVAL, AND MWK ASH STORAGE SYSTEM

8.9.1 Baghouse Commissioning Report

8.9.1.1 Description

The purpose of the final hot gas clean-up system is to filter process gas at the back end of the MWK process. The system primarily serves as a back-up filter system for the PCD systems in case of a failure. The system also provides some additional cooling of the gas before it enters the stack and discharges to the atmosphere. The system consists of three main pieces of equipment: dilution air fan, atmospheric baghouse, and screw conveyor. Process gas from the thermal oxidizer is cooled by the dilution air fan to a temperature which is acceptable for the bags in the baghouse. If, for some reason, the gas is still too hot prior to entering the baghouse, there are two opposite action dampers in parallel just upstream of the baghouse which cause the gas to bypass the baghouse and flow directly to the stack. The bypass dampers are also activated by excessive ΔP across the baghouse. The baghouse (which houses 704 cloth filter bags supported by metal cages) filters the process gas stream. The bags are cleaned using pulse jet valves which deliver compressed cleaning air to a series of plenums. Each plenum traverses the width of the baghouse above a row of bags and cleans the bags in the row simultaneously as the pulse sequence reaches its row. Any resulting solids removed from the gas are conveyed by the screw conveyor (which is attached to the baghouse collection trough along the entire underside length of the baghouse) to a pneumatic pump at one end of the baghouse. From here the solids are pneumatically conveyed to the MWK ash silo.

8.9.1.2 Commissioning Activities

The final hot gas clean-up system (baghouse) was completed by construction and turned over to operations in the early part of the second quarter 1996. Until June 1996 the system operated periodically in bypass mode to provide a flow path for the thermal oxidizer commissioning activities. In early June a technical representative from Fuller-Kovako, the supplier of the majority of the components for the system, was on-site to provide guidance and advice for start-up. The plant, however, was not yet ready for start-up activities, so the dust collecting bags had not been installed in the baghouse.

A Fuller-Kovako representative performed a preoperation inspection of the system. This inspection included blowing down the compressed air supply piping, energizing the pulse cleaning timer board, sequencing the pulse cleaning valves, bumping the screw conveyor for rotation, and performing a general inspection of the installation of the equipment. No significant problems were discovered during the vendor visit. Some of the compression fittings between the pulse tubes and the compressed air header were found to be leaking, so the insulation around the fittings was removed and they were tightened further. While pressurizing the compressed air header during the vendor visit, a sizable leak was discovered which was later eliminated by rewelding the area. However, after eliminating this large leak, it was discovered that almost every vertical connecting pipe emerging from the compressed air header was leaking from the threads. Correction of this problem was more involved than the previous ones because it required removal of the compression fittings and pulse tubes in order to tighten these threaded pipes by no less than one revolution each for alignment purposes.

During the time before commissioning activities were to begin, the PSDF technical lead examined the system control schemes in order to prepare a functional checklist for a precommissioning check. It was discovered that the existing control logic was inadequate for automation and equipment protection purposes. All equipment was independently and manually controlled and no allowances were made for equipment interactions or system interdependence. Control logic was written and incorporated into the plant DCS to address these issues. After these control issues and the aforementioned mechanical issues were resolved, the system was ready for final commissioning activities.

The functional checks of the system were also performed in June 1996 during a thermal oxidizer outage period. The system responded to logic simulations of process conditions, and timer values for pulse cleaning and screw conveyor operation were monitored and adjusted. All alarm responses were checked and responded appropriately. The system performed as designed and was ready for preconditioning and on-line service. The preconditioning involved introducing a coating material (fine alumina) through the dilution air fan and into the inlet gas stream to provide a preliminary solids coating for better filtration effectiveness. The screw conveyor was run to remove the coating alumina that had fallen from the bags. On July 10, 1996, a baghouse leak check was performed using a fluorescent powder which was blown into the baghouse through the dilution air fan. Only 1 of the 704 bags leaked and it was quickly reinstalled to prevent further leaks. Four welds on the top of the tubesheet showed slight leaks and a few slight leaks were also identified in the blow tubes. None of these leaks required repair, but a reinspection to determine whether or not the leaks have grown is recommended. After this leak test was performed and satisfactory results were produced, the system was considered commissioned and ready for MWK operation.

8.9.1.3 MWK Operation

The baghouse was fully operational for the MWK coal characterization test runs which began in July 1996. The most important operating parameter for monitoring baghouse performance is the differential pressure (ΔP) across the bags. A steady rise in ΔP indicates collection of solids in the baghouse and, more importantly, indicates a problem upstream of the baghouse since under normal operating conditions there should not be any significant accumulation of solids in the baghouse. The control logic for the system initiates a pulse cleaning sequence at a certain ΔP value, which is set in the DCS. This ΔP trigger was maintained at 6 inWG throughout the test runs.

The ΔP plots for CCT1A and CCT1B (figures 8.9.1-1 and -2) show definite and steady rises in ΔP and are good indications of MWK operating conditions. During these runs, the MWK transport reactor feed systems were venting to a point in the process gas stream that was downstream of the PCD. This was causing solids to be entrained in the "clean" gas stream and ultimate accumulate in the baghouse. Another cause of the rises in ΔP was the accumulation of alumina which had remained in the MWK system downstream of the PCD from commissioning activities prior to CCT1A. As can be seen from figures 8.9.1- 3 through -6, the ΔP remained within consistent ranges for the remainder of the tests due to the correction of the feeder vent problem and the removal over time of alumina which had remained in the MWK system downstream of the PCD.

Another operating condition of note was the large degree of oscillation of the ΔP up until CCT3. Although the three pulse cleaning cycles displayed in figure 8.9.1-1 indicate the ΔP reached the trigger value of 6 inWG three times, the baseline was actually around 3 inWG and oscillation caused the pulse cleaning to commence. This gave the appearance that there were more solids in the baghouse than actually were. The oscillation was discovered to be caused by the dilution air fan. The fan inlet vanes are adjusted automatically by a temperature controller which measures the inlet temperature of the baghouse and controls the cooling function of the dilution air fan. This temperature controller was not accurately tuned and was causing the inlet vanes to oscillate within a certain temperature range. This oscillation was, in turn, causing the actual ΔP of the baghouse to oscillate as the fan was delivering pulses of air to the inlet gas stream. The temperature controller was tuned and the oscillation of the ΔP subsided which can be clearly seen by comparing figures 8.9.1-1 through -5 to figure 8.9.1-6.

Other problems experienced during the first test runs included the screw conveyor reversing action, leaking water into the baghouse at the access doors, and level probes malfunctioning in the baghouse trough. The screw conveyor was discovered to be wired backwards; which was easily corrected. The access doors were adjusted to prevent leaking, and the level probes were replaced during the outage at the end of 1996.

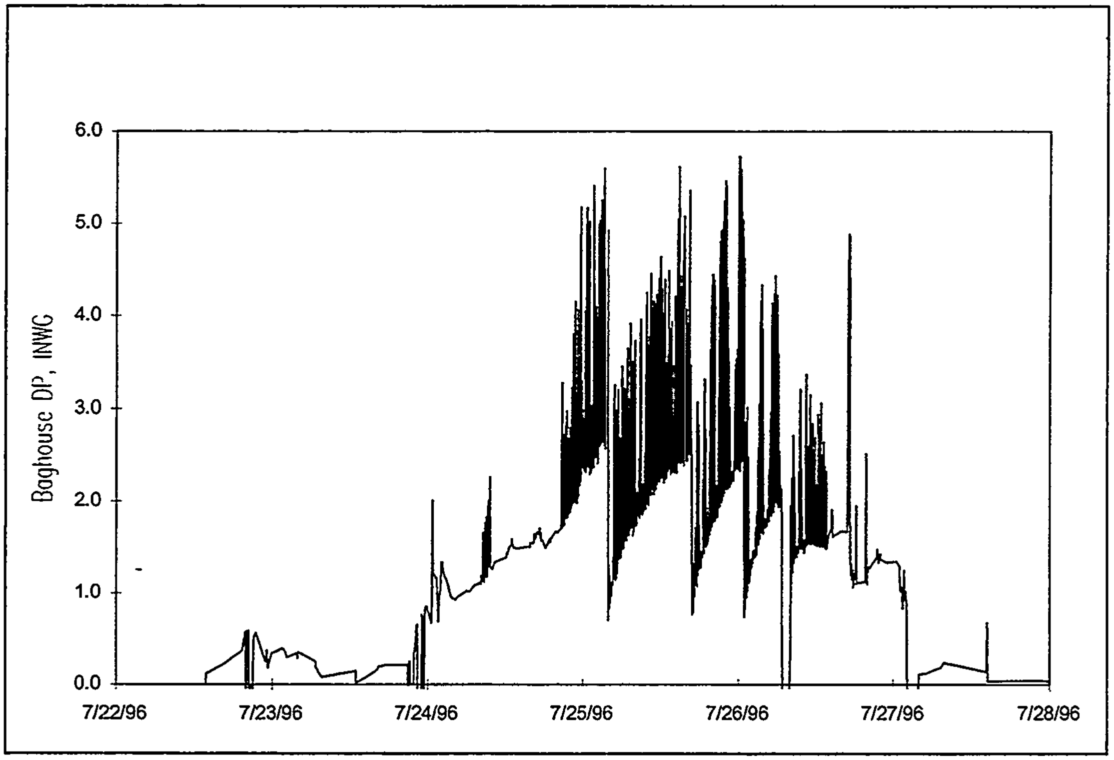


Figure 8.9.1-1 Baghouse ΔP CCT1A

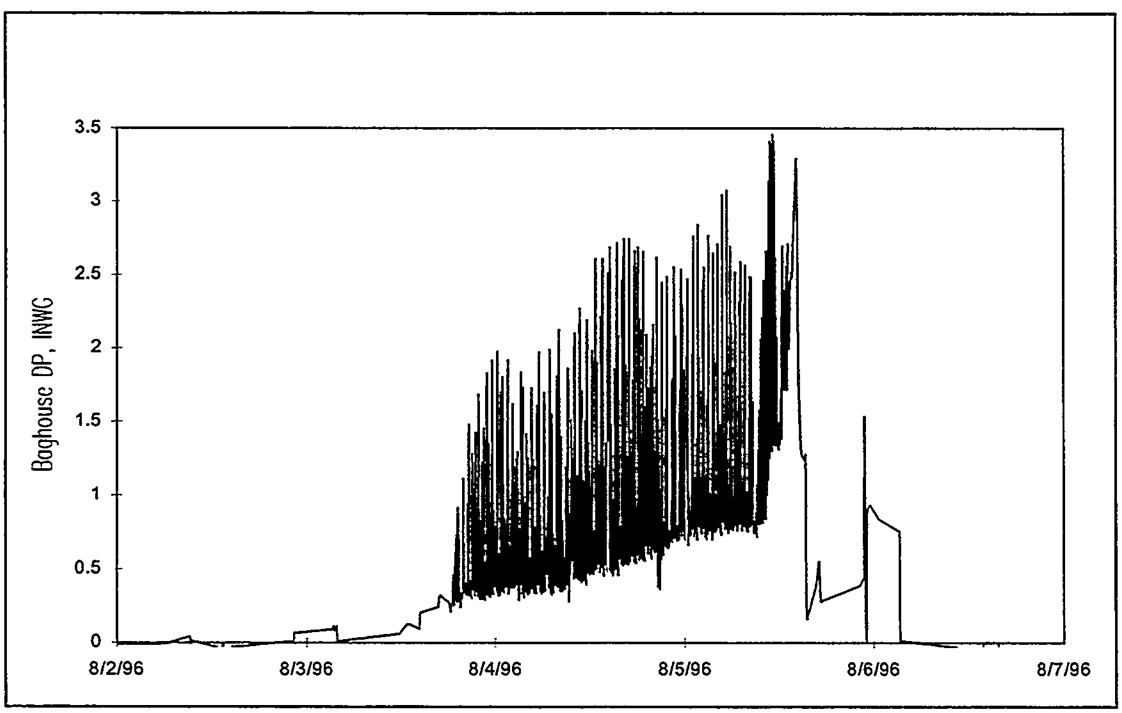


Figure 8.9.1-2 Baghouse ΔP CCT1B

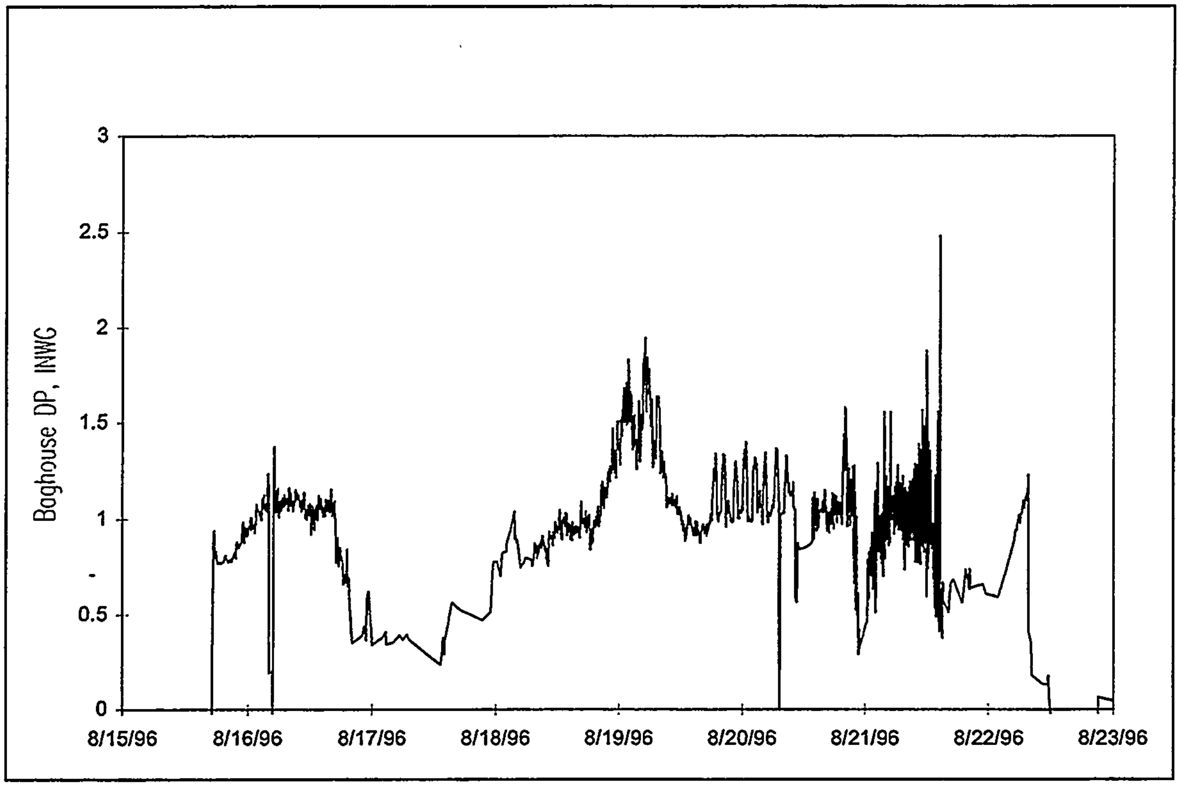


Figure 8.9.1-3 Baghouse ΔP CCT1C

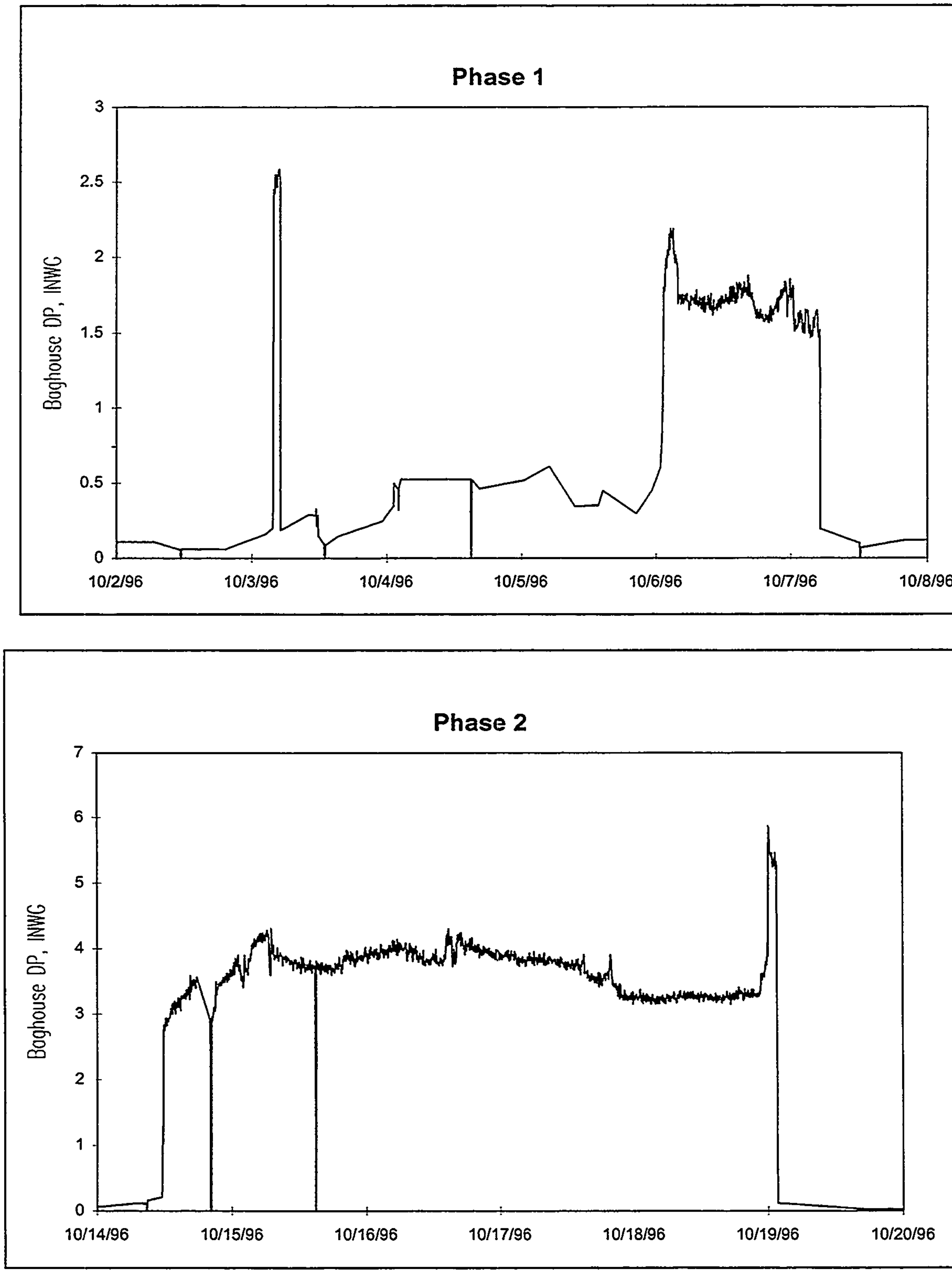


Figure 8.9.1-4 Baghouse ΔP CCT2A

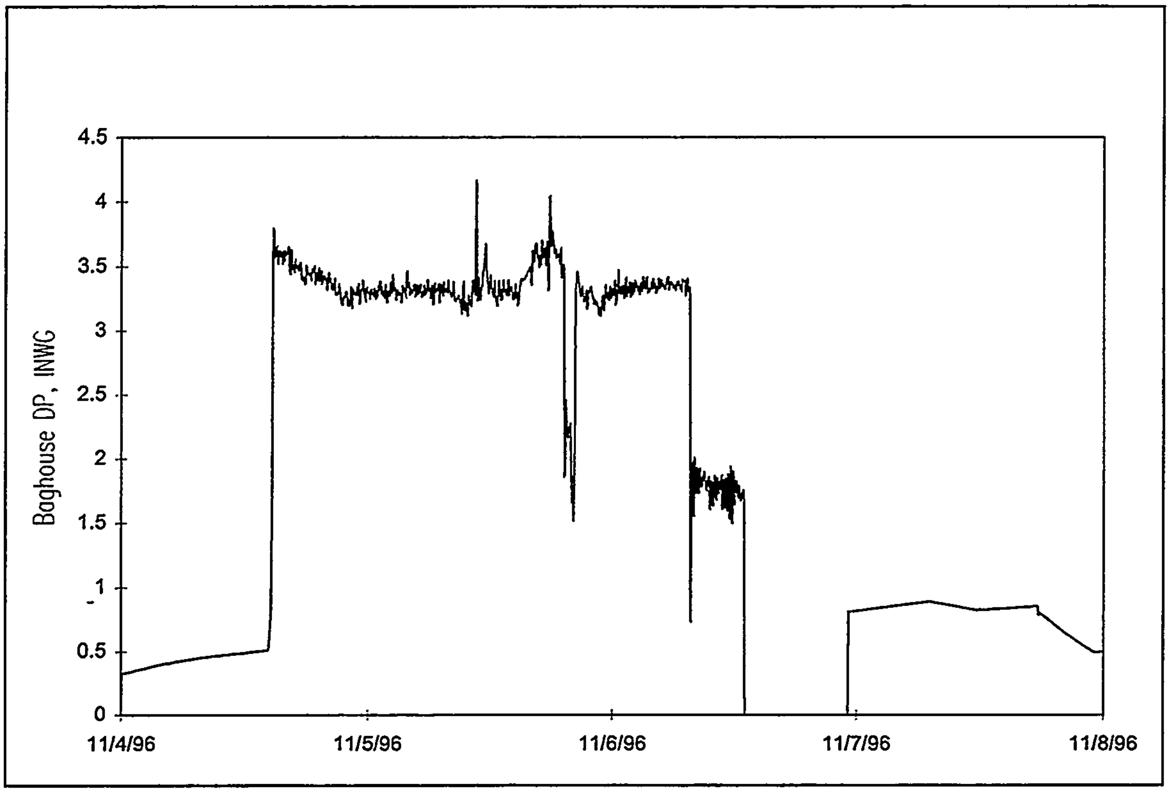


Figure 8.9.1-5 Baghouse ΔP CCT2B

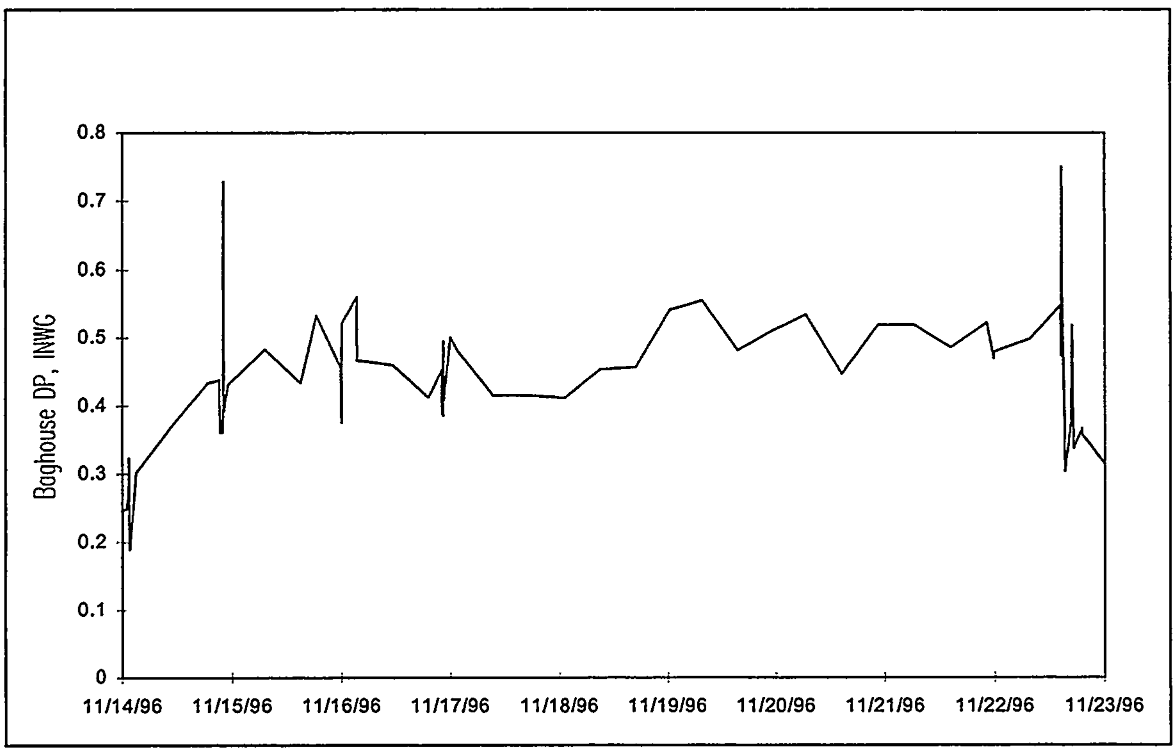


Figure 8.9.1-6 Baghouse ΔP CCT2C

8.9.2 Baghouse Ash Removal System

8.9.2.1 Description

The baghouse ash removal system (FD0820) is a Clyde Pneumatic Conveying system which conveys solids from the MWK baghouse to the MWK ash storage system during combustion and gasification modes of operation. The system consists of a 2-ft^3 surge hopper and a 4-inch inlet by 2-inch outlet dense-phase pump which pneumatically conveys the material through 2-inch NB pipework to the ash silo. The surge hopper receives material from the baghouse screw conveyor and the material falls by gravity into the pump. Conveying air then flows into the pump and blows the material to the silo. When the pressure in the pump decreases back to atmospheric pressure, the cycle ends and immediately repeats as long as there is still material in the surge hopper up to the level of the probe. If there is no material in the surge hopper up to the probe, the cycle waits for an extended amount of time before repeating.

8.9.2.2 Commissioning/Operations

Functional checks of this system were conducted in June 1996 and revealed problems with the interaction of the surge hopper level probe with the PLC control logic. After modification of the logic and the action of the probe, the system functioned as specified. However, there was additional control logic deemed necessary to prevent the baghouse screw conveyor from overfilling the surge hopper in the event the dense-phase pump could not keep up with the screw conveyor feed rate. The DCS control logic that controls the final hot gas clean-up system (baghouse, screw conveyor, etc.) was modified to incorporate the FD0820 surge hopper level probe. The modification consisted of shutting down the screw conveyor in the event that the level probe remained covered for two consecutive cycles of the dense-phase pump. The first solids conveyed by the system were alumina solids that had been used to precondition the baghouse bags in June 1996. The only problem experienced with the FD0820 system through commissioning and operation has been the occasional plugging of the surge hopper due to moisture in the baghouse solids. To date the system has completed 21,307 cycles of virtually trouble-free operation.

8.9.3 MWK Ash Storage

8.9.3.1 Description

The MWK ash storage system (SI0814) is also a Clyde Pneumatic Conveying system designed to receive ash from three different sources within the MWK process. The system consists of an approximately 3,000-ft^3 capacity storage silo which can discharge either through a 12-inch Spheri valve and retractable loading spout into a truck or bin or through an 8-inch rotary valve into a 55-gallon drum. The 12-inch Spheri valve and the retractable loading spout are controlled by a hand-held pendant located on a landing above the spout. The spout is also equipped with a capacitance probe which hangs below the end of the spout and controls a light panel also located on the landing with the pendant. When the truck or bin is full, the material touches the probe which sends a signal to the light panel telling the operator to close the Spheri valve with the pendant and stops the loading. The 8-inch rotary valve controls the flow of material to a 55-gallon sampling drum. The sampling pipe is equipped at the end with a permanent drum lid equipped with a level probe. Any 55-gallon drum can be attached to the lid and is attached or removed via an adjustable stand. When the drum becomes full during operation of the rotary valve, the level probe automatically shuts the valve down and prevents overfilling of the drum. The main silo is equipped with high and low level probes, the high level probe being used by the systems feeding the silo as a permissive to feed and the low level probe being used for indication purposes only. The silo is also equipped with temperature probes located in the top, the discharge cone, and the discharge chute sections of the silo, which have only been used for indication purposes during previous operation. These temperature probes are being considered for implementation as personnel protection during future operation by linking them through PLC control logic to the loading spout operation.

There are three separate inlet pipes connected to the silo, only two of which feed the silo at any time during operation. During combustion mode operation, ash from the FD0530 system (combined ash from the PCD and transport reactor) and ash from the FD0820 system (discussed above) feed the silo. During gasification mode operation, char from the FD0530 system must first pass through the sulfator before being fed to the silo. After the char leaves the sulfator, it is conveyed to the silo by the FD0810 system. The FD0820 system also feeds the silo in gasification mode.

8.9.3.2 Commissioning/Operations

The MWK ash storage system has been in frequent operation since June 1996 when functional checks were completed and solids were first conveyed to it from the baghouse. Its functions have been numerous and have ranged from a storage system to a sampling point. Prior to first operation, functional checks of the system were virtually problem-free with only some minor PLC control logic changes necessary for the system to function as specified. The first material conveyed to the system in June was alumina that had been used to precondition the bags in the MWK baghouse. The material was successfully collected and removed from the silo via the unloading spout. No significant operational problems have been experienced with the system through the end of 1996.

8.10 HEAT TRANSFER FLUID SYSTEM

8.10.1 Description

The heat transfer fluid system (HTF) system is used to cool the solids that are removed from the transport reactor standpipe, the sulfator, and the fines from the particulate collection devices (PCDs). The fluid is circulated through both the outer shell and the flights of the screw cooler in all three applications. The fluid used is UCON-500 which is a mixture of polyalkylene glycols from Union Carbide. The fluid is pumped from a storage tank to a surge drum at the 183-foot elevation. The storage drum operates under a nitrogen blanket at a pressure of about 50 psig. The surge drum provides about 5 minutes of fluid capacity if fluid flow to the drum is lost. From the surge drum, the fluid flows by gravity to the three screw coolers and into a return header. The fluid flows through an air-cooled heat exchanger before being returned to the storage tank. The temperature of the fluid is maintained at 210°F by diverting a portion of the flow around the exchanger. If the fluid temperature drops below 210°F, electric heaters in the tank activate to maintain set point. A total flow of about 120 gpm is provided to the screw coolers.

8.10.2 Commissioning/Operations

The HTF system was successfully commissioned during the first quarter of 1996. After loop checks and functional checks of the instrumentation and control loops, the system was filled with water. Strainers were installed in several locations and the water was circulated to flush out the piping. The electric heaters in the storage tank were also tested with water in the tank. After flushing, the water was drained and the system was refilled with HTF, leaving the strainers in place. Following the manufactures procedure, the HTF fluid was heated to about 250°F to remove water from the fluid. The fluid was circulated for several days with the strainers in place to remove any particulates left from the water flush.

During the commissioning tests, it was discovered that the three-way control valve that diverts fluid flow around the air-cooled heat exchanger was installed incorrectly and had to be repaired. Other modifications to the HTF system were made during commissioning and start-up. A line was added to the pump discharge to recirculate fluid to the storage drum in case the control valve to the surge drum was closed. An orifice, sized to allow the minimum flow to pass at the pump's discharge pressure, was installed to prevent the pump from deadheading. A drain line to the storage tank was installed at the low point in the HTF supply header. Vents were added to allow air to be vented from parts of the system. A sight glass was added to the storage tank. Lastly, a valve was added to the nitrogen line to the surge drum to allow the drum to maintain a nitrogen blanket during an outage.

With the above modifications, the HTF system has performed well during normal operation.

8.11 MEDIUM- AND LOW-PRESSURE NITROGEN SYSTEM

8.11.1 Description

The medium- and low-pressure nitrogen system comprises the nitrogen generation, liquid nitrogen storage facilities (BOC Group, Inc., owned and operated), and the SCS balance-of-plant distribution piping.

The nitrogen generation plant is a cryogenic air separation plant that generates 8,095 lb/hr of gaseous nitrogen. The liquid nitrogen storage facility holds 60,000 lb of nitrogen at 150 psig and 120,000 lb of liquid nitrogen at 450 psig.

The liquid storage facility serves as a backup to the nitrogen generation plant, provides additional nitrogen during peak demand periods, and supplies nitrogen when the nitrogen generation plant is shut down. Additionally, the liquid storage facility supplies the nitrogen required for the emergency shutdown of the M. W. Kellogg and the Foster Wheeler processes.

BOC provides gaseous nitrogen at 30, 150, and 450 psig to the various PSDF consumption points.

8.11.2 Commissioning/Operating Experience

The nitrogen generation plant and liquid nitrogen storage facility were commissioned by BOC. Numerous problems plagued the liquid nitrogen storage facility throughout the year; however, the facility was always online when required. The nitrogen generation plant operated with very few problems.

The medium pressure liquid nitrogen is stored in the insulated tanks at 300°F. Heat transferred into the storage tanks raises the temperature and boils off some nitrogen, thereby increasing the pressure. This pressure build must be bled by venting gaseous nitrogen and is termed heat release. BOC experienced many problems with their instrumentation and valve setup for this. The pressure switches and vent solenoid valves failed numerous times and the vaporizer pressure relief valves started to lift repeatedly. BOC plans to replace the vent solenoid valves in early 1997.

On one occasion when one of the vent solenoids valves failed, the pressure climbed in the tanks and one of the vaporizer pressure relief valves began to chatter. The pipe nipple holding the relief valve broke and nitrogen was lost to the atmosphere. The pressure relief valves on the medium pressure vaporizers were braced to prevent a reoccurrence.

Normally, the heat release consumes 0.5 to 1.0 percent of the tank volume per day when medium pressure nitrogen is not being consumed by any of the PSDF processes.

8.12 PROPANE SYSTEM

8.12.1 Description

The propane system consists of a truck unloading station, three liquid propane tanks (30,000 gallons each), a liquid propane pump, a propane vaporizer, condensate cooler, condensate return system, and the assorted instrumentation, piping and valves required to operate the system.

The propane system supplies low and high pressure propane. The low pressure propane is drawn from the vapor space in the storage tanks and regulated to 40 psig. The high pressure propane is pumped up to pressure as a liquid and fed to a vaporizer before distribution to the various consumption points. The high pressure propane system pressure can be regulated from tank pressure up to 235 psig. The tank pressure is nominally between 85 and 130 psig.

The original design specified low pressure propane be delivered to the auxiliary boiler to generate the steam required for vaporizing the high pressure propane liquid. However, the auxiliary boiler installation was postponed until late 1996. Since the auxiliary boiler was not available, low pressure propane piping was plumbed to the thermal oxidizer, and the thermal oxidizer was used to generate the steam for the vaporizer.

Piping was installed to provide low pressure propane to the feedstock preparation structure to allow the processing of coal when the thermal oxidizer was not operating.

8.12.2 Commissioning/Operations

The propane system vendor (Energistics, Inc.) commissioned the propane pump, pressure regulator, and vaporizer. When the propane pump was stopped, it was noted the pump spun backwards and the pump seals leaked. The propane system vendor replaced the pump seals and installed a check valve to prevent propane back-flow through the pump. No other problems were observed during the commissioning phase. Commissioning was completed by May 14, 1996.

8.12.3 Performance During Normal Operations

During operations in 1996, the propane vaporizer throughput was always less than two percent of design. The vaporizer manufacturer was surprised the vaporizer worked at all at such low throughput. Many difficulties with the propane flow to the start-up burner and the sulfator start-up heater were experienced. Some of these problems were a result of trash in the piping, condensation problems, and possibly the low propane vaporizer throughput. The thermally actuated steam flow control valve on the vaporizer was not believed to be operating correctly which may have partly been a result of the vaporizer size compared to propane throughput. A hand-actuated globe valve was installed to bypass the steam flow control valve and provide constant steam flow.

The pressure relief valve on the propane vaporizer had to be replaced because it was leaking through at 178 psig.

8.13 SERVICE AND INSTRUMENT AIR SYSTEM

8.13.1 Description

The service and instrument air system is designed to supply clean, oil-free, low-moisture (-40°F dewpoint) compressed air at approximately 100 psig to the consumption points throughout the PSDF. Due to the low amount of service air requirements, the service and the instrument air are supplied from the same system. The system consists of four Atlas Copco water-cooled air compressors rated at 600 scfm and one Sullair air-cooled compressor rated at 300 scfm. Each air compressor train consists of an aftercooler, a prefilter, a desiccant air dryer, an after filter, and a receiver tank. The five receiver tanks are tied to a common 3-inch header where the air is distributed to the plant. Two of the five compressors are tied to the emergency backup power supply.

The four Atlas Copco air compressors are controlled by a compressor controller sequencer. The compressor sequencer controller is a pressure band controller which regulates the system pressure within programmable limits by starting, loading, unloading, and stopping the compressors in accordance with a fixed sequence. The programmable limits set at the PSDF are 98 and 105 psig.

The air dryers are designed to work even when the power is turned off. The dryers fail to a fail-safe feature that allows the desiccant to continue to absorb moisture even with the power off. This feature allows the dryer to continue to operate as problems are being resolved. However, when the desiccant is saturated, the moisture will be carried over.

8.13.2 Commissioning/Operations

The four Atlas Copco compressors and the five Pneumatic Product air dryers were fully commissioned by the sellers service technicians. The Sullair air compressor was commissioned by PSDF operations in 1995. The service and instrument air system was fully operational by May 1996 and has operated without any significant problems.

One of the drain valves for the instrument air dryers failed because water from the inlet side of the instrument air dryer damaged a seal in the drain valve pilot. To remedy the problem, the air source for the pilot line was changed from the inlet side of the dryer to the outlet side on all five instrument air dryers. Filters were also installed to keep the dryer desiccant from plugging the pilot air line, valve, or orifice.

One of the solenoid valves in dryer DY2201B failed resulting in a valve malfunction warning indication and the shutdown of the dryer. The solenoid possibly got water in it sometime before the dryer was set or before the roof was placed over the instrument air pad. The service technician was able to get the solenoid operating again by manually forcing the actuation of the solenoid.

The Hydromatics service technician recommended a guard be installed over the air compressor intakes. Without the guard, the air compressor's housing could collapse if the air inlets were accidentally covered.

Preventive maintenance was performed on the air compressors in December 1996. Only a few minor problems (small oil leaks) were found and fixed.

8.14 CLOSED-LOOP COOLING, CIRCULATING, AND SERVICE WATER SYSTEMS

8.14.1 MWK Closed-Loop Cooling Water System

8.14.1.1 Description

In the MWK closed-loop cooling water system, two centrifugal pumps (one available as a spare) are designed to deliver 580 gpm of demineralized water at 115 feet of head-to-process equipment in the MWK train. The cooling water is supplied at a maximum temperature of 92°F and at a pressure of 85 psig. After returning from the MWK system, the water is cooled by exchanging heat with the circulating water system in a plate-and-frame heat exchanger. The demineralized water pumps provide initial fill for the system. Make-up during operation is provided by the MWK steam and condensate system. A head tank located at the 202-foot level of the structure provides a constant head on the pump suction. A corrosion inhibitor is fed into the system via a pot feeder.

8.14.1.2 Commissioning/Operations

The MWK cooling water pumps were installed and tested in March 1996 and the MWK closed-loop piping was flushed in April. Strainers were installed at several points and the system was flushed with demineralized water and drained several times. The only major problem was an inadequate supply of cooling water for the steam drum sample cooler. There was not enough head available at the cooler to supply water at the needed flow rate and then into the return header as designed. After the cleaning of all applicable lines failed to fix the problem, the water exiting the cooler was diverted to the drain. Both of the pumps were initially on the same MCC. This has been changed and several vents were also modified to allow them to be operated from the ground.

8.14.2 SCS Closed-Loop Cooling Water System

8.14.2.1 Description

In the SCS closed-loop cooling water system, two centrifugal pumps (one available as a spare) are designed to deliver 1,100 gpm of demineralized water at 170 feet of head to process equipment in the balance-of-plant area. The cooling water is supplied at a maximum temperature of 92°F and at a pressure of 90 psig. After returning from the BOP equipment, the water is cooled by exchanging heat with the circulating water system in a plate-and-frame heat exchanger. Initial fill for the system is provided by the demineralized water pumps and makeup during operation is provided by a booster pump connected to the MWK steam and condensate tank. A head tank located at the 173-foot level of the ash structure provides a constant head on the pump suction. A corrosion inhibitor is fed into the system via a pot feeder.

8.14.2.2 Commissioning/Operations

The SCS closed-loop system was commissioned in March 1996. Strainers were placed in the piping at several points and the system was flushed and drained with demineralized water multiple times. At first, excessive flow through the heat exchanger caused a larger pressure drop than design. This caused the pump suction to lose pressure. The problem was fixed by restricting the flow of water from the supply header to the return header in the feedstock preparation structure. Some of the air vents on the system piping were modified to allow them to be opened and closed from the ground. The original flowmeter location was changed and a second flowmeter was added to allow the water flows to the utility island and to the feedstock preparation structure to be measured separately.

8.14.3 Circulating Water System

8.14.3.1 Description

The circulating water system provides cooling water at a maximum temperature of 90°F and at a pressure of 55 to 60 psig to the MWK, SCS, and FW closed-loop cooling systems and to the MWK steam and condensate system and the FW condenser. There are four centrifugal pumps delivering 3,400 gpm each at 120 feet of head. The number of pumps in operation at any one time depends on the number of systems demanding cooling water. If both the FW and MWK trains are in operation, three pumps operate with one pump remaining as a spare. The cooling tower is a modular fiberglass design with six cells and a common basin. Each cell has two fans, each with a single-speed motor. Makeup is to the common basin. If the basin level drops below the operating level of 22 inches, a float valve opens allowing service water to gravity flow into the system from the raw water tank. If the level continues to fall, a makeup pump activates at 14 inches and a second pump activates at a level of 10 inches. Cooling tower blowdown is to an unnamed tributary of Yellow Leaf Creek.

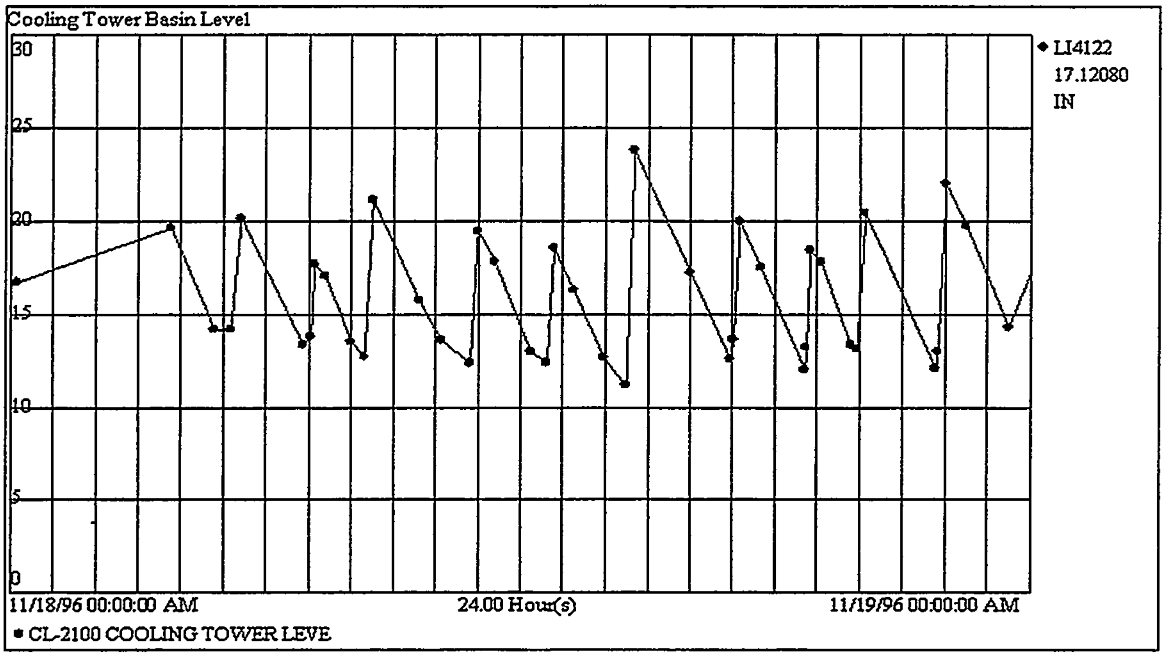
8.14.3.2 Commissioning/Operations

The circulating water system was tested, the pumps operated, and the three loops flushed in March 1996. Strainers were installed in several locations and the system was flushed with filtered river water. Initial vibration monitoring of the cooling tower fans indicated the fans had high vibrations. It was later determined that excessive vibration of the cooling tower fans was due to insufficient lateral supports. This problem was fixed by replacing the fiberglass fan supports with steel supports. The cooling towers have been operated as needed for support of commissioning and start-up activities under partial load conditions with no more than 8 (of 12 total) fans operated at any time except for vibration testing.

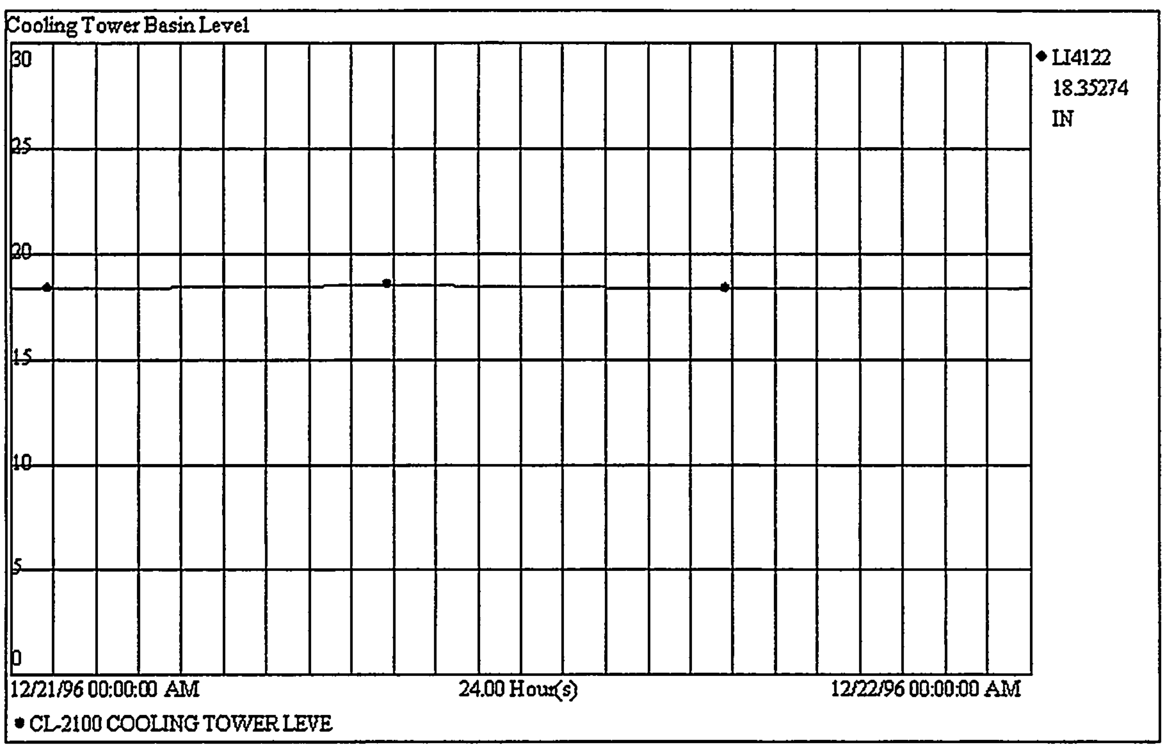
Continuous problems were experienced from the float valve on the makeup line. The turbulence in the basin loosens the float resulting in the water flow continuing to the tower when the proper operating level has already been reached. A larger float was attached and baffles were installed around the float to isolate it from much of the turbulence. Performance has improved since these modifications. (See figure 8.14.3-1.)

A few modifications were made to the system during construction. For winter operation, thermometers were installed in the drainage sump from each cell to check for ice formation within the cell. An 8-inch bypass line was also installed so the towers could be completely bypassed when operating under low load during freezing conditions. Vents were added to the pump suction header. Pressure gauges were added to the return lines to the tower to check the pressure drop across the loops. The blowdown flow meter and manual control valve were moved to a location adjacent to the wastewater treatment basin. The original location was too close to two elbows. The valve was also changed from a gate valve to a globe valve.

There have been three instances of the underground circulating water lines rupturing. In each case the break occurred at a slip joint where the lines reemerge from underground. In the first instance, a butterfly valve that controls the flow of water to one of the cooling water loops opened too quickly causing a water hammer. In the second case, a pump was started with one of the butterfly valves already open causing a water hammer. (Normal procedures call for starting pumps with only the recirculation line open.) In the third case, the pressure control valve for the steam drum was rapidly opened when trying to make a change in operating conditions. This allowed a surge in steam flow to the MWK steam and condensate system. The circulating water flow to the heat exchanger was also being greatly restricted by closing a 12-inch gate valve in the discharge line from the condenser and only letting water flow through a 2-inch bypass line. The steam flashed the circulating water causing damage to the piping before the relief valve lifted. As a result of each of these ruptures, the affected lines have had a cement thrust plate installed around the lower section of piping and the connection bolted together.



24-Hour Period Before Repairs



24-Hour Period After Repairs

Figure 8.14.3-1 Change in Behavior of Float Valve After Adding Larger Float and Installing Baffles. Graphs Show the Water Level in the Common Basin.

8.14.4 Service Water System

8.14.4.1 Description

The service water system provides water to the utility stations, the flare seal drum and makeup to the cooling tower. There are two service water pumps (one as a spare) that pump 350 gpm at 300 feet of head. The service water header is maintained at a pressure of 145 psig which is different from the design pressure of 100 psig. The cooling tower makeup pumps are sized for 350 gpm at 30 feet of head. The service water tank is maintained at a level of 30 to 35 feet, with feed coming from two raw water pumps located at the river intake structure of neighboring Plant Gaston on Yellow Leaf Creek. Each vertical raw water pump can deliver 350 gpm at 225 feet of head. The water is filtered before being sent to the storage tank. One pump is started when the tank level drops below 30 feet. A second pump is started if the level drops below 25 feet. The raw water pumps also supply the fire protection tank which take precedence over the service water when both require makeup water.

8.14.4.2 Commissioning/Operations

Raw water system pumps were first tested in early November 1995 in preparation for the MWK steam/condensate system chemical cleaning. It was necessary to extend the suction side piping of the vertical raw water pumps to ensure that the foot valve would be submerged when the river level was at its lowest normal conditions. The raw water pumps and strainers were tested again in December. At that time, the timer for the raw water filter back-flush was set and the pressure control valve in the raw water recirculation line was set. The discharge of the back-flush piping was also moved from the intake to the Gaston intake screen trough. The raw water system flush was completed in late January 1996. In March the automatic operation of the pumps and valves was demonstrated; at which point the raw water system was declared operational. During the checkout of the service water system, the level switches for the flare seal drum were also checked and the level control valve for the flare seal drum was adjusted to provide a minimum flow of water through the drum.

In testing the cooling tower makeup pumps, one of the pumps was found to have abnormally high vibration and temperature readings. Upon inspection, it was found the inboard bearing seal had leaked and allowed rainwater through the seal. The manufacturer replaced the motor. The cooling tower pumps were designed to shut off based on high pressure when the float valve closed off the makeup line. However, the flat pump curve of the makeup pumps produced a situation where a suitable setpoint for the pressure switch could not be found because of the level variation in the raw water tank. The high pressure switch was replaced with a low pressure switch.

8.15 WASTE WATER TREATMENT/CHEMICAL INJECTION

8.15.1 Description

The chemical injection system uses a combination of pumps and pot feeders for chemical injection to maintain the quality of the water in the plant. In the circulating water system, sulfuric acid (for pH control) and a corrosion inhibitor are added to the common basin, and an algaecide and sodium hypochlorite (as a biocide) are added using a pot feeder. The cooling tower blowdown is dechlorinated by adding sodium bisulfite. The closed-loop cooling water systems have molybdates added (via a pot feeder) as a corrosion inhibitor. The steam and condensate system is treated with a pH controller, oxygen scavenger, and phosphate. The wastewater treatment basin uses aluminum sulfate to flocculate suspended solids and sulfuric acid and sodium hydroxide to control pH.

The wastewater from the diesel fuel storage sump, process area sump, and the coal and limestône storage area sump are collected and pumped to the wastewater treatment system. High level switches in the sumps activate the sump pumps. The wastewater treatment area consists of an oil/water separator, a rapid mix chamber, a flocculation chamber, two settling chambers, and a hold basin that discharges to an unnamed tributary of Yellow Leaf Creek. The rapid mix chamber has a 15-hp constant speed mixer and the flocculation chamber has two 3-hp variable speed mixers. The wastewater treatment area also has a storage building and pumps for the addition of chemicals into the water. The water from the various sumps is initially sent either to the oil/water separator or to the rapid mixing chamber. The water flows into each of the chambers in succession through overflow weirs or through valves.

8.15.2 Commissioning/Operations

The chemical injection systems for the steam and condensate system, the SCS closed-looped cooling water system, the MWK closed-loop cooling water system, and the circulating water system were successfully tested in April 1996. These systems were operated without any difficulty during the second and third quarters of 1996. Two minor pump problems occurred during the fourth quarter. The pump which injects trisodium phosphate at the steam drum and the pump which feeds sulfuric acid to the cooling tower failed. Both situations were resolved and spare pumps were ordered and delivered to reduce potential downtime in the future due to the possibility of a complete pump failure.

Construction of the wastewater treatment system was completed and the wastewater basin began normal operation during the third quarter of 1996. Other than a few minor pH excursions, the wastewater basin has not required chemical treatment. The basin normally maintains a pH between 6.0 and 8.5 without any caustic or acid addition. Testing has shown the suspended solid levels have been within acceptable limits without the addition of alum. The flow meter for the basin was struck by lightening on July 7 and was repaired. The pH probe in the flocculation chamber was broken and had to be replaced.

8.16 STATION SERVICE AND DIESEL GENERATOR

8.16.1 Station Service

8.16.1.1 Description

The PSDF station service supplies electric power to all the plant equipment including outlying buildings and components. The power is supplied directly from an Alabama Power 230-kV transmission line and is stepped down through a series of transformers to supply power at 4,160 V, 480 V, 208 V, and 110 V. The power is distributed through various kinds of switchgear, breakers, starters, contactors, and breaker panels.

8.16.1.2 Commissioning/Operations

This system was the first to finish commissioning and reach operational service in September and October of 1995. Testing of the components began in April 1995 with preinstallation testing of the 4,160-V and the 480-V switchgear. This testing identified several control relays that were incorrectly installed or failed. The distributed control system was energized in early May using a temporary power supply and started system testing and configuration updating at that time. Additional testing and calibration of the protective relaying and cabling continued during the installation of the switchgear that summer. The final preparations for the testing and energizing of the 4,160-V switchgear included the following: cable being pulled between switchgear and transformers, the protective relaying and cabling being tested for integrity and function, DCS configuration and operator interface screens being designed and installed, and the completion of substation installation. The 4,160-V switchgear was energized on September 17, 1995; as well as one 480-V buss, the other 480-V busses were energized by the end of the month. This progressed smoothly, with only minor problems with transmitters and relaying found that were not previously identified. Energization of various electrical systems, such as the dc battery charger, the UPS, and more of the 480-V Motor Control Centers continued in October. There was an outage in November on the permanent power substation to correct problems with the transformer oil tank and with the lightning arrestors, and missing switcher position circuit was pulled to the DCS. Since the initial testing and energization of the switchgear was completed, there was one instance were the protective relaying setpoints were set too close to the conditions of lightly loaded busses and a heavily loaded power grid; these were adjusted and the system has since continued highly reliable operation.

8.16.2 Diesel Generator

8.16.2.1 Description

Because both the MW Kellogg and the Foster Wheeler processes cannot be safely shutdown without forced circulation of solids, purging of combustible gases, and withdrawal of partially reacted char and calcium, there is a minimum requirement for operating equipment and electrical power at all times. To meet this minimum requirement and to make equipment operation more intuitive for the operators, the station service switchgear was designed to allow operation of the minimum required equipment using a minimum of energized busses. These busses can be supplied by an on-site diesel generator sized to carry the minimum load requirements. This generator was equipped with the necessary relaying to allow synchronization with an energized buss allowing testing of the auxiliary generator and also an orderly transfer if the transmission line outage has some early warning. This ability to synchronize with the power grid is useful for load sharing and to provide an extra margin if the grid is unstable due to outside load demands or failures.

8.16.2.2 Commissioning/Operations

This diesel generator was run in the last week of May 1996. This generator required much more testing than a typical auxiliary generator because of its size (almost 2,000 hp or 1.6 megawatts), and because of the extra ability to tie the generator into the power grid while the normal power feed is operating. The diesel completed all testing with capabilities at or above design. The diesel was used during a planned 2-day outage of the supply transmission line and experienced no trouble.

8.17 FLARE SYSTEM

8.17.1 Description

The flare system consists of the collection header (RV1031), the flare seal drum (DR0402), the flare tip (BR0402), and the flame front generator (BR0402-IG01). The function of the flare system is to gather and ignite any spontaneous releases of combustible gases resulting from process upsets or controlled depressurizing and purging of equipment. Propane is the fuel gas for the pilots and the enrichment gas. The flare is required only for gasification mode of operation. At the far extremity of the collection header, a small continuous flow of nitrogen is injected as a sweep gas to provide a positive pressure against air ingress into the flare stack. The flare header is connected to the flare seal drum which knocks out any particulates in the gas stream and serves as the base for the flare stack and flare tip assembly. The water in the seal drum acts as a water seal and cools the gas. The flame front generator (FFG) is the pilot ignitor system and is controlled by hardwired logic. When the FFG is in the automatic position, it will ignite pilot #1 and then automatically switch to initiate firing of pilot #2 once pilot #1 has lit. The gases that may be discharged into the flare system from the process have a very low heat value; therefore, the flare contains an enrichment system to add propane to increase the heat value of the total outlet gas flow to a minimum of 200 Btu/scf, ensuring complete combustion (40 CFR 60.18 compliance).

8.17.2 Commissioning Tests/Runs

The flare system functional checks were completed in two parts. First, the flare seal drum level control was checked in February of 1996 and second, the burner skid hardwire logic was checked in August. All checks were satisfactorily completed with the exception of one bad switch and two bad relays. Other prechecks and punchlist items were identified and are scheduled for completion in January 1997 with the final commissioning scheduled for February 1997.

9.0 SUPPORT SERVICES

9.1 DATA MANAGEMENT SYSTEMS

Two software packages have been acquired to assist with maintaining reliable records of process and laboratory data at the PSDF. Labworks, a lab information management system (LIMS) from Automated Analytical Solutions (AAS) in Baton Rouge, Louisiana, has been purchased to serve as a database for all laboratory data. OSI Software in San Leandro, California, has provided their plant information (PI) system for recording process data under an evaluation agreement for a trial period. A purchase decision will be made at the end of the trial period.

9.1.1 LIMS

9.1.1.1 Description

Labworks serves as the permanent electronic record of laboratory analysis performed both by the on-site laboratory and by the off-site laboratory that renders the balance of the analyses. Because the off-site lab also uses the product, transferring results obtained from their lab to the on-site lab and entering the data into Labworks is much simplified. When lab personnel register a new sample the software assigns that sample an ID number and provides a list of the tests to be performed on that specimen. The software helps the lab workers track the sample all the way through until the results are validated. These results are available to the engineers who also have the software installed on their workstations. Most engineers receive needed information by having the lab personnel export the data from the software to other formats that can be sent to the process engineers.

9.1.1.2 Commissioning/Operations

The software was delivered in January 1996. Initial training occurred in February 1996. Initial use of the software was hampered for several months by the lack of a version specifically written for Windows NT. Since the problems have been resolved the software has worked well.

9.1.2 PI

9.1.2.1 Description

The plant information system at the PSDF consists of four separate programs, all supplied by OSI Software. Data Archive is a Windows NT-based program residing on a server dedicated to data acquisition. An interface between the Foxboro DCS and Data Archive runs on the same Sun Solaris box as the Foxboro application workstation. Process Book and Datalink are two client applications that plant personnel use to extract data from Data Archive.

The essential part of the PI system is the Data Archive program. It receives all plant data from the DCS, compresses the data, archives the data, and serves the data to the client applications on demand. The compression routine uses an algorithm known as "swinging door compressor" to achieve a significant reduction in the space necessary to store data. On average, the system uses 2 to 4 MB of disk space per day to store all of a day's data. Once the data has been compressed and archived, it becomes available to the client applications that are used by plant engineers. With the current resources available on the PI server, about 5 years of data should be able to be kept online at any give time.

9.1.2.2 Commissioning/Operations

The server software was installed in March 1996. The Windows NT version had only been released 4 months earlier (November 1995) as PI 3.0. There were several early version updates during 1996 and numerous bugs were found in each. The software reliability gradually increased as problems were found and resolved by OSI. With the release of PI 3.1 later in 1996, the reliability issues were finally settled. Since the installation of this version, no serious problems have been encountered. The release of version 3.1 also brought about the capability to secure the PI data on a point-by-point basis.

Process Book and Datalink both use the PI application programming interface API to access the PI database from the workstations on the LAN. Process Book uses a graphical interface to show both historical and real-time data. Displays can be built which combine graphics with current process values and trends of data. Datalink is an add-in to MS Excel that allows engineers to pull PI data directly into spreadsheets for manipulation.

The spring and summer of 1996 was spent configuring data archive for MWK operations and training plant personnel in the use of Process Book and Datalink. The bulk of the MWK configuration was done from databases provided by the DCS team. The remaining points were generally configured either from data provided by process engineers who identified a needed point and by pulling the needed information for missing points directly from the DCS. A general training session was held for the process engineers in late spring to teach them how to use the client applications. Later, operations personnel were trained in small groups on the use of Process Book. Process Book has become a very valuable supplement to the DCS for operations. Process Book's powerful, easy trending functions have become crucial to plant operations.

An example of a typical, real-time PI process and data display is given in figure 9.1.2-1.

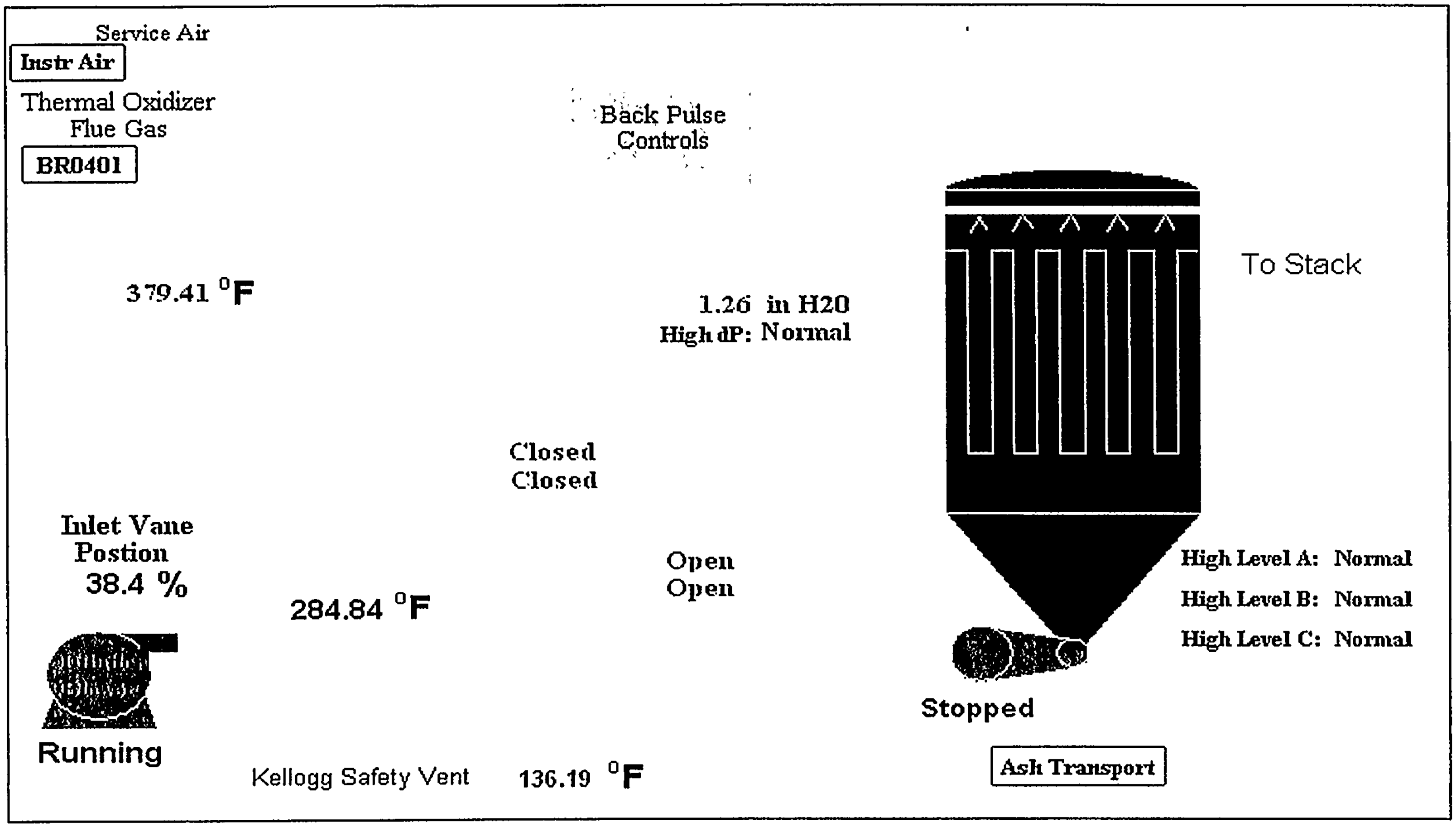


Figure 9.1.2-1 Typical PI Display

9.2 OPERATIONS AND MAINTENANCE

9.2.1 Ultrasonic Thickness Measurements

Solids are conveyed from one location to another through piping via a pneumatic transport system. As the solids are conveyed through the pipelines, erosion is a concern at the elbows or wherever a change of direction occurs. To monitor this erosion and thus prevent unnecessary shutdown due to piping component failure, thickness readings are taken (with an ultrasonic thickness gage) and trended on all change-of-direction components in each pneumatic transport system. Thickness readings cannot be taken on basalt lined elbows due to the multilayer construction, however they can be taken on all other types of components including Ni-Hard elbows and carbon steel elbows and tees. Listed below are the systems that are monitored along with the number of piping components monitored in each:

FD0104	MWK Coal Transport System	7 components
FD0140	Coke Breeze Transport System	16 components
FD0154	MWK Limestone Transport System	6 components
FD0210	Coal Feed to Reactor	4 components
FD0220	Sorbent Feed to Reactor	2 components
FD0510	Spent Solids Transport System	0 components (4 basalt lined)
FD0520	Spent Fines Transport System	1 component (4 basalt lined)
FD0530	Spent Solids Feeder System	17 components
FD0810	MWK Ash Transport System	8 components
FD0820	SCS Baghouse Ash Transport System	8 components

The actual locations on each component where thickness readings are trended are strategically selected based on the type of component (or the flow path through the component). A long radius elbow has three wear points, a short radius elbow has one wear point, a tee bend has three wear points, and some of the fabricated elbows have two wear points.

Figure 9.2.1-1 is a typical piping schematic showing how each component for a particular system is identified. Each component is assigned a unique number and then for each number the orientation of the various reading points is identified. This schematic is for system FD0210. Note in this system that readings are also taken in the piping at a location where the pipe exhibited a slight bend or kink that occurred during pipe installation. Since this is also a change of direction, the potential for wear is higher than it would be in a straight pipe section.

Thickness readings for all locations are recorded periodically. A trend plot is then created for each component. On this plot all measurements taken for that particular component are shown. Figure 9.2.1-2 shows a typical trend plot. This plot is for the pipe kinks in the FD0210 line. Readings were taken in August 1996 and then again in November 1996 after a series of coal combustion runs. As can be seen, the overall thickness reduction of this piping was very minimal and thus no maintenance was required on this section during the outage.

Monitoring these trend plots for each piping component provides a system to detect extreme erosion and thus allow replacement of the component during an outage rather than having to shutdown the entire MWK system due to component failure.

Ultrasonic thickness measurements are also periodically taken on the reactor pressure letdown valve PV287. Twice the MWK system has been shutdown due to erosion problems in this valve, and a third time the valve was replaced during a planned outage due to erosion. To prevent this from reoccurring, the valve design was changed and the anticipated high erosion regions on the valve body were identified. The erosion in these regions is monitored by taking thickness readings at 24 unique points. Any significant reduction in wall thickness will provide an early warning system for valve erosion.

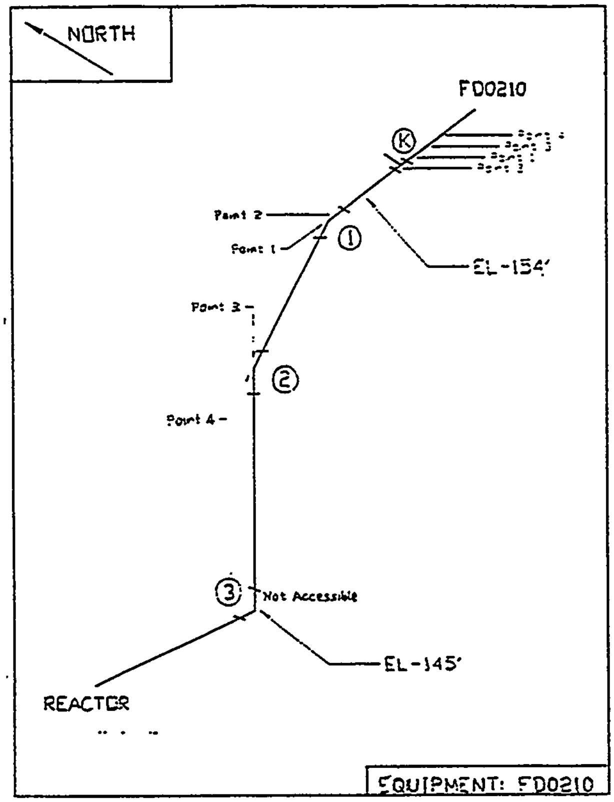


Figure 9.2.1-1 Typical Piping Schematic Showing Identified Components

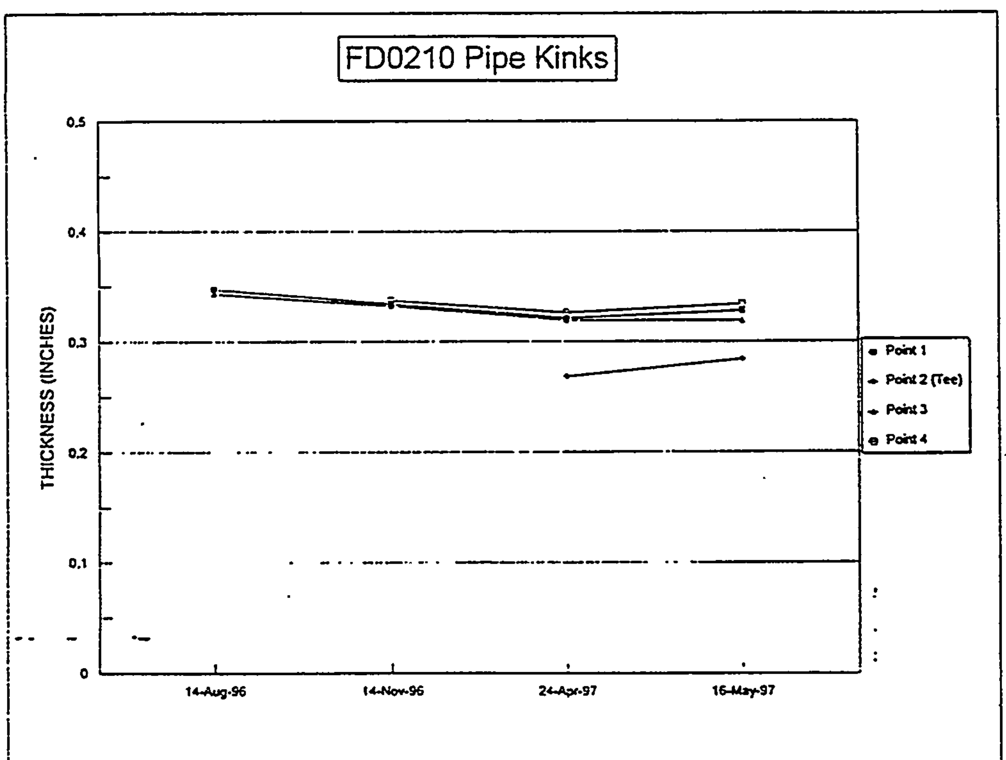


Figure 9.2.1-2 Typical Trend Plot for Pipe Kinks in the FD0210 Line

9.2.2 Vibration Monitoring

Vibration readings are periodically recorded and trended on all major pieces of rotating equipment. By monitoring the vibration and analyzing the results, such defects as misalignment, unbalance, foot/frame resonance, oil whirl, eccentric armature, loose base, bent shaft, defective bearings, etc., can be discovered and corrected before catastrophic failure occurs. Catastrophic failure would not only result in a more costly repair of the equipment, but could also necessitate shutdown of the entire MWK transport reactor system if an adequate alternate source was not available.

The list of rotating equipment that is vibration monitored includes 27 pumps, 16 fans/blowers, 8 compressors, and 2 mills. For each machine, vibration readings are recorded in the horizontal and vertical planes of each bearing housing and in the axial plane on each component (i.e., one axial for the pump and one axial for the motor). Thus for a standard pump/motor combination, 10 vibration readings are recorded. For a compressor unit with a gearbox, as many as 20 readings are recorded.

Each vibration measurement consists of a spectrum and a magnitude reading in either displacement, velocity, or acceleration units depending on the rotating speed. All of this information is recorded in a portable data collector and then down loaded to a computer software database. This database provides a historical record of the data and allows trending of the data as well as a detailed analysis of the spectrum. Pertinent information about each piece of equipment such as operating speed, number of blades, bearing types, gear sizes, etc., is also stored in the software to aid in spectrum analysis.

Figure 9.2.2-1 shows a typical spectrum. For this figure, the vibration was measured in velocity units (inches/sec) and the spectrum was recorded up to 30,000 rpm. All of the pertinent frequencies are labeled to indicate the various vibration sources. Note that the bearing frequencies include the ball pass inner and outer race frequencies (BPIR and BPOR), the ball spin frequency (BSF), and the fundamental train frequency (FTF). Thus not only can a defective bearing be discovered, but also it can be determined which component of the bearing contains the defect.

Figure 9.2.2-2 is a typical summary plot created for each piece of equipment every time a new set of data is recorded. This plot shows the vibration maximum amplitude readings for each measurement location on the equipment. If a value should significantly change from one period to the next, a detailed vibration analysis of this equipment would be performed. Figure 9.2.2-3 shows a typical plot used for the analysis. This figure includes the current spectrum, a comparison of the current spectrum with the past spectrum, and a magnitude trend plot. If a conclusion cannot be reached from this information, then further data, such as phase angle, will be measured to aid in the analysis.

Vibration readings were taken on all of the major rotating equipment during initial start-up to verify that the equipment was installed and running smoothly and also to record a baseline set of readings that will be used for future comparison. Using vibration monitoring techniques, the following problems were discovered and corrective actions taken:

- Misalignment of one of the service water pumps due to foundation settling.
- Misalignment of the main compressor motor at operating temperature.
- Inadequate support of all cooling tower fans.
- Inboard bearing defect on one of the HTF pumps.
- Misapplication of the fire protection jockey pump.
- Insufficient recirculation flow for the circulating water pumps.
- Inadequate support of the mill motors.

Discovering and correcting these problems at an early stage not only saved the cost of extensive repairs but also prevented unexpected failure of these pieces of equipment and possibly prevented a forced shutdown of the MWK transport reactor system.

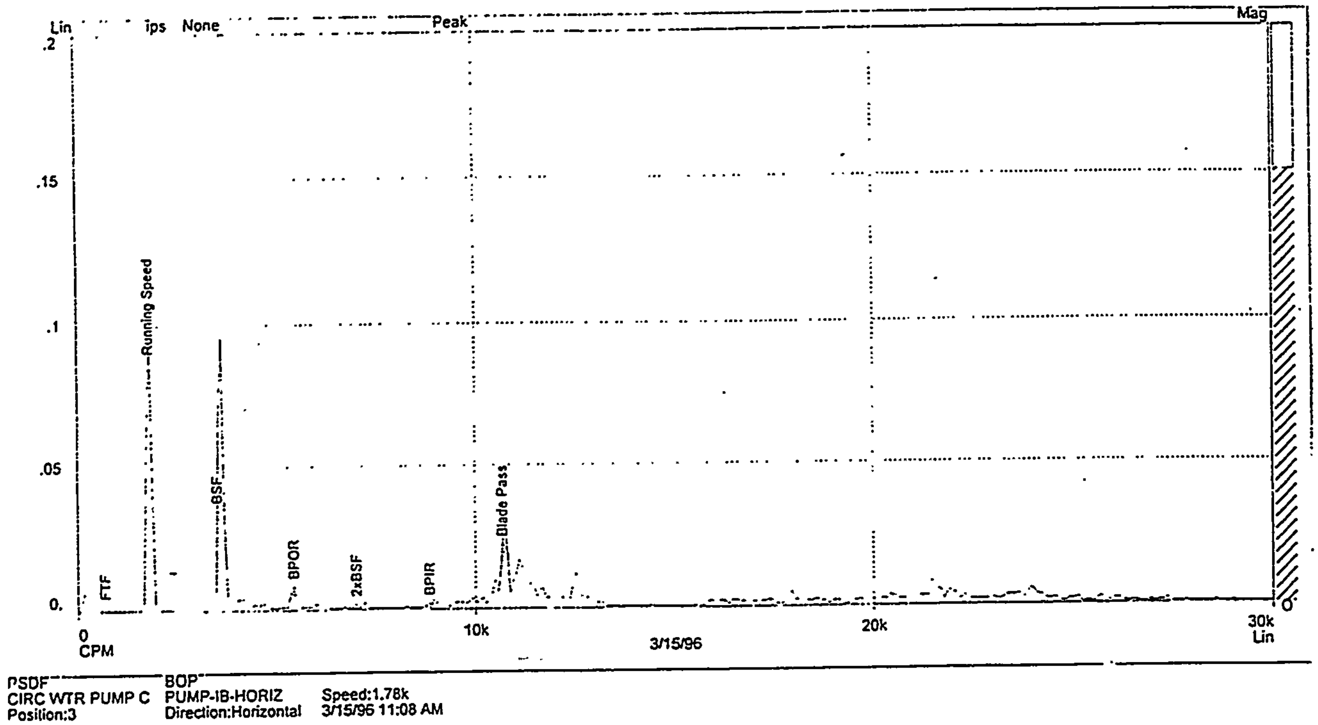


Figure 9.2.2-1 Typical Spectrum Recorded at Up to 30,000 rpm Where Vibration Was Measured In Velocity Units

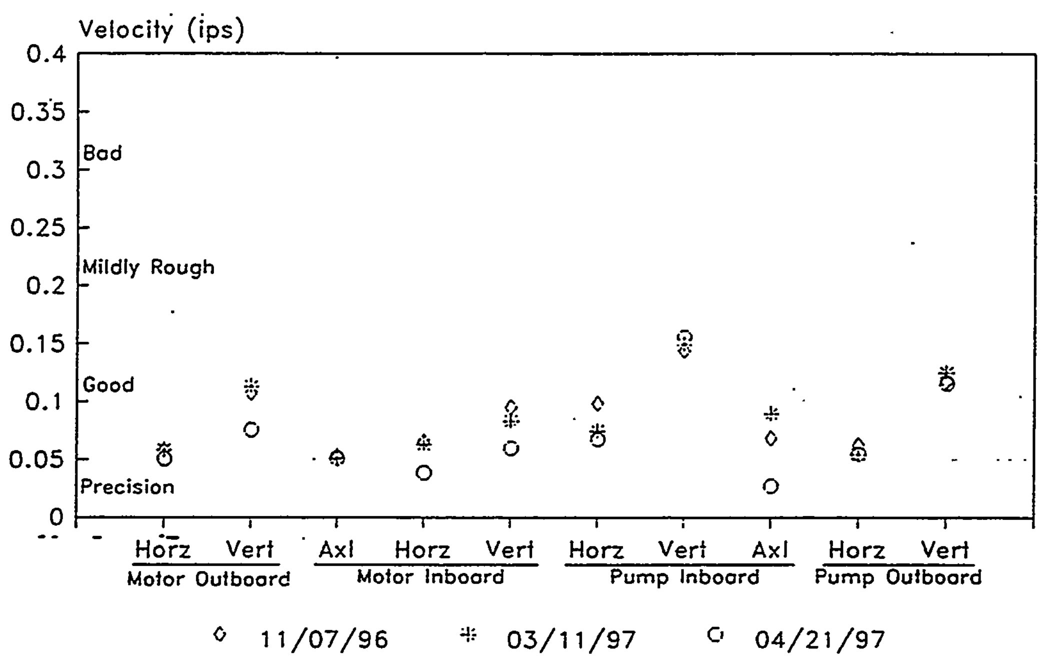


Figure 9.2.2-2 Typical Summary Plot Showing Vibration Maximum Amplitude Reading for Each Measurement Location on Fluid Pump A

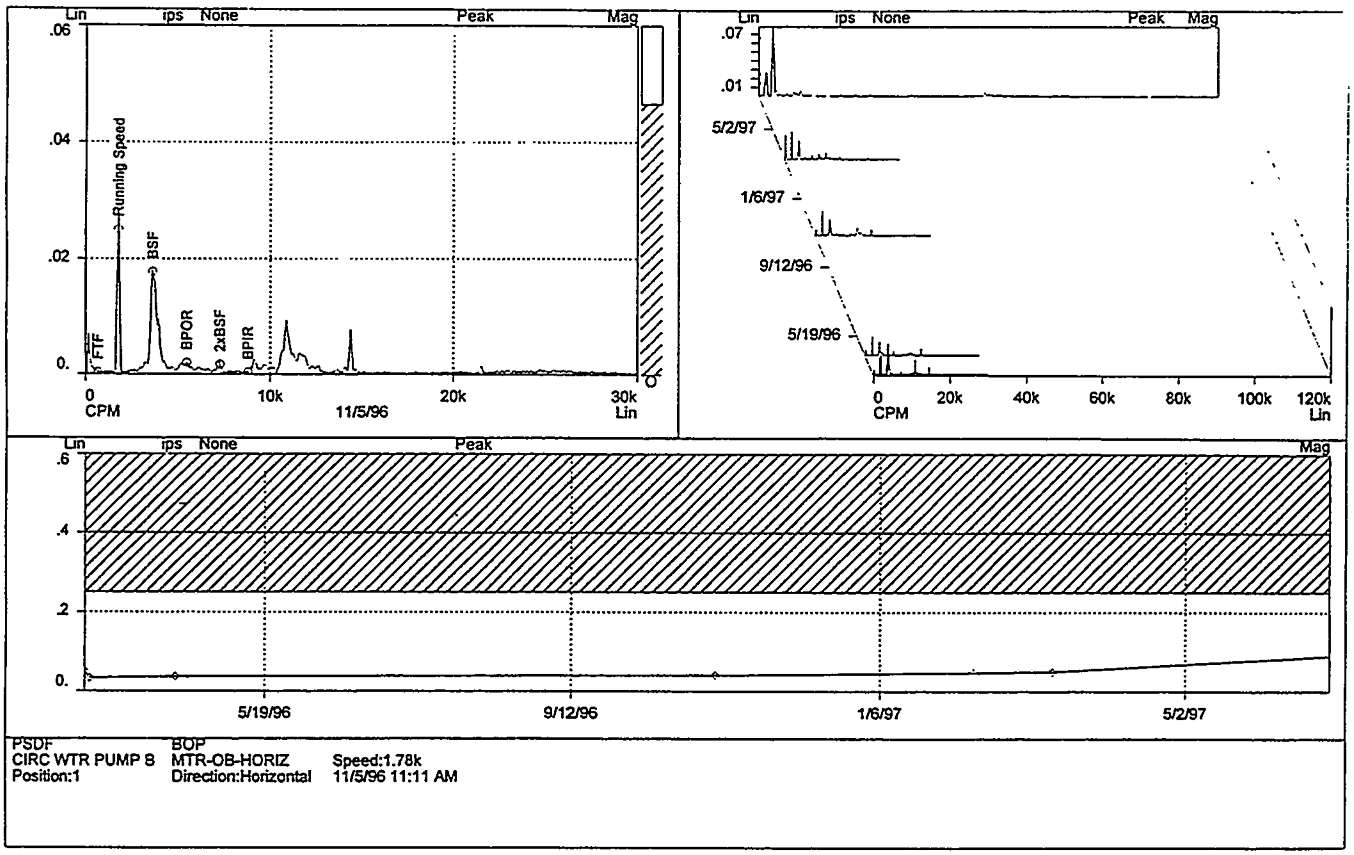


Figure 9.2.2-3 Typical Plot Including Current Spectrum, a Comparison of the Current Spectrum With the Past Spectrum, and a Magnitude Trend Plot

9.2.3 Thermal Scan

During start-up of the MWK transport reactor system and during several of the test runs, a thermal scan was performed on all piping and equipment within the system. There were three main objectives for the thermal scan. The first was to detect thermal anomalies such as "hot spots" in the piping and vessels that would indicate a breakdown in the performance of the refractory lining. A second objective was to periodically document and trend the temperature signatures of the various piping and vessels throughout the system. The third objective was to monitor these trends to assure that the integrity of the refractory is maintained and to provide a preliminary indication of degradation of the refractory lining.

All thermal scans were performed with an Agema 782 black and white short-wave infrared camera. The features of this camera include continuous real-time imaging, -5 to 1,500°F range, 0.2°F sensitivity at 86°F, 280 lines per frame, 100 elements per line, automatic and manual range and level adjustment, 9 calibrated ranges, 10-turn graduated thermal level readout, 8 aperture settings, 5 picture modes, and 2 isotherm functions. The selected thermal image is recorded on an electronically synchronized Polaroid photograph and then scanned into the computer for a stored digital image.

To date, thermal scans have been performed at the following times: (All scans except the May 13 scan were performed on the entire transport reactor system including the PCD and associated piping.)

- May 13, 1996, (thermal oxidizer only) – Internal air temperature = 1,600°F at initiation of scan.

- June 13, 1996, during test run CR02 – Start-up Burner gas outlet = 1,500°F, Primary Cyclone gas inlet = 874°F at initiation of scan.

- July 24, 1996, during test run CCT1A – Start-up Burner gas outlet = 1,590°F, Primary Cyclone gas inlet = 600°F at initiation of scan.

- August 18, 1996, start of test run CCT1C – Start-up Burner gas outlet = 2,000°F, Primary Cyclone gas inlet = 1,200°F at initiation of scan.

- August 21, 1996, after coal combustion of test run CCT1C – Primary Cyclone gas inlet = 1,644°F at initiation of scan.

- November 18, 1996, during test run CCT2C – Primary Cyclone gas inlet = 1,503°F at initiation of scan.

A thermal scan was also performed on the Foster Wheeler refractory lined piping and vessels on August 22, 1996, during cureout of the refractory.

The results of each thermal scan were documented in a report and the report included all thermal images recorded during the scan. All temperatures listed in the report (as well as all temperatures reported in the following paragraphs) were recorded with a surface probe digital thermometer. The infrared camera was used to detect the various temperature gradients, and the digital thermometer was used to record the exact temperatures.

A typical thermal image will exhibit various shades of gray from black to white. In the picture mode in which all images were taken for this project, the darker the shade the cooler the object (for a given emissivity), as shown in figure 9.2.3-1. This figure was taken during test run CR02. This is a thermal image of the top of the disengager on the left and the cyclone on the right. Note the varying shades of gray in the photograph. In this image, the large horizontal flange set at the top of the disengager (lower left hand corner of photograph) is 113°F, the smaller flange set above this is 140°F, and the primary cyclone is 182°F.

As was mentioned earlier, one of the main objectives in performing the thermal scan is to detect any "hot spots" in the piping or vessels. If a "hot spot" occurs somewhere in the system, the infrared camera would easily detect it as illustrated in figure 9.2.3-2. This is an image of the top of the combustor heat exchanger (CBHE) taken during coal combustion of test run CCT1C. In this photograph the dipleg at the left is 228°F and the large horizontal flange set at the top of the CBHE in the middle of the photograph is 220°F. Note the very bright object to the right of the CBHE. This is a spool section in the steam line that connects to the CBHE. The insulation was removed from this spool to repair a leak and had not yet been replaced at the time of the run. The temperature of this spool is 383°F, which is very easily detected. Another example of this is shown in figure 9.2.3-3. This is an image of the riser at the left and the primary gas cooler to the right taken during test run CCT1A. In this image the riser is 174°F. Note the hot section on the primary gas cooler. This is the location of the boiler feedwater (bfw)/steam piping connection on the cooler which is not insulated. The temperature of this section is 314°F. Once again note the ease of detection. During coal combustion runs these bfw/steam piping connections on the primary and secondary gas coolers are the hottest skin temperatures in the system.

During all of the thermal scans (including start-up and coal combustion), the hottest skin temperature of any object in the system was the reactor start-up burner. Figure 9.2.3-4 is an image taken at elevation 132'- 0" at the start of test run CCT1C. In this photograph the start-up burner is shown to the left. The skin temperature of the burner vessel is 448°F, as compared to the reactor at 203°F, the standpipe at 205°F, and the CBHE at 133°F. Figure 9.2.3-5 provides this same view taken after coal combustion of this same test run. Note now that the start-up burner has cooled down (since it is no longer in use) and thus does not show in the photograph. In this photograph the start-up burner is 122°F, the reactor is 242°F, the standpipe is 249°F, and the CBHE is 223°F. During coal fire the average pipe/vessel skin temperature was 230 to 270°F.

Often during the thermal scans the elbows in the piping were slightly hotter than the pipe itself. This temperature difference was not enough to cause concern but is nevertheless a point worth noting. One example of this is shown in figure 9.2.3-6. This is an image of the CBHE gas outlet taken during test CR02. In this photograph the pipe temperature is 132°F but the elbow temperature is 152°F. Figure 9.2.3-7 is another example of this occurrence. This is an image of the primary cyclone gas outlet taken during coal combustion of test run CCT1C. In this photograph the pipe temperature is 218°F but the elbow temperature is 256°F.

Another observation was made for nozzles located at a change of direction in the piping, i.e., the nozzle temperature was typically hotter than the piping. Figure 9.2.3-8 is an illustration of this. This is an image of the riser crossover to the disengager taken during the start of test run CCT1C. In this photograph the riser temperature is 201°F but the nozzle on top of the riser (H1) is 258°F. The crossover also shown in this photograph is 183°F. Another example of this is shown in figure 9.2.3-9. This is an image of a line (PM04) from the primary gas cooler to the PCD at elevation 170'-0" taken during the start of test run CCT1C. In this photograph the elbow temperature is 151°F but the nozzle temperature is 168°F.

Typically weld joints were also consistently at a higher temperature than the piping. This is expected because at a pipe weld joint there is also a refractory joint that is caulked in before welding. Figure 9.2.3-10 is an image at elevation 182'-0" taken during test run CR02. This image shows the thermal gradient at the weld joint in the riser, standpipe, and dipleg. In this photograph the bottom-to-top temperature gradient in the riser is 167°F in the region below the weld joint, 203°F in the region around the weld joint, and 193°F in the region above the weld joint. For the standpipe, the bottom-to-top gradient is 163°F, 202°F, and 181°F. For the dipleg, the bottom-to-top gradient is 183°F, 203°F, and 176°F. Figure 9.2.3-11 shows the same view taken during coal combustion of test run CCT1C. In this photograph, the riser temperature of the pipe region below the weld joint is 248°F and at the weld joint is 276°F. For the standpipe, these regions are at 248°F and 292°F, and for the dipleg these regions are 237°F and 257°F. One interesting observation in viewing these last two figures is that regardless of the absolute temperature of the piping, the temperature differential between the piping and weld joint is about the same and range from 20 to 40°F depending on the joint.

As was noted earlier, each time a thermal scan was performed the Westinghouse PCD (FL0301) was also viewed. Figure 9.2.3-12 is an image of the head of the PCD and shows the gas outlet pipe connection. This was taken during coal combustion of test run CCT1C. As can be seen, there are various temperature gradients in this component. The highest temperature point is at the top of the nozzle on the left of the head (Nozzle 11) where the temperature is 234°F. In contrast to this, the bottom of this nozzle is at 149°F. This gradient could either be due to the flow path of the gas or the construction of the refractory. The head temperature is 158°F near the gas outlet connection, and 124°F near the head to vessel flange. The gas outlet pipe skin temperature is 150°F.

The thermal oxidizer was also viewed each time a thermal scan was performed. Figure 9.2.3-13 is a typical image of the thermal oxidizer. This was taken during the start of test run CCT1C. As can be seen, the skin temperature is fairly uniform. In this photograph the skin temperature taken near the manway is 232°F.

One final observation made was at the connection of the standpipe outlet to the screw cooler (FD0206). Figure 9.2.3-14 is an image of this section taken at elevation 120'- 0" looking down. This was taken during the start of test run CCT1C. Note how much cooler the standpipe to screw cooler connecting spool is as compared to the neck of the screw cooler. In this photograph the connecting spool is 172°F while the neck of the screw cooler is 307°F. The reason for this may be due to a minimal flow of cooling fluid through the neck of the screw cooler. The connecting spool has independent inlet and outlet piping for the cooling fluid, while the neck of the screw cooler is fed from the same supply piping that feeds the screw cooler jacket and screw. Thus, the pressure drop through the neck of the cooler may limit the amount of flow that passes through the neck. However, this has not been proven and the neck is designed for 350°F. Figure 9.2.3-15 is another view of the screw cooler taken from the ground level during the same test run. This shows that the neck is at a higher temperature than the screw cooler jacket, which is about 170°F.

Thermal scans will continue to be performed on the MWK system after all major outages and at any other time necessary. Also, once the Foster Wheeler system is constructed similar thermal scans will be performed on this system. All images will continue to be stored in a database for future reference and trending. Thus significant changes in the thermal signatures may be detected and actions may be taken to correct any problems.

Disengager Inlet
Elevation 202'-0"
Viewed South

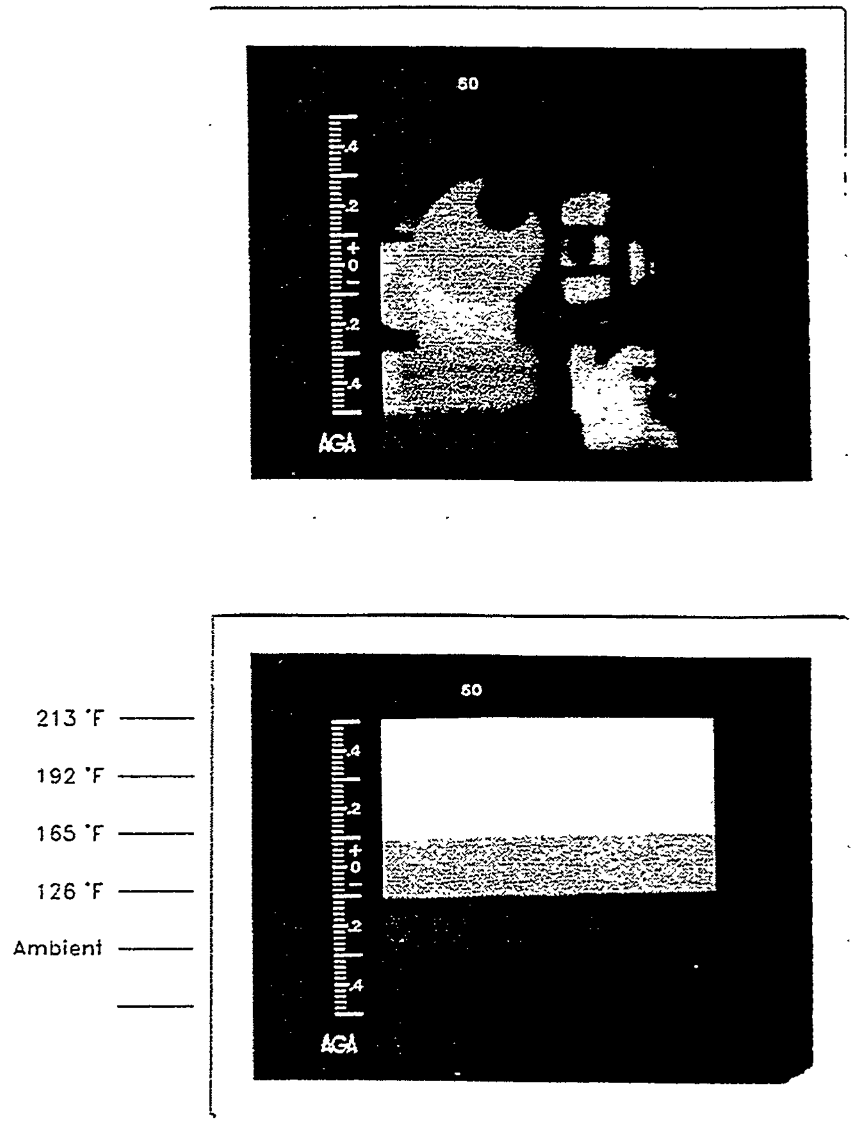
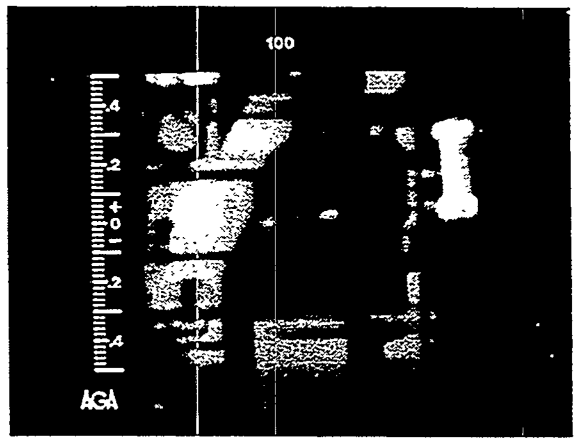


Figure 9.2.3-1 Various Shades of Gray (From Black to White) Showing a Typical Thermal Image (Test Run CR02)

Dipleg to Standpipe, Comb. Heat Exch.
Elevation 152'–0"
Viewed East



314 °F
276 °F
221 °F
89 °F
Ambient

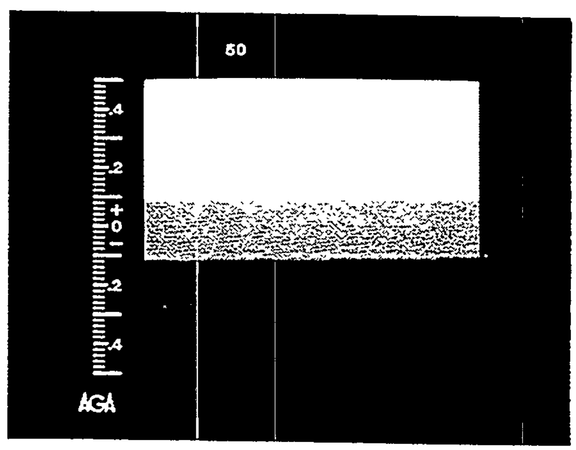
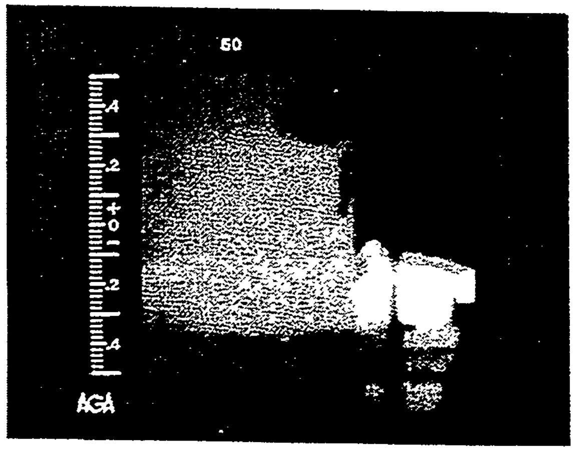


Figure 9.2.3-2 A Scanned Image of the Top of the Combustor Heat Exchanger Taken During Coal Combustion of Test Run CCT1C Showing a Hot Spots in the Piping or in the Vessels

Riser (left), Primary Gas Cooler (right)
Elevation 182'–0"
Viewed Southwest



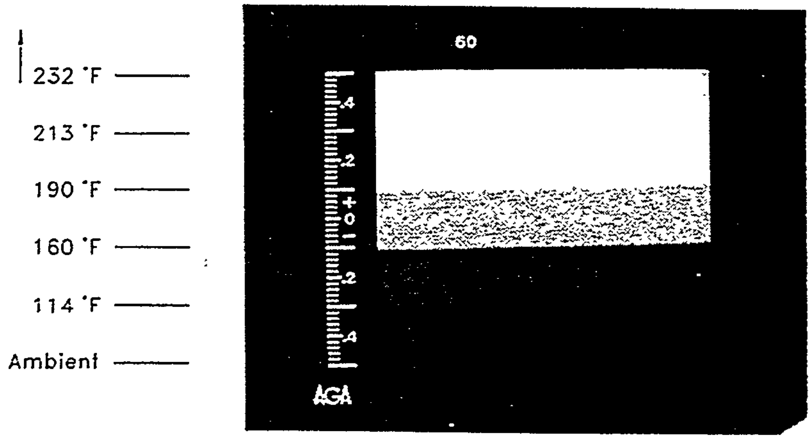
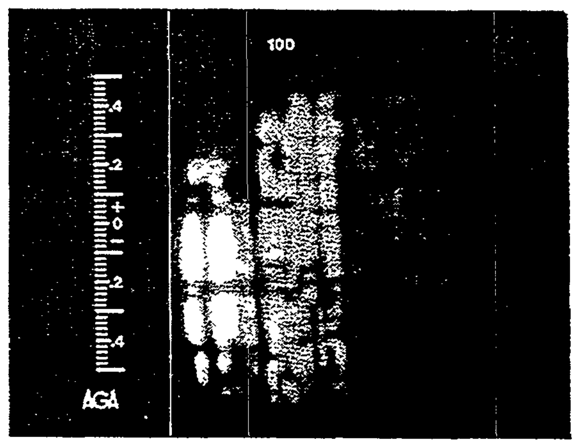


Figure 9.2.3-3 A Second Example of Scanned Image of the Top of the Combustor Heat Exchanger Taken During Coal Combustion of Test Run CCT1C Showing a Hot Spots in the Piping or in the Vessels

SU Burner, Reactor, Stdpipe, Comb Heat Exch.
Elevation 132'–0"
Viewed South



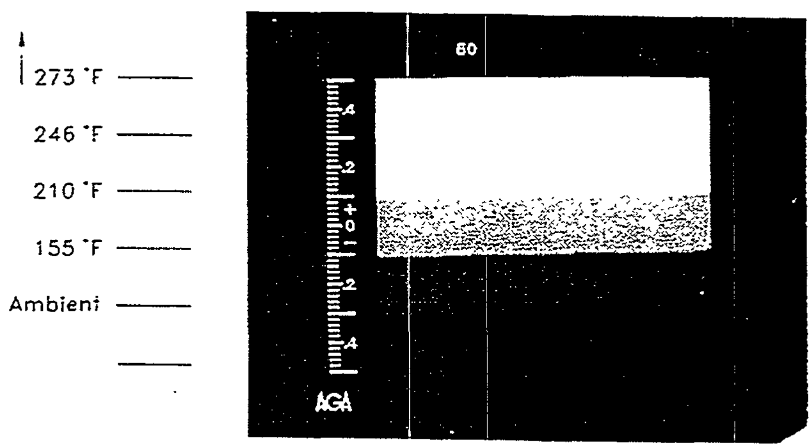
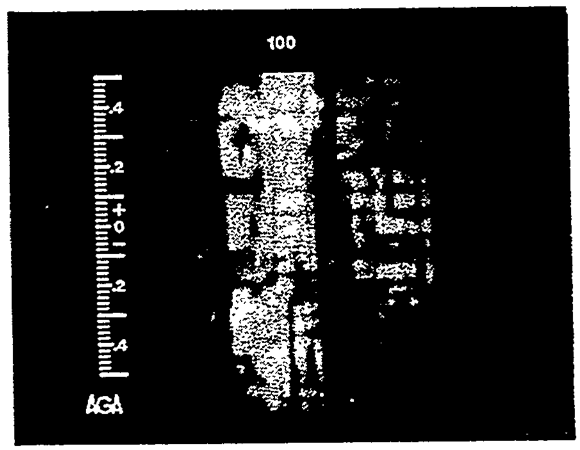


Figure 9.2.3-4 An Image Taken at Elevation 132 Feet at the Start of Test Run CCT1C Showing the Start-Up Burner on the Left

Reactor (left), Standpipe (center), CHE (right)
Elevation 132'–0"
Viewed South



324 °F
288 °F
240 °F
152 °F
Ambient

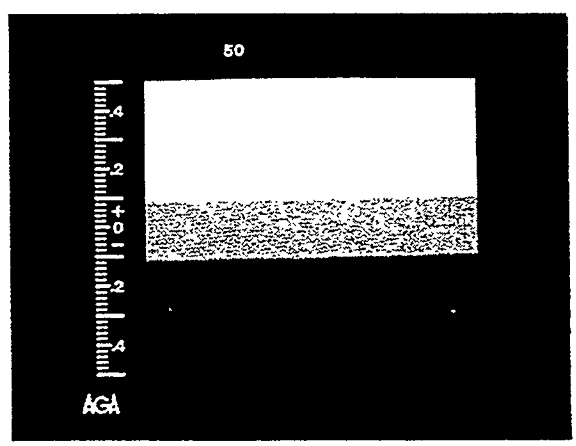
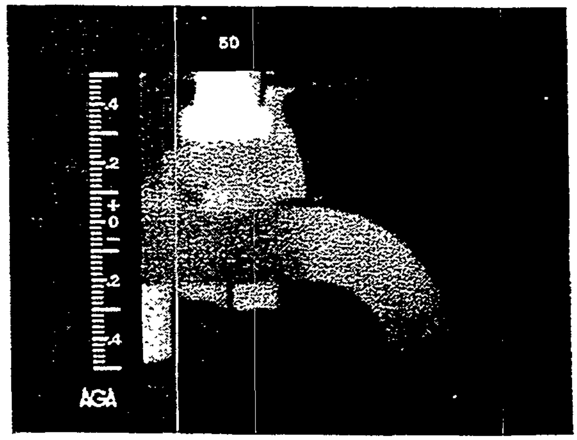


Figure 9.2.3-5 A Second View of Scanned Image Shown in Figure 9.2.3-4 Taken After Coal Combustion of Test Run CCT1C

Combustor Heat Exchanger Gas Outlet
Elevation 202'–0"
Viewed South



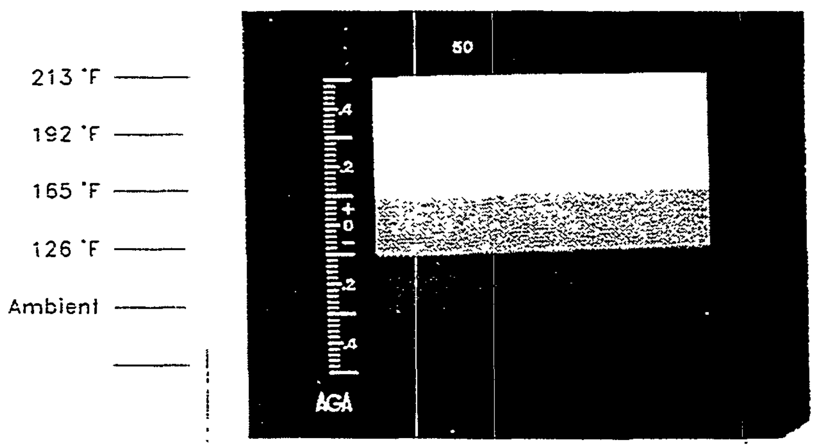
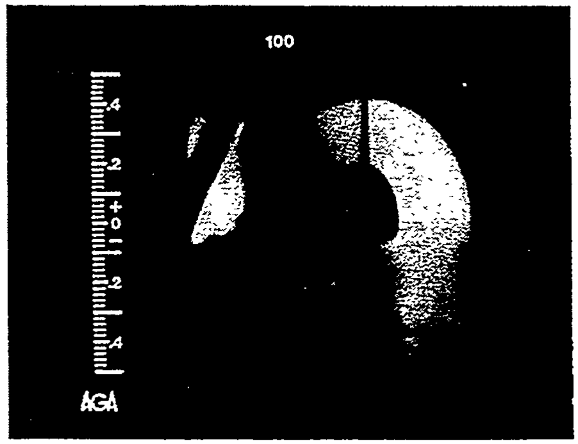


Figure 9.2.3-6 An Example of Temperature Differences Identified During Test Run CR02 Where Elbows in the Piping Were Slightly Hotter Than the Pipe Itself

Cyclone Gas Outlet
Elevation 202'–0"
Viewed Southeast



294 °F
271 °F
242 °F
205 °F
147 °F
Ambient

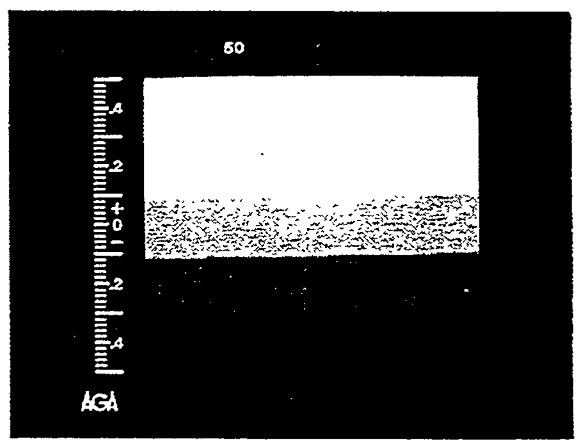


Figure 9.2.3-7 A Second Example of Temperature Differences Identified During Test Run CR02 Where Elbows in the Piping Were Slightly Hotter Than the Pipe Itself (Showing Primary Cyclone Gas Outlet During Coal Combustion of Test Run CCT1C)

Riser Crossover to Disengager
Elevation 202'–0"
Viewed Southwest

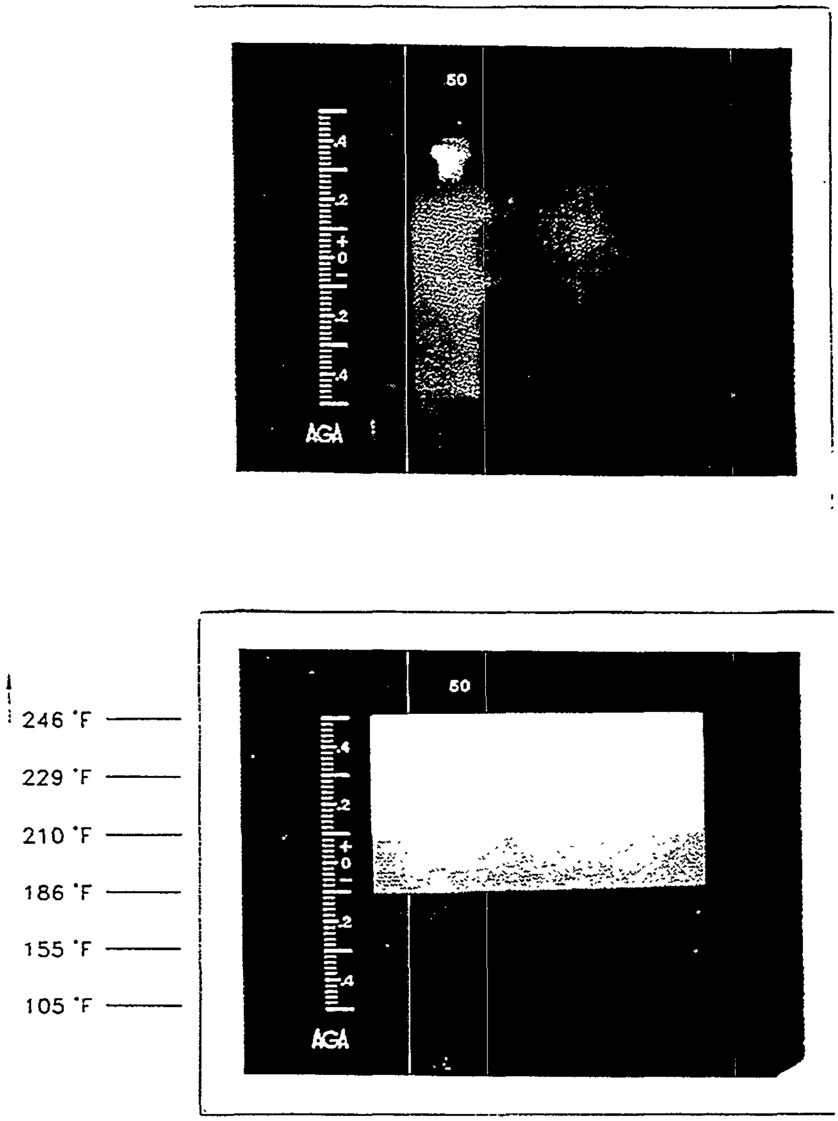
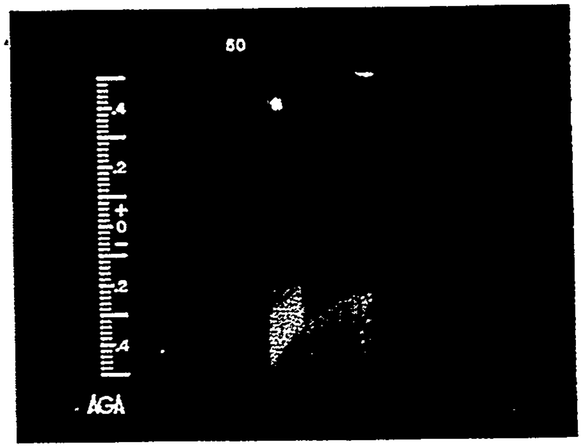


Figure 9.2.3-8 Results of Test Run CCT1C Indicating Temperature Differences Where Nozzle Temperature was Typically Hotter Than the Piping (Showing Riser Crossover to the Disengager)

PM04, Primary Gas Cooler to PCD
Elevation 170'–0"
Viewed West



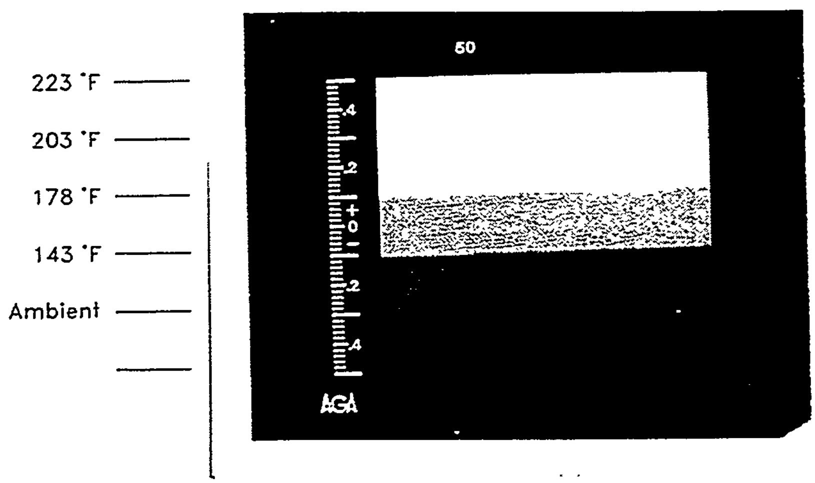
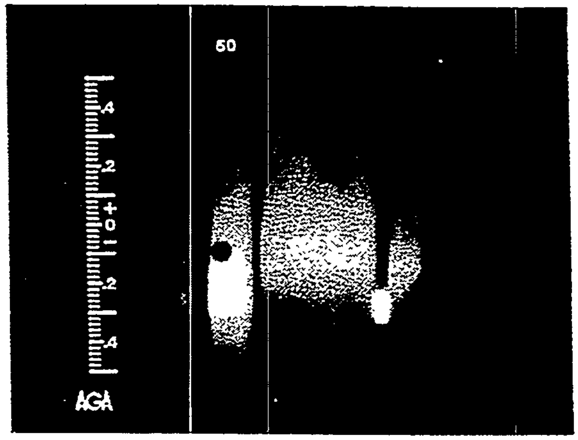


Figure 9.2.3-9 A Second Image of Results of Test Run CCT1C Indicating Temperature Differences Where Nozzle Temperature was Typically Hotter Than the Piping (Showing Line PM04 from the Primary Gas Cooler to the PCD)

Riser, Standpipe, Dipleg
Elevation 182'–0"
Viewed South



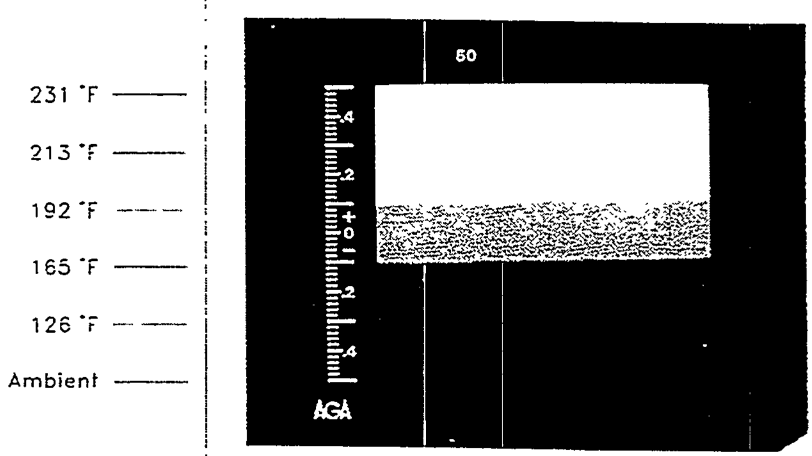
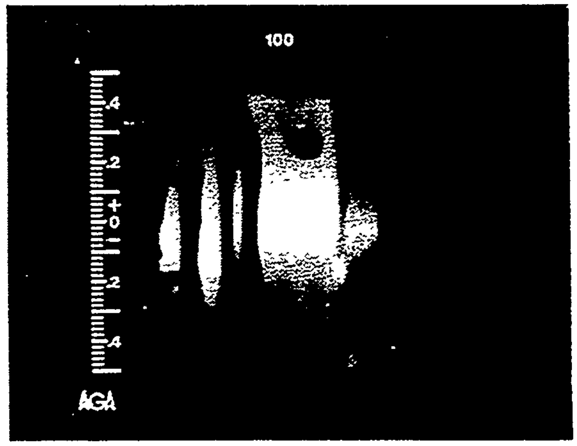


Figure 9.2.3-10 Results of Test Run CR02 Showing Temperature Differences Where Weld Joints Were Consistently at a Higher Temperature Than the Piping (Showing the Thermal Gradient at the Weld Joint in the Riser, Standpipe, and Dipleg)

Riser (left), Standpipe (center), Dipleg (right)
Elevation 182'–0"
Viewed South



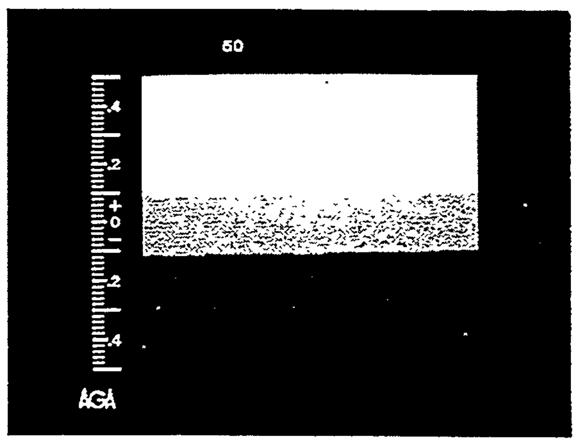
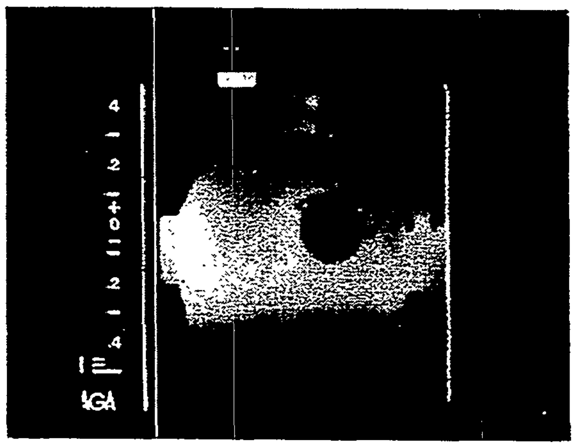


Figure 9.2.3-11 Results of Test Run CCT1C Showing Temperature Differences Where Weld Joints Were Consistently at a Higher Temperature Than the Piping (Showing the Thermal Gradient at the Weld Joint in the Riser, Standpipe, and Dipleg)

Westinghouse PCD, FL0301
Elevation 202'–0"
Viewed North



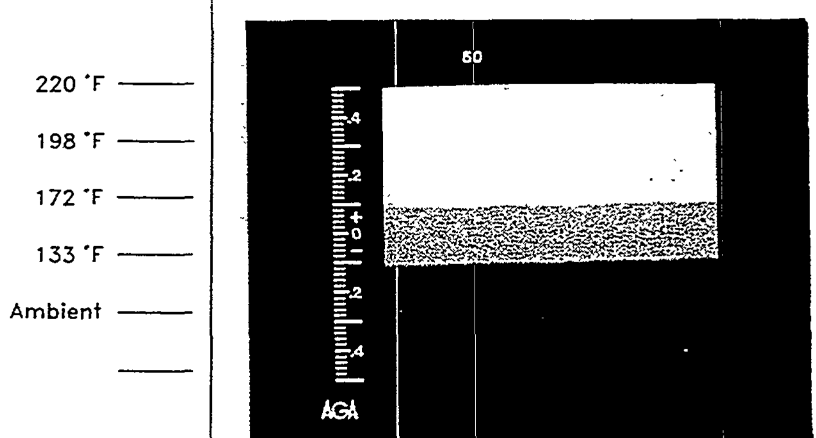
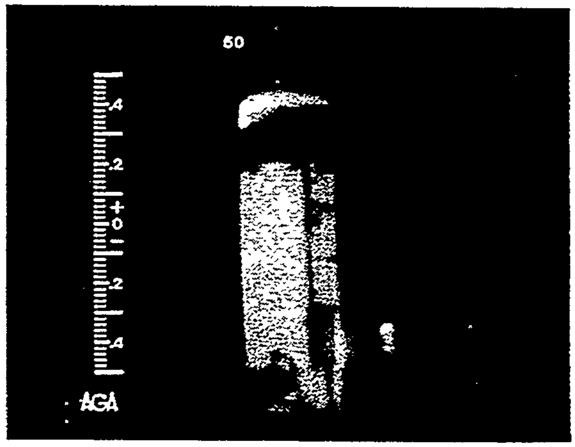


Figure 9.2.3-12 Results of Test Run CCT1C Showing Various Temperature Gradients (Showing an Image of the Head of the PCD and the Gas Outlet Pipe Connection)

Thermal Oxidizer
Elevation 100'–0"
Viewed Southeast



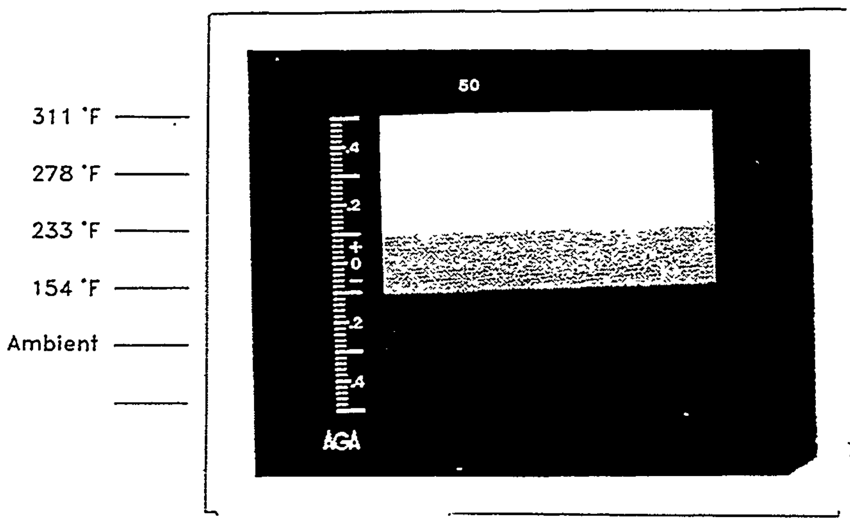
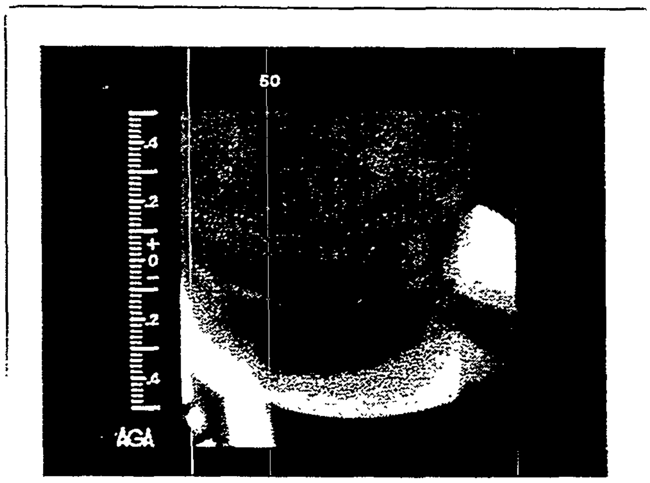


Figure 9.2.3-13 A Typical Image of the Thermal Oxidizer Taken During the Start of Test Run CCT1C Showing Fairly Uniform Temperature

Standpipe Outlet to Screw Cooler (FD0206)
Elevation 120'–0"
Viewed Northwest and Down



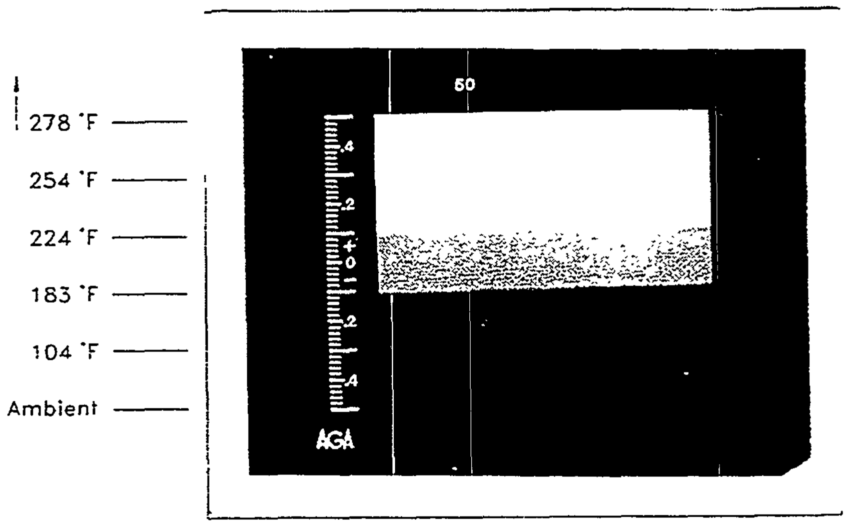


Figure 9.2.3-14 An Image of the Standpipe Outlet Connection to the Screw Cooler Taken at Elevation 120 Feet Taken at the Start of Test Run CCT1C

Screw Cooler (FD0206)
Elevation 100'–0"
Viewed Southwest and Up

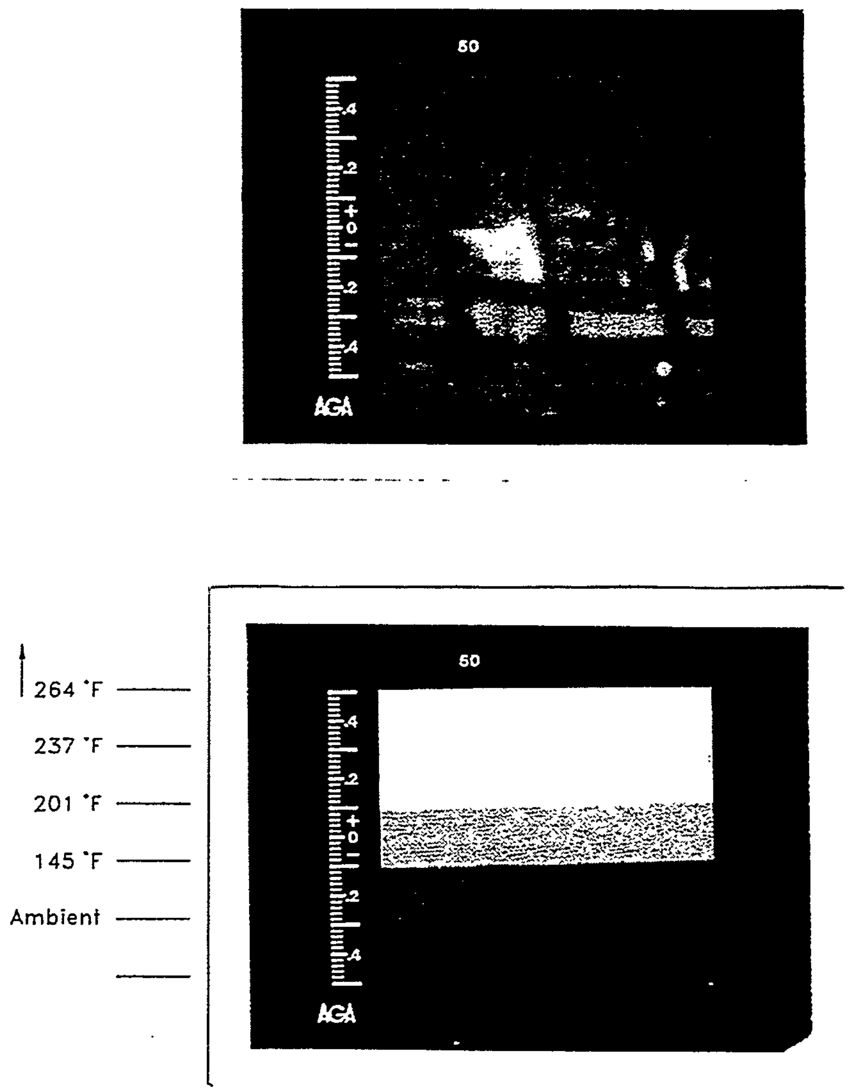


Figure 9.2.3-15 Second View of the Standpipe Outlet Connection to the Screw Cooler Taken From Ground Level During Test Run CCT1C

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Because both processes have never been integrated at this scale before, the control algorithms have yet to be developed for 'unit' control; therefore, the controls design will evolve over time and operation will be based on the project's results.

Programmable logic controllers (PLCs) are used throughout the process to implement complex high-speed binary control logic in a cost-effective manner. Systems utilizing PLCs include the pneumatic coal, limestone, and ash transport, thermal oxidizer, main air compressor, coal crusher/conveyor, and both the recycle gas booster and nitrogen compressors. In the case of the pneumatic transport systems, one large PLC controls several transport systems such as FD0210, FD0220, FD0510 etc. Each of these systems could have been controlled by a smaller PLC, however, due to interlocks required between the systems, one large PLC reduced the overall cabling and raceway costs. This was accomplished by keeping data communications between systems within the large PLC rather than interconnecting smaller PLC with binary communication paths using cable and raceways.

Most of the PLCs used on this site are Allen-Bradley models PLC-5 and the smaller and lower cost SLC504. Both models have Ethernet communication ports and are connected into the DCS via gateways to allow display of analog and binary points for the operators. A side benefit of this communication is that a programming terminal can also be attached to the same network in the control room for trouble-shooting from a central location. This allows the integrity of the PLC to be established in conjunction with the DCS and DCS displays in a timely manner. The centralized approach has the benefit of support documents being available in the control room while the alternative requires significant set-up time.

As mentioned above, most of the PLCs are provided by one manufacturer and are networked into a LAN. There are General Electric and Moore Inc. PLCs utilized on site as well. There is one Allen-Bradley PLC, the crusher/conveyor system PLC, that does not have networking capability. Having different brands of PLCs introduces training and training retention problems for the control technicians. Technicians must be trained to maintain and modify the PLC software and hardware and must keep this knowledge up-to-date by hands-on experiences. Even when the technicians receive initial training, there are not enough failures per brand to provide the technicians with the sufficient maintenance opportunities to develop a strong knowledge base for a given brand. PLCs that are not networked for centralized maintenance tend to be serviced the least. This is due to the time required for programming terminal set-up and lack of centralized support documentation. Should such a system have an annoying glitch, the glitch is usually tolerated for a while rather than being resolved immediately.

One vendor-supplied system (the pulverizers) utilizes a custom-programmed microcomputer rather than a PLC. Although the system could have been programmed initially using a PLC, the vendor quoted a "price break" if their standard microcomputer was used. The down side to the microcomputer is that on-site personnel cannot maintain and modify the system as needed. The vendor must be utilized for those services. A remote link to the vendor's technical support center via modem does reduce costs over an on-site visit.

Commissioning support from vendors of PLC-based systems varied from vendor to vendor and even within the vendor's organization. Ultimately the support and quality of the programming provided depended upon the qualities and capabilities of the individual programmer. Some systems were programmed in such a manner that plant personnel could start-up and check out the systems without vendor-supplied support. Others have required more vendor/programmer involvement.

9.4 ENVIRONMENTAL AND SAFETY

9.4.1 Environmental

For commissioning the M.W. Kellogg Transport Reactor Train, several environmental parameters had to be in place in advance of the actual commissioning period. Water discharges through the National Pollution Discharge Elimination System (NPDES) permit had been identified and the appropriate processes and procedures in place to manage these discharges. The two major discharges were cooling tower blowdown and wastewater treatment which were two different point sources. The cooling tower has established limits for total free residual chlorine, temperature, and pH. The wastewater unit collected from several sources including the runoff from the coal and limestone piles, stormwater from the immediate plant structure area, and runoff from the fuel oil storage. The wastewater treatment discharge has limits on total suspended solids (TSS), oil and grease, pH, naphthalene, and benzene. For the commissioning period, all effluent test results were within permit limits for both wastewater and cooling tower blowdown. The Alabama Department of Environmental Management (ADEM) requires a Quarterly NPDES Discharge Monitoring Report for the facility. During the 1996 fourth quarter commissioning period, the cooling tower blowdown flow averaged 2,100 gallons per day with a maximum flow of 20,500 achieved on 1 day. The wastewater treatment unit averaged 3,600 gallons of flow per day with a maximum flow achieved at 30,000 gallons for 1 day. General stormwater runoff from the plant area is diverted into underground culverts that carry the runoff to outfalls located north and south of the plant area. Stormwater is sampled twice per year for TSS. The facility has its own sewage treatment plant that is also included in the NPDES permit. The sewage treatment unit had been used in the previous coal liquefaction project and it was transferred over to the PSDF NPDES permit at the time of application submittal.

The PSDF air permit limits and reporting requirements are also established by ADEM. The ADEM requires an initial compliance test for the M.W. Kellogg reactor train operating in the combustion and gasification modes. The permit requires testing for sulfur dioxide, nitrogen oxides, carbon monoxide, particulate matter, and volatile organic compounds (VOCs). Each pollutant has established maximum daily emissions in pounds-per-hour, which are stated in the air permit. In order to be prepared for a compliance test, an outside vendor was selected to perform these tests. The vendor selected was Sanders Engineering and Environmental Testing from Mobile, Alabama. In conjunction with Southern Company Services, a compliance test protocol was prepared and submitted to ADEM before the commissioning period. The test protocol was accepted by ADEM and therefore was in place prior to the commissioning period. No compliance test was performed during the commissioning period due to operational instability. The ADEM was kept informed of plant status during this period.

Prior to the commissioning period, arrangements had been made to transport and dispose of waste generated from the process and in particular ash waste. Browning-Ferris

Industries (BFI) had been selected to transport and dispose of nonhazardous waste ash. Prior to any disposal a waste profile on the ash had to be submitted to BFI and ADEM for approval. The approval was in place prior to the commissioning period. Chemical Waste Management had been selected to dispose of hazardous waste ash generated from the facility. Ash was handled and transported in 20-cubic yard rolloff containers. After the ash was loaded into the container, a representative sample was taken and submitted to the laboratory for sulfide analysis and toxicity characteristic leaching procedure (TCLP) for metals. The ash remained on site until the analytical results were obtained and the proper disposal destination was determined based on the analytical results. During the commissioning period, all samples passed both the sulfide and TCLP for metals testing, and two loads of nonhazardous ash were shipped to the BFI facility.

9.4.2 Safety

Prior to the commissioning period, all employees at the PSDF were made aware of the potential dangers involved in commissioning a new plant. Safety awareness was made a part of commissioning individual components that made up the process and this level of awareness was transported into the commissioning period. Some of the essential safety programs that were in place prior to the commissioning period included personal protective equipment (PPE), respiratory protection program including the pulmonary function and respirator fit tests, hearing protection and audiograms, clearance procedure, confined space, hazard communications, and blood-borne pathogens. Plant operators, mechanics, and E and I personnel were trained on fire extinguishers and fire hoses in order to respond to fires at the incipient level. Each of these OSHA programs was discussed in safety meetings and special training periods well in advance of the commissioning period. Special emphasis was placed on how to handle burns, how to administer first aid, and CPR. During the commissioning period, one OSHA recordable accident occurred that involved a short period of restricted duty but there was no lost-time away from work due to the injury.

TERMS

List of Abbreviations

AAS	Automated Analytical Solutions
ADEM	Alabama Department of Environmental Management
APFBC	Advance Pressurized Fluidized-Bed Combustion
ASME	American Society of Mechanical Engineers
AW	Application Workstation
BFI	Browning-Ferris Industries
BFW	Boiler Feed Water
BMS	Burner Management System
BOC	BOC Gases
BOP	Balance-of-Plant
BPIR	Ball Pass Inner Race, Frequencies
BPOR	Ball Pass Outer Race, Frequencies
BSF	Ball Spin Frequency
CAD	Computer-Aided Design
CEM	Continuous Emissions Monitor
CFB	Circulating Fluidized Bed
CFR	Code of Federal Regulations
CHE	Combustor Heat Exchanger
CPC	Combustion Power Company
CPR	Cardiopulmonary Resuscitation
DC	Direct Current
DCS	Distributed Control System
DOE	U.S. Department of Energy
E & I	Electrical and Instrumentation
EERC	Energy and Environmental Research Center
EPRI	Electric Power Research Institute
FCC	Fluidized Catalytic Cracker
FETC	Federal Energy Technology Center
FFG	Flame Front Generator
FI	Flow Indicator
FIC	Flow Indicator Controller
FOAK	First-of-a-Kind
FTF	Fundamental Train Frequency
FW	Foster Wheeler
GBF	Granular Bed Filter
GC	Gas Chromatograph
GEESI	General Electric Environmental Services, Inc.
HTF	Heat Transfer Fluid
HTHP	High-Temperature, High-Pressure
I/O	Inputs/Outputs
ID	Inside Diameter
IF&P	Industrial Filter & Pump
IGV	Inlet Guide Vanes
IR	Infrared

LAN	Local Area Network
LIMS	Laboratory Information Management System
LOC	Limiting Oxygen Concentration
LOI	Loss on Ignition
LPG	Liquefied Propane Gas
LSLL	Level Switch, Low Level
MAC	Main Air Compressor
MCC	Motor Control Center
MS	Microsoft Corporation
MWK	The M. W. Kellogg Company
NDIR	Nondestructive Infrared
NFPA	National Fire Protection Association
NOx	Nitrogen Oxides
NPDES	National Pollutant Discharge Elimination System
NPS	Nominal Pipe Size
OD	Outside Diameter
OSHA	Occupational Safety Health Administration
OSI	OSI Software, Inc.
P&IDs	Piping and Instrumentation Diagrams
PC	Pulverized Coal
PCD	Particulate Control Device
PDI	Pressure Differential Indicator
PDT	Pressure Differential Transmitter
PFBC	Pressurized Fluidized-Bed Combustion
PI	Plant Information
PLC	Programmable Logic Controller
PPE	Personal Protection Equipment
PSD	Particle Size Distribution
PSDF	Power Systems Development Facility
PT	Pressure Transmitter
RFQ	Request for Quotation
RO	Restriction Orifice
RSSE	Reactor Solid Separation Efficiency
SCS	Southern Company Services, Inc
SRI	Southern Research Institute
TCLP	Toxicity Characteristic Leaching Procedure
TR	Transport Reactor
TRDU	Transport Reactor Demonstration Unit
TSS	Total Suspended Solids
UND	University of North Dakota
UPS	Uninterruptible Power Supply
UV	Ultraviolet
VOCs	Volatile Organic Compounds
WPC	William's Patent Crusher
XXS	Extra, Extra Strong

List of Units

acfm	Actual Cubic Feet Per Minute
Btu	British Thermal Units
°F	Degrees Fahrenheit
°C	Degrees Celsius or Centigrade
ft	Feet
gpm	Gallons Per Minute
hp	Horsepower
hr	Hour
inWG	Inches, Water Gauge
mA	milliamps
MB	Megabytes
MW	Megawatts
m/s	Meters per second
μ or μm	Microns or Micrometers
dp_{50}	Particle Size Distribution at 50 Percentile
ppm (W or V)	Parts Per Million (by weight (w) or volume(v))
lb	Pounds
pph	Pounds per hour
psia	Pounds Per Square Inch Gauge
psig	Pounds Per Square Inch Gauge
ΔP	Pressure Drop
rpm	Revolutions Per Minute
s or sec	Seconds
scf	Standard Cubic Feet
scfm	Standard Cubic Feet Per Minute
V	Volts
W/PPPM	weight/parts per million