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ADVANCED DEVELOPMENT OF A PRESSURIZED ASH
AGGLOMERATING FLUIDIZED-BED COAL GASIFICATION
SYSTEM

Quarterly Progress Report for the Period April 1—June 30, 1982

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Morgantown, West Virginia

By
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Synthetic Fuels Division
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ADVANCED DEVELOPMENT OF A
PRESSURIZED ASH AGGLOMERATING FLUIDIZED-BED
COAL GASIFICATION SYSTEM

THIRD QUARTER PROGRESS REPORT
FY-1982

Period April 1 to June 30, 1982

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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 the production of medium-Btu fuel gas for syngas, electrical power generation, chemical feedstocks, or industrial fuels and to obtain performance and scaleup 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 scaleup and component hardware designs. Past work 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 feedstock. 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.

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, including a highly caking coal. Gasification will be accomplished with oxygen to produce medium-Btu synthesis gas and agglomerated ash at a high overall carbon utilization.

In addition, combustion testing in the Test and Development Center with medium-Btu gas from the PDU is also planned to determine combustion stability over a range of preheated gas temperatures.

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 system to support the testing program. Specifically, this work involves the 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 fines recycle tests and deposit control methods. Modifications to the Test and Development Center were made to permit combustion evaluation tests of medium-Btu gas from the PDU.

1.3 SCALEUP DESIGN AND ANALYSIS

Scaleup design and analysis are performed as part of Task 3. The objective of this task is to conduct experimental and analytical work required to establish a data base for scaling up the components and subsystems of the fluidized bed gasification process. The cold flow scaleup facility (CFSF), a large 10-foot scale cold flow model, is the principal tool for providing this information. Initial operation is in the gasifier mode to determine operable geometries, measure and record operating characteristics, and develop empirical correlations to describe these characteristics.

1.4 LABORATORY SUPPORT STUDIES

This task consists of consultation and analytical and bench studies by the Westinghouse Research and Development Center in support of PDU operations and process analysis.

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 scaleup, and understanding of process phenomena to achieve reliable operation. Work has also been conducted in the areas of cold flow modeling, coal behavior, coal and chemical phenomena, environmental impact, and process and systems engineering consultation.

For the laboratory support experimental program, test facilities include:

- Two flexible 12-inch 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 to conduct investigations in gas cleaning and gasification.

SECTION 2.0

TECHNICAL PROGRESS SUMMARY

2.1 PDU TEST OPERATIONS AND RESULTS

TP-032-1 was conducted in three operational phases from March 30, 1982 through May 2, 1982. The primary objectives of this test were to shake down the full cyclone cold wall and evaluate the fines recycle system. Although each of the three phases was terminated prior to the planned completion time, this test achieved a total of 163 hours of hot operation (97 hours with Upper Freeport coal) and a total of 111 hours of coal feed operation with the full cyclone cold wall (no deposits were found). TP-032-1 was a single-stage, oxygen-blown test.

TP-032-2 was conducted in two operational phases, totaling 155 hours, from May 20, 1982 through May 27, 1982. The primary objective of this single-stage oxygen-steam blown test was to continue the shakedown and evaluation of the cold wall and fines recycle system. TP-032-2 used Upper Freeport E-seam and Western Kentucky coals.

2.2 PROCESS ANALYSIS

During TP-032-2, a 40-degree freeboard temperature transient was performed with all automatic control loops closed. Net heat production increased at a rate of 8 percent per minute, confirming that a fluidized bed gasifier can exceed the minimum response rate of 5 percent per minute required by commercial utilities for combined cycle applications.

TP-032-1 and TP-032-2 successfully served as shakedown and demonstrations of the full cyclone cold wall. After processing highly fouling coals -- Indiana No. 7, Upper Freeport, and Western Kentucky -- during these tests, no visible deposits were found on the cold wall.

Samples of product gas produced during TP-032-1 were passed through four different scrubbing solutions. One of these, a methylene chloride scrubbing solution, was analyzed for 78 EPA primary organic pollutants, all of which were found to be below detection limits.

2.3 COLD FLOW SCALEUP FACILITY

TP-M004, a CO₂ tracer gas test, was initiated on March 29 and completed on May 21, 1982. The objective of this test was to measure the gas exchange between different regions of the bed. Data were obtained at eight set points, six probe elevations, and two grid locations, with CO₂ concentrations measured at approximately 2-inch intervals across the CFSF bed diameter for each of the above conditions. A total of 1140 data points were obtained.

Data analysis of test TP-M002-2 was completed. The conclusions are summarized in this quarterly report. Data obtained from frame-by-frame analysis of films for tests TP-M003-1 and TP-M003-2 are also reported. Despite difficulties such as pitot tube plugging and bending, pressure drop data were obtained via the purged pitot tube during TP-M003-1 at five elevation levels from the jet nozzle outlet for eight different set points. The pitot tube apparently

sensed the momentum of both the gas flow and the solids in the gas stream, rather than the gas momentum alone, as originally anticipated. A methodology of analyzing the data is presented.

During the next quarter, tests TP-M007-1, -2 and -3 will be performed. Each of these will use the new 10-inch diameter air tube for air tube shakedown (TP-M007-1), jet penetration, bubble diameter, frequency, and velocity (TP-M-007-2); and CO₂ tracer gas tests (TP-M007-3).

2.4 PROCESS AND COMPONENT ENGINEERING AND DESIGN

Major focus during this quarter was directed toward the installation of a solids injection device under the secondary cyclone and a non-mechanical valve for the primary fines recycle system.

Design, procurement and fabrication of the solids injection device were completed. Drawings and design review for the non-mechanical valve were completed.

During the next quarter, efforts will involve the installation of the non-mechanical valve and a single-tube through-trap.

2.5 LABORATORY SUPPORT STUDIES

2.5.1 GAS-SOLIDS FLOW MODELING

The semicircular unit was modified to install an additional jet in the char-ash separator annulus to simulate fines feeding in the PDU. Experiments were conducted to study the jet interaction of this jet and the main jet in the gasifier.

A series of experiments was designed to study the history of injected fine particles as a function of jet injection velocity, feed point location, and slugging/non-slugging modes of bed operation. The existing 12-inch semicircular cold-flow unit was modified to include a high-performance cyclone and a sealed transparent Plexiglas dipleg. This enables monitoring of the rate at which the cyclone collects the injected fines. The fine tracers will be introduced into the fluidized bed as a pulse from a pressurized metallic container. The construction and installation of the required modifications were completed. A few trial tests were conducted and most of the shakedown completed.

The high-temperature unit was assembled and the subsystems checked out. The unit should be operational next quarter.

A program to develop one or more probes for measuring the solid circulation rate in the CFSF was initiated. Two prototype probes are being fabricated and will be tested in the 12-inch diameter laboratory cold flow model. Probes suitable for application in the CFSF will be developed.

2.5.2 COAL/ASH BEHAVIOR

Coal Gasification - Coal fines and PDU char fines for RSA coal feedstock were characterized on a thermogravimetric analyzer. Upper Freeport and Western Kentucky coals were also characterized.

Ash Agglomeration - The behavior of ash particles from Wyoming Sub-C, Pittsburgh seam, and West Virginia coals was examined on a hot-stage microscope. These ash particles were characterized for their initial sintering and melting temperatures.

Deposit Control - PDU data were reviewed to determine the effects of operating parameters on the formation of deposits. Trends in deposit formation were identified, and the parameters with the greatest influence on deposit were determined. These results were provided to assess critical tests for the PDU to limit deposit formation and to gather data essential for deposit analysis. A probe to study deposit formation in the PDU gasifier was designed and fabricated. It will be located in the gasifier freeboard, near the exit, where a large number of particles would strike its surface at exit velocity. Installation is scheduled for PDU test TP-033-1.

2.6 SUMMARY SCHEDULES

Task Description

Operation and Maintenance of the PDU

Single-Stage Gasifier Operation

Gasifier Oxygen-Blown Maintenance and Test Modification

Gas Characterization, Treatment and Utilization

Fines Recycle
Deposit Control.

PDU Modifications

Modification for Fines Recycle

Hot Rotary Feeder
Hot Educator
Upgrade CO₂ System
Hot Dipleg and Non-Mechanical Valve

Modifications for Deposit Control

Cold Wall (for side exit from gas.)
Cold Wall (standby system)
Through-Trap
Deposit Probe

Modification for Gas Characterization, Treatment and Utilization

Gas Characterization Upgrading

Conversion of Propane-Fired Components to Natural Gas

Gas Preheater for Combustion Tests

[illegible]

LEGEND:

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

Design/Approval
Procurement -----
Deleted or (D)
Deferred

Construction/Modification

SECTION 3.0

PDU TEST OPERATIONS AND RESULTS

3.1 GASIFIER TEST TP-032-1

TP-032-1, a single-stage, oxygen-steam-blown gasifier test, was conducted from March 30 to May 2 using Upper Freeport E-seam coal as the feedstock. The primary objectives of this test were to:

- Shakedown and evaluate the full cyclone cold wall.
- Obtain fines elutriation and consumption data with (1) no fines recycle, (2) primary fines recycle only, and (3) both primary and secondary fines recycle.

Secondary objectives of the test were to:

- Characterize the operation of the PDU with Upper Freeport E-seam coal from Winber, PA.
- Obtain fines elutriation and consumption data at two different freeboard velocities.
- Obtain fines elutriation and consumption data with injection of primary and secondary fines.
- Shakedown and evaluate a hot alkali sampling probe (DOE Contract No. DE-AC21-81MC16024).

Test TP-032-1 was conducted in three operational phases. The first phase was terminated as the result of a restriction in the gasifier annulus. Post-shutdown inspection revealed that a thermocouple located in the gasifier grid area was protruding about 6 to 8 inches into the gasifier in comparison to the standard 1 to 2 inches. This reduced solids recirculation in the grid area and resulted in the deposition of sintered ash on the thermocouple. These deposits periodically spalled and migrated to the bottom of the annulus. The chunks of sintered material found during post-test inspection showed indentation, which appeared to have resulted from sintering on a thermocouple well.

During the second test phase, a leak occurred in the line supplying recycle gas to the gasifier grid, necessitating a shutdown.

The third and final phase of the test was aborted when the coal/fines multi-feed line ruptured. Inspection of the coal feed tube revealed severe erosion (the tube had actually severed). An analysis of this event after shutdown indicated that severe erosion occurred in the multi-feed line and coal feed tube because of coal particles impinging the pipe walls at piping discontinuities and, to a lesser extent, because of prolonged use of abrasive coke breeze. The piping discontinuities included (1) piping bent during

installation or because of thermal expansion, (2) long, unsupported lengths of piping with inherent bending and vibration, and (3) pipe fittings. The piping runs on the feed line were replaced and realigned to minimize erosion wear caused by flow discontinuities.

Because annulus plugging occurred intermittently during the initial startup, the annulus flows were increased to obtain a higher solids recirculation. Furthermore, the ash residence time in the gasifier was reduced, resulting in maintenance of the annulus temperature interface at a lower than normal elevation. As such, the ash concentration in the withdrawal was lower than would normally be achievable.

Accomplishments of test TP-032-1 are as follows:

- A total of 163 hours of hot operation, including 97 hours with Upper Freeport coal feed, were achieved.
- A total of 111 hours of coal feed operation were achieved with the full cyclone cold wall. No deposits were found on the cold wall. However, the total coal feed hours are a combination of three startups.
- One set point was conducted with Upper Freeport E-seam coal at a nominal freeboard temperature of 1800°F with no fines recycle.
- All major process streams were characterized for composition and trace impurities during the set point. The gas stream was sampled and analyzed for 78 EPA priority pollutants using a multi-solvent scrubber train. The results of this characterization are reported in Section 4.0.
- Product gas was analyzed for alkali metals using a hot alkali sampling probe.

Table 3-1 is a chronological summary of the test, and the steady-state process data are given in Table 3-2. Heat and material balances for the steady-state periods are reported in Tables 3-3 through 3-5. Figure 3-1 depicts a flow schematic for the heat and material balance envelope.

3.2 GASIFIER TEST TP-032-2

Single-stage, oxygen-blown test TP-032-2 was conducted from May 17 to May 27 using Upper Freeport seam and Western Kentucky No. 9 coals as the feedstocks. The objectives of TP-032-2, a deposit control and fines recycle evaluation test, were to:

- Shakedown and evaluate the full cyclone cold wall.
- Obtain fines elutriation and consumption data with (1) primary fines recycle only and (2) both primary and secondary fines recycle.
- Characterize the operation of the PDU with a blend of Western Kentucky coal and Rockwell char (DOE Contract No. DE-AC01-80ET10328).

TABLE 3-1
CHRONOLOGY OF SIGNIFICANT EVENTS, TEST TP-032-1

<u>Date</u>	<u>Time</u>	<u>Event</u>
		<u>Startup No. 1</u>
03/30/82	0750	Completed pressurization at 230 psig.
	2145	Initiated coke breeze feed to gasifier.
03/31/82	0414	Achieved autogenous ignition.
	1250	Switched from air to oxygen in oxidant tube.
	2120	Initiated Indiana No. 7 coal feed to gasifier.
04/01/82	0330	Primary cyclone (C-119) dipleg plugged.
	0415	Decreased system pressure to 130 psig in an attempt to clear plug.
	0615	C-119 plug cleared.
	0715	Instrument air failure.
	0815	Increased system pressure to 230 psig.
	1055	Initiated Upper Freeport coal feed to gasifier.
	1430	Starwheel feeder casing fractured under coal storage bin.
	1515	C-119 transport line plugged.
	1525	Initiated coke breeze feed to gasifier.
	1730	Coal storage bin starwheel feeder back on line.
	1815	Changed ash withdrawal starwheel sprocket to increase ash withdrawal capability.
	2040	Initiated Upper Freeport coal feed to gasifier.
	2320	Reinitiated coke breeze feed to gasifier - ash annulus plug.
04/02/82	0100	Depressurized system to 150 psig to obtain high pressure differential flow through annulus via ash lockhoppers to clear annulus plug.
	0330	Cleared annulus plug.

TABLE 3-1 (continued)

CHRONOLOGY OF SIGNIFICANT EVENTS, TEST TP-032-1

<u>Date</u>	<u>Time</u>	<u>Event</u>
	0345	Reinitiated Upper Freeport coal feed to gasifier.
	0520	Increased system pressure to 230 psig.
	1210	<u>Achieved set point 1A test conditions.</u>
	1950	Experienced temperature excursion to 2450°F in gasifier grid area.
	2115	Switched from oxygen to air in oxidant tube.
	2240	Decreased system pressure to 150 psig to clear plug resulting from temperature excursion.
	2335	Cleared ash annulus.
04/03/82	0100	Switched from air to oxygen in oxidant tube.
	0220	Increased system pressure to 230 psig.
	0500-0900	Experienced frequent interruptions in ash withdrawal.
	1020	Ash annulus plug could not be cleared. Initiated shutdown.

Startup No. 2

04/24/82	0020	Completed pressurization at 230 psig.
04/25/82	1815	Initiated coke breeze feed to gasifier.
	2030	Annulus plugged.
	2120	Cleared annulus.
04/26/82	0355	Achieved autogenous ignition.
	2255	Switched from air to oxygen in oxidant tube.
04/27/82	0135	Initiated Upper Freeport coal feed to gasifier.
	1245	Developed leak in recycle gas line to grid.
	1335	Initiated shutdown.

TABLE 3-1 (continued)

CHRONOLOGY OF SIGNIFICANT EVENTS, TEST TP-032-1

<u>Date</u>	<u>Time</u>	<u>Event</u>
<u>Startup No. 3</u>		
04/28/82	0418	Completed pressurization at 230 psig.
	0530	Initiated coke breeze feed to gasifier.
	0730-1000	Observed defluidization in the ash annulus because of oversized and abnormally dense coke breeze. System depressured and inspected.
<u>Startup No. 4</u>		
	2200	Achieved system pressure of 230 psig.
	2230	Initiated coke breeze feed to gasifier.
04/29/82	0300-0545	Reduced pressure to 130 psig and increased gasifier flows to fluidize higher density coke breeze.
04/30/82	0555	Achieved autogenous ignition.
	1140	Increase system pressure to 230 psig.
	1315-1535	Experienced steam boiler failures - boiler back on line.
	1710	Switched from air to oxygen in oxidant tube.
	1850	Initiated Upper Freeport coal feed to gasifier.
05/01/82	0130	Oxygen failure - switched to air in oxidant tube.
	0140	Switched from air to oxygen in oxidant tube.
	0400	<u>Achieved set point 1B test conditions.</u>
05/02/82	0450	Began transition to set point 2 test conditions.
	0800	Initiated set point 2 with Freeport coal.
	0845	Coal feed line ruptured, emergency shutdown implemented.

TABLE 3-2

SUMMARY OF OPERATING DATA FOR GASIFIER TEST TP-032-1

Steady State Test Run Date and Time (1982)	Unit	1A-1 Hours 4-2 1330 - 1930	1B-1 Hours 5-1 0530 - 2000	1B-2 Hours 5-1/2 2230 - 0400
<u>Measured Gasifier Parameters</u>				
Freeboard temperature	°F	1827	1818	1819
Gasifier bed temperature	°F	1829	1846	1854
Ash annulus temperature	°F	439	761	704
Average bed height*	feet	10.99	12.07	12.36
System pressure	psig	231	231	231
Average gasifier bed density	lb/ft ³	5.93	6.46	6.7
Average annulus density	lb/ft ³	6.82	6.90	6.89
Freeboard gas velocity	fps	1.01	1.22	1.34
Oxidant tube velocity	fps	79	87	92
Oxygen concentration	%	57	56	57
Coal feed material		Upper Freeport	Upper Freeport	Upper Freeport
Coal feed rate	lb/hr	1174	1152	1333
Fines feed material		--	--	--
Fines feed rate	lb/hr	--	--	--
Carry-over to water system**	lb/hr	245	192	343
Ash withdrawal rate	lb/hr	184	167	166
<u>Product Gas Analysis, Dry Basis</u>				
Carbon monoxide	%	36.08	43.86	45.98
Carbon dioxide	%	45.72	34.99	29.84
Methane	%	2.042	2.15	2.71
Nitrogen	%	0.845	1.11	0.92
Sulfur	%	0.747	0.80	0.89
Hydrogen	%	14.56	16.83	19.70
HHV, dry basis (gas chromatograph)	Btu/scf	183	217	238
<u>Overall Process Rates</u>				
Carbon mass velocity +	lb/hr-ft ²	319	315	343
Gas make/coal	SCF/lb	36.36	29.05	33.37
Steam/coal ratio, MAF++	lb/lb	0.48	0.51	0.47
Oxygen/coal ratio, MAF	lb/lb	0.82	0.83	0.78
Total moisture/coal ratio, MAF	lb/lb	0.50	0.52	0.49
Recycle gas/coal ratio, MAF	lb/lb	3.25	3.58	3.07
<u>Solids Analysis</u>				
Ash content - fines	%	22.12	18.89	20.30
Ash content - feedstock	%	13.78	14.20	14.47
Ash content - bed	%	32.15	38.30	33.01
Ash content - agglomerate	%	58.44	58.56	52.31

* From jet inlet to top of bed.

** Estimated from isokinetic probe or ash samples.

+ Referenced at the 20" I.D. section.

++ Moisture and ash free.

TABLE 3-3

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-1, STEADY STATE 1A-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	479.00	0.00	0.00	544.00	426.33	676.61
TEMPERATURE	F	0.0	415.0	0.0	0.0	150.0	149.0	560.0
GAS	LB/HR	0.00	479.00	0.00	0.00	544.00	426.33	676.61
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	31.492	31.492
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	35.85	35.85
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	46.19	46.19
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	14.22	14.22
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	1.92	1.92
N2	VOLUME %	0.00	0.00	0.00	78.06	0.00	0.85	0.85
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	0.21	0.21
GAS CHARACTERIZATION								
	H2S PPM	0.000	0.000	0.000	0.000	0.000	7279.693	7279.693
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	0.000	0.000	0.000	0.000	148.463	136.533	216.667
HYDROGEN	LB/HR	0.000	53.600	0.000	0.000	0.000	5.185	8.229
OXYGEN	LB/HR	0.000	425.400	0.000	0.000	395.537	278.229	441.567
NITROGEN	LB/HR	0.000	0.000	0.000	0.000	0.000	3.224	5.117
SULFUR	LB/HR	0.000	0.000	0.000	0.000	0.000	3.160	5.015
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	73.461	0.000	0.000	8.373	959.118	1598.260

TABLE 3-3, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-1, STEADY STATE 1A-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	C120 CYCLONE TRANS. G.	C119 FEED & TRANS. G.
TOTAL	LB/HR	356.34	860.09	0.00	2205.89	814.00	368.00	368.00
TEMPERATURE	F	149.0	149.0	149.0	178.0	514.0	149.0	331.0
GAS	LB/HR	356.34	860.09	0.00	1031.89	814.00	368.00	368.00
SOLID	LB/HR	0.00	0.00	0.00	1174.00	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		31.492	31.492	31.492	31.492	32.034	31.492	31.492
CO	VOLUME %	35.85	35.85	35.85	35.85	0.00	35.85	35.85
CO2	VOLUME %	46.19	46.19	46.19	46.19	0.00	46.19	46.19
H2	VOLUME %	14.22	14.22	14.22	14.22	0.00	14.22	14.22
CH4	VOLUME %	1.92	1.92	1.92	1.92	0.00	1.92	1.92
N2	VOLUME %	0.85	0.85	0.85	0.85	0.00	0.85	0.85
O2	VOLUME %	0.00	0.00	0.00	0.00	99.57	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.43	0.00	0.00
H2O	VOLUME %	0.21	0.21	0.21	0.21	0.00	0.21	0.21
GAS CHARACTERIZATION								
	H2S PPM	7279.693	7279.693	7279.693	7279.693	0.000	7279.693	7279.693
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	114.117	275.443	0.000	1216.364	0.000	117.853	117.853
HYDROGEN	LB/HR	4.334	10.460	0.000	58.688	0.000	4.476	4.476
OXYGEN	LB/HR	232.549	561.302	0.000	706.883	809.635	240.163	240.163
NITROGEN	LB/HR	2.695	6.505	0.000	20.131	0.000	2.783	2.783
SULFUR	LB/HR	2.641	6.375	0.000	42.047	0.000	2.728	2.728
ARGON	LB/HR	0.000	0.000	0.000	0.000	4.365	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	161.777	0.000	0.000	0.000
HEAT CONTENT	KBTU/HR	801.651	1934.938	0.000	17872.813	80.452	827.696	845.656

TABLE 3-3, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-1, STEADY STATE 1A-1

STREAM NO.		15	15	17	18	19		
STREAM DESCRIPTION		LIQUID WATER INJECTION	PRODUCT GAS	C119 COLLEC. & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	0.00	5871.18	1080.67	184.00	5.00	0.00	-0.61
TEMPERATURE	F	0.0	0.0	356.0	226.0	1833.0	0.0	0.0
GAS	LB/HR	0.00	5626.18	1080.67	0.00	0.00	0.00	0.00
SOLID	LB/HR	0.00	245.00	0.00	184.00	6.00	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	29.568	31.492	0.000	0.000	0.000	0.000
CO	VOLUME %	0.00	31.28	35.05	0.00	0.00	0.00	0.00
CO2	VOLUME %	0.00	39.64	46.19	0.00	0.00	0.00	0.00
H2	VOLUME %	0.00	12.62	14.22	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.00	1.77	1.92	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	0.73	0.85	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	13.30	0.21	0.00	0.00	0.00	0.00
GAS CHARACTERIZATION								
	H2S PPM	0.000	6476.489	7279.693	0.000	0.000	0.000	0.000
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	0.000	1840.874	346.087	64.713	3.793	0.000	3.749
HYDROGEN	LB/HR	0.000	116.342	13.143	0.331	0.041	0.000	13.108
OXYGEN	LB/HR	0.000	3770.821	705.261	0.000	0.000	0.000	-3.340
NITROGEN	LB/HR	0.000	40.619	8.173	0.460	0.036	0.000	-13.990
SULFUR	LB/HR	0.000	48.333	8.010	10.966	0.202	0.000	-4.357
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH	LB/HR	0.000	54.194	0.000	107.530	1.929	0.000	-1.159
HEAT CONTENT								
	KBTU/HR	0.000	14314.984	2490.736	999.928	60.262	425.000	26.844

TABLE 3-4

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-1, STEADY STATE 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	495.00	0.00	0.00	142.00	587.69	844.49
TEMPERATURE	F	0.0	486.0	0.0	0.0	120.0	139.0	597.0
GAS	LB/HR	0.00	495.00	0.00	0.00	142.00	587.69	844.49
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	28.847	28.847
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	43.47	43.47
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	34.91	34.91
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	16.61	16.61
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	2.28	2.28
N2	VOLUME %	0.00	0.00	0.00	78.06	0.00	1.13	1.13
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
GAS CHARACTERIZATION								
	H2S PPM	0.000	0.000	0.000	0.000	0.000	7788.660	7788.660
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	0.000	0.000	0.000	0.000	38.753	197.354	283.590
HYDROGEN	LB/HR	0.000	55.391	0.000	0.000	0.000	9.070	13.033
OXYGEN	LB/HR	0.000	439.609	0.000	0.000	103.247	369.741	531.304
NITROGEN	LB/HR	0.000	0.000	0.000	0.000	0.000	6.440	9.254
SULFUR	LB/HR	0.000	0.000	0.000	0.000	0.000	5.088	7.311
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	92.521	0.000	0.000	1.279	1720.273	2582.545

TABLE 3-4, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-1, STEADY STATE 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	C120 CYCLONE TRANS. G.	C119 FEED & TRANS. G.
TOTAL	LB/HR	403.98	812.01	0.00	2076.68	810.00	409.05	327.85
TEMPERATURE	F	139.0	139.3	139.0	220.0	614.0	139.0	348.0
GAS	LB/HR	403.98	812.01	0.00	924.68	810.00	409.05	327.85
SOLID	LB/HR	0.00	0.03	0.00	1152.00	0.00	0.00	0.00
LIQUID	LB/HR	0.00	0.03	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		28.847	28.847	28.847	28.847	32.034	28.847	28.847
CO	VOLUME %	43.47	43.47	43.47	43.47	0.00	43.47	43.47
CO2	VOLUME %	34.91	34.91	34.91	34.91	0.00	34.91	34.91
H2	VOLUME %	16.61	16.61	16.61	16.61	0.00	16.61	16.61
CH4	VOLUME %	2.28	2.28	2.28	2.28	0.00	2.28	2.28
N2	VOLUME %	1.13	1.13	1.13	1.13	0.00	1.13	1.13
O2	VOLUME %	0.00	0.30	0.00	0.00	99.57	0.00	0.00
AR	VOLUME %	0.00	0.30	0.00	0.00	0.43	0.00	0.00
H2O	VOLUME %	0.15	0.15	0.15	0.15	0.00	0.15	0.15
GAS CHARACTERIZATION								
	H2S PPM	7788.660	7788.660	7788.660	7788.660	0.000	7788.660	7788.660
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	135.660	272.683	0.000	1185.807	0.000	137.364	110.096
HYDROGEN	LB/HR	6.235	12.532	0.000	60.351	0.000	6.313	5.060
OXYGEN	LB/HR	254.157	510.369	0.000	605.138	805.657	257.350	206.263
NITROGEN	LB/HR	4.427	8.893	0.000	23.496	0.000	4.482	3.592
SULFUR	LB/HR	3.497	7.030	0.000	38.303	0.000	3.541	2.838
ARGON	LB/HR	0.000	0.000	0.000	0.000	4.343	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	163.584	0.000	0.000	0.000
HEAT CONTENT								
	KBTU/HR	1182.502	2376.883	0.000	18173.178	99.294	1197.357	978.682

TABLE 3-4, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-1, STEADY STATE 1B-1

STREAM NO.	15	16	17	18	19		
STREAM DESCRIPTION	LIQUID WATER INJECTION	PRODUCT GAS	C119 COLLEC. & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL LB/HR	0.00	5425.48	1153.92	167.00	6.00	0.00	2.26
TEMPERATURE F	0.0	1306.0	349.0	315.0	1829.0	0.0	0.0
GAS LB/HR	0.00	5233.48	1008.92	0.00	0.00	0.00	0.00
SOLID LB/HR	0.00	192.00	145.00	167.00	6.00	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	27.635	28.847	0.000	0.000	0.000	0.000
CO VOLUME %	0.00	38.57	43.47	0.00	0.00	0.00	0.00
CO2 VOLUME %	0.00	30.77	34.91	0.00	0.00	0.00	0.00
H2 VOLUME %	0.00	14.80	16.61	0.00	0.00	0.00	0.00
CH4 VOLUME %	0.00	1.89	2.28	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	0.98	1.13	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	12.05	0.15	0.00	0.00	0.00	0.00
GAS CHARACTERIZATION							
H2S PPM	0.000	7036.000	7788.660	0.000	0.000	0.000	0.000
COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS							
CARBON LB/HR	0.000	1767.660	449.994	58.467	3.447	0.000	3.462
HYDROGEN LB/HR	0.000	120.891	16.513	0.234	0.008	0.000	13.050
OXYGEN LB/HR	0.000	3399.197	634.987	0.000	0.000	0.000	1.204
NITROGEN LB/HR	0.000	53.290	12.186	0.501	0.025	0.000	-8.936
SULFUR LB/HR	0.000	48.177	12.852	10.003	0.222	0.000	-5.394
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH LB/HR	0.000	36.269	27.390	97.795	2.298	0.000	-0.103
HEAT CONTENT							
KBTU/HR	0.000	18339.223	4674.269	902.810	53.351	425.000	14.117

TABLE 3-5

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-1, STEADY STATE 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	531.30	0.00	0.00	142.00	581.29	788.61
TEMPERATURE F	0.0	435.0	0.0	0.0	118.0	125.0	597.0
GAS LB/HR	0.00	531.30	0.00	0.00	142.00	581.29	788.61
SOLID LB/HR	0.00	2.20	0.00	0.00	0.00	0.00	0.00
LIQUID LB/HR	0.00	2.20	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT	18.016	13.016	18.016	28.963	44.011	27.552	27.552
CO VOLUME %	0.03	3.00	0.00	0.00	0.00	45.90	45.90
CO2 VOLUME %	0.03	3.00	0.00	0.00	100.00	29.61	29.61
H2 VOLUME %	0.03	3.00	0.00	0.00	0.00	19.74	19.74
CH4 VOLUME %	0.03	3.00	0.00	0.00	0.00	2.72	2.72
N2 VOLUME %	0.03	3.00	0.00	78.06	0.00	1.12	1.12
O2 VOLUME %	0.03	3.00	0.00	21.00	0.00	0.00	0.00
AR VOLUME %	0.03	3.00	0.00	0.94	0.00	0.00	0.00
H2O VOLUME %	100.03	102.00	100.00	0.00	0.00	0.08	0.08
GAS CHARACTERIZATION							
H2S PPM	0.030	2.000	0.000	0.000	0.000	14788.752	14788.752
COS PPM	0.030	2.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS							
CARBON LB/HR	0.030	7.000	0.000	0.000	38.753	198.219	268.915
HYDROGEN LB/HR	0.030	55.419	0.000	0.000	0.000	11.372	15.428
OXYGEN LB/HR	0.000	471.581	0.000	0.000	103.247	355.078	481.719
NITROGEN LB/HR	0.000	7.000	0.000	0.000	0.000	6.615	8.974
SULFUR LB/HR	0.000	7.000	0.000	0.000	0.000	10.004	13.573
ARGON LB/HR	0.000	7.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	0.000	7.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	0.000	86.430	0.000	0.000	1.219	1994.565	2816.498

TABLE 3-5, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-1, STEADY STATE 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	C120 CYCLONE TRANS. G.	C119 FEED & TRANS. G.
TOTAL	LB/HR	399.76	856.06	0.00	2292.22	874.00	401.74	324.37
TEMPERATURE	F	125.0	125.0	125.0	226.0	615.0	125.0	383.0
GAS	LB/HR	399.76	856.06	0.00	959.22	874.00	401.74	324.37
SOLID	LB/HR	0.00	0.00	0.00	1333.00	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		27.552	27.552	27.552	27.552	32.034	27.552	27.552
CO	VOLUME %	45.90	45.90	45.90	45.90	0.00	45.90	45.90
CO2	VOLUME %	29.61	29.61	29.61	29.61	0.00	29.61	29.61
H2	VOLUME %	19.74	19.74	19.74	19.74	0.00	19.74	19.74
CH4	VOLUME %	2.72	2.72	2.72	2.72	0.00	2.72	2.72
N2	VOLUME %	1.12	1.12	1.12	1.12	0.00	1.12	1.12
O2	VOLUME %	0.00	0.00	0.00	0.00	99.57	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.43	0.00	0.00
H2O	VOLUME %	0.08	0.08	0.08	0.08	0.00	0.08	0.08
GAS CHARACTERIZATION								
	H2S PPM	14788.752	14788.752	14788.752	14788.752	0.000	14788.752	14788.752
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	136.313	291.917	0.000	1280.057	0.000	136.994	110.610
HYDROGEN	LB/HR	7.821	16.747	0.000	70.486	0.000	7.859	6.346
OXYGEN	LB/HR	244.192	522.922	0.000	665.919	869.313	245.404	198.141
NITROGEN	LB/HR	4.549	9.741	0.000	27.178	0.000	4.572	3.691
SULFUR	LB/HR	6.880	14.734	0.000	55.699	0.000	6.914	5.583
ARGON	LB/HR	0.000	0.000	0.000	0.000	4.687	0.000	0.000
ASH	LB/HR	0.000	0.000	0.000	192.885	0.000	0.000	0.000
HEAT CONTENT								
	KB-U/HR	1371.683	2937.388	0.000	19905.119	107.349	1378.496	1137.278

TABLE 3-5, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-1, STEADY STATE 1B-2

STREAM NO.		15	16	17	18	19		
STREAM DESCRIPTION		LIQUID WATER INJECTION	PRODUCT GAS	C119 COLLEC. & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	0.00	6125.89	1203.61	166.00	7.00	0.00	-4.33
TEMPERATURE	F	0.0	1324.0	363.0	324.0	1843.0	0.0	0.0
GAS	LB/HR	0.00	5782.89	1035.61	0.00	0.00	0.00	0.00
SOLID	LB/HR	0.00	343.00	168.00	166.00	7.00	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	26.554	27.552	0.000	0.000	0.000	0.000
CO	VOLUME %	0.00	41.81	45.90	0.00	0.00	0.00	0.00
CO2	VOLUME %	0.00	27.13	29.61	0.00	0.00	0.00	0.00
H2	VOLUME %	0.00	17.91	19.74	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.00	2.46	2.72	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	3.84	1.12	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	3.00	0.00	0.00	0.00	0.00	0.00
AR	VOLUME %	0.00	3.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	100.00	3.07	0.08	0.00	0.00	0.00	0.00
GAS CHARACTERIZATION								
	H2S PPM	0.000	3092.770	14788.752	0.000	0.000	0.000	0.000
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	0.000	2127.740	480.435	69.903	4.439	0.000	-8.966
HYDROGEN	LB/HR	0.000	144.586	20.713	0.299	0.010	0.000	15.280
OXYGEN	LB/HR	0.000	3563.829	632.596	0.000	0.000	0.000	-3.341
NITROGEN	LB/HR	0.000	53.130	12.809	0.315	0.030	0.000	-1.477
SULFUR	LB/HR	0.000	66.938	22.931	8.649	0.209	0.000	12.930
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH	LB/HR	0.000	69.629	34.104	86.835	2.311	0.000	0.004
HEAT CONTENT								
	KBtu/HR	0.000	24626.631	5491.829	1061.963	68.007	425.000	0.197

Figure 3-1. Heat and Material Balance Flow Schematic

- Characterize the operation of the PDU with Upper Freeport E-seam coal.
- Obtain fines elutriation and consumption data with indirect injection of primary fines and direct injection of secondary fines into the annulus.
- Obtain estimates for alkali concentrations in the product gas using a hot alkali sampling probe (DOE Contract No. DE-AC21-81MC16024).

A total of 155 hours of hot operation was achieved during the test, which included 54 hours with Upper Freeport coal and 96 hours with Western Kentucky coal.

This test was conducted in two operational phases. The first startup, conducted from May 17 to May 22 with a hot operational period of 57 hours, was aborted because of a loss of coal feed to the gasifier. The loss of coal feed was caused by oversized material plugging the feed lines.

During the second startup, from May 22 to May 27, 99 hours of hot operation were achieved. A voluntary shutdown concluded TP-032-2.

Two set points were achieved with Upper Freeport E-seam coal:

Set Point 1 - 1826°F freeboard temperature, with primary fines recycle, but no secondary fines recycle.

Set Point 2 - 1825°F freeboard temperature, with primary and secondary fines recycle.

Set point 3 with Western Kentucky coal was conducted in four segments:

Set Point 3 - 1807°F freeboard temperature, with primary and secondary fines recycle.

Set Point 3A - 1860°F freeboard temperature, with primary and secondary fines recycle.

Set Point 3B - 1855°F freeboard temperature, with short duration experiments to estimate the per pass consumption of fines for the various recycle modes.

Set Point 3C - 1827°F freeboard temperature, with primary and secondary fines recycle.

Because of the relatively low coal feed rate and the high efficiency performance of the primary cyclone, it was found that an insignificant rate of fines was being recycled from the secondary cyclone through the ash annulus. Since fines consumption versus reinjection location was the primary objective, set point 3B was run with batches of fines fed individually through each of three modes. Thus, 3B consists of three short duration fines tests to estimate per pass consumption of fines (radial, coaxial, and ash annulus).

Set point 4 with Rockwell char could not be achieved. The char was moisture laden, oversized, and reliable flow of solids through the storage bins and material handling equipment could not be achieved.

Notable accomplishments during test TP-032-2 include the following:

- The cyclone cold wall system was successfully operated for 96 hours of continuous hot operation. The exit gas temperature and the gas side metal surface temperature were, respectively, 1300-1350°F and 550-650°F. During post-test visual inspection, no deposits were found on the cold wall surfaces.
- The operation of the gasifier with Upper Freeport coal was characterized in the fines recycle mode.
- The operation of the gasifier with Western Kentucky coal was characterized at various freeboard temperatures and with various modes of recycle. Data were obtained on the sensitivity of fines consumption to the injection location.
- The heat recovery unit was operated for 49 hours. (This Westinghouse heat recovery program is described in FE-14752-28.)
- The hot alkali sampling probe was operated during the test. Samples were successfully obtained and are currently being analyzed.
- A 40°F freeboard temperature transient was performed with all automatic control loops closed. The net heat production increased in a well-controlled manner at a rate of 8 percent/minute which is better than required for process applications.

A chronology of significant events for test TP-032-2 is given in Table 3-6 and steady state process data and heat and material balances are reported in Tables 3-7 to 3-17.

TABLE 3-6

CHRONOLOGY OF SIGNIFICANT EVENTS, TEST TP-032-2

<u>Date</u>	<u>Time</u>	<u>Event</u>
5/18/82	0515	Completed pressurization at 230 psig.
5/19/82	0030	Completed hot air dry out of refractory.
	0720	Initiated coke breeze feed to gasifier.
	1100-1425	Material bridged in gasifier transition section. Reduced system pressure to 100 psig - bridge cleared.
	1540	Increased system pressure to 130 psig.
	1630	Introduced secondary fines transport gas.
5/20/82	0300	Achieved autogenous ignition.
	0400	Quenched ignition to replace expansion joint under gasifier. As a result of thermal growth of piping and vessels, the expansion joint between the gasifier and ash hopper was misaligned. An inspection of the joint conditions indicated that the material had exceeded its allowable compression, thus necessitating replacement with a new joint.
	0835	Achieved autogenous ignition.
	1125	Initiated Upper Freeport coal feed to gasifier.
	1500	Increased system pressure to 230 psig.
	1730	Initiated oxygen flow to gasifier.
	1830	Site power failure.
	1945	Site power returned.
	2000	Reinitiated air flows to gasifier.
	2005	Achieved autogenous ignition.
	2120	Initiated oxygen flow to gasifier.
5/21/82	0100	Initiated primary fines recycle to gasifier.
	0400	<u>Achieved set point 1 test conditions.</u>

TABLE 3-6 (continued)

CHRONOLOGICAL SUMMARY OF EVENTS, TEST TP-032-2

<u>Date</u>	<u>Time</u>	<u>Event</u>
5/22/82	0600	<u>Achieved set point 2 test conditions.</u>
	1500	Secondary fines recycled to bed.
	1630-1800	Experienced and cleared feed line plugs.
	1800	Quenched ignition to correct feed line problems.
	2015	Reinitiated air flows to gasifier, requiring ignition.
	2305	Initiated coke breeze feed to gasifier.
5/23/82	0210	Decreased system back pressure to 200 psig - steam boiler problems.
	0430	Achieved autogenous ignition.
	0433	Experienced feed line plug.
	0450	Quenched ignition to clear feed line.
	0630	Achieved autogenous ignition.
	0930	Initiated Western Kentucky coal feed to gasifier.
	1100	Secondary fines system on line.
	1145	Increased system pressure to 230 psig.
	1300	Initiated oxygen flow to gasifier.
	1640	Initiated primary fines recycle to gasifier.
	1800	<u>Achieved set point 3 test conditions.</u>
5/24/82	0900	<u>Achieved set point 3A test conditions.</u>
5/26/82	1345	<u>Achieved set point 3B test conditions.</u>
	1400	Initiated Rockwell char feed to gasifier.
	1405	Primary cyclone on line. Recycled secondary fines to bed.
	1440	Decreased freeboard temperatures for set point 4.
	1505	Initiated primary fines recycle to gasifier.
	1630	Oversized pieces of Rockwell char found in storage bin.

TABLE 3-6 (continued)

CHRONOLOGICAL SUMMARY OF EVENTS, TEST TP-032-2

<u>Date</u>	<u>Time</u>	<u>Event</u>
5/26/82	1730	Aborted Rockwell char set point.
	1830	<u>Achieved set point 3C test conditions</u> with Western Kentucky coal.
5/27/82	0930	Initiated voluntary shutdown.

TABLE 3-7

SUMMARY OF NOMINAL OPERATING DATA FOR GASIFIER TEST TP-032-2

STEADY STATE		1A	1B	2A	3A	Mod. 3A-1	Mod. 3B-1	Mod. 3B-2	Mod. 3B-3	Mod. 3B-4	Mod. 3C-1
		Hours 5/21 0400 - 1030	Hours 5/21-22 1800 - 0400	Hours 5/22 1000 - 1500	Hours 5/23-24 2300 - 0700	Hours 5/24-25 1030 - 1200	Hours 5/25 1430 - 1830	Hours 5/25 1830 - 2300	Hours 5/26 0430 - 1030	Hours 5/26 1030 - 1430	Hours 5/26-27 2330 - 0730
TEST RUN DATE AND TIME (1982)	Unit										
<u>MEASURED GASIFIER PARAMETERS</u>											
Freeboard Temperature	°F	1827	1823	1824	1807	1860	1880	1872	1843	1851	1824
Gasifier Bed Temperature	°F	1831	1847	1845	1833	1928	1967	1957	1930	1950	1926
Ash Annulus Temperature	°F	766	397	372	363	296	334	335	461	397	397
Average Bed Height*	feet	11.35	11.36	11.30	11.69	10.70	11.24	11.80	11.38	11.75	11.61
System Pressure	psig	232	232	232	232	232	232	232	232	232	232
Average Gasifier Bed Density	lb/ft ³	7.43	7.99	7.58	11.47	10.92	11.11	11.42	10.68	10.86	10.79
Average Annulus Density	lb/ft ³	6.37	9.31	7.39	14.57	13.01	13.40	13.05	15.71	16.05	17.94
Freeboard Gas Velocity	fps	1.035	1.016	1.002	0.988	1.185	1.266	1.480	1.197	1.209	1.311
Oxidant Tube Velocity	fps	79	74	75	76	87	92	92	87	89	99
Oxygen Concentration	%	49	53	53	54	63	62	63	61	61	63
Coal Feed Material	Freeport	Freeport	Freeport	Freeport	W. Kentucky	W. Kentucky	W. Kentucky	W. Kentucky	W. Kentucky	W. Kentucky	W. Kentucky
Coal Feed Rate	lb/hr	1014	989	1080	966	1445	1468	1454	1347	1340	1497
Fines Feed Material	Recycle	Recycle	Recycle	Recycle	Recycle	Recycle	--	Recycle	--	--	Recycle
Fines Feed Rate	lb/hr	125	239	218	377	333	0	311	0	0	357
Carry-over to Water System**	lb/hr	46	559	286	22	48	7	268	239	171	160
Ash Withdrawal Rate	lb/hr	143	92	143	46	82	61	68	64	45	61
<u>PRODUCT GAS ANALYSIS, DRY BASIS</u>											
Carbon Monoxide	%	41.04	41.75	43.03	44.20	50.34	51.17	51.40	52.19	53.14	51.07
Carbon Dioxide	%	38.67	39.78	36.53	32.13	20.61	18.94	11.68	19.22	17.66	21.37
Methane	%	1.93	1.86	2.06	3.03	3.47	3.11	2.99	3.17	2.70	3.33
Nitrogen	%	1.54	1.04	0.97	1.20	0.94	0.97	0.96	1.03	1.03	0.92
Sulfur	%	0.244	0.357	0.593	0.374	0.646	0.676	0.655	0.613	0.680	0.673
Hydrogen	%	16.57	15.21	16.85	19.09	24.00	25.14	24.32	23.75	24.81	22.62
HHV, Dry Basis (Gas Chromatograph)	Btu/scf	205	202	213	234	274	277	273	276	278	270
<u>OVERALL PROCESS RATES</u>											
Carbon Mass Velocity*	lb/hr-ft ²	270.75	264.08	288.38	238.28	365.75	376.22	372.64	346.38	349.36	390.29
Gas Make/Coal	scf/lb	30.62	29.76	29.55	34.12	32.64	33.54	46.78	35.63	37.52	34.73
Steam/Coal Ratio, MAF**	lb/lb	0.630	0.590	0.536	0.570	0.348	0.364	0.367	0.389	0.413	0.410
Oxygen/Coal Ratio, MAF	lb/lb	0.833	0.866	0.840	0.875	0.791	0.784	0.804	0.794	0.847	0.875
Total Moisture/Coal Ratio, MAF	lb/lb	0.641	0.601	0.547	0.604	0.406	0.423	0.426	0.447	0.483	0.480
Recycle Gas/Coal Ratio, MAF	lb/lb	3.972	4.222	3.474	3.465	2.027	2.069	2.058	2.202	2.219	2.419
<u>SOLIDS ANALYSIS</u>											
Ash Content - Fines	%	21.39	22.47	28.64	27.60	31.54	0	31.15	0	0	29.63
Ash Content - Feedstock	%	15.49	15.49	15.49	12.03	8.96	8.35	8.35	8.31	9.97	9.97
Ash Content - Bed	%	28.74	25.50	27.17	27.38	26.20	25.54	26.06	26.54	24.93	23.51
Ash Content - Agglomerate	%	61.05	49.18	48.84	46.35	59.98	40.05	41.67	56.98	40.60	45.68

* From jet inlet to top of bed

+ Referenced at the 20" I.D. section

**Estimated from isokinetic probe or ash samples

**Moisture and ash free

TABLE 3-8

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE 1A

STREAM NO.		1	2	3	4	5	6	7
STREAM DESCRIPTION		STEAM TO GRID	STEAM TO AIR TUBE	BOGSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING
TOTAL	LB/HR	0.00	534.00	0.00	0.00	126.00	498.61	809.99
TEMPERATURE	F	0.0	481.0	0.0	0.0	138.0	141.0	594.0
GAS	LB/HR	0.00	534.00	0.00	0.00	126.00	498.61	809.99
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		0.000	18.016	0.000	0.000	44.011	28.993	28.993
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	42.87	42.87
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	35.54	35.54
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	17.38	17.38
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	2.02	2.02
N2	VOLUME %	0.00	0.00	0.00	0.00	0.00	1.67	1.67
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.00	100.00	0.00	0.00	0.00	0.15	0.15
GAS CHARACTERIZATION								
	H2S PPM	0.000	0.000	0.000	0.000	0.000	4313.398	4313.398
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	0.000	0.000	0.000	0.000	34.387	166.146	269.902
HYDROGEN	LB/HR	0.000	59.755	0.000	0.000	0.000	7.630	12.395
OXYGEN	LB/HR	0.000	474.245	0.000	0.000	91.613	313.985	510.065
NITROGEN	LB/HR	0.000	0.000	0.000	0.000	0.000	8.038	13.058
SULFUR	LB/HR	0.000	0.000	0.000	0.000	0.000	2.379	3.864
ASH	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT								
	KBTU/HR	0.000	98.542	0.000	0.000	1.616	1425.070	2420.097

TABLE 3-8, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE 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	C120 CYCLONE TRANS. G.	C119 FEED & TRANS. G.
TOTAL	LB/HR	314.43	920.91	0.00	1958.31	706.00	430.43	495.40
TEMPERATURE	F	141.0	141.0	0.0	206.0	520.0	141.0	307.0
GAS	LB/HR	314.43	920.91	0.00	944.31	706.00	430.43	370.40
SOLID	LB/HR	0.00	0.00	0.00	1014.00	0.00	0.00	125.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		28.993	28.993	0.000	28.993	31.862	28.993	28.993
CO	VOLUME %	42.87	42.87	0.00	42.87	0.00	42.87	42.87
CO2	VOLUME %	35.54	35.54	0.00	35.54	0.00	35.54	35.54
H2	VOLUME %	17.38	17.38	0.00	17.38	0.00	17.38	17.38
CH4	VOLUME %	2.02	2.02	0.00	2.02	0.00	2.02	2.02
N2	VOLUME %	1.67	1.67	0.00	1.67	0.00	1.67	1.67
O2	VOLUME %	0.00	0.00	0.00	0.00	99.57	0.00	0.00
H2O	VOLUME %	0.15	0.15	0.00	0.15	0.00	0.15	0.15
GAS CHARACTERIZATION								
	H2S PPM	4313.398	4313.398	0.000	4313.398	0.000	4313.398	4313.398
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	104.774	306.861	0.000	1066.541	0.000	143.428	215.798
HYDROGEN	LB/HR	4.812	14.092	0.000	51.056	0.000	6.587	6.156
OXYGEN	LB/HR	198.003	579.911	0.000	621.520	706.000	271.052	234.083
NITROGEN	LB/HR	5.069	14.846	0.000	26.682	0.000	6.939	6.896
SULFUR	LB/HR	1.500	4.393	0.000	35.736	0.000	2.053	5.404
ASH	LB/HR	0.000	0.000	0.000	157.069	0.000	0.000	26.737
HEAT CONTENT								
	KBTU/HR	898.667	2632.017	0.000	15763.876	70.949	1230.214	2434.436

TABLE 3-8, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE 1A

STREAM NO.	15	16	17	18	19		
STREAM DESCRIPTION	LIQUID WATER INJECTION	PRODUCT GAS	C119 COLLEC. & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL LB/HR	0.00	5096.11	1275.47	143.00	5.50	0.00	4.03
TEMPERATURE F	0.0	314.0	362.0	317.0	1819.0	0.0	0.0
GAS LB/HR	0.00	5050.31	1127.47	0.00	0.00	0.00	0.00
SOLID LB/HR	0.00	45.80	148.00	143.00	5.50	0.00	0.00
LIQUID LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT	0.000	28.449	28.993	0.000	0.000	0.000	0.000
CO VOLUME %	0.00	36.62	42.87	0.00	0.00	0.00	0.00
CO2 VOLUME %	0.00	34.50	35.54	0.00	0.00	0.00	0.00
H2 VOLUME %	0.00	14.78	17.38	0.00	0.00	0.00	0.00
CH4 VOLUME %	0.00	1.72	2.02	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	1.38	1.67	0.00	0.00	0.00	0.00
O2 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O VOLUME %	0.00	0.79	0.15	0.00	0.00	0.00	0.00
GAS CHARACTERIZATION							
H2S PPM	0.000	2176.724	4313.398	0.000	0.000	0.000	0.000
COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS							
CARBON LB/HR	0.000	1587.989	485.065	46.575	3.759	0.000	7.992
HYDROGEN LB/HR	0.000	104.814	17.831	0.200	0.013	0.000	24.387
OXYGEN LB/HR	0.000	3306.943	710.982	0.000	0.006	0.000	-0.436
NITROGEN LB/HR	0.000	68.718	19.271	0.329	0.030	0.000	-8.365
SULFUR LB/HR	0.000	13.155	9.685	8.594	0.112	0.000	42.984
ASH LB/HR	0.000	8.904	31.657	87.301	1.581	0.000	29.576
HEAT CONTENT KBTU/HR	0.000	14893.922	4902.328	723.870	57.204	425.000	22.143

TABLE 3-9

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE 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	0.00	487.00	0.00	0.00	132.00	559.98	769.59
TEMPERATURE F	0.0	425.0	0.0	0.0	142.0	149.0	593.0
GAS LB/HR	0.00	487.00	0.00	0.00	132.00	559.98	769.59
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	0.000	18.016	0.000	0.000	44.011	29.561	29.561
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	43.39	43.39
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	36.96	36.96
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	15.94	15.94
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	1.99	1.99
N2 VOLUME %	0.00	0.00	0.00	0.00	0.00	1.09	1.09
O2 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O VOLUME %	0.00	100.00	0.00	0.00	0.00	0.19	0.19
GAS CHARACTERIZATION							
H2S PPM	0.000	0.000	0.000	0.000	0.000	3992.328	3992.328
COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS							
CARBON LB/HR	0.000	0.000	0.000	0.000	36.024	187.341	257.465
HYDROGEN LB/HR	0.000	54.496	0.000	0.000	0.000	7.833	10.765
OXYGEN LB/HR	0.000	432.504	0.000	0.000	95.976	356.147	489.457
NITROGEN LB/HR	0.000	0.000	0.000	0.000	0.000	5.795	7.963
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	2.425	3.333
ASH LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT							
KBTU/HR	0.000	76.976	0.000	0.000	1.806	1545.492	2220.503

TABLE 3-9, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE 1B

STREAM NO.		8	9	10	11	12	13	14
STREAM DESCRIPTION		BOOSTER GAS	TRANSPCRT GAS (FV-33)	TRANSPORT GAS (FV-29)	COAL FEED & TRANS. G.	OXYGEN TO TUBE	C120 CYCLONE TRANS. G.	C119 FEED & TRANS. G.
TOTAL	LB/HR	408.94	1026.47	0.00	1939.43	716.00	428.46	611.98
TEMPERATURE	F	149.0	149.0	0.0	206.0	520.0	149.0	289.0
GAS	LB/HR	408.94	1026.47	0.00	950.43	716.00	428.46	372.98
SOLID	LB/HR	0.00	0.00	0.00	989.00	0.00	0.00	239.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		29.561	29.561	0.000	29.561	31.862	29.561	29.561
CO	VOLUME %	43.39	43.39	0.00	43.39	0.00	43.39	43.39
CO2	VOLUME %	36.96	36.96	0.00	36.96	0.00	36.96	36.96
H2	VOLUME %	15.94	15.94	0.00	15.94	0.00	15.94	15.94
CH4	VOLUME %	1.99	1.99	0.00	1.99	0.00	1.99	1.99
N2	VOLUME %	1.09	1.09	0.00	1.09	0.00	1.09	1.09
O2	VOLUME %	0.00	0.00	0.00	0.00	99.57	0.00	0.00
H2O	VOLUME %	0.19	0.19	0.00	0.19	0.00	0.19	0.19
GAS CHARACTERIZATION								
	H2S PPM	3992.328	3992.328	0.000	3992.328	0.000	3992.328	3992.328
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	L3/HR	136.810	343.401	0.000	1051.307	0.000	143.341	298.269
HYDROGEN	L3/HR	5.720	14.358	0.000	48.998	0.000	5.993	6.173
OXYGEN	L3/HR	260.085	652.828	0.000	630.678	716.000	272.502	240.440
NITROGEN	L3/HR	4.232	10.622	0.000	21.010	0.000	4.434	5.509
SULFUR	L3/HR	1.771	4.445	0.000	33.786	0.000	1.855	7.590
ASH	L3/HR	0.000	0.000	0.000	153.196	0.000	0.000	53.703
HEAT CONTENT								
	KBTU/HR	1128.635	2832.929	0.000	15359.688	71.953	1182.514	3583.945

TABLE 3-9, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE 1B

STREAM NO.		15	16	17	18	19		
STREAM DESCRIPTION		LIQUID WATER INJECTION	PRODUCT GAS	C119 COLLEC. & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	0.00	5686.71	1411.21	92.00	5.40	0.00	-1.63
TEMPERATURE	F	0.0	1334.0	389.0	315.0	1833.0	0.0	0.0
GAS	LB/HR	0.00	5127.41	1166.21	0.00	0.00	0.00	0.00
SOLID	LB/HR	0.00	559.30	245.00	92.00	5.40	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		0.000	28.763	29.561	0.000	0.000	0.000	0.000
CO	VOLUME %	0.00	36.47	43.39	0.00	0.00	0.00	0.00
CO2	VOLUME %	0.00	34.76	36.96	0.00	0.00	0.00	0.00
H2	VOLUME %	0.00	13.29	15.94	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.00	1.63	1.99	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	0.91	1.09	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.00	12.64	0.19	0.00	0.00	0.00	0.00
GAS CHARACTERIZATION								
	H2S PPM	0.000	3118.752	3992.328	0.000	0.000	0.000	0.000
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	0.000	1979.927	567.995	42.311	3.870	0.000	-5.711
HYDROGEN	LB/HR	0.000	108.519	17.293	0.175	0.012	0.000	18.361
OXYGEN	LB/HR	0.000	3402.401	745.008	0.000	0.024	0.000	-0.020
NITROGEN	LB/HR	0.000	49.311	13.758	0.377	0.033	0.000	-6.574
SULFUR	LB/HR	0.000	26.439	11.175	3.910	0.083	0.000	24.631
ASH	LB/HR	0.000	105.092	55.051	45.246	1.377	0.000	0.064
HEAT CONTENT								
	KBTU/HR	0.000	20316.193	5904.941	634.849	58.488	425.000	2.375

TABLE 3-10

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE 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	0.00	484.30	0.00	0.00	136.00	550.76	566.96
TEMPERATURE F	0.0	414.0	0.0	0.0	142.0	151.0	594.0
GAS LB/HR	0.00	484.30	0.00	0.00	136.00	550.76	566.96
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	0.000	18.016	0.000	0.000	44.011	28.700	28.700
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	44.33	44.33
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	34.24	34.24
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	17.55	17.55
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	2.24	2.24
N2 VOLUME %	0.00	0.00	0.00	0.00	0.00	1.01	1.01
O2 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O VOLUME %	0.00	100.00	0.00	0.00	0.00	0.23	0.23
GAS CHARACTERIZATION							
H2S FPM	0.000	0.000	0.000	0.000	0.000	4479.450	4479.450
COS FPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS							
CARBON LB/HR	0.000	0.000	0.000	0.000	37.116	186.244	191.722
HYDROGEN LB/HR	0.000	54.160	0.000	0.000	0.000	8.784	9.043
OXYGEN LB/HR	0.000	429.840	0.000	0.000	98.884	347.065	357.273
NITROGEN LB/HR	0.000	0.000	0.000	0.000	0.000	5.406	5.565
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	2.756	2.837
ASH LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	0.000	74.000	0.000	0.000	1.860	1646.391	1767.270

TABLE 3-10, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE 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	C120 CYCLONE TRANS. G.	C119 FEED & TRANS. G.
TOTAL	LB/HR	305.75	1050.90	0.00	2016.50	758.00	408.01	585.51
TEMPERATURE	F	151.0	151.0	0.0	190.0	520.0	151.0	292.0
GAS	LB/HR	305.75	1050.90	0.00	936.50	758.00	408.01	367.51
SOLID	LB/HR	0.00	0.00	0.00	1080.00	0.00	0.00	218.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		28.700	28.700	0.000	28.700	31.862	28.700	28.700
CO	VOLUME %	44.33	44.33	0.00	44.33	0.00	44.33	44.33
CO2	VOLUME %	34.24	34.24	0.00	34.24	0.00	34.24	34.24
H2	VOLUME %	17.55	17.55	0.00	17.55	0.00	17.55	17.55
CH4	VOLUME %	2.24	2.24	0.00	2.24	0.00	2.24	2.24
N2	VOLUME %	1.01	1.01	0.00	1.01	0.00	1.01	1.01
O2	VOLUME %	0.00	0.00	0.00	0.00	99.57	0.00	0.00
H2O	VOLUME %	0.23	0.23	0.00	0.23	0.00	0.23	0.23
GAS CHARACTERIZATION								
	H2S PPM	4479.450	4479.450	0.000	4479.450	0.000	4479.450	4479.450
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	103.393	355.370	0.000	1117.503	0.000	137.971	270.773
HYDROGEN	LB/HR	4.877	16.761	0.000	53.925	0.000	6.508	6.298
OXYGEN	LB/HR	192.672	662.231	0.000	618.759	758.000	257.109	231.590
NITROGEN	LB/HR	3.001	10.315	0.000	21.397	0.000	4.005	4.719
SULFUR	LB/HR	1.530	5.259	0.000	37.087	0.000	2.042	9.818
ASH	LB/HR	0.000	0.000	0.000	167.292	0.000	0.000	62.435
HEAT CONTENT								
	KBTU/HR	913.989	3141.459	0.000	16698.797	76.174	1219.661	3265.528

TABLE 3-10, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE 2A

STREAM NO.		15	16	17	18	19		
STREAM DESCRIPTION		LIQUID WATER INJECTION	PRODUCT GAS	C119 COLLEC. & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	0.00	5210.12	1374.22	143.00	6.00	0.00	1.88
TEMPERATURE	F	0.0	1332.0	352.0	309.0	1836.0	0.0	0.0
GAS	LB/HR	0.00	4924.52	1158.22	0.00	0.00	0.00	0.00
SOLID	LB/HR	0.00	285.60	216.00	143.00	6.00	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		0.000	27.993	28.700	0.000	0.000	0.000	0.000
CO	VOLUME %	0.00	38.32	44.33	0.00	0.00	0.00	0.00
CO2	VOLUME %	0.00	32.54	34.24	0.00	0.00	0.00	0.00
H2	VOLUME %	0.00	15.00	17.55	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.00	1.33	2.24	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	0.36	1.01	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	0.30	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.00	10.34	0.23	0.00	0.00	0.00	0.00
GAS CHARACTERIZATION								
	H2S PPM	0.000	5281.258	4479.450	0.000	0.000	0.000	0.000
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	0.000	1752.016	536.812	64.936	4.186	0.000	1.756
HYDROGEN	LB/HR	0.000	107.783	18.905	0.515	0.026	0.000	20.658
OXYGEN	LB/HR	0.000	3222.793	729.858	0.000	0.000	0.000	0.020
NITROGEN	LB/HR	0.000	44.116	12.470	0.586	0.034	0.000	-5.144
SULFUR	LB/HR	0.000	34.245	13.702	7.136	0.126	0.000	9.980
ASH	LB/HR	0.000	57.948	61.862	69.841	1.630	0.000	16.735
HEAT CONTENT								
	KBTU/HR	0.000	18084.613	5662.958	995.800	64.475	425.000	12.402

TABLE 3-11

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE 3A

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	468.00	0.00	0.00	144.00	430.32	521.12
TEMPERATURE F	0.0	483.0	0.0	0.0	138.0	170.0	582.0
GAS LB/HR	0.00	468.00	0.00	0.00	144.00	430.32	521.12
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	0.000	18.016	0.000	0.000	44.011	27.275	27.275
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	45.40	45.40
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	29.79	29.79
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	19.78	19.78
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	3.21	3.21
N2 VOLUME %	0.00	0.00	0.00	0.00	0.00	1.25	1.25
O2 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O VOLUME %	0.00	100.00	0.00	0.00	0.00	0.25	0.25
GAS CHARACTERIZATION							
H2S PPM	0.000	0.000	0.000	0.000	0.000	3451.323	3451.323
COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS							
CARBON LB/HR	0.000	0.000	0.000	0.000	39.299	148.571	179.921
HYDROGEN LB/HR	0.000	52.369	0.000	0.000	0.000	8.523	10.322
OXYGEN LB/HR	0.000	415.630	0.000	0.000	104.701	265.655	321.711
NITROGEN LB/HR	0.000	0.000	0.000	0.000	0.000	5.506	6.668
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	1.746	2.114
ASH LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT							
KBTU/HR	0.000	86.807	0.000	0.000	1.847	1474.597	1850.115

TABLE 3-11, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE 3A

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	C120 CYCLONE TRANS. G.	C119 FEED & TRANS. G.
TOTAL	LB/HR	199.37	894.20	0.00	1957.91	719.00	382.95	700.73
TEMPERATURE	F	170.0	170.0	0.0	201.0	550.0	170.0	266.0
GAS	LB/HR	199.37	894.20	0.00	991.91	719.00	382.95	323.73
SOLID	LB/HR	0.00	0.00	0.00	966.00	0.00	0.00	377.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		27.275	27.275	0.000	27.275	31.862	27.275	27.275
CO	VOLUME %	45.40	45.40	0.00	45.40	0.00	45.40	45.40
CO2	VOLUME %	29.79	29.79	0.00	29.79	0.00	29.79	29.79
H2	VOLUME %	19.78	19.78	0.00	19.78	0.00	19.78	19.78
CH4	VOLUME %	3.21	3.21	0.00	3.21	0.00	3.21	3.21
N2	VOLUME %	1.25	1.25	0.00	1.25	0.00	1.25	1.25
O2	VOLUME %	0.00	0.00	0.00	0.00	99.57	0.00	0.00
H2O	VOLUME %	0.25	0.25	0.00	0.25	0.00	0.25	0.25
GAS CHARACTERIZATION								
	H2S PPM	3451.323	3451.323	0.000	3451.323	0.000	3451.323	3451.323
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	68.833	308.728	0.000	1013.833	0.000	132.214	369.825
HYDROGEN	LB/HR	3.949	17.711	0.000	65.623	0.000	7.585	7.581
OXYGEN	LB/HR	123.079	552.027	0.000	697.452	719.000	236.409	199.851
NITROGEN	LB/HR	2.551	11.442	0.000	30.853	0.000	4.900	6.103
SULFUR	LB/HR	0.809	3.628	0.000	33.193	0.000	1.554	13.076
ASH	LB/HR	0.000	0.000	0.000	116.213	0.000	0.000	104.052
HEAT CONTENT								
	KBTL/HR	683.185	3054.186	0.000	15518.541	77.368	1312.256	4921.199

TABLE 3-11, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE 3A

STREAM NO.		15	16	17	18	19		
STREAM DESCRIPTION		LIQUID WATER INJECTION	PRODUCT GAS	C119 COLLEC. & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	0.00	4622.29	1409.58	46.00	6.00	0.00	5.20
TEMPERATURE	F	0.0	1315.0	370.0	250.0	1821.0	0.0	0.0
GAS	LB/HR	0.00	4600.69	1016.58	0.00	0.00	0.00	0.00
SOLID	LB/HR	0.00	21.60	393.00	46.00	6.00	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		0.000	26.450	27.275	0.000	0.000	0.000	0.000
CO	VOLUME %	0.00	39.09	45.40	0.00	0.00	0.00	0.00
CO2	VOLUME %	0.00	28.41	29.79	0.00	0.00	0.00	0.00
H2	VOLUME %	0.00	16.88	19.78	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.00	2.68	3.21	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	1.06	1.25	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.00	11.57	0.25	0.00	0.00	0.00	0.00
GAS CHARACTERIZATION								
	H2S PPM	0.000	3307.282	3451.323	0.000	0.000	0.000	0.000
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	0.000	1479.380	619.990	22.660	4.163	0.000	5.972
HYDROGEN	LB/HR	0.000	119.930	21.353	0.106	0.006	0.000	18.583
OXYGEN	LB/HR	0.000	2992.479	627.580	0.000	0.000	0.000	0.425
NITROGEN	LB/HR	0.000	52.171	15.052	0.400	0.082	0.000	0.470
SULFUR	LB/HR	0.000	19.303	16.386	1.518	0.107	0.000	33.516
ASH	LB/HR	0.000	5.458	108.468	21.321	1.643	0.000	37.851
HEAT CONTENT								
	KBTU/HR	0.000	15909.154	7515.743	336.971	62.740	425.000	16.352

TABLE 3-12

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE MOD 3A-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	443.00	0.00	0.00	141.00	335.20	411.55
TEMPERATURE	F	0.0	449.0	0.0	0.0	146.0	180.0	469.0
GAS	LB/HR	0.00	443.00	0.00	0.00	141.00	335.20	411.55
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		0.000	18.016	0.000	0.000	44.011	24.275	24.275
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	51.37	51.37
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	18.77	18.77
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	24.51	24.51
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	3.53	3.53
N2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.96	0.96
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.00	100.00	0.00	0.00	0.00	0.21	0.21
GAS CHARACTERIZATION								
	H2S PPM	0.000	0.000	0.000	0.000	0.000	6396.674	6396.674
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	0.000	0.000	0.000	0.000	38.480	122.192	150.025
HYDROGEN	LB/HR	0.000	49.572	0.000	0.000	0.000	9.025	11.081
OXYGEN	LB/HR	0.000	393.428	0.000	0.000	102.520	196.901	241.751
NITROGEN	LB/HR	0.000	0.000	0.000	0.000	0.000	3.733	4.583
SULFUR	LB/HR	0.000	0.000	0.000	0.000	0.000	2.832	3.477
ASH	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT								
	KBTU/HR	0.000	75.033	0.000	0.000	2.049	1498.953	1878.383

TABLE 3-12, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE MOD 3A-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	C120 CYCLONE TRANS. G.	C119 FEED & TRANS. G.
TOTAL LB/HR	198.33	947.88	0.00	2374.25	983.00	342.65	635.61
TEMPERATURE F	180.0	180.0	0.0	179.0	550.0	180.0	278.0
GAS LB/HR	198.33	947.88	0.00	929.25	983.00	342.65	302.61
SOLID LB/HR	0.00	0.00	0.00	1445.00	0.00	0.00	333.00
LIQUID LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT	24.275	24.275	0.000	24.275	31.862	24.275	24.275
CO VOLUME %	51.37	51.37	0.00	51.37	0.00	51.37	51.37
CO2 VOLUME %	18.77	18.77	0.00	18.77	0.00	18.77	18.77
H2 VOLUME %	24.51	24.51	0.00	24.51	0.00	24.51	24.51
CH4 VOLUME %	3.53	3.53	0.00	3.53	0.00	3.53	3.53
N2 VOLUME %	0.96	0.96	0.00	0.96	0.00	0.96	0.96
O2 VOLUME %	0.00	0.00	0.00	0.00	99.57	0.00	0.00
H2O VOLUME %	0.21	0.21	0.00	0.21	0.00	0.21	0.21
GAS CHARACTERIZATION							
H2S PPM	6396.574	6396.674	0.000	6396.674	0.000	6396.674	6396.674
COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS							
CARBON LB/HR	72.297	345.532	0.000	1354.434	0.000	124.908	326.962
HYDROGEN LB/HR	5.340	25.520	0.000	99.870	0.000	9.225	8.913
OXYGEN LB/HR	116.500	556.794	0.000	706.972	983.000	201.277	177.758
NITROGEN LB/HR	2.209	10.556	0.000	34.335	0.000	3.816	4.769
SULFUR LB/HR	1.676	8.009	0.000	47.733	0.000	2.895	11.748
ASH LB/HR	0.000	0.000	0.000	129.472	0.000	0.000	105.028
HEAT CONTENT							
KBTU/HR	886.881	4238.708	0.000	22575.854	105.776	1532.264	4539.267

TABLE 3-12, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE MOD 3A-1

STREAM NO.		15	16	17	18	19		
STREAM DESCRIPTION		LIQUID WATER INJECTION	PRODUCT GAS	C119 COLLEC. & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	0.00	4908.62	1385.30	82.00	5.88	0.00	6.32
TEMPERATURE	F	0.0	1371.0	384.0	239.0	1915.0	0.0	0.0
GAS	LB/HR	0.00	4860.40	1023.30	0.00	0.00	0.00	0.00
SOLIC	LB/HR	0.00	48.22	362.00	82.00	5.88	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		0.000	23.387	24.275	0.000	0.000	0.000	0.000
CO	VOLUME %	0.00	45.46	51.37	0.00	0.00	0.00	0.00
CO2	VOLUME %	0.00	18.61	18.77	0.00	0.00	0.00	0.00
H2	VOLUME %	0.00	21.67	24.51	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.00	3.13	3.53	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	0.85	0.96	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.00	9.68	0.21	0.00	0.00	0.00	0.00
GAS CHARACTERIZATION								
	H2S PPM	0.000	5834.672	6396.674	0.000	0.000	0.000	0.000
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CAREON	LB/HR	0.000	1707.567	608.543	29.389	4.157	0.000	7.305
HYDROGEN	LB/HR	0.000	160.200	28.384	0.041	0.005	0.000	13.689
OXYGEN	LB/HR	0.000	3072.451	601.096	0.000	0.000	0.000	0.091
NITROGEN	LB/HR	0.000	49.770	12.916	0.672	0.080	0.000	0.878
SULFUR	LB/HR	0.000	40.024	18.637	2.714	0.097	0.000	21.562
ASH	LB/HR	0.000	15.946	114.175	49.184	1.541	0.000	22.881
HEAT CONTENT								
	KBTU/HR	0.000	22543.426	8103.442	435.437	62.713	425.000	15.437

TABLE 3-13

GASIFIER HEAT AND MATERIAL BLANCE, TEST TP-032-2, STEADY STATE MOD 3B-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	462.00	0.00	0.00	145.00	350.62	422.40
TEMPERATURE	F	0.0	414.0	0.0	0.0	152.0	188.0	592.0
GAS	LB/HR	0.00	462.00	0.00	0.00	145.00	350.62	422.40
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		0.000	18.016	0.000	0.000	44.011	23.713	23.713
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	52.30	52.30
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	16.94	16.94
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	25.75	25.75
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	3.09	3.09
N2	VOLUME %	0.00	0.00	0.00	0.00	0.00	1.00	1.00
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.00	100.00	0.00	0.00	0.00	0.25	0.25
GAS CHARACTERIZATION								
	H2S PPM	0.000	0.000	0.000	0.000	0.000	6723.253	6723.253
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	0.000	0.000	0.000	0.000	39.572	128.451	154.748
HYDROGEN	LB/HR	0.000	51.698	0.000	0.000	0.000	9.791	11.796
OXYGEN	LB/HR	0.000	410.302	0.000	0.000	105.428	204.459	246.317
NITROGEN	LB/HR	0.000	0.000	0.000	0.000	0.000	4.148	4.998
SULFUR	LB/HR	0.000	0.000	0.000	0.000	0.000	3.188	3.840
ASH	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT								
	KBTU/HR	0.000	70.637	0.000	0.000	2.294	1621.238	2009.084

TABLE 3-13, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE MOD 3B-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	C120 CYCLONE TRANS. G.	C119 FEED & TRANS. G.
TOTAL	LB/HR	184.97	976.40	0.00	2386.43	996.00	454.61	298.17
TEMPERATURE	F	188.0	188.0	0.0	171.0	551.0	188.0	337.0
GAS	LB/HR	184.97	976.40	0.00	918.43	996.00	454.61	298.17
SOLID	LB/HR	0.00	0.00	0.00	1468.00	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		23.713	23.713	0.000	23.713	31.862	23.713	23.713
CO	VOLUME %	52.30	52.30	0.00	52.30	0.00	52.30	52.30
CO2	VOLUME %	16.94	16.94	0.00	16.94	0.00	16.94	16.94
H2	VOLUME %	25.75	25.75	0.00	25.75	0.00	25.75	25.75
CH4	VOLUME %	3.09	3.09	0.00	3.09	0.00	3.09	3.09
N2	VOLUME %	1.00	1.00	0.00	1.00	0.00	1.00	1.00
O2	VOLUME %	0.00	0.00	0.00	0.00	99.57	0.00	0.00
H2O	VOLUME %	0.25	0.25	0.00	0.25	0.00	0.25	0.25
GAS CHARACTERIZATION								
	H2S PPM	6723.253	6723.253	0.000	6723.253	0.000	6723.253	6723.253
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	67.766	357.708	0.000	1381.244	0.000	166.548	109.234
HYDROGEN	LB/HR	5.166	27.267	0.000	98.167	0.000	12.695	8.327
OXYGEN	LB/HR	107.864	569.374	0.000	700.716	996.000	265.100	173.871
NITROGEN	LB/HR	2.189	11.552	0.000	34.501	0.000	5.379	3.528
SULFUR	LB/HR	1.682	3.376	0.000	47.692	0.000	4.133	2.711
ASH	LB/HR	0.000	0.000	0.000	122.578	0.000	0.000	0.000
HEAT CONTENT								
	KBTU/HR	855.299	4514.788	0.000	22894.943	117.411	2102.079	1392.922

TABLE 3-13, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE MOD 3B-1

STREAM NO.	15	16	17	18	19		
STREAM DESCRIPTION	LIQUID WATER INJECTION	PRODUCT GAS	C119 COLLEC. & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL LB/HR	0.00	5014.06	1447.77	61.00	6.00	0.00	2.21
TEMPERATURE F	0.0	1378.0	341.0	248.0	1943.0	0.0	0.0
GAS LB/HR	0.00	5007.21	1133.77	0.00	0.00	0.00	0.00
SOLID LB/HR	0.00	6.85	314.00	61.00	6.00	0.00	0.00
LIQUID LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT	0.000	23.103	23.713	0.000	0.000	0.000	0.000
CO VOLUME %	0.00	47.11	52.30	0.00	0.00	0.00	0.00
CO2 VOLUME %	0.00	17.44	16.94	0.00	0.00	0.00	0.00
H2 VOLUME %	0.00	23.14	25.75	0.00	0.00	0.00	0.00
CH4 VOLUME %	0.00	2.86	3.09	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	0.89	1.00	0.00	0.00	0.00	0.00
O2 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O VOLUME %	0.00	7.93	0.25	0.00	0.00	0.00	0.00
GAS CHARACTERIZATION							
H2S PPM	0.000	6223.932	6723.253	0.000	0.000	0.000	0.000
COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS							
CARBON LB/HR	0.000	1759.150	625.928	34.965	4.311	0.000	-0.793
HYDROGEN LB/HR	0.000	163.521	32.101	0.049	0.007	0.000	12.996
OXYGEN LB/HR	0.000	3118.110	661.139	0.000	0.022	0.000	0.004
NITROGEN LB/HR	0.000	54.350	14.796	0.250	0.037	0.000	-4.734
SULFUR LB/HR	0.000	43.422	17.561	1.305	0.091	0.000	13.508
ASH LB/HR	0.000	2.226	94.388	24.431	1.532	0.000	0.000
HEAT CONTENT KBTU/HR	0.000	23717.100	8360.936	506.894	64.990	425.000	7.016

TABLE 3-14

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE MOD 3B-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	462.00	0.00	0.00	149.00	355.77	427.48
TEMPERATURE	F	0.0	417.0	0.0	0.0	149.0	183.0	592.0
GAS	LB/HR	0.00	462.00	0.00	0.00	149.00	355.77	427.48
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		0.000	18.016	0.000	0.000	44.011	24.286	24.286
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	52.05	52.05
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	18.56	18.56
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	24.59	24.59
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	2.96	2.96
N2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.97	0.97
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.00	100.00	0.00	0.00	0.00	0.22	0.22
GAS CHARACTERIZATION								
	H2S PPM	0.000	0.000	0.000	0.000	0.000	6425.546	6425.546
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	0.000	0.000	0.000	0.000	40.663	129.444	155.536
HYDROGEN	LB/HR	0.000	51.698	0.000	0.000	0.000	9.267	11.135
OXYGEN	LB/HR	0.000	410.302	0.000	0.000	108.337	209.523	251.756
NITROGEN	LB/HR	0.000	0.000	0.000	0.000	0.000	3.963	4.762
SULFUR	LB/HR	0.000	0.000	0.000	0.000	0.000	3.018	3.626
ASH	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT								
	KBTU/HR	0.000	71.287	0.000	0.000	2.261	1572.070	1945.234

TABLE 3-14, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE MOD 3B-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	C120 CYCLONE TRANS. G.	C119 FEED & TRANS. G.
TOTAL	LB/HR	188.13	1001.18	0.00	2430.96	1012.00	339.00	614.61
TEMPERATURE	F	183.0	183.0	0.0	162.0	551.0	183.0	286.0
GAS	LB/HR	188.13	1001.18	0.00	976.96	1012.00	339.00	303.61
SOLID	LB/HR	0.00	0.00	0.00	1454.00	0.00	0.00	311.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		24.286	24.286	0.000	24.286	31.862	24.286	24.286
CO	VOLUME %	52.05	52.05	0.00	52.05	0.00	52.05	52.05
CO2	VOLUME %	18.56	18.56	0.00	18.56	0.00	18.56	18.56
H2	VOLUME %	24.59	24.59	0.00	24.59	0.00	24.59	24.59
CH4	VOLUME %	2.96	2.96	0.00	2.96	0.00	2.96	2.96
N2	VOLUME %	0.97	0.97	0.00	0.97	0.00	0.97	0.97
O2	VOLUME %	0.00	0.00	0.00	0.00	99.57	0.00	0.00
H2O	VOLUME %	0.22	0.22	0.00	0.22	0.00	0.22	0.22
GAS CHARACTERIZATION								
	H2S PPM	6425.546	6425.546	0.000	6425.546	0.000	6425.546	6425.546
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	68.449	364.272	0.000	1390.273	0.000	123.344	315.323
HYDROGEN	LB/HR	4.900	26.078	0.000	97.275	0.000	8.830	8.281
OXYGEN	LB/HR	110.795	589.625	0.000	738.940	1012.000	199.650	178.807
NITROGEN	LB/HR	2.096	11.154	0.000	34.293	0.000	3.777	4.595
SULFUR	LB/HR	1.596	8.493	0.000	47.255	0.000	2.876	10.288
ASH	LB/HR	0.000	0.000	0.000	121.409	0.000	0.000	96.876
HEAT CONTENT								
	KBTU/HR	831.304	4424.020	0.000	22783.484	109.137	1497.994	4327.989

TABLE 3-14, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE MOD 3B-2

STREAM NO.		15	16	17	18	19		
STREAM DESCRIPTION		LIQUID WATER INJECTION	PRODUCT GAS	C119 COLLEC. & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	0.00	5831.41	1343.09	68.00	5.33	0.00	-3.34
TEMPERATURE	F	0.0	1375.0	340.0	263.0	1928.0	0.0	0.0
GAS	LB/HR	0.00	5563.04	1043.09	0.00	0.00	0.00	0.00
SOLID	LB/HR	0.00	268.37	300.00	68.00	5.33	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		0.000	23.471	24.286	0.000	0.000	0.000	0.000
CO	VOLUME %	0.00	47.44	52.05	0.00	0.00	0.00	0.00
CO2	VOLUME %	0.00	18.17	18.56	0.00	0.00	0.00	0.00
H2	VOLUME %	0.00	22.45	24.59	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.00	2.76	2.96	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	0.88	0.97	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.00	7.69	0.22	0.00	0.00	0.00	0.00
GAS CHARACTERIZATION								
	H2S PPM	0.000	6046.305	6425.546	0.000	0.000	0.000	0.000
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	0.000	2111.866	577.130	37.652	3.754	0.000	-5.531
HYDROGEN	LB/HR	0.000	173.686	27.529	0.136	0.004	0.000	7.407
OXYGEN	LB/HR	0.000	3468.876	614.307	0.129	0.074	0.000	-7.183
NITROGEN	LB/HR	0.000	59.132	12.791	0.279	0.027	0.000	-11.738
SULFUR	LB/HR	0.000	53.760	16.289	1.469	0.082	0.000	7.198
ASH	LB/HR	0.000	95.110	93.450	28.336	1.389	0.000	0.000
HEAT CONTENT								
	KBTU/HR	0.000	28152.102	7535.333	551.076	56.211	425.000	2.250

TABLE 3-15

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE MOD 3B-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	455.00	0.00	0.00	164.00	361.90	431.46
TEMPERATURE	F	0.0	414.0	0.0	0.0	146.0	176.0	592.0
GAS	LB/HR	0.00	455.00	0.00	0.00	164.00	361.90	431.46
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		0.000	18.016	0.000	0.000	44.011	24.741	24.741
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	51.94	51.94
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	19.71	19.71
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	23.51	23.51
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	3.07	3.07
N2	VOLUME %	0.00	0.00	0.00	0.00	0.00	1.03	1.03
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.00	100.00	0.00	0.00	0.00	0.15	0.15
GAS CHARACTERIZATION								
	H2S PPM	0.000	0.000	0.000	0.000	0.000	5871.137	5871.137
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	0.000	0.000	0.000	0.000	44.757	131.290	156.525
HYDROGEN	LB/HR	0.000	50.915	0.000	0.000	0.000	8.963	10.686
OXYGEN	LB/HR	0.000	404.085	0.000	0.000	119.243	214.180	255.348
NITROGEN	LB/HR	0.000	0.000	0.000	0.000	0.000	4.210	5.020
SULFUR	LB/HR	0.000	0.000	0.000	0.000	0.000	2.754	3.283
ASH	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT								
	KBTU/HR	0.000	69.566	0.000	0.000	2.384	1552.101	1907.410

TABLE 3-15, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE MOD 3B-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.	OXYGEN TO TUBE	C120 CYCLONE TRANS. G.	C119 FEED & TRANS. G.
TOTAL	LB/HR	190.82	1101.68	0.00	2226.84	927.00	344.98	361.90
TEMPERATURE	F	176.0	176.0	0.0	173.0	551.0	176.0	328.0
GAS	LB/HR	190.82	1101.68	0.00	879.84	927.00	344.98	361.90
SOLID	LB/HR	0.00	0.00	0.00	1347.00	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		24.741	24.741	0.000	24.741	31.862	24.741	24.741
CO	VOLUME %	51.94	51.94	0.00	51.94	0.00	51.94	51.94
CO2	VOLUME %	19.71	19.71	0.00	19.71	0.00	19.71	19.71
H2	VOLUME %	23.51	23.51	0.00	23.51	0.00	23.51	23.51
CH4	VOLUME %	3.07	3.07	0.00	3.07	0.00	3.07	3.07
N2	VOLUME %	1.03	1.03	0.00	1.03	0.00	1.03	1.03
O2	VOLUME %	0.00	0.00	0.00	0.00	99.57	0.00	0.00
H2O	VOLUME %	0.15	0.15	0.00	0.15	0.00	0.15	0.15
GAS CHARACTERIZATION								
	H2S PPM	5871.137	5871.137	0.000	5871.137	0.000	5871.137	5871.137
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CAREON	LB/HR	69.226	399.667	0.000	1281.000	0.000	125.152	131.290
HYDROGEN	LB/HR	4.726	27.286	0.000	88.198	0.000	8.544	8.963
OXYGEN	LB/HR	112.932	651.999	0.000	669.956	927.000	204.167	214.180
NITROGEN	LB/HR	2.220	12.817	0.000	30.980	0.000	4.013	4.210
SULFUR	LB/HR	1.452	8.383	0.000	43.468	0.000	2.625	2.754
ASH	LB/HR	0.000	0.000	0.000	111.936	0.000	0.000	0.000
HEAT CONTENT								
	KBTU/HR	818.381	4724.837	0.000	20945.957	99.970	1479.535	1569.127

TABLE 3-15, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE MOD 3B-3

STREAM NO.		15	16	17	18	19		
STREAM DESCRIPTION		LIQJID WATER INJECTION	PRODUCT GAS	C119 COLLEC. & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	0.00	5552.14	814.04	64.00	6.00	0.00	1.97
TEMPERATURE	F	0.0	1309.0	171.0	280.0	1892.0	0.0	0.0
GAS	LB/HR	0.00	5313.02	814.04	0.00	0.00	0.00	0.00
SOLID	LB/HR	0.00	239.12	0.00	64.00	6.00	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		0.000	23.582	24.741	0.000	0.000	0.000	0.000
CO	VOLUME %	0.00	48.50	51.94	0.00	0.00	0.00	0.00
CO2	VOLUME %	0.00	17.86	19.71	0.00	0.00	0.00	0.00
H2	VOLUME %	0.00	22.07	23.51	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.00	2.94	3.07	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	0.95	1.03	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.00	7.07	0.15	0.00	0.00	0.00	0.00
GAS CHARACTERIZATION								
	H2S PPM	0.000	5696.609	5871.137	0.000	0.000	0.000	0.000
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	0.000	2020.649	295.317	25.754	4.245	0.000	-0.298
HYDROGEN	LB/HR	0.000	162.150	20.162	0.058	0.005	0.000	12.439
OXYGEN	LB/HR	0.000	3291.280	481.767	0.000	0.040	0.000	0.000
NITROGEN	LB/HR	0.000	61.431	9.470	0.205	0.030	0.000	-12.079
SULFUR	LB/HR	0.000	48.612	6.194	1.523	0.088	0.000	12.825
ASH	LB/HR	0.000	85.103	0.000	36.467	1.592	0.000	-10.030
HEAT CONTENT								
	KBTU/HR	0.000	26768.615	3489.981	378.720	63.678	425.000	6.160

TABLE 3-16

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE MOD 3B-4

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	466.00	0.00	0.30	142.00	354.73	426.23
TEMPERATURE	F	0.0	416.0	0.0	0.0	148.0	183.0	592.0
GAS	LB/HR	0.00	466.00	0.00	0.30	142.00	354.73	426.23
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		0.000	18.016	0.000	0.000	44.011	24.145	24.145
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	53.09	53.09
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	17.63	17.63
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	24.70	24.70
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	2.67	2.67
N2	VOLUME %	0.00	0.00	0.00	0.00	0.00	1.05	1.05
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.00	100.00	0.00	0.00	0.00	0.17	0.17
GAS CHARACTERIZATION								
	H2S PPM	0.000	0.000	0.000	0.000	0.000	6488.702	6488.702
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	0.000	0.000	0.000	0.000	38.753	129.520	155.627
HYDROGEN	LB/HR	0.000	52.146	0.000	0.000	0.000	9.140	10.983
OXYGEN	LB/HR	0.000	413.854	0.000	0.000	103.247	208.114	250.064
NITROGEN	LB/HR	0.000	0.000	0.000	0.000	0.000	4.339	5.213
SULFUR	LB/HR	0.000	0.000	0.000	0.000	0.000	3.057	3.673
ASH	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT								
	KETU/HR	0.000	71.686	0.000	0.030	2.125	1581.100	1955.931

TABLE 3-16, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE MOD 3B-4

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	C120 CYCLONE TRANS. G.	C119 FEED & TRANS. G.
TOTAL	LB/HR	187.58	1068.83	0.00	2196.18	955.00	338.01	338.01
TEMPERATURE	F	183.0	183.0	0.0	180.0	550.0	183.0	356.0
GAS	LB/HR	187.58	1068.83	0.00	856.18	955.00	338.01	338.01
SOLID	LB/HR	0.00	0.00	0.00	1340.00	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		24.145	24.145	0.000	24.145	31.862	24.145	24.145
CO	VOLUME %	53.09	53.09	0.00	53.09	0.00	53.09	53.09
CO2	VOLUME %	17.63	17.63	0.00	17.63	0.00	17.63	17.63
H2	VOLUME %	24.70	24.70	0.00	24.70	0.00	24.70	24.70
CH4	VOLUME %	2.67	2.67	0.00	2.67	0.00	2.67	2.67
N2	VOLUME %	1.05	1.05	0.00	1.05	0.00	1.05	1.05
O2	VOLUME %	0.00	0.00	0.00	0.00	99.57	0.00	0.00
H2O	VOLUME %	0.17	0.17	0.00	0.17	0.00	0.17	0.17
GAS CHARACTERIZATION								
	H2S PPM	6488.702	6488.702	0.000	6488.702	0.000	6488.702	6488.702
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	68.490	390.255	0.000	1282.771	0.000	123.417	123.417
HYDROGEN	LB/HR	4.833	27.541	0.000	72.847	0.000	8.710	8.710
OXYGEN	LB/HR	110.050	627.067	0.000	635.905	955.000	198.308	198.308
NITROGEN	LB/HR	2.294	13.073	0.000	28.160	0.000	4.134	4.134
SULFUR	LB/HR	1.616	9.210	0.000	41.548	0.000	2.913	2.913
ASH	LB/HR	0.000	0.000	0.000	133.598	0.000	0.000	0.000
HEAT CONTENT								
	KBTU/HR	836.079	4763.997	0.000	20197.559	102.763	1506.598	1525.028

TABLE 3-16, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE MOD 3B-4

STREAM NO.		15	16	17	18	19		
STREAM DESCRIPTION		LIQUID WATER INJECTION	PRODUCT GAS	C119 COLLEC. & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	0.00	5283.70	935.11	45.00	6.00	0.00	3.13
TEMPERATURE	F	0.0	1322.0	193.0	273.0	1910.0	0.0	0.0
GAS	LB/HR	0.00	5112.50	935.11	0.00	0.00	0.00	0.00
SOLID	LB/HR	0.00	171.20	0.00	45.00	6.00	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		0.000	23.167	24.145	0.300	0.000	0.000	0.000
CO	VOLUME %	0.00	49.53	53.09	0.30	0.00	0.00	0.00
CO2	VOLUME %	0.00	16.46	17.63	0.30	0.00	0.00	0.00
H2	VOLUME %	0.00	23.13	24.70	0.30	0.00	0.00	0.00
CH4	VOLUME %	0.00	2.51	2.67	0.30	0.00	0.00	0.00
N2	VOLUME %	0.00	0.96	1.05	0.30	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.30	0.00	0.00	0.00
H2O	VOLUME %	0.00	6.79	0.17	0.30	0.00	0.00	0.00
GAS CHARACTERIZATION								
	H2S PPM	0.000	6338.280	6488.702	0.300	0.000	0.000	0.000
	COS PPM	0.000	0.000	0.000	0.300	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/-R	0.000	1934.199	341.431	25.556	4.316	0.000	0.292
HYDROGEN	LB/-R	0.000	158.573	24.095	0.368	0.006	0.000	6.243
OXYGEN	LB/-R	0.000	3151.234	548.615	0.300	0.069	0.000	-0.000
NITROGEN	LB/-R	0.000	60.633	11.437	0.229	0.025	0.000	-17.895
SULFUR	LB/-R	0.000	48.923	8.058	0.382	0.088	0.000	10.746
ASH	LB/-R	0.000	47.559	0.000	18.270	1.496	0.000	49.606
HEAT CONTENT								
	KETU/HR	0.000	26075.025	4170.880	372.420	64.640	425.000	4.409

TABLE 3-17

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE MOD 3C-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	516.00	0.00	0.00	149.00	361.27	529.62
TEMPERATURE	F	0.0	487.0	0.0	0.0	149.0	184.0	592.0
GAS	LB/HR	0.00	516.00	0.00	0.00	149.00	361.27	529.62
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		0.000	18.016	0.000	0.000	44.011	25.044	25.044
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	50.80	50.80
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	21.16	21.16
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	22.78	22.78
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	3.05	3.05
N2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.95	0.95
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.00	100.00	0.00	0.00	0.00	0.23	0.23
GAS CHARACTERIZATION								
	H2S PPM	0.000	0.000	0.000	0.000	0.000	6185.566	6185.566
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	0.000	0.000	0.000	0.000	40.663	129.959	190.516
HYDROGEN	LB/HR	0.000	57.741	0.000	0.000	0.000	8.643	12.671
OXYGEN	LB/HR	0.000	458.259	0.000	0.000	108.337	215.458	315.855
NITROGEN	LB/HR	0.000	0.000	0.000	0.000	0.000	3.830	5.615
SULFUR	LB/HR	0.000	0.000	0.000	0.000	0.000	2.861	4.194
ASH	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT								
	KBTU/HR	0.000	96.692	0.000	0.000	2.261	1498.053	2264.085

TABLE 3-17, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE MOD 3C-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	C120 CYCLONE TRANS. G.	C119 FEED & TRANS. G.
TOTAL LB/HR	191.04	921.16	0.00	2506.11	1102.00	344.25	867.70
TEMPERATURE F	184.0	184.0	0.0	159.0	551.0	184.0	276.0
GAS LB/HR	191.04	921.16	0.00	1009.11	1102.00	344.25	510.70
SOLID LB/HR	0.00	0.00	0.00	1497.00	0.00	0.00	357.00
LIQUID LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT	25.044	25.044	0.000	25.044	31.862	25.044	25.044
CO VOLUME %	50.80	50.80	0.00	50.80	0.00	50.80	50.80
CO2 VOLUME %	21.16	21.16	0.00	21.16	0.00	21.16	21.16
H2 VOLUME %	22.78	22.78	0.00	22.78	0.00	22.78	22.78
CH4 VOLUME %	3.05	3.05	0.00	3.05	0.00	3.05	3.05
N2 VOLUME %	0.95	0.95	0.00	0.95	0.00	0.95	0.95
O2 VOLUME %	0.00	0.00	0.00	0.00	99.57	0.00	0.00
H2O VOLUME %	0.23	0.23	0.00	0.23	0.00	0.23	0.23
GAS CHARACTERIZATION							
H2S PPM	6185.566	6185.566	0.000	6185.566	0.000	6185.566	6185.566
COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS							
CARBON LB/HR	68.722	331.361	0.000	1446.828	0.000	123.835	422.580
HYDROGEN LB/HR	4.570	22.038	0.000	80.878	0.000	8.236	12.825
OXYGEN LB/HR	113.933	549.362	0.000	751.067	1102.000	205.306	304.574
NITROGEN LB/HR	2.025	9.766	0.000	30.459	0.000	3.650	7.556
SULFUR LB/HR	1.513	7.295	0.000	46.165	0.000	2.726	13.648
ASH LB/HR	0.000	0.000	0.000	149.251	0.000	0.000	105.779
HEAT CONTENT							
KBTU/HR	792.164	3819.644	0.000	22472.426	118.843	1427.464	5616.010

TABLE 3-17, Continued

GASIFIER HEAT AND MATERIAL BALANCE, TEST TP-032-2, STEADY STATE MOD 3C-1

STREAM NO.		15	16	17	18	19		
STREAM DESCRIPTION		LIQUID WATER INJECTION	PRODUCT GAS	C119 COLLEC. & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	0.00	5875.11	1248.67	61.00	6.00	0.00	3.97
TEMPERATURE	F	0.0	1387.0	369.0	283.0	1881.0	0.0	0.0
GAS	LB/HR	0.00	5715.11	929.67	0.00	0.00	0.00	0.00
SOLID	LB/HR	0.00	160.00	319.00	61.00	6.00	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		0.000	24.149	25.044	0.000	0.000	0.000	0.000
CO	VOLUME %	0.00	47.16	50.80	0.00	0.00	0.00	0.00
CO2	VOLUME %	0.00	19.73	21.16	0.00	0.00	0.00	0.00
H2	VOLUME %	0.00	20.88	22.78	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.00	3.07	3.05	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	0.85	0.95	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.00	7.66	0.23	0.00	0.00	0.00	0.00
GAS CHARACTERIZATION								
	H2S PPM	0.000	6214.482	6185.566	0.000	0.000	0.000	0.000
	COS PPM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ELEMENTS								
CARBON	LB/HR	0.000	2099.612	547.866	31.354	4.418	0.000	2.585
HYDROGEN	LB/HR	0.000	168.846	22.784	0.091	0.009	0.000	7.645
OXYGEN	LB/HR	0.000	3569.681	554.438	0.000	0.030	0.000	0.000
NITROGEN	LB/HR	0.000	57.127	11.770	0.293	0.043	0.000	-10.066
SULFUR	LB/HR	0.000	50.132	15.943	1.403	0.089	0.000	13.818
ASH	LB/HR	0.000	45.376	94.520	27.859	1.411	0.000	33.669
HEAT CONTENT								
	KBTU/HR	0.000	27088.316	7027.149	459.438	66.424	425.000	7.981

SECTION 4.0

PROCESS ANALYSIS

4.1 AUTO-CONTROLLED TRANSIENT RESPONSE

During the transition from steady state 3 to 3A of PDU test TP-032-2, a transient was imposed on the gasifier with three automatic control loops operational. The purpose of this test was to observe how fast the gasifier could respond when certain critical parameters are controlled in concert. The controlled parameters were: a) fluidized bed level; b) freeboard temperature; and c) ash annulus level. The manipulated variables used to control these parameters are coal feed rate, oxygen feed rate, and the ash withdrawal rate, respectively.

The transient was implemented by changing the set point on the temperature indicating controller from 1820°F to 1860°F. The immediate response was an increase in oxygen flow. As bed carbon was being consumed at an accelerated rate by combustion or gasification, the coal feed rate was increased to maintain the bed level. The ash withdrawal rate was automatically adjusted to accommodate the increased carbon and ash throughput.

Figures 4-1 through 4-5 illustrate the controlled response of the gasifier to the imposed transient. Table 4-1 summarizes the results of the test.

The major highlight of the test was that net calorific heat production increased at a rate of 8 percent per minute. The total load change was observed to be 37 percent. Further testing is required to assess the sensitivity of transient response characteristics to gasifier initial conditions and feedstock properties.

4.2 FULL CYCLONE COLD WALL

TP-032-1 served as a shakedown test for the full cyclone cold wall using highly fouling Indiana No. 7 and Upper Freeport coal as the feedstocks. The amount of cooling water flow was adjusted to achieve a gas-side metal wall temperature of not greater than 400°F. This resulted in a product gas temperature drop of ~450°F. A total of 111 hours of hot coal feed were accumulated on the cold wall in this test. These hours were not, however, accumulated continuously, since two intermediate shutdowns were necessitated by unrelated problems.

TP-032-2 continued the demonstration of the full cyclone cold wall using Upper Freeport coal, again along with an equally fouling Western Kentucky No. 9 coal. During this run, cooling water flow was adjusted to achieve gas-side metal wall temperatures of no greater than 700°F. A total of 150 hours of hot coal feed hours were accumulated on the cold wall, of which 96.5 hours were continuous. No deposits were found upon visual inspection after shutdown. The absence of deposition the cooled metal surfaces of the cyclone barrel and inlet spools demonstrated the technical viability of this technique as a means of controlling deposit formation.

Figure 4-1. Temperature Ramp to New Set Point

Figure 4-2. Coal Feed Response to Transient

Figure 4-3. Input/Output Process Flow Response to Transient

Figure 4-4. Bed Height During Transient

Figure 4-5. Product Gas Composition (Dry Basis) Response to Transient W. Kentucky

TABLE 4-1

SUMMARY OF CLOSED LOOP TRANSIENT RESPONSE
OF PDU WITH WESTERN KENTUCKY COAL, TEST TP-032-2

Freeboard temperature, °F/min (°F)	5.65	(1816 - 1858)
Oxygen flow rate, %/min (lb/hr)	3.85	(766 - 1000)
Coal feed rate, %/min (lb/hr)	1.14	(1066 - 1250)
Gross product gas flow rate, %/min (lb/hr)	1.82	(4933 - 5600)
Net production		
CO, %/min (mole/hour)	7.41	(37.95 - 58.86)
H ₂ , %/min (mole/hour)	8.07	(16.49 - 26.39)
CH ₄ , %/min (mole/hour)	7.98	(2.9 - 4.62)
Net Heat Production, %/min (Btu/hr)	8.00	(3.54 x 10 ⁶ - 5.64 x 10 ⁶)

4.3 ENVIRONMENTAL DATA

During TP-032-1 samples of product gas were passed through four different scrubbing solutions: methylene chloride, dilute sulfuric acid solution, dilute sodium hydroxide solution, and distilled water. The methylene chloride scrubbing solution was analyzed for 78 EPA-priority organic pollutants. All pollutants were below detection limit, indicating their nonexistence in the product gas. Table 4-2 lists the analyses sought from the remaining scrubbing solutions.

Chemical analysis of the samples has been completed. The results are being examined for measurement inaccuracies and internal consistency. The final results from the environmental sampling campaign will be reported in the next quarterly progress report.

4.4 FINES RECYCLE

Three steady state test periods during PDU test TP-032-1 yielded fines elutriation data using Upper Freeport coal in the non-recycle mode. Table 4-3 reports the relative carry-over rates obtained, expressed as fines carry-over/load (lb/lb), and the superficial freeboard velocities. The variation of fines elutriation with freeboard velocity can be discerned from this data; fines carry-over is seen to vary with the 2.5 power of velocity. Analysis of per pass consumption data from TP-032-1 and 032-2 is under way and results will be reported in the next quarterly progress report.

TABLE 4-2

MINISCRUBBER SOLVENTS AND WATER QUALITY PARAMETERS

<u>Sulfuric Acid Solution</u>	<u>Sodium Hydroxide Solution</u>	<u>Distilled Water</u>
Hardness	Cyanide	BOD
COD	Sulfate	Alkalinity
Ammonia	Sulfite	pH
Alkali	Sulfide	Dissolved solids
Organic nitrogen	Thiosulfate	Heavy metals
T.O.C.		
Thiocyanate		

Methylene Chloride

Volatiles (benzene, toluene)

Acid fraction (phenol)

Base/neutral fraction (anthracene, fluorene)

Others (alcohols, alkanes)

Trace priority pollutants as listed in Federal Register (December 1979)

TABLE 4-3
ELUTRIATION DATA, TEST TP-032-1
(No Recycle of Fines)

<u>Closure Steady State</u>	<u>Freeboard Velocity (fps)</u>	<u>Coal Feed Rate (lb/hr)</u>	<u>Fines Carry-over* (lb/lb coal feed)</u>	<u>Carbon Balance (in-out/in) * 100</u>
1A-1	1.01	1170	.157	3.7
1B-1	1.22	1150	.293	3.5
1B-2	1.34	1330	.353	-1.7

* Determined by forced ash balance.

SECTION 5.0

COLD FLOW SCALEUP FACILITY

5.1 EXPERIMENTAL ACTIVITY - TEST TP-M004

TP-M004, a CO₂ tracer gas test with the 16-inch diameter single air tube, was conducted in the CFSF from March 29 to May 21, 1982. The objective of this test was to measure the gas exchange between different regions of the bed. During the test, CO₂ was injected individually into the solids feed line and the air tube. Gas samples were taken at different locations within the model with traversing sampling probes to map the CO₂ concentration and thereby determine gas history/mixing.

Test instrumentation included specially designed CO₂ probes, shown in Figure 5-1, made from heavy wall 0.75-inch tubing with a 200-mesh screen placed on one end to prevent the bed material from migrating to the gas analyzer. The CO₂ concentrations were measured by a thermal conductivity cell (GOW MAC "Gas Master" Model 20-150) gas analyzer and recorded on a chart recorder. A typical CO₂ trace is shown in Figure 5-2.

Upon completion of the test on May 21, approximately one-fourth of the planned set points were achieved, with sufficient data obtained to determine the gas mixing through the bed with CO₂ injected into the coaxial feed line. These data included CO₂ measurements at eight set points, six probe elevations, and two grid locations. CO₂ concentration was measured at approximately 2-inch intervals across the CFSF bed diameter for each of the above conditions, and 1140 data points were obtained.

Another series of data, although not as extensive as above, was obtained with the CO₂ injected into the air tube.

Set point flow parameters for this test are summarized in Table 5-1. During this test series, the air tube height was maintained at the bottom of the conical grid, and aeration through the conical grid was restricted to the top section (see Figure 5-3).

5.2 DATA ANALYSIS

5.2.1 TEST TP-M002

Data analysis of test TP-M002-2 was completed and the conclusions are summarized here. The jet penetration depth data from TP-M002-2 are predictable within +25 percent by employing the equation developed. The results are presented in Table 5-2. There is conclusive experimental evidence showing that substantial amounts of gas leak from the bubble to the emulsion phase during bubble formation, as shown in Figure 5-4. This is especially true when the bed is less than minimally fluidized.

Figure 5-1. CO₂ Probe Assembly

Figure 5-2. GOW MAC CO₂ Trace*

* Set Point 3, Location 2, 5/5/82 - Tracer Injection Into Coaxial Feed Line

TABLE 5-1
NOMINAL PLANNED CONDITIONS, TEST TP-M004

Set Point	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>
Air Tube Velocity (ft/sec)	50	50	50	75	75	75	75	75
Annulus Velocity (ft/sec)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Grid Flow (scfm)	1100	1100	1100	1100	1100	1100	2000	2000
Solid Transport Velocity (ft/sec)	40	30	30	40	30	30	30	30
Solids Feed Rate (lb/hr)	0	3000	6000	0	3000	6000	0	3000
Bed Height (ft)	18	18	18	18	18	18	18	18

Figure 5-3. Schematic of the CFSF

TABLE 5-2

COMPARISON OF CALCULATED AND EXPERIMENTAL JET PENETRATION DEPTH
TEST TP-M002-2

<u>Set Point</u>	<u>Min.</u>	<u>Experiments (m)</u>		<u>Calculated (m) Based on Yang (1981)</u>
		<u>Most Frequent</u>	<u>Max.</u>	
1	0.15	1.52	1.98	1.16
2	0.15	1.52	1.98	1.36
3	0.30	1.52	1.83	1.74
4	0.15	1.68	1.98	1.19
5	0.30	1.83	2.44	1.39
6	0.61	1.52	>1.83	1.57
7	0.15	1.22	1.68	1.16
*8	0.15	1.37	1.83	1.42
*9	0.15	1.37	1.83	1.60
*10	0.15	1.83	--	1.76
11	0.15	1.68	--	1.92
12	0.15	1.52	--	1.77
13	0.15	1.52	--	1.85
14	0.15	1.68	2.13	1.72
15	0.15	1.52	>1.83	1.92
*16	0.15	>1.83	--	2.38
*22	0.91<	1.37	--	1.48
*23	0.91<	2.13	--	1.84
*24	0.91<	1.98	--	1.45
*26	0.61<	1.22	--	1.20
*27	0.61<	1.68	--	1.38
*28	0.61<	1.68	--	1.76

* Lower bed height less than 4.9 m (16 ft); bed height measured from the bottom flange of the model.

Figure 5-4. Experimental Data on Gas Leakage from the Bubble to the Emulsion Phase

A model was also developed to describe this gas leakage phenomenon from the bubble by assuming that the gas leaks out through the bubble boundary at a superficial velocity equivalent to the superficial minimum fluidization velocity. For a semi-spherical bubble, the rate of change of bubble volume can be expressed as:

$$\frac{dV_B}{dt} = G - U_{mf} \frac{\pi D_B^2}{2}, \quad (1)$$

where for a semi-spherical bubble.

Equation (1) can be reduced, after a few mathematical manipulations, to show the changes of bubble diameter with respect to time in equation (2):

$$\frac{D_B^2 dD_B}{(4G - 2\pi U_{mf} D_B^2)} = \frac{dt}{\pi} \quad (2)$$

Integrating equation (2) with the boundary condition that $D_B = 0$ at $t = 0$ gives

$$t = \frac{1}{2U_{mf}} \frac{G}{\sqrt{2\pi GU_{mf}}} \ln \left(\frac{2G + D_B \sqrt{2\pi GU_{mf}}}{2G - D_B \sqrt{2\pi GU_{mf}}} \right) - D_B \quad (3)$$

The maximum bubble size, where the total gas leakage through the bubble boundary is equal to the total jet flow, can be obtained from either equation (1) or equation (3) to be:

$$(D_B)_{\max} = \sqrt{\frac{2G}{\pi U_{mf}}} \quad (4)$$

The total amount of gas leaks out of the bubble at a bubble size D_B can be found from:

$$\begin{aligned} dF &= U_{mf} \frac{\pi D_B^2}{2} dt \\ &= \frac{\pi^2 U_{mf}}{2} \frac{D_B^4 dD_B}{(4G - 2\pi U_{mf} D_B^2)} \end{aligned} \quad (5)$$

Integration of equation (5) with the boundary condition that $D_B = 0$ at $t = 0$, results in:

$$F = \frac{G}{2U_{mf}} \frac{G}{\sqrt{2\pi GU_{mf}}} \ln \left(\frac{2G + D_B \sqrt{2\pi GU_{mf}}}{2G - D_B \sqrt{2\pi GU_{mf}}} \right) - D_B - \frac{\pi D_B^2}{12} \quad (6)$$

Equation (3) and the experimental bubble frequency, $n = 1/t$, were used to predict the expected bubble diameter for all set points. They are reported in Table 5-3. The predicted bubble diameters are very close to those actually observed except for set points 26 and 28, where the grid flow was supplied solely from the topmost section of the conical grid. Whether the bubble formation in points 26 and 28 involves a completely separate mechanism will be evaluated when more data are available. The maximum bubble size attainable under the postulated bubble formation mechanism as expressed in equation (4) was also calculated for each set point (Table 5-3). The experimentally observed bubble diameter approaches that calculated from equation (4). Equations (3) and (4) were also used to calculate the expected bubble sizes and the maximum bubble sizes attainable under the operating conditions of test TP-M002-1. They are compared with the experimentally observed bubble sizes in Table 5-4. Interestingly, the bubbles attained essentially their maximum bubble sizes in test TP-M002-1, where there was no flow supplied to the char-ash separator annulus and large leakage of gas from the bubble to the emulsion phase was possible, as shown in Figure 5-4.

Theoretically, equations (3) and (6) can be solved to obtain both the bubble frequency and the bubble diameter if the total gas leakage at the moment of bubble detachment, F , is known. The only correlations available now to predict F are the empirical ones shown in Figure 5-4. If there is no net gas leakage, i.e., $F = 0$, equation (6) reduces to the Davidson and Harrison equation (1963), if it is assumed the fluidized bed is an inviscid liquid.

The experimentally observed bubble frequency is smaller by a factor of 3 to 5 than that predicted from the Davidson and Harrison model (1963), if no net gas interchange of the bubble and the emulsion phase is assumed. Part of this discrepancy is a result of the extensive bubble coalescence above the jet nozzle, but the major factor is the assumption that no gas leaks from the bubble phase. The assumption of no net gas leakage has been questioned even when the fluidized bed is fluidized above the minimum fluidization (Nguyen and Leung, 1972).

5.2.2 TEST TP-M003

Data obtained from frame-by-frame analysis of films from tests TP-M003-1 and TP-M003-2 are reported in Tables 5-5 and 5-6. For TP-M003-1 the grid flow is supplied through the bottom two grid sections, and for TP-M003-2, the top-most grid section. The experimental average bubble velocities are comparable with that calculated from the equation $U_b = 0.711 \sqrt{g D_b}$, as shown in Tables 5-5 and 5-6, where U_b is the bubble velocity and D_b is the bubble diameter.

Despite difficulties such as pitot tube plugging and bending, pressure drop data were obtained via the purged pitot tube during TP-M003-1 at five elevation levels from the jet nozzle outlet for eight different set points. The pitot tube apparently sensed the momentum of both the gas flow and the solids in the gas stream rather than the gas momentum alone, as originally hoped for. If the pitot tube measures the momentum of the gas alone, the pressure drop sensed by the pitot tube can be expressed as:

$$\Delta P = \frac{\rho_F U_g^2}{2g_c} \quad (7)$$

TABLE 5-3

DATA ON BUBBLE DIAMETER AND BUBBLE FREQUENCY
TEST TP-M002-2

Set Point	Percentage of Time Jet Penetrates Through the Bed, %	Corrected Experimental Bubble Frequency min ⁻¹ View 3	Experimental Bubble Diameter at View 2, m	Calculated Bubble Diameter, m		Maximum Bubble Diameter from Eq. (9), m
				No Leakage	Leakage	
1	10.2	22.8	1.63	2.28	1.52	1.57
2	31.5	35.4	1.50	2.00	1.46	1.61
3	16.5	28.0	1.27	2.24	1.59	1.69
4	24.7	34.7	1.37	2.02	1.40	1.47
5	20.5	36.0	1.32	1.95	1.31	1.38
6	17.5	26.8	1.33	2.23	1.43	1.48
7	25.6	34.3	1.28	2.01	1.40	1.51
*8	71.5	79.3	--	--	--	--
9	48.4	46.4	1.30	1.84	1.28	1.38
10	49.1	43.9	--	--	--	--
11	41.8	38.0	--	--	--	--
12	50.0	46.2	--	--	--	--
13	43.5	43.8	--	--	--	--
14	50.4	40.5	1.49	2.23	1.59	1.67
15	35.9	37.1	1.47	2.29	1.55	1.63
*16	58.8	50.6	1.39	2.27	1.74	1.99
*22	61.0	57.1	1.15	1.72	1.25	1.40
*23	74.6	60.6	1.38	1.99	1.55	1.80
*24	43.9	40.4	--	--	--	--
*26	17.0	36.5	0.811	1.99	1.31	1.34
*27	7.1	27.7	--	--	--	--
*28	46.1	50.1	0.805	2.11	1.55	1.72

*Lower bed height less than 4.9 m (16 ft); bed height measured from the bottom flange of the mode.

TABLE 5-4
COMPARISON OF CALCULATED AND EXPERIMENTAL BUBBLE SIZE
TEST TP-M002-1

<u>Set Point</u>	<u>Experimental Bubble Size, m</u>	<u>Calculated Bubble Size (Eq. 8), m</u>	<u>Calculated Maximum Bubble Size (Eq. 9), m</u>
1A	1.01	0.90	0.90
1B	0.96	0.90	0.90
1C	1.02	0.90	0.90
2A	1.05	0.97	0.97
2C	1.05	0.97	0.97
3A	1.13	0.97	0.97
3B	1.12	1.04	1.04
3C	1.06	1.02	1.02

TABLE 5-5

DATA OBTAINED FROM FRAME-BY-FRAME ANALYSIS OF FILMS
TEST TP-M003-1

<u>Set Point</u>	<u>Average Jet Penetration Depth, m</u>	<u>Fraction of Time Jet Penetrates the Bed, %</u>	<u>Average Bubble Size, m</u>	<u>Experimental Average Bubble Velocity, m/s</u>		<u>Calculated Bubble Velocity, m/s</u>	<u>Average Bubble Frequency, min⁻¹</u>
				<u>View 2</u>	<u>View 3</u>		
1	2.98	16.7	1.27	2.39	1.95	2.51	37.1
2	2.91	10.9	1.21	2.44	2.41	2.45	32.0
3	2.94	19.6	1.23	2.57	--	2.47	34.4
4	2.96	26.4	1.45	2.08	2.30	2.68	48.3
5	3.06	18.2	1.41	2.43	2.39	2.64	37.6
6	2.94	22.8	1.44	2.44	2.30	2.67	38.2
7	2.63	24.6	1.30	2.70	2.17	2.54	46.7
8	2.72	29.9	1.22	2.24	2.17	2.46	35.0
9	2.66	7.5	1.22	2.30	2.30	2.46	40.9

TABLE 5-6

DATA OBTAINED FROM FRAME-BY-FRAME ANALYSIS OF FILMS
TEST TP-M003-2

<u>Set Point</u>	<u>Average Jet Penetration Depth, m</u>	<u>Fraction of Time Jet Penetrates the Bed, %</u>	<u>Average Bubble Size, m</u>	<u>Experimental Average Bubble Velocity, m/s</u>		<u>Calculated Bubble Velocity, m/s</u>	<u>Average Bubble Frequency, min⁻¹</u>	
				<u>View 2</u>	<u>View 3</u>		<u>View 2</u>	<u>View 3</u>
1	2.74	1.61	1.54	2.02	2.05	2.76	35.9	32.6
2	2.72	0	1.44	1.97	2.00	2.67	38..9	32.2
3	2.69	2.59	1.39	2.36	2.12	2.62	35.3	32.8
4	2.69	4.88	1.54	2.31	2.07	2.76	32.9	32.8
5	2.80	10.34	1.46	3.38	2.41	2.69	42.0	36.5
6	2.78	4.07	1.37	3.69	3.06	2.61	40.1	36.0
7	2.72	3.72	1.37	3.14	3.00	2.61	40.2	39.8
8	2.71	7.00	1.45	3.31	2.98	2.68	37.4	40.8
9	2.74	1.28	1.40	2.54	2.79	2.63	35.5	38.9

The local gas velocity can be calculated readily from:

$$U_g = \sqrt{\frac{2g_c \Delta P}{\rho_f}} \quad (8)$$

The experimental pressure drop measured by the pitot tube was substantially larger than that calculated from equation (7). It was concluded that the pitot tube must have been measuring both the gas and the solids momentum. The correct equation should be

$$\Delta P = \frac{\rho_f \cdot \epsilon \cdot U_g^2}{2g_c} + \frac{\rho_s (1-\epsilon) \cdot U_s^2}{2g_c} \quad (9)$$

Equation (9) has three unknowns, i.e., the gas velocity U_g , the solid particle velocity, U_s , and the local voidage, ϵ . In order to calculate the gas velocity profiles from the measured pressure profiles using equation (9), two more assumptions were made. The voidage distribution in the jet was assumed to depend exponentially only on the distance from the jet nozzle. The voidage at any height, ϵ_h , can then be calculated from:

$$\epsilon_h = \epsilon_0 \cdot \exp \left[\frac{\ln \epsilon_L}{L} \cdot h \right], \quad (10)$$

where ϵ_0 = voidage at the jet nozzle; $\epsilon_0 = 1$ when the jet is a pure gas jet

ϵ_L = voidage at the end of jet penetration can be assumed to be equal to ϵ_{mf} , voidage at minimum fluidization

L = jet penetration depth

The slip velocity between the gas and the solid particles was assumed to be equal to the terminal velocity of a single particle. Or,

$$U_s = U_g - U_t \quad (11)$$

Solving equations (9) through (11), the gas velocity profile can be obtained. A typical gas velocity profile using these assumptions is shown in Figure 5-5. Reasonable results have been obtained through this approach. The detailed results will be reported in the next quarterly report.

Figure 5-5. Gas Velocity Profiles for Three Bed Heights

5.2.3 NOMENCLATURE

D_B	diameter of the gas bubble
$(D_B)_{\max}$	maximum bubble diameter predicted from equation (9)
F	total amount of gas leaks out of bubble after growing to a diameter D_B
g	gravitational acceleration
G	Volumetric gas flow rate through the jet nozzle
h	distance for jet nozzle
L	jet penetration depth
n	bubble frequency
ΔP	pressure drop measured by pitot tube
t	time
U_g	local gas velocity in the jet
U_{mf}	superficial minimum fluidization velocity
U_s	local solid particle velocity in the jet
U_t	terminal velocity of a single particle
V_B	volume of the gas bubble
ϵ_h	voidage in the jet at a distance of h from jet nozzle
ϵ_L	voidage in the jet at the jet penetration depth
ϵ_0	voidage at the jet nozzle
ρ_f	fluid density
ρ_s	solid particle density

5.3 CFSF MODIFICATIONS

A number of modifications and maintenance work items were completed during this report period. These are described below.

Air Tube Conversion

The previous air tube configuration consisted of a concentric semicircular assembly of 16-inch and 8-inch pipes to form the air tube and solids transport pipe. This assembly was replaced with a 10-inch x 4-inch system to conduct subsequent 1982 tests with the smaller diameter air tube.

Grid Flow System Upgrade

In an effort to improve the distribution of gas on the conical grid section, the flow loops leading to the grid were upgraded to handle more flow. In addition, individual sectors on the conical grid were separately manifolded to obtain uniform controlled aeration at selected zones.

Solids Handling Equipment

Rotary feed valves used for transporting acrylic material were upgraded. The inside surfaces of the housings were machined and sleeved with case-hardened material to minimize erosion wear.

Fines Recycle Modifications

Ports were installed on the coaxial solids feed line and on the side of the fluidized bed for insertion of special fines recycle components to be installed later in September.

The material transfer cyclone, which separates the coarse acrylic withdrawn from the "ash" discharge port, was repaired. The barrel section of the cyclone was patch welded to seal leaks caused by erosion.

Tracer Gas System

- The carbon dioxide tracer gas supply system was upgraded. A 12-ton storage unit equipped with a refrigeration coil was installed to minimize evaporation losses.
- Two rear entry ports were installed on the model in an effort to sample tracer gas concentrations in the emulsion phase diametrically opposite the semicylindrical jet opening.
- Additional tracer gas analyzers were installed to permit simultaneous measurement of tracer concentration at eight locations in the system.

Miscellaneous Items

- New acrylic bed material was procured and loaded with the CFSF storage system. The old material had undergone attrition after several months of use and also was contaminated with the sand used in earlier char-ash separation tests.
- The computer data acquisition system was upgraded. The software was converted to FORTRAN to improve system efficiency and additional measurement points were added.

WORK FORECAST FOR NEXT QUARTER:

- Perform TP-M007-1, a 10-inch diameter air tube shakedown test
- Perform TP-M007-2, a 10-inch air tube jet penetration, bubble diameter, bubble frequency, and bubble velocity test
- Perform TP-M007-3, a 10-inch air tube CO₂ tracer gas test

SECTION 6.0

PROCESS AND COMPONENT ENGINEERING AND DESIGN

Activities centered around design and procurement of components and hardware for the PDU construction/modification downtime period between June 1 and July 15. The major focus was on the following projects:

- Solids injection device installation - piping and vessel modifications to secondary fines recycle system for hot recycle.
- Non-mechanical valve - preparatory work to modify the primary fines recycle system for hot recycle by September.

The major areas of process and component engineering and design in support of PDU operations were as follows:

- Final design and review of the PDU modifications required for hot recycle of fines using the solids injection device under the secondary cyclone.
- Design and fabrication of a solids injection device on the PDU.
- Design, fabrication, and installation of piping and feed lines for fines recycle.
- Completion of modification/maintenance work on the PDU for the July test.
- Preparation of design documents, drawings, and specifications for the PDU material handling system.

Vessel piping, feed line piping, fabrication drawings, and instrumentation diagrams were completed. Long-lead hardware items were received, and almost all of the components are scheduled for installation on the PDU by the end of June. The design, procurement, and fabrication of a high pressure solids injection device were completed during June. The arrangement drawing and design review for the non-mechanical valve, which will be installed in September, was completed during the month of June. In addition, design and preliminary work for the 1800°F dipleg, fabrication of a high pressure (CO₂) gas supply for solids injection device operation, and on-site fabrication of retractory lined piping were completed.

The design work and drawings for the hot rotary feeder drive installation were approximately 50 percent completed. A purchase order was placed for the Reeves Motodrive Unit (estimated delivery in late July). However, installation of the hot rotary feeder was deferred in favor of the non-mechanical valve test series.

Purchase orders for hardware to implement testing on the PDU by July 15 were placed. Some material has been received, and no delay is expected for the remaining items. During June the following installation was completed:

- A lateral sample spool to provide sampling capability at the inlet to the solids injection device.
- Secondary cyclone instrumentation spools to provide temperature and pressure data at the inlet to the solids injection device.
- Feed lines and a spring support system to connect the solids injection device with the gasifier.

The process and instrumentation drawing for the non-mechanical valve was completed, and material was ordered. The solids injection device and non-mechanical valve programs will be conducted in a sequential effort, with schedule dates for completion of the respective modifications of July 15 and October 1, 1982.

The Auburn 1090 void fraction monitor was calibrated. Although the meter worked very well during the last PDU test, some debugging remains to be accomplished.

WORK FORECAST FOR NEXT QUARTER

- Fabricate and install the non-mechanical valve outlet piping, through-trap, and relocate the primary cyclone to a higher elevation.
- Install the non-mechanical valve and hot dipleg under the primary cyclone.
- Install the single-tube through-trap above gasifier in gas exit piping.

SECTION 7.0

LABORATORY SUPPORT STUDIES

Support work 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 from PDU operation, develop unit process correlation models and understand process phenomena to achieve reliable operation. Work was conducted this quarter in the areas of gas-solids flow modeling and coal/ash behavior.

7.1 GAS-SOLIDS FLOW MODELING

7.1.1 JET PHENOMENA

The objective of this task is to investigate different jetting phenomena in a fluidized bed: jet penetration depth, gas and solids entrainment into jets, and different jetting regimes. The 12-inch diameter semicircular unit was modified to install an additional jet in the char-ash separator annulus to simulate fines feeding in the PDU. Experiments were conducted to study the jet interaction between this jet and the main jet in the gasifier. Visual observation indicated that the jet located in the annulus tended to merge with the main jet at low jet velocities. At high jet velocities, however, the main jet was bent toward the annulus jet. Currently, the data are being analyzed.

The high-temperature unit was assembled, and the natural gas burner and electrical preheaters for the jet stream were checked out. Shakedown and operation is planned for next quarter.

7.1.2 FINE PARTICLE HISTORY

The objective of this task is to study the fate of fines that are injected either concentrically or radially into the gasifier to develop a meaningful unit process correlation model and to understand gasifier performance.

The 12-inch diameter semicircular Plexiglas cold flow model will be modified to conduct tests of fine particle history as a function of jet injection velocity, feed point location, and slugging/non-slugging modes of bed operation. The test procedure will involve the injection of a pulse of tracer fines into a steady operating fluidized bed and the collection of the injected fines through a high-performance cyclone into a transparent Plexiglas dipleg. The mean residence time of the injected fines in the fluidized bed will be calculated as the time by which 50 percent of the injected fines will be recovered.

During this quarter, the limiting design conditions for selecting a proper cyclone were determined, different cyclone manufacturers were contacted, and a 4-inch high-performance cyclone from Fisher-Klosterman, Inc., was ordered and received.

A 20-pound sample of antistatic polyethylene resin was received from the Richmond Division of Dixico, Inc. These pellets were shipped to Air Products and Chemicals, Inc., to be crushed cryogenically into particles with a mean particle size of about 100 μm . Most of this 3-pound sample received consisted of particles larger than 100 mesh (150 μm) and only 60 g fell in the range between 74 and 150 μm . This quantity will probably be enough to initiate the experiments. The small quantity of crushed material within the needed size range was probably a result of the resins being crushed cryogenically in a hammer mill and not in a grinder. A new sample of 250 pounds of the antistatic resin was ordered and is expected soon. This material will be sent for cryogenic crushing in a grinder. Two service companies with such facilities were contacted: Midwest Elastomers, inc., in Wapakoneta, Ohio, and Specialty Recycling Services, in Cleveland, Ohio.

Modifications to the existing 12-inch Plexiglas semicircular test apparatus were completed as follows:

- The high performance cyclone was installed.
- A cyclone dipleg with a transparent, Plexiglas lower section was constructed and installed.
- A few trial tracer injection tests were conducted to select the size of the tracer particle injection tube and to determine the corresponding air-pressure needed for the instantaneous discharge of the tracers.

7.1.3 CFSF SUPPORT

The objective of this task is to provide technical support to the operation of the CFSF and its data analysis. A program to develop one or more probes for measuring the solid circulation rate in the CFSF was initiated. Preliminary conception of the probes was completed, and two prototype probes are being fabricated. The probe will be tested in the 12-inch diameter laboratory cold flow model. One or more final probes suitable for application in the CFSF will be developed.

7.2 COAL/ASH BEHAVIOR

7.2.1 GASIFICATION

The objective of this task is to characterize coals for reactivity using coke breeze as a reference. Western Kentucky and Upper Freeport coals and PDU char fines with RSA coal feedstock were characterized for reactivity on a thermogravimetric analyzer.

The average reactivities and proximate analyses of various coals and chars tested in this period are given in Table 7-1.

The size fraction of $-0.125 + 0.105$ mm ($-120 + 140$ mesh) from RSA coal was characterized by preparing char in a $\text{N}_2\text{-H}_2$ atmosphere. The average relative reactivity of these fines was found to be 17.6. This result compares very well with the value of 22.4 obtained for PDU char ($-1.0 + 0.25$ mm) from a test with RSA coal. From these tests it is concluded that the reactivity of fines is the same as that of the larger size distribution ($-1.0 + 0.25$ mm).

TABLE 7-1
REACTIVITY AND ANALYSIS OF COALS/CHARS

Coal/Char	RSA 2 Char Fines 120 x 140 Mesh TP-031-2	RSA 2 Coal 120 x 140 Mesh	Western Kentucky Coal CO-80-0165	Western Kentucky Char from PDU TP-0-27-4	Upper Freeport Coal CO-82-0002
<u>Reactivity Data*</u>					
Average reaction rate x 10^2 , min ⁻¹	1.41	5.27	5.07	7.02	0.72
Average relative reactivity	4.7	17.6	16.9	23.4	2.4
<u>Proximate Analysis, Wt. % *</u>					
Moisture	4.29	5.04	5.55	0.25	1.29
Volatile matter	1.54	23.19	37.64	0.37	18.49
Ash	22.49	19.00	6.21	33.60	16.42
Fixed carbon	71.68	52.76	50.43	65.78	64.30
<u>Analysis of Char, Wt. %</u>					
Carbon	76.11	73.51	89.04	65.68	79.67
Ash	23.89	26.49	10.96	34.32	20.33

Test Conditions:

Temperature: 982°C

Particle size: -1 + 0.25 mm

Gas composition for pyrolysis stage: N₂ - 50%, H₂ - 50%

Gas composition for gasification stage: Steam - 33.3% H₂ - 16.7%, N₂ - 50%

* Average of two or three tests.

Char fines of -120 + 140 mesh obtained from the primary cyclone during PDU test TP-031-2 with RSA coal were characterized for reactivity. An average relative reactivity of 4.7 was obtained for these fines. The low reactivity of these fines may be attributed to a loss in reactivity caused by long storage time.

Western Kentucky coal was characterized at 1800°F by preparing char in the presence of hydrogen. An average relative reactivity of 16.9 was obtained from two tests. This compares very well with the average relative reactivity of 23.4 for Western Kentucky char obtained from a PDU test, as reported earlier.

Upper Freeport seam coal was characterized at 1800°F by preparing char both in the presence and in the absence of hydrogen during pyrolysis. The average relative reactivity of char prepared in the absence of H₂ is about 2.4. PDU char from Upper Freeport coal will be characterized in an effort to develop the desired method of char preparation to characterize low-reactivity coals.

7.2.2 ASH BEHAVIOR

The objective of this task is to study the behavior of coal ashes. The behavior of ash particles prepared from Wyoming Sub-C, Pittsburgh seam, and West Virginia coal ashes by a high-temperature ashing method was examined on the hot-stage microscope while the particles were being heated in an oxidizing atmosphere. Only those particles that predominate in the sample prepared are used for this study. The experimental method consisted of placing ash particles on an electrically heated platinum strip and observing their behavior. A Rt-Rh thermocouple, Type S, was welded to the platinum strip to measure its temperature. Changes occurring on the ash particle surface are recorded on a videotape and monitored on a video screen.

The behavior of ash particles from Wyoming Sub-C coal are described to illustrate the behavior of coal ashes and to identify distinctly different stages in the process of melting. Three particles were placed very close to each other. They moved away from each other when they started to sinter, and only one particle could be examined at a magnification of about 75X. This particle began to sinter slowly around 1925°F, followed by initial melting at one spot on the particle surface. With continued heating of this particle, the entire particle surface melted, followed by an evolution of bubbles around 2270°F that indicated the vaporization of some compounds. Further shrinking of the particle was observed at about 2395°F. On the basis of these changes, three stages in ash behavior could be identified, namely, initial sintering temperature, initial melting temperature, and fluid temperature. Note that these are different from the temperatures used in characterizing ash behavior by the ASTM method. A comparison of the ASTM results with those of the present study on this coal ash is given in Table 7-2.

A substantial amount of ash must melt before the deformation of the ash cone can be noticed in the ASTM method. Hence, the large difference between the initial deformation temperature using the ASTM method and the initial sintering temperature of the HSM can be explained.

TABLE 7-2

BEHAVIOR OF WYOMING SUB-C COAL ASH

<u>HS Method</u>	<u>Temp., °F</u>	<u>ASTM Method</u>	<u>Temp., °F</u>
Initial Sintering	1925	Initial Deformation	2200
Initial Melting	2140	Ash Softening	2270
Fluid Temperature	2230	Ash Fusion	2340

For Pittsburgh seam coal ash, initial sintering was observed at about 1850°F, and complete melting took place near 2380°F. Initial melting and complete melting for this ash particle were indistinguishable. For West Virginia coal ash, no sintering or melting was observed up to a temperature of 2400°F. Additional particles of these three ashes will be examined in future tests.

7.2.3 DEPOSIT CONTROL

On the basis of currently available operating data from the PDU, the following trends in deposit formation were identified:

- Several cyclone deposits formed when the gasifier was operated at high temperature with a high-fouling coal.
- High-fouling coals contained significant amounts of pyritic sulfur (1.0 percent or more) and potassium (or sodium) aluminum silicates.
- The product gas temperature greatly and directly affected cyclone deposition formation. There appeared to be a "threshold" temperature below which deposits would not form. This threshold was low for high pyritic sulfur coals and became higher as the pyritic sulfur content in the coal decreased.
- The cyclone inlet velocity and the duration of coal feed also influenced deposit formation. For high-fouling coals, the cyclone inlet velocity had to be low and the duration of coal feed short, to avoid cyclone deposits. These relations, however, were overshadowed by the effect of product gas temperature.
- High operating pressure in the gasifier seemed to favor the formation of sticky molten material, which led to severe deposits.
- There was no consistent trend in deposit formation as the bed ash contents and the steam-to-coal ratios were varied.
- The cyclone deposits appeared to be less severe under air-blown than under oxygen-blown conditions. This finding, however, was based on a limited number of PDU tests. More experience with air-blown tests is required to lend support to this observation.

A probe to study deposit formation in the PDU gasifier was designed and fabricated. It consists of two, concentric, stainless steel tubes: an inner tube for the inflow of cooling gas (CO_2) and an outer tube for the gas outflow and for the collection of deposits. Thermocouples are located in grooves along the inner wall of the outer tube to record the probe wall temperature. As deposits form on the probe, this temperature will decrease because the deposits insulate the probe. The probe will be located in the gasifier freeboard, near the exit, where there would be a large number of particles striking its surface at exit velocity. It is scheduled for installation for test TP-033-1.

7.3 REFERENCES

1. Davidson, J. F., and D. Harrison, "Fluidized Particles", Cambridge University Press, England; 1963.
2. Nguyen, X. T., and L. S. Leung, "A Note on Bubble Formation at an Orifice in a Fluidized Bed," Chem. Eng. Sci., 27: 1748; 1972.

WORK FORECAST FOR NEXT QUARTER

- Complete assembly of high-temperature unit.
- Complete shutdown of high-temperature unit.
- Complete modification of existing 12-inch diameter semicircular test apparatus to study fate of injected fine tracer particles.
- Conduct preliminary tests to determine proper functioning of fines injection apparatus.
- Initiate particle separation tests using PDU material.