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THIRD QUARTER - FISCAL YEAR 1978
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WESTINGHOUSE ELECTRIC CORPORATION
ADVANCED COAL CONVERSION DEPARTMENT
MADISON, PENNSYLVANIA 15663

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ADVANCED COAL GASIFICATION SYSTEM FOR ELECTRIC POWER GENERATION

THIRD QUARTERLY PROGRESS REPORT

Period April 1 to June 30, 1978

Contributors:

H. K. Altiner
E. J. Chelen
P. Cherish
Z. F. Hudson
S. Katta
D. L. Keairns
L. K. Rath
N. D. Rohatgi
L. A. Salvador
C. C. Sun
R. A. Wenglarz
W. C. Yang

WESTINGHOUSE ELECTRIC CORPORATION
ADVANCED COAL CONVERSION DEPARTMENT
Box 158, Madison, Pennsylvania 15663

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SECTION 1.0

OBJECTIVE AND SCOPE OF WORK

The overall objective of the Westinghouse coal gasification program is the development of a process to produce a clean low-Btu fuel gas from a variety of caking or non-caking high-sulfur coals suitable for use in a combined cycle electrical generating plant. To achieve this goal, the program is divided into several areas of development.

1.1 PHASE I, TASK 2 - OPERATION OF THE PDU

The Task 2 objective is operation of the Process Development Unit (PDU) to evaluate the process feasibility and operability of the Westinghouse advanced fluidized bed coal gasification process and to provide data for scale-up and component hardware designs. The initial work in this task involved evaluation of the devolatilizer system for de-caking and devolatilizing fresh coal feedstocks. Process feasibility of the devolatilizer was demonstrated through a series of tests with a variety of coal feedstocks, including high-caking Eastern bituminous coals. Following these tests, the gasifier-agglomerator system feasibility was demonstrated with chars produced in the devolatilizer and with other materials including coke breeze, chars from another gasification process and both non-caking and highly-caking coals. These materials were successfully gasified and ash agglomerates were successfully produced from each feedstock.

Present work involves continued testing of the gasifier-agglomerator reactor with direct coal feed as well as with oxygen-blown gasification of a char or coal bed. These tests will be followed by evaluation of the integrated system consisting of the devolatilizer and gasifier-agglomerator.

A portion of the work under this task involves the modification and upgrading of the PDU to provide for integration of the two reactors as well as to modify the hardware to achieve better performance as dictated by the results of prior testing efforts.

1.2 PHASE I, TASK 3 - LABORATORY SUPPORT STUDIES

Support studies are being conducted to provide background information on process technology, to provide PDU design data, to project operating conditions for the PDU, to provide troubleshooting capability during PDU operation and to develop commercial plant design data. Primary areas of investigation include: support tasks for the current PDU gasifier-agglomerator test program, support tasks for the devolatilizer to prepare for integrated plant operation, coal behavior studies, ash behavior studies and reactor analysis.

Fluidization studies are directed toward development of the devolatilizer and the gasifier-agglomerator units. Test facilities include a flexible 1-foot diameter semicircular unit which operates at atmospheric pressure and ambient temperature, a 4-inch scale pressurized unit and atmospheric pressure units. The semicircular unit has been used for investigation of important devolatilizer design parameters (area ratio of downcomer/draft tube, draft tube height, distributor plate design and methods of solids feeding); operating parameters (flow ratio of downcomer/draft tube, amount of downcomer aeration); and startup and shutdown procedures in relation to solids circulation rate, jet penetration length, solids mixing and gas bypassing. A pneumatic transport line of 2.54 cm (1 inch) ID is an integral part of this experimental system so that concentric solids feeding into the reactor similar to that of the PDU can be simulated.

The coal and ash behavior programs complement the fluidization model studies. The coal behavior program is to develop an understanding of coal devolatilization and coal and char gasification and to develop models for projecting performance. A fluidizied bed test unit, operating at design temperature and pressure, is utilized to carry out experimental investigations. The ash behavior program is to develop an understanding of ash agglomeration phenomena, to develop the ability to specify optimum design and operating conditions for high ash residue to acceptable rates and to identify potential environmental impact from "agglomerated" ash disposal. An atmospheric pressure fluidized bed agglomerator, operating at design temperatures, is utilized to carry out experimental investigations.

The calcium-based sorbent studies provide data to support PDU, to recommend process options for first generation plants, to project operating conditions for investigation in the PDU, to develop design and operating criteria and to evaluate the potential for advanced systems. Work was previously conducted to develop sorbent selection criteria, a once-through process, regenerative process options, spent sorbent disposition options, and to provide technical and economic assessment of the alternatives. A pressurized thermogravimetric analysis system, differential thermal analysis and a pressurized, high-temperature fluidized bed test unit have been used to conduct these investigations. No sorbent behavior work was scheduled for this quarter.

Mathematical analyses are performed on the gasification process using the collected data and reactor performance at different reactor configurations and at different operating conditions. Solids fluidization and transport investigations are conducted as needed to provide data to complement information from the PDU. Objectives are to provide a basis to develop models and scaling relationships to design and predict performance of the PDU and larger scale fluidized bed gasification plants.

SECTION 2.0

SUMMARY OF PROGRESS TO DATE

2.1 PHASE I, TASK 2 - OPERATION OF THE PDU

Operation of the PDU during the third quarter (April-June) was directed to testing of the gasifier reactor. The goals of the testing programs were to evaluate the performance of the gasifier with the expanded freeboard section using direct coal feed and to assess the effectiveness of the upgraded gas quench-waste system. These goals were accomplished as Tests TP-015, -016 and -017 were conducted. Other, more specific test objectives were also realized, and these are described in this report. Heat and material balances as well as product characterization analyses were also accomplished and are included in Section 3.0.

Over 500 hours of operation were achieved with approximately 270 hours being logged using a highly-caking Pittsburgh seam coal feedstock. High carbon conversions were achieved in all tests with the various feedstocks used. The first operation of the gasifier with the newly-installed oxygen supply system was attempted in Test TP-018-1. Also undergoing initial testing was the modified oxidant tube which was changed to accommodate a reduction in operating pressure from 230 to 150 psig. Further experience in operating the gasifier with oxygen will be reported in TP-018-2 and subsequent tests in the next Quarterly Progress Report.

2.1.1 Gasifier Test TP-015

Gasifier test TP-015-1 was the shakedown test following redesign and modification of the gasifier reactor. The principal aim of the modification was to expand the internal systems of the reactor and to add a new 30-inch diameter freeboard section for increased coal utilization and higher throughput to product gas. This and other changes are described in more detail in Section 3.0. A total of four set points were achieved using feedstocks of coke breeze, Western Kentucky FMC char, and Wyoming Sub-C coal. Ash concentrations attained in the boot ranged from 75-78 percent for steady-state Points 1 and 2 to a high of 92 percent during Point 3 operation, and to 23 percent in steady-state Point 4. The freeboard temperatures were varied from test to test, with 1833°F for Points 1 and 2 and 1675°F for Point 4. A very successful carbon utilization figure was reached during Set Point 4 with a high of 97 percent being realized. HHV product gas heating values on a dry basis ranged from a low of 39.7 Btu/scf to a high of 105.3 Btu/scf.

2.1.2 Gasifier Test TP-016

Test TP-016 was conducted from April 26 to May 2 and successfully demonstrated the capability of the gasifier to operate with the direct feed of a highly-caking Pittsburgh seam coal. Feedstock was an unwashed, run-of-mine coal from a strip mine near Adamsburg, Pennsylvania. The coal had a free swelling index (FSI) of 7-1/2 and a Gieseler plasticity of 31,000 ddm. Of the total 141 hours of operating time, 113 were with the Pittsburgh seam coal. From solid and liquid samples taken during the test, no measurable tars or oils were detected, and from a post-test inspection no buildup was found on the internal walls of the gasifier. Some difficulty was encountered in the feeding of coal to the gasifier as a result of wet feedstock. In a deviation from the test plan, an experimental operating design was conducted in an effort to determine the effects of gasifier temperature and steam flow rate as variables on product gas heating values. The results of Test TP-016 show that HHV product gas heating values on a dry basis were from 76-86 Btu/scf and that a carbon utilization of over 90 percent was achieved.

2.1.3 Gasifier Test TP-017

Test TP-017 was run from May 5 to May 25. In addition to continuing the single-stage gasifier evaluation studies, the experimental design started in TP-016 was completed with TP-017. A total of 160 hours of operation were accumulated during the test with the Pittsburgh seam coal as feedstock. During the test, a reduction in output of 4:1 was achieved based on the gas heating value. This reflects the ability of the single-stage gasifier reactor to perform successfully over a broad range of temperatures and steam inputs. Other performance indicators of the test include a greater than 90 percent carbon utilization and a HHV heating value on a dry basis of 91.3 Btu/scf.

2.1.4 Gasifier Test TP-018

Test TP-018-1 was the first test of the gasifier following installation of the oxygen supply system and the new oxidant tube. The test began June 25 with pressurization to 150 psig in preparation for oxygen-blown testing. This was in contrast to the 250 psig used for air-blown tests and in effect demonstrated the success of the new oxidant tube design. Autogenous ignition was achieved, however, a problem was discovered with the steam generation system and the reactor was ramped at 1600^{o}F with air feeding to the oxidant tube. During final checkout procedures in preparation for oxygen testing, a major leak in the oxygen system was discovered which precluded testing with oxygen. System pressure was then increased to 230 psig using air and Set Point 1 conditions were achieved. Following a steady-state period of 10 hours, a controlled shutdown was initiated.

2.1.5 Modifications for Integrated Operation

Much of the work required to begin integrated operation of the PDU was delayed this quarter. This was so that efforts could be concentrated in operating the gasifier to test the expanded freeboard section and installing the oxygen supply system preparatory to operating the gasifier with oxygen. Only minor work was done which was limited to electrical, instrumentation and piping installations. A preliminary schedule was completed which calls for work to be accomplished in time for an early 1979 startup of integrated operation.

2.1.6 Modifications for Operation with Oxygen

Modifications to the PDU to permit operation with oxygen were completed by June 25 at which time Test TP-018-1 was intitiated. The work accomplished in this quarter included the design and procurement of equipment, construction and installation, commissioning of equipment and subsystems for oxygen service, and the establishment of safety procedures. Airco was selected to supply the oxygen system and 2.4 million pounds of oxygen to the PDU during the first eight months of oxygen testing.

In working out the design of the oxygen flow control system, both CE Lummus and Stearns-Roger companies were consulted with regard to similar systems at the Synthane and Bi-Gas pilot plants, respectively. In particular, the safety and reliability of each system was studied. Finally, a failure mode analysis was conducted of the newly-installed oxygen flow loops and control logic. Potential failure modes were identified and their criticality to plant operation and personnel safety were defined. This information along with supplier's documents was reviewed by the safety committee to develop operating procedures and a failure action plan. Extensive training programs were then conducted covering the operating and failure action plans.

2.1.7 Process and Design Engineering

The activities in this area fell into three categories that included general engineering, product characterization and environmental safety and health.

In the general engineering area, activities centered on:

- Development of a flow totalizer for the water system to perform water balances.
- Development of an in-line solids flow measurement device.
- Location of local suppliers of coal and char feedstocks.
- Evaluation of the quench water system based on data collected from gasifier test TP-015-1. Modifications to improve waste water cleanup and operation in the recycle mode were determined to be successful.
- Design of a replacement section for the gasifier withdrawal boot and the placement of a purchase requisition.
- Evaluation of the reactor vessel creep properties to determine time limits to rupture relative to pressure and temperature conditions.

- Relocation of one of the two radiation measurement devices in the Kay Ray nuclear bed level indicating system. This became necessary for operation of the gasifier with the expanded section.

Work conducted in product characterization this quarter consisted of modifications to the measurement apparatus along with a change in techniques and an analysis of data obtained from test TP-015. From the experience gained during TP-015, a number of procedural, design, and hardware problems were identified and corrected. One change involved the isokinetic sampling train, which after modification produced good usable results for the first time during Test TP-016. A miniscrubber gas sampling train was installed and used during Test TP-016, and following this test was relocated downstream of the cyclone for better results.

Product characterization data were generated from analyses conducted in conjunction with gasifier test TP-015. Analyses were performed on solids, product gas, and quench scrubber solids and water. From dump liquid samples taken from the product gas cooling system, some positive trends were apparent:

- No visible tars or oils were found in the filtrate and pH varied from 7 to 9.

- No hydrocarbons were detected using the gravimetric method in the acetone extract of the residue.

A number of work activities were carried out as part of the environmental safety and health program for the Westinghouse ACCD site. Among these were:

- An OSHA-type inspection of the PDU conducted by DOE. Findings will be reported later.

- American Red Cross industrial first aid classes for site personnel. This brings participation to the 75 percent level.

- Removal of benzene from the site except for analytical use, and a survey of Lab employees to determine 8-hour average exposure to benzene.

- Following closely the design and installation of the liquid oxygen system throughout the quarter to assure safety and establish cleaning procedures. The reliability of using CO_2 as a purge gas was investigated, and classes were held on the potential hazards and the safe handling of oxygen systems.

Finally, environmental sampling was conducted to determine potential toxic respiratory exposure to PDU process personnel. Sampling included individual personnel and area samplings, as well as crew member sampling for five consecutive shifts during PDU operation. Results will yield data with which to compare PDU personnel exposure to proposed OSHA and NIOSH standards. Stack gas analyses for SO_2 and NO_x were also made. No samples taken yielded detectable SO_2 or NO_x levels.

2.2 PHASE I, TASK 3 - LABORATORY SUPPORT STUDIES

Support work on fuel processing was conducted to investigate operating conditions for the PDU test program, provide troubleshooting capability for PDU operation, obtain data for PDU modifications, analyze and interpret results from the PDU operation and develop information for future process development. Primary effort was expended to provide support for the PDU in areas of fluidization and fluid-particle systems, coal behavior, ash behavior, environmental impact studies, and reactor analysis.

2.2.1 Cold Flow and Analytical Modeling

Experimental tests and analysis of data were carried out on jet phenomena, distributor design, draft tube design and particle entrainment. The jet penetration correlation developed for the multiple vertical jets was compared with published correlations and found to provide improved predictive capability. A comparison of the data and the model is presented in Section 3.0.

Experiments to study gas entrainment into a jet in the fluidized bed were partially completed. Some results of tracer concentration profile in the bed are also presented in Section 3.0. Work is being carried out to map the velocity profile in the jet with a two-dimensional pitot tube. The rate of gas entrainment into the jet along the jet height can be obtained by combining the concentration and velocity profiles. Because of the large number of data points, about 80, required to complete the concentration and velocity profile mapping of a jet at one single set of operating conditions, the initiation of the investigation on jet penetration of a gas-solids two-phase jet will be initiated in two months.

A test facility to study the performance of the conical grid in the devolatilizer has been designed and is being fabricated. Solids weeping and the potential for plugging will be investigated.

A transparent two-dimensional unit, 50.8 cm wide x 2.54 cm deep x 2.44 m high (20x1x96 inches) was constructed with three draft tubes of 2.54 cm x 2.54 cm (1 inch x 1 inch) cross section and 0.91 m high (36 inches). The unit is instrumented with three 6-way valves and a differential pressure transmitter. Pressures between any of the 15 pressure probe locations can be compared and recorded continuously during operation. The information obtained in this unit will be utilized in design of the 3-meter cold flow test facility now under development. Preliminary experiments are being carried out in this unit.

Particle entrainment data from the PDU gasifier-agglomerator were analyzed and a mathematical model was developed to predict the entrainment at different operating conditions for different feedstocks. The model is described in detail in Section 3.0, and the calculated particle entrainment rates are compared with the actual pilot plant data.

2.2.2 Coal Behavior

Preparations are being made to make surface area measurements of chars and coals employing the Dubinin-Polanyi method with carbon dioxide as the adsorbate.

The ash agglomeration unit was operated successfully with steam, with large and dense agglomerates obtained. A comparison of these agglomerates with those obtained in the PDU at similar operating conditions shows the former to be denser and as having been formed at a higher temperature.

The original reactor shell and refractory have been damaged as the result of failure of the latter which is possibly due to steam condensation. The reactor design is being modified and the reactor will be replaced.

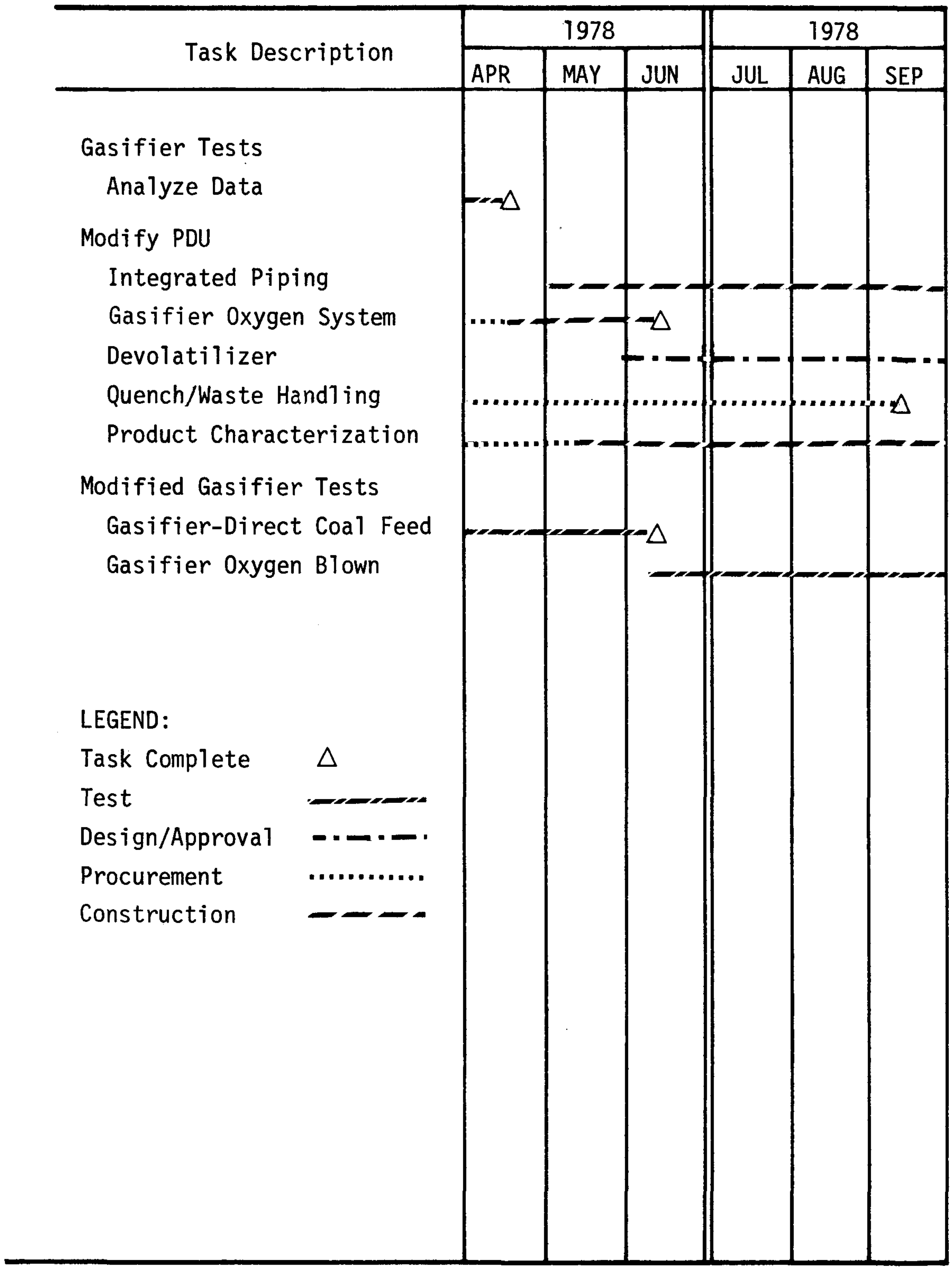
Thermodynamic calculations have been used to predict the various chemical compounds (solid, liquid or gas) which were stable under the operating conditions of the PDU gasifier-agglomerator. The operating conditions chosen were those of PDU test run TP-012-3. X-rays of samples of gasifier wall deposit from the same test run indicated the presence of some of the chemical compounds projected by thermodynamic calculations. These calculations have also been used to study the effects of temperature, pressure, combustor ash content, and steam flow to the combustor on the different chemical compounds formed and their relative amounts at equilibrium.

2.2.3 Environmental Impact Studies

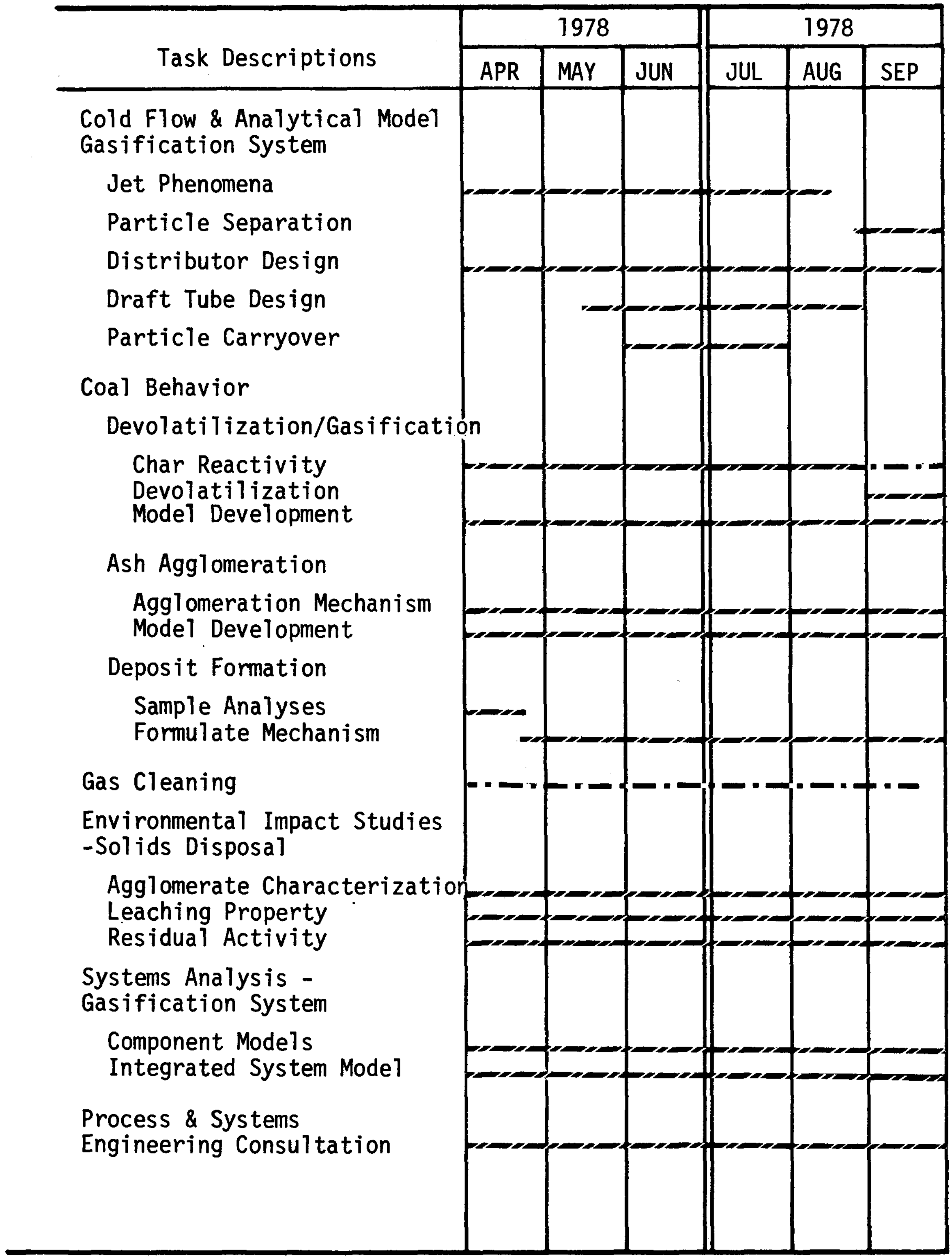
Tests to evaluate the potential for environmental impact from ash agglomerates produced in the gasifier using PDU devolatilizer coal char have been completed. Agglomerates from TP-014-1 and TP-013-2 were tested. Agglomerate composition and morphology were determined. Leaching properties were determined using two shake test procedures. Heat release was determined. No problems were identified that would preclude disposal. These data indicate that leachate from the agglomerated ash will meet toxic trace element standards being considered. Further tests and comparisons are being carried out to extend the analysis and evaluation.

2.3 SUMMARY SCHEDULES

2.3.1 Phase I, Task 2 - Operation of the PDU



2.3.2 Phase I, Task 3 - Laboratory Support Studies



SECTION 3.0

DETAILED DESCRIPTION OF TECHNICAL PROGRESS

3.1 PHASE I, TASK 2 - OPERATION OF THE PDU

3.1.1 Modified Gasifier Tests

As discussed in the Second Quarterly Progress Report (January-March 1978), the integrated operation tests have been delayed to allow continued evaluation of the gasifier with direct coal feed. The test sequence being followed as a result of the revised scope of work for CY-1978 as approved by the Department of Energy (DOE) in February is as follows:

- Modified Gasifier Operation Direct Feed - Feeding of various coals directly to the gasifier operating as a single reactor (one-stage) to evaluate process performance, ability to gasify coal without pretreatment, and ability to produce minimal tars in the product gas.

- Modified Gasifier Operation Oxygen Blown - Gasification of coal, char or coke breeze with oxygen and steam rather than air and steam as part of a single-reactor configuration concept to evaluate process feasibility for producing medium-Btu gas.

- Integrated Operation - Evaluation of the gasifier and devolatilizer as a two-reactor integrated system with air and oxygen.

The principal objective of testing this quarter has been to evaluate gasifier operation with direct coal feed with the expanded freeboard section. In addition, operating experience with the upgraded gas quench-waste system and an initial test attempt with the liquid oxygen supply system were realized. These tasks were accomplished during TP-015, TP-016, TP-017, and TP-018-1.

3.1.1.1 Work Accomplished - Gasifier Test TP-015

Test TP-015-1, which was conducted in early April, was planned as a "shakedown" test to validate the operability of the new gasifier configuration following redesign and modification. Several major modifications were made to the gasifier test system. These included:

- A reactor configuration change to incorporate an internal expansion of the system. The new reactor design is divided into four sections: (1) the ash annulus area (2) the combustor area (3) the gasifier bed area, and (4) the new 30-inch diameter freeboard area.

- Product gas effluent piping changes from vertical to horizontal.

- Rerouting of the feedlines to the C-115 gasifier to permit radial feed via the C-102A and C-102B lockhopper system, and coaxial feed via the C-103A and C-103B lockhopper system. These arrangements permit the use of the larger F-122 (35.5 kw) transport gas heater for the coaxial coal feed instead of the F-114 (15.1 kw) transport gas heater used in previous tests. The C-102A lockhopper was modified so as to receive feedstock material from the D-105 storage bin, usual configuration, or recycled fines from the C-108A lockhopper, new design. This change also makes the C-105 A/B lockhopper system available for use as an alternate char drawoff system for integrated operation.

- New elbow design for feedlines to evaluate a variety of materials for their erosion resistance qualities and to better understand feedline erosion mechanisms.

Four test points were included in the plan for TP-015-1. In the start-up phase and in test points 1 and 2, the reactor was to be operated with coke breeze until the various subsystems that had undergone modification were functionally checked out. Test points 3 and 4 were to be demonstrations of gasifier operation with Western Kentucky FMC char and Wyoming Sub-C coal respectively.

The following deviations from the test plan were made during the test:

- In test point 3, some difficulty was experienced with ash withdrawal. Examination of the material being withdrawn indicated that it was probably because of stagnation on top of the air tube. A minor modification to the air tube was implemented prior to test TP-016, thereby eliminating the stagnant area.

- Before proceeding with test point 4, time was allotted for the reactor to purge itself of the fragments that had caused withdrawal difficulties. During this period L-60 coke breeze was fed coaxially in place of the FMC char.

- In test point 4, steam flow to the booster sparger was shut off and replaced with recycle gas. Steam flow was eliminated to reduce the gasification heat load on the reactor.

Chronology of the main events during the test is shown in Table 3.1-1. Steady-state set point operating conditions are given in Table 3.1-2. Ash concentrations of 75 to 78 percent were attained in the boot during Set Points 1 and 2, which were run with coke breeze as the feedstock material and 1833°F as the freeboard temperature. In Set Point 3 with Western

TABLE 3.1-1

CHRONOLOGY OF EVENTS, TP-015-1

Date	Time	Events
March 28	0000	Pressure leak test of system started.
April 1	2350	Started hot-air heatup.
April 3	1345	Began pressurizing system to 230 psig.
April 4	1525	Started feeding L-60 (-6 Mesh) coke breeze from C-103B and C-102B.
April 5	1130	Achieved autogenous combustion of coke breeze.
	1550	Initiated a shutdown to repair leaking CO_2 weld in booster sparger.
April 6	0655	Started repressurizing system to 230 psig.
	1900	Achieved autogenous combustion of coke breeze.
April 7	1130	Achieved Set Point No. 1 conditions.
April 8	1610	Terminated Set Point No. 1.
	2130	Achieved Set Point No. 2 conditions.
April 9	1610	Terminated Set Point No. 2.
	1635	Began feeding W. Kentucky FMC char through C-102B (radial) feed system.
	2045	Achieved Set Point No. 3 conditions.
April 10	0615	Terminated Set Point No. 3.
April 10 to April 12	0615 to 0630	Intermittent reactor operating anomolies
	1000	Started feeding 1150 lb/hr of Sub-C coal through C-103B (coaxial) feed line.
	1200	Achieved Set Point No. 4 conditions.
April 13	0930	Terminated Set Point No. 4 conditions.
	1145	Initiated a normal shutdown.

TABLE 3.1-2
SUMMARY OF OPERATING DATA FOR MODIFIED GASIFIER TEST TP-015-1

SET POINT		1	2	3	4
TEST RUN DATE AND TIME (1978)	Unit	April 8 0130 to 1530 Hours	April 8, 9 2130 to 0400 Hours	April 10 0130 to 0545 Hours	April 13 0600 to 0930 Hours
MEASURED GASIFIER PARAMETERS					
TE-504-4 Freeboard Temperature	°F	1833	1833	1770	1675
TE-507-3 Gasifier Bed Temperature	°F	1904	1900	1829	1695
TE-504-10 Ash Annulus Temperature	°F	463	463	475	463
Average Bed Height	feet	24	24	24	24.5
System Pressure	psig	230	230	230	230
Average Gasifier Bed Density	lb/ft^3	25.05	26.62	17.61	13.23
Average Ash Annulus Density	lb/ft^3	27.80	22.65	34.33	16.45
Freeboard Gas Velocity	fps	1.35	1.30	1.35	1.59
Oxidant Tube Velocity	fps	71.28	76.74	92.23	97.24
Coal Feed Material		-6 mesh Coke Breeze	-6 mesh Coke Breeze	W. Kentucky FMC Char	Sub-C Coal
Coal Feed Rate, WR-27	lb/hr	297	428	757	1125
Fines Feed Material		-6 mesh Coke Breeze	Recycled Fines	W. Kentucky FMC Char	Recycled Fines
Fines Feed Rate, WR-14	lb/hr	335	432	302	264
Cyclone Collection Rate, WR-19	lb/hr	140	413	320	400
Carryover to Water System*	lb/hr	75	60	139	124
Ash Withdrawal Rate	lb/hr	62	67	82	25
PRODUCT GAS ANALYSIS, DRY BASIS					
Carbon Monoxide	%	9.72	9.47	18.71	21.60
Carbon Dioxide	%	24.33	24.42	20.99	16.69
Methane	%	0.0	0.0	0.0	0.99
Nitrogen	%	62.85	62.21	54.32	52.64
Oxygen	%	0.0	0.0	0.0	0.0
Hydrogen	%	3.10	2.88	5.99	8.01
HVV, Dry Basis (Gas Chromatograph)	Btu/scf	41.2	39.7	78.6	105.3
OVERALL PROCESS RATES					
Steam/Coal Ratio, MAF**	lb/lb	---	---	---	0
Oxygen/Coal Ratio, MAF	lb/lb	---	---	---	0.99
Total Moisture/Coal Ratio, MAF	lb/lb	---	---	---	0.21
SOLIDS ANALYSIS					
Ash Content - Fines	%	10.40	13.48	12.32	15.81
Ash Content - Feedstock	%	10.40	11.40	12.32	2.80
Ash Content - Bed	%	21.21	20.61	54.43	8.69
Ash Content - Agglomerate	%	74.93	77.62	92.00	23.09

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

Kentucky FMC char as the feedstock, an ash concentration of 92 percent was attained in the boot with a freeboard temperature of 1770°F. During Set Point 4, an ash concentration of 23 percent was obtained in the boot with Wyoming Sub-C coal as feedstock with a freeboard temperature of 1675°F based on total fines being recycled. This percentage represents a carbon utilization of over 97 percent.* As Table 3.1-2 shows, product gas heating values (HHV, dry basis) produced during the test ranged from 39.7 Btu/scf to 105.3 Btu/scf.

Highlights of Test TP-015-1 include:

- Achieved 196 hours of hot operation with direct coal or char feed
- Checked out all modified hardware
- Demonstrated carbon utilization of greater than 90 percent
- Found reactor free of material after the test
- Obtained a product gas higher heating value of 105 Btu/scf (dry basis) for Sub-C coal feed with no utility steam input and a reactor exit temperature of 1675°F.

Flow streams for TP-015-1 are shown in Figure 3.1-1, and heat and material balance data are given in Tables 3.1-3, -4, -5 and -6 for the four steady-state set points.

3.1.1.2 Work Accomplished - Gasifier Test TP-016

Test TP-016 was conducted from April 26 to May 2, 1978. The purpose of this test was to evaluate the operating characteristics of the gasifier while feeding a highly-caking Pittsburgh Seam coal feedstock. The coal was fed directly to the gasifier without the benefit of pre-treatment or devolatilization.

The coal feedstock for this test was an unwashed, run-of-mine coal supplied from a strip mine located at Adamsburg, Pennsylvania. A total of 141 hours of gasifier operation was logged in this test: 113 hours with the Adamsburg coal and 28 hours with coke breeze.

During Set Point number 1, a decision was implemented to deviate from the original test plan to a new experimental design effort to explore the product gas heating value dependance on gasifier temperature and steam flow rate. The experimental design presented in Table 3.1-7 shows the points achieved in TP-016.

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*All fines collected by the PDU roughing cyclone are recycled to the gasifier and consumed. Because of inherent cyclone inefficiencies, some of the fines are lost to the quench system. These quantities are reported in the heat and material balances which follow. However, the carbon utilization figures quoted in this and previous reports assume that no carbon is lost in the water system. These figures are considered a more realistic estimate of the process performance for a larger plant in which fines collection is more efficient.

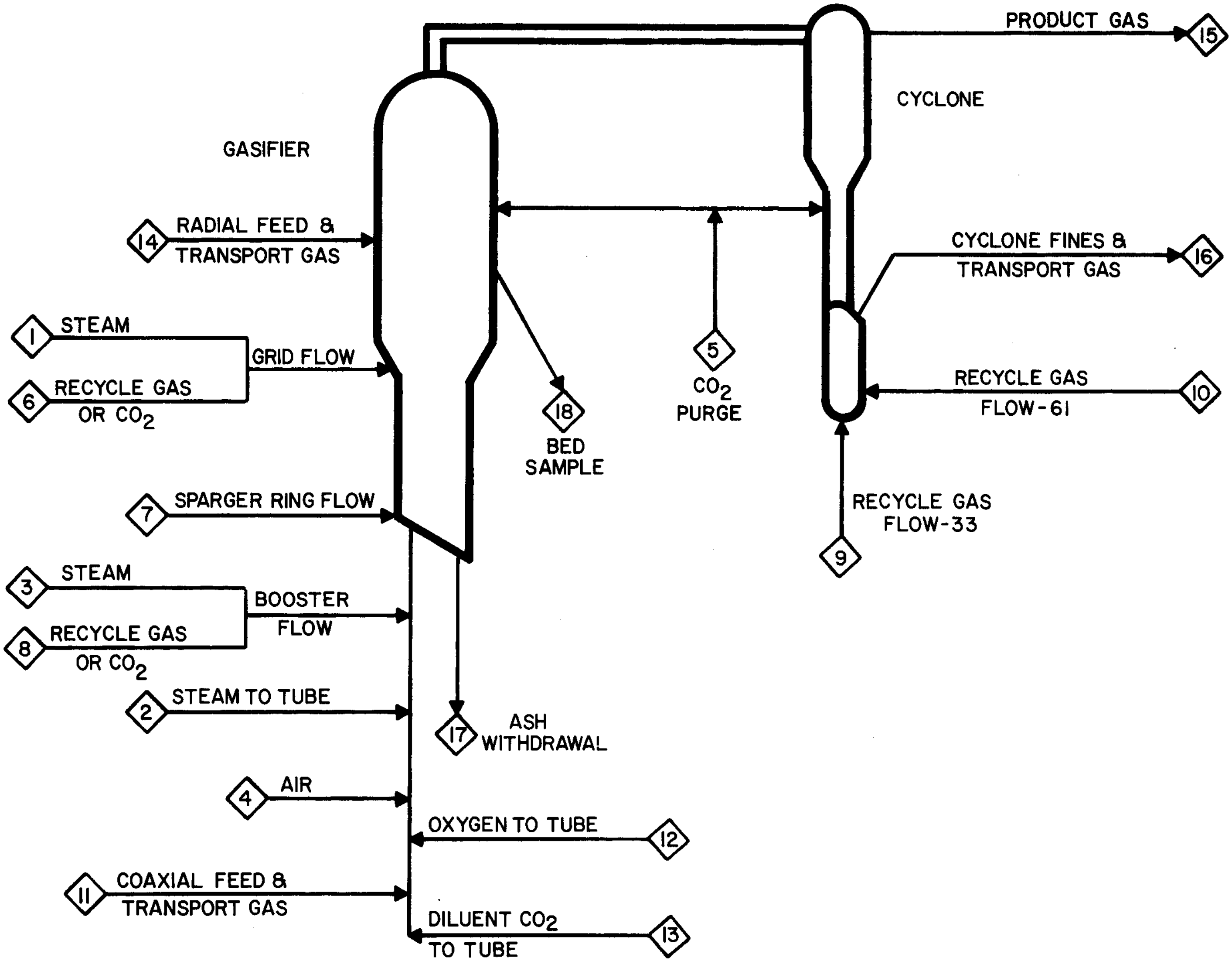


Figure 3.1-1. Heat and Material Balance Flow Schematic, Tests TP-015, -016, -017 and -018

TABLE 3.1-3

GASIFIER HEAT AND MATERIAL BALANCES

TEST TP-015-1 - SET POINT 1

STREAM NO.	1	2	3	4	5	6	7	8	9	10
STREAM DESCRIPTION	STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING FLOW	BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-61)
TOTAL LB/HR	0.00	0.00	325.00	2740.00	443.00	498.53	1172.40	0.00	1376.25	184.84
TEMPERATURE F	406.0	208.0	552.0	1006.0	117.0	151.0	600.0	151.0	151.0	300.0
GAS LB/HR	0.00	0.00	325.00	2740.00	443.00	498.53	1172.40	0.00	1376.25	184.84
SOLID LB/HR	0.00	0.00	0.00	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	0.00	0.00	0.00
MOLECULAR WEIGHT	18.016	18.016	18.016	28.963	44.011	31.237	31.237	31.237	31.237	31.237
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	9.69	9.69	9.69	9.69	9.69
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	25.11	25.11	25.11	25.11	25.11
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	3.01	3.01	3.01	3.01	3.01
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	0.00	0.00	78.06	0.00	62.07	62.07	62.07	62.07	62.07
O2 VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00
AR VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00
H2O VOLUME %	100.00	100.00	100.00	0.00	0.00	0.12	0.12	0.12	0.12	0.12
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	120.899	66.704	156.868	0.000	184.144	24.731
HYDROGEN LB/HR	0.000	0.000	36.368	0.000	0.000	1.007	2.368	0.000	2.780	0.373
OXYGEN LB/HR	0.000	0.000	288.632	635.730	322.101	153.290	360.492	0.000	423.172	56.834
NITROGEN LB/HR	0.000	0.000	0.000	2068.746	0.000	277.532	652.671	0.000	766.153	102.899
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	35.524	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	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	0.000	0.000	71.007	636.518	3.708	256.065	735.075	0.000	706.892	101.684

(Continued)

TABLE 3.1-3 (Continued)

STREAM NO.	11	12	13	14	15	16	17	18		
STREAM DESCRIPTION	COAXIAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	RADIAL FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL LB/HR	857.85	0.00	0.00	980.35	7509.04	1593.35	61.90	9.00	0.00	-6.94
TEMPERATURE F	303.0	1006.0	1006.0	221.0	1060.0	420.0	476.0	1900.0	0.0	0.0
GAS LB/HR	560.85	0.00	0.00	645.35	7434.04	1453.35	0.00	0.00	0.00	0.00
SOLID LB/HR	297.00	0.00	0.00	335.00	75.00	140.00	61.90	9.00	0.00	0.00
LIQUID LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT	31.237	32.000	44.011	31.237	30.341	31.237	0.000	0.000	0.000	0.000
CO VOLUME %	9.69	0.00	0.00	9.69	9.16	9.69	0.00	0.00	0.00	0.00
CO2 VOLUME %	25.11	0.00	100.00	25.11	22.92	25.11	0.00	0.00	0.00	0.00
H2 VOLUME %	3.01	0.00	0.00	3.01	2.92	3.01	0.00	0.00	0.00	0.00
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	62.07	0.00	0.00	62.07	59.20	62.07	0.00	0.00	0.00	0.00
O2 VOLUME %	0.00	100.00	0.00	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	0.00	0.00	0.00
H2O VOLUME %	0.12	0.00	0.00	0.12	5.80	0.12	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	333.135	0.000	0.000	377.463	1010.251	318.248	15.667	6.954	0.000	-6.897
HYDROGEN LB/HR	3.509	0.000	0.000	3.983	43.366	3.481	0.217	0.022	0.000	6.552
OXYGEN LB/HR	173.847	0.000	0.000	200.007	2383.283	446.880	0.000	0.000	0.000	-8.265
NITROGEN LB/HR	314.184	0.000	0.000	361.474	4064.121	809.777	0.068	0.056	0.000	-7.271
SULFUR LB/HR	2.287	0.000	0.000	2.579	0.548	1.022	0.192	5.940	0.000	-58.256
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH LB/HR	30.888	0.000	0.000	34.840	7.470	13.944	46.382	1.999	0.000	-6.187
HEAT CONTENT KBTU/HR	4132.151	0.000	0.000	4649.336	6552.028	2645.521	241.907	136.072	425.000	11.440

TABLE 3.1-4

GASIFIER HEAT AND MATERIAL BALANCES

TEST TP-015-1 - SET POINT 2

STREAM NO.	1	2	3	4	5	6	7	8	9	10
STREAM DESCRIPTION	STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING FLOW	BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-61)
TOTAL LB/HR	0.00	0.00	250.00	2950.00	426.00	438.39	1066.78	0.00	1401.15	180.45
TEMPERATURE F	383.0	210.0	553.1	1006.0	117.5	142.3	600.2	142.3	142.3	295.0
GAS LB/HR	0.00	0.00	250.00	2950.00	426.00	438.39	1066.78	0.00	1401.15	180.45
SOLID LB/HR	0.00	0.00	0.00	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	0.00	0.00	0.00
MOLECULAR WEIGHT	18.016	18.016	18.016	28.963	44.011	31.548	31.548	31.548	31.548	31.548
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	8.95	8.95	8.95	8.95	8.95
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	26.44	26.44	26.44	26.44	26.44
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	2.65	2.65	2.65	2.65	2.65
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	0.00	0.00	78.06	0.00	61.89	61.89	61.89	61.89	61.89
O2 VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00
AR VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00
H2O VOLUME %	100.00	100.00	100.00	0.00	0.00	0.07	0.07	0.07	0.07	0.07
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	116.259	59.077	143.758	0.000	188.816	24.317
HYDROGEN LB/HR	0.000	0.000	27.975	0.000	0.000	0.761	1.851	0.000	2.432	0.313
OXYGEN LB/HR	0.000	0.000	222.025	684.454	309.741	137.637	334.927	0.000	439.904	56.654
NITROGEN LB/HR	0.000	0.000	0.000	2227.299	0.000	240.915	586.246	0.000	769.995	99.166
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	38.247	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	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	0.000	0.000	54.753	685.302	3.611	203.525	617.907	0.000	650.492	90.478

(Continued)

TABLE 3.1-4 (Continued)

STREAM NO.	11	12	13	14	15	16	17	18		
STREAM DESCRIPTION	COAXIAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	RADIAL FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL LB/HR	985.69	0.00	0.00	1105.51	7212.41	1841.09	66.90	9.00	0.00	-3.70
TEMPERATURE F	294.0	1006.0	1006.0	215.0	1062.4	420.0	480.0	1901.2	0.0	0.0
GAS LB/HR	557.59	0.00	0.00	673.51	7152.41	1427.79	0.00	0.00	0.00	0.00
SOLID LB/HR	428.10	0.00	0.00	432.00	60.00	413.30	66.90	9.00	0.00	0.00
LIQUID LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT	31.548	32.000	44.011	31.548	30.786	31.548	0.000	0.000	0.000	0.000
CO VOLUME %	8.95	0.00	0.00	8.95	9.08	8.95	0.00	0.00	0.00	0.00
CO2 VOLUME %	26.44	0.00	100.00	26.44	24.38	26.44	0.00	0.00	0.00	0.00
H2 VOLUME %	2.65	0.00	0.00	2.65	2.76	2.65	0.00	0.00	0.00	0.00
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	61.89	0.00	0.00	61.89	59.66	61.89	0.00	0.00	0.00	0.00
O2 VOLUME %	0.00	100.00	0.00	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	0.00	0.00	0.00
H2O VOLUME %	0.07	0.00	0.00	0.07	4.11	0.07	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	442.664	0.000	0.000	458.436	984.925	544.166	14.611	7.034	0.000	-8.191
HYDROGEN LB/HR	4.821	0.000	0.000	2.681	32.395	3.925	0.207	0.072	0.000	10.371
OXYGEN LB/HR	176.860	0.000	0.000	211.454	2303.233	448.268	0.000	0.000	0.000	-6.910
NITROGEN LB/HR	309.249	0.000	0.000	371.764	3883.358	786.207	0.060	0.028	0.000	-1.412
SULFUR LB/HR	3.296	0.000	0.000	2.938	0.408	2.810	0.214	0.058	0.000	44.000
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH LB/HR	48.803	0.000	0.000	58.234	8.088	55.713	52.349	1.867	0.000	-10.258
HEAT CONTENT KBTU/HR	5754.725	0.000	0.000	5652.381	5983.301	5875.253	226.916	109.098	425.000	7.975

TABLE 3.1-5
GASIFIER HEAT AND MATERIAL BALANCES
TEST TP-015-1 - SET POINT 3

STREAM NO.	1	2	3	4	5	6	7	8	9	10
STREAM DESCRIPTION	STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING FLOW	BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-61)
TOTAL LB/HR	0.00	0.00	280.00	3550.00	426.00	409.34	899.30	0.00	1152.55	159.19
TEMPERATURE F	370.0	221.0	535.3	1004.0	121.0	165.0	600.0	165.0	165.0	238.0
GAS LB/HR	0.00	0.00	280.00	3550.00	426.00	409.34	899.30	0.00	1152.55	159.19
SOLID LB/HR	0.00	0.00	0.00	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	0.00	0.00	0.00
MOLECULAR WEIGHT	18.016	18.016	18.016	28.963	44.011	29.918	29.918	29.918	29.918	29.918
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	18.82	18.82	18.82	18.82	18.82
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	21.50	21.50	21.50	21.50	21.50
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	5.84	5.84	5.84	5.84	5.84
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	0.00	0.00	78.06	0.00	53.68	53.68	53.68	53.68	53.68
O2 VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00
AR VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00
H2O VOLUME %	100.00	100.00	100.00	0.00	0.00	0.16	0.16	0.16	0.16	0.16
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	116.259	66.253	145.556	0.000	186.546	25.765
HYDROGEN LB/HR	0.000	0.000	31.332	0.000	0.000	1.655	3.636	0.000	4.660	0.644
OXYGEN LB/HR	0.000	0.000	248.668	823.665	309.741	135.662	298.044	0.000	381.977	52.757
NITROGEN LB/HR	0.000	0.000	0.000	2680.309	0.000	205.767	452.064	0.000	579.369	80.021
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	46.026	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	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	0.000	0.000	58.929	822.818	3.926	420.673	1025.935	0.000	1184.471	166.514

(Continued)

TABLE 3.1-5 (Continued)

STREAM NO.	11	12	13	14	15	16	17	18		
STREAM DESCRIPTION	COAXIAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	RADIAL FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL LB/HR	1269.70	0.00	0.00	923.24	7596.13	1519.07	81.60	9.00	0.00	-1.50
TEMPERATURE F	203.0	1004.0	1004.0	228.0	1047.0	420.0	502.0	1835.0	0.0	0.0
GAS LB/HR	512.70	0.00	0.00	621.24	7457.13	1199.07	0.00	0.00	0.00	0.00
SOLID LB/HR	757.00	0.00	0.00	302.00	139.00	320.00	81.60	9.00	0.00	0.00
LIQUID LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT	29.918	32.000	44.011	29.918	29.401	29.918	0.000	0.000	0.000	0.000
CO VOLUME %	18.82	0.00	0.00	18.82	18.05	18.82	0.00	0.00	0.00	0.00
CO2 VOLUME %	21.50	0.00	100.00	21.50	20.26	21.50	0.00	0.00	0.00	0.00
H2 VOLUME %	5.84	0.00	0.00	5.84	5.78	5.84	0.00	0.00	0.00	0.00
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	53.68	0.00	0.00	53.68	52.42	53.68	0.00	0.00	0.00	0.00
O2 VOLUME %	0.00	100.00	0.00	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	0.00	0.00	0.00
H2O VOLUME %	0.16	0.00	0.00	0.16	3.50	0.16	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	679.121	0.000	0.000	338.376	1280.753	456.411	6.381	3.862	0.000	-12.166
HYDROGEN LB/HR	12.368	0.000	0.000	6.619	48.134	6.416	0.171	0.030	0.000	10.116
OXYGEN LB/HR	204.893	0.000	0.000	219.843	2518.952	398.801	0.000	0.045	0.000	-9.066
NITROGEN LB/HR	269.159	0.000	0.000	316.848	3725.573	605.152	0.449	0.027	0.000	5.505
SULFUR LB/HR	10.901	0.000	0.000	4.349	1.807	4.160	0.449	0.138	0.000	57.025
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH LB/HR	93.262	0.000	0.000	37.206	20.906	48.128	75.072	4.899	0.000	-14.207
HEAT CONTENT										
KBTU/HR	9505.641	0.000	0.000	4229.790	11040.151	5160.152	111.021	61.398	425.000	3.565

ERROR IN 13. TOTAL PERCENT IS 166.340

TABLE 3.1-6

GASIFIER HEAT AND MATERIAL BALANCES

TEST TP-015-1 - SET POINT 4

STREAM NO.	1	2	3	4	5	6	7	8	9	10
STREAM DESCRIPTION	STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING FLOW	BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-61)
TOTAL LB/HR	0.00	0.00	0.00	3900.00	400.00	403.88	1216.67	303.51	1060.17	117.12
TEMPERATURE F	58.0	103.1	48.7	945.0	123.6	195.7	696.6	195.7	195.7	270.0
GAS LB/HR	0.00	0.00	0.00	3900.00	400.00	403.88	1216.67	303.51	1060.17	117.12
SOLID LB/HR	0.00	0.00	0.00	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	0.00	0.00	0.00
MOLECULAR WEIGHT	18.016	18.016	18.016	28.963	44.011	28.545	28.545	28.545	28.545	28.545
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	21.81	21.81	21.81	21.81	21.81
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	16.78	16.78	16.78	16.78	16.78
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	7.79	7.79	7.79	7.79	7.79
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.92	0.92	0.92	0.92	0.92
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	0.00	0.00	78.06	0.00	52.52	52.52	52.52	52.52	52.52
O2 VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00
AR VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00
H2O VOLUME %	100.00	100.00	100.00	0.00	0.00	0.18	0.18	0.18	0.18	0.18
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	109.164	67.139	202.256	50.455	176.240	19.470
HYDROGEN LB/HR	0.000	0.000	0.000	0.000	0.000	2.797	8.425	2.102	7.342	0.811
OXYGEN LB/HR	0.000	0.000	0.000	904.871	290.836	125.756	378.841	94.506	330.110	36.469
NITROGEN LB/HR	0.000	0.000	0.000	2944.565	0.000	208.183	627.152	156.450	546.481	60.373
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	50.564	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	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	0.000	0.000	0.000	843.615	3.907	573.294	1892.373	430.830	1504.895	168.530

(Continued)

TABLE 3.1-6 (Continued)

STREAM NO.	11	12	13	14	15	16	17	18		
STREAM DESCRIPTION	COAXIAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	RADIAL FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH- DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL LB/HR	1932.75	0.00	0.00	802.16	8822.50	1564.17	25.00	9.00	0.00	-2.81
TEMPERATURE F	141.0	945.0	945.0	266.7	1021.0	420.0	462.5	1727.0	0.0	0.0
GAS LB/HR	807.75	0.00	0.00	538.16	8698.50	1164.17	0.00	0.00	0.00	0.00
SOLID LB/HR	1125.00	0.00	0.00	264.00	124.00	400.00	25.00	9.00	0.00	0.00
LIQUID LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT	28.545	32.000	44.011	28.545	28.120	28.545	0.000	0.000	0.000	0.000
CO VOLUME %	21.81	0.00	0.00	21.81	20.87	21.81	0.00	0.00	0.00	0.00
CO2 VOLUME %	16.78	0.00	100.00	16.78	16.12	16.78	0.00	0.00	0.00	0.00
H2 VOLUME %	7.79	0.00	0.00	7.79	7.74	7.79	0.00	0.00	0.00	0.00
CH4 VOLUME %	0.92	0.00	0.00	0.92	0.96	0.92	0.00	0.00	0.00	0.00
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	52.52	0.00	0.00	52.52	50.85	52.52	0.00	0.00	0.00	0.00
O2 VOLUME %	0.00	100.00	0.00	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	0.00	0.00	0.00
H2O VOLUME %	0.18	0.00	0.00	0.18	3.45	0.18	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	943.266	0.000	0.000	305.177	1511.452	520.368	18.948	7.615	0.000	-9.888
HYDROGEN LB/HR	57.906	0.000	0.000	5.100	82.369	10.142	0.080	0.071	0.000	-9.682
OXYGEN LB/HR	466.388	0.000	0.000	170.818	2801.443	367.413	0.000	0.443	0.000	-13.246
NITROGEN LB/HR	431.329	0.000	0.000	278.064	4407.034	601.088	0.075	0.067	0.000	4.652
SULFUR LB/HR	2.250	0.000	0.000	1.267	0.595	1.920	0.125	0.022	0.000	24.295
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH LB/HR	31.500	0.000	0.000	41.738	19.604	63.240	5.727	0.782	0.000	-22.004
HEAT CONTENT KBTU/HR	14616.066	0.000	0.000	3913.875	15740.926	6492.002	275.909	114.015	425.000	3.756

TABLE 3.1-7

EXPERIMENTAL DESIGN FOR TP-016

Steam Input (lb/hr)	Reactor Temperature (^oF)			
	1650	1750	1800	1850
125				
250			TP-016	TP-016
500		TP-016		

The heating values observed during TP-016 ranged from 76 to 86 Btu/scf (HHV, dry basis).

The following accomplishments were achieved during this test:

- Demonstrated gasifier operability with a highly-caking Pittsburgh seam coal
- Post-test inspection showed no material buildup on the walls or internals of the gasifier
- No measurable tars or oils were detected in solid or liquid samples taken during the test
- Demonstrated carbon utilization greater than 90 percent.

A chronology of the key events of TP-016 is given in Table 3.1-8 and steady-state point operating data are presentd in Table 3.1-9. Flow streams for TP-016 are shown in Figure 3.1-1, and heat and material balance data are given in Tables 3.1-10, -11, -12 and -13 for the four steady-state set points.

3.1.1.3 Work Accomplished - Gasifier Test TP-017

Test TP-017 was conducted from May 5 to May 25, 1978. This test was a continuation of the single-stage gasifier evaluation studies begun during TP-015. Basically the experimental design started during TP-016 was completed during TP-017. These data provide a basis for identifying the relative sensitivity of single-stage gasification to temperature and steam throughput. Five set points were run in which over 100 hours of operation were logged with the Pittsburgh seam coal from the Adamsburg mine used during TP-016. This coal has a free swelling index of 7-1/2, and a Gieseler plasticity of 31,000 ddm. Significant accomplishments of the test include the following:

- Processed a highly-caking Pittsburgh seam coal for 160 hours
- Demonstrated carbon utilization greater than 90 percent
- Demonstrated a reactor output range of 4:1, based on the calorific heating value of the gas
- Produced data to evaluate the relative sensitivity of the product gas heating value to gasifier temperature and steam flow.

TABLE 3.1-8

CHRONOLOGY OF EVENTS, TP-016

Date	Time	Events
April 25	0500	Started pressurization to 200 psig.
	1230	Acceptable pressure-leak rate attained.
	2040	Started hot-air heatup.
April 27	0300	Started coke breeze feed to build bed.
	0930	Achieved autogenous combustion of coke breeze.
	0600	Achieved Set Point No. 1 conditions.
April 29	0930	Changed system pressure from 200 psig to 230 psi.
	1100	Achieved Set Point No. 2 conditions.
	1710	Terminated Set Point No. 2.
	2100	Achieved Set Point No. 3 conditions.
April 30	1715	Terminated Set Point No. 3.
May 1	0100 to 1835	Experienced intermittent operational problems.
	1835	Unit lined out.
May 2	0100	Achieved Set Point No. 4 conditions.
	1800	Terminated Set Point No. 4. Started ramping to high steam/high temperature set point.
	2330	Terminated efforts because of wet material packing starwheel feeder.
May 3	1330	Initiated shutdown.

TABLE 3.1-9

SUMMARY OF OPERATING DATA FOR MODIFIED GASIFIER TEST TP-016-1

SET POINT		1	2	3	4
TEST RUN DATE AND TIME (1978)	Unit	April 28, 29 1900 to 0800 Hours	April 29 1300 to 1730 Hours	April 29, 30 2130 to 0700 Hours	May 2 0400 to 0830 Hours
MEASURED GASIFIER PARAMETERS					
TE-504-4 Freeboard Temperature	°F	1807	1796	1867	1743
TE-507-3 Gasifier Bed Temperature	°F	1871	1860	1930	1760
TE-504-10 Ash Annulus Temperature	°F	419	459	444	452
Average Bed Height	feet	23.5	22.3	24.3	21.7
System Pressure	psig	199	229	229	229
Average Gasifier Bed Density	lb/ft^3	10.11	8.7	14.25	8.86
Average Ash Annulus Density	lb/ft^3	21.83	13.97	20.9	12.18
Freeboard Gas Velocity	fps	1.60	1.40	1.61	1.48
Oxidant Tube Velocity	fps	87.04	69.55	89.47	80.00
Coal Feed Material		Pgh. Seam Coal	Pgh. Seam Coal	Pgh. Seam Coal	Pgh. Seam Coal
Coal Feed Rate, WR-27	lb/hr	763	670	803	770
Fines Feed Material		Recycled Fines	Recycled Fines	Recycled Fines	Recycled Fines
Fines Feed Rate, WR-14	lb/hr	156	150	230	208
Cyclone Collection Rate, WR-19	lb/hr	223	100	276	212
Carryover to Water System*	lb/hr	105	210	125	43
Ash Withdrawal Rate	lb/hr	68	67	81	84
PRODUCT GAS ANALYSIS, DRY BASIS					
Carbon Monoxide	%	16.69	16.52	17.42	12.75
Carbon Dioxide	%	16.59	14.81	14.00	19.11
Methane	%	0.60	0.63	0.39	0.92
Nitrogen	%	57.94	60.13	60.89	52.73
Oxygen	%	0.0	0.0	0.0	0.0
Hydrogen	%	8.22	7.87	7.52	7.68
HVV, Dry Basis (Gas Chromatograph)	Btu/scf	86.1	84.8	84.9	76.5
OVERALL PROCESS RATES					
Steam/Coal Ratio, MAF**	lb/lb	0.37	0.41	0.34	0.79
Oxygen/Coal Ratio, MAF	lb/lb	1.01	1.05	1.13	1.05
Total Moisture/Coal Ratio, MAF	lb/lb	0.39	0.44	0.37	0.81
SOLIDS ANALYSIS					
Ash Content - Fines	%	15.43	18.37	19.8	22.9
Ash Content - Feedstock	%	9.45	9.45	9.45	9.45
Ash Content - Bed	%	21.32	23.19	19.74	26.37
Ash Content - Agglomerate	%	51.21	46.78	48.20	51.30

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

TABLE 3.1-10

GASIFIER HEAT AND MATERIAL BALANCES

TEST TP-016 - SET POINT 1

STREAM NO.	1	2	3	4	5	6	7	8	9	10
STREAM DESCRIPTION	STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING FLOW	BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-61)
TOTAL LB/HR	0.00	0.00	248.00	2928.00	305.00	423.90	882.54	0.00	735.45	103.17
TEMPERATURE F	0.0	0.0	492.0	1003.0	120.0	198.0	597.0	198.0	198.0	229.0
GAS LB/HR	0.00	0.00	248.00	2928.00	305.00	423.90	882.54	0.00	735.45	103.17
SOLID LB/HR	0.00	0.00	0.00	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	0.00	0.00	0.00
MOLECULAR WEIGHT	18.016	18.016	18.016	28.963	44.011	29.214	29.214	29.214	29.214	29.214
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	15.58	15.58	15.58	15.58	15.58
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	20.98	20.98	20.98	20.98	20.98
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	7.71	7.71	7.71	7.71	7.71
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.60	0.60	0.60	0.60	0.60
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	0.00	0.00	78.06	0.00	54.60	54.60	54.60	54.60	54.60
O2 VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00
AR VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00
H2O VOLUME %	100.00	100.00	100.00	0.00	0.00	0.40	0.40	0.40	0.40	0.40
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	83.237	64.747	134.799	0.000	112.332	15.758
HYDROGEN LB/HR	0.000	0.000	27.751	0.000	0.000	2.722	5.666	0.000	4.722	0.662
OXYGEN LB/HR	0.000	0.000	220.249	679.349	221.763	134.489	279.996	0.000	233.330	32.731
NITROGEN LB/HR	0.000	0.000	0.000	2210.689	0.000	221.945	462.074	0.000	385.062	54.016
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	37.962	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	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	0.000	0.000	47.062	677.882	2.746	459.059	1049.732	0.000	796.439	112.547

(Continued)

TABLE 3.1-10 (Continued)

STREAM NO.	11	12	13	14	15	16	17	18		
STREAM DESCRIPTION	COAXIAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	RADIAL FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL LB/HR	1177.71	0.00	0.00	557.43	7104.72	1056.51	68.00	0.00	0.00	-11.79
TEMPERATURE F	161.0	1003.0	1003.0	325.0	1533.0	250.0	444.0	0.0	0.0	0.0
GAS LB/HR	414.71	0.00	0.00	401.43	6999.72	833.51	0.00	0.00	0.00	0.00
SOLID LB/HR	763.00	0.00	0.00	156.00	105.00	223.00	68.00	0.00	0.00	0.00
LIQUID LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT	29.214	32.000	44.011	29.214	27.424	29.214	0.000	0.000	0.000	0.000
CO VOLUME %	15.58	0.00	0.00	15.58	15.02	15.58	0.00	0.00	0.00	0.00
CO2 VOLUME %	20.98	0.00	100.00	20.98	14.93	20.98	0.00	0.00	0.00	0.00
H2 VOLUME %	7.71	0.00	0.00	7.71	7.40	7.71	0.00	0.00	0.00	0.00
CH4 VOLUME %	0.60	0.00	0.00	0.60	0.54	0.60	0.00	0.00	0.00	0.00
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	54.60	0.00	0.00	54.60	52.15	54.60	0.00	0.00	0.00	0.00
O2 VOLUME %	0.00	100.00	0.00	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	0.00	0.00	0.00
H2O VOLUME %	0.40	0.00	0.00	0.40	9.98	0.40	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	655.736	0.000	0.000	186.832	1019.485	306.736	31.008	0.000	0.000	-8.280
HYDROGEN LB/HR	41.499	0.000	0.000	3.716	95.755	6.979	0.340	0.000	0.000	-18.832
OXYGEN LB/HR	185.517	0.000	0.000	129.746	2242.542	267.853	0.476	0.000	0.000	-18.596
NITROGEN LB/HR	229.874	0.000	0.000	211.303	3729.552	438.009	0.240	0.000	0.000	-10.409
SULFUR LB/HR	10.987	0.000	0.000	1.763	1.187	2.520	1.088	0.000	0.000	62.397
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH LB/HR	54.097	0.000	0.000	24.071	16.201	34.409	34.823	0.000	0.000	-9.295
HEAT CONTENT KBTU/HR	11090.505	0.000	0.000	2301.274	11850.424	3559.698	468.740	0.000	425.000	1.411

TABLE 3.1-11

GASIFIER HEAT AND MATERIAL BALANCES

TEST TP-016 - SET POINT 2

STREAM NO.	1	2	3	4	5	6	7	8	9	10
STREAM DESCRIPTION	STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING FLOW	BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-61)
TOTAL LB/HR	0.00	0.00	246.00	2668.00	305.00	415.54	1080.81	0.00	902.72	78.81
TEMPERATURE F	0.0	0.0	501.0	1003.0	123.0	212.0	597.0	212.0	212.0	185.0
GAS LB/HR	0.00	0.00	246.00	2668.00	305.00	415.54	1080.81	0.00	902.72	78.81
SOLID LB/HR	0.00	0.00	0.00	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	0.00	0.00	0.00
MOLECULAR WEIGHT	18.016	18.016	18.016	28.963	44.011	29.331	29.331	29.331	29.331	29.331
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	15.40	15.40	15.40	15.40	15.40
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	20.73	20.73	20.73	20.73	20.73
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	7.30	7.30	7.30	7.30	7.30
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.61	0.61	0.61	0.61	0.61
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	0.00	0.00	78.06	0.00	55.65	55.65	55.65	55.65	55.65
O2 VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00
AR VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00
H2O VOLUME %	100.00	100.00	100.00	0.00	0.00	0.32	0.32	0.32	0.32	0.32
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	83.237	62.519	162.611	0.000	135.817	11.857
HYDROGEN LB/HR	0.000	0.000	27.528	0.000	0.000	2.524	6.564	0.000	5.482	0.479
OXYGEN LB/HR	0.000	0.000	218.472	619.025	221.763	129.633	337.175	0.000	281.617	24.586
NITROGEN LB/HR	0.000	0.000	0.000	2014.385	0.000	220.861	574.456	0.000	479.802	41.887
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	34.591	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	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	0.000	0.000	47.737	617.687	2.940	440.015	1255.292	0.000	955.894	82.906

(Continued)

TABLE 3.1-11 (Continued)

STREAM NO.	11	12	13	14	15	16	17	18		
STREAM DESCRIPTION	COAXIAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	RADIAL FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL LB/HR	1120.34	0.00	0.00	598.29	7184.91	1134.75	67.00	0.00	0.00	-13.10
TEMPERATURE F	173.0	1003.0	1003.0	322.0	1522.0	250.0	463.0	1858.0	0.0	0.0
GAS LB/HR	450.34	0.00	0.00	448.29	6974.91	1034.75	0.00	0.00	0.00	0.00
SOLID LB/HR	670.00	0.00	0.00	150.00	210.00	100.00	67.00	0.00	0.00	0.00
LIQUID LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT	29.331	32.000	44.011	29.331	27.539	29.331	0.000	0.000	0.000	0.000
CO VOLUME %	15.40	0.00	0.00	15.40	15.36	15.40	0.00	0.00	0.00	0.00
CO2 VOLUME %	20.73	0.00	100.00	20.73	13.77	20.73	0.00	0.00	0.00	0.00
H2 VOLUME %	7.30	0.00	0.00	7.30	7.32	7.30	0.00	0.00	0.00	0.00
CH4 VOLUME %	0.61	0.00	0.00	0.61	0.59	0.61	0.00	0.00	0.00	0.00
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	55.65	0.00	0.00	55.65	55.92	55.65	0.00	0.00	0.00	0.00
O2 VOLUME %	0.00	100.00	0.00	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	0.00	0.00	0.00
H2O VOLUME %	0.32	0.00	0.00	0.32	7.04	0.32	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	587.942	0.000	0.000	183.366	1066.377	232.961	35.644	0.000	0.000	-8.770
HYDROGEN LB/HR	36.838	0.000	0.000	3.743	80.806	6.964	0.315	0.000	0.000	-5.926
OXYGEN LB/HR	187.858	0.000	0.000	142.701	2027.429	324.706	0.429	0.000	0.000	-8.772
NITROGEN LB/HR	250.546	0.000	0.000	239.349	3969.518	550.697	0.389	0.000	0.000	-18.301
SULFUR LB/HR	9.648	0.000	0.000	1.575	2.205	1.050	0.864	0.000	0.000	63.296
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH LB/HR	47.503	0.000	0.000	27.555	38.577	18.370	31.343	0.000	0.000	-17.628
HEAT CONTENT KBTU/HR	9821.685	0.000	0.000	2193.358	13013.390	2241.626	532.431	0.000	425.000	-5.156

TABLE 3.1-12

GASIFIER HEAT AND MATERIAL BALANCES

TEST TP-016 - SET POINT 3

STREAM NO.	1	2	3	4	5	6	7	8	9	10
STREAM DESCRIPTION	STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING FLOW	BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-61)
TOTAL LB/HR	0.00	0.00	244.00	3458.00	305.00	406.78	1070.20	0.00	766.89	102.45
TEMPERATURE F	0.0	0.0	511.0	992.0	120.0	204.0	597.0	204.0	204.0	289.0
GAS LB/HR	0.00	0.00	244.00	3458.00	305.00	406.78	1070.20	0.00	766.89	102.45
SOLID LB/HR	0.00	0.00	0.00	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	0.00	0.00	0.00
MOLECULAR WEIGHT	18.016	18.016	18.016	28.963	44.011	28.812	28.812	28.812	28.812	28.812
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	16.50	16.50	16.50	16.50	16.50
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	18.17	18.17	18.17	18.17	18.17
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	7.16	7.16	7.16	7.16	7.16
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.35	0.35	0.35	0.35	0.35
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	0.00	0.00	78.06	0.00	56.94	56.94	56.94	56.94	56.94
O2 VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00
AR VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00
H2O VOLUME %	100.00	100.00	100.00	0.00	0.00	0.24	0.24	0.24	0.24	0.24
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	83.237	59.375	156.212	0.000	111.940	14.955
HYDROGEN LB/HR	0.000	0.000	27.304	0.000	0.000	2.306	6.068	0.000	4.348	0.581
OXYGEN LB/HR	0.000	0.000	216.696	802.319	221.763	119.889	315.418	0.000	226.025	30.196
NITROGEN LB/HR	0.000	0.000	0.000	2610.848	0.000	225.205	592.498	0.000	424.577	56.723
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	44.833	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	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	0.000	0.000	48.514	790.590	2.746	439.992	1269.446	0.000	829.511	113.075

(Continued)

TABLE 3.1-12 (Continued)

STREAM NO.	11	12	13	14	15	16	17	18		
STREAM DESCRIPTION	COAXIAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	RADIAL FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL LB/HR	1293.97	0.00	0.00	804.15	8013.88	1133.17	81.00	0.00	0.00	-9.19
TEMPERATURE F	182.0	992.0	992.0	289.0	15.8	250.0	461.0	1905.0	0.0	0.0
GAS LB/HR	490.97	0.00	0.00	574.15	7888.88	857.17	0.00	0.00	0.00	0.00
SOLID LB/HR	803.00	0.00	0.00	230.00	125.00	276.00	81.00	0.00	0.00	0.00
LIQUID LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT	28.812	32.000	44.011	28.812	27.665	28.812	0.000	0.000	0.000	0.000
CO VOLUME %	16.50	0.00	0.00	16.50	16.20	16.50	0.00	0.00	0.00	0.00
CO2 VOLUME %	18.17	0.00	100.00	18.17	13.20	18.17	0.00	0.00	0.00	0.00
H2 VOLUME %	7.16	0.00	0.00	7.16	7.09	7.16	0.00	0.00	0.00	0.00
CH4 VOLUME %	0.35	0.00	0.00	0.35	0.37	0.35	0.00	0.00	0.00	0.00
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	56.94	0.00	0.00	56.94	57.42	56.94	0.00	0.00	0.00	0.00
O2 VOLUME %	0.00	100.00	0.00	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	0.00	0.00	0.00
H2O VOLUME %	0.24	0.00	0.00	0.24	5.73	0.24	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	695.114	0.000	0.000	258.446	1114.242	334.684	40.508	0.000	0.000	-7.986
HYDROGEN LB/HR	43.657	0.000	0.000	4.727	78.722	6.627	0.243	0.000	0.000	3.821
OXYGEN LB/HR	201.476	0.000	0.000	173.797	2207.164	258.126	0.000	0.000	0.000	-6.834
NITROGEN LB/HR	285.229	0.000	0.000	319.481	4587.831	476.492	0.389	0.000	0.000	-12.186
SULFUR LB/HR	11.563	0.000	0.000	2.162	1.175	2.594	0.818	0.000	0.000	66.576
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH LB/HR	56.933	0.000	0.000	45.540	24.750	54.648	39.042	0.000	0.000	-15.582
HEAT CONTENT KBTU/HR	11734.888	0.000	0.000	3195.469	9773.078	4009.346	599.468	0.000	425.000	19.634

TABLE 3.1-13

GASIFIER HEAT AND MATERIAL BALANCES

TEST TP-016 - SET POINT 4

STREAM NO.	1	2	3	4	5	6	7	8	9	10
STREAM DESCRIPTION	STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING FLOW	BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-61)
TOTAL LB/HR	286.00	0.00	250.00	3069.00	305.00	0.00	1050.59	0.00	884.82	105.68
TEMPERATURE F	516.0	0.0	522.0	1003.0	127.0	183.0	597.0	183.0	183.0	263.0
GAS LB/HR	286.00	0.00	250.00	3069.00	305.00	0.00	1050.59	0.00	884.82	105.68
SOLID LB/HR	0.00	0.00	0.00	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	0.00	0.00	0.00
MOLECULAR WEIGHT	18.016	18.016	18.016	28.963	44.011	30.057	30.057	30.057	30.057	30.057
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	12.64	12.64	12.64	12.64	12.64
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	26.17	26.17	26.17	26.17	26.17
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	7.73	7.73	7.73	7.73	7.73
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.95	0.95	0.95	0.95	0.95
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	0.00	0.00	78.06	0.00	52.34	52.34	52.34	52.34	52.34
O2 VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00
AR VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00
H2O VOLUME %	100.00	100.00	100.00	0.00	0.00	0.17	0.17	0.17	0.17	0.17
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	83.237	0.000	166.892	0.000	140.558	16.788
HYDROGEN LB/HR	32.004	0.000	27.975	0.000	0.000	0.000	6.899	0.000	5.811	0.694
OXYGEN LB/HR	253.996	0.000	222.025	712.064	221.763	0.000	364.284	0.000	306.803	36.644
NITROGEN LB/HR	0.000	0.000	0.000	2317.146	0.000	0.000	512.519	0.000	431.648	51.555
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	39.790	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	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	57.548	0.000	51.022	710.525	3.199	0.000	1140.626	0.000	863.413	105.292

(Continued)

TABLE 3.1-13 (Continued)

STREAM NO.		11	12	13	14	15	16	17	18		
STREAM DESCRIPTION		COAXIAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	RADIAL FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	1189.51	0.00	0.00	729.15	7749.28	1173.49	84.00	0.00	0.00	-14.45
TEMPERATURE	F	127.0	1003.0	1003.0	266.0	1495.0	250.0	461.0	1794.0	0.0	0.0
GAS	LB/HR	419.51	0.00	0.00	521.15	7706.28	961.49	0.00	0.00	0.00	0.00
SOLID	LB/HR	770.00	0.00	0.00	208.00	43.00	212.00	84.00	0.00	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		30.057	32.000	44.011	30.057	27.698	30.057	0.000	0.000	0.000	0.000
CO	VOLUME %	12.64	0.00	0.00	12.64	12.02	12.64	0.00	0.00	0.00	0.00
CO2	VOLUME %	26.17	0.00	100.00	26.17	18.02	26.17	0.00	0.00	0.00	0.00
H2	VOLUME %	7.73	0.00	0.00	7.73	7.24	7.73	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.95	0.00	0.00	0.95	0.87	0.95	0.00	0.00	0.00	0.00
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	VOLUME %	52.34	0.00	0.00	52.34	49.72	52.34	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	100.00	0.00	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	0.00	0.00	0.00
H2O	VOLUME %	0.17	0.00	0.00	0.17	12.12	0.17	0.00	0.00	0.00	0.00
ELEMENTS											
CARBON	LB/HR	664.470	0.000	0.000	237.664	1065.145	310.593	38.632	0.000	0.000	-7.999
HYDROGEN	LB/HR	41.948	0.000	0.000	4.359	118.549	7.268	0.378	0.000	0.000	-5.436
OXYGEN	LB/HR	199.901	0.000	0.000	182.431	2679.746	335.148	0.000	0.000	0.000	-20.600
NITROGEN	LB/HR	217.513	0.000	0.000	255.694	3875.704	470.535	0.403	0.000	0.000	-14.806
SULFUR	LB/HR	11.088	0.000	0.000	2.642	0.546	2.692	1.789	0.000	0.000	63.381
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH	LB/HR	54.593	0.000	0.000	46.363	9.585	47.255	43.092	0.000	0.000	1.015
HEAT CONTENT	KBTU/HR	11141.561	0.000	0.000	2783.750	11259.826	3261.700	586.926	0.000	425.000	7.851

The completed experimental design is presented in Table 3.1-14.

TABLE 3.1-14

EXPERIMENTAL DESIGN FOR STEAM AND TEMPERATURE EFFECTS

Steam Input (lb/hr)	Reactor Temperature (^oF)			
	1650	1750	1800	1850
125	TP-017			TP-017
250	TP-017	TP-017	TP-016	TP-016
500		TP-016		TP-017

The HHV heating values on the dry basis observed during test TP-017 ranged from 48.1 to 91.3 Btu/scf. An unanticipated result demonstrated by these data is the broad calorific heat production turndown. Because the net gas flow ranges from 2990 to 6000 lb/hr, the calorific heat content of these flows ranges from 1.8 (10^6) to 7.4 (10^6) Btu/hr respectively, which represents a 4:1 turndown. Whereas the results of this parameter study do not constitute a thorough analysis of the load-follow and turndown problem associated with integrated coal gasifier-combined cycle plants, they do indicate that one method of reactor output control with a heating value may be practical. These results were achieved primarily as a result of the ability of the single-stage gasifier to operate successfully over such a wide temperature range with an attendant broad steam input.

A chronology of the key events of TP-017 is given in Table 3.1-15, and steady-state set point operating data are presented in Table 3.1-16. Flow streams are shown in Figure 3.1-1, and Tables 3.1-17 through 3.1-21 present the heat and material balances for the set point conditions.

3.1.1.4 <u>Work Accomplished - Gasifier Test TP-018-1</u>

Test TP-018 was conducted between June 25 and June 29, 1978. This test was a shakedown test for the newly-installed oxygen supply system and the new oxidant tube installed in the gasifier. Because of the lower operating pressure of 150 psig instead of 230 psig used in previous air-blown tests, the physical design of the oxidant tube was changed. Characterization of this new design was one of the goals of the test. In addition to the shakedown aspects, the test was intended to investigate the response of the gasifier with various mixtures of oxygen and steam in the oxidant tube.

The test began on June 25 with pressurization and leak check of the gasifier and associated systems. Following the hot air refractory heatup, the gasifier was charged with coke breeze, and autogenous ignition was achieved at 2100 hours on June 27. For the next 18 hours the reactor temperature was ramped to

TABLE 3.1-15

CHRONOLOGY OF EVENTS, TP-017

Date	Time	Events
May 16	0220	Started pressurization.
May 18	1102	Started coke breeze feed to build bed.
	1400	Achieved autogenous combustion of coke breeze.
May 19	0005	Started coal feed.
	0400	Achieved Set Point No. 1 conditions.
	1125	Terminated Set Point No. 1.
	1200	Achieved Set Point No. 2 conditions.
May 20	0630	Terminated Set Point No. 2.
	1230	Achieved Set Point No. 3 conditions.
	2315	Lost solids leg in Cyclone C-119. Leg was regained at 0450 on May 21.
May 21	0000	Operating problems experienced for most of the day with the gas chromatograph sampling system.
May 22	0500	Terminated Set Point No. 3.
	0600	Achieved Set Point No. 4 conditions.
	0700	Another gas chromatograph problem occurred when a hole developed in the product gas sample line. The hole was patched and the product gas line brought back on stream at 0900.
	1700	Terminated Set Point No. 4.
	1705	Process air compressor shut down, but was brought back on line immediately.
	1730	Achieved Set Point No. 5 conditions.
May 22 thru May 25	2100 1115	While operating at Set Point No. 5, coal feedline plugging interrupted steady-state operations.
May 25	1600	Terminated Set Point No. 5.
	1650	Initiated shutdown.

TABLE 3.1-16

SUMMARY OF OPERATING DATA FOR MODIFIED GASIFIER TEST TP-017-1

SET POINT		1	2	3	4	5
TEST RUN DATE AND TIME (1978)	Unit	May 19 0630 to 1125 Hours	May 19, 20 2230 to 0630 Hours	May 21, 22 1500 to 0500 Hours	May 22 0730 to 1700 Hours	May 25 1300 to 1600 Hours
MEASURED GASIFIER PARAMETERS						
TE-504-4 Freeboard Temperature	°F	1716	1753	1847	1651	1852
TE-507-3 Gasifier Bed Temperature	°F	1759	1768	1864	1683	1835
TE-504-10 Ash Annulus Temperature	°F	390	357	443	443	533
Average Bed Height	feet	26.18	26.01	25.81	25.45	25.67
System Pressure	psig	230	230	232	231	231
Average Gasifier Bed Density	lb/ft^3	12.41	7.22	7.85	7.6	7.86
Average Ash Annulus Density	lb/ft^3	13.64	17.84	18.89	18.52	19.44
Freeboard Gas Velocity	fps	1.13	1.41	1.56	1.01	1.86
Oxidant Tube Velocity	fps	63.41	81.19	89.76	53.37	105.28
Coal Feed Material		Pgh. Seam Coal	Pgh. Seam Coal	Pgh. Seam Coal	Pgh. Seam Coal	Pgh. Seam Coal
Coal Feed Rate, WR-27	lb/hr	529	676	731	377	934
Fines Feed Material		Recycled Fines	Recycled Fines	Recycled Fines	Recycled Fines	--
Fines Feed Rate, WR-14	lb/hr	321	113	174	135	0
Cyclone Collection Rate, WR-19	lb/hr	229	130	208	140	140
Carryover to Water System*	lb/hr	74	127	198	130	270
Ash Withdrawal Rate	lb/hr	79	70	43	32	102
PRODUCT GAS ANAL SIS, DRY BASIS						
Carbon Monoxide	%	12.33	14.92	19.42	10.49	16.80
Carbon Dioxide	%	19.07	15.89	14.63	21.92	15.95
Methane	%	0.80	0.95	0.45	0.54	0.97
Nitrogen	%	61.87	61.82	60.56	64.37	57.86
Oxygen	%	0.0	0.0	0.0	0.0	0.0
Hydrogen	%	5.58	6.42	4.89	2.73	8.40
HVV, Dry Basis (Gas Chromatograph)	Btu/scf	67.15	78.52	83.05	48.06	91.3
OVERALL PROCESS RATES						
Steam/Coal Ratio, MAF**	lb/lb	0.55	0.42	0.21	0.40	0.61
Oxygen/Coal Ratio, MAF	lb/lb	1.23	1.23	1.27	1.45	1.20
Total Moisture/Coal Ratio, MAF	lb/lb	0.58	0.45	0.24	0.44	0.65
SOLIDS ANALYSIS						
Ash Content - Fines	%	21.38	21.66	21.81	21.29	16.63
Ash Content - Feedstock	%	7.09	---	---	---	9.05
Ash Content - Bed	%	23.30	24.66	29.35	20.10	20.45
Ash Content - Agglomerate	%	41.95	48.44	70.91	43.02	29.19

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

TABLE 3.1-17

GASIFIER HEAT AND MATERIAL BALANCES

TEST TP-017 - SET POINT 1

STREAM NO.	1	2	3	4	5	6	7	8	9	10
STREAM DESCRIPTION	STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING FLOW	BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-61)
TOTAL LB/HR	254.00	0.00	0.00	2439.00	305.00	0.00	944.92	427.34	1109.84	140.03
TEMPERATURE F	526.0	0.0	0.0	1005.0	132.0	165.0	512.0	165.0	165.0	241.0
GAS LB/HR	254.00	0.00	0.00	2439.00	305.00	0.00	944.92	427.34	1109.84	140.03
SOLID LB/HR	0.00	0.00	0.00	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	0.00	0.00	0.00
MOLECULAR WEIGHT	18.016	18.016	18.016	28.963	44.011	30.124	30.124	30.124	30.124	30.124
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	12.32	12.32	12.32	12.32	12.32
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	22.35	22.35	22.35	22.35	22.35
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	5.23	5.23	5.23	5.23	5.23
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.71	0.71	0.71	0.71	0.71
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	0.00	0.00	78.06	0.00	59.17	59.17	59.17	59.17	59.17
O2 VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00
AR VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00
H2O VOLUME %	100.00	100.00	100.00	0.00	0.00	0.21	0.21	0.21	0.21	0.21
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	83.237	0.000	133.313	60.291	156.581	19.756
HYDROGEN LB/HR	28.423	0.000	0.000	0.000	0.000	0.000	4.338	1.962	5.095	0.643
OXYGEN LB/HR	225.577	0.000	0.000	565.893	221.763	0.000	287.287	129.926	337.429	42.573
NITROGEN LB/HR	0.000	0.000	0.000	1841.486	0.000	0.000	519.979	235.161	610.732	77.055
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	31.622	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	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	52.324	0.000	0.000	565.952	3.522	0.000	862.677	351.894	913.900	117.976

(Continued)

TABLE 3.1-17 (Continued)

STREAM NO.	11	12	13	14	15	16	17	18		
STREAM DESCRIPTION	COAXIAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	RADIAL FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL LB/HR	1175.19	0.00	0.00	859.32	6416.90	1298.38	78.80	6.50	0.00	-1.91
TEMPERATURE F	210.0	1005.0	1005.0	260.0	1384.0	250.0	392.0	1763.0	0.0	0.0
GAS LB/HR	646.19	0.00	0.00	538.32	6342.90	1069.38	0.00	0.00	0.00	0.00
SOLID LB/HR	529.00	0.00	0.00	321.00	74.00	229.00	78.80	6.50	0.00	0.00
LIQUID LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT	30.124	32.000	44.011	30.124	28.851	30.124	0.000	0.000	0.000	0.000
CO VOLUME %	12.32	0.00	0.00	12.32	11.98	12.32	0.00	0.00	0.00	0.00
CO2 VOLUME %	22.35	0.00	100.00	22.35	17.96	22.35	0.00	0.00	0.00	0.00
H2 VOLUME %	5.23	0.00	0.00	5.23	5.26	5.23	0.00	0.00	0.00	0.00
CH4 VOLUME %	0.71	0.00	0.00	0.71	0.75	0.71	0.00	0.00	0.00	0.00
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	59.17	0.00	0.00	59.17	58.28	59.17	0.00	0.00	0.00	0.00
O2 VOLUME %	0.00	100.00	0.00	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	0.00	0.00	0.00
H2O VOLUME %	0.21	0.00	0.00	0.21	5.78	0.21	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	490.457	0.000	0.000	315.383	865.523	321.685	44.349	4.809	0.000	1.799
HYDROGEN LB/HR	29.893	0.000	0.000	4.494	56.067	6.352	0.292	0.030	0.000	16.174
OXYGEN LB/HR	244.710	0.000	0.000	167.456	1888.811	327.832	0.000	0.036	0.000	0.267
NITROGEN LB/HR	364.588	0.000	0.000	298.192	3589.486	509.869	0.418	0.041	0.000	-5.893
SULFUR LB/HR	8.041	0.000	0.000	5.168	1.191	3.687	1.497	0.070	0.000	51.207
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH LB/HR	37.506	0.000	0.000	68.630	15.762	48.777	33.057	1.515	0.000	6.620
HEAT CONTENT KBTU/HR	7689.532	0.000	0.000	3992.362	8453.019	3425.663	659.262	73.135	425.000	10.406

TABLE 3.1-18

GASIFIER HEAT AND MATERIAL BALANCES

TEST TP-017 - SET POINT 2

STREAM NO.	1	2	3	4	5	6	7	8	9	10
STREAM DESCRIPTION	STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING FLOW	BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-61)
TOTAL LB/HR	246.00	0.00	0.00	3123.00	305.00	0.00	1240.24	448.47	1094.88	111.34
TEMPERATURE F	553.0	0.0	0.0	1005.0	138.0	167.0	495.0	167.0	167.0	240.0
GAS LB/HR	246.00	0.00	0.00	3123.00	305.00	0.00	1240.24	448.47	1094.88	111.34
SOLID LB/HR	0.00	0.00	0.00	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	0.00	0.00	0.00
MOLECULAR WEIGHT	18.016	18.016	18.016	28.963	44.011	29.761	29.761	29.761	29.761	29.761
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	14.13	14.13	14.13	14.13	14.13
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	21.31	21.31	21.31	21.31	21.31
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	5.93	5.93	5.93	5.93	5.93
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.83	0.83	0.83	0.83	0.83
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	0.00	0.00	78.06	0.00	57.57	57.57	57.57	57.57	57.57
O2 VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00
AR VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00
H2O VOLUME %	100.00	100.00	100.00	0.00	0.00	0.25	0.25	0.25	0.25	0.25
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	83.237	0.000	181.549	65.647	160.270	16.299
HYDROGEN LB/HR	27.528	0.000	0.000	0.000	0.000	0.000	6.577	2.378	5.806	0.590
OXYGEN LB/HR	218.472	0.000	0.000	724.593	221.763	0.000	380.045	137.423	335.501	34.119
NITROGEN LB/HR	0.000	0.000	0.000	2357.917	0.000	0.000	672.074	243.019	593.302	60.336
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	40.490	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	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	53.865	0.000	0.000	724.670	3.912	0.000	1286.691	427.042	1042.571	108.083

(Continued)

TABLE 3.1-18 (Continued)

STREAM NO.	11	12	13	14	15	16	17	18		
STREAM DESCRIPTION	COAXIAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	RADIAL FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL LB/HR	1355.40	0.00	0.00	639.82	7686.53	1223.85	70.25	6.50	0.00	-4.94
TEMPERATURE F	170.0	1005.0	1005.0	315.0	1458.0	250.0	388.0	1780.0	0.0	0.0
GAS LB/HR	679.40	0.00	0.00	526.82	7556.53	1093.85	0.00	0.00	0.00	0.00
SOLID LB/HR	676.00	0.00	0.00	113.00	130.00	130.00	70.25	6.50	0.00	0.00
LIQUID LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT	29.761	32.000	44.011	29.761	28.427	29.761	0.000	0.000	0.000	0.000
CO VOLUME %	14.13	0.00	0.00	14.13	14.44	14.13	0.00	0.00	0.00	0.00
CO2 VOLUME %	21.31	0.00	100.00	21.31	15.38	21.31	0.00	0.00	0.00	0.00
H2 VOLUME %	5.93	0.00	0.00	5.93	6.21	5.93	0.00	0.00	0.00	0.00
CH4 VOLUME %	0.83	0.00	0.00	0.83	0.92	0.83	0.00	0.00	0.00	0.00
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	57.57	0.00	0.00	57.57	59.84	57.57	0.00	0.00	0.00	0.00
O2 VOLUME %	0.00	100.00	0.00	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	0.00	0.00	0.00
H2O VOLUME %	0.25	0.00	0.00	0.25	3.21	0.25	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	598.137	0.000	0.000	161.404	1078.434	257.086	35.090	4.718	0.000	-8.589
HYDROGEN LB/HR	38.417	0.000	0.000	3.811	61.527	6.971	0.274	0.041	0.000	19.146
OXYGEN LB/HR	269.636	0.000	0.000	161.658	2059.226	335.445	0.000	0.017	0.000	3.565
NITROGEN LB/HR	377.557	0.000	0.000	286.337	4456.732	593.731	0.393	0.046	0.000	-10.028
SULFUR LB/HR	0.000	0.000	0.000	1.785	2.054	2.054	0.991	0.070	0.000	-189.500
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH LB/HR	61.381	0.000	0.000	24.826	28.561	28.561	34.205	1.608	0.000	-7.804
HEAT CONTENT KBTU/HR	9586.136	0.000	0.000	1793.280	12116.320	2525.957	523.841	72.696	425.000	-4.243

TABLE 3.1-19

GASIFIER HEAT AND MATERIAL BALANCES

TEST TP-017 - SET POINT 3

STREAM NO.	1	2	3	4	5	6	7	8	9	10
STREAM DESCRIPTION	STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING FLOW	BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-61)
TOTAL LB/HR	133.00	0.00	0.00	3505.00	375.00	0.00	1131.59	471.50	1039.34	102.50
TEMPERATURE F	411.0	0.0	0.0	995.0	140.0	161.0	598.0	161.0	161.0	241.0
GAS LB/HR	133.00	0.00	0.00	3505.00	375.00	0.00	1131.59	471.50	1039.34	102.50
SOLID LB/HR	0.00	0.00	0.00	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	0.00	0.00	0.00
MOLECULAR WEIGHT	18.016	18.016	18.016	28.963	44.011	29.417	29.417	29.417	29.417	29.417
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	18.81	18.81	18.81	18.81	18.81
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	16.66	16.66	16.66	16.66	16.66
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	4.62	4.62	4.62	4.62	4.62
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.38	0.38	0.38	0.38	0.38
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	0.00	0.00	78.06	0.00	59.37	59.37	59.37	59.37	59.37
O2 VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00
AR VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00
H2O VOLUME %	100.00	100.00	100.00	0.00	0.00	0.18	0.18	0.18	0.18	0.18
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	102.341	0.000	165.624	69.010	152.122	15.002
HYDROGEN LB/HR	14.883	0.000	0.000	0.000	0.000	0.000	4.309	1.795	3.958	0.390
OXYGEN LB/HR	118.117	0.000	0.000	813.224	272.659	0.000	321.918	134.133	295.675	29.159
NITROGEN LB/HR	0.000	0.000	0.000	2646.333	0.000	0.000	639.737	266.557	587.585	57.947
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	45.443	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	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	20.148	0.000	0.000	804.098	4.970	0.000	1307.187	491.185	1082.744	108.840

(Continued)

TABLE 3.1-19 (Continued)

STREAM NO.	11	12	13	14	15	16	17	18		
STREAM DESCRIPTION	COAXIAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	RADIAL FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL LB/HR	1458.74	0.00	0.00	628.07	8247.02	1342.66	43.00	6.50	0.00	-8.98
TEMPERATURE F	109.0	995.0	995.0	274.0	1553.0	250.0	464.0	1884.0	0.0	0.0
GAS LB/HR	727.74	0.00	0.00	454.07	8049.02	1134.66	0.00	0.00	0.00	0.00
SOLID LB/HR	731.00	0.00	0.00	174.00	198.00	208.00	43.00	6.50	0.00	0.00
LIQUID LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT	29.417	32.000	44.011	29.417	28.688	29.417	0.000	0.000	0.000	0.000
CO VOLUME %	18.81	0.00	0.00	18.81	18.84	18.81	0.00	0.00	0.00	0.00
CO2 VOLUME %	16.66	0.00	100.00	16.66	14.19	16.66	0.00	0.00	0.00	0.00
H2 VOLUME %	4.62	0.00	0.00	4.62	4.74	4.62	0.00	0.00	0.00	0.00
CH4 VOLUME %	0.38	0.00	0.00	0.38	0.44	0.38	0.00	0.00	0.00	0.00
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	59.37	0.00	0.00	59.37	58.74	59.37	0.00	0.00	0.00	0.00
O2 VOLUME %	0.00	100.00	0.00	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	0.00	0.00	0.00
H2O VOLUME %	0.18	0.00	0.00	0.18	3.04	0.18	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	651.695	0.000	0.000	197.186	1276.353	322.344	11.133	4.433	0.000	-19.312
HYDROGEN LB/HR	40.856	0.000	0.000	2.721	50.078	5.506	0.107	0.025	0.000	19.148
OXYGEN LB/HR	267.412	0.000	0.000	129.611	2256.246	323.313	0.000	0.000	0.000	-8.298
NITROGEN LB/HR	422.390	0.000	0.000	257.907	4618.088	642.911	0.138	0.047	0.000	-7.845
SULFUR LB/HR	10.234	0.000	0.000	2.697	3.069	3.224	1.131	0.086	0.000	41.920
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH LB/HR	66.156	0.000	0.000	37.949	43.184	45.365	30.491	1.908	0.000	-16.179
HEAT CONTENT KBTU/HR	10620.829	0.000	0.000	2418.271	14147.790	3516.337	173.690	68.090	425.000	-8.735

TABLE 3.1-20
GASIFIER HEAT AND MATERIAL BALANCES
TEST TP-017 - SET POINT 4

STREAM NO.	1	2	3	4	5	6	7	8	9	10
STREAM DESCRIPTION	STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING FLOW	BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-61)
TOTAL LB/HR	133.00	0.00	0.00	2064.00	409.00	0.00	1186.36	502.86	1061.71	105.64
TEMPERATURE F	411.0	0.0	0.0	1003.0	141.0	174.0	1.0	174.0	174.0	220.0
GAS LB/HR	133.00	0.00	0.00	2064.00	409.00	0.00	1186.36	502.86	1061.71	105.64
SOLID LB/HR	0.00	0.00	0.00	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	0.00	0.00	0.00
MOLECULAR WEIGHT	18.016	18.016	18.016	28.963	44.011	31.249	31.249	31.249	31.249	31.249
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	10.06	10.06	10.06	10.06	10.06
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	25.13	25.13	25.13	25.13	25.13
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	2.65	2.65	2.65	2.65	2.65
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.53	0.53	0.53	0.53	0.53
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	0.00	0.00	78.06	0.00	61.33	61.33	61.33	61.33	61.33
O2 VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00
AR VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00
H2O VOLUME %	100.00	100.00	100.00	0.00	0.00	0.29	0.29	0.29	0.29	0.29
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	111.620	0.000	162.867	69.034	145.754	14.503
HYDROGEN LB/HR	14.883	0.000	0.000	0.000	0.000	0.000	3.060	1.297	2.738	0.272
OXYGEN LB/HR	118.117	0.000	0.000	478.886	297.380	0.000	368.133	156.039	329.451	32.781
NITROGEN LB/HR	0.000	0.000	0.000	1558.354	0.000	0.000	652.304	276.488	583.762	58.086
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	26.760	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	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	20.148	0.000	0.000	477.851	5.508	0.000	644.656	293.895	620.513	62.928

(Continued)

TABLE 3.1-20 (Continued)

STREAM NO.	11	12	13	14	15	16	17	18		
STREAM DESCRIPTION	COAXIAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	RADIAL FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL LB/HR	1112.27	0.00	0.00	598.77	6102.40	1297.84	31.80	6.50	0.00	-3.69
TEMPERATURE F	218.0	1003.0	1003.0	295.0	1374.0	250.0	462.0	1698.0	0.0	0.0
GAS LB/HR	735.27	0.00	0.00	463.77	5972.40	1157.84	0.00	0.00	0.00	0.00
SOLID LB/HR	377.00	0.00	0.00	135.00	130.00	140.00	31.80	6.50	0.00	0.00
LIQUID LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT	31.249	32.000	44.011	31.249	30.305	31.249	0.000	0.000	0.000	0.000
CO VOLUME %	10.06	0.00	0.00	10.06	10.12	10.06	0.00	0.00	0.00	0.00
CO2 VOLUME %	25.13	0.00	100.00	25.13	21.15	25.13	0.00	0.00	0.00	0.00
H2 VOLUME %	2.65	0.00	0.00	2.65	2.63	2.65	0.00	0.00	0.00	0.00
CH4 VOLUME %	0.53	0.00	0.00	0.53	0.52	0.53	0.00	0.00	0.00	0.00
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	61.33	0.00	0.00	61.33	62.12	61.33	0.00	0.00	0.00	0.00
O2 VOLUME %	0.00	100.00	0.00	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	0.00	0.00	0.00
H2O VOLUME %	0.29	0.00	0.00	0.29	3.47	0.29	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	389.760	0.000	0.000	166.781	851.725	265.883	17.073	4.984	0.000	-7.483
HYDROGEN LB/HR	20.897	0.000	0.000	1.790	28.932	3.602	0.156	0.034	0.000	27.179
OXYGEN LB/HR	251.003	0.000	0.000	143.910	1762.198	359.282	0.000	0.001	0.000	2.492
NITROGEN LB/HR	410.121	0.000	0.000	255.928	3430.305	637.587	0.235	0.063	0.000	-7.197
SULFUR LB/HR	5.429	0.000	0.000	2.147	2.067	2.226	0.598	0.107	0.000	34.021
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH LB/HR	35.061	0.000	0.000	28.903	27.833	29.974	13.755	1.311	0.000	-13.925
HEAT CONTENT KBTU/HR	5661.030	0.000	0.000	1799.438	7066.854	2267.654	257.230	76.083	425.000	-5.288

TABLE 3.1-21

GASIFIER HEAT AND MATERIAL BALANCES

TEST TP-017 - SET POINT 5

STREAM NO.	1	2	3	4	5	6	7	8	9	10
STREAM DESCRIPTION	STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING FLOW	BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-61)
TOTAL LB/HR	92.00	0.00	436.00	4429.00	700.00	404.66	1115.09	0.00	1027.29	101.92
TEMPERATURE F	411.0	0.0	568.0	855.0	137.0	189.0	749.0	189.0	189.0	222.0
GAS LB/HR	92.00	0.00	436.00	4429.00	700.00	404.66	1115.09	0.00	1027.29	101.92
SOLID LB/HR	0.00	0.00	0.00	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	0.00	0.00	0.00
MOLECULAR WEIGHT	18.016	18.016	18.016	28.963	44.011	28.514	28.514	28.514	28.514	28.514
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	16.49	16.49	16.49	16.49	16.49
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	17.25	17.25	17.25	17.25	17.25
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	8.06	8.06	8.06	8.06	8.06
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.92	0.92	0.92	0.92	0.92
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	0.00	0.00	78.06	0.00	56.73	56.73	56.73	56.73	56.73
O2 VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00
AR VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00
H2O VOLUME %	100.00	100.00	100.00	0.00	0.00	0.55	0.55	0.55	0.55	0.55
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	191.036	59.094	162.839	0.000	150.019	14.884
HYDROGEN LB/HR	10.295	0.000	48.789	0.000	0.000	2.992	8.244	0.000	7.595	0.754
OXYGEN LB/HR	81.705	0.000	387.211	1027.609	508.964	117.052	322.551	0.000	297.155	29.482
NITROGEN LB/HR	0.000	0.000	0.000	3343.969	0.000	225.522	621.452	0.000	572.523	56.802
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	57.422	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	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	13.937	0.000	98.619	854.309	8.829	487.507	1513.989	0.000	1237.611	123.666

(Continued)

TABLE 3.1-21 (Continued)

STREAM NO.	11	12	13	14	15	16	17	18		
STREAM DESCRIPTION	COAXIAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	RADIAL FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL LB/HR	1775.16	0.00	0.00	403.65	9637.09	1274.26	102.00	6.50	0.00	-5.10
TEMPERATURE F	163.0	855.0	855.0	283.0	1611.0	250.0	558.0	1876.0	0.0	0.0
GAS LB/HR	791.16	0.00	0.00	403.65	9367.09	1134.26	0.00	0.00	0.00	0.00
SOLID LB/HR	984.00	0.00	0.00	0.00	270.00	140.00	102.00	6.50	0.00	0.00
LIQUID LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT	28.514	32.000	44.011	28.514	27.699	28.514	0.000	0.000	0.000	0.000
CO VOLUME %	16.49	0.00	0.00	16.49	15.88	16.49	0.00	0.00	0.00	0.00
CO2 VOLUME %	17.25	0.00	100.00	17.25	15.07	17.25	0.00	0.00	0.00	0.00
H2 VOLUME %	8.06	0.00	0.00	8.06	7.94	8.06	0.00	0.00	0.00	0.00
CH4 VOLUME %	0.92	0.00	0.00	0.92	0.91	0.92	0.00	0.00	0.00	0.00
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	56.73	0.00	0.00	56.73	54.68	56.73	0.00	0.00	0.00	0.00
O2 VOLUME %	0.00	100.00	0.00	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	0.00	0.00	0.00
H2O VOLUME %	0.55	0.00	0.00	0.55	5.53	0.55	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	849.402	0.000	0.000	58.946	1493.033	268.903	70.135	5.071	0.000	-23.612
HYDROGEN LB/HR	57.116	0.000	0.000	2.984	106.272	9.478	0.479	0.034	0.000	16.218
OXYGEN LB/HR	310.129	0.000	0.000	116.761	2790.046	328.629	0.000	0.000	0.000	2.499
NITROGEN LB/HR	455.682	0.000	0.000	224.960	5182.881	633.622	0.877	0.051	0.000	-5.754
SULFUR LB/HR	13.776	0.000	0.000	0.000	6.426	3.332	1.091	0.056	0.000	20.838
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH LB/HR	89.052	0.000	0.000	0.000	58.401	30.282	29.774	1.329	0.000	-34.512
HEAT CONTENT KBTU/HR	14246.443	0.000	0.000	496.248	18356.523	2935.313	1039.317	77.495	425.000	-19.666

1600°F with air fed to the oxidant tube. In the interim period, repairs were made on the steam generation system. On June 28 at 2000 hours while completing the checkout procedures prior to admitting oxygen, a major leak was noted on the vaporizer inlet flange of the oxygen generation system. Since this leak precluded any further testing with oxygen fed to the gasifier, it was decided to spend more time generating data to allow characterization of the new oxidant tube design.

Accordingly, the system pressure was ramped to 230 psig and Set Point 1 conditions were achieved at 0200 hours on June 29. On achieving 10 hours of steady-state conditions, an orderly shutdown was initiated at noon on June 29. Highlights of the test results were:

- Achieved autogenous ignition and a controlled temperature ramp at off-design pressure of 150 psig. Historically, the gasifier has been operated at 200 to 230 psig pressure.
- Determined the effect of a smaller air tube diameter on reactor response; namely, axial temperature profile, fines carryover rate and product gas heating value.
- Logged 39 hours of operation with coke breeze.

Analyses of the results are underway and will be reported in a subsequent report. Significant events of TP-018 are given in Table 3.1-22, and steady-state operating data are presented in Table 3.1-23. Figure 3.1-1 shows the flow streams of the test and Table 3.1-24 presents the heat and materials balance.

3.1.1.5 Work Forecast for Next Quarter - Gasifier Tests

Analysis of the gasifier data from the standpoint of process characterization and hardware performance will continue. Work is underway to compare PDU results with the analytical models generated in the technical support program.

Tests to be run next quarter will concentrate on the single-reactor oxygen-blown configuration. The emphasis, after the initial shakedown test, will be on reactor characterization. In addition to exploring the response to operating parameters such as reactor temperature and steam flow rate, the response to coals of differing reactivity will be explored.

3.1.2 PDU Modifications for Integrated Operation

3.1.2.1 Work Accomplished

Because of the concentrated work effort in preparing the PDU for expanded freeboard gasifier tests and the construction of the oxygen supply system, modification work on the PDU structure for integrated operation was limited to some electrical, instrumentation, and small piping jobs.

TABLE 3.1-22

CHRONOLOGY OF EVENTS, TEST TP-018-1

Date	Time	Events
June 25	0500	System pressurized to 200 psig
	1940	Achieved acceptable leak rate. Detected hairline crack on an Incoloy pressure relief valve line on C-111 quench scrubber.
June 26	0900 to 1200	Depressurized to carry out repairs on steam valve TV-44 and weld cracks on Incoloy line.
	1700	Began hot-air heatup.
June 27	1720	Initiated coke breeze feed to establish bed.
	2100	Achieved autogenous ignition of coke breeze.
June 28	0300	Steam boiler shutdown due to malfunctioning boiler feedwater pump.
	1445	Steam boiler recommissioned after bypassing malfunctioning pump.
	2040	Significant leak developed on the vaporizer inlet flange of the oxygen supply system.
	2130	Deleted set points 2 through 5. Proceeded to ramp gasifier pressure to 230 psig in preparation for Set Point 1.
June 29	0200	Achieved Set Point No. 1 conditions.
	1200	Initiated a normal shutdown.

TABLE 3.1-23

SUMMARY OF OPERATING DATA FOR MODIFIED GASIFIER TEST TP-018-1

SET POINT		1	2	3	4
TEST RUN DATE AND TIME (1978)	Unit	June 29 0530 to 113 Hours			
MEASURED GASIFIER PARAMETERS					
TE-504-4 Freeboard Temperature	°F	1807			
TE-507-3 Gasifier Bed Temperature	°F	1856			
TE-504-10 Ash Annulus Temperature	°F	390			
Average Bed Height	feet	23.3			
System Pressure	psig	229.0			
Average Gasifier Bed Density	lb/ft^3	26.82			
Average Ash Annulus Density	lb/ft^3	16.24			
Freeboard Gas Velocity	fps	0.92			
Oxidant Tube Velocity	fps	184.40			
Coal Feed Material		---			
Coal Feed Rate, WR-27	lb/hr	0			
Fines Feed Material		Coke Breeze			
Fines Feed Rate, WR-14	lb/hr	445			
Cyclone Collection Rate, WR-19	lb/hr	80			
Carryover to Water System*	lb/hr	8			
Ash Withdrawal Rate	lb/hr	71			
PRODUCT GAS ANALYSIS, DRY BASIS					
Carbon Monoxide	%	5.86			
Carbon Dioxide	%	26.97			
Methane	%	0.0			
Nitrogen	%	63.92			
Oxygen	%	0.0			
Hydrogen	%	3.22			
HVV, Dry Basis (Gas Chromatograph)	Btu/scf	32.2			
OVERALL PROCESS RATES					
Steam/Coal Ratio, MAF**	lb/lb	---			
Oxygen/Coal Ratio, MAF	lb/lb	---			
Total Moisture/Coal Ratio, MAF	lb/lb	---			
SOLIDS ANALYSIS					
Ash Content - Fines	%	10.26			
Ash Content - Feedstock	%	---			
Ash Content - Bed	%	17.91			
Ash Content - Agglomerate	%	63.91			

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

TABLE 3.1-24
GASIFIER HEAT AND MATERIAL BALANCES
TEST TP-018-1 - SET POINT 1

STREAM NO.	1	2	3	4	5	6	7	8	9	10
STREAM DESCRIPTION	STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING FLOW	BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-61)
TOTAL LB/HR	0.00	0.00	425.00	2137.00	300.00	413.90	759.69	0.00	1215.51	127.84
TEMPERATURE F	0.0	0.0	503.0	1005.0	133.0	162.0	596.0	162.0	162.0	236.0
GAS LB/HR	0.00	0.00	425.00	2137.00	300.00	413.90	759.69	0.00	1215.51	127.84
SOLID LB/HR	0.00	0.00	0.00	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	0.00	0.00	0.00
MOLECULAR WEIGHT	18.016	18.016	18.016	28.963	44.011	30.744	30.744	30.744	30.744	30.744
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	6.58	6.58	6.58	6.58	6.58
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	22.72	22.72	22.72	22.72	22.72
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	3.40	3.40	3.40	3.40	3.40
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	0.00	0.00	78.06	0.00	67.09	67.09	67.09	67.09	67.09
O2 VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00
AR VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00
H2O VOLUME %	100.00	100.00	100.00	0.00	0.00	0.20	0.20	0.20	0.20	0.20
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	81.873	47.380	86.963	0.000	139.141	14.634
HYDROGEN LB/HR	0.000	0.000	47.558	0.000	0.000	0.979	1.796	0.000	2.874	0.302
OXYGEN LB/HR	0.000	0.000	377.442	495.823	218.127	112.500	206.487	0.000	330.379	34.747
NITROGEN LB/HR	0.000	0.000	0.000	1613.471	0.000	253.044	464.449	0.000	743.118	78.156
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	27.706	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	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	0.000	0.000	82.878	495.875	3.529	172.642	400.658	0.000	506.998	55.643

(Continued)

TABLE 3.1-24 (Continued)

STREAM NO.	11	12	13	14	15	16	17	18		
STREAM DESCRIPTION	COAXIAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	RADIAL FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL LB/HR	514.50	0.00	0.00	1011.89	5106.10	1451.64	71.00	9.00	0.00	3.88
TEMPERATURE F	385.0	1009.0	1009.0	228.0	1631.0	170.0	426.0	1838.0	0.0	0.0
GAS LB/HR	514.50	0.00	0.00	566.89	5098.10	1371.64	0.00	0.00	0.00	0.00
SOLID LB/HR	0.00	0.00	0.00	445.00	8.00	80.00	71.00	9.00	0.00	0.00
LIQUID LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT	30.744	32.000	44.011	30.744	31.003	30.744	0.000	0.000	0.000	0.000
CO VOLUME %	6.58	0.00	0.00	6.58	5.65	6.58	0.00	0.00	0.00	0.00
CO2 VOLUME %	22.72	0.00	100.00	22.72	26.00	22.72	0.00	0.00	0.00	0.00
H2 VOLUME %	3.40	0.00	0.00	3.40	3.10	3.40	0.00	0.00	0.00	0.00
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2 VOLUME %	67.09	0.00	0.00	67.09	61.62	67.09	0.00	0.00	0.00	0.00
O2 VOLUME %	0.00	100.00	0.00	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	0.00	0.00	0.00
H2O VOLUME %	0.20	0.00	0.00	0.20	3.63	0.20	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	58.895	0.000	0.000	446.346	632.128	227.685	25.624	7.388	0.000	-2.010
HYDROGEN LB/HR	1.216	0.000	0.000	5.568	22.321	3.243	0.000	0.000	0.000	57.601
OXYGEN LB/HR	139.841	0.000	0.000	161.558	1612.228	372.816	0.000	0.000	0.000	4.423
NITROGEN LB/HR	314.544	0.000	0.000	349.467	2838.493	838.570	0.000	0.000	0.000	3.647
SULFUR LB/HR	0.000	0.000	0.000	3.382	0.000	0.000	0.000	0.000	0.000	100.000
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH LB/HR	0.000	0.000	0.000	45.657	0.933	9.328	45.376	1.612	0.000	-25.389
HEAT CONTENT KBTU/HR	243.179	0.000	0.000	5905.697	4056.783	1576.451	367.579	108.935	425.000	16.936

Based on the current schedule for the gasifier test program, a preliminary scoping schedule was developed for completing the remaining phase of the integrated construction work. Start-up of the integrated system is expected to begin in early 1979, based on the following work plan assumptions:

- About 20 percent of the work on the structure can be accomplished during oxygen testing of the gasifier
- General Mechanical Corporation, the contractor, can work during downtime periods between gasifier tests
- Upgrading and modification activities between gasifier tests are not extensive
- Inclement weather will not be a major factor.

Integrated operation construction work selected to be deferred to expedite the gasifier test program includes the following items:

- Final installation of the integrated piping, including the refractory-lined, draw-off pipe
- Final assembly and alignment of the devolatilizer, C-101, collection cyclone, C-110, and interconnecting piping
- Fabrication of some reactor components and installation of others into the devolatilizer reactor including the draft tube, grid plate, lower plenum internals and coal feed pipe
- Rebuilding and final installation of the synthesis gas generator and flow control system for use as an auxiliary heat source for the devolatilizer
- Installation of the Edens separator in the waste water system.

3.1.2.2 Work Forecast for Next Quarter

Complete procurement of all outstanding reactor components and the Eden's separator. Complete rebuild of subassemblies for the PDU and install refractory-lined piping.

3.1.3 PDU Modifications for Operation with Oxygen

3.1.3.1 Work Accomplished

In conjunction with the test operation of the air-blown gasifier with the expanded configuration, the modification of the PDU for operation with oxygen was completed this quarter. Work accomplished included the design, procurement of hardware and equipment, construction and installation of components and equipment, and commissioning of equipment and subsystems for oxygen service.

During the last quarter, a program scoping and preliminary design study of the PDU was initiated and procurement of long-lead-time items was investigated to incorporate an oxygen system for the PDU gasifier tests. Following approval by DOE, detail design of this PDU modification and hardware procurement was initiated in early April 1978 for a June 12, 1978 completion date. The tasks completed during this period were:

- Specification and procurement of the oxygen supply system
- Design and procurement of a new oxygen feed tube
- Design and installation of the support pad for the oxygen storage tank and vaporizer unit
- Design, procurement and construction of a 2-inch diameter (5 cm) supply header from the storage tank to the PDU structure
- Design, procurement and fabrication of a process flow control system and an operational safety evaluation of the system
- Preparation of piping and component cleaning and inspection procedures for the oxygen system
- Mechanical completion inspection and repairs, functional checkout of instrumentation and control systems, and commissioning of equipment for operation.

The final purchase order for the oxygen supply system was placed in April 1978 with Airco to supply up to 2.4 million pounds of oxygen to the PDU during the next 8 months of testing. It will be supplied at a nominal rate of 1500 pounds-per-hour and at a supply pressure of 180 to 190 psig.

Following the installation and curing of the concrete support pad in May, the installation of the oxygen supply storage tank, vaporizer, and gas regulating system was completed by Airco on June 20. However, because of the inability to achieve a satisfactory gas pressure check on the system at 250 psig, the final acceptance of the pressure check was delayed until June 26, following the repair of several leaking flanges. Charging the tank with liquid oxygen occurred on this date. The tank and vaporizer were later pressure-checked visually under flow conditions with oxygen vented to the atmosphere. All flow checks were satisfactory, and the vaporizer fan temperature control worked as intended.

Figures 3.1-2 and 3 show the as-installed oxygen supply systems.

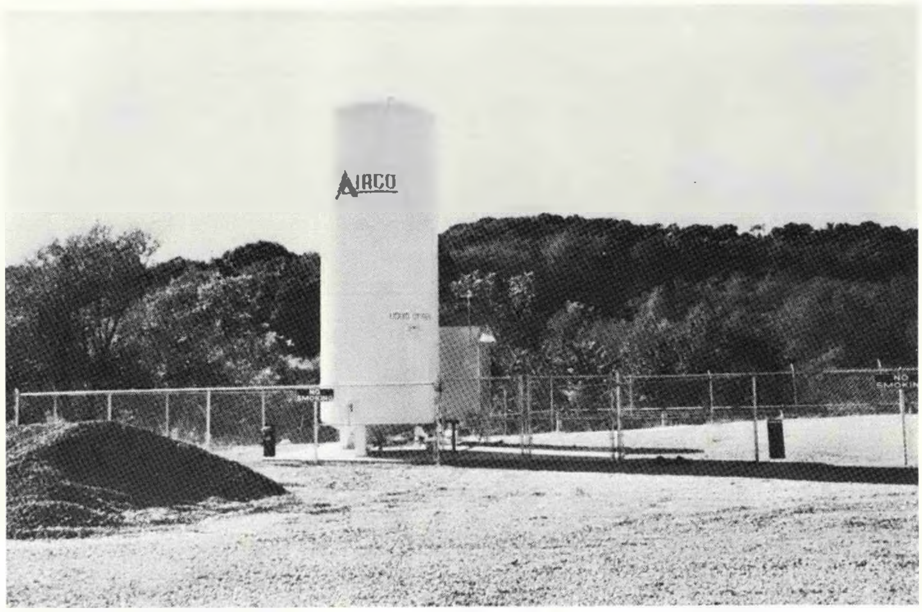


Figure 3.1-2. Oxygen Storage Installation

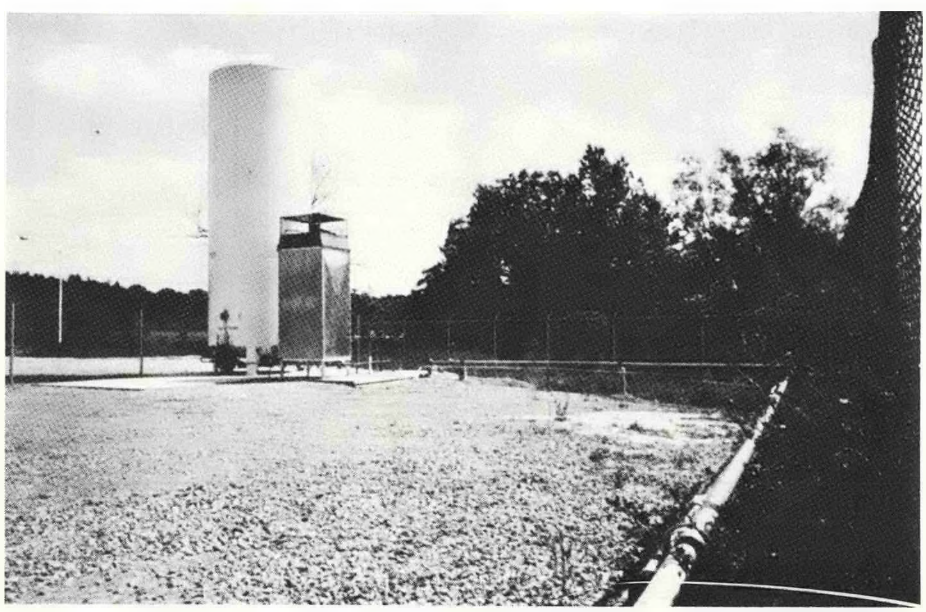


Figure 3.1-3. Stainless Steel Oxygen Supply Feederline from Storage Tank to PDU

Detail design and ordering of the components and hardware for the oxygen piping system were completed in April 1978. The flow control system supplying oxygen to the PDU gasifier was designed based on consultation with CE Lummus and Stearns-Roger companies regarding their oxygen flow systems, including the safety and reliability of each system installed at the Synthane and Bi-Gas pilot plants, respectively. The system incorporates two oxygen supply block valves with the ability to pressurize with nitrogen between them when oxygen flow is not used. The steam/oxygen/CO_2 mixture is preheated to 600^oF by a direct-contact electric heater identical to the F-120 air heater, with the exception that a better "A" grade heat ribbon is used.

Bench welding of subassemblies of piping components for the oxygen flow system was initiated in May and field assembly of the oxygen flow system on the PDU structure was completed in June. Figure 3.1-4 shows the oxygen flow system as-installed in the PDU structure.

Design and procurement of electrical and instrumentation components for the oxygen system were completed in May, and installation was completed in June. Work completed included:

- Installation of control room components
- Installation of conduits for field power and control units
- Wiring of instrumentation and control components both in the control room and mounted in field units.

A failure mode analysis was performed for the newly installed oxygen flow loops and control logic to identify potential failure modes and to assess their criticality on plant operation and personnel safety. An action plan was written to summarize the corrective actions to be taken by operators in response to each of the identified failure modes. The test plan, procedure, and the failure action plan were reviewed extensively by the operators and shift engineers in training sessions conducted by the test coordinator. Two meetings of the Safety Committee where held at which the test plan and operating procedures were discussed.

A final operational safety committee review of the operation, instrumentation and controls for the oxygen supply and piping system was held on June 16. All action items identified by the committee that were pertinent to the initial start-up of the test were incorporated or investigated. Based on the results of this review, together with a review of supplier's documents, subsystem operating procedures and a failure action plan were finalized for the test.

Mechanical completion and commissioning work for the oxygen system was initiated and completed in June. Field verification and inspection of the oxygen piping and header flow control system, pressure testing the containment piping, spot radiographic inspection of welds, and cleaning the oxygen service equipment were accomplished. In addition, the interfacing

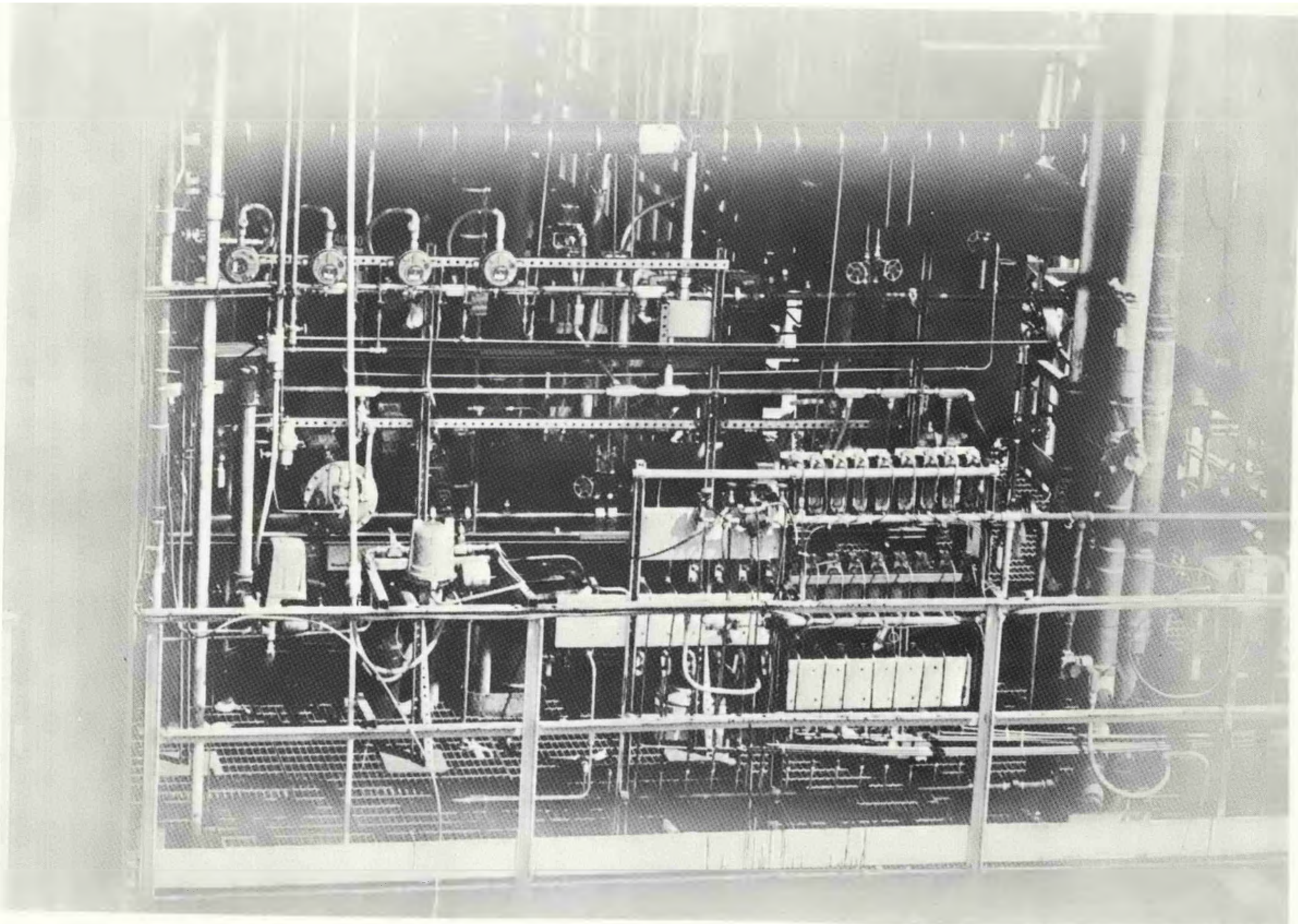


Figure 3.1-4. Oxygen Flow System Installation in PDU (External View)

branch piping of carbon dioxide, process air, and steam systems to the oxygen system were inspected with ultraviolet light for hydrocarbons. The piping was qualified acceptable for oxygen service. Inquiries were also submitted to the suppliers of carbon dioxide to determine whether hydrocarbons in the carbon dioxide were within the acceptable limits for oxygen service. Although there were some questions regarding the maximum tolerance limit for hydrocarbons, it was established that the products being supplied were well within acceptable limits needed for oxygen service.

The instrumentation and control circuits for the oxygen system were installed and a functional checkout performed. During this commissioning phase, the logic functions were verified and changes incorporated as necessary. All mechanical completion, precommissioning, and commissioning tasks were completed by June 25, and Test TP-018-1 was then initiated.

3.1.3.2 Work Forecast for Next Quarter

Repairs and modifications will be made to the oxygen supply and flow system found deficient during the startup phase.

3.1.4 PDU Process and Design Engineering

3.1.4.1 Work Accomplished, General Engineering

Process and design engineering activities were conducted in support of PDU operation. In addition to these support items described in Subsections 3.1.2 and 3.1.3, the following general engineering activities were accomplished:

- Instrumentation development to design and provide a flow totalizer for the water system to better perform water balances was completed. Components for the electronics flow totalizer, the square root, rate limiter and integrator modules were obtained and installed. Preliminary tests indicate that the circuitry will accurately follow the step function input signal, with an expected accuracy of 3 to 5 percent. An on-line calibration attempt will be made during future gasifier tests.

- Instrumentation development for an in-line solids flow measurement device was done. A survey of possible methods for measuring solids flow in the transfer standpipe between reactors during integrated operation was conducted. A number of devices are available:

  - Load Cells
  - Level Detectors
  - Doppler Radar
  - Starwheel Feeders
  - Thermal Mass Flow
  - Nuclear Flow Meters
  - C. F. Braun Dry Solids Mass Flow Meter
  - Differential Pressure Accoustical Flow Meters

A modified version of a thermal mass flow measuring technique is being tested in situ during the gasifier tests. This method relies on the use of existing process gas heaters and additional thermocouples for measuring temperatures. Since the specific heat of the gas and solids, along with gas mass flow, is known, it may be possible to do a heat balance by measuring solids temperature, gas temperature and mixed solids/gas temperature. Solids mass flow can be calculated from measured data. The scheme is currently being evaluated on the char lockhopper feed system to the gasifier. Data will be gathered and compared with actual load cell material feed information.

- Efforts continued in surveying local contractors to identify alternate suppliers of coal and char feedstock for the gasifier tests. An inspection of coal screening facilities indicated that a coal sizing facility in Adamsburg, Pennsylvania, can adequately meet short-term, small quantity needs. It offers a relatively wide range of feed materials. A further review of coal material needs resulted in an order for both high-ash and low-ash fusion temperature coal.

- A review of the operational data obtained on the quench water system during the TP-015-1 gasifier test was evaluated. This system includes the design modification, procurement and installation of the following items:

  - Multi-weired separator pit for solid waste removal

  - Slurry pump and settling pan for solids removal from the separator pit during testing

  - Pump addition of flocculant

  - Vertical turbine regenerative pumps for recycled make-up supply to quench scrubbers and coolers

  - Incineration of separator pit surface wastes in the thermal oxidizer.

The waste water cleanup and recycle modes of this system were successfully demonstrated throughout the test period.

Modification to the quench water waste system was made to improve operation of the recirculation loop and sampling technique. Pump G-114 was modified to enable it to serve a dual role. This pump can continue to be used to pump water and fines from the top of the water separator pit, however by using the new swivel piping, it can take suction at any level of the pit enabling selective pumping from any depth. The second role is as a recirculation pump to enable selective sampling of any one of the three cooling water vessels, or all three at the same time. The pump recirculates water from flash drum Z-107 and mixes it so that a good homogeneous sample can be obtained.

- Conceptual design of a replacement section for the gasifier withdrawal boot was finalized and detailed construction drawings completed. This design features a transition spool piece adapter between the offset cone section and the delumper. A purchase requisition for the boot section and adapter was released to fabricate the units.

- An evaluation of the reactor vessel creep properties was made to define operating time limits to rupture at various pressure-temperature conditions. This analysis was performed to establish operational action plans in cases where partial failure of refractory may occur, thus exposing the shell to high temperature conditions.

- The Kay Ray nuclear bed level indicating system was reviewed with regard to operation with the expanded section modification of the gasifier vessel. An analysis showed a requirement for a major change in position of one of the two radiation measuring sources in order to maintain a useable level of output. This was implemented.

3.1.4.2 Work Accomplished, Product Characterization

Product characterization work completed this period includes the modification of measuring apparatus and techniques used for the gasifier tests and evaluation of results obtained from TP-015.

3.1.4.2.1 Gas Sampling Modifications

The isokinetic probe and sampling train was modified to incorporate two isolation valves next to the flange. The hot box which houses the minicyclone was close-coupled adjacent to the isolation valves to insure that the isokinetic sample collected was above the dew points of water and condensible hydrocarbons in the sampling gas.

During TP-015 gasifier test, a number of procedural, design, and hardware problems were identified and corrected for TP-016. During TP-016 gasifier test, the isokinetic sampling train produced good results for the first time, indicating quantitative loading of particulates downstream of the cyclone. With only limited capacity of 2 grams in the catch pot, isokinetic test duration was very short. A larger cylindrical catch pot, 2 inches in diameter by 3 inches long, was fabricated and installed for Test TP-017, and better particulate loading data were obtained.

A miniscrubber gas sampling train was also designed, fabricated and installed for the TP-016 gasifier test. The sampling train was installed to bubble a bypass stream of product gas downstream of the cyclone to characterize the product gas with respect to ammonia, hydrogen cyanide, sulfur compounds, chlorides, alkali metals, and metallic elements such as lead, vanadium and arsenic.

Problems experienced in the miniscrubber operation during TP-016 were:

- Inability to retain scrubbing fluid because of the length of sampling time and high particulate loading (All the scrubbing water was absorbed by particulates collected during the scrubbing time selected.)
- Inability to effectively chill the scrubbing water externally
- Inadequate operational procedure to control repeatable sampling conditions.

Several changes in the product characterization hardware systems were incorporated following the TP-016 gasifier test to improve the accuracy and operability of this equipment. The miniscrubber will be relocated downstream of the cyclone used with the isokinetic sampling train. This change will enable the isokinetic probe and miniscrubber trains to simultaneously sample the gas stream to improve reliability of the data.

The minicyclone, the solids separation device used in the isokinetic sampling train, was relocated closer to the sampling connection to minimize heat loss in the sample line. This was done to prevent the possibility of tar condensation in the line upstream of the minicyclone. No tar, however, has been detected in the isokinetic samples collected in TP-016, and TP-017 tests. The miniscrubber uses water to scrub certain compounds, notably ammonia, out of the sampled gas so that they can be detected in the more concentrated water solution. Also, a minor change to the gas chromatograph filter rack was made to enable on-line change-out of filters more easily.

3.1.4.2.2 TP-015 Product Characterization Data

Evaluation of product characterization data from air-blown gasifier test TP-015 was completed this quarter. TP-015 was the initial "shakedown" test to characterize the reactor with the new, expanded freeboard configuration in which a total of four set points were achieved. The test can be characterized by the following table.

TP-015 OPERATING DATA

	SET POINTS 1	2	3	4
Freeboard temperature (^{o}F)	1833	1833	1770	1675
Coaxial feedstock	L60, Coke Breeze	L-60, Coke Breeze	W. Kentucky FMC Char	Wyoming Sub-C Coal
Radial feedstock	L-60, Coke Breeze	Recycled Fines	W. Kentucky FMC Char	Recycled Fines
Bed Ash Content (%)	22	21	54	9
Withdrawal Ash Content (%)	75	78	92	23

Gasifier process streams and sample collection points used in product characterization analyses are shown in Figure 3.1-5.

SOLIDS ANALYSIS

Laboratory analysis of feedstock and reactor solids were also conducted, with both proximate and ultimate analyses made for each test point. Tables 3.1-25, -26, -27 and -28 summarize these results by feed material and set point, and Tables 3.1-29 through 3.1-32 provide size distribution of the solids, again by feed material and set point.

The results of these analyses represent only the steady-state conditions reached during the defined set points of the test. Equal quantities from various solid samples collected during steady-state periods are composited to represent one single sample for the analysis.

PRODUCT GAS ANALYSIS

The on-line gas chromatograph data for product gas and recycle gas streams, averaged over the steady-state periods, are used for heat and material balance. The data for trace hydrocarbons and sulfur compounds obtained by laboratory mass spectrometer are described in Table 3.1-33.

QUENCH SCRUBBER SOLIDS AND WATER ANALYSIS

Figure 3.1-6 shows Coulter Counter particle size distribution data for the samples collected upstream of the scrubbers. The upstream data was measured with a Total Condensibles Analyzer (TCA). Tables 3.1-34 provides a tabulation of the components measured in the liquid samples collected from the scrubbers.

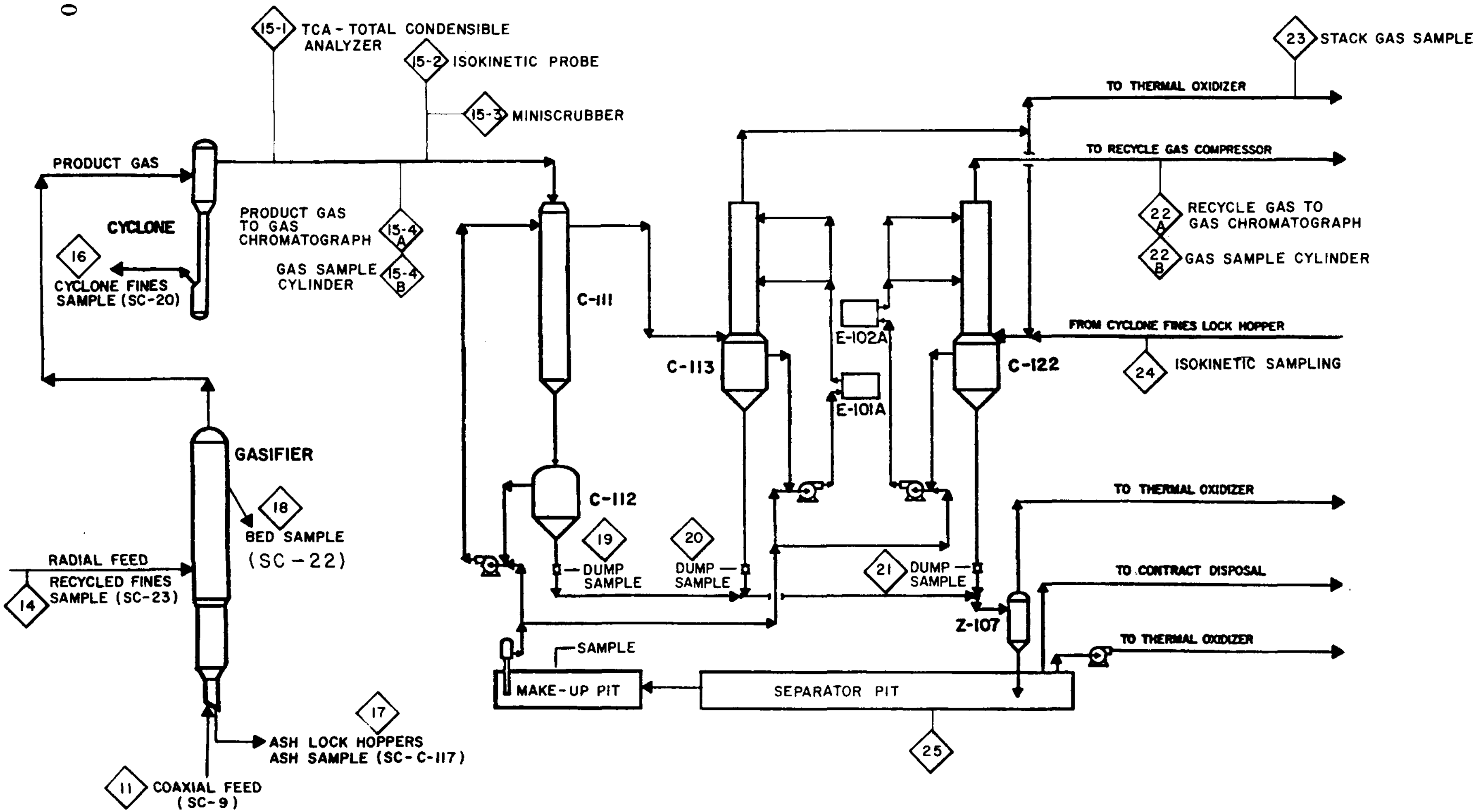


Figure 3.1-5. PDU Gasifier Process Schematic for Solids, Liquids, Gas and Particulate Sampling Locations

TABLE 3.1-25

FEEDSTOCKS AND REACTOR SOLIDS
PRODUCT CHARACTERIZATION DATA
COKE BREEZE FEED
AIR BLOWN GASIFIER TEST TP-015 - SET POINT 1

	11		14		18		16		15-1	19	20	21	17	
	SC-9 Coaxial		SC-23 Radial		SC-22 Bed Material		SC-20 Fines Carryover		TCA-78- -006-007 -008 Composite	LQ-78- 0145 C-111 Dump	LQ-78- 0146 C-113 Dump	LQ-78- 0147 C-122 Dump	C-117 Ash Lockhoppers	
PROXIMATE (%) *	AS REC	DRY	AS REC	DRY	AS REC	DRY	AS REC	DRY	DRY	DRY	DRY	DRY	AS REC	DRY
MOISTURE	1.36	--	1.36	--	0.30	--	0.45	--	--	--	--	--	0.27	--
VOLATILE MATTER	2.24	2.27	2.24	2.27	1.74	1.75	2.21	2.22	--	--	--	--	1.51	1.52
FIXED CARBON	85.16	86.33	85.16	86.33	75.81	76.04	89.42	89.82	--	--	--	--	23.49	23.55
ASH	11.24	11.40	11.24	11.40	22.15	22.21	7.92	7.96	15.98	17.04	18.91	--	74.73	74.93
ULTIMATE (%) **														
CARBON	85.72	86.90	85.72	86.90	77.04	77.27	88.02	88.42	--	--	--	--	24.24	24.31
HYDROGEN	0.95	0.80	0.95	0.80	0.27	0.24	0.43	0.39	--	--	--	--	0.37	0.35
OXYGEN	1.68	0.47	1.68	0.47	0.26	0.0	0.40	0.00	--	--	--	--	0.24	0.0
NITROGEN	0.65	0.66	0.65	0.66	0.62	0.62	0.50	0.50	--	--	--	--	0.11	0.11
SULFUR	0.76	0.77	0.76	0.77	0.66	0.66	0.73	0.73	--	--	--	--	0.31	0.31
ASH	10.26	10.40	10.26	10.40	21.15	21.21	9.92	9.96	--	--	--	--	74.73	74.93
MISCELLANEOUS ANALYSIS														
BULK DENSITY (lb/ft^3)	38.8	--	38.8	--	32.2	--	35.5	--	--	--	--	--	50.5	--
AVERAGE SIZE (μ) †	766	--	766	--	1053	--	129	--	--	--	--	--	1453	--
CALORIFIC VALUE Btu/lb	12403	--	--	--	--	--	--	--	11574	11424	11084	--	--	--

* Weight mean diameter
** Analysis by WACCD Laboratory, Waltz Mill, PA
† Analysis by Warner Laboratory, Creson, PA
-- Not measured

TABLE 3.1-26

FEEDSTOCKS AND REACTOR SOLIDS
PRODUCT CHARACTERIZATION DATA
COKE BREEZE WITH RECYCLED FINES FEED
AIR BLOWN GASIFIER TEST TP-015 - SET POINT 2

	11		14		18		16		15-1	19	20	21	17	
	SC-9 Coaxial		SC-23 Radial		SC-22 Bed Material		SC-20 Fines Carryover		TCA-78-0009	LQ-78-0048 C-111 Dump	LQ-78-0049 C-113 Dump	LQ-78-0050 C-122 Dump	C-117 Ash Lockhoppers	
PROXIMATE (%) *	AS REC	DRY	AS REC	DRY	AS REC	DRY	AS REC	DRY	DRY	DRY	DRY	DRY	AS REC	DRY
MOISTURE	1.36	--	0.39	--	0.01	--	0.39	--	--	--	--	--	0.06	--
VOLATILE MATTER	2.21	2.27	1.46	1.47	1.94	1.94	1.46	1.47	--	--	--	--	1.06	1.06
FIXED CARBON	85.16	86.33	86.52	84.85	77.31	77.32	84.52	87.85	--	--	--	--	20.68	20.69
ASH	11.24	11.40	13.63	13.68	20.74	20.74	13.63	13.68	8.31	10.07	9.07	9.27	78.20	78.25
ULTIMATE (%)**														
CARBON	84.68	85.85	84.78	85.11	77.64	77.65	84.78	85.11	--	--	--	--	21.65	21.66
HYDROGEN	1.05	0.90	0.38	0.35	0.79	0.79	0.38	0.35	--	--	--	--	0.32	0.31
OXYGEN	1.62	0.42	0.35	0.00	0.01	0.00	0.35	0.00	--	--	--	--	0.05	0.00
NITROGEN	0.65	0.66	0.38	0.38	0.30	0.30	0.38	0.38	--	--	--	--	0.09	0.09
SULFUR	0.76	0.77	0.68	0.68	0.65	0.65	0.68	0.68	--	--	--	--	0.32	0.32
ASH	11.24	11.40	13.43	13.48	20.61	20.61	13.43	13.48	--	--	--	--	77.57	77.62
MISCELLANEOUS ANALYSIS														
BULK DENSITY (lb/ft^3)	38.8	--	31.4	--	33.7	--	31.4	--	--	--	--	--	52.5	--
AVERAGE SIZE (μ) †	766	--	140	--	947	--	140	--	--	--	--	--	1239	--
CALORIFIC VALUE Btu/lb	12403	--	--	--	--	--	--	--	12899	12850	12696	12659	--	--

* Weight mean diameter
** Analysis by WACCD Laboratory, Waltz Mill, PA
† Analysis by Warner Laboratory, Creson, PA
-- Not measured

TABLE 3.1-27

FEEDSTOCKS AND REACTOR SOLIDS
PRODUCT CHARACTERIZATION DATA
FMC W. KENTUCKY FEED
AIR BLOWN GASIFIER TEST TP-015 - SET POINT 3

	11		14		18		16		15-1	19	20	21	17	
	SC-9 Coaxial		SC-23 Radial		SC-22 Bed Material		SC-20 Fines Carryover		TCA-78-0014	LQ-78-0080 C-111 Dump	LQ-78-0081 C-113 Dump	LQ-78-0082 C-122 Dump	C-117 Ash Lockhoppers	
PROXIMATE (%) *	AS REC	DRY	AS REC	DRY	AS REC	DRY	AS REC	DRY	DRY	DRY	DRY	DRY	AS REC	DRY
MOISTURE	4.00	--	4.00	--	0.16	--	0.79	--	--	--	--	--	0.09	--
VOLATILE MATTER	9.31	9.70	9.31	9.70	2.05	2.05	2.68	2.72	--	--	--	--	1.27	1.27
FIXED CARBON	73.90	76.98	73.90	76.98	43.27	43.52	83.48	84.13	--	--	--	--	6.18	6.18
ASH	12.79	13.32	12.79	13.32	54.52	54.43	13.05	13.15	9.36	10.69	9.41	9.72	92.46	92.55
ULTIMATE (%) * *														
CARBON	75.60	78.75	75.60	78.75	42.84	42.91	81.33	81.98	--	--	--	--	6.81	6.82
HYDROGEN	1.70	1.36	1.70	1.36	0.35	0.33	0.58	0.49	--	--	--	--	0.22	0.21
OXYGEN	8.06	4.62	8.06	4.62	0.64	0.50	1.14	0.44	--	--	--	--	0.08	0.00
NITROGEN	1.44	1.51	1.44	1.51	0.30	0.30	0.74	0.75	--	--	--	--	0.52	0.52
SULFUR	1.37	1.44	1.37	1.44	1.53	1.53	1.29	1.30	--	--	--	--	0.45	0.45
ASH	11.83	12.32	11.83	12.32	54.34	54.43	14.92	15.04	--	--	--	--	91.92	92.00
MISCELLANEOUS ANALYSIS														
BULK DENSITY (lb/ft^3)	27.3	--	27.3	--	28.1	--	26.3	--	--	--	--	--	49.3	--
AVERAGE SIZE (μ) †	618	--	618	--	819	--	168	--	--	--	--	--	680	--
CALORIFIC VALUE Btu/lb	12379	--	--	--	--	--	--	--	12154	11964	12431	12364	--	--

* Weight mean diameter
** Analysis by WACCD Laboratory, Waltz Mill, PA
† Analysis by Warner Laboratory, Creson, PA
-- *Not measured*

TABLE 3.1-28

FEEDSTOCKS AND REACTOR SOLIDS
PRODUCT CHARACTERIZATION DATA
WYOMING SUB-C COAL FEED WITH RECYCLED FINES
AIR BLOWN GASIFIER TEST TP-015 - SET POINT 4

	11		14		18		16		15-1	19	20	21	17	
	SC-9 Coaxial		SC-23 Radial		SC-22 Bed Material		SC-20 Fines Carryover		TCA-78-0023	LQ-78-0118	LQ-78-0119	LQ-78-0120	C-117 Ash Lockhoppers	
PROXIMATE (%) *	AS REC	DRY	AS REC	DRY	AS REC	DRY	AS REC	DRY	DRY	DRY	DRY	DRY	AS REC	DRY
MOISTURE	16.58	--	0.53	--	0.49	--	0.53	--	--	--	--	--	0.93	--
VOLATILE MATTER	43.35	51.97	5.05	5.08	4.04	4.06	5.05	5.08	--	--	--	--	3.71	3.74
FIXED CARBON	37.48	44.93	80.28	80.71	86.82	87.25	80.28	80.71	--	--	--	--	75.14	75.85
ASH	2.59	3.10	14.14	14.21	8.65	8.69	14.14	14.21	21.55	23.01	10.0	15.61	20.22	20.41
ULTIMATE (%)**														
CARBON	59.99	71.91	81.28	81.71	84.20	84.61	81.28	81.71	--	--	--	--	75.09	75.79
HYDROGEN	6.50	4.66	0.56	0.52	0.83	0.79	0.56	0.52	--	--	--	--	0.41	0.32
OXYGEN	29.89	19.10	1.70	1.23	5.33	4.92	1.70	1.23	--	--	--	--	0.82	0.00
NITROGEN	1.11	1.33	0.25	0.25	0.74	0.74	0.25	0.25	--	--	--	--	0.30	0.30
SULFUR	0.17	0.20	0.48	0.48	0.25	0.25	0.48	0.48	--	--	--	--	0.50	0.50
ASH	2.34	2.80	15.73	15.81	8.65	8.69	15.73	15.81	--	--	--	--	22.88	23.09
MISCELLANEOUS ANALYSIS														
BULK DENSITY (lb/ft^3)	41.3	--	20.2	--	17.0	--	20.2	--	--	--	--	--	49.9	--
AVERAGE SIZE (μ) †	1169	--	198	--	1067	--	198	--	--	--	--	--	1152	--
CALORIFIC VALUE Btu/lb	11863	--	--	--	--	--	--	--	10114	10510	9241	11307	--	--

* Weight mean diameter
** Analysis by WACCD Laboratory, Waltz Mill, PA
† Analysis by Warner Laboratory, Creson, PA
-- Not measured

TABLE 3.1-29

FEEDSTOCKS AND REACTOR SOLIDS PRODUCT
SIZE DISTRIBUTION DATA
COKE BREEZE FEED
AIR BLOWN GASIFIER TEST TP-015 - SET POINT 1

◇11 and ◇14		◇18		◇16		◇17	
SC-9 & -23 (COAXIAL & RADIAL FEEDSTOCK)		SC-22 (BED SAMPLE)		SC-20 (FINES CARRYOVER)		C-117 (ASH LOCKHOPPERS)	
Mesh	Wt. %	Mesh	Wt. %	Mesh	Wt. %	Mesh	Wt. %
+6	0.22	+6	0.27	+40	0	+8	5.37
-6 +10	6.67	-6 +10	13.41	-40 +50	0.47	-8 +12	26.40
-10 +20	22.45	-10 +20	32.57	-50 +70	4.21	-12 +16	35.85
-20 +40	24.57	-20 +40	22.58	-70 +100	27.44	-16 +20	19.74
-40 +70	24.22	-40 +70	19.87	-100 +200	52.87	-20 +40	11.15
-70 +100	11.14	-70 +100	7.55	-200 +270	6.71	-40 +70	1.24
-100	10.74	-100	3.75	-270	8.31	-70	0.25

TABLE 3.1-30

FEEDSTOCKS AND REACTOR SOLIDS PRODUCT
SIZE DISTRIBUTION DATA
COKE BREEZE WITH RECYCLED FINES FEED
AIR BLOWN GASIFIER TEST TP-015 - SET POINT 2

11		18		16 and 14		17	
SC-9 (COAXIAL FEEDSTOCK)		SC-22 (BED SAMPLE)		SC-20 (FINES CARRYOVER) AND SC-23 (RADIAL FEEDSTOCK)		C-117 (ASH LOCKHOPPERS)	
Mesh	Wt. %	Mesh	Wt. %	Mesh	Wt. %	Mesh	Wt. %
+6	0.22	+6	0.35	+40	0.04	+8	4.48
-6 +10	6.67	-6 +10	7.82	-40 +50	1.04	-8 +12	15.84
-10 +20	22.45	-10 +20	35.71	-50 +70	6.76	-12 +16	28.46
-20 +40	24.57	-20 +40	22.25	-70 +100	31.71	-16 +20	26.26
-40 +70	24.22	-40 +70	17.77	-100 +200	50.10	-20 +40	19.73
-70 +100	11.14	-70 +100	8.40	-200 +270	4.80	-40 +70	2.41
-100	10.74	-100	7.71	-270	5.57	-70	2.81

TABLE 3.1-31

FEEDSTOCKS AND REACTOR SOLIDS PRODUCT
SIZE DISTRIBUTION DATA
FMC FEED
AIR BLOWN GASIFIER TEST TP-015 - SET POINT 3

⟨11⟩ and ⟨14⟩ SC-9 & -23 (COAXIAL & RADIAL FEEDSTOCK)		⟨18⟩ SC-22 (BED SAMPLE)		⟨16⟩ SC-20 (FINES CARRYOVER)		⟨17⟩ C-117 (ASH LOCKHOPPERS)	
Mesh	Wt. %	Mesh	Wt. %	Mesh	Wt. %	Mesh	Wt. %
+6	0.0	+6	0.15	+40	1.76	+8	0.43
-6 +10	0.49	-6 +10	2.28	-40 +50	7.75	-8 +12	1.40
-10 +20	23.85	-10 +20	27.87	-50 +70	14.48	-12 +16	3.74
-20 +40	28.02	-20 +40	45.88	-70 +100	26.89	-16 +20	12.23
-40 +70	17.66	-40 +70	20.00	-100 +200	37.12	-20 +40	67.32
-70 +100	7.61	-70 +100	2.13	-200 +270	5.22	-40 +70	11.17
-100	22.37	-100	1.69	-270	6.77	-70	3.71

TABLE 3.1-32

FEEDSTOCKS AND SOLIDS PRODUCT
SIZE DISTRIBUTION DATA
COKE BREEZE WITH RECYCLED FINES FEED
AIR BLOWN GASIFIER TEST TP-015 - SET POINT 4

11		18		16 and 14		17	
SC-9 (COAXIAL FEEDSTOCK)		SC-22 (BED SAMPLE)		SC-20 (FINES CARRYOVER) AND SC-23 (RADIAL FEEDSTOCK)		C-117 (ASH LOCKHOPPERS)	
Mesh	Wt. %	Mesh	Wt. %	Mesh	Wt. %	Mesh	Wt. %
+6	0.09	+6	0.0	+40	2.43	+8	1.96
-6 +10	9.87	-6 +10	2.27	-40 +50	14.80	-8 +12	20.90
-10 +20	49.11	-10 +20	54.65	-50 +70	22.68	-12 +16	23.36
-20 +40	25.79	-20 +40	31.30	-70 +100	22.76	-16 +20	18.35
-40 +70	11.64	-40 +70	9.40	-100 +200	28.47	-20 +40	17.08
-70 +100	1.47	-70 +100	1.34	-200 +270	3.64	-40 +70	15.41
-100	2.03	-100	1.03	-270	5.22	-70	2.94

TABLE 3.1-33

PRODUCT GAS ANALYSIS OF TRACE CONSTITUENTS
BY LABORATORY MASS SPECTROMETER
AIR BLOWN GASIFIER TEST TP-015

		15-4B Set Point 1 Coke Breeze Feed Percent (Dry Basis)	15-4B Set Point 2 Coke Breeze Feed Percent (Dry Basis)	15-4B Set Point 3 FMC W. Ky Char Percent (Dry Basis)	15-4B Set Point 4 Wyoming Sub-C Coal Percent (Dry Basis)
Hydrogen Sulfide	H_2S	Trace	0.03	0.18	0.01
Carbonyl Sulfide	COS	ND	ND	0.06	-
Methane	CH_4	0.07	0.5	0.17	1.16
Ethylene	C_2H_4	ND	ND	ND	ND
Ethane	C_2H_6	0.04	ND	0.02	0.03
Propylene	C_3H_6	ND	ND	0.01	ND
Acetylene	C_2H_2	ND	ND	ND	ND
Ammonia	NH_3	0.11	ND	0.11	0.07

ND - Not Detectable

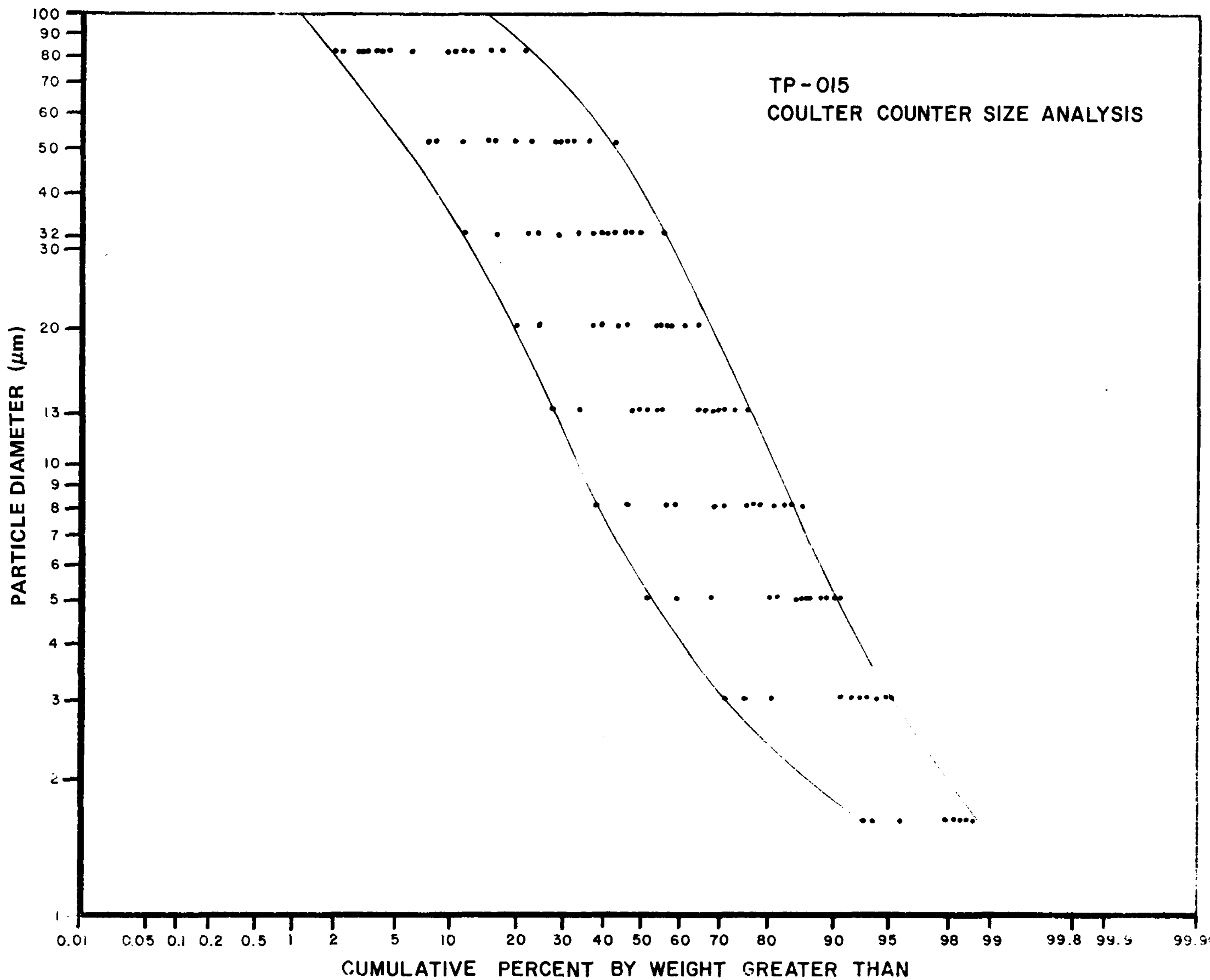


Figure 3.1-6 Quench Scrubber Particulate Size Distribution Data (Coulter Counter Analysis)

TABLE 3.1-34

QUENCH SCRUBBER WATER SAMPLE ANALYSIS
TEST TP-015

Set Pt. # and Feed	Sample ID No.	Stream No.	Solids % Wt/Wt	Tars & Oils Acetone Extractables % Wt/Wt	PH	Total NH_3 Ng/L	Total Alkalinity as $CaCO_3$ mg/L	Total Cyanide CN mg/L	Total Sulfur S mg/L	Total Suphate SO_4" mg/L	Total Sulfide S" mg/L	Total Thio-Sulfates S_2O_3" Mg/L	Total Chloride Cl' mg/L	Total Phenols mg/L	* COD mg/L	** BOD mg/L	Filterable Total Dissolved Solids
Set Point 2 Coke Breeze and Recycled Fines	LQ-78-0048 C-111 Dump	20	3.4	No Extractable Material With Acetone	7.2	220	550	2.5	612	295	<.02	897	143	0.04	91	12.0	445
	LQ-78-0049 C-113 Dump	21	0.8		8.5	176	280	0.13	650	410	<.02	897	194	0.04	130	7.2	612
	LQ-78-0050 C-122 Dump	23	2.3		7.0	232	650	4.1	725	250	<.02	1122	117	0.03	99	7.2	365
	Avg.		2.2		7.6	209	493	2.2	662	318	<.02	972	151	0.04	106	8.8	474
Set Point 3 W. Kentucky Fine Char	LQ-78-0080	20	0.13	No Extractable Material With Acetone	7.3	440	1420	6.6	570	50	<.02	964	61	0.01	61	4.8	153
	LQ-78-0081	21	1.10		6.8	296	1080	3.5	622	125	<.02	1009	77	0.07	87	11.0	357
	LQ-78-0082	22	0.33		7.0	400	1430	7.5	602	65	<.02	1009	56	0.03	53	1.2	221
	Avg.		0.52		7.0	378	1310	5.9	598	80	<.02	994	65	0.04	67	6.0	244
Set Point 4 Sub-C Coal	LQ-78-0118	20	1.62	No Extractable Material With Acetone	9.2	560	1710	2.6	940	150	<.02	1547	92	0.1	170	4.5	344
	LQ-78-0119	21	0.03		7.7	1240	4380	21.0	954	75	<.02	1614	56	0.06	140	2.4	242
	LQ-78-0120	22	0.18		7.2	880	3020	9.2	887	105	<.02	1480	82	0.01	170	2.4	301
	Avg.		0.61		8.0	893	3036	11.0	927	110	<.02	1547	77	0.03	160	3.0	296
780-412-1400		25	--	--	--	449	1259	7.6	875	185	<.02	1368	235	0.02	180	11.0	358
780-404-1300 Prefeed Coal Pit Sample		25	--	--	--	2.2	190	0.061	280	110	<.02	426	77	0.04	24	2.4	435
Set Pt. 3 780410-0130 Pit Sample		25	--	--	--	208	670	1.7	767	180	<.02	1233	143	0.04	320	13.0	386

*COD - Chemical Oxygen Dissolved

**BOD - Biological Oxygen Dissolved

Dump liquid samples were collected from each vessel in the product gas cooling system during steady-state periods of each set point. The results of these analyses show the following trends:

- No visible tars and oils were found in the filtrate from the dump liquid samples. P_H of the filtrate varied from 7 to 9.

- No hydrocarbons were detected by gravimetric method in the acetone extract of the residue within the accuracy of measurement technique.

3.1.4.3 Environmental Safety and Health

On May 3, 1978 an OSHA-type inspection of the PDU was conducted by the Department of Energy (DOE). The inspecting group was led by Mr. Jack Abrahams, Fossil Energy Division, DOE, and included two consultants, A. F. Meyer and A. Thomas. A formal report on the findings will be issued by DOE.

Westinghouse ACCD was represented at a meeting of DOE and DOE contractor safety officers held in Albuquerque, New Mexico in June. Improved methods of overviewing contractor operations were explored, as well as possible solutions to many common problems.

American Red Cross industrial first aid classes were given again this quarter with twenty-two employees awarded a three-year certification. This increases site personnel participation to 75 percent. Efforts continue to provide the most effective state-of-the-art personnel protective equipment, particularly in the areas of full face visors, gloves, respirators, and eye protection wear.

In compliance with an OSHA proposed standard on benzene exposure, sources of benzene have been removed from the site, except a small amount used in the analytical lab and that produced by the coal gasification process.

Surveys made on analytical lab employees engaged in typical procedures involving benzene showed the 8-hour average exposure to be much less than the proposed OSHA standard of 1 ppm. Process exposure will now be considered based on the results of the extended personnel sampling program.

Safety aspects of the design and installation of the liquid oxygen system were monitored extensively during April, May and June, and cleaning procedures were written for the oxygen and systems components. Procedures for the protection of personnel involved in the cleaning operations were established and monitored. An investigation of the reliability of using CO_2 as a purge gas was also conducted, and classes were held on the potential hazards and the safe handling of oxygen systems.

3.1.4.3.1 Environmental Sampling

During TP-017, environmental sampling was performed to determine the extent of potentially toxic respiratory exposure to PDU process technicians. Individual personnel samples were taken to determine 8-hour time-weighted average exposure to total particulate matter, benzene soluble fraction of total particulate matter and benzene. Area samples were taken for simultaneous phenolic exposure. Crew members were sampled for five consecutive shifts, spanning several set points during which various feed rates of Pittsburgh seam coal were being processed, as well as during the shutdown phase. Analysis of the samples will yield data with which PDU personnel exposure can be compared to OSHA and NIOSH proposed standards. The data can also be observed for substances in significant amounts which might have to be considered in future carcinogenic or other debilitating substance studies.

Of the common coal gasification effluents, the liquid slurry from the quench systems represents a disposal problem which requires careful monitoring to avoid contamination of water supplies and to prevent hazard to personnel. The materials from the tests reported herein were analyzed for contaminant content and leachate values and were found to be acceptable for landfill disposal.

Stack gas analysis for SO_2 and NO_x was performed by Bendix/Gastec detector tubes utilizing a Bendix/Gastec multistroke gas sampling pump. The NO_x was measured by two different Gastec tubes: $NO + NO_2$ and NO_2. The stack gas sample is drawn into a sample bomb cylinder by a vacuum pump. None of the samples taken yielded detectable SO_2 or NO_x levels.

Bids were requested and received for continuous monitoring instruments to record levels of SO_2 and NO_x emanating from the thermal oxidizer stack. No further action has been taken. In the interim, instantaneous "grab" samples, utilizing Gastec tubes, will continue to be used to monitor stack gases.

3.2 PHASE I, TASK 3 - LABORATORY SUPPORT STUDIES

Work has been conducted in the following areas: cold flow and analytical modeling, coal behavior and ash agglomeration studies, deposit formation analysis, environmental impact studies, and reactor analysis.

3.2.1 Coal Flow and Analytical Modeling

3.2.1.1 Work Accomplished - Jet Phenomena

JET PENETRATION DEPTH OF MULTIPLE VERTICAL GRID JET

No correlation has been proposed for calculating the jet penetration depth for multiple grid jets, though Basov, et al, (1969)[1], found that their correlation developed for a single jet (Equation 1) could be applied satisfactorily to their data on multiple jets:

$$\frac{L}{d_o} = \left[\frac{0.919\ d_p}{0.0007 + 0.566\ d_p}\right] \cdot \frac{U_o^{0.35}}{d_o^{0.3}} \quad . \tag{1}$$

Merry (1975)[2] has reviewed the literature on the penetration of vertical jets into fluidized beds. He also proposed an expression for predicting the jet penetration depth, as shown in Equation 2:

$$\frac{L}{d_o} = 5.2\left(\frac{\rho_f d_o}{\rho_p d_p}\right)^{0.3} \left[1.3\left(\frac{U_o^2}{g d_o}\right)^{0.2} - 1\right] \quad . \tag{2}$$

The additional correlations that Merry reviewed were those by Shakhova (1968)[3] in Equation 3 and by Zenz (1968)[4] in Equation 4:

$$\left(\frac{L}{d_o} + \frac{1}{2}\cot\theta\right) = 13\left[\frac{\rho_f U_o}{\rho_p \sqrt{g d_p}}\right] \tag{3}$$

and

$$0.0144\frac{L}{d_o} + 1.3 = 0.5\log_{10}\left(\rho_f U_o^2\right) \quad . \tag{4}$$

The ρ_f and U_o in Equation 4 are in pounds-per-cubic-foot (lb/ft^3) and feet-per-second (ft/s), respectively.

More recent studies on jets were conducted by Wen, et al., (1977)[5] using a two-dimensional bed and by Yang and Keairns (1978)[6] employing a semi-circular unit. The correlation proposed by Wen, et al., is presented in Equation 5:

$$\frac{L}{d_o} = 814.2\left(\frac{\rho_p d_p}{\rho_f d_o}\right)^{-0.585}\left(\frac{\rho_f d_o U_o}{\mu}\right)^{-0.654}\left(\frac{U_o^2}{g d_o}\right)^{0.47} \quad . \tag{5}$$

There are three major groups of data on multiple jets. The most extensive data were by Basov, et al. They performed experiments on a 50-cm (20 inches) diameter bed with six different grids and four different orifice diameters of 3-, 8-, 14-, and 20-mm (0.1, 0.3, 0.5 and 0.78 inches). The bed material used was a cracking catalyst of 125-μm average particle size. The second group of data were by Behie, et al., (1971)(7) from their study of momentum dissipation of jets in fluidized beds. Two sizes of orifice, 12.7 and 19.1 mm (1/2 and 3/4-inches) were employed, and a cracking catalyst of 50-μm average particle size was used as the bed material. Wen, et al., provided the third group of data. They performed the experiments in a two-dimensional bed with three jets of 3.2-mm (0.12 inch) diameter using three different bed materials, i.e., 450-μm P.V.C. bead, 280-μm glass bead, and 830-μm sand. The data from different sources were summarized and presented in the second Quarterly Progress Report, FY-1978, FE-1514-84.

The available jet penetration data on multiple jets were correlated with the two-phase Froude number to give Equation 7. The developed correlation is accurate to $\pm$40 percent:

$$\frac{L}{d_o} = 15.0 \left(\frac{\rho_f}{\rho_p - \rho_f} \cdot \frac{U_o^2}{g d_o} \right)^{0.187} \qquad (7)$$

The same data base was also used to compare with that predicted by different proposed correlations in Figures 3.2-1 through 3.2-5. (The correlation by Shakhova was excluded because of difficulty in determining the jet half angle, θ.) Note that the use of the two-phase Froude number results in a superior formula that successfully correlates the available literature jet penetration data, including both the single-jet and the multiple-jet data obtained in either two-dimensional or three-dimensional beds.

The major uncertainty and ambiguity in studying the jets in fluidized beds is the definition of jet penetration depth. According to Merry, the jet penetration depth is the height at which the jet degenerates into a gas bubble. There is evidence, however, that the detached gas bubbles may still possess great momentum transferred from the jet. Yang and Keairns in their study using hollow epoxy spheres (ρ_p = 0.21 g/cm^3) as the bed material, observed that these gas bubbles issued at rapid succession from the jet actually possessed enough momentum to penetrate the bed at high jet velocities. Merry's definition does not adequately describe this physical phenomenon. A more precise definition should be based on the momentum dissipation of the jet. In fact, Behie, et al., (1971) have studied the jetting phenomenon in a fluidized bed from the point of view of momentum dissipation. The definition of jet penetration depth by Basov, et al., based on voidage distribution along the bed height is also in agreement with this definition.

Curve 695536-A

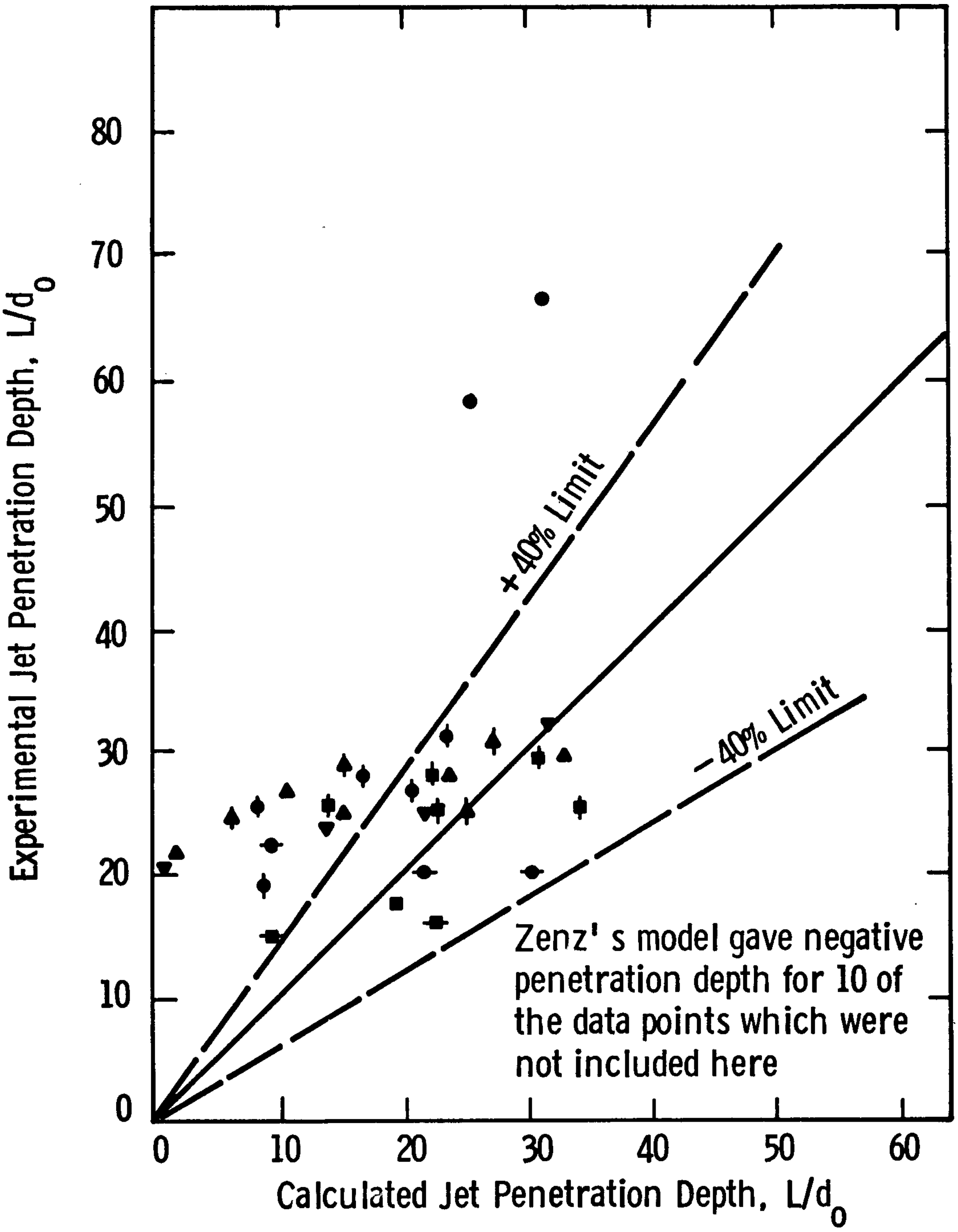


Figure 3.2-1. Comparison of Experimental Jet Penetration Depths with that Calculated from the Model by Zenz (1968)

Curve 695531-A

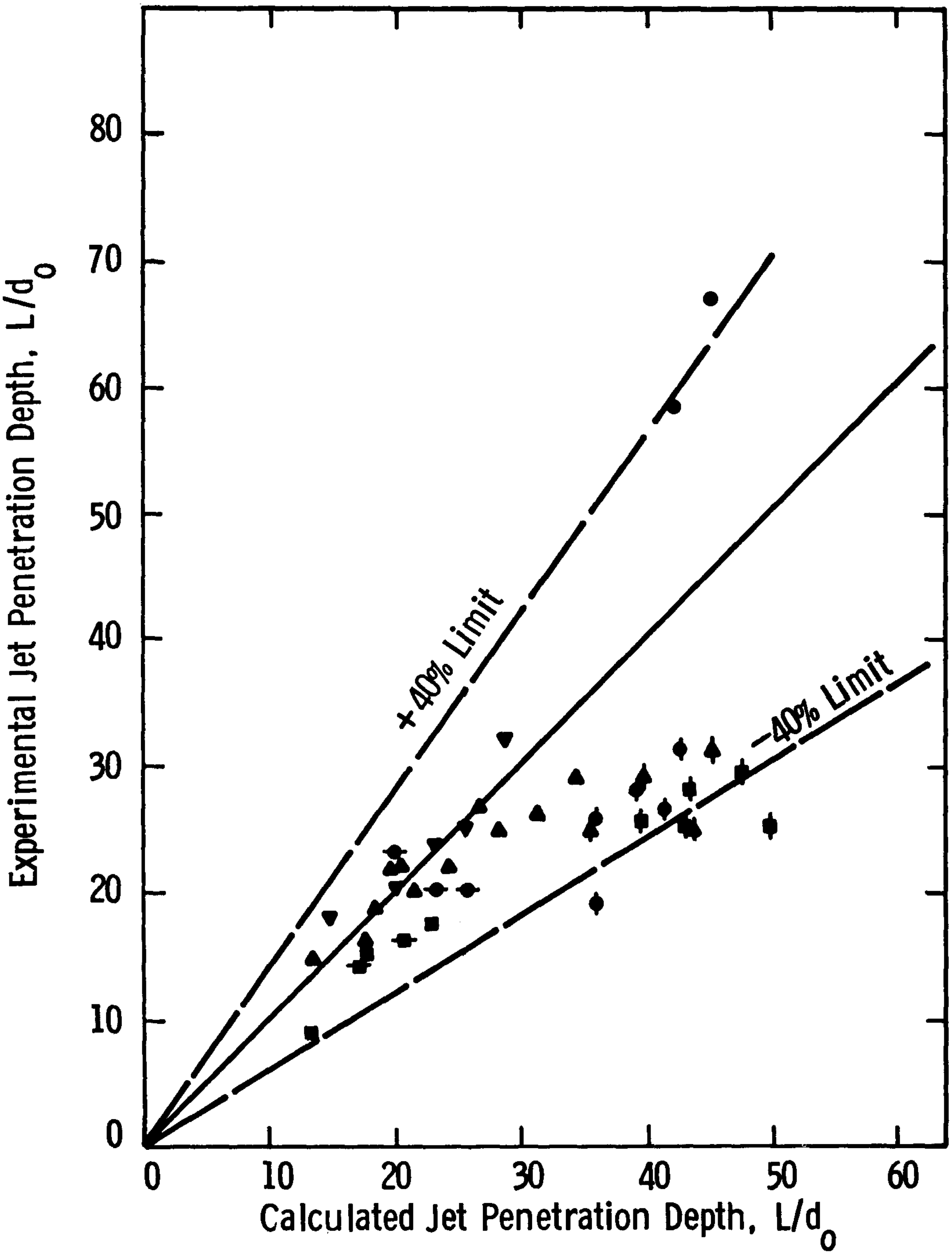


Figure 3.2-2. Comparison of Experimental Jet Penetration Depths with that Calculated from the Model by Basov et al. (1969)

Curve 695534-A

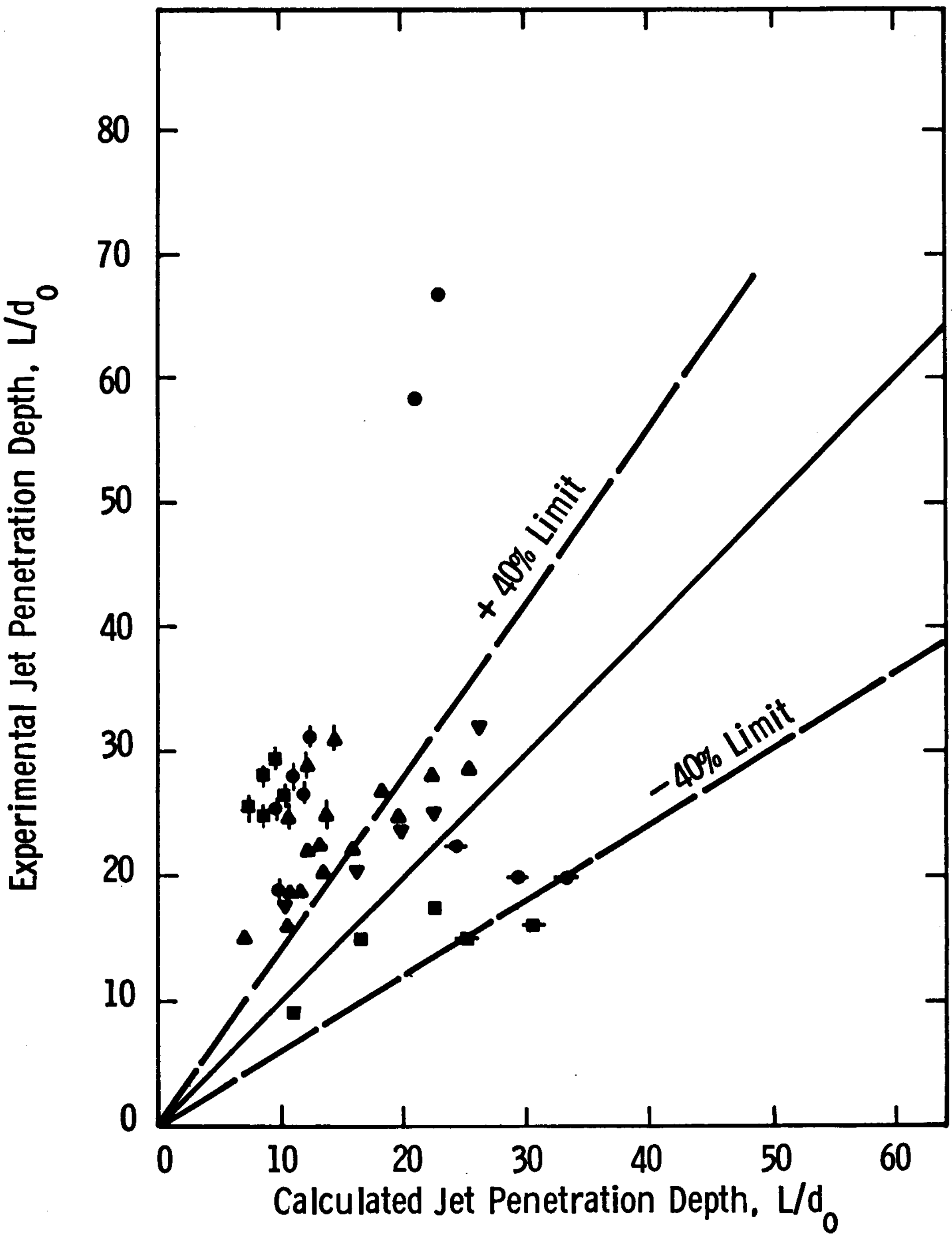


Figure 3.2-3. Comparison of Experimental Jet Penetration Depths with that Calculated from the Model by Merry (1975)

Curve 695533-A

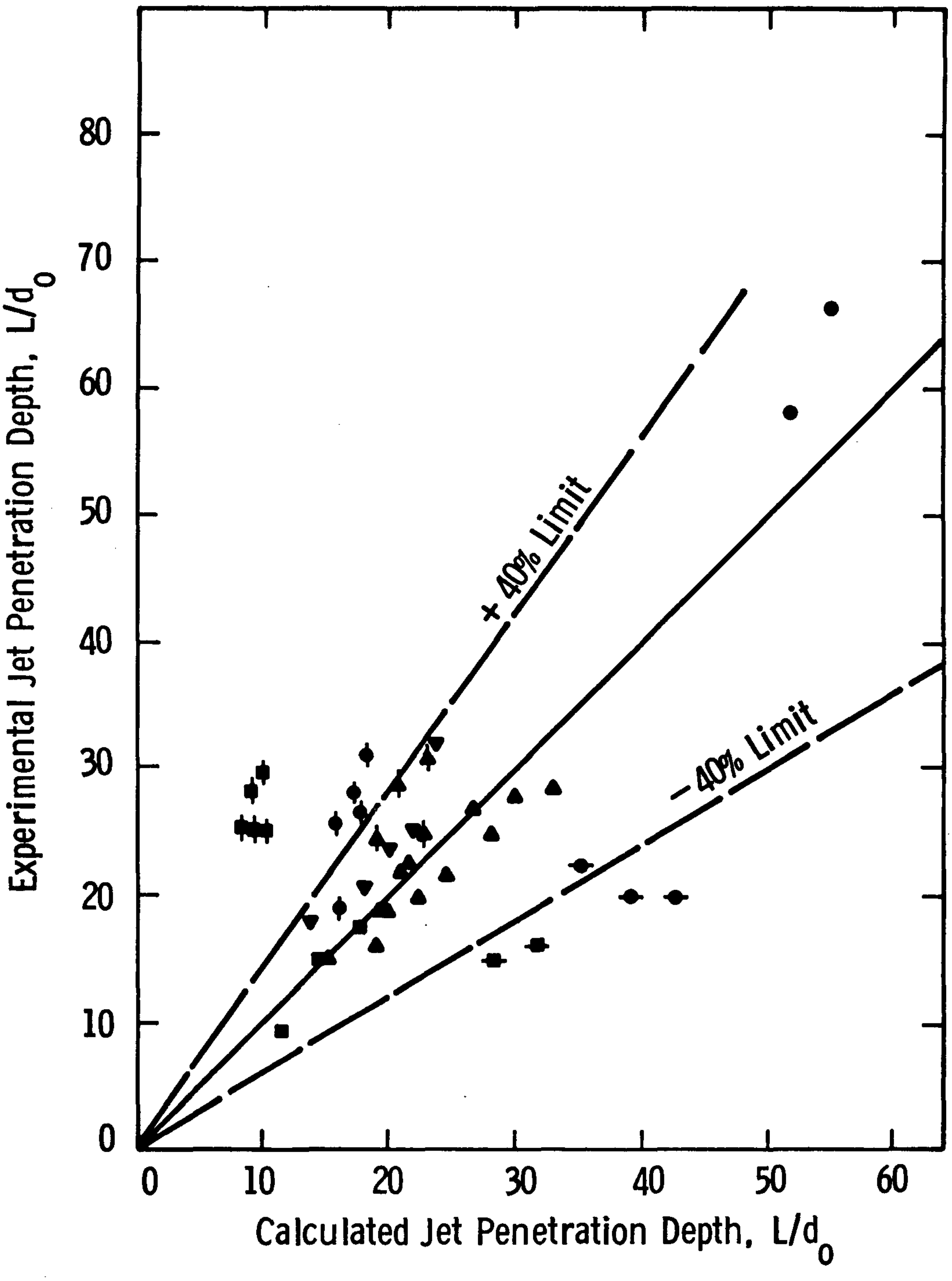


Figure 3.2-4. Comparison of Experimental Jet Penetration Depths with that Calculated from the Model by Wen et al. (1977)

Curve 695535-A

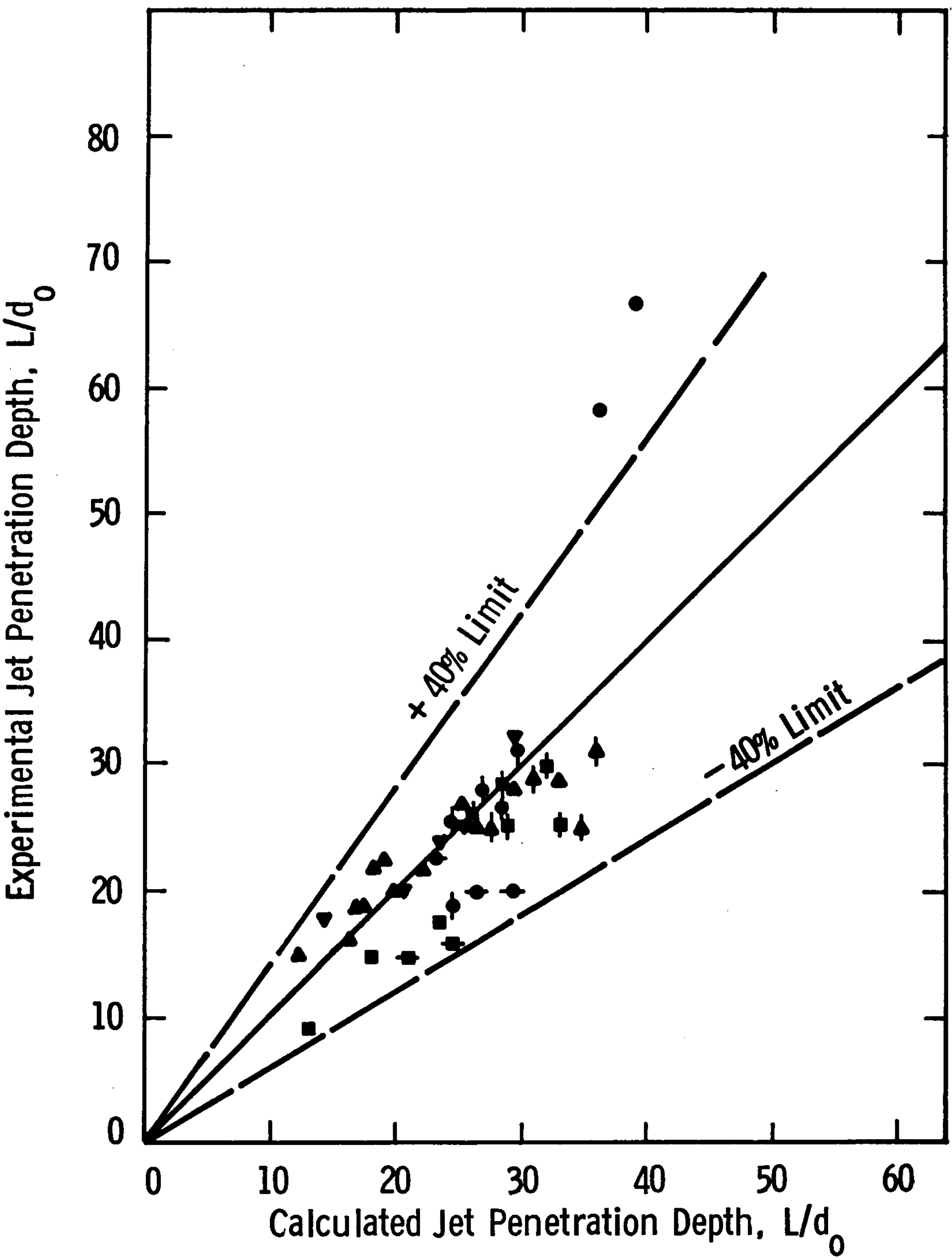


Figure 3.2-5. Comparison of Experimental Jet Penetration Depths with that Calculated from the Present Model

The model Zenz proposed has a defect in that the jet penetration depth will become negative if the momentum flux of the jet ($\rho_f U_0^2$) is less than 398 lb/ft^2-sec. This is equivalent to an air jet of about 22.3 m/s (73 ft/s). Zenz's model gave a negative penetration depth for 10 of the data points where positive jet penetration was observed. The model by Basov, et al., is reasonably good, especially when a cracking catalyst is the bed material. The model, however, is purely empirical and may not be generally applicable for bed materials considerably different from the cracking catalyst. In fact, the model started to break down when it was compared to the data by Wen, et al., who used plastic bead, glass bead, and sand as the bed material. Merry developed his model on the basis of the theory of bubble formation at the orifice. This mechanism does not seem to agree with the data very well, as shown in Figure 3.2-3. Wen, et al., proposed a correlation based on dimensional analysis and the data by Basov, et al. The correlation agreed with the data by Basov, et al., fairly well but failed on their own data and on the data by Behie, et al., (1971).

The equations developed here by using the two-phase Froude number correlated the data to within $\pm$40 percent, including both single-jet and multiple-jet data obtained in both two-dimensional and three-dimensional beds. The scatter of the data from different authors may be attributed partly to the different techniques employed to determine the jet penetration depth. Behie, et al., (1971) measured the dissipation of jet momentum to arrive at the jet penetration depth. Basov, et al., used a γ-densimeter to measure the bed density distribution in the zone near the grid. The jet penetration depth was then determined to be the height where the bed density started to level off. Wen, et al., performed experiments in a two-dimensional bed and visually observed the depth of jet penetration. The reasonable agreement between the present correlation and the literature data leads to the conclusion that the jet penetration in a fluidized bed is primarily dominated by the balance between the inertial force of the jet and the gravitational force of the bed.

It should be noted that the particle size is not in the present proposed correlation. Basov, et al., predict a slight increase of penetration depth with particle size for a given d_0 and U_0 (see Equation 1). Shakhova, however, predicts just the opposite trend in Equation 3. More data are needed to clarify this point. Judging from the facts that the jets possess intrinsic fluctuation, that subjectiveness is involved in visual observation, and that varieties of method are employed in measuring jet penetration depth, Equation 7 with accuracy to $\pm$40 percent should be adequate for engineering design.

GAS ENTRAINMENT INTO A JET IN THE FLUIDIZED BED

Experiments to study the gas entrainment into a jet were partially completed. Concentration profiles were mapped at seven different operating conditions. Tracer gas, helium, was injected with the jet and gas samples were taken from the sampling ports located at 1.7, 9.3, 23.6, 33.8, and 45.5 cm (1-1/16, 3-11/16, 9-5/16, 13-5/16 and 18 inches) above the top of the jet nozzle. The sampling probes were 0.64 cm (1/4 in.) stainless steel tubes and were adjustable to give different penetration into the jet. Gas samples were taken at 0.64 cm or 1.27 cm (1/4 inch or 1/2 inch) intervals traversing the entire jet cross section at each sampling port location. The results showed that the tracer gas concentration profile across the jet was essentially bell-shaped with the maximum concentration occurring close to the axis of the jet. The "bell" expanded as the distance from the top of the jet nozzle increased. The shape and size of the bell-shaped concentration profile was also dependent on the amount of aeration from the sparger and from the conical grid at the same jet velocity. This is a clear indication of different gas entrainment characteristics with different flow combinations. The results at two different operating conditions are shown in Figures 3.2-6 and -7. The concentration profiles can be normalized as shown in Figures 3.2-8 and -9, where C is the tracer concentration at any location, Cm is the tracer concentration at the axis, Co is the original tracer concentration at the jet nozzle, γ is the radial distance from the jet axis, and $\gamma 1/2$ is the radial distance from the jet axis where the tracer concentration is one-half of that at the axis.

To arrive at a quantitative description of gas entrainment into a jet is difficult because an accurate knowledge of the velocity distribution inside the jet and of the jet boundaries are required in addition to the concentration profiles. Experiments are being carried out to investigate the velocity profile in the jet using a two-dimensional pitot tube. The implications of low conical flow and different flow combinations on the performance of the gasifier-agglomerator will be discussed once the information on velocity profile is available.

3.2.1.2 Work Accomplished - Particle Separation

No work was performed this quarter. Prior work reported in previous Quarterly Progress Reports was published in the April 1978 issue of INDUSTRIAL AND ENGINEERING CHEMISTRY[8].

3.2.1.3 Work Accomplished - Distributor Design

Analysis of the conical grid design for integrated PDU operation with respect to performance during startup, shutdown, and turndown is being carried out. Particular concerns are solids weeping and potential plugging of the inlet gas flow path.

Preparations were made to conduct studies that simulate the solids and gas feed system of the devolatilizer for integrated operation of the PDU. It is proposed to use a conical gas distributor for the devolatilizer. Fresh coal is fed to the bed through a central feed tube, and the gas/fine char mixture from the gasifier enters through an annulus around the central coal feed tube.

To investigate the flow of gas-solids mixture entering the devolatilizer, a scaled-down model of the PDU inlet system has been designed to fit the existing semicircular cold model. This is a geometric scale-down of the PDU arrangement with a scaling factor of 0.56. The outer shell and the stem leading into the conical distributor will be made of Plexiglass so that flows can be observed.

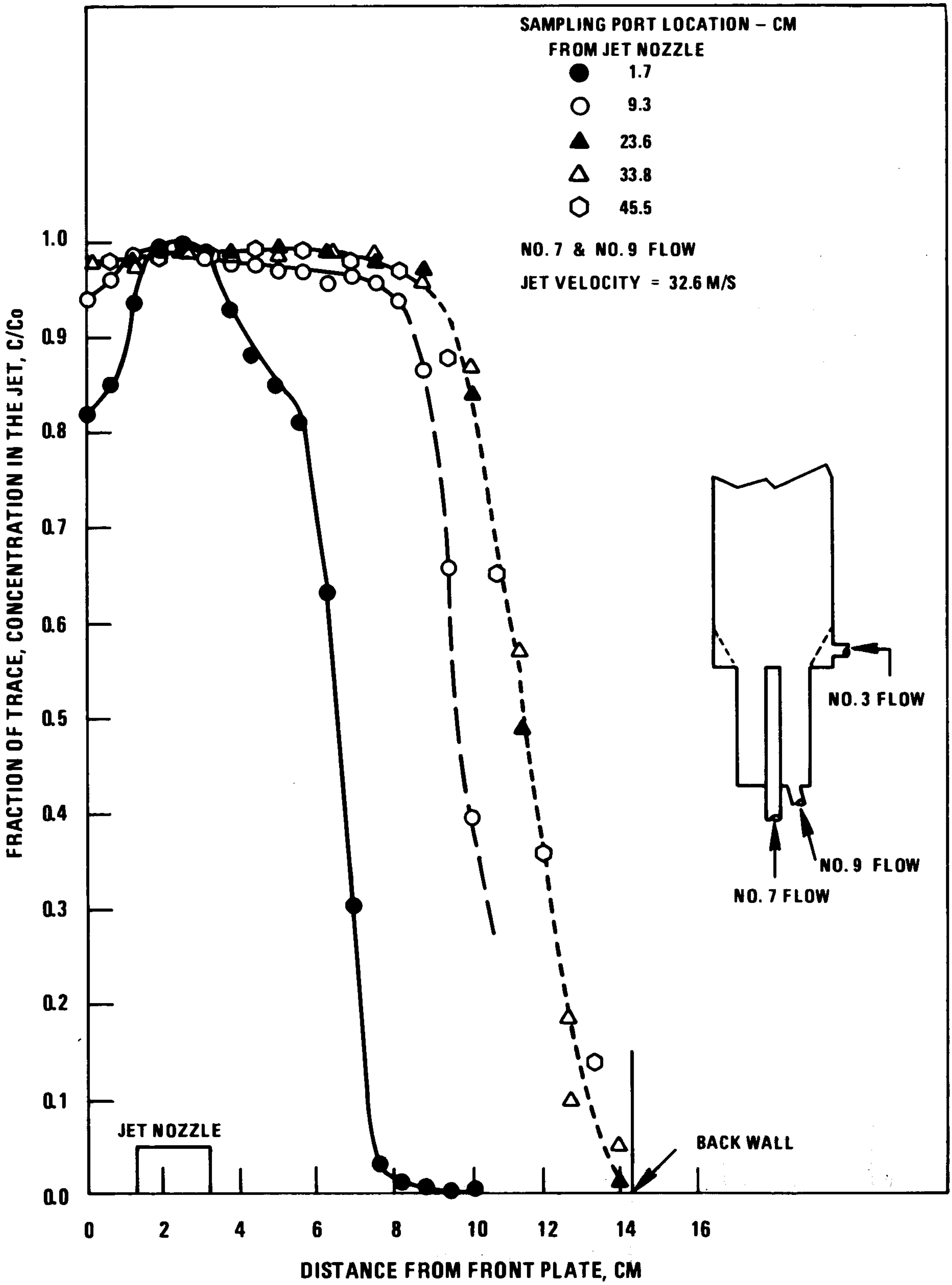


Figure 3.2-6. Concentration Profiles at Different Distances from the Jet Nozzle (Run 1)

0892-1

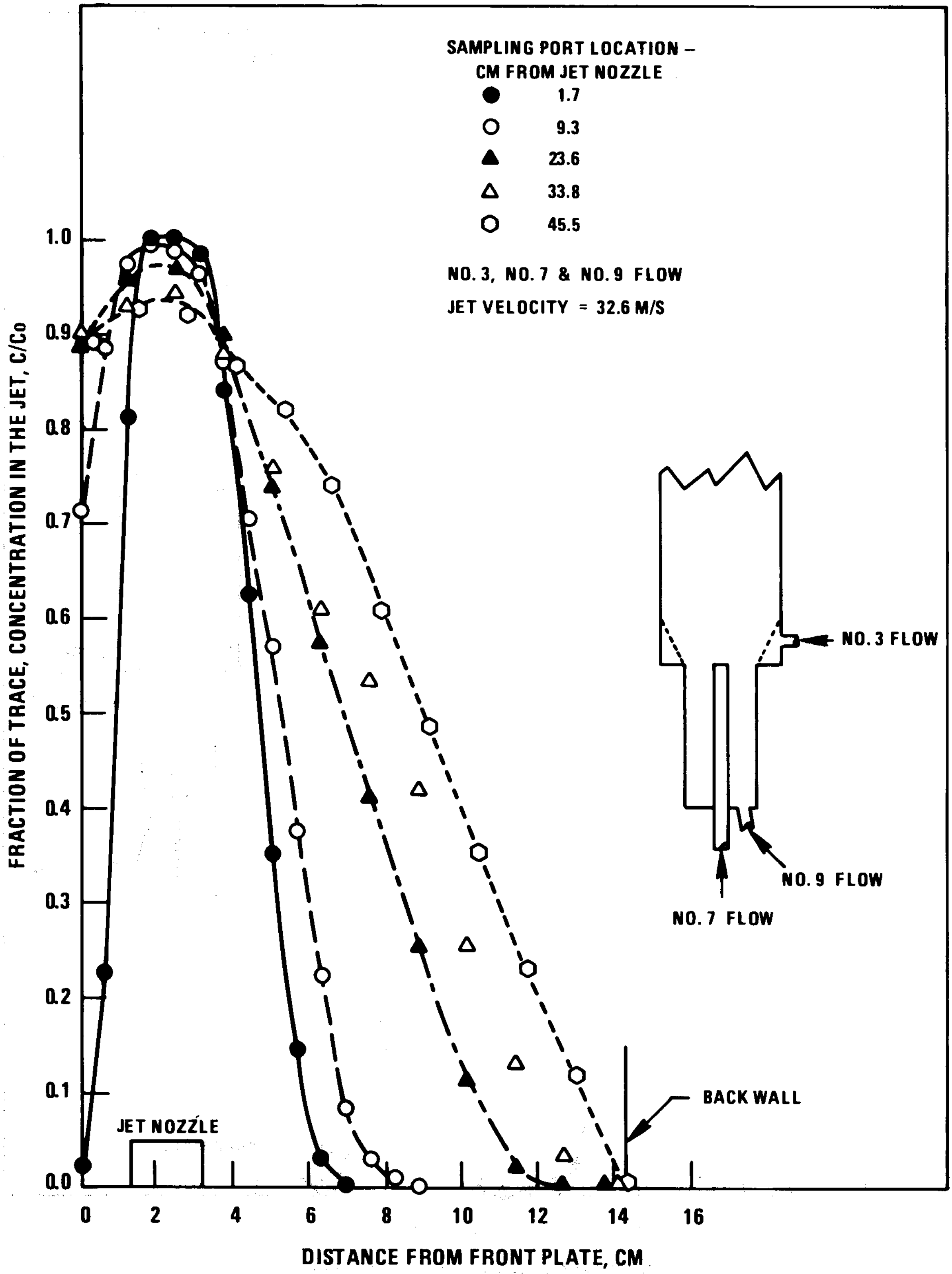


Figure 3.2-7. Concentration Profiles at Different Distances from the Jet Nozzle (Run 3)

0892-2

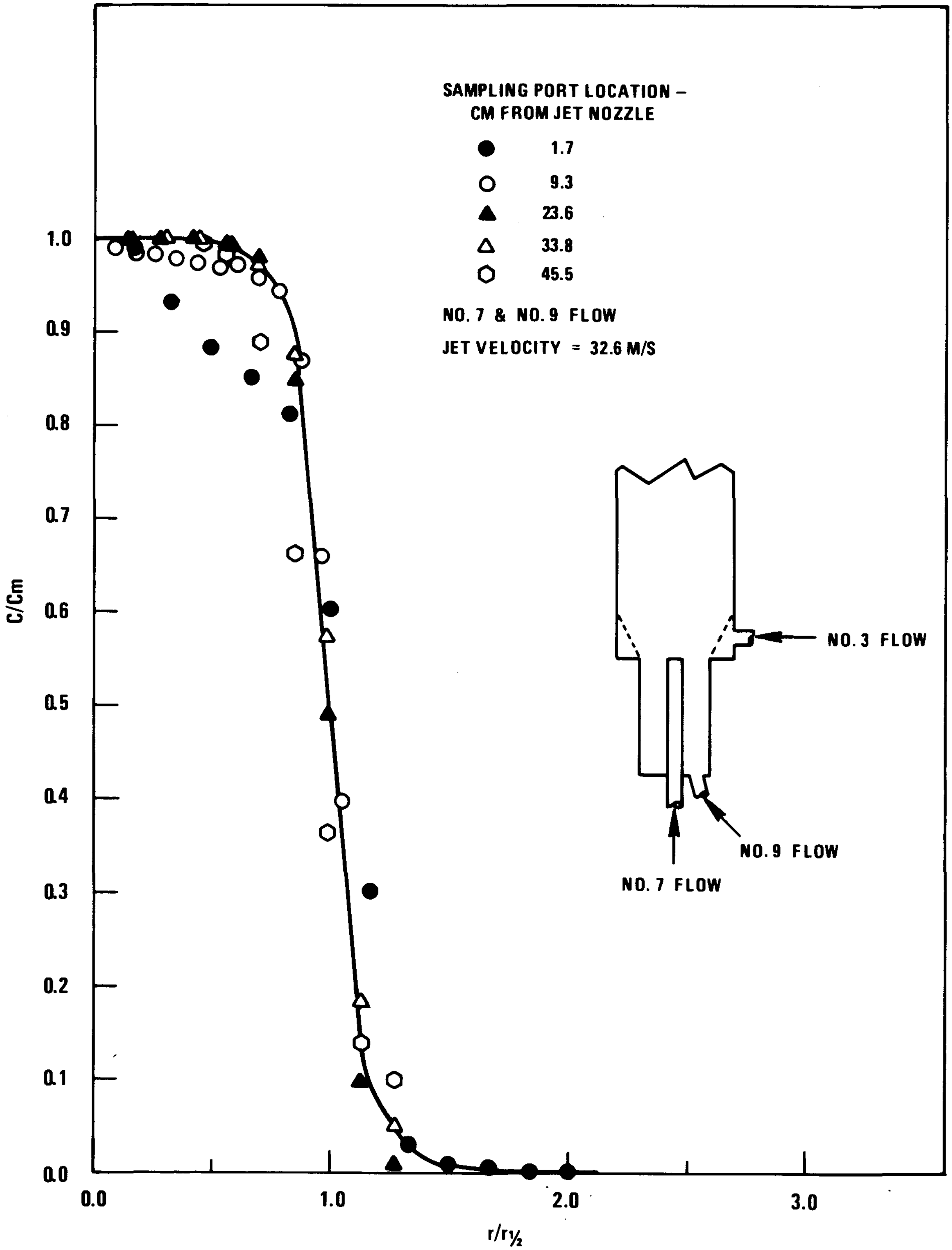


Figure 3.2-8. Normalized Concentration Profiles for Run 1

0892-3

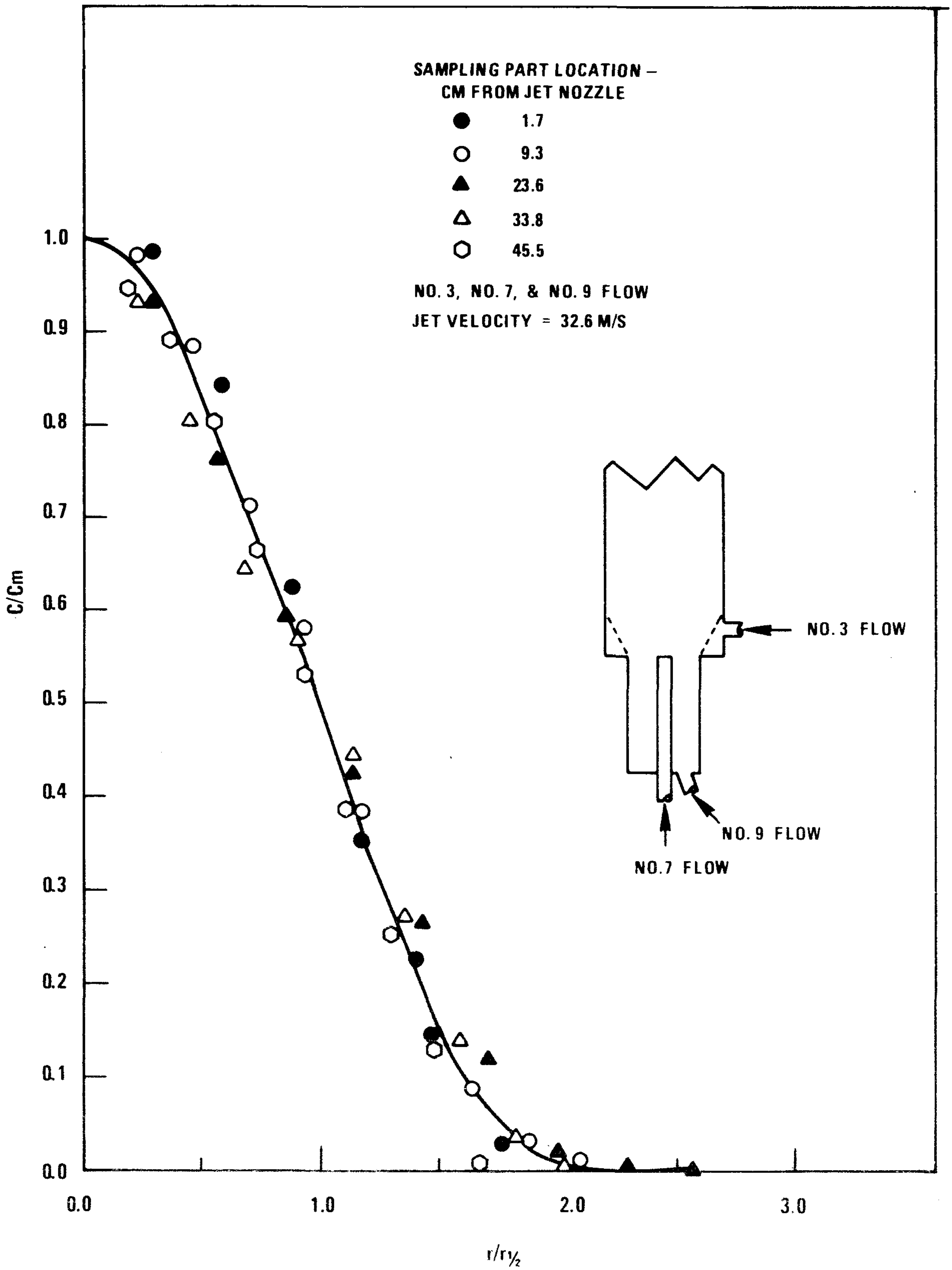


Figure 3.2.9. Normalized Concentration Profiles for Run 3

0892-4

To keep the solids-gas density ratio the same as in the PDU, it is proposed to use hollow macrospheres for the bed material, and sodium borosilicate glass spheres to simulate fines solids from the gasisifer. The particles in the devolatilizer will have a mean diameter of about 500μm; this is to keep the particle diameter/annulus width ratio the same as in the PDU. The mean particle size entering with the gas from the gasifier will be kept the same, about 100μ, so as to avoid having too cohesive a powder to handle.

Preliminary tests may have to be run, however, to test the suitability of these hollow particles against attrition and breakup in the bed. Tests will also be carried out to find the most suitable method of feeding the particles from the bunkers without breakup and blockage of the feeding mechanism.

The main purpose of the experiments is to study the three modes of operation: start-up, steady state and shutdown. Factors affecting steady-state operation and smooth transition between these modes will be evaluated. By means of theoretical analogy, these results will be related to the PDU conditions.

Apparatus for the study is being fabricated by the Westinghouse R&D machine shops and is in the late stages of completion. Particles, and possibly a solids feeder, will be purchased after the preliminary tests with the sample particles.

3.2.1.4 Work Accomplished - Draft Tube Design

A transparent two-dimensional unit, 50.8 cm wide x 2.54 cm deep x 2.44 m high, (20 inch x 1 inch x 96 inches) was constructed with three draft tubes of 2.54 cm x 2.54 cm (1 inch x 1 inch) cross section and 0.91 m (36 inches) high. The unit is instrumented with three 6-way valves and a differential pressure transmitter. Pressures between any of the 15 pressure probe locations can be compared and recorded continuously during operation. The information obtained in this unit will be utilized in design of the 3-meter cold-flow test facility now under development.

3.2.1.5 Work Accomplished - Particle Carryover

Entrainment and elutriation from the gasifier-agglomerator in the PDU were studied this quarter. During the pilot plant tests in the gasifier-agglomerator, feedstocks of different particle size distributions, densities, and reactivities were fed into the reactor both coaxially and radially. Widely different entrainment and elutriation characteristics were observed.

A mathematical model was developed in an attempt to explain these phenomena. The development of the mathematical model is described briefly in the following. (See also Figure 3.2-10.) At steady-state operation, the rate of material input should be equal to the rate of material output. Thus:

$$F_{co} + F_{do} = F_1 + F_2 \quad . \qquad (8)$$

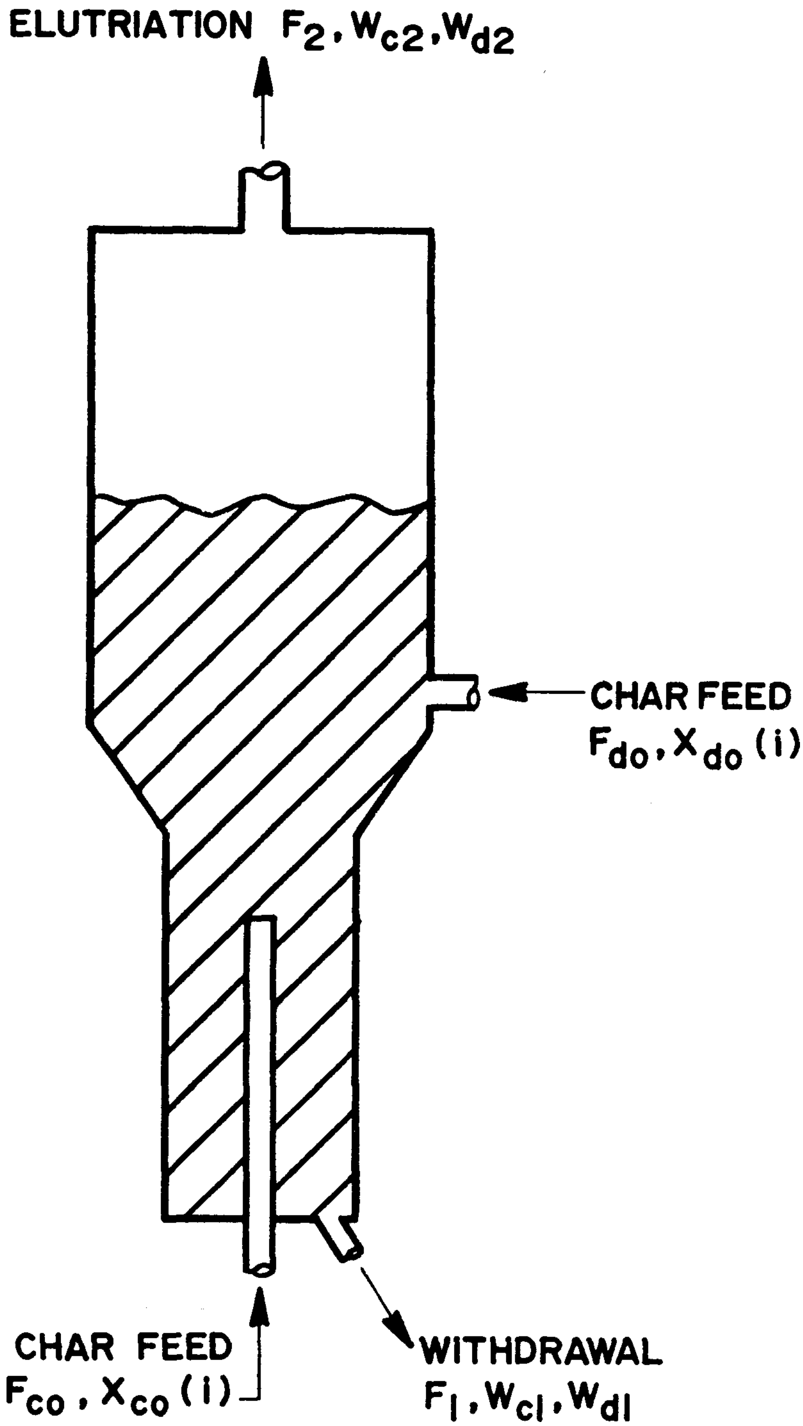


Figure 3.2-10. Material Balance in the Gasifier for the Entrainment Model

If the char or coal loses material during gasification by an amoung of $(1-\alpha)$ for feed F_{co} and $(1-\beta)$ for feed F_{do}, Equation 8 becomes:

$$\alpha F_{co} + \beta F_{do} = F_1 + F_2 \quad . \tag{9}$$

The same material balance should also apply individually for each feed stream of characteristics. Thus:

$$\alpha F_{co} = F_i \cdot \omega_{c1} + F_2 \cdot \omega_{c2} \quad , \tag{10}$$

and

$$\beta F_{do} = F_i \cdot \omega_{d1} + F_2 \cdot \omega_{d2} \quad .* \tag{11}$$

The material balance should also apply for a definite particle size fraction for each feed stream giving:

$$\alpha F_{co} \cdot \chi_{co}(i) = F_i \cdot \omega_{ci} \cdot \chi_i(i) + F_2 \cdot \omega_{c2} \cdot \chi_{c2}(i) \quad , \tag{12}$$

and

$$\beta F_{do} \cdot \chi_{do}(i) = F_i \cdot \omega_{di} \cdot \chi_i(i) + F_2 \cdot \omega_{d2} \cdot \chi_{d2}(i) \quad . \tag{13}$$

Assuming that the char or coal particles do not change their size during gasification, then the density changes of these particles would be $(1-\alpha)$ and $(1-\beta)$, respectively, for the two feed streams.

Solving Equation 9 through 13 with some mathematical manipulation, we have:

$$\bar{\tau}_c(i) = \frac{B}{F_1 + K_c^*(i) \cdot A_t} \quad , \tag{14}$$

$$\bar{\tau}_d(i) = \frac{B}{F_1 + K_d^*(i) \cdot A_t} \quad , \tag{15}$$

and

$$F_1 = \alpha F_{co} \sum_i \frac{\chi_{co}(i)}{1 + K_c^*(i) \cdot A_t / F_1} + \beta F_{do} \sum_i \frac{\chi_{do}(i)}{1 + K_d^*(i) \cdot A_t / F_1} \quad , \tag{16}$$

where $K_c^*(i)$ and $K_d^*(i)$, the elutriation constants for the two different feedstocks of particle size i, are defined as:

$$K^*_c(i) = \frac{F_2}{A_t} \cdot \frac{\omega_{c2} \cdot \chi_{c2}(i)}{\omega_{cb} \cdot \chi_{cb}(i)} \quad , \tag{17}$$

and

$$K_d^*(i) = \frac{F_2}{A_t} \cdot \frac{\omega_{d2} \cdot \chi_{d2}(i)}{\omega_{db} \cdot \chi_{db}(i)} \quad . \tag{18}$$

---

*See Subsection 3.2.5, Glossary, for definition of terms.

The empirical model by Merrick and Highley (1974)[9] was used for calculating the elutriation constants. They found that the elutriation constant could be calculated by the following equation:

$$\frac{K^*(i)}{G} = A + 130 \exp\left[-10.4\left(\frac{U_t}{U_f}\right)^{0.5}\left(\frac{U_{mf}}{U_f - U_{mf}}\right)^{0.25}\right] \tag{19}$$

where the value of A was 0.0001 for a 0.91-m combustor with 4-m freeboard and 0.0015 for a 0.6 x 1.2-m combustor with 1.8-m freeboard. A = 0.0015 was used for the present calculation. Attrition of char particles and agglomeration of ash particles were not taken into account in the calculation.

The calculated entrainment rates from the developed mathematical model were compared with the experimental data obtained at the PDU in Table 3.2-1 and Figure 3.2-11, along with the operating conditions and feedstocks for each test series. The agreement is generally better than ± 30 percent. The extent of gasification of the fines collected in the cyclone, i.e., the parameters α and β, was obtained from comparison of ash contents in the original feedstocks with that of the collected fines. In the case of -6 mesh coke breeze feed, the fines were not reactive enough to experience any degree of gasification before they were elutriated, i.e., $\alpha = \beta \cong 1$. Up to 30 percent gasification was noted, however, for FMC char and Minnehaha char fines before they were elutriated.

3.2.1.6 Work Forecast for Next Quarter

The following work is planned for the next quarter:

- Initiate experiments to evaluate the performance of multi-draft-tube using the two-dimensional bed
- Perform experiments to investigate the velocity profile inside a jet using a pitot tube
- Carry out gas entrainment experiments by injecting tracer gas into the annular flow or conical flow rather than into the jet flow
- Initiate experiments on jet penetration with a two-phase jet consisting of gases and solids
- Initiate test program on conical grid.

3.2.2 Coal Behavior Studies

3.2.2.1 Work Accomplished - General

The literature search on studies of surface areas of coals and chars has been completed. Several experimental studies (10, 11, 12) concluded that nitrogen is not a suitable adsorbate for surface area measurements of coals and chars due to activated diffusion. The use of carbon dioxide (CO_2) at about 77°F

TABLE 3.2-1

COMPARISON OF CALCULATED AND EXPERIMENTAL ENTRAINMENT RATES
FROM THE GASIFIER-AGGLOMERATOR IN THE PDU

	Radial Feed			Coaxial Feed			Freeboard Velocity			Entrainment Rate	
Run No. (Set Pt)	Material*	Rate (kg/hr)	Transp. Gas	Material*	Rate (kg/hr)	Transp. Gas	m/s	α	β	Expt. (kg/hr)	Calc. (kg/hr)
TP012-1 (1)	-6CB	233.6	Recycle Gas	-6CB	143.2	Recycle Gas	0.98	1.0	1.0	121.4	160.5
TP012-2 (1)	-6CB	288.6	Recycle Gas	-6CB	152.3	Recycle Gas	1.07	1.0	1.0	245.5	185.0
(2)	-6CB	256.8	Recycle Gas	-6CB	152.3	Recycle Gas	0.95	1.0	1.0	177.3	170.9
TP012-3 (1)	-6CB	260.5	Recycle Gas	-6CB	152.3	Recycle Gas	0.99	1.0	1.0	195.0	175.0
(2)	-6CB	227.7	Recycle Gas	-6CB	135.0	Recycle Gas	0.94	1.0	1.0	117.7	153.6
TP012-4 (1)	-6CB	182.3	Recycle Gas	-6CB	146.4	Recycle Gas	1.01	1.0	1.0	131.8	141.4
(2)	-6CB	241.8	Recycle Gas	-6CB	133.6	Recycle Gas	0.98	1.0	1.0	155.9	159.1
TP012-5	-6CB	223.6	Recycle Gas	-6CB	130.9	Recycle Gas	0.88	1.0	1.0	160.0	127.3
TP012-6 (1)	-6CB	197.4	Recycle Gas	-34CB	156.2	Air	0.86	1.0	0.8	166.1	192.6
(2)	None	-	-	-34CB	395.5	Air	0.72	-	0.8	220.5	280.4
TP013-1 (1)	-6CB	214.5	Recycle Gas	-6CB	129.5	Recycle Gas	0.97	1.0	1.0	103.2	145.9
(2)	-6CB	242.7	Recycle Gas	-34CB	129.5	Recycle Gas	0.98	1.0	1.0	192.3	228.2
(4)	-6CB	226.8	Recycle Gas	RC	240.5	Recycle Gas	0.96	1.0	1.0	278.2	337.3
TP013-2 (2)	REC	327.3	Recycle Gas	REF	107.3	Air	0.83	0.9	0.9	107.3	99.1
(3)	-6CB	143.2	Recycle Gas	FMC	379.1	Air	0.92	1.0	0.87	138.2	267.7
(4)	-6CB	113.2	Recycle Gas	FMC	326.8	Air	0.94	1.0	0.68	154.5	205.5
TP014-1 (1A)	-6CB	102.7	Recycle Gas	-6CB	202.7	Air	0.59	1.0	1.0	103.2	85.5
(1B)	-6CB	200.0	Recycle Gas	RC	203.2	Air	0.59	1.0	1.0	238.2	248.2
(2)	MIC	226.8	Recycle Gas	MIF	109.1	Air	0.52	0.73	0.73	101.4	93.6

*Material designation: -6CB = -6 mesh coke breeze; -34CB = -34 mesh coke breeze; RC = recycled char; REC = Renton Char; REF - Renton fines; FMC = FMC char; MIC = Minnehaha char; MIF = Minnehaha fines.

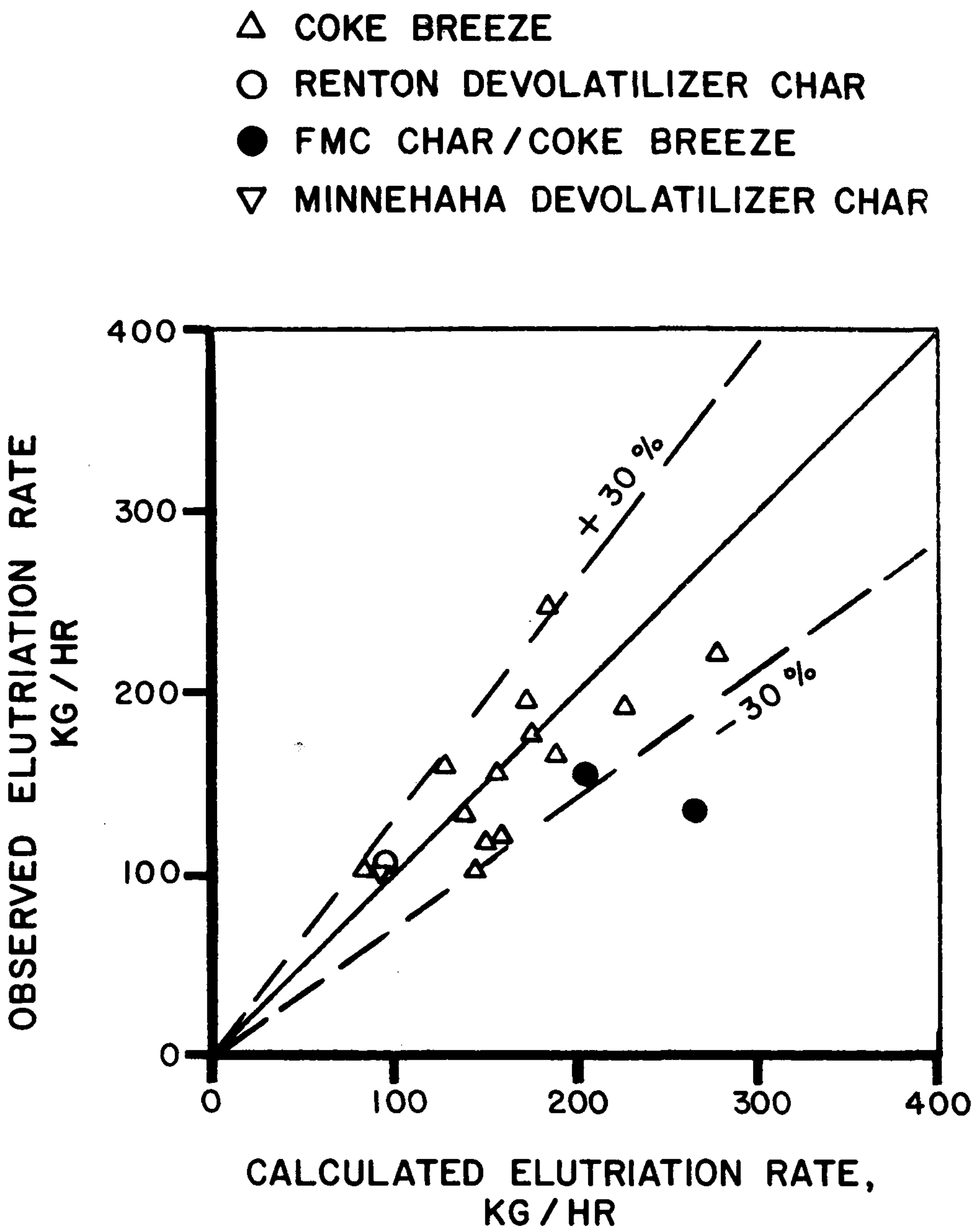


Figure 3.2-11. Comparison of Calculated Elutriation Rates with Observed Rates

(298 K), either by the BET method or by the Dubinin-Polanyi method (D-P method), is reported as the best system yet available. Use of the BET equation requires very high pressures since the saturation vapor pressure of CO_2 at 298 K is about 63.5 atmosphere (atm). Application of the D-P equation requires pressures below one atm. Hence, it is easier to employ the D-P method. Preparations are being made to measure surface areas using carbon dioxide as the adsorbate on a Micromeritics surface area analyzer.

3.2.2.2 Work Accomplished - Ash Agglomeration

Tests were performed with steam as the gasifying medium. Experimental conditions in these tests were close to those of the earlier tests. In the first test, both nitrogen and steam were preheated to a temperature of about 300^oF. The air tube top was at the same level as the bottom of the conical portion of the reactor. The test had to be shut off after an hour of steady-state period because of steam condensation. No agglomerates were obtained.

In the second test, the air tube was lowered by about 4 inches to reduce the length of the annulus. Steam and nitrogen were preheated to a temperature of about 450^oF. This test was terminated after a steady-state period of about 3 hours, again because of steam condensation.

An additional test was conducted successfully without any problem of steam condensation after the discharge screw and the lines to and from the discharge screw were heated and insulated. This test was performed for a steady-state period of about 6-1/2 hours at a temperature of 1940^oF. Large and dense agglomerates were obtained. A comparison of these agglomerates with those obtained in the PDU at similar operating conditions shows the former to be denser, which is probably the result of formation at a higher temperature. The reactor wall was colder in this test than in the earlier tests as a result of the failure of two furnace heating elements. Significant wall deposits with a high ash content (97 percent) were observed. These are believed to be caused by the lower temperature of the reactor wall.

Operation of the reactor was smooth and the temperature control was excellent during the steady-state period of the last two tests. At the end of the last test, an examination of the reactor revealed extensive damage to both the shell and the refractory lining. The refractory lining, made of stabilized zirconia, appeared to have spalled in the high temperature zone of the reactor, possibly due to steam condensation on the reactor wall in the earlier runs. As a result of the failure of the refractory lining, there was damage to the reactor, possibly from oxidation and sulfidation. The causes of damage to the reactor will be established after the analysis on the shell and the refractory lining is completed. Efforts are under way to design and build a new reactor.

3.2.2.3 Work Accomplished - Coal and Ash Chemical Phenomena

Thermodynamic calculations have been used to predict the various chemical compounds (solid, liquid or gas) which were stable under the operating conditions of the PDU gasifier-agglomerator. The chemical equilibrium program developed by Westinghouse, determines the equilibrium compositions of various species in a polyphase, multicomponent system by minimizing the Gibbs free energy of the system, in addition to satisfying the mass conservation equations. The species standard thermochemical data as reported in the literature, the total gas pressure, temperature, and mass constraints on the system were used as inputs to the program. When the operating conditions of PDU test run TP-012-3 were input to the program, the following solid and liquid phases were projected at equilibrium (Tables 3.2-2 and -3): $MgAl_2O_4$, K_2SiO_3, K_2SO_4, $Al_2SiO_5/Al_6Si_2O_{13}$, $Al_2O_3.TiO_2$, Fe_2O_3, SiO_2 and $CaO.Al_2O_3.2SiO_2$ in the combustor; only iron was reduced in the gasifier, changing from Fe_2O_3 to $FeO.Al_2O_3$. Some of these chemical compounds were identified in the X rays of samples of gasifier wall deposits from PDU test run TP-012-3, as shown in Table 3.2-4. K_2SiO_3 did not apear in the X-ray analyses, because it may have been in an amorphous state or in a very small amount. Moreover, phase diagrams of the compounds showed them to have high melting points (Table 3.2-5) and high melting eutectics (Tm>1300^oC), except for K_2SiO_3 which melts at 976^oC (1789^oF) with a eutectic at 742^oC (1368^oF) and K_2SO_4 which melts at 1071^oC (1960^oF). Potassium silicate and sulfate may have existed as melts in the combustor/gasifier and may have acted as binding agents for deposits and agglomerates.

Thermodynamic calculations were also used to study the effects of operating parameters on the existence of various chemical compounds in the combustor/ gasifier and their relative amounts at equilibrium. The following parameters were studied in the operation of the combustor:

Temperature = 1500; 1700; 1900; 2000 and 2200^oF
Pressure = 1; 5; 10 and 15 atmospheres
Ash content in the combustor = 60, 80 and 100 percent
Steam flow to the combustor (booster flow and air tube flow) = 0, 200, 400 and 600 lb/hr.

It was assumed that the total material held up in the combustor was 80 lb; the air flow rate was kept constant at 3000 lb/hr and the transport gas flow at 2000 lb/hr. Potassium was the only mineral element whose distribution changes with the parameters studied (besides the change of Al_2SiO_5 to $Al_6Si_2O_{13}$, at high temperatures). As shown in Figures 3.2-12, -13, -14 and -15, the distribution of potassium between the different compounds (KOH, K_2SiO_3 and K_2SO_4) and phases (solid/liquid/gas) was more sensitive to changes of pressure, combustor ash content and steam flow, at high temperatures ($T \geq 2000^oF$). Pressure had the greatest effect, followed by steam flow and combustor ash content. At high pressure, high ash content and low steam flow, more potassium existed in the solid/liquid phases in the combustor and less potassium was volatilized as $K_2SO_4(g)$ or KOH(g). The following reactions may have been involved in the chemical and physical changes of potassium:

TABLE 3.2-2

COMPOUNDS AT EQUILIBRIUM IN THE COMBUSTOR
AS PROJECTED BY THERMODYNAMIC CALCULATIONS*

Compounds	Phase	Total Moles
CO_2	G (Gas)	0.278800+02
H_2O	G	0.196650+02
N_2	G	0.111260+03
O_2	G	0.150530+02
AR	G	0.900000+00
$Al_6Si_2O_{13}$	SS (Solid)	0.110000+00
$CaO.Al_2O_3.2SiO_2$	SS	0.250000-01
$Al_2O_3.TiO_2$	SS	0.400000-02
K_2SO_4	CC (Condensed)	0.300000-02
$MGAl_2O_4$	CC	0.110000-01
K_2SiO_3	CC	0.800000-02
Fe_2O_3	SS	0.650000-01
SiO_2 (L,H)	SS	0.352000+00

*Operating parameters from PDU Test TP-012-3. Includes most active terms at 0.135000 + 04 degrees K (1971°F).

TABLE 3.2-3

COMPOUNDS AT EQUILIBRIUM IN THE GASIFIER
AS PROJECTED BY THERMODYNAMIC CALCULATIONS*

Compounds	Phase	Total Moles
CO_2	G (Gas)	0.233820+02
CO	G	0.452480+02
H_2O	G	0.235940+02
H_2S	G	0.600000-02
N_2	G	0.118350+03
Ar	G	0.900000+00
$Al_6Si_2O_{13}$	SS (Solid)	0.193333-01
$CAO.Al_2O_3.2SiO_2$	SS	0.490000-01
$Al_2O_3.TiO_2$	SS	0.800000-02
$FeO.Al_2O_3$	SS	0.256000+00
$MGAl_2O_4$	CC (Condensed)	0.210000-01
K_2SiO_3	CC	0.200000-01
SiO_2 (L,H)	SS	0.104633+01

*Operating parameters from PDU Test TP-012-3. Includes most active terms at 0.133800 + 04 degrees K (1949°F).

Curve 696649-A

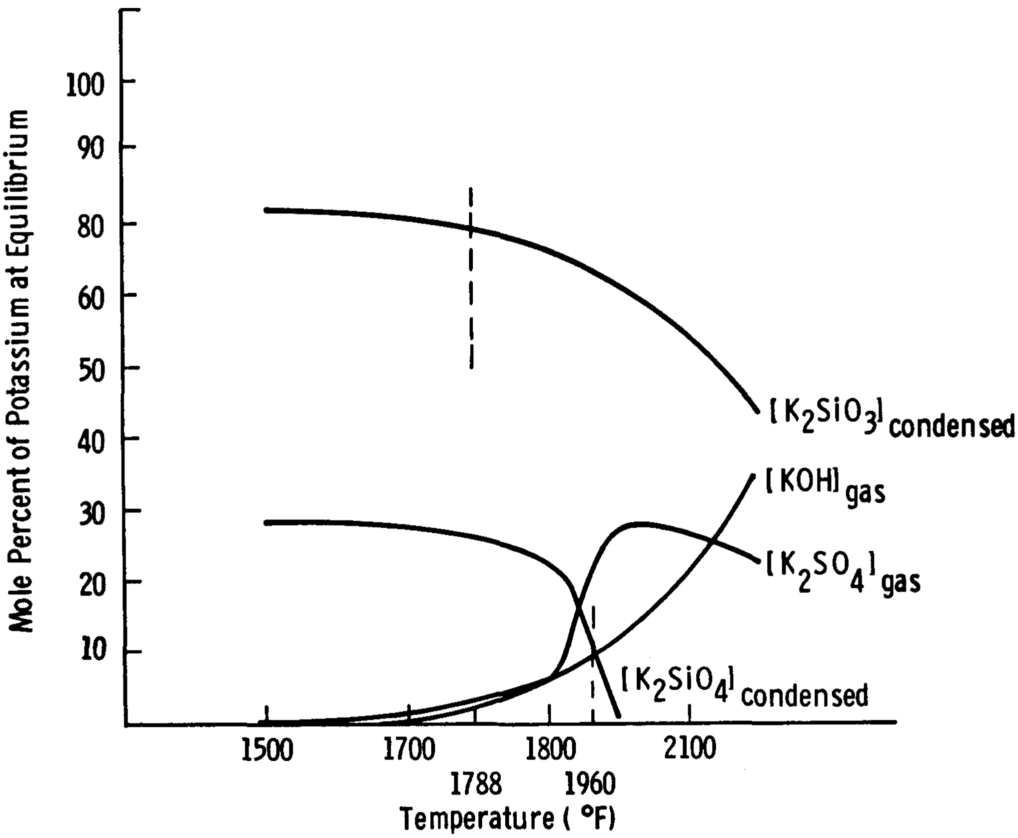


Figure 3.2-12. Distribution of Potassium in Different Compounds at Equilibrium (Combustor Operating at 80% Ash with 200 Lb/Hr Steam in Booster and Air-Tube Flow; Operating Pressure = 16 atm)

Curve 696651-B

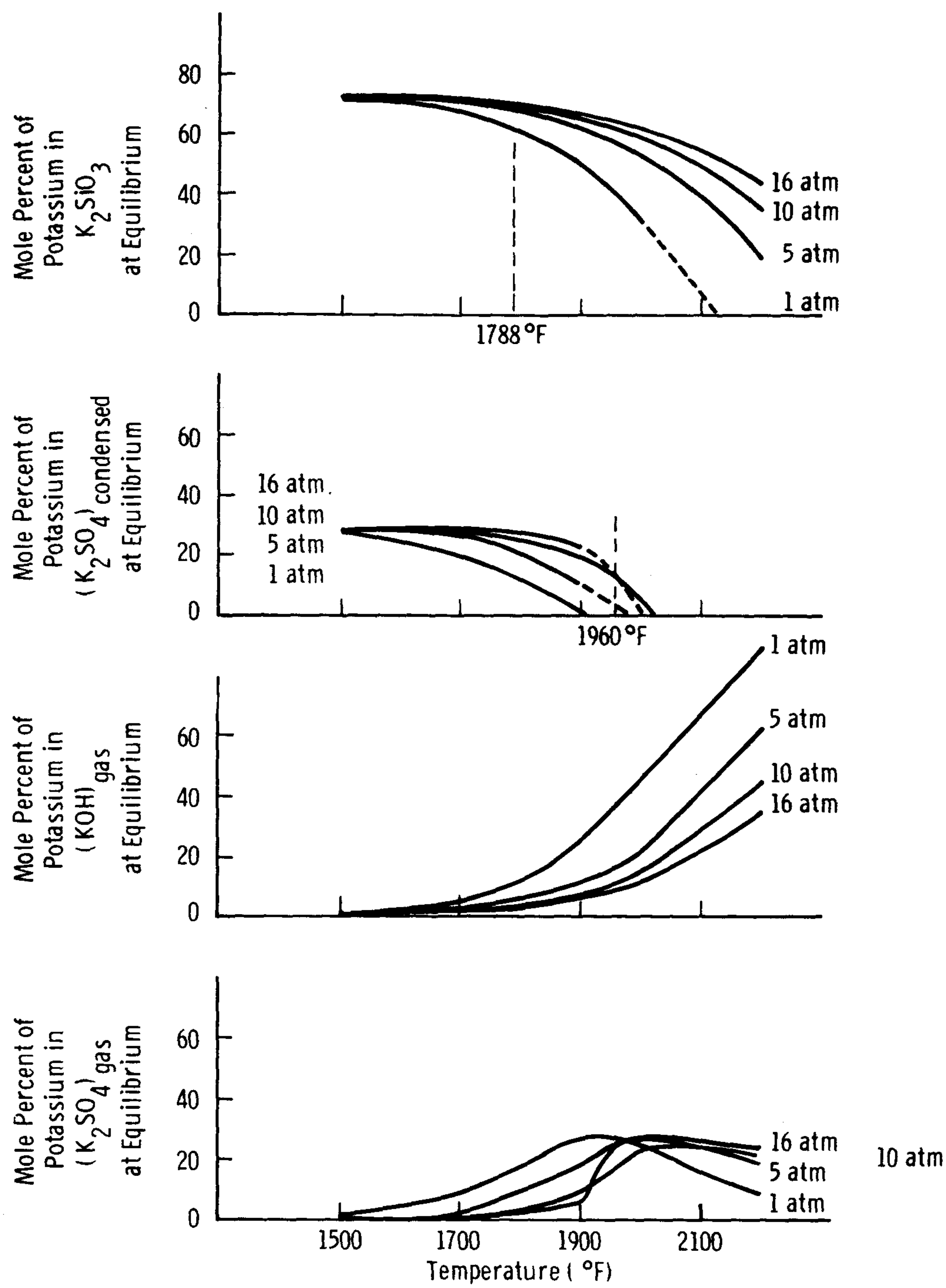


Figure 3.2-13. Effect of Pressure on the Distribution of Potassium in the Combustor at Equilibrium

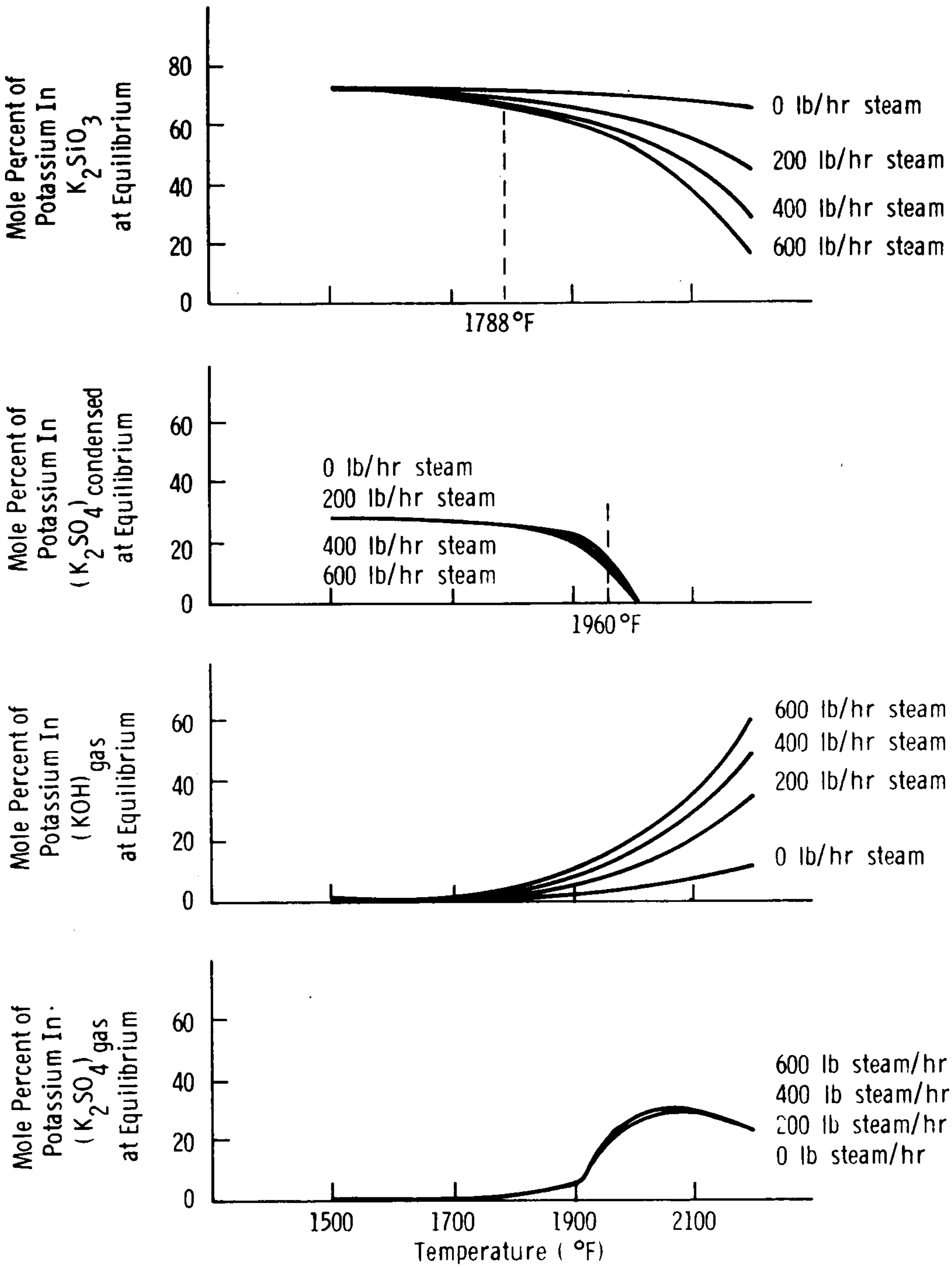


Figure 3.2-14. Effect of Steam on the Distribution of Potassium in the Combustor at Equilibrium

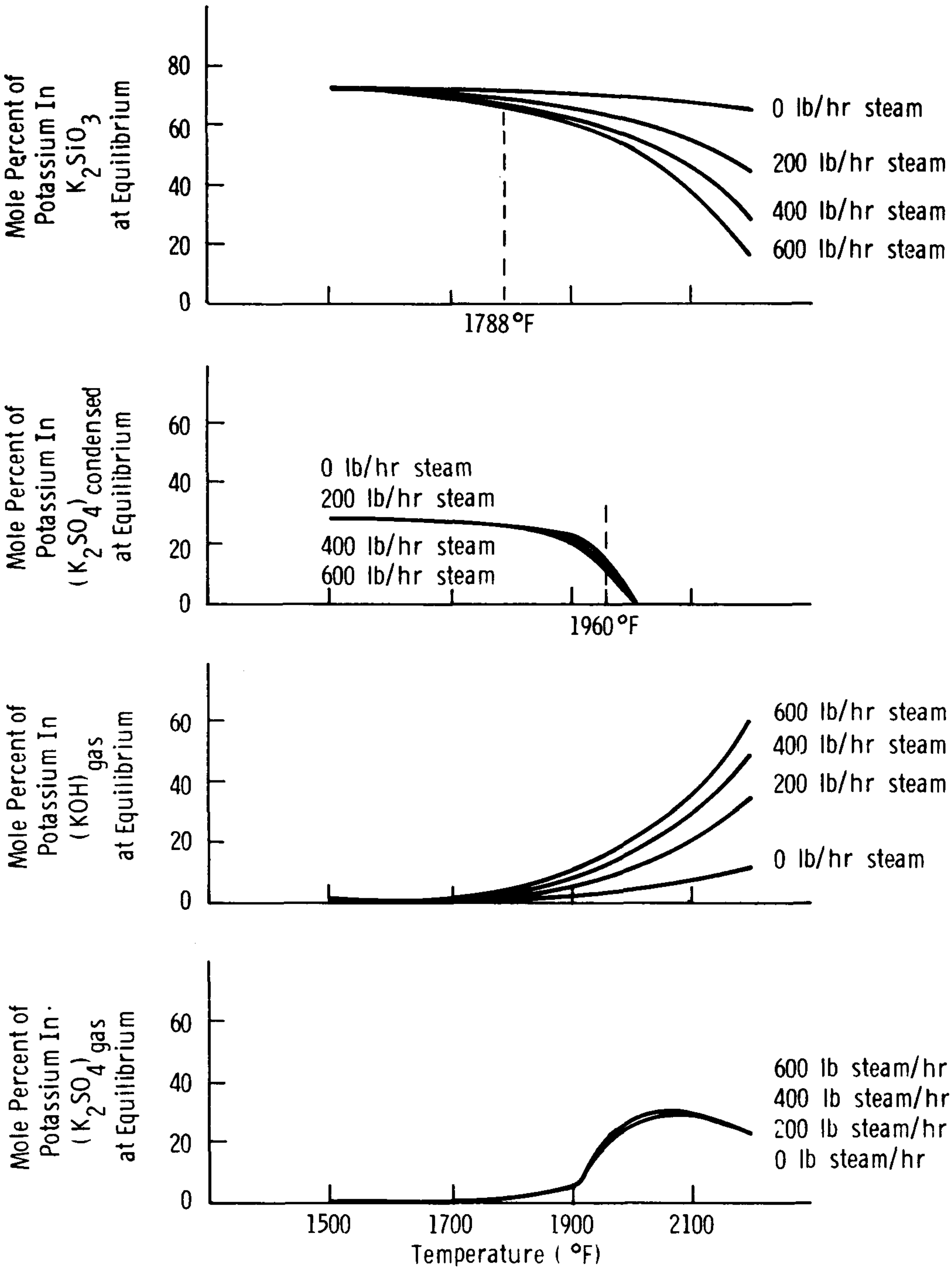


Figure 3.2-15. Effect of Ash Content on the Distribution of Potassium in the Combustor at Equilibrium

TABLE 3.2-4

X-RAY ANALYSES OF GASIFIER WALL DEPOSITS
(Test TP-012-3)

Sample	Chemical Compounds	Relative Amount
1. From steam grid	SiO_2 (Cristobalite)	Major
	SiO_2 (Quartz)	Minor
	Spinel[(1)]	Minor
	Al_2SiO_5	Trace
	$Mg_2Al_4Si_5O_{18}$	Possible
	$CaCo_3$	Possible
	αFe_2O_3	Possible
2. From 16-foot elevation	SiO_2 (Quartz)	Major
	SiO_2 (Cristobalite)	Major
	Spinel[(1)]	Major
	$Mg_2Al_4Si_5O_{18}$	Low minor
	Al_2SiO_5	Trace
	$CaCO_3$	Possible

Note: (1) Spinel may be either $(Mg\ Fe)_2\ SiO_4$ or $FeAl_2O_4$ or $(Mg\ Fe)\ Al_2\ O_4$

TABLE 3.2-5

MELTING POINTS AND EUTECTICS OF CHEMICAL COMPOUNDS PROJECTED BY THERMODYNAMIC CALCULATIONS[13]

Compound	System	Melting Point of Compound		Lowest Eutectic Temperature of System	
		°C	°F	°C	°F
$MgAl_2O_4$	$MgO-Al_2O_3$	2105	3821	1920	3488
K_2SiO_3	K_2O-SiO_2	976	1789	742	1368
K_2SO_4	--	1071	1960	--	--
Al_2SiO_5	$Al_2O_3-SiO_2$	1850	3362	1595	2303
$Al_6Si_2O_{13}$	$Al_2O_3-SiO_2$	1860	3380	1595	2903
$Al_2O_3.TiO_2$	$Al_2O_3-TiO_2$	1860	3380	1705	3101
Fe_2O_3	--	1565	2849	--	--
SiO (Quartz)	--	1610	2930	--	--
SiO (Tridymite)		1703	3097	--	--
SiO(Cristobalite)		1713	3115	--	--
$CaO.Al_2O_3.2SiO_2$	$CaO-Al_2O_3-SiO_2$	1550	2822	1310	2390
$FeO.Al_2O_3$	$FeO-Al_2O_3$	1780	3236	1330	2426

$$K_2SO_4(s/\ell) \longleftrightarrow K_2SO_4(g)$$
$$K_2SO_4(s/\ell) + H_2O(g) \longleftrightarrow 1KOH(g) + SO_3(g)$$
$$K_2SiO_3(s/\ell) + H_2O(g) \longleftrightarrow 2KOH(g) + SiO_2(s)$$

Further analyses of the results from thermodynamic calculations will help in the formulation of mechanisms for ash deposition and agglomeration.

3.2.2.4 Work Forecast for Next Quarter

The following coal behavior studies are forecast to be completed in the next quarter:

- Complete surface area measurements on chars and coals for reactivity study
- Complete installation of the new reactor in ash agglomeration test facility
- Continue thermodynamic projections of the chemical and physical phases formed in the combustor/gasifier and analyses of the results to aid in the formulation of a mechanism for ash deposition.

3.2.3 Environmental Impact Studies

3.2.3.1 Work Accomplished - Solids Disposal

Testing for environmental impact of two batches of ash agglomerates produced from PDU devolatilizer chars in the PDU gasifier-agglomerator has been completed. Agglomerates from test TP-014-1 were generated from Minnehaha char at 1740°F freeboard temperature and 1814°F bed temperature. Agglomerates from test TP-013-2 were produced from Renton char at a freeboard temperature of 1750°F and bed temperature of 1814°F.

The agglomerates from TP-014-1 were of irregular shape and have a particle size distribution as shown in Table 3.2-6. X-ray diffraction indicated that both samples contained large quantities of amorphous material, with SiO_2 quartz being dominant in the crystalline phase present. Thermogravimetric (TG) analysis showed the presence of $\geq$60 percent of free carbon (weight loss in air at $\sim$600°C) in both samples as shown in Figure 3.2-16 when comparing the TG curves of non-isothermal heating in air and N_2. Electron microprobe analysis on the cross sections showed that the particles were highly porous and contained Si, Al, Fe, K, S, Ca and Ti as the major elements. Figure 3-2-17 shows SEM and EDAX of TP-014-1, again illustrating the porosity and elemental distribution. It should be noted that the cenospheres which were observed to be embedded on the porous skeleton on the particle surface for the previous agglomerates produced from coke breeze (TP-011-5 and AAC-7) were absent in the ash agglomerates produced with PDU devolatilizer char. The lower gasifier-agglomerator temperature in these runs (TP-013-2 and TP-014-1) is suspected as being a major cause of the different morphological characteristics.

TABLE 3.2-6

PARTICLE SIZE DISTRIBUTION OF ASH AGGLOMERATE
SAMPLE TP-014-1

Particle Size, μ	wt%
> 4 mm	4.12
2.38 to 4 mm	8.88
1.68 to 2.38 mm	15.64
1.00 to 1.68 mm	21.63
595 to 1000 μ	27.72
430 to 595 μ	8.14
250 to 430 μ	7.67
149 to 250 μ	2.68
125 to 149 μ	0.47
74 to 125 μ	0.99
63 to 74 μ	0.59
44 to 63 μ	0.78
< 44 μ	0.68

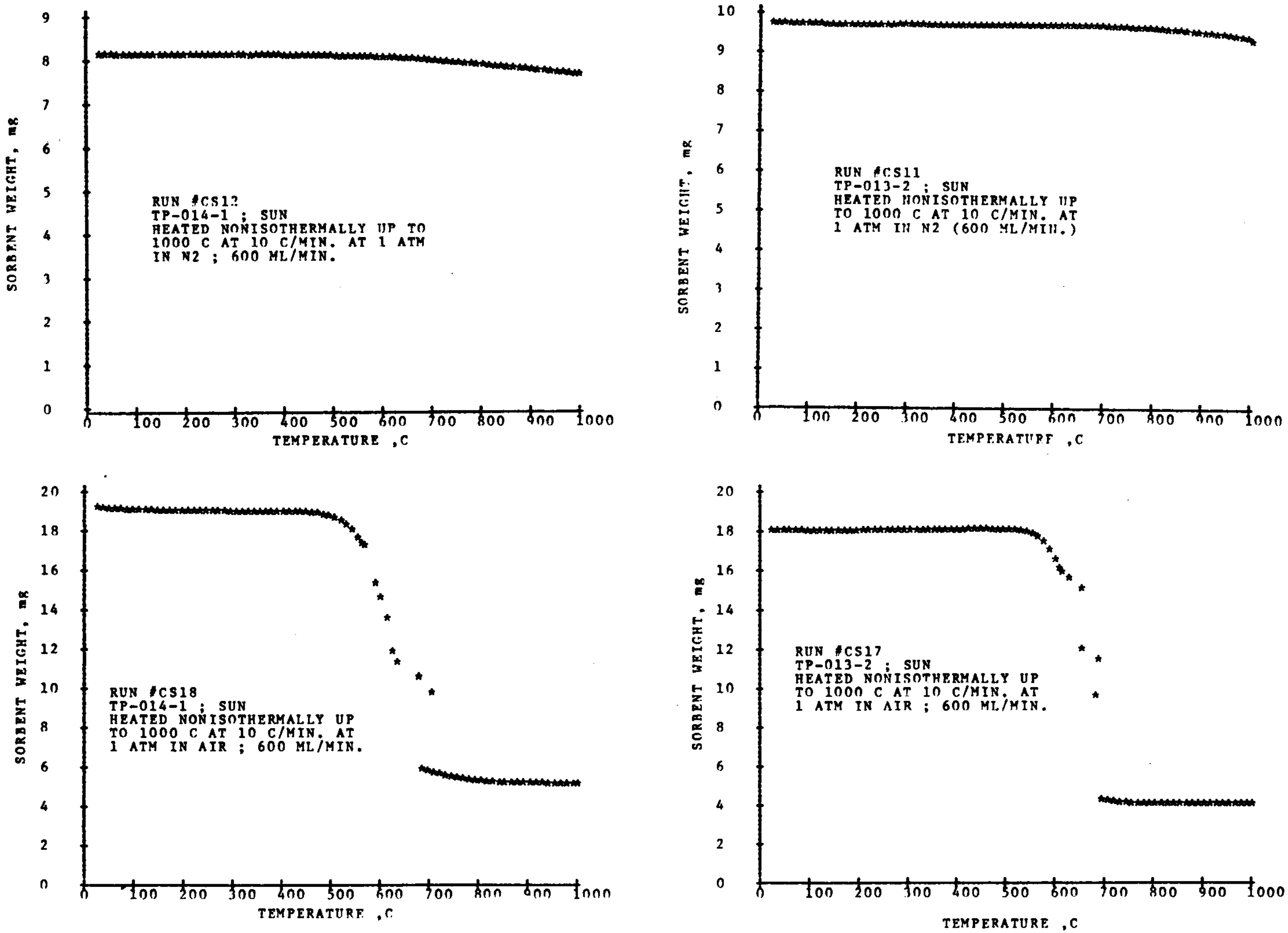
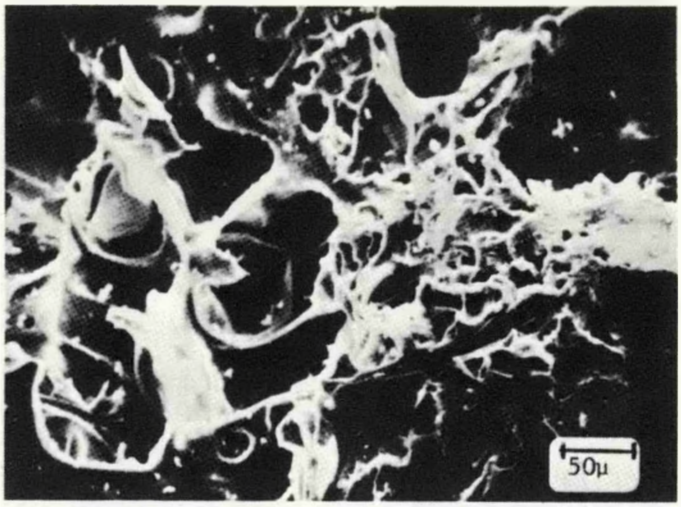


Figure 3.2-16. TG Analysis of Ash Agglomerates in Air and N_2 of Ash Agglomerates TP-013-2 and TP-014-1 Produced from PDU Char



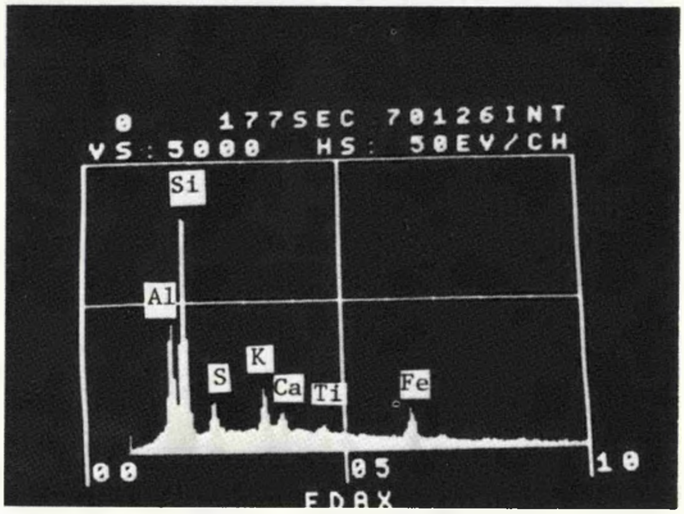


Figure 3.2-17. SEM and EDAX of Ash Agglomerates TP-014-1 Produced from PDU Char

Leaching property was investigated using two shake methods: continuous and intermittent shake. The continuous shake test establishes equilibrium conditions between the solid and its aqueous surrounding and provides the worst possible case with respect to contamination release. A 1:10 solid-to-water ratio is used.

The intermittent shake method of 10 cycles of 72-hour shake provides leaching rate, aging effect, and long-term leachability of the worst case and makes possible the calculation of total fraction leached for any specific ion or for total dissolved solids (TDS) as a function of total leach time or total leachate passing the sample. Leachate is analyzed at the end of each interval and a fresh charge of deionized water is added for each 72-hour leach cycle. A 1:3 solid-to-water ratio is used. Both shake tests are more severe than conditions anticipated under actual land disposal. Results from the shake tests, therefore, are expected to project the worst case.

Figure 3.2-18 summarizes the leachate characteristics of ash agglomerates as a function of continuous shake time for major soluble species Ca, Mg, SO_4 pH and specific conductance, which is a good approximation for TDS. Both deionized water (pH$\simeq$7) and a $CH_3COOH/NaC_2H_3O_2$ acetate buffer solution (pH$\simeq$4.4) were used as the leaching media to simulate actual leaching conditions in cases of neutral or acidic rain or surface water leaching. Figure 3.2-19 summarizes the results from a ten cycle 72-hour intermittent leaching test. Both tests resulted in relatively pure leachates with deionized water, even when comparing with Drinking Water Standard (DWS). However, leaching with acetate buffer medium resulted in increased concentrations of Ca, Mg, SO_4 and TDS, and decreased leachate pH. Figure 3.2-19 also shows that the leachate quality improves with total leachate volume passing the sample and total leaching time.

Table 3.2-7 summarizes the solid and leachate compositions including major, minor and trace species, pH, total organic carbon (TOC) and TDS. The leachate characteristics are compared with DWS to put data into perspective due to the lack of definite leachate criteria. Such guidelines and criteria are currently being developed by the U.S. Environmental Protection Agency (EPA) under the Resource Conservation and Recovery Act of 1976 (Public Law 94-580). It should be noted that increased leachability of Al, B, Mn, Co, Si, Ca, Mg, and TDS was observed with acidic leaching medium.

Heat-release tests were also carried out on these agglomerates. Neither TP-013-2 nor TP-014-1 agglomerates showed any potential heat-release property when contacting water.

3.2.3.2 Work Forecast for Next Quarter

Environmental impact studies will be performed on agglomerated ash from gasifier tests with coal feed.

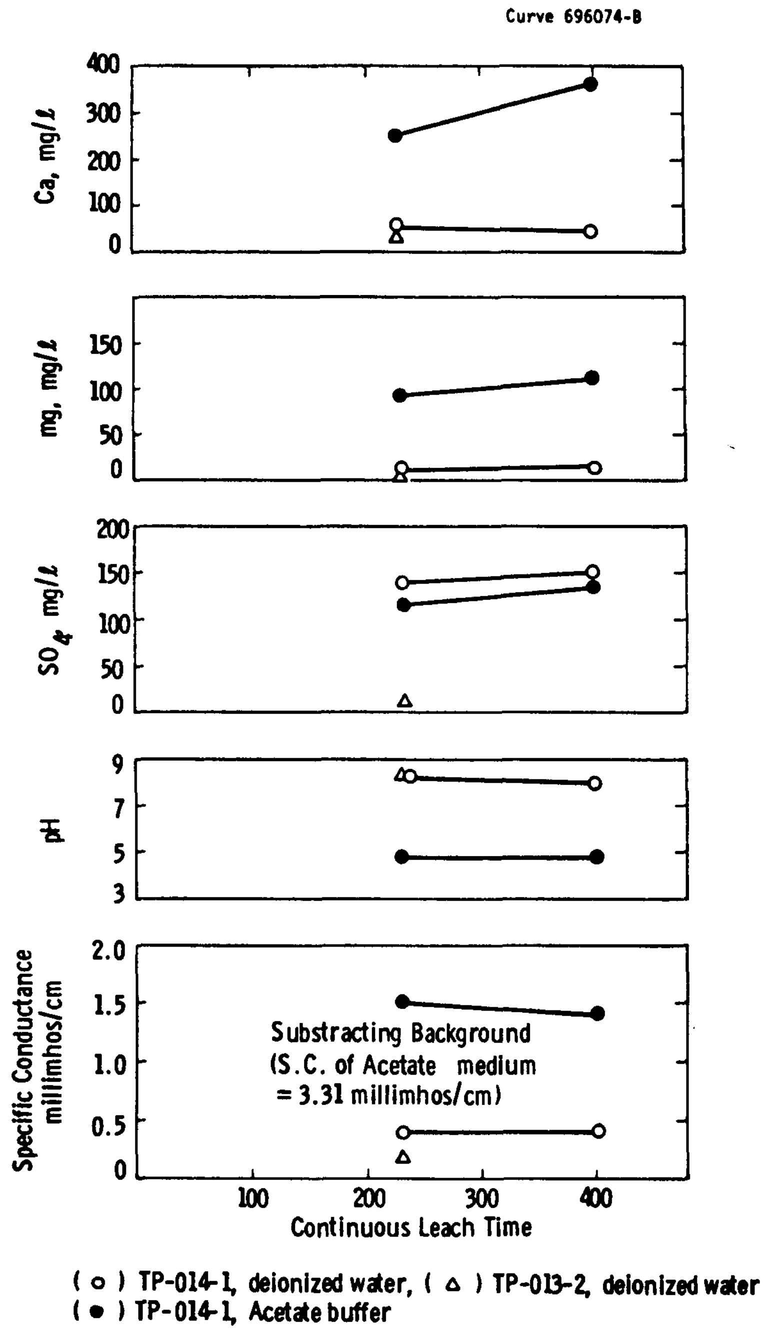


Figure 3.2-18. Leachate Characteristics of Ash Agglomerates as a Function of Continuous Leach Time and Leaching Medium

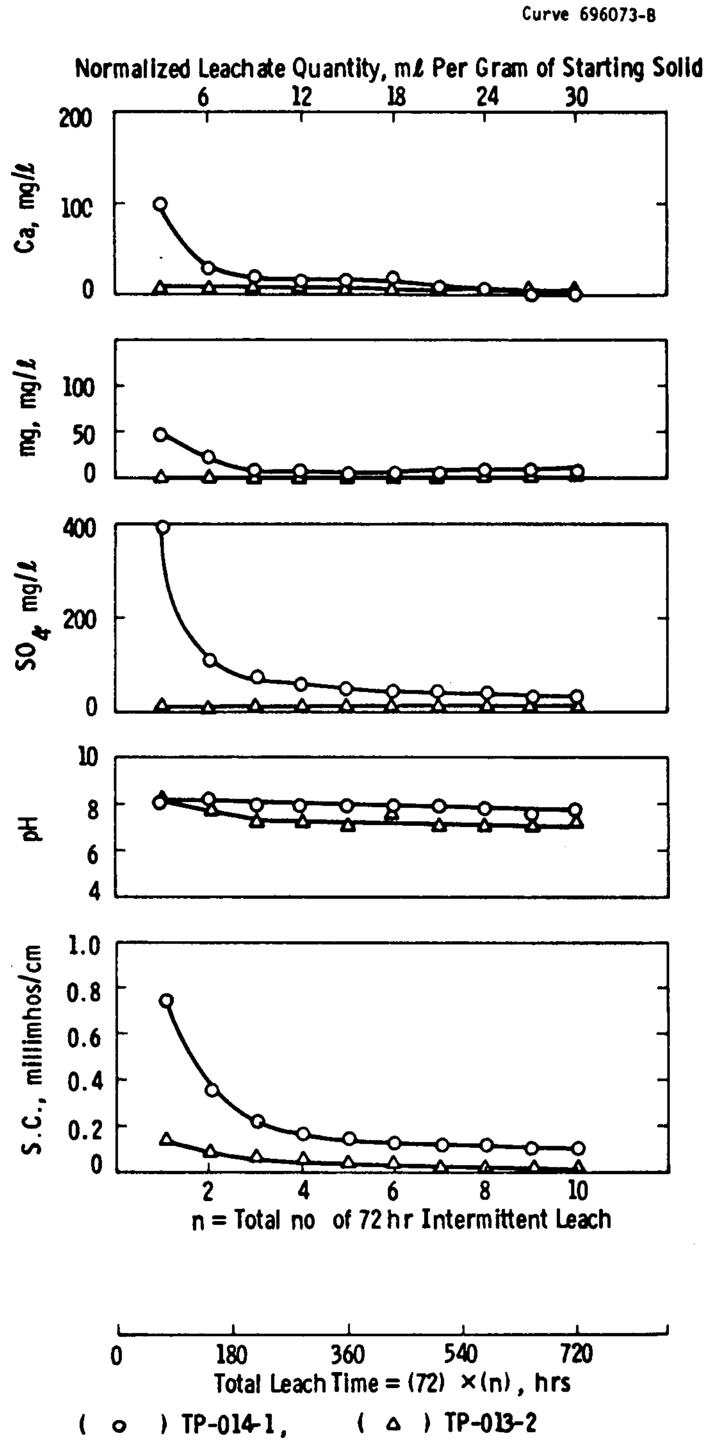


Figure 3.2-19. Leachate Characteristics as a Function of Intermittent Leach with Deionized Water

TABLE 3.2-7

CHEMICAL CHARACTERISTICS OF ASH AGGLOMERATE, TP-013-2 AND TP-014-1 AND THEIR LEACHATES

Substance	Solid (ppm)		Leachate (200 hr, aerobic), mg/ℓ			DWS (mg/ℓ)
	TP-013-2	TP-014-1	TP-013-2	TP-014-1		
			Deionized H_2O	Deionized H_2O	Acetate Buffer	
Aℓ	9.8%	24.9%	<1	<1	6	
Ag	<1	<1	< .01	< .01	< .01	0.05
As			<0.05	<0.05	<0.05	0.05
B	100	100	<1	<1	6	
Ba	300	300	<1	<1	<1	1.0
Be	8	8	< .01	< .01	< .01	
Bi	<1	<1	< .01	< .01	< .01	
Ca	0.32%	0.8%	28	52	296	75
Cd	<1	<1	< .01	< .01	< .01	0.01
Co	10	10	< .04	< .04	0.1	
Cr	33	33	< .03	< .03	< .03	0.05
Cu	30	30	<1	<1	<1	1.0
Fe	1.3%	3.01%	.3	.4	.2	0.3
Hg			<0.002	<0.002	<0.002	0.002
K	0.42%	1.08%				
Mg	0.19%	0.48%	<10	12	92	50
Mn	100	100	< .01	< .01	> 1	0.05
Mo	10	10	< .05	< .05	< .05	
Na	0.45%	3.04%			>> 2	
Ni	30	30	<1	<1	<1	2.0
Pb	10	10	< .02	< .02	< .02	0.05
Sb	<33	<33	< .5	< .5	< .5	
Se			<0.01	<0.01	<0.01	0.01
Si	6.4%	11.6%	2	2	> 6	
Sn	<5	<5	< .2	< .2	< .2	1.0
Sr	300	200				
Ti	> 1000	> 1000	< .2	< .2	< .2	
V	100	100	< .05	< .05	< .05	
Zn	100	150	<4	<4	<4	5.0
Zr	500	500	<1	<1	<1	
SO_3			<10	<10	<10	
$S^=$	<0.1%	<0.1%	<10	<10	<10	
SO_4	<1%	<1%	11	137	111	250
F	<0.02%	<0.03%	<1	<1	<1	2.4
Cl	<0.01%	<0.01%	<1	<1	<1	250
Br			<1	<1	<1	
NO_2			<1	3	<10	
NO_3 (as N)			<1	<1	<1	10
PO_4	0.22%	0.14%	<1	<1	<1	
free C	> 50	> 50				
TOC			<20	<20		
pH			8.2	8.2	4.8	5 to 9.0
S.C. (μmhos/cm)*			160	410	1500	~750
TDS (Approximate)*			~107	~273	~1000	500

DWS — NIPDWR, USPHS and WHO Drinking Water Standards

Dwg. 2618C85

▨ Exceed DWS (shaded cells: Ca, Mg, Mn, pH, S.C., TDS in Acetate Buffer; Fe in TP-014-1 Deionized H_2O)

* Subtracting Background Due to Leaching Medium

3.2.4 Glossary

The following definitions apply to terms in the equations and figures of Subsection 3.2.1.

F_1 - Solid withdrawing rate of char from the bed

F_2 - Solid elutriation rate

F_{co} - Coaxial char feeding rate

F_{do} - Radial char feeding rate

$K_c^*(i)$ - Elutriation constant for coaxially fed char particles of size i

$K_d^*(i)$ - Elutriation constant for radially fed char particles of size i

$\bar{t}_c(i)$ - Average residence time of coaxially fed char particles of size i

$\bar{t}_d(i)$ - Average residence time of radially fed char particles of size i

ω_{c1} - Fraction of coaxially fed char in the withdrawn solids

$\omega_{c1}(i)$ - Fraction of coaxially fed char particles of size i in the withdrawn solids

ω_{c2} - Fraction of coaxially fed char in the elutriated solids

$\omega_{c2}(i)$ - Fraction of coaxially fed char particles of size i in the elutriated solids

$\omega_{co}(i)$ - Fraction of coaxially fed particles of size i in the coal feed

ω_{d1} - Fraction of radially fed char in the withdrawn solids

$\omega_{d1}(i)$ - Fraction of radially fed char particles of size i in the withdrawn solids

ω_{d2} - Fraction of radially fed char in the elutriated solids

$\omega_{d2}(i)$ - Fraction of radially fed char particles of size i in the elutriated solids

$\omega_{do}(i)$ - Fraction of radially fed char particles of size i in the dolomite feed

α - Fraction of original coaxially fed char density after gasification

β - Fraction of original radially fed char density after gasification

3.2.5 References

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