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Quarterly Progress Report for Period April 1-June 30, 1980

Third Quarter-Fiscal Year 1980

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Westinghouse Electric Corporation
Madison, Pennsylvania

FOSSIL ENERGY



U. S. DEPARTMENT OF ENERGY

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ADVANCED COAL GASIFICATION SYSTEM
FOR ELECTRIC POWER GENERATION

QUARTERLY PROGRESS REPORT
THIRD QUARTER - FISCAL YEAR 1980
PERIOD APRIL 1 TO JUNE 30, 1980

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SECTION 1.0

OBJECTIVE AND SCOPE OF WORK

The overall objective of the Westinghouse Coal Gasification Program is to demonstrate the viability of the Westinghouse pressurized fluidized bed gasification system for production of low- and intermediate-Btu fuel gas for electric power generation, syngas, feedstocks or industrial fuels and to obtain performance and scale-up data for the process and hardware.

1.1 OPERATION AND MAINTENANCE OF THE PDU

The Task 1 objective is operation of the process development unit (PDU) to evaluate the process feasibility and operability of the Westinghouse advanced fluidized bed coal gasification process and to provide data for scale-up and component hardware designs. The initial work in this task involved evaluation of the devolatilizer system for decaking and devolatilizing fresh coal feedstocks. Process feasibility of the devolatilizer was demonstrated through a series of tests with a variety of coal feedstocks, including highly caking Eastern bituminous coals. Following these tests, the gasifier-agglomerator system feasibility was demonstrated with chars produced in the devolatilizer and with other materials, including coke breeze, chars from another gasification process and both non-caking and highly caking coals. These materials were successfully gasified and ash agglomerates were successfully produced from each feedstock.

Additional testing of the gasifier-agglomerator reactor included direct coal feed as well as oxygen-blown gasification of a char or coal bed. These tests were followed by evaluation of the integrated system consisting of the devolatilizer and gasifier-agglomerator. Based on the results of the two-stage air-blown tests, further analytical comparisons are being made of the single- and two-stage operation to determine the advisability of operating the PDU in the two-stage mode.

Single-stage gasifier testing will continue under Task 1 with the gasifier operating at or near design temperature, pressure and solids feed capacity using a variety of feedstocks to include a highly caking coal. Gasification will be accomplished with air and with oxygen to produce low-Btu gas and medium-Btu synthesis gas and agglomerated ash at a high overall carbon utilization.

In addition, combustion tests with both low- and medium-Btu gas from the PDU are also planned with the objective of determining combustion stability over the entire turndown range for the process.

1.2 PDU MODIFICATIONS

Under Task 2, present work involves the modification and upgrading of the PDU to achieve better performance as dictated by the results of prior testing efforts. One subtask includes modifications to upgrade the high-pressure

oxygen system to support the testing program. Specifically, this work involves the oxygen supply, process piping, flow controls, instrumentation and related process hardware. The PDU will also be modified to provide the capability of evaluating the equipment and subsystems necessary for heat recovery and fines recycle tests using the PDU-derived fuel gas. Modifications to both the PDU and the Test and Development Center are planned to permit combustion evaluation tests of medium- and low-Btu gas from the PDU.

1.3 SCALE-UP DESIGN AND ANALYSIS

Scale-up design and analysis of the Westinghouse process are performed as part of Task 3. The objectives of this task are to conduct experimental and analytical work required to establish a data base as well as design models and procedures for scaling up the components and subsystems of the fluidized bed gasification process. The Cold Flow Scale-up Facility (CFSF), a large 3-meter scale cold flow model, is the principle tool for providing this information. Initial operation is in the gasifier mode to determine scale-up criteria, develop analytical models for scale-up and determine operable geometries.

1.4 LABORATORY SUPPORT STUDIES

This task consists of consultation and analytical and bench studies by personnel from the chemical engineering research and other departments of the Westinghouse Research and Development Center in support of PDU operations and systems analysis and scale-up considerations. General areas of work include gas-solids flow modeling, coal and ash behavior, ash agglomeration, gasification, fluidization, analysis of operating and reliability problems, gas cleaning, heat recovery, scale-up and turbine effects.

Support work has included studies and experiments in fuel processing, analysis of operating conditions for the PDU, obtaining data for PDU modifications, analysis and interpretation of results from PDU operation, development of process models for scale-up, and understanding of process phenomena to achieve reliable operation. Work has also been conducted in the areas of cold flow and analytical modeling, coal behavior, coal and ash chemical phenomena, environmental impact, and process and systems engineering consultation.

For the laboratory support experimental program, test facilities include:

- Two flexible 1-foot diameter semicircular units, which operate at atmospheric pressure and ambient temperature for fluidization studies.
- A fluidized bed test unit, operating at design temperature and pressure, for devolatilization and gasification investigations.
- An atmospheric pressure fluidized bed agglomerator, operating at design temperatures.

- A pressurized thermogravimetric analysis system, differential thermal analysis and a pressurized high temperature fluidized bed test unit are available to conduct investigations in gas cleaning and gasification.

SECTION 2.0

TECHNICAL PROGRESS SUMMARY

2.1 OPERATION AND MAINTENANCE OF THE PDU

2.1.1 Gasifier Test TP-023-4

Test TP-023-4 continued a series of oxygen-blown, single-stage gasifier feedstock characterization tests at 130 psig begun during 1979. The objectives of TP-023-4 were to:

- Operate the gasifier with the modified oxidant tube at oxygen concentrations over 50 percent, evaluating the effectiveness of this tube design for reducing sintered-material formation at the tip.
- Obtain data relating product gas composition and process efficiency to reactor temperature, steam/coal ratio and recycle gas/coal ratio.
- Evaluate the cyclone cold wall as a means of reducing accumulation of solids.
- Continue heat recovery experiments.
- Evaluate gasifier operability with Texas lignite as the feedstock.

This test demonstrated the effectiveness of the modified oxidant tube for avoiding formation of sintered material. A new apparatus in the cyclone, using a "cold-wall" principle, showed promise as a means of controlling solids buildup downstream of the gasifier.

The test took place in three campaigns. The first was ended when solids buildup from a small ledge in the gasifier outlet piping restricted product gas flow. The second was terminated by the ignition of an accumulation of flammable gas in the head space of the water separation pit; only minor equipment damage resulted. Final shutdown was caused by numerous interruptions in the flow of lignite feedstock, due to moisture, which led to operational upsets in the grid area and eventual formation of a clinker.

The total onstream time for test TP-023-4 was 175.5 hours. Pittsburgh seam coal was fed to the gasifier for 106.5 hours; Texas lignite feeding took place during the last 14 hours of the test. Three steady-state periods of significant duration were accomplished with Pittsburgh seam coal.

2.1.2 Gasifier Test TP-027-1

Test TP-027-1 was the first of a series of high-pressure oxygen-blown gasifier tests with coal feedstocks. Shakedown of the entire PDU for this configuration was a priority item for this test. Otherwise, the objectives of test TP-027-1 were to:

- Establish baseline data for gasification of Indiana #7 coal with oxygen at 230 psig.
- Operate with Indiana #7 coal and Texas lignite feedstocks at high oxygen concentrations in the oxidant tube to generate data at low steam/coal and recycle gas/coal ratios.
- Continue heat recovery experiments.
- Further evaluate water injection and the cyclone cold wall insert as a means of controlling solids accumulation in the cyclone.
- Demonstrate carbon conversion at 90 percent with heat and material balance closures within 5-10 percent for total mass balances and carbon balances.
- Evaluate raw gas composition and process efficiency relative to steam/coal and recycle gas/coal ratios and to gasifier temperatures.
- Study the relationship of withdrawal rate with bed ash content.

PDU operation at the higher pressure was successfully demonstrated.

The modified oxidant tube allowed injection of 63-65 percent (vol) oxygen without sintering. Ash withdrawal concentrations ranged from 60-80 percent. Run termination was dictated by plugging of a gas cooler in the recycle gas system.

The total onstream time for TP-027-1 was 87 hours, during which a blend of Ohio #9 and Indiana #7 coal was fed for 69.5 hours. Lignite feedstock was not tested as planned as a result of the premature shutdown.

2.1.3 Gasifier Test TP-027-2

Test run TP-027-2 was the second in a series of oxygen-blown single-stage gasifier tests at 225 psig. Specific objectives of test TP-027-2 were to:

- Establish base-case performance data and demonstrate gasifier operability for oxygen-blown gasification of high-ash bituminous coals, Ohio #9 and Pittsburgh seam, at 225 psig.
- Evaluate gasifier operability with Texas lignite as the feedstock.
- Operate the modified oxidant tube at oxygen concentrations of at least 60 percent.
- Achieve and maintain greater than 70 percent ash concentration in the withdrawal stream.
- Continue testing of water injection, the cyclone cold wall, and the heat recovery system.

Test TP-027-2 was a continuation of oxygen-blown single-stage gasifier testing at 225 psig, which began with test TP-027-1 in April. Operation of the PDU was relatively smooth during TP-027-2, with significant operating periods where Pittsburgh seam and Ohio #9 coals were used as feedstocks. The test was interrupted for a few hours for repair of a leaking exchanger; combustion was not quenched during this period. The modified oxidant tube continued to perform well. Ash concentrations in the withdrawal stream were consistent and ranged between 60 and 75 percent. Run termination was necessary when bed defluidization occurred as a result of attempts to clear a congestion in the grid area of the gasifier.

The total onstream time for test run TP-027-2 was 164.5 hours, during which Ohio #9 coal was fed for 61 hours and Pittsburgh seam coal was fed for 64 hours. Lignite feedstock was not tested as planned as a result of a premature shutdown.

2.1.4 Gasifier Test TP-027-3

Test TP-027-3, a high-pressure oxygen-blown gasifier test with Texas lignite, Pittsburgh #8 and Upper Freeport seam coals, was initiated on June 12, 1980. This test will be completed in July, the results of which will be discussed in the next quarterly report.

2.2 PROCESS ANALYSIS AND DESIGN

2.2.1 Cyclone Deposit Control

The chemical characterization of cyclone deposits from test TP-027-3 was completed. The results indicate that, in addition to the crystalline $Fe_{1-x}S$ glue, there is possibly an amorphous sulfur-containing compound that provides a binding matrix for the deposits.

Hardware developments in the area of deposit control include a demonstration of the viability of quench water injection as a means of eliminating cyclone deposits in the PDU. Further, a scoping evaluation was conducted on the cyclone cold wall concept that promises to be a potential long-term solution to this problem.

2.2.2 PDU Operational Analysis

A cause-effects analysis was conducted on the recycle gas after cooler plug incident that occurred during gasifier test TP-027-1. The analysis shows that the plug was a result of fines lodging in a separator vessel located downstream of the cooler and eventually caused the deposition to backfill into the cooler.

The precision and accuracy of product gas flow measurement at the PDU were investigated. A systems model based on control theory shows that, in order to reduce the oscillations recorded on the flow meter, it will be necessary to sacrifice the tolerance on the maximum deviation in system pressure from set

point conditions. The inaccuracies in measurement during test TP-023-4 were ascribed to a buildup of material on the orifice plate. Steps have been taken to routinely inspect and clean the orifice plate after each shutdown to minimize system inaccuracies in the flow measurement.

2.2.3 PDU Process Analysis

Fines carryover data from the 1978 gasifier test series was correlated using an elutriation constant method of relating the carryover rate to the particle size, the fluidized bed properties and the operating velocities.

A steady-state ash balance was performed using generalized parameters to describe various modes of operation on the PDU gasifier. A functional relationship was obtained between the ash content in the bed and that in the withdrawal stream.

2.3 PROCESS AND COMPONENT ENGINEERING AND DESIGN

Process and component engineering work accomplished this quarter consisted of a variety of tasks.

- Following commissioning of the high-pressure oxygen supply pump, a new, larger tank pressure building coil was installed and commissioned.
- System and component design, as well as process and instrumentation and component drawings, were completed for the advanced heat recovery test loop. Fabrication of components is approximately 80 percent complete.
- The bid package for the design phase of the PDU power upgrade was approved and a contract awarded.
- The design for power feed upgrading of the steam system was completed.
- Electrical/instrumentation installation for the total condensable analyzer was completed.

In fines recycle and utilization work:

- The surge vessel, all material required to fabricate the fines coolers, including the internals, and all piping, valves, and fittings for the glycol cooling loop were received on site.
- The fabrication drawings for the fines coolers and the preliminary arrangement drawing for major piping spool pieces and vessels were completed.
- Fabrication of the C-120 particulate separation vessel was initiated, with the refractory clips, refractory and nozzle sleeves ordered and received.

2.4 SCALE-UP MODEL

During this report period, general contractor site work was completed except for miscellaneous items and preparation of the final deficiency list for building acceptance by Westinghouse. In addition, all six model test sections were finish-welded, three of which were finish-machined and delivered to the site. Following erection of the observation platform, the first two model sections, as well as the drawoff cone and the feed tube, were installed in the observation platform structure.

The model internals were assembled as a single unit, which is now being prepared for installation in the interior of the model sections.

In other work, the design of the in-line filters for the air compressors and the lifting beams for the main model was completed. Precommissioning activities for the scale-up facility were initiated, including preparation of equipment and valve lists and operating procedures for the main air compressor subsystems.

Currently, a setup for hydrotest of the cooling water lines is being prepared, installation of process piping is continuing, and the initial charge of bed material is being prepared for shipment to the site.

2.5 LABORATORY SUPPORT STUDIES

2.5.1 Gas-Solids Flow Modeling

Experiments using a jet nozzle configuration similar to that employed in the PDU are continuing. Tracer gas is injected into the jet to simulate the oxygen flow and gas samples are collected from the bed to investigate the dispersion of the tracer. The literature data on jet penetration were analyzed to test the correlation developed previously. A correlation was developed which successfully correlated recent jet penetration data available in the literature.

The experiments to study the rate of particle separation for the acrylic-dolomite system were completed, the results of which are discussed in Section 7.1. Exploratory experiments are being conducted with different pairs of materials of different density ratios in order to select a suitable pair for further studies.

2.5.2 Coal/Ash Behavior Gasification

Gasification - A screening test and procedure for coal/char characterization on the thermogravimetric analyzer (TGA) was established to obtain reproducible data.

Ash Agglomeration - Three steady-state ash agglomeration tests were completed using coke breeze and Indiana #7 coal. Operating temperatures and fines concentrations were investigated.

Deposit Control - A program to develop deposit control techniques was formulated, consisting of three parallel efforts:

- A deposition formation mechanism study to determine the mineral compounds in coal that are responsible for deposit formation. Samples of various coals, including Pittsburgh, Montana, Western Kentucky, and Indiana, as well as Texas lignite were analyzed by infrared spectra and by chemical analyses. Pittsburgh coal, which was shown to have high concentrations of pyrite and hydrated potassium-aluminum-silicon oxides, was expected to have a high fouling potential. Montana coal would be moderately fouling, followed by Western Kentucky and Indiana coals and Texas lignite.
- Development of a coal screening test for deposit potential. The agglomerating combustor/gasifier at the Westinghouse R&D Center will be used for the coal deposit potential screen test development. A probe to be installed in the unit freeboard was designed.
- A deposit control technique development effort was initiated to assess the commercial feasibility of water injection and hardware cooling as deposit control techniques.

2.5.3 Gasifier System Model Integration

A tentative sequence for a design procedure was established and a compilation of all available models/correlations describing the relevant phenomena is being prepared.

2.5.4 Particulate/Chemical Profiles and Control

The solids handling and heat transfer requirements associated with the proposed continuous recycle of char carryover from the PDU fluidized bed gasifier were analyzed. The analysis focused on (1) determining the total recycle rate as a function of bed operating parameters and (2) investigating various options for cooling the recycle char to temperatures ($\sim 400^{\circ}\text{F}$) that the proposed starwheel feeder can tolerate.

2.5.5 Environmental Impact Assessment

The final RCRA Phase I regulations on hazardous waste management as promulgated on May 19 were reviewed to assess the impact on Westinghouse gasification ash agglomerates disposal. An analysis of the effects of leaching medium, solids particle size and contact surface area on leachate characteristics was completed on TP-020-2 ash agglomerates.

2.6 SUMMARY SCHEDULES

Task Description	FY 1980			FY 1980		
	APR	MAY	JUNE	JULY	AUG	SEPT
<u>Operation and Maintenance of the PDU</u>						
Single-Stage Gasifier Operation						
Gasifier Oxygen-Blown						
Gasifier Air-Blown						
Maintenance and Test Modification	-----	-----	-----	-----	-----	-----
Two-Stage Operation	-----				-----	-----
Gas Characterization, Treatment and Utilization						
Systems Integration, Control and Reliability				-----	-----	-----
<u>PDU Modifications</u>						
Modification for Improved Operation						
Coal Preparation	-----	-----	-----	-----	-----	
Power Distribution
Modification for Oxygen Gasification						
Oxygen System Upgrading	-----	-----	-----	-----	-----	
Modification for Gas Characterization, Treatment and Utilization						
Gas Characterization Upgrading	-----	-----	-----	-----	-----	-----
Fines Collection and Recycle	-----	-----	-----	-----	-----	-----
Structural Modifications
Heat Recovery Phase I	-----	-----	-----	-----	-----	-----
Modification for System Integration, Control and Reliability			
PDU/TDC Pipeline	-----	-----	-----	-----	-----
<u>Scale-Up Design and Analysis</u>						
Operation of Cold Flow Scale-Up Facility	-----	-----	-----	-----	-----	-----
Process and Systems Analysis and Design			

LEGEND:

Task Complete ▼
 Test _____
 Eval./Test -----
 Planning - - - - -

Design/Approval
 Procurement -----

Construction/Modification -----

Task Description	FY 1980			FY 1980		
	APR	MAY	JUNE	JULY	AUG	SEPT
<u>Laboratory Support Studies</u>						
Gas-Solids Flow Modeling						
Jet Phenomena						
PDU Simulation Tests			▼ ¹			
Circular Unit		▼ ²				
Coal Feed Particle History						
Char/Ash Separation						
Acrylic-Dolomite Mixture Simulation				▼ ³		
Density Effect Tests						
PDU Char/Ash						
Dynamic Test Simulation						
CFSF						
Coal/Ash Behavior						
Devolatilization/Combustion						
Gasification						
Coal Characterization Tests						
Ash Agglomeration						
Reactor Tests						
Model Development						
Deposit Control						
Formation Mechanism						
Screening Test						
Control Technique Dev.						
Gasifier System Model Integration						
Particulate/Chemical Profiles and Control						
Particulate						
Fines Recycle Analysis			▼ ⁴			
PDU Data Analysis						

Task Description	FY 1980			FY 1980		
	APR	MAY	JUNE	JULY	AUG	SEPT
<u>Laboratory Support Studies (Cont'd.)</u>						
Alkali						
PDU Measurement Support						
Sulfur						
Ammonia						
Environmental Impact Assessment						
Ash Agglomerates						
Screening Tests						5▼
RCRA Impact				6▼	7▼
Solid/Liquid Residues						8▼

1. Complete velocity profiles mapping for jet nozzle similar to that in the PDU.
2. Design completed and bids received, awaiting decision to construct.
3. Complete rate of particle separation studies for acrylic-dolomite mixture; preliminary mathematical model developed; initiate tests with hollow spheres-cork mixture to study density ratio effect.
4. Topical report issued.
5. Perform screening tests on TP-023-4 (Texas lignite ash agglomerates).
6. RCRA Phase I regulations impact assessed.
7. Perform RCRA/EP test on TP-023-4.
8. Complete TP-025-2 separation pit sludge screening tests.

SECTION 3.0

PDU TEST OPERATIONS AND RESULTS

3.1 GASIFIER OPERATION

3.1.1 Gasifier Test TP-023-4

A single-stage, oxygen-blown gasifier test, TP-023-4, was conducted from March 6 to April 2, 1980. Prior to this test startup, the following modifications were made to the cyclone collection system: (1) a cold wall segment was embedded in the cyclone barrel, with the metal wall exposed to the incoming hot dust-laden gas, and (2) the gasifier/cyclone connecting spool piece was recast to a rectangular inlet configuration. The former geometry was a circular-to-rectangular transition.

The objectives of test TP-023-4 were to:

- Demonstrate the operability of the gasifier with the modified oxidant tube at an oxygen concentration greater than 50 percent and evaluate the effectiveness of the modified tube in reducing tube buildup.
- Provide data for the evaluation of product gas composition and process efficiency as a function of gasifier temperature, steam-to-coal ratio and recycle-gas-to-coal ratio.
- Evaluate the cold wall as a method of controlling solids deposits in the cyclone.
- Operate and obtain data from the heat recovery test loop.
- Evaluate the operability of the gasifier using Texas lignite.

The test was conducted in three campaigns. During the first campaign, PDU operations were initiated on March 6, 1980 with pressurization, leak check and hot air dryout. After completing 33 hours of hot operation, which was comprised of 8 hours of Pittsburgh #8 seam coal feed, an abnormally high pressure drop was noted across the cyclone, necessitating a shutdown. During coal feed operations, the gasifier quench spray injection was not employed, which permitted an independent evaluation of the cold wall concept as a means of combatting cyclone deposition. A post-test inspection revealed that the impedance was caused primarily by material deposition in the cyclone inlet piping. During reassembly of the PDU hardware prior to the test, there was a slight misalignment of the gasifier-to-cyclone spool piece, such that a small refractory ledge 1/4-inch high extended into the gas stream. It appears that solids impinged and adhered on this ledge, restricting the gas flow. An

inspection of the cyclone internals showed that the metal cold wall was virtually free of solids buildup, whereas the uncooled refractory portion of the barrel was coated with a minor accumulation of material.

After conducting repairs on the cyclone inlet piping, the test was resumed on March 19. The test plan was modified to include operation of the gasifier water spray injection system to quench the off-gas and the entrained solids below the estimated eutectic temperature of the "glue" present in the solids. PDU operations proceeded smoothly through initiation of Pittsburgh coal feed, and while preparations were under way to start set point 1, an incident not directly concerned with gasifier operation forced a premature termination of the test. The incident related to a minor detonation of combustible gases in the head space of the waste water separation pit, which resulted in damage to the metal cover of the pit and to a duct that connects the pit's vent blower to the thermal oxidizer. During this campaign, 22 hours of hot operation were logged, with approximately 10 hours in the coal-feed mode.

Immediately following this incident, an extensive safety review was conducted. Discoveries made and corrective actions taken include:

- The Z-107 vessel, which collects the blowdowns from the water quench system, was previously arranged to vent to the thermal oxidizer. A portion of the vent header, however, is underground; this portion was found to be blocked by a pocket of water and process solids.
- Inspection of the gasifier relief devices showed that the rupture disc was wrinkled and had a pinhole leak, such that raw gas could escape and backflow from the blocked vent header and Z-107 to the separator pit.
- The separator pit blower itself does not appear to have been the source of ignition. The blower has an induction motor; clearances and grounding all appear satisfactory.
- The vent header line was cleaned and pressure gauges have been installed at both ends of the line to allow detection of any restriction to flows.
- The Z-107 vessel is now vented directly to the separator pit, such that the tie-in from the vent header to Z-107 to the pit is avoided.
- Several modifications were made in the blower and pit system:
 - The blower was relocated to a new pad near the thermal oxidizer.
 - Flame arrestors were installed at the blower inlet and just before the duct connects to the thermal oxidizer.

- A 3-inch diameter vent was installed in the vent cover to avoid negative gauge pressure below the cover.
- Drain valves were installed in the duct so that disconnection is not necessary for drainage.
- A combustible gas monitor was installed at the separator pit.
- Procedural modifications include the following:
 - The underground portion of the vent header line is inspected prior to each test run.
 - Scrubber blowdowns are controlled to avoid blowing flammable gas to Z-107.

Test TP-023-4 was reinitiated on March 24. After a normal startup phase, set point 1 conditions were achieved on March 27 at 1900 hours. The goals of this set point were to conduct a 48-hour duration test with Pittsburgh #8 seam coal at a freeboard temperature of 1825°F, a recycle-gas-to-MAF-coal ratio of 2.10 and a steam-to-MAF-coal ratio of 1.05, and further to characterize the performance of the modified oxidant feed tube at an oxygen concentration of 50 percent. During this set point, smooth operation of the gasifier was demonstrated at a temperature of 1825°F and at reduced recycle gas and steam usage rates that were, respectively, 1.5 and 0.9 on a pound/pound MAF coal basis. The oxidant tube was operated at an oxygen concentration of 59 percent without any evidence of ash sintering at the tip of the tube. This set point logged 48 hours of operation and was divided into two steady-state periods, 1A and 1B.

On March 30 at 0530 hours, set point 2 was initiated, which was a similar evaluation of the performance of the gasifier but at the lower temperature of 1725°F. As in set point 1, the economies achieved in recycle gas and steam usage surpassed the requirements of the test plan. A total of 43 hours of operation was logged in this period.

Set point 3 was planned as a scoping evaluation of Texas lignite. After an interim bed turnover and cooldown period, lignite feed was initiated on April 1 at 1045 hours. During this set point, frequent interruptions in the coal feed were encountered due to the high moisture content of 24 percent in the lignite. However, with the aid of the multifeed system, which delivers feedstock from independent lock hopper trains into a common pneumatic transport line, it was possible to sustain feed during these interruptions in any one system by temporarily increasing the coal feed in another train. At 2140 hours on April 1, simultaneous blockages in both systems caused a total loss of lignite feed to the gasifier. The carbon inventory in the bed was depleted and a temperature excursion was noticed in the grid area of the gasifier, which contributed to a blockage of ash withdrawal from the gasifier. The test was terminated on April 2 after completing 10 hours of lignite testing.

A post-test inspection of the cyclone showed that the inlet piping and the cyclone barrel were essentially free of solids accumulation. This condition was attributed to the quench water injection system, which was operational all through the third campaign of this test. Post-test inspection of the gasifier vessel showed a buildup of material in the grid area, attributed to the loss of lignite feed to the gasifier.

A chronology of test events is shown in Table 3.1-1 and a summary of steady-state data is presented in Table 3.1-2. Heat and material balances are presented in Tables 3.1-3 to 3.1-7. Product gas flow measurement data for this test were invalid because of a buildup of material on the orifice plate. Hence the balances were performed by simultaneously forcing closures for hydrogen and oxygen species. Figure 3.1-1 is a flow schematic for the balances.

Notable accomplishments of test TP-023-4 are as follows:

- A total of 146 hours of hot operation was logged, including 117 hours of Pittsburgh coal feed (46 tons) and 12 hours of Texas lignite feed (9 tons).
- Operability of the modified oxidant feed tube was demonstrated at oxygen concentrations between 53 and 63 percent.
- Stable operation of the char-ash annulus was possible by the total absence of sintered ash deposits from the oxidant tube tip. In earlier oxygen-blown gasifier tests of the 1978-79 campaigns, this was a chronic problem, particularly with Pittsburgh seam coal at oxygen concentrations less than 40 percent.
- The cyclone cold wall concept was identified as a promising candidate for solving the cyclone deposition problem in a thermally efficient manner. The use of quench water injection was shown to be an expedient means of avoiding cyclone buildup in the PDU, thereby permitting long-duration testing of the gasifier.
- Heat recovery testing was achieved for approximately 23 hours. Data on heat transfer characteristics are reported in Section 3.2.

3.1.2 Gasifier Test TP-027-1

TP-027-1 marked the first of a series of high-pressure, 230-psig tests on the single-stage oxygen-blown gasifier. Prior to this test, experience on the PDU oxygen-blown gasifier was confined to operation at a pressure of 130 psig. This test was intended to be a checkout test of the modified oxygen storage and delivery system using an Indiana #7 seam coal as the feedstock. Some of the other objectives of this test were to:

TABLE 3.1-1
 CHRONOLOGICAL SUMMARY OF EVENTS, TEST TP-023-4

DATE	TIME	EVENT
		FIRST STARTUP
3-6-80	0030	Initiated pressurization and leak check
	1600	Depressurized system
	1800	Repaired leaks
3-7-80	0000	Initiated pressurization and leak check
	0800	Conducted operational checkout of cyclone cold wall flow loop
	1600	Ramped temperature to 250°F, began hot air dryout
3-8-80	0800	Ramped temperature to 500°F, began hot air dryout
3-9-80	0900	Started up feed systems
3-10-80	0600	Established coke breeze bed
	1530	Achieved autogenous ignition
	1600	Ramped temperature to 1800°F
3-11-80	0620	Initiated oxygen flow to gasifier
	1600	Initiated coal feed
	2045	Initiated fines recycle
	2200 to 2400	Observed increase in cyclone pressure drop
3-12-80	0000	Initiated routine shutdown and interim inspection
		SECOND STARTUP
3-19-80	0235	Started system pressurization
	1046	Achieved acceptable leak rate, began ramping temperatures
3-20-80	0345	Began 12-hour hot air dryout hold
	2300	Initiated coke breeze feed to gasifier

TABLE 3.1-1 (Continued)

DATE	TIME	EVENT
3-21-80	0935	Achieved autogenous ignition
	1930	Initiated oxygen flow to gasifier
	2125	Initiated feeding Pittsburgh seam coal to gasifier
3-22-80	0035	Initiated recycle fines feed to gasifier
	0145 to 0710	Experienced minor detonation of combustible gases in the separator pit, initiated shutdown to investigate the incident and repair the disabled separator pit fan housing
THIRD STARTUP		
3-24-80	0410	Initiated computer controlled pressurization of system for restart
3-25-80	0700	Achieved acceptable leak rate, began ramping gasifier temperatures
3-26-80	0010	Started 12-hour hot air dryout hold
	1600	Initiated coke breeze feed to gasifier
	2310	Achieved autogenous ignition
3-27-80	0605	Initiated oxygen flow to gasifier
	0900	Initiated Pittsburgh seam coal feed
	1335	Initiated recycle fines feed to gasifier
3-27-80	1900	<u>Achieved Set Point No. 1A conditions</u>
	2210 to 0230	Began feeding coke breeze as a result of problems with transferring coal to C-103A lockhopper
3-28-80	0230	Restored Pittsburgh coal feed
	0335	Began recycling fines to gasifier
3-29-80	1300	<u>Achieved Set Point No. 1B conditions</u>
3-30-80	0530	<u>Achieved Set Point No. 2 conditions</u>
3-31-80	1430	Started heat recovery experiment

TABLE 3.1-1 (Continued)

DATE	TIME	EVENT
4-01-80	0021	Began decreasing reactor temperatures for transition to lignite feedstock
	1045	Initiated lignite feed to gasifier
	1315	Started feeding recycled fines
	1330	<u>Achieved Set Point No. 3 conditions</u>
	2140	Loss of lignite feed through C-103 and C-109 systems
	2150 to 2230	Restored lignite feed through C-103 and C-109 systems
	2250	Temperature excursion on bed thermocouples - the oxygen flow was reduced because of problems in feeding lignite to the gasifier.
4-02-80	0020 to 0035	Unable to recover normal operation. Lost ash withdrawal, indicating a restriction at the top of the ash annulus. Terminated test TP-023-4

TABLE 3.1-2

SUMMARY OF OPERATING DATA FOR GASIFIER TEST TP-023-4

Steady State		1A	1B	2A	2B	3
TEST RUN DATE AND TIME (1980)	Unit	Hours 3/28-29/80 1230-0730	Hours 3-29-80 1700-2300	Hours 3-31-80 0830-1600	Hours 3-31-80 1630-2100	Hours 4-1-80 1630-1930
<u>MEASURED GASIFIER PARAMETERS</u>						
Freeboard Temperature	°F	1821	1820	1786	1779	1524
Gasifier Bed Temperature	°F	1852	1850	1824	1816	1532
Ash Annulus Temperature	°F	939	923	1268	1295	835
Average Bed Height*	feet	10.33	10.45	10.54	11.08	10.17
System Pressure	psig	135	135	135	134	135
Average Gasifier Bed Density	lb/ft ³	16.69	17.10	14.51	15.06	21.50
Average Annulus Density	lb/ft ³	11.94	11.84	12.59	13.05	17.84
Freeboard Gas Velocity	fps	1.93	1.88	1.83	1.82	1.72
Oxidant Tube Velocity	fps	99	100	99	100	87
Oxygen Concentration	%	58	58	53	52	63
Coal Feed Material		Pgh. Seam	Pgh. Seam	Pgh. Seam	Pgh. Seam	Lignite
Coal Feed Rate	lb/hr	890	856	718	681	1546
Fines Feed Material				Recycle Fines		
Fines Feed Rate	lb/hr	279	263	248	257	411
Cyclone Collection Rate	lb/hr	288	300	248	259	432
Carryover to Water System**	lb/hr	105	207	100	133	80
Ash Withdrawal Rate	lb/hr	47	43	48	35	325
<u>PRODUCT GAS ANALYSIS, DRY BASIS</u>						
Carbon Monoxide	%	38.14	37.63	34.36	34.55	25.93
Carbon Dioxide	%	26.84	30.28	34.64	35.66	43.66
Methane	%	4.11	3.55	3.60	3.29	6.89
Nitrogen	%	0.00	0.00	0.00	0.00	0.00
Hydrogen Sulfide	%	0.54	0.50	0.53	0.51	0.37
Hydrogen	%	30.36	28.04	26.88	26.00	23.15
HHV, Dry Basis (Gas Chromatograph)	Btu/scf	262	247	234	228	228
<u>OVERALL PROCESS RATES</u>						
Steam/Coal Ratio, MAF+	lb/lb	0.91	1.01	1.25	1.33	0.42
Oxygen/Coal Ratio, MAF	lb/lb	1.06	1.17	1.21	1.25	0.97
Total Moisture/Coal Ratio, MAF	lb/lb	1.91	2.01	2.25	2.33	1.42
Recycle Gas/Coal Ratio, MAF	lb/lb	1.41	1.68	2.23	2.45	2.05
<u>SOLIDS ANALYSIS</u>						
Ash Content - Fines	%	25.36	22.47	21.61	20.36	42.92
Ash Content - Feedstock	%	7.03	9.94	7.57	7.31	21.52
Ash Content - Bed	%	29.51	28.19	34.11	40.40	59.72
Ash Content - Agglomerate	%	67.89	66.63	63.11	57.34	86.81

+Moisture and ash free.

*From jet inlet to top of bed.

**Estimated from ash balance.

TABLE 3.1-3
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-023-4, SET POINT 1A

STREAM NO.		1	2	3	4	5	6	7
STREAM DESCRIPTION		STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING
TOTAL	LB/HR	226.00	511.00	0.00	0.00	214.00	0.00	169.15
TEMPERATURE	F	418.0	438.0	0.0	0.0	102.0	209.0	188.0
GAS	LB/HR	226.00	511.00	0.00	0.00	214.00	0.00	169.15
SOLID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	18.016	18.016	28.963	44.011	23.923	23.923
CO	VOLUME X	0.00	0.00	0.00	0.00	0.00	37.48	37.48
CO2	VOLUME X	0.00	0.00	0.00	0.00	100.00	26.94	26.94
H2	VOLUME X	0.00	0.00	0.00	0.00	0.00	30.21	30.21
CH4	VOLUME X	0.00	0.00	0.00	0.00	0.00	4.42	4.42
H2S	VOLUME X	0.00	0.00	0.00	0.00	0.00	0.50	0.50
N2	VOLUME X	0.00	0.00	0.00	78.06	0.00	0.00	0.00
O2	VOLUME X	0.00	0.00	0.00	21.00	0.00	0.00	0.00
AR	VOLUME X	0.00	0.00	0.00	0.94	0.00	0.00	0.00
H2O	VOLUME X	100.00	100.00	100.00	0.00	0.00	0.46	0.46
ELEMENTS								
CARBON	LB/HR	0.000	0.000	0.000	0.000	58.403	0.000	58.457
HYDROGEN	LB/HR	25.290	57.181	0.000	0.000	0.000	0.000	5.703
OXYGEN	LB/HR	202.710	453.819	0.000	0.000	155.597	0.000	103.864
NITROGEN	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SULFUR	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	1.128
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT	KBTU/HR	34.978	83.898	0.000	0.000	1.116	0.000	719.842

TABLE 3.1-3 (Continued)
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-023-4, SET POINT 1A

STREAM NO.		8	9	10	11	12	13	14
STREAM DESCRIPTION		BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-29)	COAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	FINE FEED & TRANS. G.
TOTAL	LB/HR	186.71	690.47	68.40	1462.16	854.00	0.00	490.67
TEMPERATURE	F	209.0	209.0	0.0	180.0	507.0	507.0	301.0
GAS	LB/HR	186.71	690.47	68.40	572.16	854.00	0.00	211.67
SOLID	LB/HR	0.00	0.00	0.00	890.00	0.00	0.00	279.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		23.923	23.923	23.923	23.923	32.300	44.011	23.923
CO	VOLUME %	37.48	37.48	37.48	37.48	0.30	0.00	37.48
CO2	VOLUME %	26.94	26.94	26.94	26.94	0.30	100.00	26.94
H2	VOLUME %	30.21	30.21	30.21	30.21	0.30	0.00	30.21
CH4	VOLUME %	4.42	4.42	4.42	4.42	0.30	0.00	4.42
H2S	VOLUME %	0.50	0.50	0.50	0.50	0.30	0.00	0.50
N2	VOLUME %	0.00	0.00	0.00	0.00	0.30	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	100.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.30	0.00	0.00
H2O	VOLUME %	0.46	0.46	0.46	0.46	0.30	0.00	0.46
ELEMENTS								
CARBON	LB/HR	64.526	238.620	23.638	869.771	0.000	0.000	274.589
HYDROGEN	LB/HR	6.295	23.279	2.306	66.994	0.000	0.000	8.141
OXYGEN	LB/HR	114.648	423.970	42.000	428.752	854.000	0.000	130.921
NITROGEN	LB/HR	0.000	0.000	0.000	13.706	0.000	0.000	1.479
SULFUR	LB/HR	1.246	4.605	0.456	20.371	0.000	0.000	4.788
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	62.567	0.000	0.000	70.754
HEAT CONTENT	KBTJ/HR	795.860	2943.105	286.990	14661.075	83.199	0.000	3848.890

TABLE 3.1-3 (Continued)
 GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-023-4, SET POINT 1A

STREAM NO.		15	16	17	18	19		
STREAM DESCRIPTION		LIQUID WATER INJECTION	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	825.00	4742.04	935.03	47.00	6.00	0.00	-0.57
TEMPERATURE	F	50.0	1132.0	200.0	73.0	1826.0	0.0	0.0
GAS	LB/HR	0.00	4637.04	647.03	0.00	0.00	0.00	0.00
SOLID	LB/HR	0.00	105.00	288.00	47.00	6.00	0.00	0.00
LIQUID	LB/HR	825.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	21.726	23.923	0.000	0.000	0.000	0.000
CO	VOLUME %	0.00	23.84	37.48	0.00	0.00	0.00	0.00
CO2	VOLUME %	0.00	16.77	26.94	0.00	0.00	0.00	0.00
H2	VOLUME %	0.00	18.98	30.21	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.00	2.57	4.42	0.00	0.00	0.00	0.00
H2S	VOLUME %	0.00	0.34	0.50	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	100.00	37.50	0.46	0.00	0.00	0.00	0.00
ELEMENTS								
CARBON	LB/HR	0.000	1182.799	431.542	14.387	4.127	0.000	-2.824
HYDROGEN	LB/HR	92.318	266.942	22.851	0.099	0.019	0.000	-0.836
OXYGEN	LB/HR	732.682	3240.752	398.274	0.160	0.002	0.000	0.049
NITROGEN	LB/HR	0.000	0.556	1.526	0.122	0.036	0.000	85.241
SULFUR	LB/HR	0.000	24.368	7.801	0.324	0.046	0.000	0.171
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	26.628	73.037	31.908	1.771	0.000	-0.017
HEAT CONTENT	KBTU/HR	-888.607	16508.457	5787.472	210.763	62.727	425.000	-1.879

TABLE 3.1-4
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-023-4, SET POINT 1B

STREAM NO.		1	2	3	4	5	6	7
STREAM DESCRIPTION		STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING
TOTAL	LB/HR	226.00	517.00	0.00	0.00	214.00	0.00	173.81
TEMPERATURE	F	418.0	438.0	0.0	0.0	102.0	209.0	188.0
GAS	LB/HR	226.00	517.00	0.00	0.00	214.00	0.00	173.81
SOLID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	18.016	18.016	28.963	44.011	25.258	25.258
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	36.77	36.77
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	30.80	30.80
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	27.77	27.77
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	3.73	3.73
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.48	0.48
N2	VOLUME %	0.00	0.00	0.00	78.06	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00
H2O	VOLUME %	100.00	100.00	100.00	0.00	0.00	0.46	0.46
ELEMENTS								
CARBON	LB/HR	0.000	0.000	0.000	0.000	58.403	0.000	58.931
HYDROGEN	LB/HR	25.290	57.069	0.000	0.000	0.000	0.000	5.018
OXYGEN	LB/HR	200.710	452.931	0.000	0.000	155.597	0.000	108.807
NITROGEN	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SULFUR	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	1.054
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT	KBTU/HR	34.978	63.733	0.000	0.000	1.116	0.000	655.581

TABLE 3.1-4 (Continued)
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-023-4, SET POINT 1B

STREAM NO.		8	9	10	11	12	13	14
STREAM DESCRIPTION		BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-29)	COAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	FINE FEED & TRANS. G.
TOTAL	LB/HR	191.86	709.49	82.63	1494.25	854.00	0.00	480.50
TEMPERATURE	F	209.0	209.0	0.0	180.0	507.0	507.0	301.0
GAS	LB/HR	191.86	709.49	82.63	638.25	854.00	0.00	217.50
SOLID	LB/HR	0.00	0.00	0.00	856.00	0.00	0.00	263.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		25.258	25.258	25.258	25.258	32.000	44.011	25.258
CO	VOLUME %	36.77	36.77	36.77	36.77	0.00	0.00	36.77
CO2	VOLUME %	30.80	30.80	30.80	30.80	0.00	100.00	30.80
H2	VOLUME %	27.77	27.77	27.77	27.77	0.00	0.00	27.77
CH4	VOLUME %	3.73	3.73	3.73	3.73	0.00	0.00	3.73
H2S	VOLUME %	0.48	0.48	0.48	0.48	0.00	0.00	0.48
N2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	100.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.46	0.46	0.46	0.46	0.00	0.00	0.46
ELEMENTS								
CARBON	LB/HR	65.049	240.553	28.016	825.274	0.000	0.000	271.546
HYDROGEN	LB/HR	5.539	20.485	2.386	62.512	0.000	0.000	7.174
OXYGEN	LB/HR	120.104	444.147	51.728	492.687	854.000	0.000	137.157
NITROGEN	LB/HR	0.000	0.000	0.000	13.525	0.000	0.000	1.394
SULFUR	LB/HR	1.164	4.303	0.501	15.170	0.000	0.000	4.133
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	85.086	0.000	0.000	59.096
HEAT CONTENT								
	KBTU/HR	724.906	2680.718	306.942	13363.600	83.199	0.000	3705.916

TABLE 3.1-4 (Continued)
 GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-023-4, SET POINT 1B

STREAM NO.		15	16	17	18	19		
STREAM DESCRIPTION		LIQUID WATER INJECTION	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	889.00	4866.06	964.85	43.00	6.30	0.00	-2.34
TEMPERATURE	F	50.0	1132.0	208.0	73.0	1826.0	0.0	0.0
GAS	LB/HR	0.00	4559.06	664.85	0.00	0.30	0.00	0.00
SOLID	LB/HR	0.00	207.00	300.00	43.00	6.30	0.00	0.00
LIQUID	LB/HR	889.00	0.00	0.00	0.00	0.30	0.00	0.00
MOLECULAR WEIGHT		18.016	22.327	25.258	0.000	0.030	0.000	0.000
CO	VOLUME %	0.00	22.67	36.77	0.00	0.03	0.00	0.00
CO2	VOLUME %	0.00	18.24	30.80	0.00	0.03	0.00	0.00
H2	VOLUME %	0.00	16.89	27.77	0.00	0.03	0.00	0.00
CH4	VOLUME %	0.00	2.14	3.73	0.00	0.03	0.00	0.00
H2S	VOLUME %	0.00	0.30	0.48	0.00	0.03	0.00	0.00
N2	VOLUME %	0.00	0.00	0.00	0.00	0.03	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	0.03	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.03	0.00	0.00
H2O	VOLUME %	100.00	39.76	0.46	0.00	0.03	0.00	0.00
ELEMENTS								
CARBON	LB/HR	0.000	1234.622	451.048	13.825	4.196	0.000	-10.074
HYDROGEN	LB/HR	90.528	258.289	20.216	0.099	0.018	0.000	-0.950
OXYGEN	LB/HR	718.472	3333.172	417.342	0.004	0.030	0.000	0.423
NITROGEN	LB/HR	0.000	1.097	1.590	0.146	0.037	0.000	00.759
SULFUR	LB/HR	0.000	22.368	7.242	0.275	0.050	0.000	-13.740
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	46.513	67.410	28.651	1.691	0.000	-0.057
HEAT CONTENT								
	KBTU/HR	-871.374	16155.821	5788.953	203.417	63.729	425.000	-9.040

TABLE 3.1-5
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-023-4, SET POINT 2A

STREAM NO.		1	2	3	4	5	6	7
STREAM DESCRIPTION		STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING
TOTAL	LB/HR	226.00	583.00	0.00	0.00	171.00	0.00	383.92
TEMPERATURE	F	412.0	413.0	0.0	0.0	113.0	173.0	554.0
GAS	LB/HR	226.00	583.00	0.00	0.00	171.00	0.00	383.92
SOLID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	18.016	18.016	28.963	44.011	26.186	26.186
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	34.22	34.22
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	34.64	34.64
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	26.69	26.69
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	3.44	3.44
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.51	0.51
N2	VOLUME %	0.00	0.00	0.00	78.06	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00
H2O	VOLUME %	100.00	100.00	100.00	0.00	0.00	0.51	0.51
ELEMENTS								
CARBON	LB/HR	0.000	0.000	0.000	0.000	46.667	0.000	127.322
HYDROGEN	LB/HR	25.290	65.238	0.000	0.000	0.000	0.000	10.225
OXYGEN	LB/HR	200.710	517.762	0.000	0.000	124.333	0.000	243.990
NITROGEN	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SULFUR	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	2.385
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT								
	KBTU/HR	34.342	88.863	0.000	0.000	1.287	0.000	1361.333

TABLE 3.1-5 (Continued)
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-023-4, SET POINT 2A

STREAM NO.		8	9	10	11	12	13	14
STREAM DESCRIPTION		BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-29)	COAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	FINE FEED & TRANS. G.
TOTAL	LB/HR	264.05	784.29	94.77	1341.75	780.00	0.00	475.26
TEMPERATURE	F	173.0	173.0	173.0	183.0	502.0	502.0	303.0
GAS	LB/HR	264.05	784.29	94.77	623.75	780.00	0.00	227.26
SOLID	LB/HR	0.00	0.00	0.00	718.00	0.00	0.00	248.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		26.186	26.186	26.186	26.186	32.000	44.011	26.186
CO	VOLUME %	34.22	34.22	34.22	34.22	0.00	0.00	34.22
CO2	VOLUME %	34.64	34.64	34.64	34.64	0.00	100.00	34.64
H2	VOLUME %	26.69	26.69	26.69	26.69	0.00	0.00	26.69
CH4	VOLUME %	3.44	3.44	3.44	3.44	0.00	0.00	3.44
H2S	VOLUME %	0.51	0.51	0.51	0.51	0.00	0.00	0.51
N2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	100.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.51	0.51	0.51	0.51	0.00	0.00	0.51
ELEMENTS								
CARBON	LB/HR	67.570	260.096	31.430	745.143	0.000	0.000	264.145
HYDROGEN	LB/HR	5.434	20.888	2.524	54.307	0.000	0.000	7.342
OXYGEN	LB/HR	129.577	498.428	60.229	460.884	780.000	0.000	144.427
NITROGEN	LB/HR	0.000	0.000	0.000	10.770	0.000	0.000	1.290
SULFUR	LB/HR	1.268	4.873	0.589	16.297	0.000	0.000	4.512
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	54.353	0.000	0.000	53.593
HEAT CONTENT	KBTU/HR	698.847	2696.087	324.583	11878.131	75.070	0.000	3569.353

TABLE 3.1-5 (Continued)
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-023-4, SET POINT 2A

STREAM NO.		15	16	17	18	19		
STREAM DESCRIPTION		LIQUID WATER INJECTION	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	775.00	4888.00	972.33	48.00	6.40	0.00	-0.27
TEMPERATURE	F	50.0	1111.0	164.0	217.0	1798.0	0.0	0.0
GAS	LB/HR	0.00	4708.00	724.33	0.00	0.00	0.00	0.00
SOLID	LB/HR	0.00	100.00	248.00	48.00	6.40	0.00	0.00
LIQUID	LB/HR	775.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	22.714	26.186	0.000	0.000	0.000	0.000
CO	VOLUME %	0.00	19.80	34.22	0.00	0.00	0.00	0.00
CO2	VOLUME %	0.00	19.96	34.64	0.00	0.00	0.00	0.00
H2	VOLUME %	0.00	15.49	26.69	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.00	2.07	3.44	0.00	0.00	0.00	0.00
H2S	VOLUME %	0.00	0.31	0.51	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	100.00	42.38	0.51	0.00	0.00	0.00	0.00
ELEMENTS								
CARBON	LB/HR	0.000	1117.537	428.990	16.930	4.093	0.000	-1.626
HYDROGEN	LB/HR	86.723	260.937	20.581	0.101	0.019	0.000	-1.319
OXYGEN	LB/HR	688.277	3385.870	460.324	0.029	0.015	0.000	0.064
NITROGEN	LB/HR	0.000	0.520	1.290	0.274	0.036	0.000	82.423
SULFUR	LB/HR	0.000	21.546	7.600	0.374	0.049	0.000	1.183
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	21.610	53.593	30.293	2.188	0.000	0.243
HEAT CONTENT								
	KBTU/HR	-834.753	13756.667	5253.930	249.143	62.350	425.000	0.684

TABLE 3.1-6
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-023-4, SET POINT 2B

STREAM NO.		1	2	3	4	5	6	7
STREAM DESCRIPTION		STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING
TOTAL	LB/HR	226.00	569.00	0.00	0.00	161.00	0.00	461.42
TEMPERATURE	F	413.0	419.0	0.0	0.0	114.3	170.0	554.0
GAS	LB/HR	226.00	569.00	0.00	0.00	161.00	0.00	461.42
SOLID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	18.016	18.016	28.963	44.011	26.759	26.759
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	33.60	33.60
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	36.51	36.51
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	25.69	25.69
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	3.30	3.30
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.46	0.46
N2	VOLUME %	0.00	0.00	0.00	78.06	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00
H2O	VOLUME %	100.00	100.00	100.00	0.00	0.00	0.36	0.36
ELEMENTS								
CARBON	LB/HR	0.000	0.000	0.000	0.000	43.93E	0.000	152.189
HYDROGEN	LB/HR	25.230	65.909	0.000	0.000	0.00E	0.000	11.563
OXYGEN	LB/HR	200.710	523.091	0.000	0.000	117.062	0.000	295.138
NITROGEN	LB/HR	0.000	0.000	0.000	0.000	0.00E	0.000	0.000
SULFUR	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	2.534
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT	KBTU/HR	34.448	91.437	0.000	0.000	1.246	0.000	1560.797

TABLE 3.1-6 (Continued)
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-023-4, SET POINT 2B

STREAM NO.		8	9	10	11	12	13	14
STREAM DESCRIPTION		BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-29)	COAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	FINE FEED & TRANS. G.
TOTAL	LB/HR	202.36	836.82	95.80	1289.06	766.00	0.00	486.73
TEMPERATURE	F	170.0	170.0	170.0	199.0	503.0	503.0	291.0
GAS	LB/HR	202.36	836.82	95.80	608.06	766.00	0.00	229.73
SOLID	LB/HR	0.00	0.00	0.00	681.00	0.00	0.00	257.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		26.759	26.759	26.759	26.759	32.000	44.011	26.759
CO	VOLUME %	33.60	33.60	33.60	33.60	0.00	0.00	33.60
CO2	VOLUME %	36.51	36.51	36.51	36.51	0.00	100.00	36.51
H2	VOLUME %	25.69	25.69	25.69	25.69	0.00	0.00	25.69
CH4	VOLUME %	3.38	3.38	3.38	3.38	0.00	0.00	3.38
H2S	VOLUME %	0.46	0.46	0.46	0.46	0.00	0.00	0.46
N2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	100.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.36	0.36	0.36	0.36	0.00	0.00	0.36
ELEMENTS								
CARBON	LB/HR	66.744	276.004	31.599	714.164	0.000	0.000	273.842
HYDROGEN	LB/HR	5.071	20.971	2.401	51.467	0.000	0.000	6.888
OXYGEN	LB/HR	125.436	535.251	61.279	447.362	766.000	0.000	148.229
NITROGEN	LB/HR	0.000	0.000	0.000	10.419	0.000	0.000	1.516
SULFUR	LB/HR	1.111	4.596	0.526	15.870	0.000	0.000	3.934
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	49.781	0.000	0.000	52.325
HEAT CONTENT								
	KBTU/HR	660.211	2730.149	312.554	11326.309	73.903	0.000	3651.597

TABLE 3.1-6 (Ccontinued)
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-023-4, SET POINT 2B

STREAM NO.		15	16	17	18	19		
STREAM DESCRIPTION		LIQUID WATER INJECTION	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	759.00	4851.07	1070.40	35.00	5.50	0.00	-0.66
TEMPERATURE	F	50.0	1117.0	174.0	190.0	1791.0	0.0	0.0
GAS	LE/HR	0.00	4668.07	811.40	0.00	0.00	0.00	0.00
SOLID	LE/HR	0.00	133.00	259.00	35.00	5.50	0.00	0.00
LIQUID	LE/HR	759.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	22.866	26.759	0.000	0.000	0.000	0.000
CO	VOLUME %	0.00	19.52	33.60	0.00	0.30	0.00	0.00
CO2	VOLUME %	0.00	20.15	36.51	0.00	0.30	0.00	0.00
H2	VOLUME %	0.00	14.69	25.69	0.00	0.30	0.00	0.00
CH4	VOLUME %	0.00	1.86	3.38	0.00	0.30	0.00	0.00
H2S	VOLUME %	0.00	0.29	0.46	0.00	0.30	0.00	0.00
N2	VOLUME %	0.00	0.00	0.00	0.00	0.30	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	0.30	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.30	0.00	0.00
H2O	VOLUME %	100.00	43.49	0.36	0.00	0.00	0.00	0.00
ELEMENTS								
CARBON	LB/HR	0.000	1120.968	467.232	14.420	3.174	0.000	-3.036
HYDROGEN	LB/HR	84.933	256.538	21.474	0.000	0.015	0.000	-1.317
OXYGEN	LB/HR	674.067	3375.453	520.208	0.000	0.019	0.000	0.048
NITROGEN	LB/HR	0.000	0.785	1.528	0.161	0.030	0.000	79.020
SULFUR	LB/HR	0.000	20.249	7.150	0.277	0.039	0.000	3.002
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	27.079	52.732	20.069	2.222	0.000	0.004
HEAT CONTENT								
	KBTU/HR	-817.519	13519.572	5558.449	211.507	40.586	425.000	-0.703

TABLE 3.1-7
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-023-4, SET POINT 3

STREAM NO.		1	2	3	4	5	6	7
STREAM DESCRIPTION		STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING
TOTAL	LB/HR	0.00	353.00	0.00	0.00	145.00	292.04	465.48
TEMPERATURE	F	413.0	413.0	0.0	0.0	124.0	194.0	554.0
GAS	LB/HR	0.00	353.00	0.00	0.00	145.00	292.04	465.48
SOLID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	18.016	18.016	28.963	44.011	27.818	27.818
CO	VOLUME %	0.30	0.00	0.00	0.00	0.00	29.22	29.22
CO2	VOLUME %	0.30	0.00	0.00	0.00	100.00	40.98	40.98
H2	VOLUME %	0.30	0.00	0.00	0.00	0.00	23.19	23.19
CH4	VOLUME %	0.30	0.00	0.00	0.00	0.00	5.62	5.62
H2S	VOLUME %	0.30	0.00	0.00	0.00	0.00	0.31	0.31
N2	VOLUME %	0.30	0.00	0.00	78.06	0.00	0.00	0.00
O2	VOLUME %	0.30	0.00	0.00	21.00	0.00	0.00	0.00
AR	VOLUME %	0.30	0.00	0.00	0.94	0.00	0.00	0.00
H2O	VOLUME %	100.00	100.00	100.00	0.00	0.00	0.67	0.67
ELEMENTS								
CARBON	LB/HR	0.300	0.000	0.000	0.000	39.572	95.614	152.395
HYDROGEN	LB/HR	0.300	39.501	0.000	0.000	0.000	7.496	11.948
OXYGEN	LB/HR	0.300	313.499	0.000	0.000	105.428	187.898	299.482
NITROGEN	LB/HR	0.300	0.000	0.000	0.000	0.000	0.000	0.000
SULFUR	LB/HR	0.300	0.000	0.000	0.000	0.000	1.037	1.652
ARGON	LB/HR	0.300	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.300	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT	KBTU/HR	0.000	53.806	0.000	0.000	1.428	917.146	1513.765

TABLE 3.1-7 (Continued)
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-023-4, SET POINT 3

STREAM NO.		8	9	10	11	12	13	14
STREAM DESCRIPTION		BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-29)	COAL FEED & TRANS. G.	OX*GEN TO TUBE	CO2 TO TUBE	FINE FEED & TRANS. G.
TOTAL	LB/HR	279.09	442.24	98.68	2255.68	819.20	0.00	679.12
TEMPERATURE	F	194.0	194.0	194.0	128.0	506.0	506.0	264.0
GAS	LB/HR	279.09	442.24	98.68	709.68	819.20	0.00	268.12
SOLID	LB/HR	0.00	0.00	0.00	1546.00	0.00	0.00	411.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		27.818	27.818	27.818	27.818	32.000	44.011	27.818
CO	VOLUME %	29.22	29.22	29.22	29.22	0.00	0.00	29.22
CO2	VOLUME %	40.98	40.98	40.98	40.98	0.00	100.00	40.98
H2	VOLUME %	23.19	23.19	23.19	23.19	0.00	0.00	23.19
CH4	VOLUME %	5.62	5.62	5.62	5.62	0.00	0.00	5.62
H2S	VOLUME %	0.31	0.31	0.31	0.31	0.00	0.00	0.31
N2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	100.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.67	0.67	0.67	0.67	0.00	0.00	0.67
ELEMENTS								
CARBON	LB/HR	91.372	275.747	32.306	862.495	0.000	0.000	315.599
HYDROGEN	LB/HR	7.164	21.619	2.533	105.874	0.000	0.000	8.526
OXYGEN	LB/HR	179.561	541.889	63.488	932.611	819.000	0.000	172.507
NITROGEN	LB/HR	0.000	0.000	0.000	12.059	0.000	0.000	2.055
SULFUR	LB/HR	0.991	2.989	0.350	9.940	0.000	0.000	4.034
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	332.699	0.000	0.000	176.401
HEAT CONTENT	KBTU/HR	876.453	2645.011	309.889	13513.828	79.596	0.000	4208.571

TABLE 3.1-7 (Continued)
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-023-4, SET POINT 3

STREAM NO.		15	16	17	18	19		
STREAM DESCRIPTION		LIQUID WATER INJECTION	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	784.00	5395.21	1231.38	325.00	6.00	0.00	0.79
TEMPERATURE	F	50.0	1069.0	228.0	228.0	1543.0	0.0	0.0
GAS	LB/HR	0.00	5315.21	799.38	0.00	0.00	0.00	0.00
SOLID	LB/HR	0.00	80.00	432.00	325.00	6.00	0.00	0.00
LIQUID	LB/HR	784.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	24.229	27.818	0.000	0.000	0.000	0.000
CO	VOLUME %	0.00	15.86	29.22	0.00	0.00	0.00	0.00
CO2	VOLUME %	0.00	26.70	40.98	0.00	0.00	0.00	0.00
H2	VOLUME %	0.00	14.16	23.19	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.00	4.21	5.62	0.00	0.00	0.00	0.00
H2S	VOLUME %	0.00	0.23	0.31	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	100.00	38.85	0.67	0.00	0.00	0.00	0.00
ELEMENTS								
CARBON	LB/HR	0.000	1276.611	501.173	40.430	2.344	0.000	2.388
HYDROGEN	LB/HR	87.730	273.009	22.247	0.423	0.020	0.000	-1.131
OXYGEN	LB/HR	696.270	3794.342	514.313	0.618	0.006	0.000	0.055
NITROGEN	LB/HR	0.000	0.400	2.160	0.585	0.021	0.000	77.568
SULFUR	LB/HR	0.000	16.515	6.077	0.812	0.026	0.000	-11.614
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	34.336	185.414	292.133	3.583	0.000	0.714
HEAT CONTENT	KBTU/HR	-844.446	14345.497	6048.092	609.366	36.866	425.000	7.778

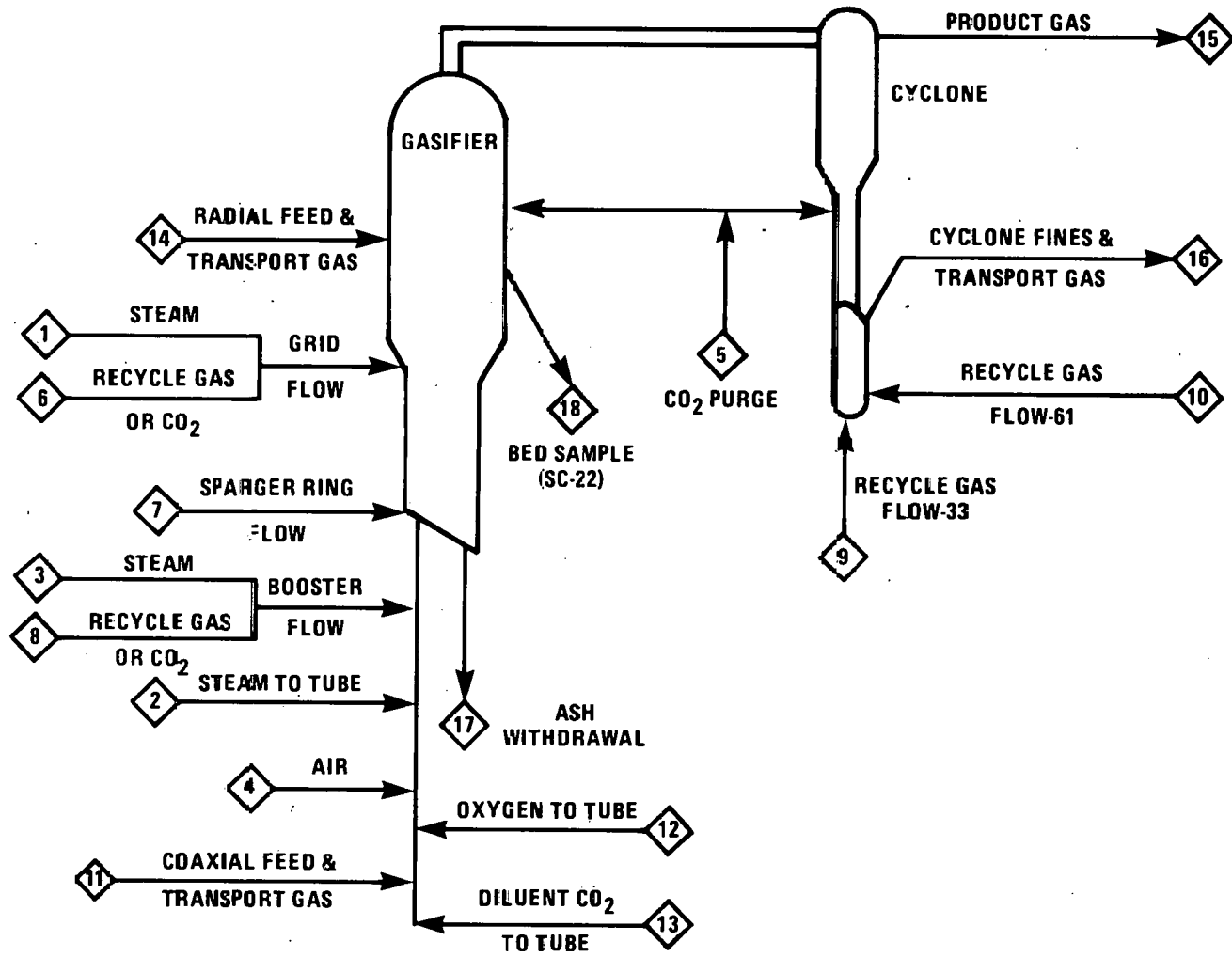


Figure 3.1-1. Heat and Material Balance Flow Schematic

- Establish performance data on Indiana #7 coal feed to the oxygen-blown gasifier at 230 psig.
- Continue the operability evaluation of the modified oxidant feed tube design at oxygen concentrations between 50 and 60 percent.
- Continue the evaluation of the cold wall concept and gasifier quench spray injection on cyclone deposition control.

The feedstock actually used in this test was a blend of Indiana #7 and Ohio #9 coals. These coals had been independently procured and were sent separately to an outside coal preparation facility for drying. Apparently the two batches of coal were processed in a single run and consequently mixed together. Sulfur and ash analyses performed on several samples taken from the resulting coal pile indicated that a fairly homogeneous blended feedstock was inadvertently produced. Although it was clear that this material would not afford an effective means of feedstock characterization, it did fulfill the need for a checkout test.

Test TP-027-1 began with normal startup activities early on April 24. Initial operation with coke breeze was hampered by repeated failures of the steam boiler feedwater pump. After conducting repairs on a flow switch, the oxygen and steam flows were restored on April 28. At this time it became necessary to decrease the system pressure from 230 psig to 200 psig for the following reasons:

- Since the oxygen vaporizer was limiting the capacity of the system, slugs of liquid oxygen were carried into the supply header. This caused frosting and periodically resulted in actuating a low temperature switch and interrupted oxygen flow to the gasifier. It was reasoned that the decreased system pressure would demand less oxygen and accommodate the limited capability of the oxygen feed system.
- The water injection supply pressure was insufficient to provide gas quenching to 1150°F. Additional pressure drop would be available at a 200-psig system pressure.
- Limited mass flow capability in the recycle gas supply to the ash annulus required a decrease in pressure to produce a higher fluidizing velocity.

Conditions for set point 1 were obtained on April 28. The freeboard temperature at the maximum available oxygen flow was a nominal 1780°F, slightly different from the planned temperature of 1850°F. A total of 26 hours of stable gasifier operation was achieved until April 30. The set point period was divided into three segments, 1A, 1B and 1C, to differentiate between small changes made in the recycle gas flow rate to the ash annulus.

The test was prematurely terminated when the recycle gas compressor discharge pressure began to increase. After it was established that a restriction existed in the aftercooler, the PDU was shut down.

Following the shutdown, the gasifier and cyclone internals were inspected and found to be free of deposits or accumulation of material. The recycle gas compressor aftercooler was plugged on the exit side only, with little fouling observed on the inlet side of the shell and tube heat exchanger. An analysis of this failure is given in Section 4.3.2.

A chronology of significant events for test TP-027-1 is given in Table 3.1-8. Steady-state operational data are reported in Table 3.1-9. No steady state was obtained during set point 1A. Two steady states were obtained for set point 1B and one for set point 1C. The heat and material balances for this test are reported in Tables 3.1-10 to 3.1-12. The data used in these balances are as measured by plant instruments; the moisture in the product gas was measured by the newly installed water gas chromatograph.

Notable accomplishments for this test were:

- Eighty-six hours of hot operation, which included 69 hours of coal feed, on the first high-pressure oxygen-blown test were achieved while processing 50 tons of blended Indiana #7 - Ohio #9 coals.
- Functional checkout of the oxygen-blown gasifier was completed at a system pressure of 200 psig.
- The modified oxidant feed tube was tested at an oxygen concentration of 63 to 65 percent for the entire duration of coal feed.
- The ash agglomerator was operated at steady conditions, with the ash discharge concentration above 60 percent. Also achieved sustained operation for 6 hours at an ash concentration of 80 percent.
- The cyclone inlet gas temperature was controlled by water injection at 1150°F, thereby eliminating material deposition in the cyclone.
- Heat recovery testing was conducted for 17 hours during this test. The data are reported in Section 3.2.

3.1.3 Gasifier Test TP-027-2

Test TP-027-2 continued the series of high-pressure, 230-psig, oxygen-blown gasifier tests to evaluate the feasibility of producing medium-Btu gas in the single-stage gasifier. This test was designed to use Ohio #9 and Pittsburgh #8 coals as the primary feedstocks. The objectives of test TP-027-2 also were to:

TABLE 3.1-8
CHRONOLOGY OF SIGNIFICANT EVENTS, TEST TP-027-1

DATE	TIME	EVENT
4-24-80	0615	Started system pressurization.
4-25-80	1700	Initiated temperature ramp for hot air dryout.
4-26-80	2005	Stated coke breeze bed buildup.
	2210	Achieved ignition.
4-27-80	0650	Initiated oxygen flow to gasifier.
	1045	Began feeding Indiana-Ohio blend coal to gasifier.
	1450	Started recycling fines.
	1625 to 2230	Lost oxygen and steam flow because of a boiler feedwater pump failure. Gasifier was idled in an air-blown mode.
4-28-80	2300	Restored oxygen and steam flows to gasifier.
	0840 to 0940	Lost oxygen and steam because of feedwater pump failure. Gasifier switched to air-blown mode to idle until pump was repaired.
	1310	System pressure lowered to 200 psig, to obtain <ul style="list-style-type: none"> - Steady gasifier operation with limited oxygen flow capability. - Higher pressure drop and water flow across spray injection nozzle. - Higher fluidization velocity in the ash annulus.
4-29-80	1800	<u>Achieved Set Point 1 Conditions.*</u>
	0020 to 0350	Coal feed interrupted because of feedline plug. Gasifier switched to air-blown mode. Substituted coke breeze.
	0405	Restored coal feed and oxygen flow to gasifier.
4-29-80	1925	Initiated testing of heat recovery loop at a gas flow of 1000 lb/hr.
4-30-80	0810	Noted an abnormal increase in the discharge pressure on the recycle gas compressor.
	1200	Began normal shutdown.

*Two deviations were made that are shown in Table 3.1-9 as set Points 1B and 1C.

TABLE 3.1-9

SUMMARY OF OPERATING DATA FOR GASIFIER TEST TP-027-1

Steady State		1B-1	1B-2	1C
TEST RUN DATE AND TIME (1980)	Unit	Hours 4-29-80 1440-1845	Hours 4-29-80/2345 4-30-80/0400	Hours 4-30-80 0500-1200
<u>MEASURED GASIFIER PARAMETERS</u>				
Freeboard Temperature	°F	1787	1793	1758
Gasifier Bed Temperature	°F	1777	1780	1754
Ash Annulus Temperature	°F	451	411	430
Average Bed Height*	feet	11.35	10.87	10.72
System Pressure	psig	208	206	206
Average Gasifier Bed Density	lb/ft ³	21.49	21.47	22.21
Average Annulus Density	lb/ft ³	15.73	14.33	14.79
Freeboard Gas Velocity	fps	2.02	2.15	1.92
Oxidant Tube Velocity	fps	130	135	119
Oxygen Concentration	%	65	62	64
Coal Feed Material		← Ohio-Indiana Blend →		
Coal Feed Rate	lb/hr	1451	1430	1435
Fines Feed Material		← Recycle Fines →		
Fines Feed Rate	lb/hr	253	319	229
Cyclone Collection Rate	lb/hr	227	230	219
Carryover to Water System**	lb/hr	300	300	300
Ash Withdrawal Rate	lb/hr	122	116	116
<u>PRODUCT GAS ANALYSIS, DRY BASIS</u>				
Carbon Monoxide	%	36.39	37.69	36.42
Carbon Dioxide	%	31.87	30.92	35.57
Methane	%	4.13	4.05	3.63
Nitrogen	%	.49	.49	.49
Hydrogen Sulfide	%	.61	.57	.70
Hydrogen	%	26.51	26.28	23.19
HHV, Dry Basis (Gas Chromatograph)	Btu/scf	243.17	246.63	229.00
<u>OVERALL PROCESS RATES</u>				
Steam/Coal Ratio, MAF†	lb/lb	0.486	0.535	0.465
Oxygen/Coal Ratio, MAF	lb/lb	1.146	1.173	1.048
Total Moisture/Coal Ratio, MAF	lb/lb	0.600	0.609	0.525
Recycle Gas/Coal Ratio, MAF	lb/lb	2.106	2.461	2.554
<u>SOLIDS ANALYSIS</u>				
Ash Content - Fines	%	25.85	33.56	31.76
Ash Content - Feedstock	%	12.46	12.95	12.98
Ash Content - Bed	%	40.55	35.65	43.74
Ash Content - Agglomerate	%	72.57	73.59	69.56

†Moisture and ash free.

*From jet inlet to top of bed.

**Estimated from quench water samples, isokinetic probe, or total condensables analysis (TCA).

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TABLE 3.1-10
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-027-1, SET POINT 1B-1

STREAM NO.		1	2	3	4	5	6	7
STREAM DESCRIPTION		STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING
TOTAL	LB/HR	0.00	575.00	0.00	0.00	219.00	298.20	622.28
TEMPERATURE	F	0.0	414.0	0.0	0.0	0.0	170.0	551.0
GAS	LB/HR	0.00	575.00	0.00	0.00	219.00	298.20	622.28
SOLID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	18.016	18.016	28.963	44.011	25.742	25.742
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	36.49	36.49
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	31.65	31.65
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	26.33	26.33
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	3.94	3.94
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.58	0.58
N2	VOLUME %	0.00	0.00	0.00	78.06	0.00	0.49	0.49
O2	VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00
H2O	VOLUME %	100.00	100.00	100.00	0.00	0.00	0.52	0.52
ELEMENTS								
CARBON	LB/HR	0.000	0.000	0.000	0.000	59.767	100.290	209.207
HYDROGEN	LB/HR	0.000	64.343	0.000	0.000	0.000	8.246	17.208
OXYGEN	LB/HR	0.000	510.657	0.000	0.000	159.233	185.935	388.012
NITROGEN	LB/HR	0.000	0.000	0.000	0.000	0.000	1.582	3.301
SULFUR	LB/HR	0.000	0.000	0.000	0.000	0.000	2.143	4.472
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT	KBTU/HR	0.000	87.914	0.000	0.000	-3.436	1009.440	2349.292

TABLE 3.1-10 (Continued)
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-027-1, SET POINT 1B-1

STREAM NO.	8	9	10	11	12	13	14
STREAM DESCRIPTION	BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-29)	COAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	FINE FEED & TRANS. G.
TOTAL LB/HR	373.94	961.71	99.72	2328.33	1356.00	0.00	573.25
TEMPERATURE F	170.0	170.0	0.0	149.0	506.0	506.0	246.0
GAS LB/HR	373.94	961.71	99.72	877.33	1356.00	0.00	320.25
SOLID LB/HR	0.00	0.00	0.00	1451.00	0.00	0.00	253.00
LIQUID LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT	25.742	25.742	25.742	25.742	32.000	44.011	25.742
CO VOLUME X	36.49	36.49	36.49	36.49	0.00	0.00	36.49
CO2 VOLUME X	31.65	31.65	31.65	31.65	0.00	100.00	31.65
H2 VOLUME X	26.33	26.33	26.33	26.33	0.00	0.00	26.33
CH4 VOLUME X	3.94	3.94	3.94	3.94	0.00	0.00	3.94
H2S VOLUME X	0.58	0.58	0.58	0.58	0.00	0.00	0.58
N2 VOLUME X	0.49	0.49	0.49	0.49	0.00	0.00	0.49
O2 VOLUME X	0.00	0.00	0.00	0.00	100.00	0.00	0.00
AR VOLUME X	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O VOLUME X	0.52	0.52	0.52	0.52	0.00	0.00	0.52
ELEMENTS							
CARBON LB/HR	125.765	323.443	33.537	1261.280	0.000	0.000	287.919
HYDROGEN LB/HR	10.341	26.595	2.750	97.682	0.000	0.000	9.818
OXYGEN LB/HR	233.166	599.655	62.178	731.460	1356.000	0.000	201.634
NITROGEN LB/HR	1.984	5.101	0.529	24.670	0.000	0.000	2.837
SULFUR LB/HR	2.687	6.911	0.717	32.560	0.000	0.000	5.641
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	0.000	0.000	0.000	100.790	0.000	0.000	65.401
HEAT CONTENT KBTU/HR	1366.178	3513.531	359.248	20593.701	131.785	0.000	3005.000

TABLE 3.1-10 (Continued)
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-027-1, SET POINT 1B-1

STREAM NO.		15	16	17	18	19		
STREAM DESCRIPTION		LIQUID WATER INJECTION	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	1349.00	7843.78	1185.83	122.00	5.88	0.00	-4.58
TEMPERATURE	F	50.0	1150.0	212.0	198.0	1764.0	0.0	0.0
GAS	LB/HR	0.00	7543.78	958.83	0.00	0.00	0.00	0.00
SOLID	LB/HR	0.00	300.00	227.00	122.00	5.88	0.00	0.00
LIQUID	LB/HR	1349.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	22.583	25.742	0.000	0.000	0.000	0.000
CO	VOLUME %	0.00	21.46	36.49	0.00	0.00	0.00	0.00
CO2	VOLUME %	0.00	18.79	31.65	0.00	0.00	0.00	0.00
H2	VOLUME %	0.00	15.63	26.33	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.00	2.44	3.94	0.00	0.00	0.00	0.00
H2S	VOLUME %	0.00	0.36	0.58	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	0.29	0.49	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	100.00	41.04	0.52	0.00	0.00	0.00	0.00
ELEMENTS								
CARBON	LB/HR	0.000	1926.170	484.168	31.488	3.357	0.000	-1.828
HYDROGEN	LB/HR	150.954	418.002	27.378	0.378	0.022	0.000	-14.908
OXYGEN	LB/HR	1198.046	5351.192	599.610	0.000	0.049	0.000	-5.774
NITROGEN	LB/HR	0.000	28.386	6.108	0.378	0.026	0.000	12.780
SULFUR	LB/HR	0.000	42.483	9.887	1.220	0.041	0.000	2.736
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	77.550	58.680	88.535	2.384	0.000	7.736
HEAT CONTENT	KBTU/HR	-1453.008	24860.035	5871.353	479.105	51.548	425.000	0.479

TABLE 3.1-11
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-027-1, SET POINT 1B-2

STREAM NO.		1	2	3	4	5	6	7
STREAM DESCRIPTION		STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING
TOTAL	LB/HR	0.00	620.00	0.00	0.00	264.00	302.17	658.85
TEMPERATURE	F	0.0	415.0	0.0	0.0	0.0	171.0	551.0
GAS	LB/HR	0.00	620.00	0.00	0.00	264.00	302.17	658.85
SOLID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	18.016	18.016	28.963	44.011	25.603	25.603
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	37.47	37.47
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	30.70	30.70
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	26.23	26.23
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	4.12	4.12
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.57	0.57
N2	VOLUME %	0.00	0.00	0.00	78.06	0.00	0.49	0.49
O2	VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00
H2O	VOLUME %	100.00	100.00	100.00	0.00	0.00	0.43	0.43
ELEMENTS								
CARBON	LB/HR	0.000	0.000	0.000	0.000	72.048	102.476	223.437
HYDROGEN	LB/HR	0.000	59.378	0.000	0.000	0.000	8.438	18.399
OXYGEN	LB/HR	0.000	550.622	0.000	0.000	151.952	187.499	408.818
NITROGEN	LB/HR	0.000	0.000	0.000	0.000	0.000	1.613	3.517
SULFUR	LB/HR	0.000	0.000	0.000	0.000	0.000	2.148	4.683
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT	KBTU/HR	0.000	95.085	0.000	0.000	-4.142	1130.636	2545.496

TABLE 3.1-11 (Continued)
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-027-1, SET POINT 1B-2

STREAM NO.		8	9	10	11	12	13	14
STREAM DESCRIPTION		BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-29)	COAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	FINE FEED & TRANS. G.
TOTAL	LB/HR	461.87	985.89	96.58	2499.88	1368.88	8.88	688.46
TEMPERATURE	F	171.8	171.8	8.8	162.8	498.8	498.8	273.8
GAS	LB/HR	461.87	985.89	96.58	1869.88	1368.88	8.88	361.46
SOLID	LB/HR	8.88	8.88	8.88	1438.88	8.88	8.88	319.88
LIQUID	LB/HR	8.88	8.88	8.88	8.88	8.88	8.88	8.88
MOLECULAR WEIGHT		25.683	25.683	25.683	25.683	32.888	44.811	25.683
CO	VOLUME %	37.47	37.47	37.47	37.47	8.88	8.88	37.47
CO2	VOLUME %	38.78	38.78	38.78	38.78	8.88	188.88	38.78
H2	VOLUME %	26.23	26.23	26.23	26.23	8.88	8.88	26.23
CH4	VOLUME %	4.12	4.12	4.12	4.12	8.88	8.88	4.12
H2S	VOLUME %	8.57	8.57	8.57	8.57	8.88	8.88	8.57
N2	VOLUME %	8.49	8.49	8.49	8.49	8.88	8.88	8.49
O2	VOLUME %	8.88	8.88	8.88	8.88	188.88	8.88	8.88
AR	VOLUME %	8.88	8.88	8.88	8.88	8.88	8.88	8.88
H2O	VOLUME %	8.43	8.43	8.43	8.43	8.88	8.88	8.43
ELEMENTS								
CARBON	LB/HR	156.633	334.344	32.753	1382.497	8.888	8.888	325.689
HYDROGEN	LB/HR	12.898	27.532	2.697	181.927	8.888	8.888	11.179
OXYGEN	LB/HR	286.588	611.744	59.928	856.558	1368.888	8.888	227.285
NITROGEN	LB/HR	2.466	5.263	8.516	25.584	8.888	8.888	3.588
SULFUR	LB/HR	3.283	7.888	8.686	27.333	8.888	8.888	5.664
ARGON	LB/HR	8.888	8.888	8.888	8.888	8.888	8.888	8.888
ASH	LB/HR	8.888	8.888	8.888	185.185	8.888	8.888	187.856
HEAT CONTENT	KBTU/HR	1728.156	3688.879	356.424	28888.814	129.688	8.888	4328.128

TABLE 3.1-11 (Continued)
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-027-1, SET POINT 1B-2

STREAM NO.		15	16	17	18	19		
STREAM DESCRIPTION		LIQUID WATER INJECTION	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	1299.00	8155.39	1205.37	116.00	6.00	0.00	-2.77
TEMPERATURE	F	50.0	1124.0	189.0	184.0	1674.0	0.0	0.0
GAS	LB/HR	0.00	7855.39	975.37	0.00	0.00	0.00	0.00
SOLID	LB/HR	0.00	300.00	230.00	116.00	6.00	0.00	0.00
LIQUID	LB/HR	1299.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	22.414	25.603	0.000	0.000	0.000	0.000
CO	VOLUME %	0.00	21.64	37.47	0.00	0.00	0.00	0.00
CO2	VOLUME %	0.00	17.75	30.70	0.00	0.00	0.00	0.00
H2	VOLUME %	0.00	15.09	26.23	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.00	2.33	4.12	0.00	0.00	0.00	0.00
H2S	VOLUME %	0.00	0.33	0.57	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	0.28	0.49	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	100.00	42.59	0.43	0.00	0.00	0.00	0.00
ELEMENTS								
CARBON	LB/HR	0.000	1947.180	477.218	28.700	3.659	0.000	3.647
HYDROGEN	LB/HR	145.359	443.761	28.020	0.336	0.034	0.000	-18.689
OXYGEN	LB/HR	1153.641	5595.900	607.379	0.000	0.043	0.000	-5.237
NITROGEN	LB/HR	0.000	29.183	6.403	0.313	0.047	0.000	15.517
SULFUR	LB/HR	0.000	39.688	9.164	1.206	0.038	0.000	1.394
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	100.680	77.188	85.364	2.139	0.000	9.194
HEAT CONTENT	KBTU/HR	-1339.153	25162.756	5782.579	437.565	57.071	425.000	4.687

TABLE 3.1-12
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-027-1, SET POINT 1C

STREAM NO.		1	2	3	4	5	6	7
STREAM DESCRIPTION		STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING
TOTAL	LB/HR	0.00	548.00	0.00	0.00	275.00	314.95	723.40
TEMPERATURE	F	0.0	413.0	0.0	0.0	0.0	181.0	551.0
GAS	LB/HR	0.00	548.00	0.00	0.00	275.00	314.95	723.40
SOLID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	18.016	18.016	28.963	44.011	27.123	27.123
CO	VOLUME X	0.00	0.00	0.00	0.00	0.00	36.08	36.08
CO2	VOLUME X	0.00	0.00	0.00	0.00	100.00	35.22	35.22
H2	VOLUME X	0.00	0.00	0.00	0.00	0.00	23.33	23.33
CH4	VOLUME X	0.00	0.00	0.00	0.00	0.00	3.77	3.77
H2S	VOLUME X	0.00	0.00	0.00	0.00	0.00	0.65	0.65
N2	VOLUME X	0.00	0.00	0.00	78.06	0.00	0.48	0.48
O2	VOLUME X	0.00	0.00	0.00	21.00	0.00	0.00	0.00
AR	VOLUME X	0.00	0.00	0.00	0.94	0.00	0.00	0.00
H2O	VOLUME X	100.00	100.00	100.00	0.00	0.00	0.47	0.47
ELEMENTS								
CARBON	LB/HR	0.000	0.000	0.000	0.000	75.050	104.711	240.507
HYDROGEN	LB/HR	0.000	61.321	0.000	0.000	0.000	7.488	17.200
OXYGEN	LB/HR	0.000	486.679	0.000	0.000	199.950	198.789	456.593
NITROGEN	LB/HR	0.000	0.000	0.000	0.000	0.000	1.554	3.570
SULFUR	LB/HR	0.000	0.000	0.000	0.000	0.000	2.409	5.533
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT	KBTU/HR	0.000	83.528	0.000	0.000	-4.314	1039.047	2469.019

TABLE 3.1-12 (Continued)
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-027-1, SET POINT 1C

STREAM NO.		8	9	10	11	12	13	14
STREAM DESCRIPTION		BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-29)	COAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	FINE FEED & TRANS. G.
TOTAL	LB/HR	496.85	1065.91	102.36	2533.39	1234.00	0.00	604.97
TEMPERATURE	F	181.0	181.0	0.0	162.0	501.0	501.0	247.0
GAS	LB/HR	496.85	1065.91	102.36	1098.39	1234.00	0.00	375.97
SOLID	LB/HR	0.00	0.00	0.00	1435.00	0.00	0.00	229.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		27.123	27.123	27.123	27.123	32.000	44.011	27.123
CO	VOLUME %	36.08	36.08	36.08	36.08	0.00	0.00	36.08
CO2	VOLUME %	35.22	35.22	35.22	35.22	0.00	100.00	35.22
H2	VOLUME %	23.33	23.33	23.33	23.33	0.00	0.00	23.33
CH4	VOLUME %	3.77	3.77	3.77	3.77	0.00	0.00	3.77
H2S	VOLUME %	0.65	0.65	0.65	0.65	0.00	0.00	0.65
N2	VOLUME %	0.48	0.48	0.48	0.48	0.00	0.00	0.48
O2	VOLUME %	0.00	0.00	0.00	0.00	100.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.47	0.47	0.47	0.47	0.00	0.00	0.47
ELEMENTS								
CARBON	LB/HR	164.915	354.388	34.031	1321.606	0.000	0.000	275.428
HYDROGEN	LB/HR	11.794	25.344	2.434	99.301	0.000	0.000	9.901
OXYGEN	LB/HR	313.092	672.776	64.606	867.915	1234.000	0.000	238.815
NITROGEN	LB/HR	2.448	5.260	0.505	24.362	0.000	0.000	2.496
SULFUR	LB/HR	3.794	8.152	0.783	33.944	0.000	0.000	5.601
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	186.263	0.000	0.000	72.730
HEAT CONTENT	KBTU/HR	1636.499	3515.525	332.375	20925.084	118.473	0.000	3452.149

TABLE 3.1-12 (Continued)
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-027-1, SET POINT 1C

STREAM NO.		15	16	17	18	19		
STREAM DESCRIPTION		LIQUID WATER INJECTION	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	1366.00	7937.19	1265.23	116.00	6.00	0.00	-0.65
TEMPERATURE	F	50.0	1073.0	188.0	187.0	1743.0	0.0	0.0
GAS	LB/HR	0.00	7637.19	1046.23	0.00	0.00	0.00	0.00
SOLID	LB/HR	0.00	300.00	219.00	116.00	6.00	0.00	0.00
LIQUID	LB/HR	1366.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	23.787	27.123	0.000	0.000	0.000	0.000
CO	VOLUME X	0.00	22.68	36.08	0.00	0.00	0.00	0.00
CO2	VOLUME X	0.00	22.15	35.22	0.00	0.00	0.00	0.00
H2	VOLUME X	0.00	14.44	23.33	0.00	0.00	0.00	0.00
CH4	VOLUME X	0.00	2.26	3.77	0.00	0.00	0.00	0.00
H2S	VOLUME X	0.00	0.44	0.65	0.00	0.00	0.00	0.00
N2	VOLUME X	0.00	0.31	0.48	0.00	0.00	0.00	0.00
O2	VOLUME X	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	VOLUME X	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME X	100.00	37.72	0.47	0.00	0.00	0.00	0.00
ELEMENTS								
CARBON	LB/HR	0.000	2013.256	491.697	32.666	3.230	0.000	1.159
HYDROGEN	LB/HR	152.856	370.983	25.795	0.406	0.029	0.000	-2.470
OXYGEN	LB/HR	1213.144	5380.928	661.797	0.000	0.021	0.000	-1.621
NITROGEN	LB/HR	0.000	28.288	5.776	0.487	0.024	0.000	13.980
SULFUR	LB/HR	0.000	48.451	10.608	1.752	0.071	0.000	-1.108
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	95.280	69.554	80.690	2.624	0.000	4.187
HEAT CONTENT	KBTU/HR	-1471.319	23427.463	5559.395	499.902	50.564	425.000	6.651

- Evaluate the operability of the Westinghouse gasifier with Texas lignite.
- Demonstrate the operability of the gasifier with the modified oxidant tube at an oxygen concentration of at least 60 percent.
- Achieve and maintain at least 70 percent ash in the withdrawal material.
- Continue to evaluate the cyclone cold wall and water injection as methods of reducing solids deposits in the cyclone.
- Operate and obtain data from the heat recovery test loop.

Test TP-027-2 was started on May 8 with pressurization and the leak check. The normal pre-startup activities proceeded smoothly and ignition of a coke breeze bed was achieved on May 10. The normal sequence of operations was somewhat altered in that Ohio coal feed was initiated prior to the switchover from the air-blown to the oxygen-blown mode of operation. A flow check of the multifeed system was performed to determine the full range of solids feed rates and operating gas velocities for the Ohio coal.

Set point 1 conditions were established on May 12, and gasifier operation proceeded smoothly until May 13, when a leak in a water tube was discovered in the E-102A air-cooled exchanger associated with the C-122 recycle gas cooler. The gasifier was depressurized to 100 psig and cooled in the air-blown coke breeze mode while the tube was plugged. Set point conditions were subsequently restored on May 14. Fines recycle was halted on May 15 to allow an inventory of fines to build up in the collection lock hopper and to obtain performance data on fines consumption. A total of 44 hours of gasifier operation was obtained at nominal set point 1 conditions on Ohio coal. This period was divided into three segments, 1, 1A and 1B, to differentiate between marginal changes in the gas and solids flow settings.

Pittsburgh coal feed was initiated on May 14 and set point 2 conditions were established the following day. As was done in the Ohio coal set points, fines recycle was halted for a period of 4.5 hours, followed by a 45.5 hour period where all the process conditions required by the test plan, including fines recycle, were met. The steady-state operation during this long set point was interrupted once for two hours when a suspected bridge in the ash annulus was successfully overcome with a temporary increase in the ash fluidizing flows.

Test TP-027-2 was terminated on May 17 after repeated attempts at clearing a bridge that had formed in the region of the gasifier grid proved to be unsuccessful. An inspection of the gasifier showed a buildup of slag and sintered material at the grid area, covering most of the cross-sectional area and extending about 22 inches in height from the bottom of the conical grid section. There was a blowhole through the buildup that was centered above the oxidant tube outlet. A post-shutdown analysis of differential pressure traces and thermocouple readings, aided by an inspection of gasifier internals, revealed the following scenario as the likely cause of the problem.

The ash annulus was operated in a virogously slugging mode, which caused a slug of material to remain stationary at the top of the annulus. In order to dislodge this slug, an attempt was made to partially slump the fluidized bed above the slug by simultaneously lowering all flows to the grid and the ash annulus. However this action resulted in a reduction in the solids circulation and heat dissipation around the oxygen jet, leading to slag formation. In future tests, the slugging behavior of the ash annulus will be closely monitored to prevent the formation of stationary slugs, and in the event of stagnation, the corrective action will involve a momentary increase in annular gas flows.

A chronology of significant events during TP-027-2 is given in Table 3.1-13, and the nominal operating data are reported in Table 3.1-14. The chemical analyses of samples taken during TP-027-2 were completed and the heat and material balances are being prepared. These results will be reported in the next quarterly progress report.

The following accomplishments were achieved during TP-027-2:

- A total of 165 hours of hot operation were achieved, including 63 hours of Ohio #9 coal (34 tons) and 65 hours of Pittsburgh #8 coal feed (29 tons).
- Two long-duration set points on Pittsburgh #8 and Ohio #9 coal demonstrated that the operability characteristics of the PDU gasifier at the higher pressure differ insignificantly from those at the lower pressure. An indepth analysis of the effects of pressure on the performance characteristics, in particular, methane formation and carbon conversion, will be presented in the next quarterly report.
- The long-duration test on Ohio #9 coal was a significant achievement. Prior experience with this coal during the TP-023 test series indicated that the high ash content in the coal gave it a greater propensity for sintering at the outlet of the oxidant tube. However, test TP-027-2 was free of sintered deposits in more than 60 hours of steady operation on Ohio coal, thereby demonstrating the improved performance of the modified oxidant tube at oxygen concentrations greater than 58 percent.
- For the third consecutive test, the cyclone barrel and inlet piping were free of deposits as a result of quenching the gasifier off-gas by means of spray water injection.

3.1.4 Gasifier Test TP-027-3

High-pressure, oxygen-blown gasifier testing continued in June with TP-027-3, which was designed as a feedstock characterization test with Texas lignite, Pittsburgh #8 coal and Upper Freeport seam coal. The first set point with lignite is intended to be a low-pressure, 130-psig test that will essentially duplicate the conditions that were achieved during TP-023-4. The second set

TABLE 3.1-13

CHRONOLOGY OF SIGNIFICANT EVENTS, TEST TP-027-2

DATE	TIME	EVENT
5-08-80	1400	Initiated system pressurization and pressure leak check
5-09-80	0005-0405	Achieved acceptable leak rate, initiated temperature ramp
	0900	Began 12-hour hot air dryout
5-10-80	0915	Started system pressure ramp to 230 psig
	1700	Initiated coke breeze feed to gasifier
	2200	Achieved autoogenous ignition
5-11-80	1400	Initiated Ohio #9 coal feed
	1700	Oxygen flow to gasifier
	1940	Began feeding recycled fines to gasifier
5-12-80	0030	<u>Achieved set point 1 conditions</u>
	1115-1150	Started heat recovery system, experienced unstable heat recovery flow control
	1250	Heat recovery system shut down
	1815	Restarted heat recovery system, flows still erratic
5-13-80	0101-0200	Shut down heat recovery system, initiated coke breeze feed to gasifier
	0400-0430	Began depressurization to 100 psig for E-102A cooler repair, exchanged air for oxygen to gasifier
	0945	Started pressure ramp to 230 psig
	1620	Reinitiated oxygen flow to gasifier
	1910	Began Ohio #9 coal feed
	1940	Started feeding recycle fines to gasifier

TABLE 3.1-13 (Continued)

DATE	TIME	EVENT
5-14-80	0030	<u>Achieved modified set point 1 conditions*</u>
	0920	Started heat recovery system
5-14-80	2030	Initiated Pittsburgh seam coal feed
5-15-80	0400	<u>Achieved set point 2 conditions**</u>
	0515	Heat recovery system shut down, flow control problems
5-16-80	2005- 2200	Ash annulus temperatures decreased, indicating the presence of a stationary slug of material at the top of the annulus. Reduced O ₂ concentration in oxidant tube, increased bed level and alternately increased and decreased gas flows in ash annulus.
	5-17-80	0710
1010- 1100		Ash annulus temperatures dropped, indicating presence of a stationary slug of material near the oxidant tube outlet. In the attempt to dislodge the slug, gas flows in the grid and sparger were pulsed downward in an attempt to regain ash annulus temperature.
	1230	No withdrawal from gasifier
	1250	Started feeding coke breeze to gasifier
	1320	Stopped coal feed
	1335	Oxygen flow stopped, air flow to oxidant tube initiated, reduced freeboard temperature to 1600°F
	1410	Began depressurization to 130 psig
	1830	Initiated shutdown

*Two deviations were made that are shown in Table 3.1-14 as set points 1A and 1B.

**Two deviations were made that are shown in Table 3.1-14 as set points 2A and 2B.

TABLE 3.1-14

SUMMARY OF NOMINAL OPERATING DATA FOR GASIFIER TEST TP-027-2

SET POINT		1	Modified 1A	Modified 1E	2A	2B
TEST RUN DATE AND TIME (1980)	Unit	Hours 5-12-80/0030 to 5-13-80/0200	Hours 5-14-80/0030 to 5-14-80/0815	Hours 5-14-80/0815 to 5-14-80/2015	Hours 5-15-80/0815 to 5-15-80/1230	Hours 5-15-80/1230 to 5-17-80/1000
<u>MEASURED GASIFIER PARAMETERS</u>						
Freeboard Temperature	°F	1817	1822	1834	1837	1830
Gasifier Bed Temperature	°F	1770	1790	1811	1790	1790
Ash annulus temperature	°F	450	460	414	612	550
Average Bed Height*	feet	11.58	10.75	10.96	11.64	10.55
System Pressure	psig	230	233	232	233	233
Average Gasifier Bed Density	lb/ft ³	15	15	15	13	14
Average Annulus Density	lb/ft ³	12	11	11	9	12
Freeboard Gas Velocity	fps	1.10	1.01	0.89	1.02	1.03
Fines Feed Material		Recycle Fines	Recycle Fines	--	--	Recycle Fines
Fines Feed Rate	lb/hr	337	205	--	--	136
Coal Feed Material		Ohio #5	Ohio #9	Ohio #9	Pgh. #8 Seam	Pgh. #8 Seam
Coal Feed Rate	lb/hr	1147	1004	985	1206	934
Carryover to Water System**	lb/hr	48		47	60	92
Ash Withdrawal Rate	lb/hr	1.72	1.42	1.31	66	41
HHV, Dry Basis (Gas Chromatograph)	Btu/scf	234	236	242	258	253
<u>SOLIDS ANALYSIS</u>						
Ash Content - Fines	%	32	29	36	28	26
Ash Content - Feedstock	%	14	14	14	8	8
Ash Content - Bed	%	36	35	36	22	27
Ash Content - Agglomerate	%	64	66	62	53	66

*From jet inlet to top of bed

**Estimated from quench water samples, isokinetic probe, or total condensables analysis (TCA)

point will be a 100-hour test on Pittsburgh coal aimed at maximizing the ash content in the withdrawal stream. The third set point will be a 48-hour set point with Upper Freeport seam coal at process conditions identical to set point 2.

This test was started on June 12 and will be completed as planned in July, at which time a detailed chronology and process data will be available.

3.1.5 Gasifier Test TP-025-2

TP-025-2 was an air-blown gasifier test with Indiana #7 coal, conducted in October 1979. The chronology of significant events was reported in the October to December 1979 quarterly progress report. The steady-state process data and the heat and material balances for this test were completed during this reporting period and are presented in Tables 3.1-15 to 3.1-18.

3.1.6 Gasifier Test TP-023-3

TP-023-3 was an oxygen-blown, low-pressure gasifier test with Upper Freeport and Pittsburgh #8 coals, conducted in December 1979. The chronology was reported in the October to December 1979 quarterly progress report. An analysis of process data gathered during this test was completed, and the results show that no significant steady state with accurate process data were obtained. In lieu of steady-state information, Table 3.1-19 gives the nominal operating conditions that were achieved in the test.

Work Forecast for Next Quarter

- Complete TP-027-3, a high-pressure, oxygen-blown gasifier test.
- Conduct oxygen-blown gasifier tests TP-027-4 and -5.

3.2 HEAT RECOVERY TEST DATA

The Phase I heat recovery test loop, consisting of four water-cooled double pipe heat exchangers in series, was operated for a total duration of 90 hours. Heat transfer data were acquired during set point operation for all gasifier tests conducted in this reporting period. The tube fluid was a slip stream of gas taken downstream of the cyclone at a temperature of 1200°F to 1300°F.

Tables 3.2-1 to 3.2-3 present the heat transfer data obtained in the six set points that were conducted (HR-1 through HR-6). Measured values of tube and shell side fluid flow rates, the inlet and outlet temperatures and estimates for heat duty are reported. On comparing the heat balance between the gas and the water streams, it is noted that the closure as defined by:

TABLE 3.1-15

SUMMARY OF OPERATING DATA FOR AIR-BLOWN GASIFIER TEST TP-025-2

Set Point		2A-1	2A-2	2A-3
TEST RUN DATE AND TIME (1979)	Unit	Hours 11-10-79 0945-2030	Hours 11-10-79/2130 to 11-11-79/0400	Hours 11-11-79 0630 to 1130
<u>MEASURED GASIFIER PARAMETERS</u>				
Freeboard Temperature	°F	1792	1809	1803
Gasifier Bed Temperature	°F	1825	1848	1843
Ash Annulus Temperature	°F	289	298	290
Average Bed Height*	feet	14.2	12.3	12.1
System Pressure	psig	229	230	229
Average Gasifier Bed Density	lb/ft ³	11.24	9.94	10.29
Average Annulus Density	lb/ft ³	11.62	11.20	10.92
Freeboard Gas Velocity	fps	2.01	1.75	1.67
Air Tube Velocity	fps	90	87	86
Coal Feed Material		← Indiana #7 →		
Coal Feed Rate	lb/hr	1239	1094	1135
Fines Feed Material		← Recycle Fines →		
Fines Feed Rate	lb/hr	213	302	370
Cyclone Collection Rate	lb/hr	222	341	432
Carryover to Water System**	lb/hr	120	114	114
Ash Withdrawal Rate	lb/hr	128	114	134
<u>PRODUCT GAS ANALYSIS, DRY BASIS</u>				
Carbon Monoxide	%	11.64	13.91	13.26
Carbon Dioxide	%	10.09	10.09	10.32
Methane	%	0.95	0.85	0.94
Nitrogen	%	46.60	52.34	52.91
Oxygen	%	0.0	0.0	0.0
Hydrogen	%	8.92	9.54	9.30
HHV, Dry Basis (Gas Chromatograph)	Btu/scf	96.94	96.98	94.65
<u>OVERALL PROCESS RATES</u>				
Steam/Coal Ratio, MAF+	lb/lb	0.323	0.378	0.357
Total Moisture/Coal Ratio, MAF	lb/lb	0.453	0.521	0.499
Recycle Gas/Coal Ratio, MAF	lb/lb	2.20	2.50	2.47
<u>SOLIDS ANALYSIS</u>				
Ash Content - Fines	%	22.57	26.14	24.70
Ash Content - Feedstock	%	10.44	12.13	10.46
Ash Content - Bed	%	24.98	32.44	31.30
Ash Content - Agglomerate	%	49.04	58.24	48.81

+Moisture and ash free.

*From jet inlet to top of bed.

**Estimated from quench water samples, isokinetic probe, or total condensables analysis (TCA).

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TABLE 3.1-16
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-025-2, SET POINT 2A-1

STREAM NO.		1	2	3	4	5	6	7
STREAM DESCRIPTION		STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING
TOTAL	LB/HR	318.00	0.00	0.00	4118.00	190.00	0.00	400.20
TEMPERATURE	F	413.0	0.0	0.0	801.0	153.0	137.0	602.0
GAS	LB/HR	318.00	0.00	0.00	4118.00	190.00	0.00	400.20
SOLID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	18.016	18.016	28.963	44.011	27.205	27.205
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	15.46	15.46
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	12.65	12.65
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	10.31	10.31
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	1.00	1.00
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	0.00	0.00	70.06	0.00	60.27	60.27
O2	VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00
H2O	VOLUME %	100.00	100.00	100.00	0.00	0.00	0.23	0.23
ELEMENTS								
CARBON	LB/HR	0.000	0.000	0.000	0.000	51.853	0.000	51.576
HYDROGEN	LB/HR	35.584	0.000	0.000	0.000	0.000	0.000	3.765
OXYGEN	LB/HR	292.416	0.000	0.000	955.451	138.147	0.000	96.497
NITROGEN	LB/HR	0.000	0.000	0.000	3109.159	0.000	0.000	248.360
SULFUR	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON	LB/HR	0.000	0.000	0.000	53.390	0.000	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT	KBTU/HR	43.471	0.000	0.000	736.870	3.047	0.000	501.962

TABLE 3.1-16 (Continued)
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-025-2, SET POINT 2A-1

STREAM NO.		8	9	10	11	12	13	14
STREAM DESCRIPTION		BCOSFER GAS	TRANSPORT GAS TO C119 (FV-33)	SPARGER GAS TO C119 (FV-29)	AXIAL COAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	AXIAL FINES FEED & TRANS. G.
TOTAL	LB/HR	632.95	828.98	1.97	1853.10	0.00	0.00	666.43
TEMPERATURE	F	137.0	137.0	137.0	120.0	0.0	0.0	190.0
GAS	LB/HR	692.95	828.98	1.97	614.10	0.00	0.00	453.43
SOLID	LB/HR	0.00	0.00	0.00	1239.00	0.00	0.00	213.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		27.205	27.205	27.205	27.205	32.030	44.011	27.205
CO	VOLUME %	15.46	15.46	15.46	15.46	0.00	0.00	15.46
CO2	VOLUME %	12.65	12.65	12.65	12.65	0.00	100.00	12.65
H2	VOLUME %	10.31	10.31	10.31	10.31	0.00	0.00	10.31
CH4	VOLUME %	1.00	1.00	1.00	1.00	0.00	0.00	1.00
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	VOLUME %	60.27	60.27	60.27	60.27	0.00	0.00	60.27
O2	VOLUME %	0.00	0.00	0.00	0.00	100.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.23	0.23	0.23	0.23	0.00	0.00	0.23
ELEMENTS								
CARBON	LB/HR	89.306	105.837	0.254	889.201	0.000	0.000	216.056
HYDROGEN	LB/HR	6.519	7.799	0.019	72.559	0.000	0.000	5.309
OXYGEN	LB/HR	167.087	199.886	0.475	352.755	0.000	0.000	112.803
NITROGEN	LB/HR	430.042	514.460	1.223	399.689	0.000	0.000	283.140
SULFUR	LB/HR	0.000	0.000	0.000	9.540	0.000	0.000	1.044
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	129.352	0.000	0.000	48.074
HEAT CONTENT	KBTU/HR	918.716	1099.061	2.614	15316.729	0.000	0.000	2896.451

TABLE 3.1-16 (Continued)

GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-025-2, SET POINT 2A-1

STREAM NO.		15	16	17	18	19		
STREAM DESCRIPTION		LIQUID WATER INJECTION	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TCTAL	LB/HR	698.00	8647.14	1112.10	128.00	3.35	0.00	-1.26
TEMPERATURE	F	70.0	1302.0	193.0	160.0	1756.0	0.0	0.0
GAS	LB/HR	0.00	8527.14	890.10	0.00	0.00	0.00	0.00
SCLID	LB/HR	0.00	120.00	222.00	128.00	3.35	0.00	0.00
LIQUID	LB/HR	698.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	25.013	27.205	0.000	0.000	0.000	0.000
CO	VOLUME %	0.00	11.64	15.46	0.00	0.00	0.00	0.00
CO2	VOLUME %	0.00	10.09	12.65	0.00	0.00	0.00	0.00
H2	VOLUME %	0.00	8.92	10.31	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.00	0.95	1.08	0.00	0.00	0.00	0.00
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	46.60	60.27	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	100.00	21.80	0.23	0.00	0.00	0.00	0.00
ELEMENTS								
CARBON	LB/HR	0.000	1017.076	270.993	62.298	2.414	0.000	3.153
HYDROGEN	LB/HR	78.107	224.745	9.462	0.435	0.013	0.000	-11.921
OXYGEN	LB/HR	619.893	2926.265	218.240	0.883	0.046	0.000	-7.521
NITROGEN	LB/HR	0.000	4451.378	554.207	0.755	0.027	0.000	-0.407
SULFUR	LB/HR	0.000	0.588	1.088	0.858	0.014	0.000	75.931
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH	LB/HR	0.000	27.084	50.105	62.771	0.837	0.000	20.644
HEAT CONTENT								
	KBTU/HR	-737.856	14506.400	3579.116	911.302	36.372	425.000	6.747

TABLE 3.1-17
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-025-2, SET POINT 2A-2

STREAM NO.		1	2	3	4	5	6	7
STREAM DESCRIPTION		STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING
TOTAL	LB/HR	318.00	0.00	0.00	3911.00	211.00	0.00	401.16
TEMPERATURE	F	413.0	0.0	0.0	824.0	148.0	135.0	602.0
GAS	LB/HR	318.00	0.00	0.00	3911.00	211.00	0.00	401.16
SOLID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	18.016	18.016	28.963	44.011	27.069	27.069
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	16.14	16.14
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	12.31	12.31
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	10.69	10.69
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.97	0.97
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	0.00	0.00	78.06	0.00	59.73	59.73
O2	VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00
H2O	VOLUME %	100.00	100.00	100.00	0.00	0.00	0.15	0.15
ELEMENTS								
CARBON	LB/HR	0.000	0.000	0.000	0.000	57.584	0.000	52.359
HYDROGEN	LB/HR	35.564	0.000	0.000	0.000	0.000	0.000	3.819
OXYGEN	LB/HR	282.416	0.000	0.000	907.423	153.416	0.000	97.007
NITROGEN	LB/HR	0.000	0.000	0.000	2952.870	0.000	0.000	247.973
SULFUR	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON	LB/HR	0.000	0.000	0.000	50.706	0.000	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT	KBTU/HR	48.471	0.000	0.000	723.032	3.157	0.000	599.177

TABLE 3.1-17 (Continued)
 GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-025-2, SET POINT 2A-2

STREAM NO.		8	9	10	11	12	13	14
STREAM DESCRIPTION		BOOSTER GAS	TRANSPORT GAS TO C119 (FV-33)	SPARGER GAS TO C119 (FV-29)	AXIAL COAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	AXIAL FINES FEED & TRANS. G.
TOTAL	LB/HR	693.18	816.08	96.36	1650.51	0.00	0.00	755.27
TEMPERATURE	F	135.0	135.0	135.0	124.0	0.0	0.0	190.0
GAS	LB/HR	693.18	816.08	96.36	556.51	0.00	0.00	453.27
SOLID	LB/HR	0.00	0.00	0.00	1094.00	0.00	0.00	302.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		27.069	27.069	27.069	27.069	32.000	44.011	27.069
CO	VOLUME %	16.14	16.14	16.14	16.14	0.00	0.00	16.14
CO2	VOLUME %	12.31	12.31	12.31	12.31	0.00	100.00	12.31
H2	VOLUME %	10.69	10.69	10.69	10.69	0.00	0.00	10.69
CH4	VOLUME %	0.97	0.97	0.97	0.97	0.00	0.00	0.97
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	VOLUME %	59.73	59.73	59.73	59.73	0.00	0.00	59.73
O2	VOLUME %	0.00	0.00	0.00	0.00	100.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.15	0.15	0.15	0.15	0.00	0.00	0.15
ELEMENTS								
CARBON	LB/HR	90.474	106.515	12.577	767.873	0.000	0.000	266.031
HYDROGEN	LB/HR	6.600	7.770	0.917	62.077	0.000	0.000	5.946
OXYGEN	LB/HR	167.622	197.342	23.301	319.896	0.000	0.000	120.238
NITROGEN	LB/HR	428.482	504.455	59.562	359.755	0.000	0.000	282.510
SULFUR	LB/HR	0.000	0.000	0.000	8.205	0.000	0.000	1.601
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	132.702	0.000	0.000	78.943
HEAT CONTENT	KBTU/HR	945.733	1113.416	131.464	13107.635	0.000	0.000	3613.972

TABLE 3.1-17 (Continued)

GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-025-2, SET POINT 2A-2

STREAM NO.		15	16	17	18	19		
STREAM DESCRIPTION		LIQUID WATER INJECTION	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	0.00	7574.80	1398.95	114.00	2.57	0.00	-2.69
TEMPERATURE	F	0.0	554.0	455.0	161.0	1760.0	0.0	0.0
GAS	LB/HR	0.00	7462.80	1057.96	0.00	0.00	0.00	0.00
SOLID	LB/HR	0.00	114.00	341.00	114.00	2.57	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	25.718	27.069	0.000	0.000	0.000	0.000
CO	VOLUME %	0.00	13.91	16.14	0.00	0.00	0.00	0.00
CO2	VOLUME %	0.00	10.09	12.31	0.00	0.00	0.00	0.00
H2	VOLUME %	0.00	9.54	10.69	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.00	0.85	0.97	0.00	0.00	0.00	0.00
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	52.34	59.73	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	100.00	13.27	0.15	0.00	0.00	0.00	0.00
ELEMENTS								
CARBON	LB/HR	0.000	943.804	371.670	45.794	1.665	0.000	-0.709
HYDROGEN	LB/HR	0.000	143.959	11.914	0.331	0.010	0.000	-27.300
OXYGEN	LB/HR	0.000	2202.006	267.834	0.300	0.033	0.000	-8.803
NITROGEN	LB/HR	0.000	4254.543	656.593	0.581	0.018	0.000	-1.574
SULFUR	LB/HR	0.000	0.604	1.007	0.730	0.010	0.000	67.861
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH	LB/HR	0.000	29.800	89.137	66.394	0.834	0.000	12.039
HEAT CONTENT								
	KBTU/HR	0.000	13955.617	4929.503	673.305	25.276	425.000	1.170

TABLE 3.1-18
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-025-2, SET POINT 2A-3

STREAM NO.		1	2	3	4	5	6	7
STREAM DESCRIPTION		STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING
TOTAL	LB/HR	318.00	0.00	0.00	3958.00	198.00	0.00	402.89
TEMPERATURE	F	413.0	0.0	0.0	829.0	141.0	134.0	602.0
GAS	LB/HR	318.00	0.00	0.00	3958.00	198.00	0.00	402.89
SOLID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	18.016	18.015	28.963	44.011	27.303	27.303
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	14.65	14.65
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	14.52	14.52
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	11.05	11.05
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	1.18	1.18
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	0.00	0.00	78.06	0.00	58.40	58.40
O2	VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00
H2O	VOLUME %	100.00	100.00	100.00	0.00	0.00	0.20	0.20
ELEMENTS								
CARBON	LB/HR	0.000	0.000	0.000	0.000	54.036	0.000	53.790
HYDROGEN	LB/HR	35.584	0.000	0.000	0.000	0.000	0.000	4.047
OXYGEN	LB/HR	282.416	0.000	0.000	895.126	143.964	0.000	103.630
NITROGEN	LB/HR	0.000	0.000	0.000	2912.854	0.000	0.000	241.425
SULFUR	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON	LB/HR	0.000	0.000	0.000	50.019	0.000	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT	KBTU/HR	48.471	0.000	0.000	718.217	2.666	0.000	588.800

TABLE 3.1-18 (Continued)

GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-025-2, SET POINT 2A-3

STREAM NO.		8	9	10	11	12	13	14
STREAM DESCRIPTION		BOOSTER GAS	TRANSPORT GAS TO C-19 (FV-33)	SFARGER GAS TO C-119 (FV-29)	AXIAL COAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	AXIAL FINES FEED & TRANS. G.
TOTAL	LB/HR	697.16	820.60	90.85	1777.85	0.00	0.00	826.22
TEMPERATURE	F	134.0	134.0	134.0	123.0	0.0	0.0	180.0
GAS	LB/HR	697.16	820.60	90.85	642.85	0.00	0.00	456.22
SOLID	LB/HR	0.00	0.00	0.00	1135.00	0.00	0.00	370.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		27.303	27.303	27.303	27.303	32.000	44.011	27.303
CO	VOLUME %	14.65	14.65	14.65	14.65	0.00	0.00	14.65
CO2	VOLUME %	14.52	14.52	14.52	14.52	0.00	100.00	14.52
H2	VOLUME %	11.05	11.05	11.05	11.05	0.00	0.00	11.05
CH4	VOLUME %	1.18	1.18	1.18	1.18	0.00	0.00	1.18
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	VOLUME %	58.40	58.40	58.40	58.40	0.00	0.00	58.40
O2	VOLUME %	0.00	0.00	0.00	0.00	100.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.20	0.20	0.20	0.20	0.00	0.00	0.20
ELEMENTS								
CARBON	LB/HR	93.077	109.557	12.129	818.355	0.000	0.000	326.643
HYDROGEN	LB/HR	7.003	8.242	0.913	67.407	0.000	0.000	6.284
OXYGEN	LB/HR	179.320	211.070	23.368	362.387	0.000	0.000	124.376
NITROGEN	LB/HR	417.761	451.727	54.439	402.467	0.000	0.000	276.228
SULFUR	LB/HR	0.000	0.000	0.000	8.512	0.000	0.000	1.295
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	118.721	0.000	0.000	91.390
HEAT CONTENT								
	KBTU/HR	923.364	1092.734	120.977	13924.086	0.000	0.000	4458.968

TABLE 3.1-18 (Continued)
GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-025-2, SET POINT 2A-3

STREAM NO.		15	16	17	18	19		
STREAM DESCRIPTION		LIQUID WATER INJECTION	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	0.00	7481.51	1331.59	134.00	3.60	0.00	0.43
TEMPERATURE	F	0.0	1629.0	410.0	158.0	1750.0	0.0	0.0
GAS	LB/HR	0.00	7367.51	899.59	0.00	0.00	0.00	0.00
SOLID	LB/HR	0.00	114.00	432.00	134.00	3.60	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	25.009	27.303	0.000	0.000	0.000	0.000
CO	VOLUME %	0.00	13.26	14.65	0.00	0.00	0.00	0.00
CO2	VOLUME %	0.00	10.32	14.52	0.00	0.00	0.00	0.00
H2	VOLUME %	0.00	9.30	11.05	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.00	0.94	1.18	0.00	0.00	0.00	0.00
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	52.91	58.40	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	100.00	13.27	0.20	0.00	0.00	0.00	0.00
ELEMENTS								
CARBON	LB/HR	0.000	922.555	430.366	65.606	2.373	0.000	3.181
HYDROGEN	LB/HR	0.000	141.182	11.023	0.415	0.014	0.000	-17.883
OXYGEN	LB/HR	0.000	2156.770	239.597	0.938	0.044	0.000	-3.083
NITROGEN	LB/HR	0.000	4232.450	542.391	0.884	0.025	0.000	0.441
SULFUR	LB/HR	0.000	0.399	1.512	0.750	0.018	0.000	72.684
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH	LB/HR	0.000	28.158	106.704	65.405	1.127	0.000	4.149
HEAT CONTENT	KBTU/HR	0.000	13720.559	5776.109	956.042	35.991	425.000	4.394

TABLE 3.1-19

SUMMARY OF NOMINAL OPERATING DATA FOR GASIFIER TEST TP-023-3

Set Point		3
TEST RUN DATE AND TIME (1979)	Unit	Hours 12-16 0700-1130
<u>MEASURED GASIFIER PARAMETERS</u>		
Freeboard Temperature	°F	1837
Gasifier Bed Temperature	°F	1903
Ash Annulus Temperature	°F	280
Average Bed Height*	feet	20.28
System Pressure	psig	130
Average Gasifier Bed Density	lb/ft ³	19.05
Average Annulus Density	lb/ft ³	9.95
Freeboard Gas Velocity	fps	1.64
Fines Feed Material		Recycle Fines
Fines Feed Rate	lb/hr	279
Coal Feed Material		Champion Coal
Coal Feed Rate	lb/hr	821
Carryover to Water System**	lb/hr	N/A
Ash Withdrawal Rate	lb/hr	72
HHV, Dry Basis (Gas Chromatograph)	Btu/scf	274
<u>SOLIDS ANALYSIS</u>		
Ash Content - Fines	%	15
Ash Content - Feedstock	%	6.8
Ash Content - Bed	%	21
Ash Content - Agglomerate	%	46

*From jet inlet to top of bed.

**Estimated from quench water samples, isokinetic probe, or total condensables analysis (TCA).

TABLE 3.2-1

PDU HEAT RECOVERY TEST RESULTS, TEST TP-023-4

Set Point	HR-1	HR-2
Date/Time (1980)	3/31 @ 1500 - 4/1 @ 0300	4/1 @ 1400 - 4/2 @ 0100
Duration, hr	12	11
Gas Side Conditions		
Flow Rate, lb/hr	825	756
Inlet/Avg Velocity, fps	180/140	160/125
Temperature In, °F	1110	1075
Temperature Out, °F	468	450
Predicted Duty, Btu/hr	185,400	165,400
Water Side Conditions		
Flow Rate, lb/hr	3300	3300
Temperature In, °F	40	40
Temperature Out, °F	107	105
Calculated Duty, Btu/hr	221,100	214,500
Experimental Gas Side Film Coefficient*	182	152

*Uses gas side heat duty, theoretical specific heat, and estimate of shell side coefficient.

TABLE 3.2-2

PDU HEAT RECOVERY TEST RESULTS, TEST TP-027-1

Set Point	HR-3	HR-4
Date/Time (1980)	4/29 @ 1900 - 5/30 @ 0830	4/30 @ 0900 - 5/30 @ 1200
Duration, hr	14	13
Gas Side Conditions		
Flow Rate, lb/hr	1010	1310
Inlet/Avg Velocity, fps	145/120	180/150
Temperature In, °F	1100	1030
Temperature Out, °F	495	500
Predicted Duty, Btu/hr	214,000	236,000
Water Side Conditions		
Flow Rate, lb/hr	3300	4400
Temperature In, °F	47	50
Temperature Out, °F	115	110
Calculated Duty, Btu/hr	224,400	264,000
Experimental Gas Side Film Coefficient	239	251

*Uses gas side heat duty, theoretical specific heat, and estimate of shell side coefficient.

TABLE 3.2-3

PDU HEAT RECOVERY TEST RESULTS, TEST TP-027-2

Set Point	HR-5	HR-6
Date/Time (1980)	5/12 @ 1747 - 5/13 @ 0047	5/14 @ 1312 - 2242
Duration, hr	7	9-1/2
Gas Side Conditions		
Flow Rate, lb/hr	1008	1022
Inlet/Avg Velocity, fps	134/109	136/110
Temperature In, °F	1098	1098
Temperature Out, °F	504	504
Predicted Duty, Btu/hr	221,500	218,500
Water Side Conditions		
Flow Rate, lb/hr	4400	4400
Temperature In, °F	48	48
Temperature Out, °F	90	100
Calculated Duty, Btu/hr	185,000	229,000
Experimental Gas Side Film Coefficient	155	181

$$\frac{(\text{Gas Side Duty} - \text{Water Side Duty})}{(\text{Gas Side Duty})}$$

varied from -30 percent to +16 percent. A preliminary operational analysis indicates that the discrepancy in the heat balance is a probable result of inaccuracies in the rotameter measurement of water flow rates. Steps are being taken to replace the rotameter with an orifice plate flow meter, and thereby enhance the accuracy of measurement. The gas side flows, however, are measured by means of an orifice with pressure-temperature compensation and are accurate within +5 percent. Although the dust loading in the gas stream is not directly measured, it is possible to infer this quantity from the isokinetic sampling apparatus located in the main hot gas stream. The magnitude of error as a result of excluding the effect of fines on the gas side heat duty is estimated to be less than 2 percent. The experimental gas side heat transfer coefficients varied from 152 to 239 Btu/hr-ft²-°F.

Post-test inspections of the test loop apparatus have revealed that the tubes were essentially free of deposits. A few ounces of material found in the first exchanger after test TP-023-4 were verified, by an ash analysis, to be char fines.

Operational problems in the heat recovery loop were encountered for the first time during test TP-027-2, when it was difficult to control the gas flow at a steady value. A post-test inspection revealed that the flow control valve was eroded at its seat. An evaluation of this problem is presently being conducted.

Work Forecast for Next Quarter

Continue heat recovery testing during oxygen-blown gasifier tests TP-027-3, TP-027-4 and TP-027-5.

SECTION 4.0

PROCESS ANALYSIS AND DESIGN

4.1 PRODUCT CHARACTERIZATION

4.1.1 Hardware Upgrade

The gas chromatograph to measure water in the raw gasifier off-gas was functionally checked out and routinely operated during gasifier test TP-027-1. The measured moisture content in the raw gas was compared with the estimated content obtained by forcing an elemental hydrogen closure in the heat and material balances for test TP-027-1. These results are shown below:

<u>Steady State</u>	<u>Moisture Content in Raw Gas (%)</u>	
	<u>As Measured on GC</u>	<u>Estimated</u>
1B-1	41.0	35.9
1B-2	42.6	36.2
1C	37.7	37.3

Installation of the water vapor analyzer (WVA) train is under way and a functional checkout will be performed in the forthcoming gasifier tests. The WVA train will continuously sample a slip stream of product gas and obtain a measure of moisture by condensing the vapor. This unit will also provide a means of measuring water-soluble trace compounds such as ammonia and chlorides.

The on-line infrared analyzer to measure ammonia and water in the raw gas was also installed and a functional checkout was performed in gasifier test TP-027-3. Preliminary results from this instrument indicate that the ammonia content in the gas is less than 500 ppm.

4.1.2 Analysis of Samples

The chemical characterization of cyclone deposit samples from gasifier test TP-023-3 was completed, the results of which are discussed in Section 4.2. Solids samples from gasifier tests TP-023-4, TP-027-1 and TP-027-2 were analyzed. The results of the ultimate analyses have been used in the heat and material balances for the respective tests.

Work Forecast for Next Quarter

Commission the water vapor analyzer and the ammonia-water infrared analyzer.

4.2 CYCLONE DEPOSIT CONTROL

Material deposition in the PDU cyclone has historically been the primary cause for the premature termination of oxygen-blown gasifier tests conducted in 1978 and 1979. Work on deposit control during this reporting period was focused on three areas:

- An investigation of possible mechanisms for cyclone deposition based on the chemical analyses of deposits from test TP-023-3.
- A demonstration of the viability of quench water injection as a near-term method of eliminating deposits and permitting long duration tests in the PDU.
- A scoping evaluation of the cyclone cold wall device, which has emerged as a promising long-term solution to the deposit control problem.

4.2.1 Characterization of Cyclone Deposits, Test TP-023-3

Gasifier test TP-023-3, conducted in December 1979, was an oxygen-blown test using Pittsburgh #8 and Upper Freeport seam coals. The test was terminated after completing 68 hours of operation with Pittsburgh #8 coal, when it was clear that material deposition in the cyclone was restricting gas flow from the gasifier. Following the shutdown, a systematic investigation of the buildup patterns in the cyclone and associated equipment was initiated. Unlike the previous gasifier tests, when grab samples of deposit were taken, during this evaluation samples were systematically obtained from key locations in the process such as the gasifier wall, the interconnecting piping, the cyclone barrel, the cyclone downcomer, the exit pipe from the cyclone, and the collected fines. Furthermore, at each location the samples were subdivided to obtain the distribution of various species across the thickness of the specimen. The chemical characterization of the samples included a qualitative x-ray diffraction analysis and a quantitative determination of the mineral oxides and the various types of sulfur, namely sulfate, pyritic and organic, present in the deposits.

On collating the chemical analyses, the following salient conclusions were drawn:

- The deposits in the cyclone and interconnecting spool piece showed a significant enrichment of iron and sulfur as compared to these species in the mineral matter of the coal.
- Although it was evident that iron and sulfur were selectively deposited, the exact structure of the associated iron-sulfur compound was not clear. The x-ray diffraction analyses showed the presence of SiO_2 and complex magnesium-iron silicates. Unlike previous data on Pittsburgh coal deposits, the x-ray results did not reveal any significant amounts of crystalline Fe_{1-x}S .

- The ratio of organic sulfur to total sulfur in the deposits was significantly greater than in the coal feedstock. This finding, in conjunction with the x-ray results, suggested that a sulfur-containing amorphous compound, possibly of an organic nature, could act as a low-melting binding matrix for the deposits.
- It now appears that the presence of $Fe_{1-x}S$ as a major crystalline phase is primarily influenced by the operating temperature of the cyclone. In prior runs with Pittsburgh coal, the cyclone was operated without water injection at 1800°F and the deposits showed a significant concentration of $Fe_{1-x}S$. However, in this test the gas temperature was maintained between 1400°F 1550°F by quench water injection and the deposits were free of $Fe_{1-x}S$. This result was corroborated in a previous test with Ohio #9 coal, TP-023-1, when water injection was employed and similar x-ray results were obtained, showing the absence of $Fe_{1-x}S$.

The overall conclusion from this study is that in addition to the previously suspected low melting "glues" such as $Fe_{1-x}S$ and the eutectics of the K-Al-Si system, there could exist an amorphous sulfur-containing compound of an indeterminate structure that would act as a binder. From an operational standpoint, the results of test TP-023-3 indicated the need to quench the gas to a temperature less than 1400°F in order to eliminate deposition.

4.2.2 Evaluation of Quench Spray Injection

The three gasifier tests conducted during this reporting period, TP-023-4, TP-027-1 and TP-027-2, demonstrated the feasibility of the quench spray injection method as a means of combatting the cyclone deposition problem in the PDU. On all three tests, the off-gas from the gasifier was quenched from a nominal 1820°F to 1150°F by injecting a cold water spray in the freeboard section of the gasifier. In more than 400 hours of cumulative hot operation, the cyclone vessel and the interconnecting piping were free of deposits.

4.2.3 Evaluation of Cyclone Cold Wall

The cyclone cold wall consists of a cooled metal segment embedded in the cyclone barrel section. The purpose of this wall is to quench the impacting solids particles to a temperature below the stickiness threshold for the "glue" material and thereby prevent their deposition on the wall. This concept was evaluated during the first startup of test TP-023-4, when the gasifier was operated at a freeboard temperature of 1800°F using Pittsburgh #8 coal. The system was operated without the quench water spray to provide an independent evaluation of the cold wall concept. After completing 33 hours of hot operation, including 8 hours with Pittsburgh #8 coal feed, the cold wall was essentially free of deposits, whereas the rest of the cyclone barrel showed signs of buildup. This short-duration scoping test showed that the

cold wall concept is a potential long-term solution to the cyclone deposit problem, which would avoid the thermal penalty of excess cooling, as is the case with the quench spray method.

In subsequent tests the cyclone cold wall operation was continued, in conjunction with quench water injection, to evaluate the extent of wear and metal degradation on the impacting surface of the wall.

Work Forecast for Next Quarter

Future oxygen-blown gasifier tests will include operation of the quench water injection system to control the cyclone inlet temperature at 1150°F. Studies on the cold wall design and hardware performance will continue to consolidate the long-term design for a water-cooled interconnecting pipe and cyclone.

Studies on the deposit mechanism will continue at the Westinghouse R&D Center where a bench-scale agglomerator unit will be adapted to simulate PDU conditions in the cyclone and associated equipment.

4.3 PDU OPERATIONAL ANALYSIS

4.3.1 Recycle Gas Aftercooler Plug, Test TP-027-1

Gasifier test TP-027-1 was terminated when an abnormally high-pressure drop was noted across the recycle gas compression system. Following test shutdown an inspection of the E-106 aftercooler, which is a water-cooled shell and tube exchanger for the spillback to the compressor, showed an extensive plug on the cold exit side of the tube bundle. An investigation into the probable causes and mechanisms of buildup was completed. The conclusions are summarized below:

- The aftercooler plug was caused by a gradual buildup of material consisting primarily of char fines that escape the scrubbers and the 10-micron filters located upstream of the recycle gas compressor. The deposit showed an ash concentration of about 29 percent, the remainder being carbon.
- The deposit originated in a moisture separator pot located downstream of the cooler and finally migrated back to the exit side of the tube bundle.
- Although an abrupt increase in the recycle gas supply pressure was noted in the last three hours of operation during TP-027-1, it is not clear that the deposit was formed continually over 300 hours of testing. During normal operation the spillback loop has an available pressure drop of 80 psi, most of which is throttled across an automatic control valve located upstream of the cooler. Any increase in the pressure drop across the cooler was thus automatically compensated by the control valve, thereby "disguising" an impending plug in the system.

- As a result of this investigation the following action items have been implemented: (1) a differential pressure indicator was mounted across the cooler to closely monitor the pressure drop, (2) the moisture separator and the cooler were cleaned, and (3) a secondary bank of filters will be installed upstream of the compressor.

4.3.2 Product Gas Flow Measurement

Measurement of the PDU product gas flow rate is accomplished by a pressure- and temperature-compensated orifice plate flow meter, FT-26, located upstream of the back pressure control valve, PCV-15, which maintains the system at the operating pressure. Historically, this flow meter has been suspected of causing undesirable heat-material balance closures due to the tendency of this instrument to oscillate in a wide span. In 1979, it was thought that the oscillation was caused by mist entrainment from the particulate scrubbers, and in an effort to eliminate this problem a mist eliminator was installed on the exit pipe of the scrubber. However, gasifier tests TP-023-4 and TP-027-1 have shown that this problem has persisted, with the amplitude of the oscillation approaching 60 to 100 percent of the mean value of the indicated flow.

In order to characterize this disturbance from basic control theory, the system was modeled as a single capacitor and single flow restriction. The conclusions drawn from this study are as follows:

- The observed flow oscillations are time flow changes caused by changes in the pressure resulting from the intermittent dumps of water from the quench scrubber system. During a dump, approximately 5 cubic feet of water is removed from a vessel. As the gas displaces the volume the resulting decrease in pressure of about 3 psi calls for the automatic control action to close PCV-15 in order to rebuild pressure. The closing of PCV-15 induces a change in the actual gas flow.
- The magnitude of flow oscillations could be reduced by retuning the pressure controller. However, if significant benefit is to be gained, the control action of PCV-15 would have to be slowed to the point where subsequent water system dumps would occur before the controller had completely responded to the initial dump. This would defeat the function of the pressure controller.

Following test TP-023-4 the orifice plate on FT-26 was inspected in an effort to resolve the measurement errors that were evident during the test from on-line material balances. The orifice was found to be partially restricted by a mixture of char fines and white crystalline material which smelled of naphthalene. Since the gas flow measurement is sensitive to small changes in the effective orifice bore diameter, it was decided to implement a routine inspection and cleanup of this critical orifice plate following every gasifier test. Post-test inspection after tests TP-027-1 and TP-027-2 showed that the orifice plate was essentially free of deposits, suggesting that the deposits seen after test TP-023-4 represented a cumulative laydown of trace naphthalene over several months of PDU operation.

4.4 PDU PROCESS ANALYSIS

4.4.1 Fines Carryover Analysis

The fines carryover data from the gasifier tests conducted in 1978 were analyzed to obtain a correlation for estimated values of the elutriation constant.

The results have been plotted in Figure 4.4-1. A comparison of this data with a similar correlation in the published literature¹ shows that the elutriation constant for the PDU fluidized bed gasifier is slightly higher than predicted for the identical Reynolds' number and particle size.

4.4.2 Ash Agglomerator Performance

A set of steady-state mass balances was performed to obtain a functional relationship between the ash concentration in the bed and that in the withdrawal.

The significance of the results are summarized and discussed below.

- High-ash coals result in higher bed ash concentrations than coals with similar reaction rates and lower ash fractions.
- Highly reactive coals result in higher bed ash concentrations than coals with similar ash fractions and lower reactive rates.
- If ash balance is maintained, changes in the withdrawal ash fraction should not greatly affect the bed ash fraction in PDU operation.

All three of the above results have been observed in PDU operation:

- With high-ash coals, and particularly the reactive feedstocks such as lignite, the bed ash content has been higher than with Pittsburgh seam coal.
- During ash annulus upsets, such as in test TP-023-4, the bed ash content increased marginally while the withdrawal ash decreased substantially as a result of poor physical separation.

4.5 DATA ACQUISITION SYSTEM UPGRADE

The PDU data acquisition system was modified to conform to the new IAS (Interactive Applications System) version 3.0 operating system and the new FORTRAN version 2.2. This change was necessary since the vendor upgraded the

1. Yagi, Aochi Correlation; pp. 315, Fluidization Engineering, Kunii & Levensfael, Wiley (1969).

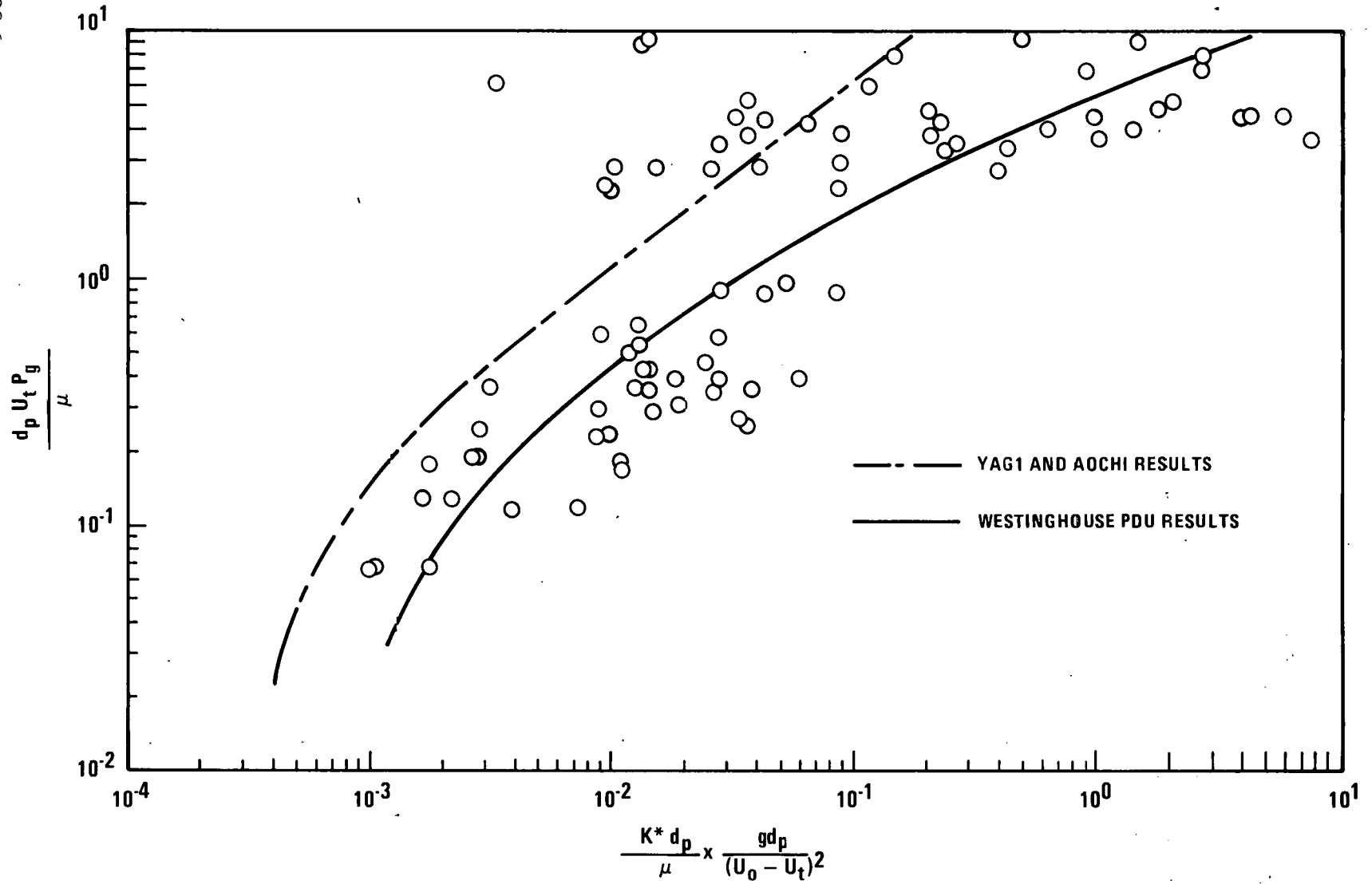


Figure 4.4-1. Correlation for Fines Elutriation Constant

operating system software to the new IAS version 3.0 and consequently dropped support for the old RSX 11D version 6.2 operating system. The new system also has a scheduling algorithm, which can be utilized to effectively schedule application tasks in and out of memory. A block read feature in scanning analog points was utilized to further improve the speed of the system.

A feature to scan different analog points at different multiples of base scan rate has also been added in the scan task. This feature will be particularly useful for supervisory control when some points may need to be scanned at a different rate than other points.

SECTION 5.0

PROCESS AND COMPONENT ENGINEERING AND DESIGN

5.1 OXYGEN SYSTEM UPGRADE

Following commissioning of the high-pressure oxygen supply pump for operation at 230 psig, a new, larger, tank pressure building coil was installed and commissioned.

Modifications to upgrade PDU steam system capacity included installation of a new 4-inch steam supply line. In addition, the new superheater, heating element and electrical components for the steam boiler system were received for installation.

Work Forecast for Next Quarter

Install and check out the superheater and associated equipment.

5.2 FINES RECYCLE AND UTILIZATION

During this quarter, the following was accomplished:

- The surge vessel, all material required to fabricate the fines coolers, including the internals, and all piping, valves, and fittings for the glycol cooling loop were received on site.
- The fabrication drawings for the fines coolers and the preliminary arrangement drawing for major piping spool pieces and vessels were completed.
- Fabrication of the C-120 particulate separation vessel was initiated, with the refractory clips, refractory and nozzle sleeves ordered and received.

Related structural work includes completion of the steel framing design for the entire structure, the foundation plan drawing, the concrete footing and retaining wall calculations with reinforcement determination, and the preliminary specifications for general construction activities, such as excavation, concrete, etc.

Work Forecast for Next Quarter

- Fabricate fines coolers and internals.
- Initiate glycol cooling system upgrade.
- Complete fabrication of C-120 fines vessel and initiate installation of refractory.

- Initiate C-108A particulate removal modifications.
- Approve structure design and select contractor.
- Initiate fabrication of C-120 internals cyclone and surge vessel cooling internals.

5.3 HEAT RECOVERY

System and component design, as well as process and instrumentation and component drawings, for the advanced Phase I heat recovery test loop were completed this quarter. Fabrication of components is approximately 80 percent complete.

Work Forecast for Next Quarter

Complete installation of the advanced Phase I heat recovery test loop, including the test loop itself, the upgraded plant water system, and the 105 lock hopper system.

5.4 ELECTRICAL AND INSTRUMENTATION UPGRADE

In this report period, the following was accomplished:

- The bid package for the design phase of the PDU power upgrade was approved and a contract awarded. The design was completed, reviewed and approved with minor changes, which the contractor will incorporate in the final design.
- The design for power feed upgrading of the steam system was completed.
- Electrical/instrumentation installation for the total condensables analyzer was completed.

Work Forecast for Next Quarter

- Submit a bid package for procurement and installation of PDU power upgrade work.
- Install power feeder hardware for the steam system upgrade.

SECTION 6.0

SCALE-UP MODEL

During this report period, general contractor site work was completed except for miscellaneous items and preparation of the final deficiency list for building acceptance by Westinghouse. In addition, all six model test sections were finish-welded, three of which were finish-machined and delivered to the site (see Figure 6.0-1). Following erection of the observation platform, shown in Figure 6.0-2, the first two model sections, as well as the drawoff cone and the feed tube, were installed in the observation platform structure.

The model internals were assembled as a single unit, which is now being prepared for installation in the interior of the model sections.

Significant accomplishments for this quarter are as follows:

- Completed all electrical subcontract work.
- Installed all six weigh cells under their respective bins.
- Completed erection of the observation platform.
- Completed piping installation in the compressor shelter.
- Completed pipework on external storage bins.
- Completed test run of main drive motors.
- Installed air intake filters.
- Installed cyclone separators.
- Aligned couplings on the compressor.
- Fabricated vibration support and pit ladder.
- Performed grouting on steel work and piping supports.

In other work, the design of the in-line filters for the air compressors and the lifting beams for the main model was completed. Precommissioning activities for the scale-up facility were initiated, including preparation of equipment and valve lists and operating procedures for the main air compressor subsystems.

Currently, a setup for hydrotest of the cooling water lines is being prepared, installation of process piping is continuing, and the initial charge of bed material is being prepared for shipment to the site.

4498-1

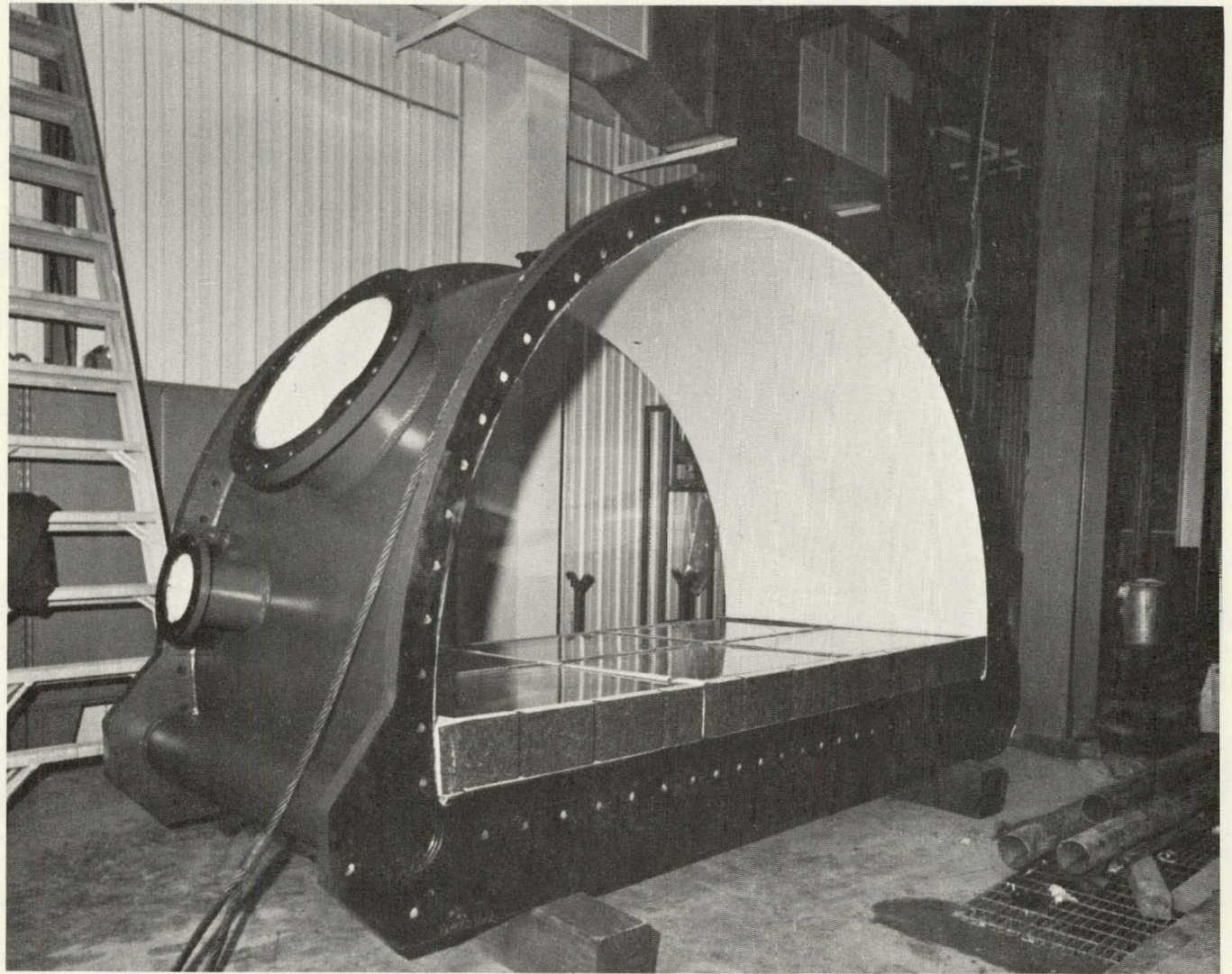


Figure 6.0-1. Cold Flow Test Facility Model Section



Figure 6.0-2. Cold Flow Test Facility Observation Platform

4498-2

Work Forecast for Next Quarter

- Complete installation of scale-up model test sections, model internals, computer console and process piping.
- Perform initial startup of air compressors.
- Pressure/leak test and flush water and air lines.
- Complete procedures and test plans for system commissioning.

SECTION 7.0

LABORATORY SUPPORT STUDIES

Support work on fuel processing was conducted to investigate operating conditions for the PDU test program, provide troubleshooting capability for PDU operation, obtain data for PDU modifications, analyze and interpret results for PDU operation, develop process models for scale-up, and understand process phenomena to achieve reliable operation. Work was conducted in the areas of gas-solids flow modeling, coal/ash behavior, gasifier system model integration, particulate/chemical profiles and environmental impact.

7.1 GAS-SOLIDS FLOW MODELING

7.1.1 Jet Phenomena

Experiments using a jet nozzle configuration similar to that employed in the PDU are continuing. Tracer gas was injected into the jet to simulate the oxygen, and gas samples were collected from the bed to investigate the dispersion of the tracer. In the meantime, the literature data on jet penetration were analyzed to test the correlation developed previously. A correlation was developed which successfully correlated the jet penetration data available in the literature¹ obtained from fluidized beds of sand ($\rho_p = 2629 \text{ kg/m}^3$), FMC char ($\rho_p = 1158 \text{ kg/m}^3$), and siderite ($\rho_p = 3988 \text{ kg/m}^3$) at pressures up to 5300 kPa ($\sim 53 \text{ atm}$). The limiting case of the developed correlation at one atmospheric pressure (101 kPa) reduces to a form similar to that developed earlier using jet penetration data collected in the Westinghouse laboratory at ambient pressure, although the numerical coefficients are slightly different.

The developed correlation is presented in Figure 7.1-1 and equation 1:

where

$$\frac{L_{\max}}{d_o} = 7.65 \left[\frac{1}{R_{cf}} \cdot \frac{\rho_f}{(\rho_p - \rho_f)} \cdot \frac{U_o^2}{g d_o} \right]^{0.472} \quad (1)$$

d_o = jet nozzle diameter

L_{\max} = jet penetration depth

R_{cf} = ratio of complete fluidization velocity at pressure P over that at atmospheric pressure

U_o = average jet nozzle velocity

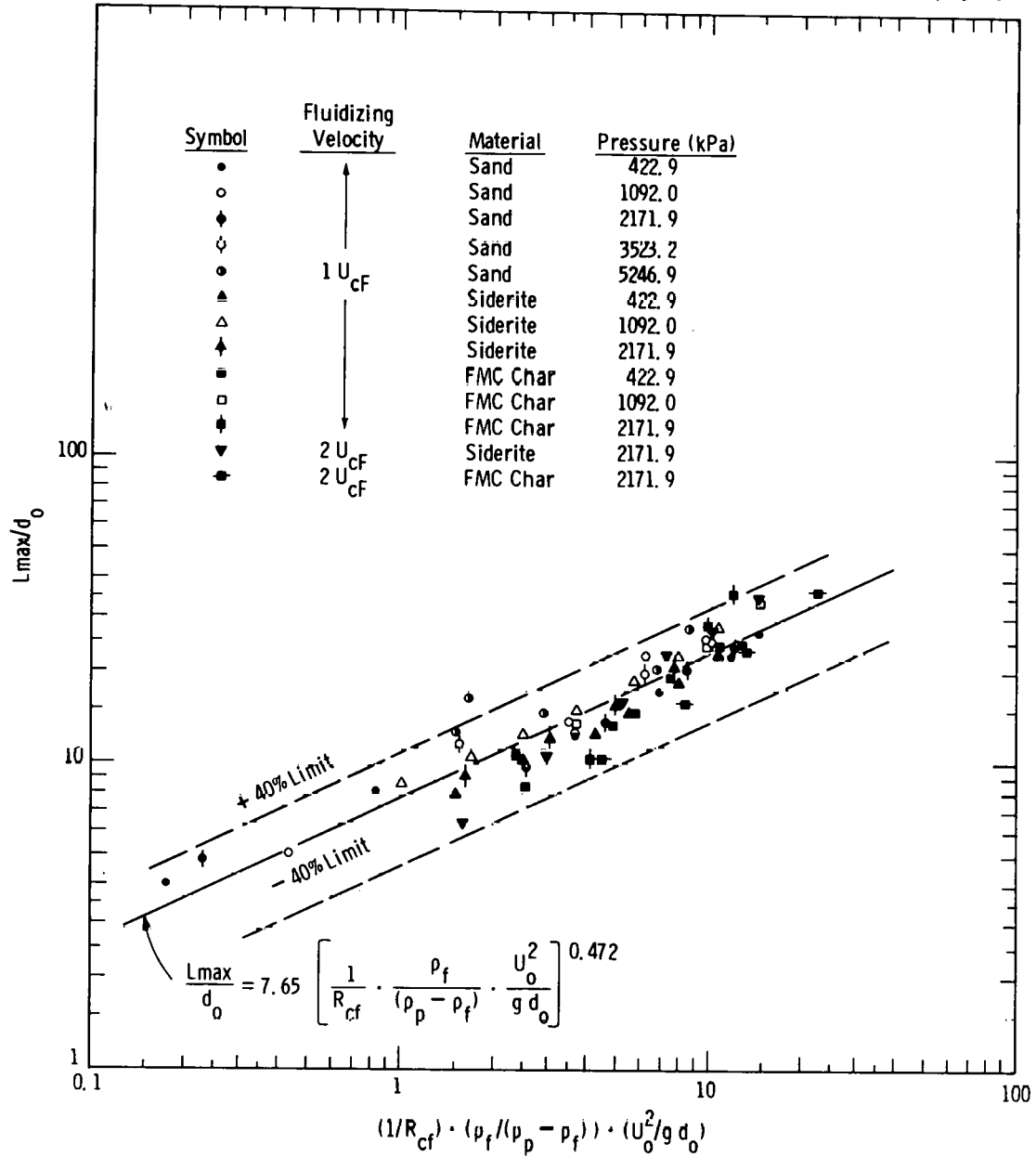


Figure 7.1-1. Comparison of the Correlation with the High-Pressure Jet Penetration Data of Knowlton and Hirsan (1980)

ρ_f = fluid density

ρ_p = particle density.

The correlation successfully correlates the data to +40 percent.

7.1.2 Particle Separation

The experiments to study the rate of particle separation for the acrylic-dolomite system were completed. Exploratory experiments are being conducted with different pairs of materials of different density ratios in order to select a suitable pair for further studies. The results of the acrylic-dolomite system are summarized below.

The experimental results for the rate of separation of dolomite from acrylic for mixtures of 20 percent and 40 percent dolomite by weight were presented in two previous quarterly reports, FE-1514-113 and FE-1514-117. The results for the 60 percent dolomite mixture are presented in Figures 7.1-2 to 7.1-5. It took between 15 to 20 seconds for the 20-percent dolomite mixture to reach an equilibrium concentration in both the top and the bottom layers, while it takes only half that time, 7-10 seconds, for the 60-percent dolomite mixture, as shown in Figures 7.1-2 to 7.1-5. The separation fluidizing velocity does not seem to affect the total time required to reach equilibrium for a particular mixture.

A mathematical model was developed to predict the rate of particle separation. The present mathematical model assumes that the particle segregation in a fluidized bed can be simulated with two perfectly mixed fluidized beds in series with particles interchange between them.

$$\ln \left(\frac{V_{J1}}{V_{J1}^0} \right) = -mt, \quad (2a)$$

$$m = \frac{(U - U_{mf2}) \cdot A \cdot f_w \cdot (1 - \epsilon_w)}{V_1}, \quad (2b)$$

Equation 2a was used to fit the experimental data with excellent results. Four cases for both the 20-percent and the 60 percent dolomite mixtures are presented in Figures 7.1-6 and 7.1-7. The success of the correlation suggests possible physical significance of the parameter, m , defined in equation 2b. A constant m means a constant volumetric exchange rate between the two fluidized beds during the transient period. This assumption seems to be a reasonable approximation as evident from comparison with the experimental data shown in Figures 7.1-6 and 7.1-7.

Work Forecast for Next Quarter

- Continue tracer injection study to simulate oxygen injection in the PDU with a similar jet nozzle configuration.

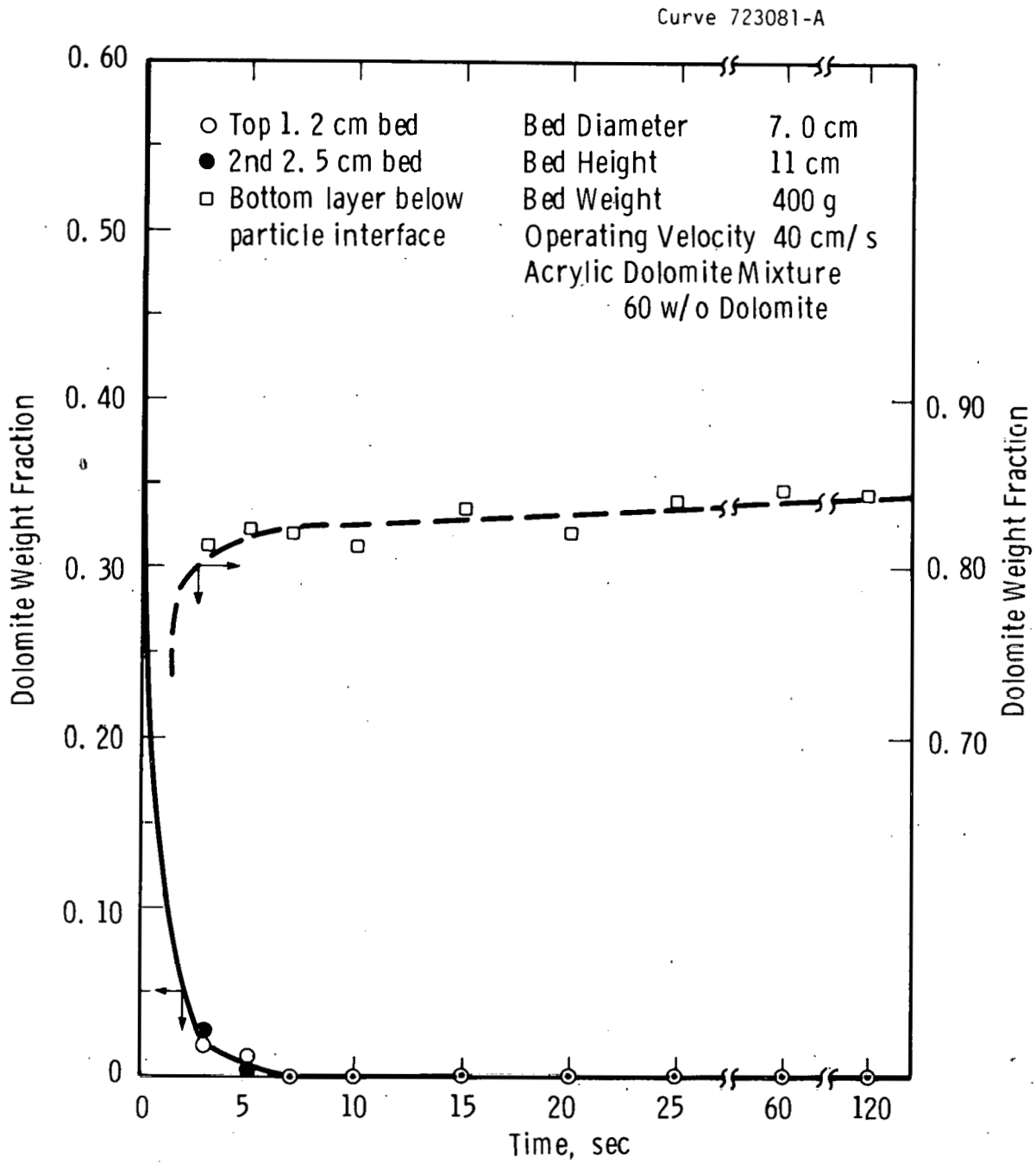


Figure 7.1-2. Rate of Particle Separation at a Velocity of 40 cm/s—60 w/o Dolomite Mixture

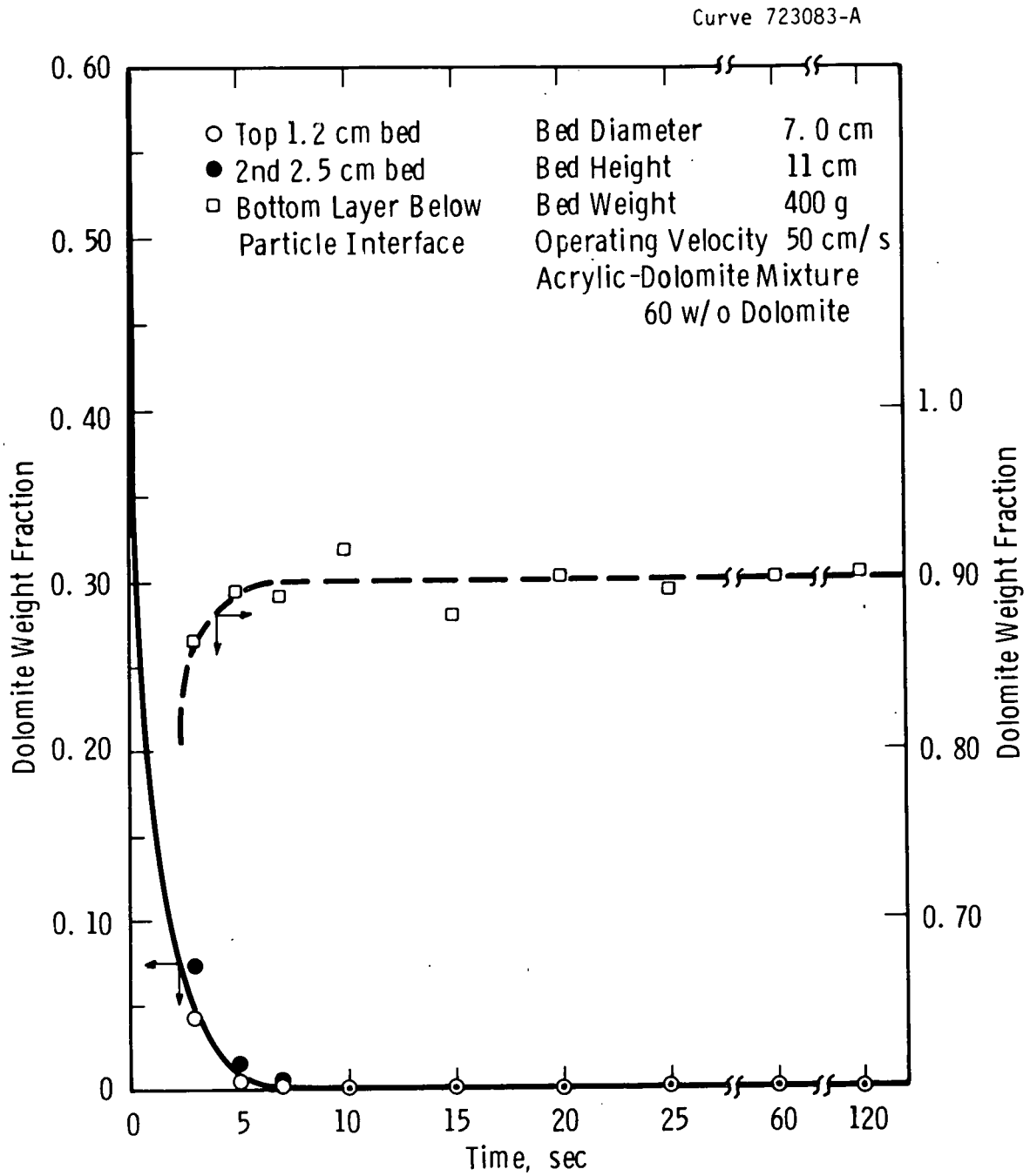


Figure 7.1-3. Rate of Particle Separation at a Velocity of 50 cm/s—60 w/o Dolomite Mixture

Curve 723078-A

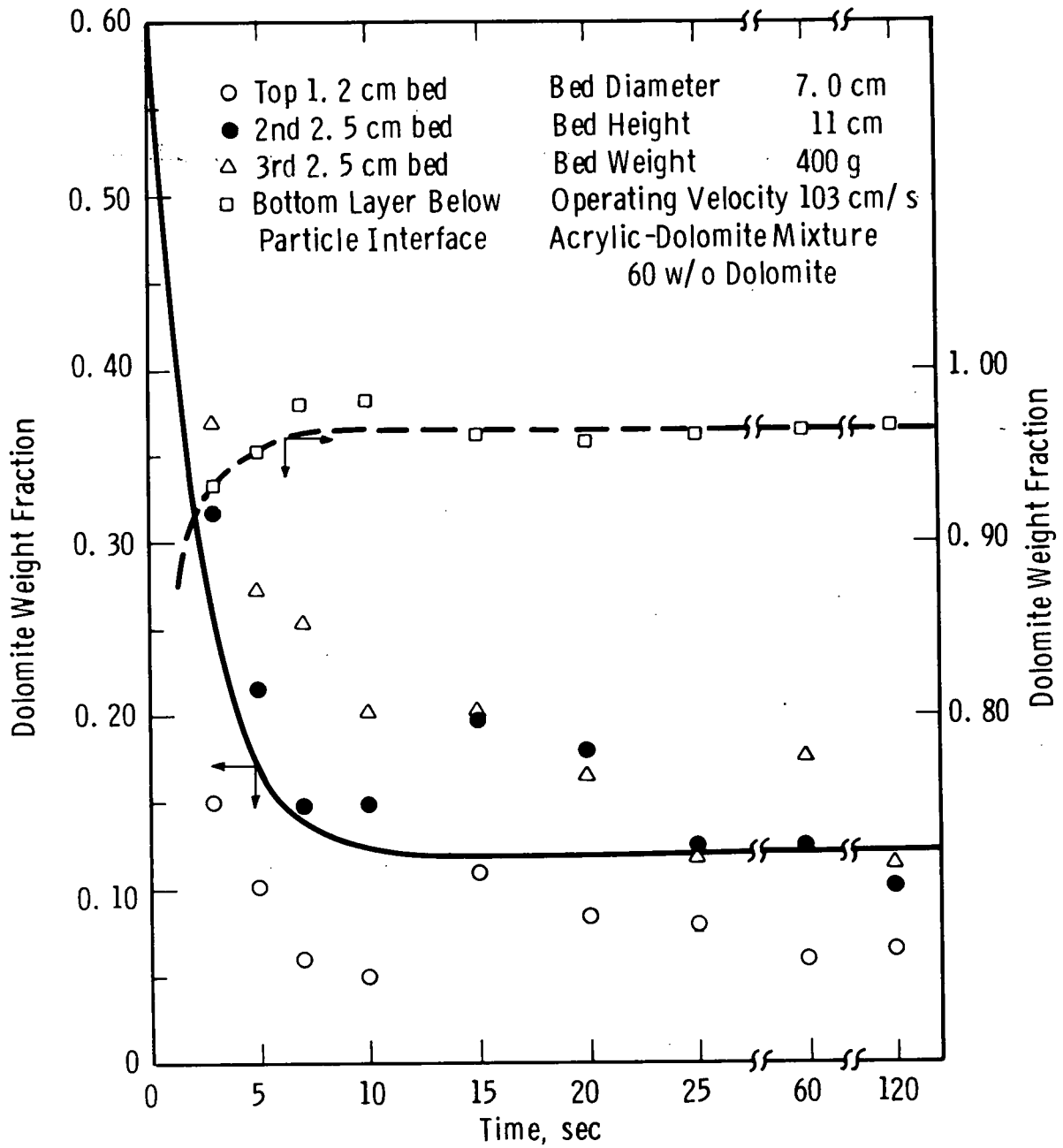


Figure 7.1-5. Rate of Particle Separation at a Velocity of 103 cm/s—60 w/o Dolomite Mixture

Curve 723085-A

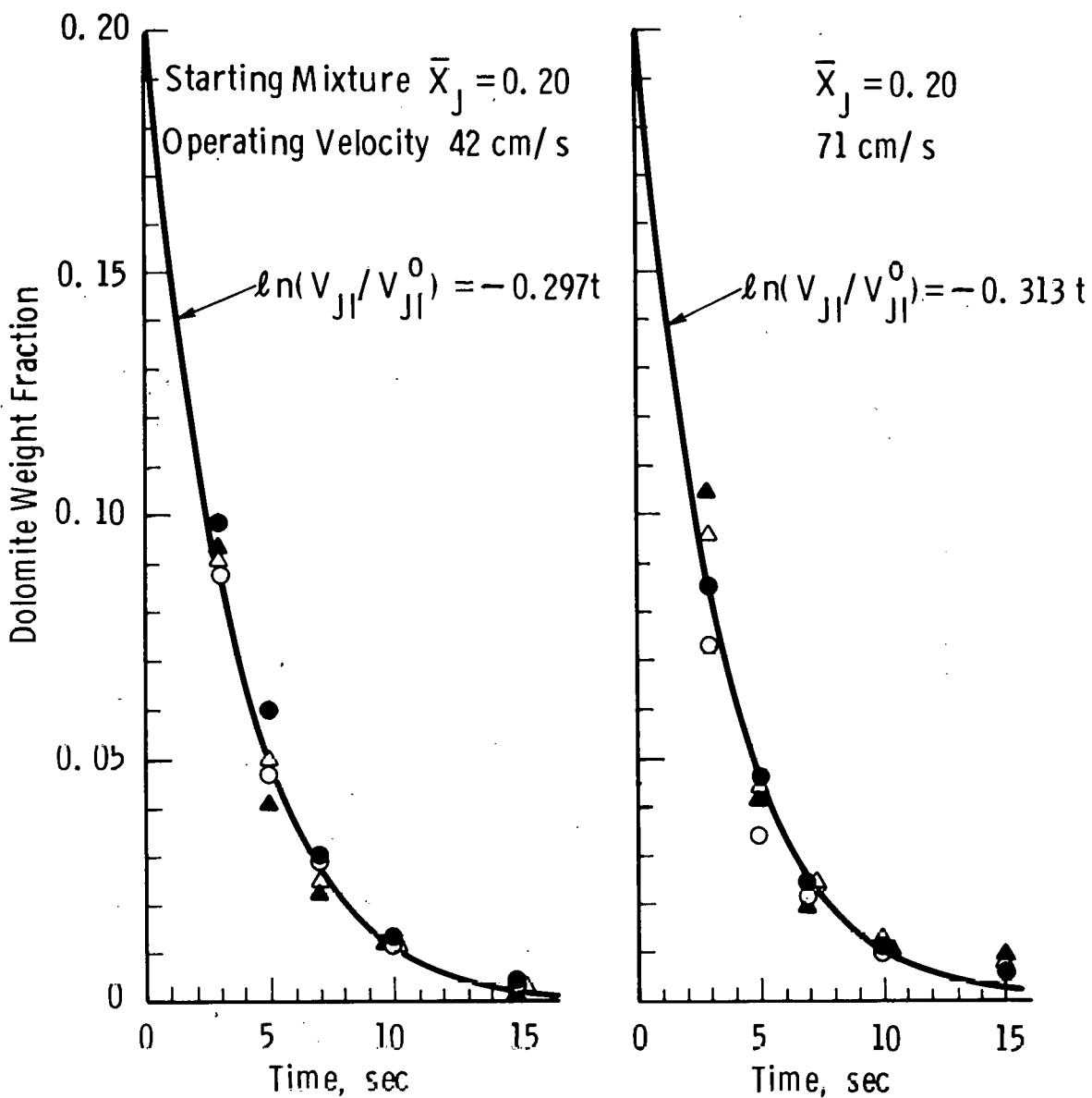


Figure 7.1-6. Comparison of Experimental Data with the Theoretical Rate Equation for a 20-Percent Dolomite Starting Mixture

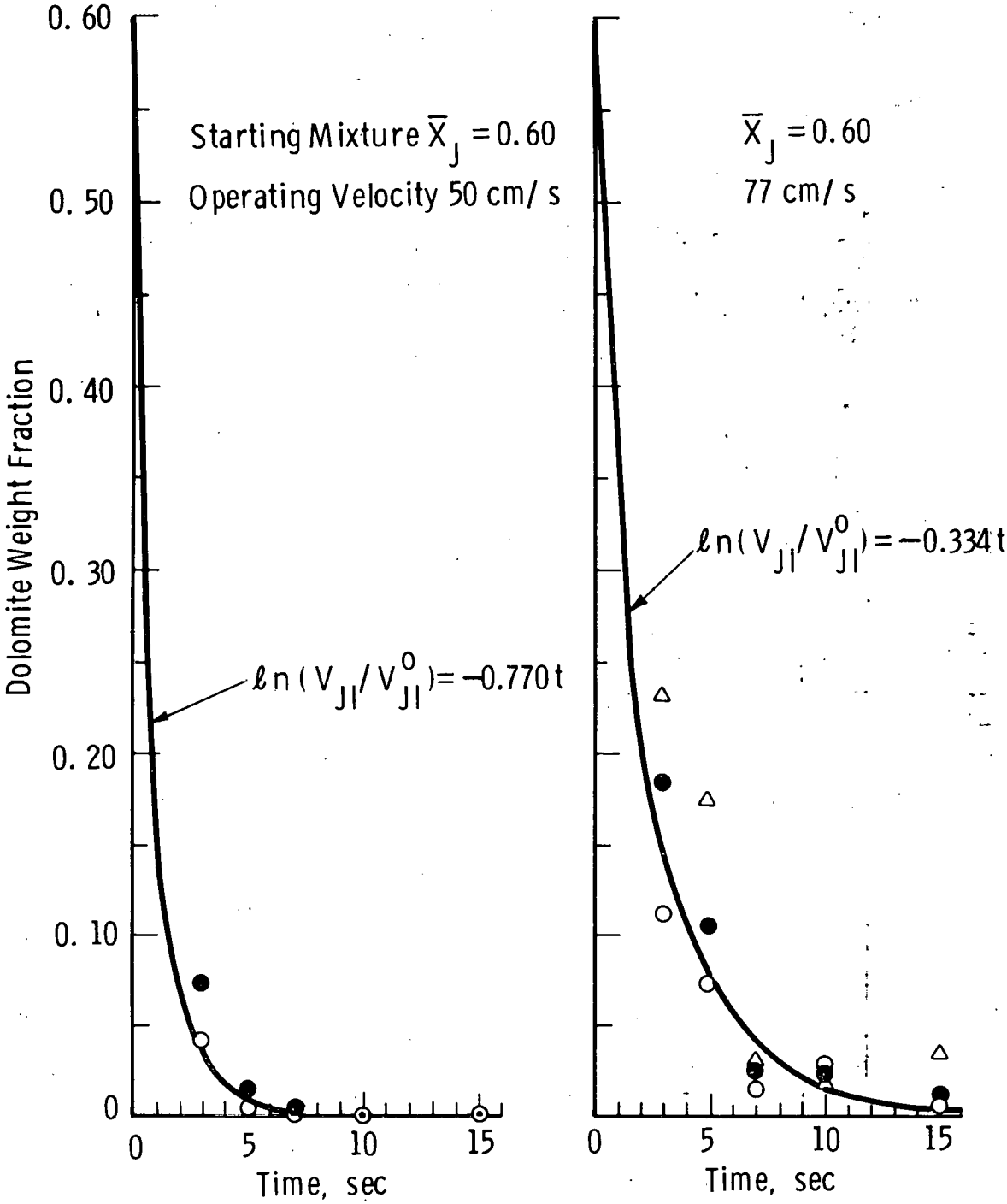


Figure 7.1-7. Comparison of Experimental Data with the Theoretical Rate Equation for a 60 Percent Dolomite Starting Mixture

- Perform exploratory experiments for different pairs of bed materials of different density ratios and select a pair of materials for further study on the rate of particle separation.

7.2 COAL/ASH BEHAVIOR

7.2.1 Gasification

Experimental conditions and procedures for coal/char characterization on the thermogravimetric analyzer (TGA) were established to obtain reproducible data. A flow rate of 300 ml/min and a sample weight of about 5 mg are being used for these tests. A number of coals and chars were characterized and the results are shown in Figures 7.2-1 through 7.2-5. The total area shown on the graphs represents the average reaction rate for the temperature and gas composition given in the legend.

7.2.2 Ash Agglomeration

Tests MG-4 and MG-5 were conducted in the ash agglomeration test facility with coke breeze for a steady-state period of approximately 5 hours. The following conditions were maintained in these tests:

Bed temperature = 1950°F
Jet Velocity = 71 ft/s
Superficial velocity in the gasifier = 4 ft/s
Bed ash content = 25 percent.

In test MG-4, the size distribution of the feedstock was -12 + 35 mesh (-1.7 + 0.5 mm). Agglomerates of desirable quality were obtained. The ash content and bulk density of the agglomerates were 99.8 percent and 38.9 lb/ft³, respectively. No molten phase was observed in the agglomerates in a microscopic examination. Almost all agglomerates were found to be larger than 0.067 in (1.7 mm). Their low bulk density indicates that they are fairly porous.

The objective of test MG-5 was to study the effect of fines on agglomeration. In this test, the size of the feedstock was -12 mesh (-1.7 mm) and the amount of coke breeze smaller than -35 mesh (0.5 mm) was approximately 39 percent. No problems were experienced in using air as the transport gas despite the large amount of fines. The operating conditions in this test were the same as in test MG-4 except for the size distribution of the feedstock. No agglomerates were produced in this test. From the information available in the literature, it is known that it is more difficult to agglomerate fines than larger particles. This test has supported this view.

Test MG-6 was conducted with Indiana #7 coal at a temperature of about 1850°F. The following conditions were maintained:

Size distribution = -12 + 35 mesh
Jet velocity = 61.8 ft/s
Bed ash content = 29.6 percent

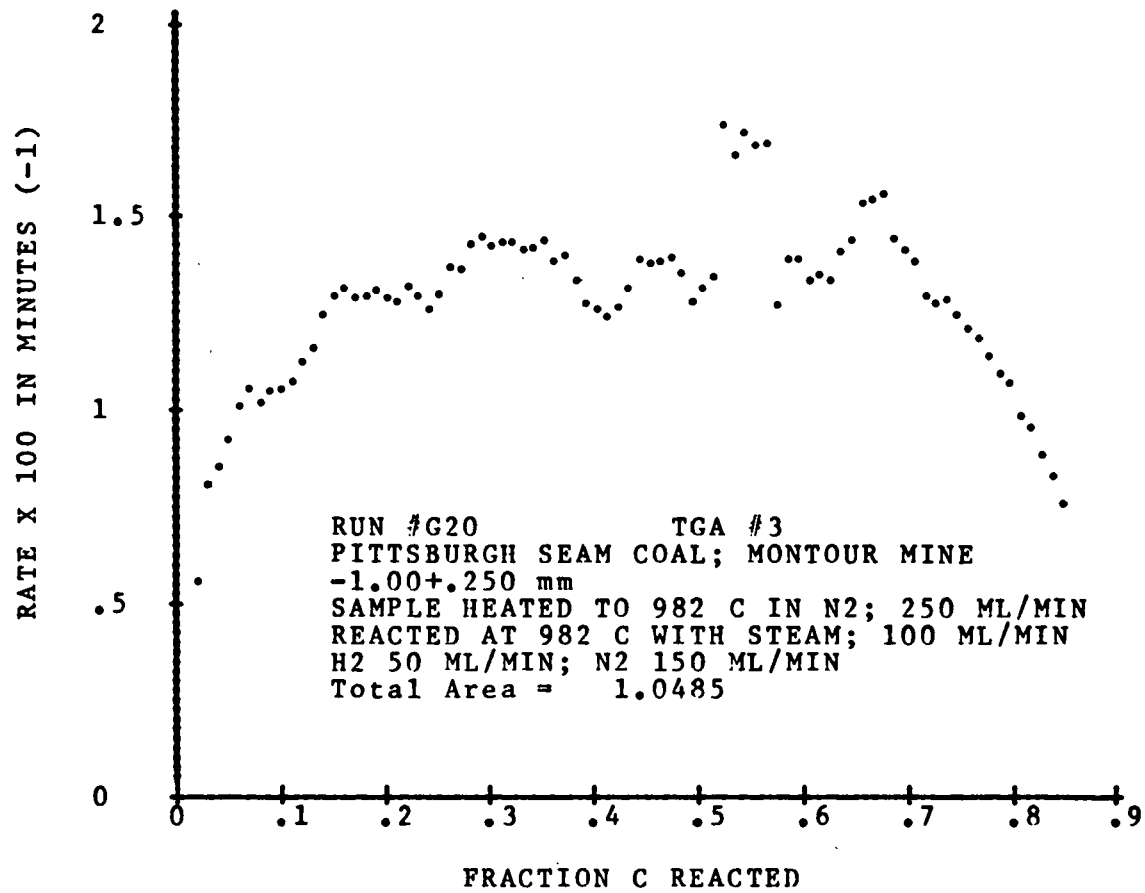


Figure 7.2-1. Reactivity of Pittsburgh Seam Coal

RUN #G26 TGA #3
WYOMING SUB-C CHAR; SC22 TP 15-1
-1.00+.250 mm
SAMPLE HEATED TO 982 C IN N2; 250 ML/MIN
REACTED AT 982 C IN STEAM; 100 ML/MIN
H2 50 ML/MIN; N2 150 ML/MIN
Total Area = 13.0423

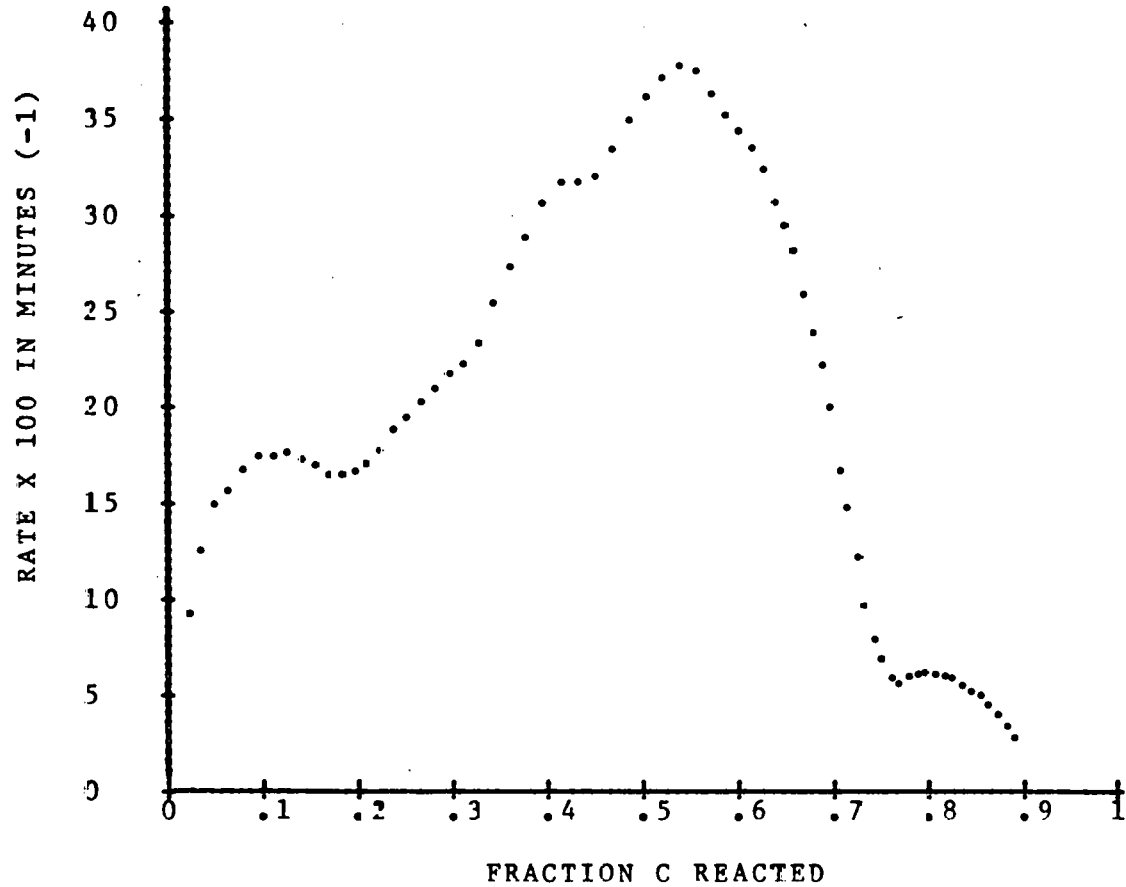


Figure 7.2-2. Reactivity of Wyoming Sub-C Char

RUN #G25 TGA #3
MINNEHAHA COAL; -1.00+.850 mm
SAMPLE HEATED TO 982 C IN N2; 250 ML/MIN
REACTED AT 982 C WITH STEAM; 100 ML/MIN
H2 50 ML/MIN; N2 150 ML/MIN

Total Area = 1.7129

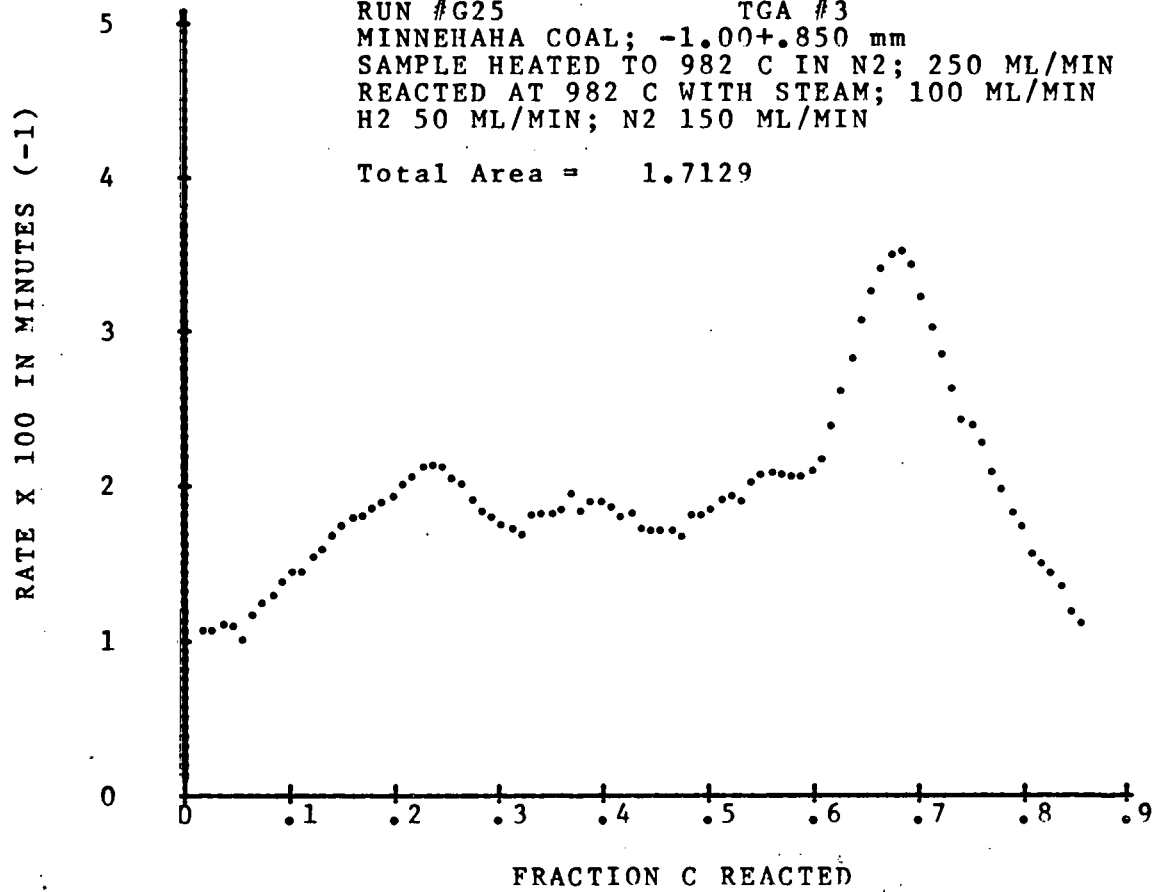


Figure 7.2-3. Reactivity of Minnehaha Coal

RUN #G22 TGA #3
ILLINOIS #6 COAL; -1.00+.250 mm
SAMPLE HEATED TO 982 C IN N2; 250 ML/MIN
REACTED AT 982 C WITH STEAM; 100 ML/MIN
H2 50 ML/MIN; N2 150 ML/MIN
Total Area = 2.0044

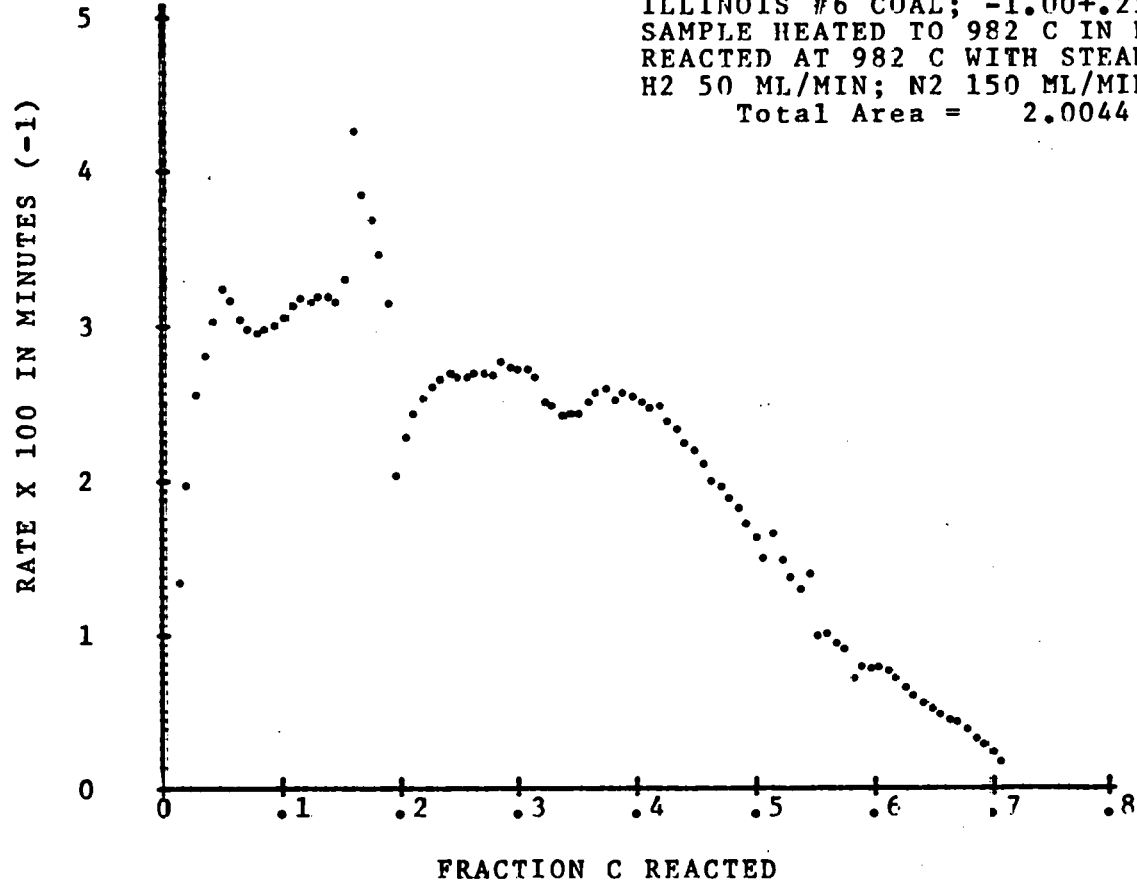


Figure 7.2.4. Reactivity of Illinois # 6 Coal

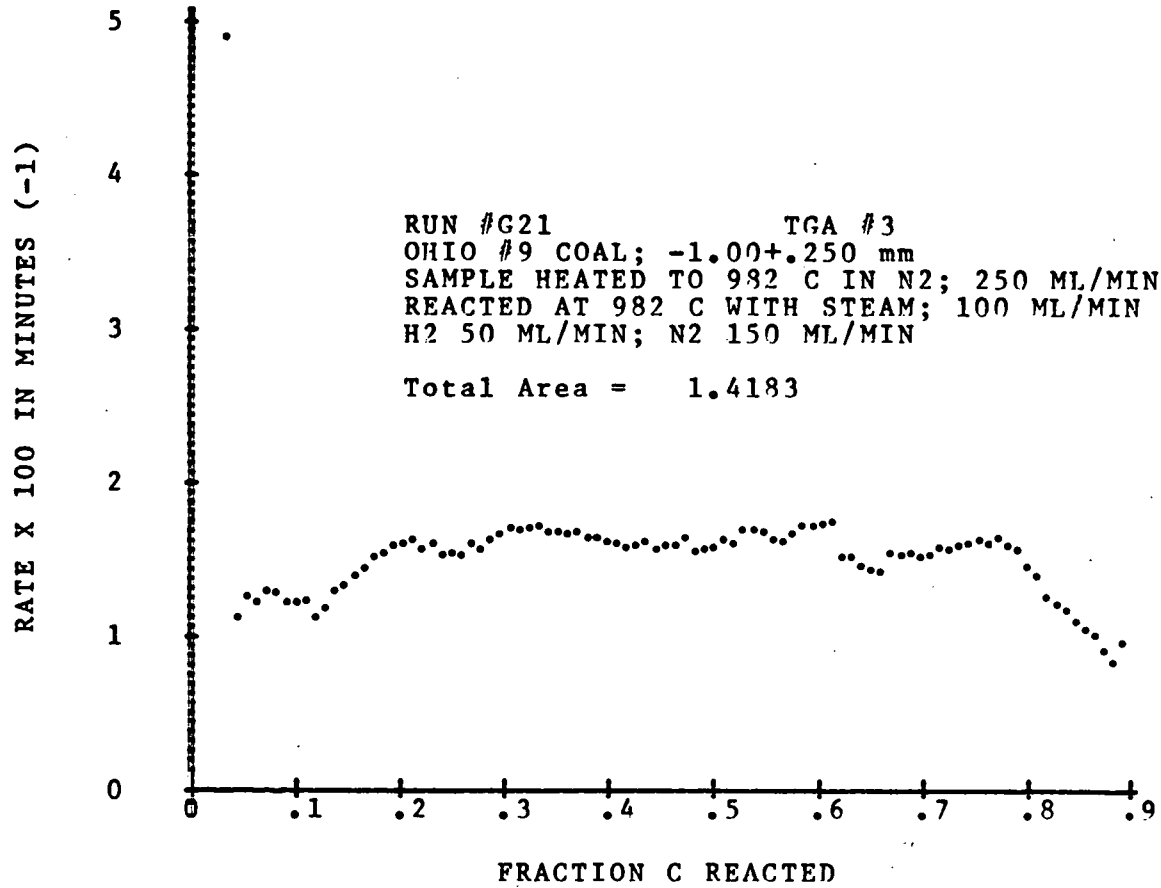


Figure 7.2.5. Reactivity of Ohio # 9 Coal

No ash agglomerates were obtained during this test. It is believed that this temperature is not high enough for agglomerate formation. Minnehaha coal was fed pneumatically without any problem and the mixed mean temperature of solids and gas was maintained below 400°F. Control of the operating conditions was excellent until the test was terminated after a steady-state operation of about 1-1/2 hours because of failure of the air supply.

Following several successful tests on the ash agglomeration reactor, some modifications were performed: the discharge screw conveyor, which failed during operation, was replaced, and a new steam generator was installed to replace the on-loan steam generator.

7.2.3 Deposit Control

A deposit control program was devised based on the objective of developing techniques to control the formation of deposits in the gasifier system. The program consists of three parallel efforts: (1) a deposit formation mechanism study to verify proposed mechanisms of deposit formation, (2) a coal screening test development effort to evolve a method to determine the deposit formation potential of coals, and (3) a deposit formation control technique development effort to identify commercially feasible deposit control techniques based on laboratory data, PDU verification tests and commercial design evaluations.

Deposit Formation Mechanisms

Infrared spectra were obtained for samples of various coals, including Pittsburgh, Montana, Western Kentucky, Texas lignite and Indiana coals. Among the minerals identified in these coal samples were hydrated potassium-aluminum-silicon oxides ($K_2O-Al_2O_3-SiO_2-xH_2O$), aluminum silicates ($Al_2O_3-SiO_2$), carbonates ($MgCO_3$ or $CaCO_3$) and sulfates. The patterns for $K_2O-Al_2O_3-SiO_2-xH_2O$ were strongest in Pittsburgh and Montana coals. They were also present in Western Kentucky coal. Indiana coal did not show patterns for this mineral although other silicates, probably $Al_2O_3-SiO_2$, were indicated. Based on this analytical result and on previous conclusions that low-melting eutectics of the K-Al-Si oxide system may be involved in the binding matrix of ash deposits, more deposit problems can be expected with Pittsburgh or Montana than with Western Kentucky coal.

Indiana coal may not present any serious problem as far as the alkali-aluminum-silicate deposits are concerned. However, other minerals, such as pyrite (FeS_2) may also be responsible for the binding matrix in deposits. The infrared spectrum of pure pyrite does not show characteristic peaks, so pyrite could not be identified in the spectra of coal samples. Therefore, chemical analyses were performed to determine the pyrite contents and consequent fouling potentials of the various coals used in the PDU gasifier. The results (Table 7.2-1) show that the concentration of pyritic sulfur is highest in Pittsburgh and Western Kentucky coals. Montana coal is fairly rich, while Indiana coal and Texas lignite are low in pyritic sulfur.

Pittsburgh coal, with high concentrations of pyrite and hydrated potassium-aluminum-silicon oxides, was expected to have a high fouling potential. Western Kentucky coal, though rich in pyrite, was shown to have fairly low

TABLE 7.2-1
SULFUR AND IRON DISTRIBUTIONS IN VARIOUS COALS

Coal Sample	Percent of Total Sample Weight					
	Total F _e	Non-pyritic F _e	Total S	Sulfate S	Pyritic S	Organic S
Pittsburgh	1.25	0.32	2.16	0.26	1.07	0.83
Western Kentucky	1.02	0.10	2.67	0.05	1.06	1.56
Montana Rosebud	0.80	0.19	0.82	0.06	0.70	0.06
Indiana #7	1.33	1.06	0.91	0.01	0.30	0.60
Texas Lignite	0.45	0.42	0.53	0.06	0.03	0.44

concentrations of K-Al-Si oxides. Depending on the operating conditions of the gasifier, deposit formation from either pyrite or K-Al-Si oxides may dominate, and Western Kentucky coal may be either highly fouling, due to pyrite, or only fairly troublesome, due to K-Al-Si oxides. Montana coal was expected to be moderately fouling, followed by Indiana coal and Texas lignite.

Coal Screening Test Development

The small-scale agglomerating combustor/gasifier located at the Westinghouse R&D Center will be used for the coal screening test development. Coals will be tested in the unit for deposit formation potential under operating conditions suitable for ash agglomerate formation. Deposit formation will be measured on a refractory probe located in the freeboard area of the unit. The probe will also be capable of cooling to study the influence of probe temperature on deposit formation. The air-cooled probe is made of a disk of Castolast G material (4-inch-diameter) cast over a coil of Incoloy or stainless steel tubing. Thermocouples are embedded in the disk to measure its temperature.

Deposit Formation Control Technique Development

Two deposit control techniques were tested on the PDU which show technical promise: (1) injection of water into the fuel gas outlet to cool the gas below the deposit formation temperature (2) and cooling of a section of the cyclone internal surface below the formation temperature. The first step in the deposit formation control technique development effort is to assess the commercial feasibility of those two techniques as a function of the gasifier application. This feasibility evaluation was initiated this quarter with the development of a basis for the evaluation and a definition of the scope of the assessment.

The conclusions from the assessment of water injection and hardware cooling can potentially lead to the formulation of a variety of program objectives, ranging from developing a greater understanding of the commercial design of these techniques to developing alternate control techniques. In general, the steps involved in the development of alternate control techniques are:

- Propose alternate control techniques based on current understanding of deposit formation mechanisms.
- Characterize the proposed techniques in the laboratory and rank their technical and commercial potentials.
- Verify the high-ranking techniques on the PDU.
- Perform commercial design evaluations.

Work Forecast for Next Quarter

- Continue coal/char characterization tests on the thermogravimetric analyzer.

- Perform ash agglomeration tests with Indiana #7 and Pittsburgh seam coals.
- Complete construction of the deposit formation probe for the coal screening tests and test using a variety of coals and gasifier operating conditions.
- Verify deposit formation mechanisms by chemical/physical characterization of deposits generated on the probe in the coal screening test.
- Complete the assessment of commercial feasibility of deposit control by water injection and hardware cooling and define the development effort objectives based on the conclusions.

7.3 GASIFIER SYSTEM MODEL INTEGRATION

A design procedure is being prepared for the Westinghouse gasifier to reflect all the conceivable phenomena affecting gasifier performance. This procedure will enable accommodation of new developments and improvements on the existing models. A tentative sequence for the procedure was prepared, and a compilation of all available models/correlations describing relevant phenomena is in progress.

Work Forecast for Next Quarter

Complete compilation of all available models and correlations relevant to the design procedure for the gasifier system model integration. These will be put in programmable forms, and will be inserted into the final procedure sequence.

7.4 PARTICULATE/CHEMICAL PROFILES AND CONTROL

The solids handling and heat transfer requirements associated with the proposed continuous recycle of char carryover from the PDU fluidized bed gasifier were analyzed. The analysis focused on: (1) determining the total recycle rate as a function of bed operating parameters and (2) investigating various options for cooling the recycle char to temperatures ($\sim 400^{\circ}\text{F}$) that the proposed starwheel feeder can tolerate.

An existing particle profile computer program developed by Westinghouse for fluidized bed combustion systems was used to project the PDU gasifier char recycle rates. A description of the particle profile program was previously documented.^{2,3} A recent research memo⁴ provides details of the modifications and calibrations performed on the program to facilitate its use for the PDU gasification system. Table 7.4-1 summarizes the program projections for the continuous recycle mode of gasifier operation. The significant result is that, depending on the performance of the C-119 cyclone, char recycle rates may vary from one to as much as seven times the coal feed rate. For the base case studied, this corresponds to solid flows from 800 to 4900 pounds/hour.

TABLE 7.4-1

PARTICLE PROFILE PROGRAM PROJECTIONS FOR RECYCLE MODE OF OPERATION

Parameter	Grade Efficiency Assumed for the C-119 Recycle Cyclone and the Second-Stage Cyclone is:		
	"Worst Case" from PDU Performance Curves for C-119	"Best Case" from PDU Performance Curves for C-119	As Supplied by Ducon
Coal Feed Rate	87.9 g/s (697 lb/hr)	87.9 g/s (697 lb/hr)	87.9 g/s (697 lb/hr)
Ash Withdrawal Rate	11.9 g/s (94.3 lb/hr)	13.7 g/s (108.3 lb/hr)	14.8 g/s (117.4 lb/hr)
Bed Carryover Rate	108.2 g/s (858.1 lb/hr)	303.8 g/s (2409 lb/hr)	611.6 g/s (4849.5 lb/hr)
Primary Cyclone Recycle Rate	102.1 g/s (809.2 lb/hr)	299.4 g/s (2373.8 lb/hr)	608.4 g/s (4824 lb/hr)
Primary Cyclone Emission Rate	5.7 g/s (45.1 lb/hr)	3.9 g/s (31.1 lb/hr)	2.8 g/s (21.9 lb/hr)
Primary Cyclone Efficiency	94.3%	98.6%	99.5%
Secondary Cyclone Collection Rate	1.9 g/s (15 lb/hr)	1.7 g/s (13.5 lb/hr)	2.2 g/s (17.4 lb/hr)
Secondary Cyclone Emission Rate	3.8 g/s (30.1 lb/hr)	2.2 g/s (17.6 lb/hr)	0.6 g/s (4.8 lb/hr)
Secondary Cyclone Efficiency	33.2%	43.5%	78.1%

Several options were examined for cooling the recycle char from its exit temperature of 1600°F to the required 400°F. These included: (1) a fixed bed mode with jacketed pipe cooling, (2) a fixed bed mode with a central cylindrical cooling surface, and (3) a "free fall" mode of cooling. The first option is not viable since the analysis showed that for recycle loop mass flows of more than 75 pounds/hour the 480°F temperature cannot be reached at the end of the proposed 20-foot fall. Option two approaches the lower limit of the required cooling rate with the constraint that the spacing between cooling surfaces should not exceed 1-1/2 to 2 inches. Both the first and second options are susceptible to water condensation problems given the potential for a high partial pressure of water vapor in the gas, especially with the cyclone spray system being considered. The third option examined gave promising results only for the limiting case for which all the char particles were assumed to have an optically clear view of the cooled pipe walls and radiation was strong. However, considering the high solids: gas mass ratio in the cooler (2.5 pounds/pound), this assumption is not valid. Option three is also susceptible to water condensation problems. Another potential problem with option three is that of transport gas leaking past the feeder and flowing up the cooler leg into the cyclone, where it will have deleterious effects on cyclone performance. In summary, none of the three cooling options analyzed appear viable.

A high temperature solids feeder will obviate the problem of char cooling. Toward this end, a high temperature solids feeder was identified (Figure 7.4-1). Available from the General Atomic Company, the unit is rated for 1300°F operational duty in transferring solids across pressure boundaries and has been used for transferring graphite fines ($\sim 125 \mu\text{m}$) from a recycle cyclone back into a fluidized bed system. The unit is available in a variety of sizes. The 6-inch unit has been operated at 1200°F for extended periods of time, transferring approximately 2 tons per hour at 6 rpm.

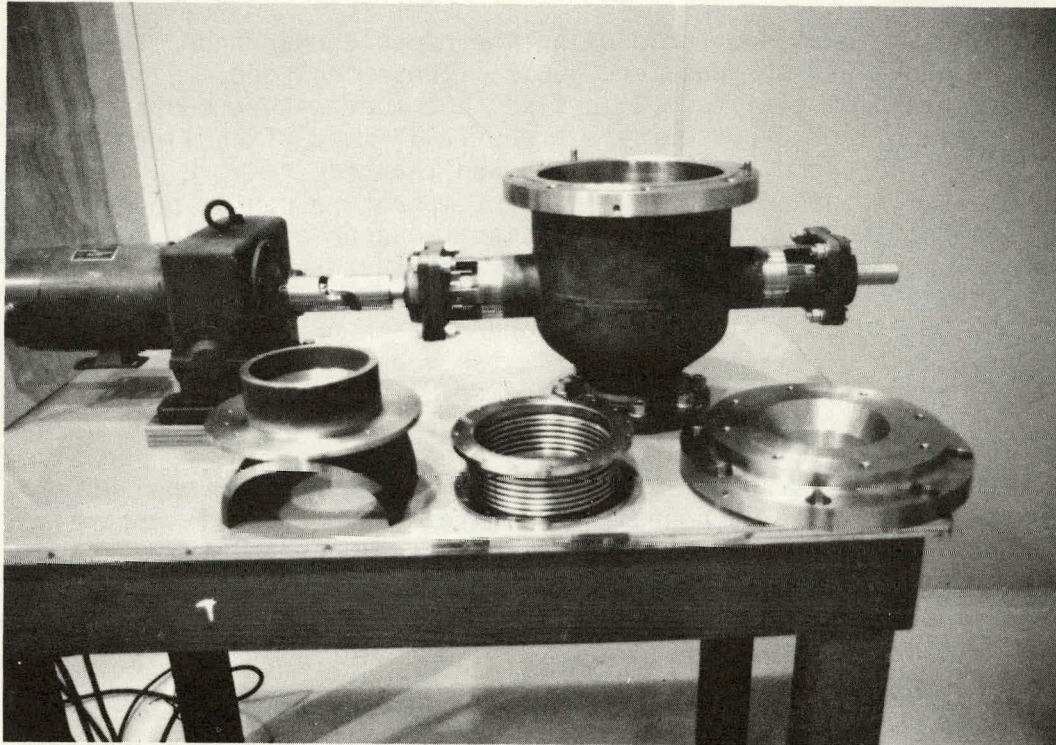
Work Forecast for Next Quarter

Apply the particle profile model to interpretation of PDU data.

7.5 ENVIRONMENTAL IMPACT STUDIES

The final Resource Conservation and Recovery Act (RCRA) regulations (Phase I) on hazardous waste management as promulgated in the Federal Register, May 19, 1980, were carefully reviewed and are outlined in Figure 7.5-1. The promulgation schedule for the three-phased RCRA program is summarized in Table 7.5-1. The hazardous waste identification mechanism as modified in the final regulations is shown in Figure 7.5-2. Special attention was directed toward identifying the changes from the previously proposed regulations (Federal Register, December 18, 1978). Two of the major changes that could have impact on Westinghouse coal gasification residue disposal are:

- Extraction procedure (EP) toxicity criteria were relaxed from 10xDWS to 100xDWS.
- The "special waste category," which was proposed to include utility waste, was eliminated in the final regulations.



- TRANSFERS ABRASIVE SOLIDS ACROSS PRESSURE BOUNDARY
- RATED FOR 700°C OPERATION
- GRAPHITE FIBER SEALS—N₂ PURGED
- SOLID LUBRICANT BEARINGS
- FLAME-SPRAYED COATINGS ON ROTOR TO MINIMIZE WEAR RATE
- AVAILABLE IN VARIETY OF SIZES—6" IS STANDARD
- CAN BE CONSTRUCTED FOR CHEMICAL CORROSION RESISTANCE

Figure 7.4-1. High Temperature Rotary Solids Feeder

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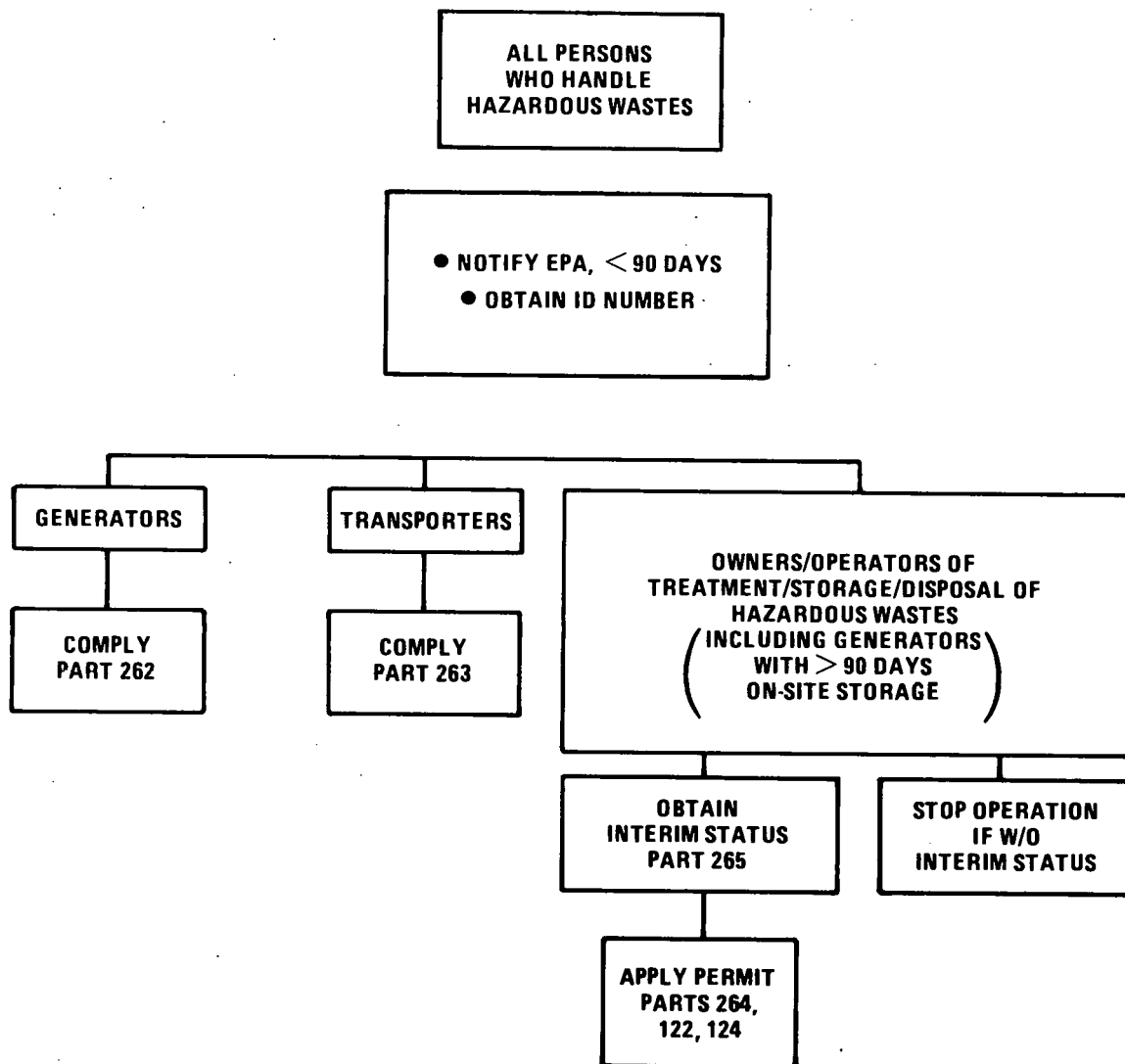


Figure 7.5-1. Hazardous Waste Regulations – Phase 1

TABLE 7.5-1

RCRA SCHEDULE

<p>May 19, 1980</p>	<ul style="list-style-type: none"> ● Promulgation of Phase I Hazardous Waste Regulations
<p>August 16, 1980</p>	<ul style="list-style-type: none"> ● Generators Determine if Waste Hazardous ● Notify EPA of All Hazardous Waste Activities: Generation, Storage, Transport, Treatment and Disposal
<p>November 19, 1980</p>	<ul style="list-style-type: none"> ● Phase I Regulations Effective
<p>November, 1980</p>	<ul style="list-style-type: none"> ● Scheduled Promulgation of Phase II Regulations ● Promulgation of Additional Hazardous Waste List by EPA
<p>After 1981</p>	<ul style="list-style-type: none"> ● Phase III Regulations to be Proposed

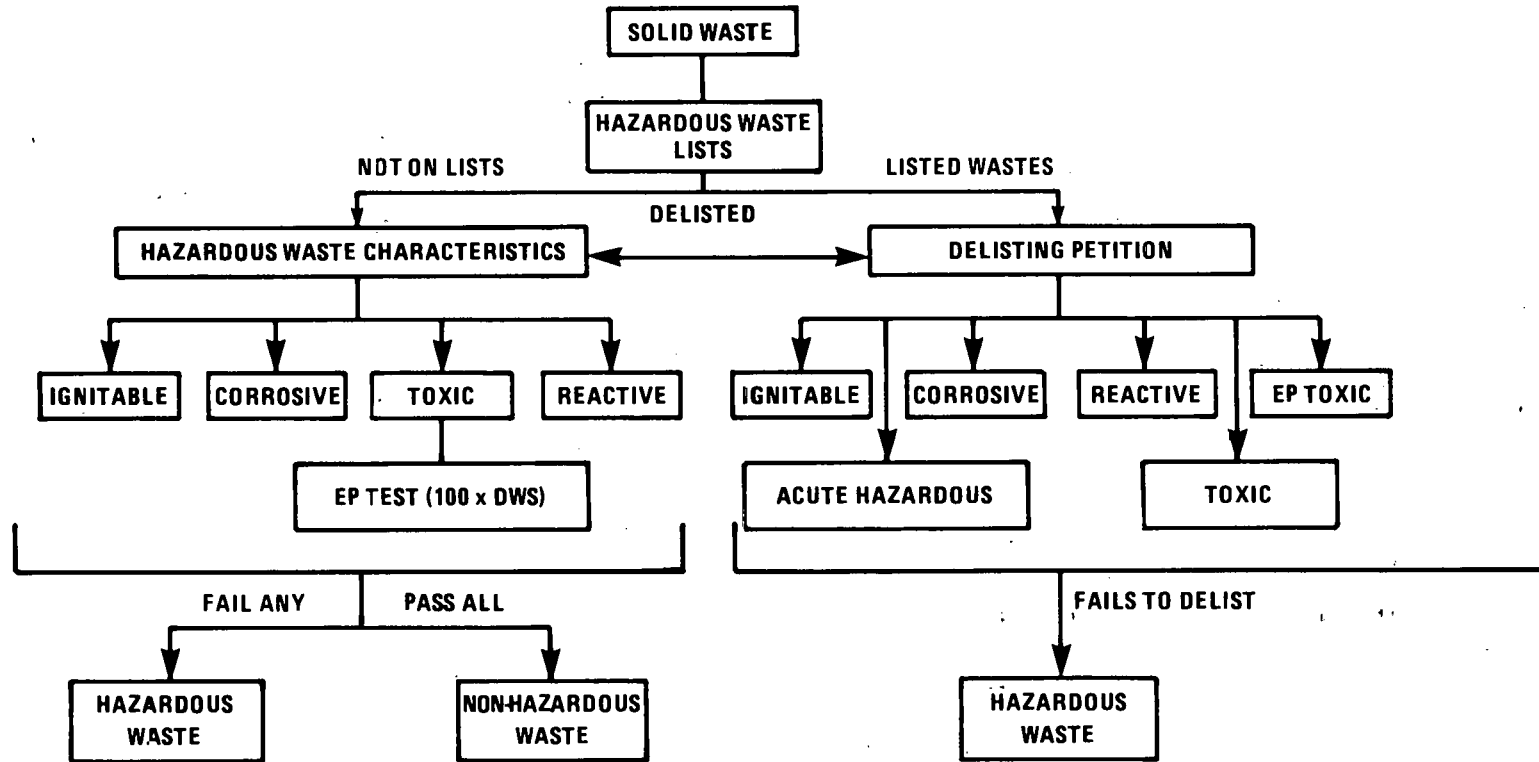


Figure 7.5-2. Hazardous Waste Identification Mechanism

However, utility waste will be temporarily exempted from the Phase I regulations. The Environmental Protection Agency (EPA) plans to develop specific standards in the Phase II and Phase III program that are applicable to energy wastes from fossil fuel processes to incorporate more flexible, site-specific factors.

These changes do not alter the previous conclusion, based on the proposed regulations, that the ash agglomerates from the Westinghouse coal gasification process are not hazardous according to the RCRA.

Leachate analyses were completed to investigate the effects of the following variables:

- Leaching Medium - Table 7.5-2 summarizes the results of test TP-020-2, an air-blown devolatilizer/gasifier test, using deionized water, CO₂-saturated water and acetate buffer as the media. Only a very slight difference was noted between the deionized and CO₂-saturated water leaching. Leachate with CO₂-saturated water (pH ~4) had a slightly lower pH and a slightly higher Ca, SO₄ and TDS. But acetate-buffered leachate had a much lower pH and higher concentrations of TDS, Fe, Mn, Cl, Al, B, Ca, Ga and Si.
- Particle Size - Table 7.5-3 summarizes the results of leachate characteristics of two particle size fractions (<500 μm and >1400 μm). Higher concentrations (Mn, B, Hg, Mg, Si, SO₄ and TDS) are seen in the leachate from the smaller particle size.
- Surface Area - Table 7.5-4 summarizes the results from the leaching tests on test TP-020-2 agglomerates before crushing and after crushing to increase the surface area. Higher concentrations of B, SO₄, S and TDS are found in the leachate of the crushed solids, which had a higher solid/liquid contact surface area.

Work Forecast for Next Quarter

Test the Texas lignite ash agglomerates from TP-023-4.

7.6 REFERENCES

1. Knowlton, T. M. and Hirsan, I., "The Effect of Pressure on Jet Penetration in Semi-cylindrical Gas-Fluidized Beds," Proc. Third Engineering Foundation Conference on Fluidization, Henniker, New Hampshire, August 3-8, 1980.
2. Ciliberti, D. F., Ranadive, A. Y. and Keairns, D. L., "Particle Profiles in Fluidized Bed Systems," Report to the Argonne National Laboratory, Westinghouse R&D Center, Pittsburgh, PA, January 1979.

TABLE 7.5-2

LEACHATE CHARACTERISTICS OF TP-020-2 ASH AGGLOMERATES
AS A FUNCTION OF LEACH MEDIUM

Substance	Solid, ppm	Leachate by 200 Hr Shake Test			DWS mg/ℓ
		Deionized H ₂ O, mg/ℓ	CO ₂ Saturated Deionized H ₂ O, mg/ℓ	Acetic Acid Buffer mg/ℓ	
Al	6.66%	< 0.2	< 0.2	1	
Ag	< 1	< 0.02	< 0.02	< 0.03	0.05
As		< 0.001	< 0.001	< 0.001	0.05
B	200	0.5	0.3	30	
Ba	500	< 0.7	< 0.7	< 1	1.0
Be	7	< 0.02	< 0.02	< 0.03	
Bi	10	< 0.02	< 0.02	< 0.1	
Ca	< 0.88%	< 5	12	192	200
Cd	< 10	< 0.02	< 0.02	< 0.005	0.01
Co	30	< 0.07	< 0.07	< 0.1	
Cr	100	< 0.02	< 0.02	< 0.02	0.05
Cu	33	< 0.1	< 0.1	< 1	1.0
Fe	10,75%	< 0.07	< 0.07	> 100	0.3
Ga	30	< 0.07	< 0.07	0.5	
Ge	< 10	< 0.07	< 0.07	< 0.1	
Hg		0.0016	0.0016	0.0013	0.002
K	0.78%				
Mg	0.17%	14.58	14.58	< 5	150
Mn	1000	< 0.02	< 0.02	3	0.05
Mo	50	< 0.07	< 0.07	< 0.1	
Na	0.17%				
Ni	50	< 0.2	< 0.2	0.1	2.0
Pb	< 10	< 0.02	< 0.02	< 0.05	0.05
Sb	< 30			< 1	
Se		< 0.001	< 0.001	< 0.002	0.01
Si	12.4%	3	1	20	
Sn	< 10	< 0.07	< 0.07	< 0.1	1.0
Sr	200	< 1	< 1	< 5	
Ti	> 1000	< 0.1	< 0.1	< 1	
V	100	< 0.02	< 0.02	< 0.1	
Zn	200	< 0.7	< 0.7	< 5	5.0
Zr	200	< 0.07	< 0.07	< 1	
SO ₄	0.22%	17	31.8	< 10	250
S=	3.05%	< 5	< 5	< 2	
F		< 1	< 1	< 1	2.4
Cl		< 1	< 1	170	250
NO ₃ (asN)		< 1	< 1	< 1	10
PO ₄		< 1	< 1	< 1	
TOC		< 10	< 10	< 10	
pH		7.85	7.75	4.75	6.5-8.5
SC, μ mho/cm		139	184	4960	~ 750

DWS - NIPDWR, NSDWR, and WHO Drinking Water Standards

 Exceeds DWS

 Exceeds 10 x DWS

TABLE 7.5-3

LEACHATE CHARACTERISTICS OF TP-020-2 ASH AGGLOMERATES
AS A FUNCTION OF SOLID PARTICLE SIZE

Substance	Leachate by 200 Hr Shake Test		DWS, mg/l
	>1400 μ	<500 μ	
Al	<0.2	<0.2	
Ag	<0.02	<0.02	0.05
As	<0.001	<0.001	0.05
B	<0.2	1	
Ba	<0.7	<0.7	1.0
Be	<0.02	<0.02	
Bi	<0.02	<0.02	
Ca	<5	<10	200
Cd	<0.02	<0.02	0.01
Co	<0.07	<0.07	
Cr	<0.02	<0.02	0.05
Cu	<0.1	<0.1	1.0
Fe	<0.07	<0.07	0.3
Ga	<0.07	<0.07	
Ge	<0.07	<0.07	
Hg	0.0014	0.0016	0.002
K			
Mg	12.15	14.58	150
Mn	<0.02	0.06	0.05
Mo	<0.07	<0.07	
Na			
Ni	<0.2	<0.2	2.0
Pb	<0.02	<0.02	0.05
Sb			
Se	<0.001	<0.001	0.01
Si	2	3	
Sn	<0.07	<0.07	1.0
Sr	<1	<1	
Ti	<0.1	<0.1	
V	<0.02	<0.02	
Zn	<0.7	<0.7	5.0
Zr	<0.07	<0.07	
SO ₄	21.2	40.8	250
S=	<5	<5	
F	<1	<1	2.4
Cl	<1	<1	250
NO ₃ (asN)	<1	<1	10
PO ₄	<1	<1	
TOC	<10	<10	
pH	7.76	7.77	6.5-8.5
SC, μ mho/cm	133	188	~750

DWS - NIPDWR, NSDWR, and WHO Drinking Water Standards

 Exceeds DWS Exceeds 10 x DWS

TABLE 7.5-4

LEACHATE CHARACTERISTICS OF TP-020-2 ASH AGGLOMERATES
AS A FUNCTION OF ASH SURFACE AREA (CRUSHED VERSUS
UNCRUNCHED AGGLOMERATES)

Substance	Solid ppm	Leachate by 200 Hr Shake Test		DWS, mg/l
		Uncrushed	Crushed	
Al	6.66%	< 0.2	< 0.2	
Ag	< 1	< 0.02	< 0.02	0.05
As		< 0.001	< 0.001	0.05
B	200	0.5	0.7	
Ba	500	< 0.7	< 0.7	1.0
Be	7	< 0.02	< 0.02	
Bi	10	< 0.02	< 0.02	
Ca	< .88%	< 5	< 5	200
Cd	< 10	< 0.02	< 0.02	0.01
Co	30	< 0.07	< 0.07	
Cr	100	< 0.02	< 0.02	0.05
Cu	33	< 0.1	< 0.1	1.0
Fe	10.75%	< 0.07	< 0.07	0.3
Ga	30	< 0.07	< 0.07	
Ge	< 10	< 0.07	< 0.07	
Hg		0.0016	0.0016	0.002
K	0.78%			
Mg	0.17%	14.58	14.58	150
Mn	1000	< 0.02	< 0.1	0.05
Mo	50	< 0.07	< 0.07	
Na	0.17%			
Ni	50	< 0.2	< 0.2	2.0
Pb	< 10	< 0.02	< 0.02	0.05
Sb	< 30			
Se		< 0.001	0.001	0.01
Si	12.4%	3	2	
Sn	< 10	< 0.07	< 0.07	1.0
Sr	200	< 1	< 1	
Ti	> 1000	< 0.1	< 0.1	
V	100	< 0.02	< 0.02	
Zn	200	< 0.7	< 0.7	5.0
Zr	200	< 0.07	< 0.07	
SO ₄	0.22%	17	34	250
S=	3.05%	< 5	21.28	
F		< 1	< 1	2.4
Cl		< 1	< 1	250
NO ₃ (asN)		< 1	< 1	10
PO ₄		< 1	< 1	
TOC		< 10	< 10	
pH		7.85	7.92	6.5-8.5
SC, μ mho/cm		139	225	~ 750

3. Ranadive, A. Y., Ciliberti, D. F. and Keairns, D. L., "Particle Profiles in Fluidized Bed Systems, Topical Report in Preparation to the Environmental Protection Agency under Contract No. 68-02-3110, Westinghouse R&D Center, Pittsburgh, PA.
4. Ciliberti, D. F. and Ranadive, A. Y., "PDU Fines Recycle Considerations," Westinghouse R&D Center, Memo No. 80-9E3-PDULS-M1, May 14, 1980.