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ADVANCED COAL GASIFICATION SYSTEM FOR ELECTRIC POWER GENERATION

FOURTH QUARTERLY PROGRESS REPORT
FY-1978

Period July 1 to September 30, 1978

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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 systems 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 the 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 fourth quarter of FY-78 centered on testing the gasifier to evaluate performance with coke breeze and char derived from coal using oxygen and steam as the gasification media. However, since suitable chars were not available, direct coal feed to the gasifier was used. Four tests were run, TP-018-1 through -4, and operating summaries and test results are described in this report. A fifth test, TP-018-5, was started and will be described in the next quarterly report. The operating results for Test TP-018-1 were reported previously in the Third Quarterly Progress Report, FE-1514-88. Consequently, this test is only summarized in Section 3.0, with additional comparative studies being presented showing the effects of air tube diameter changes on product gas characteristics, fines elutriation and axial temperature profiles from the results of TP-018-1 and TP-015-1.

Test TP-018-2 was the first gasifier test to be run with oxygen. Total time for the test exceeded 180 hours, with 50 hours of operation using Pittsburgh seam coal as feedstock. Product gas higher heating values on a dry basis ranged from 120 Btu/scf for coke breeze to 260 Btu/scf for Pittsburgh coal.

As part of the overall test objectives, effort was devoted to increasing ash content in the withdrawal steam, with the results that in TP-018-4 concentration was increased from 30 percent to 80 percent.

An experimental test grid designed to show the effect of increased oxygen flow on reactor temperatures and heating values with the highly-caking Pittsburgh seam coal was established and added to with each test conducted. Cumulative results are shown in Figure 3.1-4.

Successful operation of the single-stage gasifier reactor with oxygen was demonstrated with this series of tests with some rather significant results. Summaries of these results are given in the following subsections.

2.1.1 Gasifier Test TP-018-1

Test TP-018-1 was conducted from June 25 to June 29, and the operating data, including heat and material balances, were reported in the Third Quarterly Progress Report, FE-1514-88. In this report, the test is summarized and an assessment of the effects of a smaller air tube diameter on reactor response is made by comparing these results with those of Test TP-015-1 which was run with a larger diameter air tube. Comparisons include product gas characteristics, fines elutriation and axial temperature profiles.

2.1.2 Gasifier Test TP-018-2

The first use of oxygen in the gasifier was accomplished in test TP-018-2. The test was conducted July 17 to July 31 with the initial objectives to functionally checkout and shakedown the oxygen supply subsystem including the safety interlocks, flow loop operation and the oxygen heater controls. Other objectives included a stepped increase in oxygen concentration in the gas exiting the air/oxygen tube with coke breeze as feedstock. Results showed concentrations of 17, 26 and 37 percent achieved for set points 1, 2 and 3, respectively. An experimental design to show the effect of increased oxygen flow on reactor temperature and heating values for a highly-caking Pittsburgh seam coal was also conducted, and the results are given in Figure 3.1-2.

Operating time for the test exceeded 180 hours, with 50 hours dedicated to operating with Pittsburgh seam coal. Higher heating values, on a dry basis, of the product gas ranged from 120 Btu/scf for coke breeze to 260 Btu/scf for Pittsburgh coal.

A normal shutdown was initiated on July 31 after a flow impedance was detected in the external gasifier cyclone. Inspection revealed a buildup at the cyclone inlet throat and at the outer circumference where the cyclone inlet meets the wall. No significant deposits were found in the gasifier vessel or the outlet piping.

In addition to operating data, brief analyses are given for both ash characteristics and tar.

2.1.3 Gasifier Test TP-018-3

The experimental test grid was continued with test TP-018-3, which was run between August 16 and August 23, 1978. Both Rosebud and Pittsburgh seam coals were used. Use of the Pittsburgh coal was intended to verify TP-018-2, set point 4 conditions, and to add new information to the test grid by operating with a high steam flow split between the grid and oxidant tube, and a moderate oxygen flow.

Several accomplishments of the test can be identified. These include a 50 percent concentration of oxygen during set point 3 from the oxidant feed tube; the first complete recycling of gasifier fines collected by the cyclone for oxygen-blown operation; solving the problem of high ambient H_2S concentrations near the product gas cooling water separation pit; achieving a carbon conversion in excess of 95 percent in conjunction with the 61 percent ash discharge obtained in set point 3 (note that the carbon conversion figure assumes that no carbon is lost in the water system), and determining that there were no measurable tars or oils samples taken from the water system and isokinetic solids.

Effort was also devoted to increasing ash content in the withdrawal during set points 2 and 3, since during set point 1 the ash withdrawal rate was high with the result that ash concentration in the discharge was low. In set point 3, an ash product in excess of 60 percent was achieved. An ash plot is presented in Figure 3.1-3 for a 10-hour period from set point 3.

2.1.4 Gasifier Test TP-018-4

Test TP-018-4 was started on September 12 and continued through September 18. It was conducted principally to measure the effects of steam flow and reactor temperature on the gasification of Pittsburgh seam coal with oxygen and steam. Other objectives of the test were to progressively increase the oxygen concentration in the oxidant tube from 36 to 60 percent by decreasing the steam input, and to observe changes in the gasification rate and gasifier temperature resulting from reduced steam input; to test the effect of reduced and unreacted steam in the product gas as it affects gasification of a stagnant region of fines in the cyclones, and finally to evaluate the effect of increased gas inlet velocity to the cyclone as a means of preventing formation of deposits. This latter effort had no significant effect, and other changes are being considered.

In conjunction with measuring gasifier sensitivity to changes in steam flow rates and reactor temperatures, a change was also introduced in the gasifier ash annulus operation that balanced the net ash input with a 70 percent concentration in the withdrawal stream as opposed to the usual method of withdrawing ash at the maximum rate during start-up. The results of this change were significant as shown in Figure 3.1-4. Ash content of the withdrawal stream incrased steadily over a 14-hour period from less than 30 percent to over 80 percent.

Another aspect of the test was the frequent loss of material withdrawal when oerating the oxidant tube with steam at an oxygen concentration of 47 percent. Withdrawal could be regained by momentarily increasing flow in the annular region. Accomplishments included achieving an ash content of 68 to 81 percent in the discharge material, sustained operation with an oxygen concentration of 47 percent for the oxidant tube with no major ill effects on overall plant operation, and a product gas higher heating value of 235 Btu/scf, dry basis.

2.1.5 PDU Modifications for Integrated Operation

Work continued on a limited basis this quarter in view of PDU gasifier operation and has concentrated on the design and procurement of major hardware components. Among the items purchased is the Edens separator which is now on site. Plans call for installation next quarter. Other items installed this quarter are the 12-inch refractory-lined pipe connecting the gasifier and devolatilizer, and the 10-inch refractory-lined pipe for the devolatilizer draw-off leg. Assembly and casting of refractory for the bottom section of the devolatilizer was started, and other refractory work was either completed or planned.

2.1.6 PDU Modifications for Operation with Oxygen

The construction phase for the PDU oxygen supply system was completed in July with post-operational repairs and modifications following shakedown test TP-018-1. Chief among the items to be repaired was the supply system flange that caused test TP-018-1 to be ended earlier than planned. Minor modifications were also made to the oxygen control interlock logic. The operating characteristics of the oxygen supply and control system were functionally checked during TP-018-2, the first oxygen-blown gasifier test. With the exception of minor problems with the oxygen supply pressure regulator, overall performance was satisfactory.

2.1.7 PDU Process and Design Engineering

A variety of work was accomplished in process and design engineering. In general terms this includes direct support of the gasifier tests, analyzing experimental test and equipment performance data, developing heat and material balance computer models, conducting product characterization studies, designing the scale-up cold flow model and administering the environmental, safety and health program. Subsection 3.1.4 lists fifteen specific work items under general engineering that were completed this quarter.

In the area of product characterization, Subsection 3.1.4.2, work accomplished included modifying and developing sample apparatus to improve measurement techniques, and evaluating chemical and physical property data of samples analyzed from air-blown gasifier tests TP-016 and TP-017. Solids, product gas and liquids analyses are included.

The current status of product characterization analyses of the minimum requirements adopted as standard is presented in Table 3.1-27. The analysis of deposits found in the cyclone following test TP-018-3 has also been initiated.

As part of the environmental safety and health program, a water-spray deluge protection system for the liquid propane tank was installed, and on August 4, it was functionally tested with good results.

2.2 PHASE I, TASK 3 - LABORATORY SUPPORT STUDIES

2.2.1 Cold Flow and Analytical Modeling

The mapping of the velocity profiles along the jet height inside a fluidized bed by means of a two-dimensional pitot tube was completed in this quarter. The gas velocity profiles inside the jet at three different jet velocities and at eight different fluidized bed operating conditions were analyzed. The gas entrainment into the jet under these conditions was obtained by graphical integration of the velocity profiles. The results and some preliminary conclusions are presented in this Quarterly Progress Report.

Experiments were also carried out in the two-dimensional unit with three separate draft tubes. Pressure drops across each of the three draft tubes, each of the four downcomers, and between the downcomers and draft tubes were measured. The solid particle velocity in every downcomer was obtained by following tracer particles with a stop watch. The preliminary findings are discussed in Subsection 3.2.

2.2.2 Coal Behavior Studies

Surface area measurements on several chars were performed using the Dubinin-Polanyi method with carbon dioxide as the adsorbate. Scanning electron microscope photos were also made of various unreacted chars for study.

Fabrication of the new reactor for ash agglomeration studies is underway. The shell is complete and machining of the transition piece connecting the reactor and cyclone is underway. A cold model was set up to visualize operations and to collect data to help in startup of the new test facility when it is completed.

In coal and ash chemical phenomena studies, thermodynamic calculations were used to study the effects of temperature, gasifier bed ash content, and steam flow to the grid plate, on the different chemical compounds formed in the gasifier and their relative amounts at equilibrium. Of all the chemical compounds predicted by thermodynamics, potassium and iron were shown to be affected by the changes in operating conditions. The majority of the potassium, 90 to 99 percent, was tied up as K_2SiO_3 in the gasifier. Since K_2SiO_3 melts at 1789°F (976°C) and has a low melting eutectic at 1368°F (742°C), it may have acted as a binding matrix for ash deposits. Iron, on the other hand, was stable as FeO Al_2O_3 which metls at 3092°F (1700°C) with a eutectic at 2426°F (1330°C), and may not have been part of the binding matrix. Increasing the temperatures, increasing steam flows to the grid plate and decreasing bed ash contents, increased the decomposition of (K_2SiO_3) liquid into (KOH) gas and (KCN) gas.

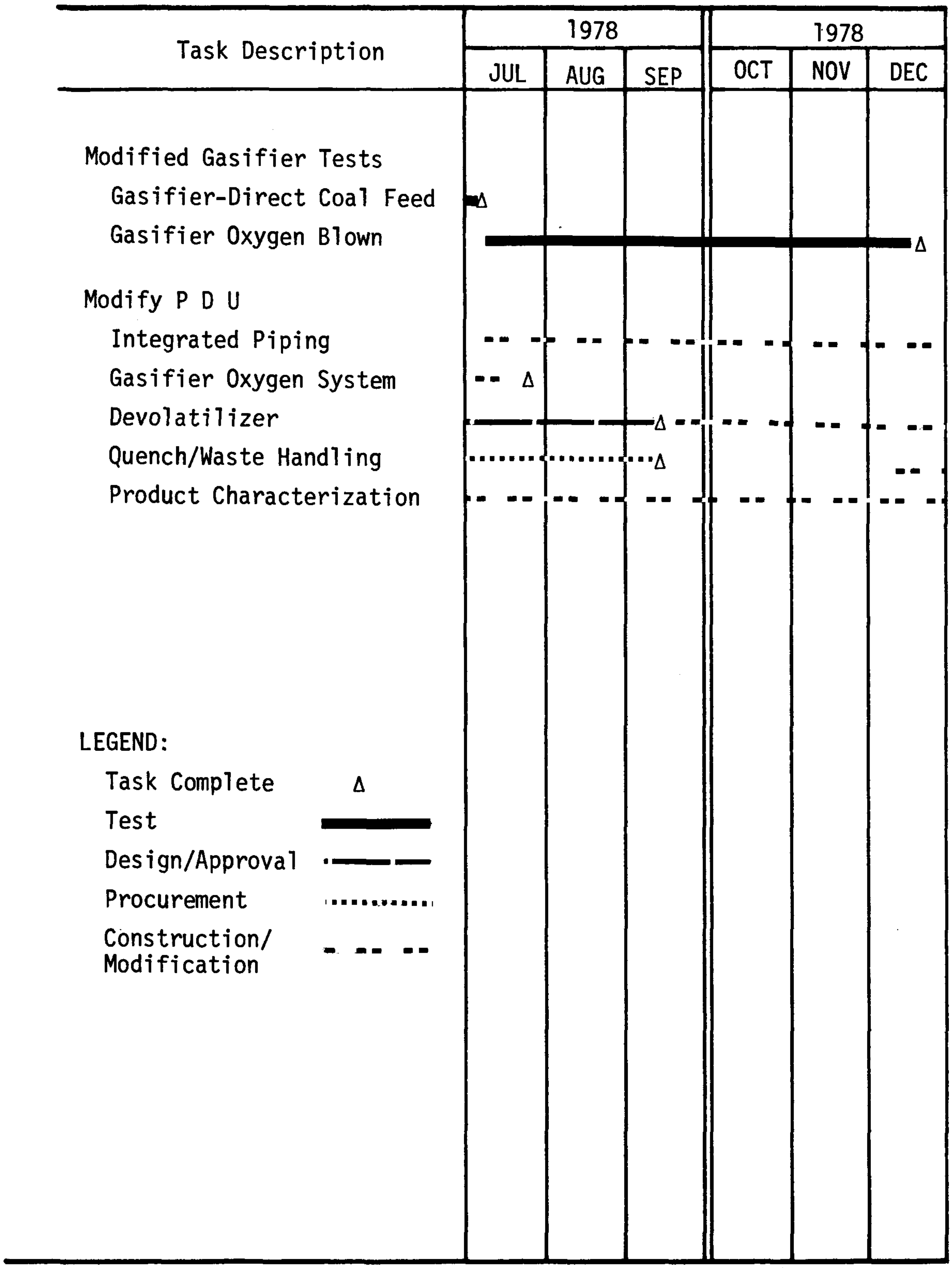
2.2.3 Environmental Impact Studies

Ash agglomerates from test TP-016, which used Pittsburgh seam coal as feedstock to the gasifier, have been tested for the environmental impact from disposal. Ash content of the samples tested was 67 percent, and leachate did not exceed drinking water standards.

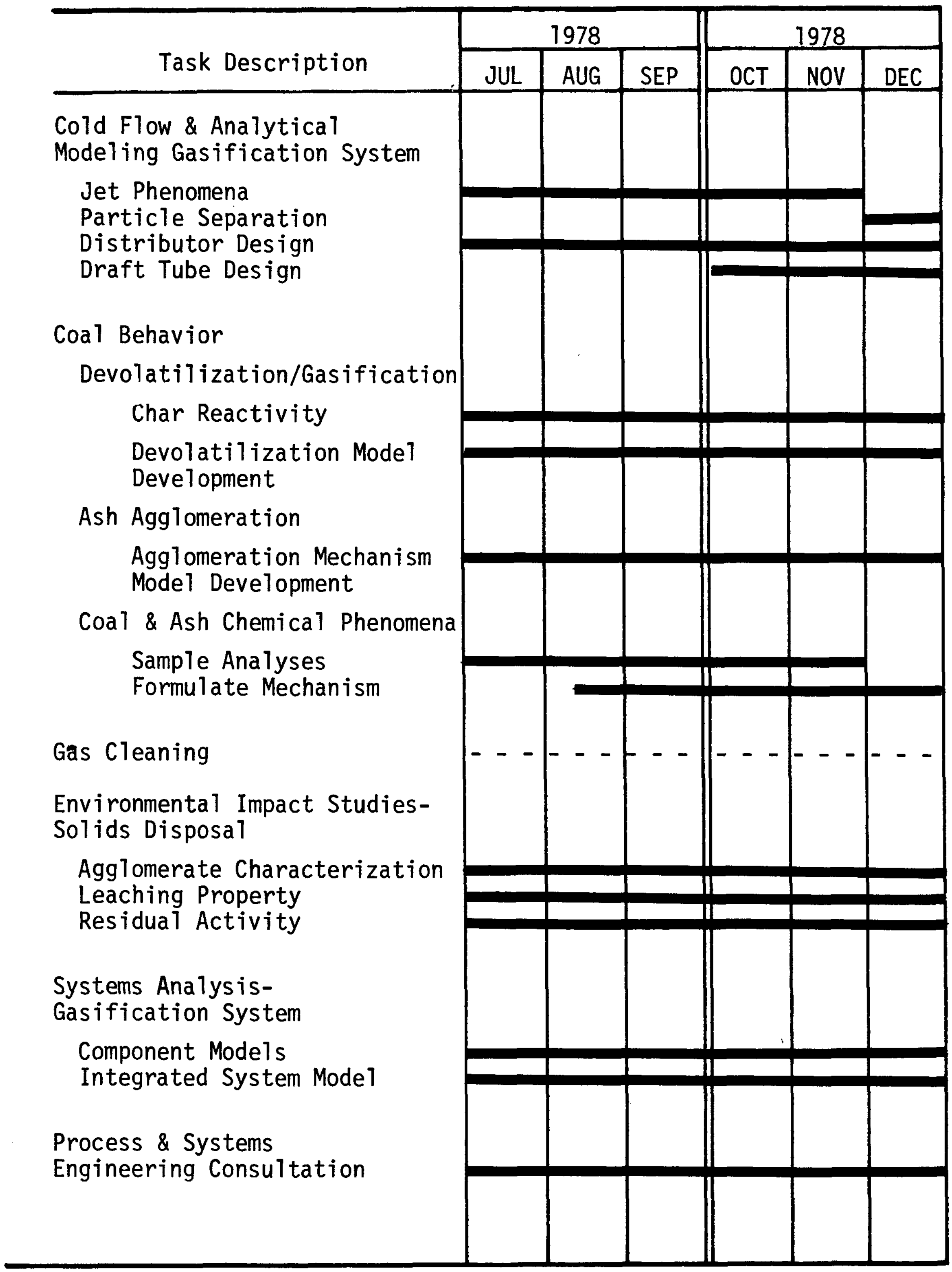
Ash agglomerates from TP-014-1 were tested using a proposed test version in the draft of the Resource Conservation and Recovery Act (RCRA, PL 94-580, 1976). Cr was the only constitutent to exceed the tentative criteria. These tests are made to provide perspective and are not definitive, since further changes in the draft procedure will be made.

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 noted in the Third Quarterly Progress Report (April-June 1978) the test sequence for the CY-1978 was revised in February to include the following:

- 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 conducted in the fourth quarter has been to evaluate gasifier operation with coke breeze and char derived from coal in an oxygen-plus-steam gasification environment. Since suitable chars from outside sources were not available, direct coal feed to the gasifier was used to provide char for oxygen and steam gasification studies.

Considerable operating experience was gained with oxygen-blown gasification in the modified gasifier configuration including successful operation of the oxygen supply system, sampling for product characterization and direct feed of a highly-caking Pittsburgh seam coal to the single-stage gasifier reactor in conjunction oxygen-blown operation.

These tasks were completed during the TP-018-2, TP-018-3 and TP-018-4 tests. TP-018-5 test was started during this quarter, but since it carried over into the next quarter results will be reported later.

3.1.1.1 Work Accomplished - Gasifier Test TP-018-1

The significant events, steady state operating data, flow diagram and heat and material balance data for this test were presented in the last quarterly report. The test conducted from June 25 to June 29 was shortened to an air-blown test when a major leak occurred on the oxygen supply system vaporizer flange during a routine venting flow check at the oxygen farm prior to introduction of oxygen into the gasification system. The leak was apparently caused by a misalignment in the flange faces. The gas seal became progressively worse when the metal contracted after liquid oxygen flow was initiated to the vent. In view of the severity of the leak it was decided to omit set points 2 through 5 of the test plan which called for oxygen inputs to the gasifier.

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, at 230 psig.

The effect of a smaller diameter air tube on gasifier performance was briefly assessed. The steady state data from this test, conducted with a 2-inch air tube, are compared with TP-015-1, Set Point Number 1, conducted with a 2-1/2-inch air tube, in Table 3.1-1. These two set points were similar in the following respects:

- -6 mesh coke breeze was used as a feed material
- Steam flow was admitted to the booster sparger
- Freeboard temperature was controlled between 1800°F and 1850°F
- System pressure was controlled at 230 psig.

The composition of the product gas is intrinsically affected by the overall steam/carbon gasification rate. This rate was determined for the two cases as outlined:

TABLE 3.1-1

GASIFIER RESPONSE FOR TWO OXIDANT TUBE GEOMETRIES

Temperature and Flows	Test TP-015-1 Set Pt. 1	Test TP-018-1 Set Pt. 1
Freeboard Temp, °F*	1833	1807
Air Flow, lb/h	2740	2137
Total Recycle Gas Usage, lb/h	2714	2152
Steam Flow to Booster, lb/h	325	425
Gross Coke Breeze Feed, lb/h	632	445
Fines Carryover, lb/h	140	80
Fluid-Dynamic Data		
Superficial Velocity, 30" Section, ft/s	1.38	0.98
Jet Velocity, ft/s	70	183
Jet Length, inches**	44	88
Product Gas Data (Dry Basis)		
CO %	9.72	6.56
CO_2 %	24.33	22.77
H_2 %	3.10	3.41
N_2 %	62.85	67.23
Particulate Data, (Avg Dia)		
Bed Sample, μ	720	625
Ash Agglomerates, μ	1425	1100
Cyclone Fines, μ	128	115
Ash Annulus Conditions		
Annular Gas Flow, lb/moles/h	53	48

*Axial Temperature Profiles are presented in Figure 3.1-1.
**Calculated from empirical model.

	TP-015-1 (2-1/2" Tube)	TP-018-1 (2" Tube)
Gasification Rate (moles H_2/hr)-G	3.73	2.92
Average Bed Density (lb/ft^3)	24.1	26.4
Carbon Holdup In Bed (lbs)-C	570	604
Specific Gasification Rate, min^{-1} $\left[\text{(Defined as } \frac{G \times 12}{C \times 60}\text{)}\right]$	1.31×10^{-3}	9.67×10^{-4}
Partial Pressure of Inlet Steam, (P_{H_2O}, psia)	20.6	32.6

The rate expression for reaction kinetics correlated for the PDU data is:

$$R = K \exp(-E/RT) \, (P_{H_2O})^n$$

where

R = specific gasification rate, min^{-1}
E = activation energy, Btu/lb mole°R
P_{H_2O} = partial pressure of steam, psia
K, n = empirically determined constants.

It is clear that the 'K' factor for TP-015-1 (2-1/2" tube) was identical to the one empirically determined from previous gasifier tests. However, the 'K' factor for TP-018-1 (2" tube) was lower by 35 percent. This discrepancy could be attributed to the following:

- Less gas-solid mixing in TP-018-1 due to lower superficial velocity in the gasifier bed (1.53 ft/s vs 2.16 ft/s)
- Reduction in the available bed volume due to increased jet penetration (88 inches vs 44 inches)
- Inherent scatter in the PDU data.

Fines elutriation from the gasifier is dependent on the superficial freeboard velocity. Comparing the elutriation rates in Table 3.1-1, it is evident that the higher rate in TP-015-1 was a result of the higher superficial velocity. It may also be inferred that the higher jet penetration in TP-018-1 had no appreciable effect on fines elutriation.

It may be argued that for the same mass flow rate, a smaller air tube diameter would produce a longer air jet which causes the combustion reactions to occur at a higher elevation in the bed. However this was not borne out in the two tests under comparison. The axial temperature profiles for TP-018-1 and TP-015-1 depicted in Figure 3.1-1 are virtually identical, which suggests that the temperatures measured at the outer periphery of the gasifier do not reflect changes in the location of the combustion zone or that the combustion zone did not, in fact, change locations.

3.1.1.2 Work Accomplished - Gasifier Test TP-018-2

Operation of the PDU gasifier using oxygen-plus-steam gasification was initiated with Test TP-018-2 during the July 17 to July 31, 1978 time period. The objectives of the TP-018-2 test were:

- To functionally checkout and shakedown the oxygen supply subsystem, including safety interlocks, flow loop operation, and oxygen heater controls.

- To obtain a stepped increase in oxygen concentration in the gas exiting the air/oxygen tube using coke breeze (-6 mesh) as the feed material through both the coaxial and radial feed points, without recycling gasifier overhead fines. This constituted the initial three set points of TP-018-2 with oxygen concentrations of 17, 26 and 37 percent, respectively.

- To show the effect of increased oxygen flow on reactor temperature and heating value through an experimental design for highly caking Pittsburgh seam coal as shown in Table 3.1-2. The set points chosen for TP-018-2 permitted this evaluation and provided scoping data for use in planning later oxygen tests with bituminous coals.

During the time frame of the test, over 180 hours of operation in the modified oxygen-blown gasifier mode were logged from ignition to shutdown. On a dry basis, the gas produced in this operating mode varied from 120 Btu/scf for coke breeze to 260 Btu/scf for Pittsburgh seam coal. The highly caking Pittsburgh coal was fed to the gasifier for 50 hours without affecting the character of reactor fluidization or gas-solids mixing. The steam/coal ratios run during this test were conservatively high at 0.9 to 1.8 lb steam/lb (MAF) coal.

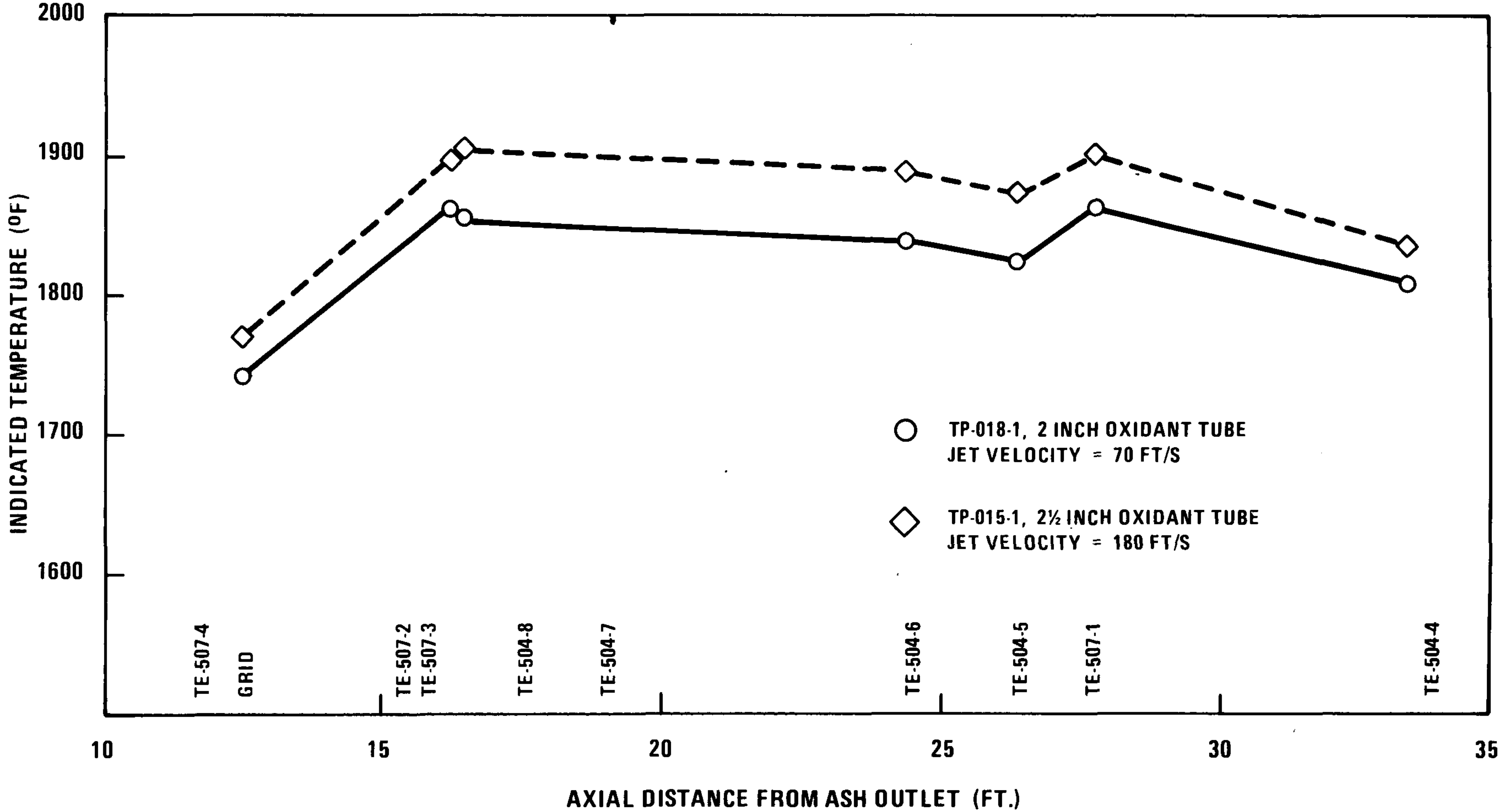


Figure 3.1-1. Axial Temperature Profiles for TP-015-1 and TP-018-1 (Air Tube Diameter Comparison)

TABLE 3.1-2

EXPERIMENT TEST GRID, TP-018 SERIES TEST
USING PITTSBURGH #8 COAL

		All Steam Flow to Oxidant Tube	Steam Split Between Grid and Oxidant Tube	Steam Split Between Booster and Oxidant Tube
LOW OXYGEN FLOW RATE	Low Steam Flow 350-450 Lb/h			
	Med. Steam Flow 500-600 Lb/h		////	
	High Steam Flow 700-800 Lb/h	////	////	
MEDIUM OXYGEN FLOW RATE	Low			////
	Medium	////	////	
	High		////	
HIGH OXYGEN FLOW RATE	Low	Not Planned for Gasifier Testing since Reactor Temperature Would Exceed 1900°F		
	Medium			
	High	////	////	

//// Designates planned tests

Test TP-018-2 was terminated when a significant pressure drop of more than 5 psid was discovered across the external gasifier cyclone, indicative of some flow impedance in the unit. Normal shutdown was begun on July 31. A post test inspection of the cylcone revealed a heavy buildup at the cyclone inlet throat and at the outer circumference where the cyclone inlet meets the wall. Chemical analysis of these cyclone deposits indicated a very high content of ferrous sulfide ($Fe_{(1-x)}S$) and various sulfates. The crystalline structure of these compounds was found to represent up to 50 percent of the characteristic ash deposit found in the cyclone entry. Analysis of the distortions in the gas flow path into the cyclone indicate that the irregularities in gas flow would account for the deposit laydown observed at the annular region circumferential wall.

No significant deposits were observed in the gasifier vessel or in the outlet piping exept for the normal coatings experienced on bed thermowells and pressure taps.

The chronology of events for Test TP-018-2 is given in Table 3.1-3. The steady state operating conditions for the three coke breeze set points and three Pittsburgh seam coal set points are shown in Table 3.1-4. A flow diagram of these conditions is shown in Figure 3.1-2. The composition of the product gas during steady state periods was determined by two methods; namely, gas chromatograph analysis of on-line samples and mass spectrometric analysis of gas bomb samples. The results are compared in Table 3.1-5 and these show that the mass spectrometric analysis gave higher values of H_2 and lower values of CO_2, indicating some error in this type of analysis since it is not calibrated versus a standard sample gas.

A rough estimate of tar/oils production was determined by analyzing the solids collected in the TCA catch-pot during steady state periods when Pittsburgh coal was fed to the gasifier. Results are reported in Table 3.1-6.

TABLE 3.1-6

TAR-ANALYSIS REPORT
TEST TP-018-2

Set Point	4	5	6
Tar Rate, lb/h	0.41	0.12	0.0
Coal Feed Rate, lb/h	520	505	995
Yield, lb/lb Coal, %	0.08	0.02	0.0
Reactor Exit Temp TE-504-4	1710°F	1700°F	1860°F

It should be noted that since no recycling of gasifier fines was performed during any test, the yields reported for the low 1700°F reactor operation would possibly drop with fines recycle.

TABLE 3.1-3

CHRONOLOGY OF EVENTS TP-018-2

Date	Time	Event
July 17	0800	Pressurization and leak check.
July 19	0800	Extended hot-air heatup for steam superheater installation.
July 22	0800	Initiated coke breeze feed.
	1620	Autogenous combustion of coke breeze.
July 23	1200	Initiated oxygen flow.
	2015	Achieved Set Point Number 1 conditions.
July 24	2200	Terminated Set Point Number 1.
July 25	0545	Achieved Set Point Number 2 conditions.
	0845	Initiated shutdown to repair control valve PV-21.
July 26	0430	System pressurization for re-start.
	1715	Autogenous combustion of coke breeze.
July 27	2200	Re-achieved Set Point Number 2 conditions.
July 29	0950	Concluded Set Point Number 3.
	1400	Initiated Pittsburgh coal feed.
	1500	Acieved Set Point Number 4 conditions.
July 30	0345	Terminated Set Point Number 4.
	0430	Achieved Set Point Number 5 conditions.
	1745	Terminated Set Point Number 5.
	2145	Achieved Set Point Number 6 conditions.
July 31	1140	Terminated Set Point Number 6. Initiated shutdown.

TABLE 3.1-4

SUMMARY OF OPERATING DATA FOR MODIFIED GASIFIER TEST TP-018-2

SET POINT		1	2	3	4	5	6A
TEST RUN DATE AND TIME (1978)	Unit	7-24 Hours 0815/2230	7-28 Hours 0800/1145	7-28/29 Hours 2345/0530	7-29 Hours 2000/2300	7-30 Hours 1000/1730	7-30/31 Hours 2200/0300
MEASURED GASIFIER PARAMETERS							
TE-504-4 Freeboard Temperature	°F	1754	1866	1831	1710	1703	1857
TE-507-3 Gasifier Bed Temperature	°F	1822	1927	1851	1726	1696	1844
TE-504-10 Ash Annulus Temperature	°F	464	95	107	120	124	112
Average Bed Height	feet	24.45	25.19	24.95	24.84	26.74	24.07
System Pressure	psig	130.0	129.0	129.0	129.0	129.0	129.0
Average Gasifier Bed Density	lb/ft^3	33.23	25.67	24.61	15.65	10.45	11.92
Average Ash Annulus Density	lb/ft^3	30.85	21.65	23.95	18.29	16.19	14.26
Freeboard Gas Velocity	fps	1.12	1.23	1.25	1.20	1.27	1.72
Oxidant Tube Velocity		327.80	164.79	120.92	121.50	165.38	193.27
Coal Feed Material		Coke Breeze	Coke Breeze	Coke Breeze	Pgh. Seam Coal	Pgh. Seam Coal	Pgh. Seam Coal
Coal Feed Rate, WR-27	lb/hr	370	300	300	520	505	995
Fines Feed Material		Coke Breeze	Coke Breeze	Coke Breeze	--	--	--
Fines Feed Rate, WR-14	lb/hr	145	195	175	0	0	0
Cyclone Collection Rate, WR-19	lb/hr	107	83	92	165	95	130
Carryover to Water System*	lb/hr	13	84	35	35	27	76
Ash Withdrawal Rate	lb/hr	50	92	62	70	32	45
PRODUCT GAS ANALYSIS, DRY BASIS							
Carbon Monoxide	%	8.76	27.48	24.54	30.41	30.36	44.90
Carbon Dioxide	%	52.69	60.60	66.17	47.08	46.71	24.17
Methane	%	0.0	0.0	2.70	2.75	2.75	2.71
Nitrogen	%	34.34	0.0	0.0	0.0	0.0	0.0
Oxygen	%	0.0	0.0	0.0	0.0	0.0	0.0
Hydrogen	%	4.21	11.92	9.28	18.86	19.26	27.29
HHV, Dry Basis (Gas Chromatograph)	Btu/scf	41.73	126.73	108.75	192.01	193.46	265.69
OVERALL PROCESS RATES							
Steam/Coal Ratio, MAF**	lb/lb	--	--	--	1.70	1.74	0.89
Oxygen/Coal Ratio, MAF	lb/lb	--	--	--	1.10	1.10	0.92
Total Moisture/Coal Ratio, MAF	lb/lb	--	--	--	1.72	1.77	0.91
SOLIDS ANALYSIS							
Ash Content - Fines	%	14.94	12.54	14.32	--	--	--
Ash Content - Feedstock	%	14.94	12.54	14.32	9.03	9.03	9.03
Ash Content - Bed	%	26.16	16.51	18.80	21.02	28.27	23.44
Ash Content - Agglomerate	%	44.95	55.49	62.53	42.39	40.30	47.42

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

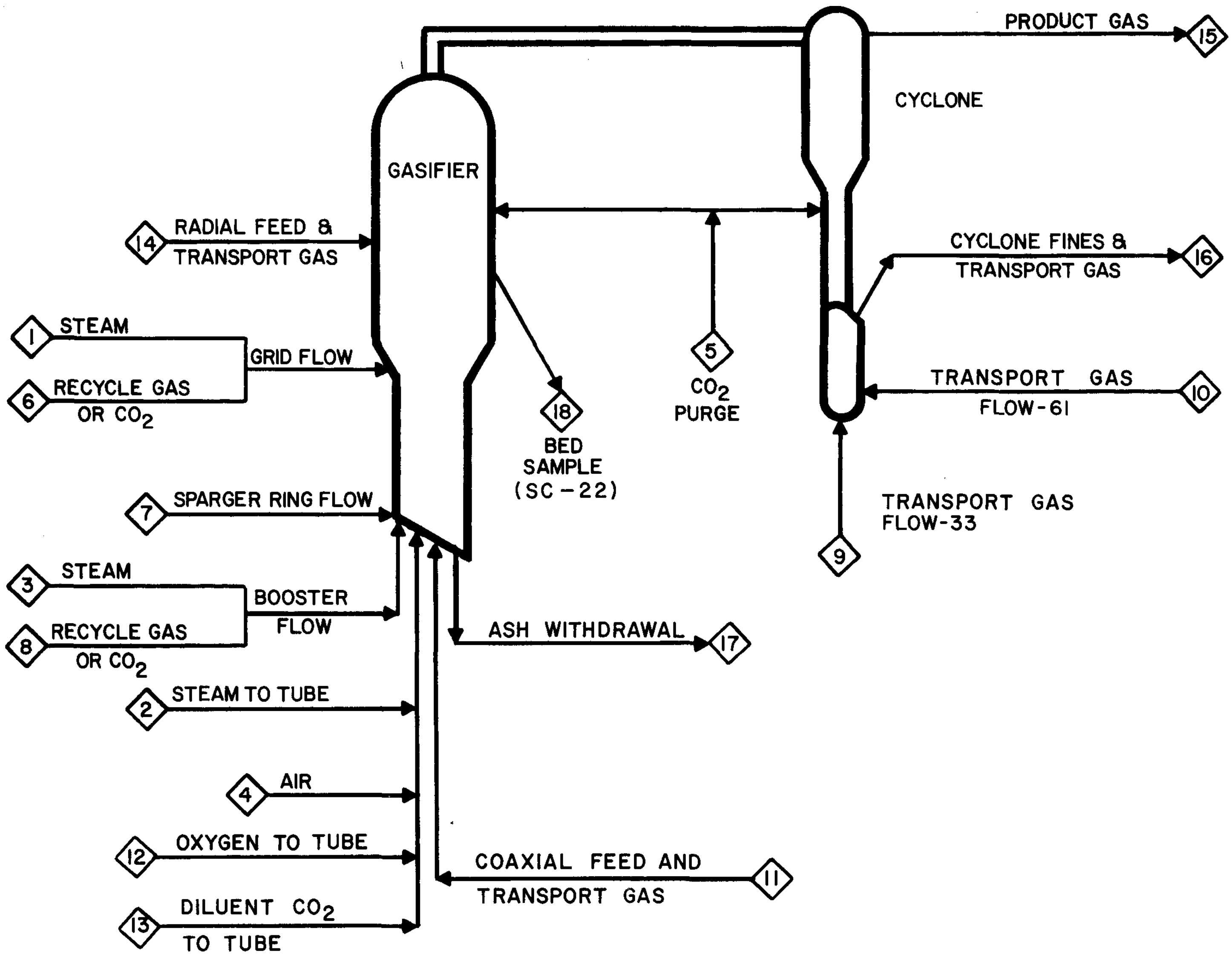


Figure 3.1-2. Heat and Material Balance Flow Schematic for Test TP-018-2, -3, and -4.

TABLE 3.1-5

PRODUCT GAS ANALYSIS*
TEST TP-018-2

SET POINT	1		2		3		4		5		6	
	GC	MS	GC	MS	GC	MS	GC	MS	GC	MS	GC	MS
DRY BASIS, %												
CO	8.76	--	27.48	30.11	24.54	28.45	30.41	29.10	30.36	33.00	44.90	34.49
CO_2	52.69	--	60.60	51.00	66.17	56.77	47.08	41.00	46.71	34.11	24.17	24.22
CH_4	0.0	--	0.0	0.67	0.0	0.58	2.70	3.20	2.75	2.94	2.71	2.99
N_2	34.34	--	0.0	0.41	0.0	0.37	0.0	0.0	0.0	0.0	0.0	0.0
O_2	0.0	--	0.0	0.08	0.0	0.0	0.0	0.02	0.0	0.03	0.0	0.01
H_2	4.21	--	11.92	17.53	9.28	13.44	18.86	26.07	19.26	29.51	27.29	37.79
H_2S	0.0	--	0.0	0.01	0.0	0.20	0.96	0.50	0.93	0.31	0.93	0.37
COS	0.0	--	0.0	0.08	0.0	0.03	0.0	0.01	0.0	0.01	0.0	0.02
C_2H_6	0.0	--	0.0	0.00	0.0	0.01	0.0	0.02	0.0	0.00	0.0	0.00
A	0.0	--	0.0	0.13	0.0	0.15	0.0	0.09	0.0	0.10	0.0	0.07
HHV, Btu/scf Dry Basis	41.73	--	126.73	160.128	108.75	141.90	192.01	213.30	193.46	233.11	265.69	265.62
Moisture Content, % (on TCA)	22.91	--	33.49		30.00		23.00		31.97		18.26	

*GC - Field gas chromatograph
MS - Mass spectrometer
TCA - Total condensibles analyzer

The characteristics of ash discharge samples are reported below in Table 3.1-7.

TABLE 3.1-7

ASH CHARACTERISTICS
TEST TP-018-2

Set Point	1	2	3	4	5	6
Feedstock	Coke	Coke	Coke	Coal	Coal	Coal
Max. Ash Content, %	56	59	70	62	47	55
Particle Density, lb/ft^3	91	88	123	84	63	60
Particle Shape*	ANG	SPH	SPH	ANG	ANG	SPH
Type**	DC	SA	A	DC	DC	A
Avg. Size, μ	1500	2000	2500	1200	1200	1200

*SPH = spherical, ANG = Angular

**DC = Denuded Carton, SA = Semi-Agglomerate, A = Agglomerate

The agglomerates produced in this test were found to be denser than those made in the earlier air-blown gasifier tests, which is perhaps indicative of the higher combustion temperatures prevailing in the oxygen-steam jet.

Heat and material balance data are shown in Tables 3.1-8, -9, -10, -11, -12 and -13 for the six steady state points.

3.1.1.3 Work Accomplished - Gasifier Test TP-018-3

Test TP-018-3, which was conducted between August 16 and August 23, 1978, was intended to explore additional conditions of the experimental test grid shown in Table 3.1-14. The test points for Pittsburgh coal were intended to both verify the TP-018-2 Set Point Number 4 conditions and add new data in the form of a high steam flow with steam split between grid and oxidant tube and a moderate oxygen flow rate. Since sufficient Rosebud Coal was not on site for the four set points planned for this coal, another Pittsburgh coal set point was added during the run that consisted of medium steam flow split between grid and tube with a low oxidant flow.

TABLE 3.1-8

GASIFIER HEAT AND MATERIAL BALANCES
TEST TP-018-2 - SET POINT 1

TEST NO. :TP-108-2 DATE :JULY 24 ISSUED BY :HALDIPUR DATE :
POINT NO. :SET POINT 1 TIME :8:15 22:30 COMPLETED BY : DATE :

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	617.00	0.00	756.00	300.00	307.40	58.77	356.00	445.28	105.10
TEMPERATURE F	0.0	503.0	0.0	1006.0	134.0	180.0	92.0	180.0	180.0	225.0
GAS LB/HR	0.00	617.00	0.00	756.00	300.00	307.40	58.77	356.00	445.28	105.10
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	35.762	35.762	35.762	35.762	35.762
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	8.20	8.20	8.20	8.20	8.20
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	55.14	55.14	55.14	55.14	55.14
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	3.95	3.95	3.95	3.95	3.95
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	32.23	32.23	32.23	32.23	32.23
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	0.48	0.48	0.48	0.48	0.48
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	81.873	65.397	12.502	75.735	94.729	22.360
HYDROGEN LB/HR	0.000	69.043	0.000	0.000	0.000	0.768	0.147	0.890	1.113	0.263
OXYGEN LB/HR	0.000	547.957	0.000	175.406	218.127	163.616	31.280	189.482	237.003	55.942
NITROGEN LB/HR	0.000	0.000	0.000	570.793	0.000	77.618	14.839	89.889	112.433	26.539
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	9.802	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	120.320	0.000	175.623	3.592	134.887	24.593	156.211	195.388	47.235

(continued)

TABLE 3.1-8 (Continued)

TEST NO. :TP-108-2 | DATE :JULY 24 | ISSUED BY :HALDIPUR | DATE :
POINT NO. :SET POINT 1 | TIME :8:15 22:30 | COMPLETED BY : | DATE :

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	727.13	260.00	434.00	530.38	3579.86	988.51	50.00	6.00	0.00	5.57
TEMPERATURE F	301.0	500.0	500.0	318.0	1393.0	357.0	168.0	1800.0	0.0	0.0
GAS LB/HR	357.13	260.00	434.00	385.38	3566.86	881.51	0.00	0.00	0.00	0.00
SOLID LB/HR	370.00	0.00	0.00	145.00	13.00	107.00	50.00	6.00	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	35.762	32.000	44.011	35.762	31.377	35.762	0.000	0.000	0.000	0.000
CO VOLUME %	8.20	0.00	0.00	8.20	6.75	8.20	0.00	0.00	0.00	0.00
CO2 VOLUME %	55.14	0.00	100.00	55.14	40.62	55.14	0.00	0.00	0.00	0.00
H2 VOLUME %	3.95	0.00	0.00	3.95	3.25	3.95	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 %	32.23	0.00	0.00	32.23	26.47	32.23	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 %	0.48	0.00	0.00	0.48	22.91	0.48	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	390.698	0.000	118.443	205.323	657.703	277.276	27.525	4.430	0.000	9.383
HYDROGEN LB/HR	0.892	0.000	0.000	0.963	59.941	2.203	0.000	0.000	0.000	16.110
OXYGEN LB/HR	190.084	260.000	315.557	205.122	2017.088	469.194	0.000	0.000	0.000	3.989
NITROGEN LB/HR	90.174	0.000	0.000	97.308	843.033	222.582	0.000	0.000	0.000	1.295
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	0.000	0.000	0.000	0.000	0.000	0.000	100.000
ASH LB/HR	55.278	0.000	0.000	21.663	2.097	17.259	22.475	1.570	0.000	43.592
HEAT CONTENT KBTU/HR	4637.408	24.901	41.653	1934.241	2946.984	1700.360	390.424	65.533	425.000	26.251

TABLE 3.1-9

GASIFIER HEAT AND MATERIAL BALANCES
TEST TP-018-2 - SET POINT 2

TEST NO. :TP018-2 DATE :7-28-78 ISSUED BY :HALDIPUR DATE :
POINT NO. :SET POINT 2B TIME :800 - 11:45 COMPLETED BY :CROWLEY DATE :

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	793.00	0.00	0.00	300.00	317.60	644.12	500.37	593.98	110.33
TEMPERATURE F	0.0	507.0	0.0	0.0	108.0	175.0	124.0	175.0	175.0	197.0
GAS LB/HR	0.00	793.00	0.00	0.00	300.00	317.60	644.12	500.37	593.98	110.33
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	34.773	34.773	34.773	34.773	34.773
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	26.83	26.83	26.83	26.83	26.83
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	61.22	61.22	61.22	61.22	61.22
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	11.49	11.49	11.49	11.49	11.49
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	0.00	0.00	0.00	0.00	0.00
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	0.45	0.45	0.45	0.45	0.45
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	81.873	96.599	195.909	152.186	180.657	33.555
HYDROGEN LB/HR	0.000	88.737	0.000	0.000	0.000	2.198	4.457	3.463	4.110	0.763
OXYGEN LB/HR	0.000	704.263	0.000	0.000	218.127	218.808	443.758	344.718	409.209	76.007
NITROGEN LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	0.000	156.155	0.000	0.000	1.942	434.934	874.090	685.212	813.403	151.680

(continued)

TABLE 3.1-9 (Continued)

TEST NO. :TP018-2 DATE :7-28-78 ISSUED BY :HALDIPUR DATE :
POINT NO. :SET POINT 2B TIME :800 - 11:45 COMPLETED BY :CROWLEY DATE :

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	633.21	497.00	0.00	560.52	3515.07	1083.73	92.00	6.00	0.00	5.12
TEMPERATURE F	253.0	500.0	500.0	266.0	1484.0	360.0	96.0	1884.0	0.0	0.0
GAS LB/HR	333.21	497.00	0.00	365.52	3431.07	1000.73	0.00	0.00	0.00	0.00
SOLID LB/HR	300.00	0.00	0.00	195.00	84.00	83.00	92.00	6.00	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	34.773	32.000	44.011	34.773	29.052	34.773	0.000	0.000	0.000	0.000
CO VOLUME %	26.83	0.00	0.00	26.83	18.28	26.83	0.00	0.00	0.00	0.00
CO2 VOLUME %	61.22	0.00	100.00	61.22	40.31	61.22	0.00	0.00	0.00	0.00
H2 VOLUME %	11.49	0.00	0.00	11.49	7.93	11.49	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 %	0.00	0.00	0.00	0.00	0.00	0.00	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 %	0.45	0.00	0.00	0.45	33.49	0.45	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	363.724	0.000	0.000	281.720	905.486	377.967	40.958	5.009	0.000	4.098
HYDROGEN LB/HR	2.306	0.000	0.000	2.530	98.614	6.925	0.000	0.000	0.000	2.786
OXYGEN LB/HR	229.556	497.000	0.000	251.821	2501.451	689.436	0.000	0.000	0.000	5.964
NITROGEN LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	37.620	0.000	0.000	24.453	9.517	9.404	51.051	0.991	0.000	-14.321
HEAT CONTENT KBTU/HR	4186.415	47.598	0.000	2929.718	6457.249	2463.428	580.039	73.916	425.000	2.738

TABLE 3.1-10

GASIFIER HEAT AND MATERIAL BALANCES
TEST TP-018-2 - SET POINT 3

TEST NO. :TP-018-2 DATE :7/28 7/29 ISSUED BY :HALDIPUR DATE :
POINT NO. :SET POINT 3 TIME :23:45 5:30 COMPLETED BY :DMC DATE :

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	296.00	499.00	0.00	0.00	300.00	0.00	1224.17	521.07	610.95	116.05
TEMPERATURE F	505.0	522.0	0.0	0.0	104.0	170.0	140.0	170.0	170.0	230.0
GAS LB/HR	296.00	499.00	0.00	0.00	300.00	0.00	1224.17	521.07	610.95	116.05
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	36.243	36.243	36.243	36.243	36.243
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	24.07	24.07	24.07	24.07	24.07
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	66.46	66.46	66.46	66.46	66.46
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	9.11	9.11	9.11	9.11	9.11
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	0.00	0.00	0.00	0.00	0.00
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	0.38	0.38	0.38	0.38	0.38
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	81.873	0.000	367.270	156.329	183.294	34.816
HYDROGEN LB/HR	33.123	55.838	0.000	0.000	0.000	0.000	6.457	2.748	3.222	0.612
OXYGEN LB/HR	262.877	443.162	0.000	0.000	218.127	0.000	850.446	361.993	424.433	80.619
NITROGEN LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	58.005	101.839	0.000	0.000	1.690	0.000	1386.130	593.718	696.127	133.904

(continued)

TABLE 3.1-10 (Continued)

TEST NO. :TP-018-2   DATE :7/28 7/29   ISSUED BY :HALDIPUR   DATE :
POINT NO. :SET POINT 3   TIME :23:45 5:30   COMPLETED BY :DMC   DATE :

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	641.31	512.00	0.00	569.78	3777.47	1136.42	62.00	6.00	0.00	5.83
TEMPERATURE F	276.0	500.0	500.0	306.0	1473.0	365.0	103.0	1817.0	0.0	0.0
GAS LB/HR	341.31	512.00	0.00	394.78	3742.47	1044.42	0.00	0.00	0.00	0.00
SOLID LB/HR	300.00	0.00	0.00	175.00	35.00	92.00	62.00	6.00	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	36.243	32.000	44.011	36.243	30.733	36.243	0.000	0.000	0.000	0.000
CO VOLUME %	24.07	0.00	0.00	24.07	17.18	24.07	0.00	0.00	0.00	0.00
CO2 VOLUME %	66.46	0.00	100.00	66.46	46.32	66.46	0.00	0.00	0.00	0.00
H2 VOLUME %	9.11	0.00	0.00	9.11	6.50	9.11	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 %	0.00	0.00	0.00	0.00	0.00	0.00	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 %	0.38	0.00	0.00	0.38	30.00	0.38	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	359.439	0.000	0.000	268.381	960.336	396.434	23.231	4.872	0.000	4.584
HYDROGEN LB/HR	1.800	0.000	0.000	2.082	89.596	5.509	0.000	0.000	0.000	10.179
OXYGEN LB/HR	237.113	512.000	0.000	274.261	2724.152	725.567	0.000	0.000	0.000	5.875
NITROGEN LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	42.960	0.000	0.000	25.060	3.388	8.906	38.769	1.128	0.000	23.272
HEAT CONTENT KBTU/HR	4047.142	49.035	0.000	2592.846	5641.322	2421.518	329.107	71.821	425.000	7.988

TABLE 3.1-11

GASIFIER HEAT AND MATERIAL BALANCES
TEST TP-018-2 - SET POINT 4

TEST NO. :TP018-2
POINT NO. :SET POINT 4

DATE :7/29
TIME :2000 - 2300

ISSUED BY :HALDIPUR
COMPLETED BY :DMC

DATE :
DATE :

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	297.00	500.00	0.00	0.00	300.00	0.00	936.45	468.75	553.31	100.22
TEMPERATURE F	501.0	514.0	0.0	0.0	114.0	185.0	147.0	185.0	185.0	209.0
GAS LB/HR	297.00	500.00	0.00	0.00	300.00	0.00	936.45	468.75	553.31	100.22
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	30.517	30.517	30.517	30.517	30.517
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	29.72	29.72	29.72	29.72	29.72
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	47.62	47.62	47.62	47.62	47.62
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	18.36	18.36	18.36	18.36	18.36
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	2.63	2.63	2.63	2.63	2.63
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.88	0.88	0.88	0.88	0.88
N2 VOLUME %	0.00	0.00	0.00	78.06	0.00	0.00	0.00	0.00	0.00	0.00
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	0.78	0.78	0.78	0.78	0.78
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	81.873	0.000	294.737	147.533	174.148	31.544
HYDROGEN LB/HR	33.234	55.950	0.000	0.000	0.000	0.000	15.646	7.831	9.244	1.674
OXYGEN LB/HR	263.766	444.050	0.000	0.000	218.127	0.000	617.385	309.036	364.787	66.075
NITROGEN LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	8.688	4.349	5.133	0.930
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	57.634	100.130	0.000	0.000	2.321	0.000	2195.875	1103.972	1303.130	236.694

(continued)

TABLE 3.1-11 (Continued)

TEST NO. :TP018-2 DATE :7/29 ISSUED BY :HALDIPUR DATE :
POINT NO. :SET POINT 4 TIME :2000 - 2300 COMPLETED BY :DMC DATE :

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	829.02	517.00	0.00	295.45	3417.31	1130.69	70.00	6.00	0.00	3.61
TEMPERATURE F	209.0	500.0	500.0	368.0	1377.0	363.0	115.0	1706.0	0.0	0.0
GAS LB/HR	309.02	517.00	0.00	295.45	3382.31	965.69	0.00	0.00	0.00	0.00
SOLID LB/HR	520.00	0.00	0.00	0.00	35.00	165.00	70.00	6.00	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	30.517	32.000	44.011	30.517	27.536	30.517	0.000	0.000	0.000	0.000
CO VOLUME %	29.72	0.00	0.00	29.72	23.42	29.72	0.00	0.00	0.00	0.00
CO2 VOLUME %	47.62	0.00	100.00	47.62	36.25	47.62	0.00	0.00	0.00	0.00
H2 VOLUME %	18.36	0.00	0.00	18.36	14.52	18.36	0.00	0.00	0.00	0.00
CH4 VOLUME %	2.63	0.00	0.00	2.63	2.08	2.63	0.00	0.00	0.00	0.00
H2S VOLUME %	0.88	0.00	0.00	0.88	0.74	0.88	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	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 %	0.78	0.00	0.00	0.78	23.00	0.78	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	491.680	0.000	0.000	92.988	938.911	435.607	40.327	4.739	0.000	-7.994
HYDROGEN LB/HR	32.307	0.000	0.000	4.936	105.300	17.338	0.000	0.000	0.000	23.743
OXYGEN LB/HR	236.646	517.000	0.000	194.782	2338.465	642.761	0.000	0.000	0.000	7.749
NITROGEN LB/HR	7.696	0.000	0.000	0.000	0.305	1.436	0.000	0.000	0.000	77.391
SULFUR LB/HR	13.735	0.000	0.000	2.741	29.114	8.959	0.000	0.000	0.000	-7.018
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	46.956	0.000	0.000	0.000	5.215	24.585	29.673	1.261	0.000	-29.343
HEAT CONTENT KBTU/HR	7945.917	49.514	0.000	710.906	8794.640	4238.697	571.269	69.693	425.000	-2.869

TABLE 3.1-12

GASIFIER HEAT AND MATERIAL BALANCES
TEST TP-018-2 - SET POINT 5

TEST NO. :TP-018-2 DATE :JULY 30 ISSUED BY :HALDIPUR DATE :
POINT NO. :SET POINT 5 TIME :100-1730 COMPLETED BY :CROWLEY DATE :

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	794.00	0.00	0.00	300.00	300.14	725.94	464.23	549.39	92.43
TEMPERATURE F	0.0	512.0	0.0	0.0	108.0	187.0	145.0	187.0	187.0	230.0
GAS LB/HR	0.00	794.00	0.00	0.00	300.00	300.14	725.94	464.23	549.39	92.43
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	30.200	30.200	30.200	30.200	30.200
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	29.63	29.63	29.63	29.63	29.63
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	46.84	46.84	46.84	46.84	46.84
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	19.03	19.03	19.03	19.03	19.03
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	2.68	2.68	2.68	2.68	2.68
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.89	0.89	0.89	0.89	0.89
N2 VOLUME %	0.00	0.00	0.00	78.06	0.00	0.00	0.00	0.00	0.00	0.00
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	0.94	0.94	0.94	0.94	0.94
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	81.873	94.483	228.524	146.138	172.946	29.097
HYDROGEN LB/HR	0.000	88.849	0.000	0.000	0.000	5.255	12.710	8.128	9.619	1.618
OXYGEN LB/HR	0.000	705.151	0.000	0.000	218.127	197.560	477.836	305.569	361.624	60.840
NITROGEN LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LFUR LB/HR	0.000	0.000	0.000	0.000	0.000	2.841	6.872	4.394	5.200	0.875
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	0.000	158.248	0.000	0.000	1.942	723.868	1742.504	1119.616	1325.004	224.018

(continued)

TABLE 3.1-12 (Continued)

TEST NO. :TP-018-2 DATE :JULY 30 ISSUED BY :HALDIPUR DATE :
POINT NO. :SET POINT 5 TIME :100-1730 COMPLETED BY :CROWLEY DATE :

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	811.37	502.00	0.00	295.98	3506.97	1021.38	32.00	6.00	0.00	5.57
TEMPERATURE F	206.0	500.0	500.0	371.0	1362.0	370.0	111.0	1672.0	0.0	0.0
GAS LB/HR	306.37	502.00	0.00	295.98	3479.97	926.38	0.00	0.00	0.00	0.00
SOLID LB/HR	505.00	0.00	0.00	0.00	27.00	95.00	32.00	6.00	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	30.200	32.000	44.011	30.200	26.310	30.200	0.000	0.000	0.000	0.000
CO VOLUME %	29.63	0.00	0.00	29.63	20.65	29.63	0.00	0.00	0.00	0.00
CO2 VOLUME %	46.84	0.00	100.00	46.84	31.78	46.84	0.00	0.00	0.00	0.00
H2 VOLUME %	19.03	0.00	0.00	19.03	13.10	19.03	0.00	0.00	0.00	0.00
CH4 VOLUME %	2.68	0.00	0.00	2.68	1.87	2.68	0.00	0.00	0.00	0.00
H2S VOLUME %	0.89	0.00	0.00	0.89	0.63	0.89	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	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 %	0.94	0.00	0.00	0.94	31.97	0.94	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	479.487	0.000	0.000	93.175	883.071	363.423	19.104	4.304	0.000	4.211
HYDROGEN LB/HR	31.725	0.000	0.000	5.182	132.120	17.169	0.000	0.000	0.000	8.460
OXYGEN LB/HR	233.628	502.000	0.000	194.826	2459.987	614.558	0.000	0.000	0.000	5.607
NITROGEN LB/HR	7.474	0.000	0.000	0.000	0.319	1.121	0.000	0.000	0.000	80.739
SULFUR LB/HR	13.455	0.000	0.000	2.802	26.832	8.769	0.000	0.000	0.000	2.300
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	45.601	0.000	0.000	0.000	4.647	16.349	12.896	1.696	0.000	21.958
HEAT CONTENT KBTU/HR	7748.157	48.077	0.000	729.179	8484.304	3337.742	270.594	63.463	425.000	8.969

TABLE 3.1-13

GASIFIER HEAT AND MATERIAL BALANCES
TEST TP-018-2 - SET POINT 6

TEST NO. :TP-018-2 DATE :JULY 30/31 ISSUED BY :HALDIPUR DATE :
POINT NO. :SET POINT 6A TIME : 2200 - 0300 COMPLETED BY :CROWLEY DATE :

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	795.00	0.00	0.00	300.00	270.97	590.70	417.24	493.19	83.45
TEMPERATURE F	0.0	516.0	0.0	0.0	108.0	193.0	149.0	193.0	193.0	232.0
GAS LB/HR	0.00	795.00	0.00	0.00	300.00	270.97	590.70	417.24	493.19	83.45
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	24.615	24.615	24.615	24.615	24.615
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	44.26	44.26	44.26	44.26	44.26
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	24.51	24.51	24.51	24.51	24.51
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	26.69	26.69	26.69	26.69	26.69
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	2.61	2.61	2.61	2.61	2.61
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.86	0.86	0.86	0.86	0.86
N2 VOLUME %	0.00	0.00	0.00	78.06	0.00	0.00	0.00	0.00	0.00	0.00
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	0.99	0.99	0.99	0.99	0.99
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	81.873	94.383	205.749	145.331	171.784	29.066
HYDROGEN LB/HR	0.000	88.961	0.000	0.000	0.000	7.495	16.339	11.541	13.642	2.308
OXYGEN LB/HR	0.000	706.039	0.000	0.000	218.127	166.052	361.981	255.685	302.226	51.137
NITROGEN LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	3.040	6.628	4.681	5.534	0.936
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	0.000	159.967	0.000	0.000	1.942	1097.625	2384.668	1690.116	1997.755	339.044

(continued)

TABLE 3.1-13 (Continued)

TEST NO. :TP-018-2 | DATE :JULY 30/31 | ISSUED BY :HALDIPUR | DATE :
POINT NO. :SET POINT 6A | TIME : 2200 - 0300 | COMPLETED BY :CROWLEY | DATE :

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	1314.73	823.00	0.00	266.28	4125.11	890.41	45.00	6.00	0.00	5.38
TEMPERATURE F	166.0	500.0	500.0	383.0	1528.0	379.0	112.0	1802.0	0.0	0.0
GAS LB/HR	319.73	823.00	0.00	266.28	4049.11	760.41	0.00	0.00	0.00	0.00
SOLID LB/HR	995.00	0.00	0.00	0.00	76.00	130.00	45.00	6.00	0.00	0.00
LIQUID LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT	24.615	32.000	44.011	24.615	23.329	24.615	0.000	0.000	0.000	0.000
CO VOLUME %	44.26	0.00	0.00	44.26	36.70	44.26	0.00	0.00	0.00	0.00
CO2 VOLUME %	24.51	0.00	100.00	24.51	19.76	24.51	0.00	0.00	0.00	0.00
H2 VOLUME %	26.69	0.00	0.00	26.69	22.31	26.69	0.00	0.00	0.00	0.00
CH4 VOLUME %	2.61	0.00	0.00	2.61	2.22	2.61	0.00	0.00	0.00	0.00
H2S VOLUME %	0.86	0.00	0.00	0.86	0.76	0.86	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	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 %	0.99	0.00	0.00	0.99	18.26	0.99	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	866.073	0.000	0.000	92.750	1277.003	357.005	23.661	4.594	0.000	1.467
HYDROGEN LB/HR	60.783	0.000	0.000	7.366	160.745	22.126	0.000	0.000	0.000	12.266
OXYGEN LB/HR	258.913	823.000	0.000	163.179	2625.855	469.905	0.000	0.000	0.000	6.369
NITROGEN LB/HR	14.726	0.000	0.000	0.000	0.532	0.910	0.000	0.000	0.000	90.208
SULFUR LB/HR	24.383	0.000	0.000	2.988	42.305	8.532	0.000	0.000	0.000	-5.493
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	89.848	0.000	0.000	0.000	18.666	31.928	21.339	1.406	0.000	18.375
HEAT CONTENT KBTU/HR	15092.027	78.820	0.000	1094.765	17305.160	4485.471	335.182	67.847	425.000	5.506

TABLE 3.1-14

EXPERIMENT TEST GRID, TP-018 SERIES TEST*
USING PITTSBURGH #8 COAL

		All Steam Flow to Oxidant Tube	Steam Split Between Grid and Oxidant Tube	Steam Split Between Booster and Oxidant Tube
LOW OXYGEN FLOW RATE	Low Steam Flow 350-450 Lb/h			
	Med. Steam Flow 500-600 Lb/h		TP-018-3 (S.P. #3)** 1757°F 225 HHV†	
	High Steam Flow 700-800 Lb/h	TP-018-2 (S.P. #5)	TP-018-2 (S.P. #4) TP-018-3 (S.P. #1) 1749°F 195 HHV	
MEDIUM OXYGEN FLOW RATE	Low Steam			
	Medium Steam			
	High Steam		TP-018-3 (S.P. #2) 1779°F 214 HHV	
HIGH OXYGEN FLOW RATE	Low Steam	Not Planned for Gasifier Testing since Reactor Temperature Would Exceed 1900°F		
	Medium Steam			
	High Steam	TP-018-2 (S.P. #6)		

*Includes Tests TP-018-2 and -3.
**S.P. = Set Point.
†HHV = Higher Heating Value.

Highlights of TP-018-3 include the following:

- Achieved a 50 percent concentration of oxygen for set point 3 for the oxidant feed tube
- Completed recycling of gasifier fines collected by the cyclone for the oxygen-blown gasifier for the first time during all three set points
- Successfully solved the operational problem of high ambient H_2S concentrations in the vicinity of the product gas cooling water separation pit, a problem experienced in the first oxygen-blown test, TP-018-2, with a ventilation system.
- Determined that lowering gasifier exit gas temperatures to less than 1800°F at fixed steam inputs had no measurable effect on the buildup mechanism in the cyclone inlet.
- Achieved a carbon conversion in excess of 95 percent with the 61 percent ash discharge obtained during set point 3. (This conversion figure assumes the only carbon loss was in the ash withdrawal system.)
- Detected no measurable tars or oils in the water system samples or isokinetic solids taken while testing with Pittsburgh seam coal.

A chronological list of events for TP-018-3 is shown in Table 3.1-15 and operating data are summarized in Table 3.1-16.

Considerable effort was expended between set points 2 and 3 in attempting to increase the ash content of the withdrawal. In set point 1, the ash withdrawal rate was too high, so that the ash discharge balanced at a low concentration. During set point 2, although the ash withdrawal was decreased, char/ash separation was not achieved because annular velocities were set too high and mixing of the char bed occurred throughout the complete annular region. Finally in set point 3, the combination of lowering annular velocity with ash-char interface high in the annulus and lowered ash withdrawal rates produced an ash product in excess of 60 percent ash. The ash product produced during all steady state periods was essentially denuded carbon, with only minor agglomeration noted since the gasifier exit temperature was conservatively kept less than 1800°F. Table 3.1-17 gives a summary of ash characteristics achieved during the test.

Figure 3.1-3 shows the ash plot for a 10-hour period during set point 3. The 7-hour period between 2130 hours August 23 and 0430 hours August 24 represents the longest sustained high ash period achieved for TP-018-3. During this period, the ash withdrawal was held to 30 lb/h $\pm$ 8 lb/h; the ash bed sample

TABLE 3.1-15

CHRONOLOGY OF EVENTS, TEST TP-018-3

Date	Time	Event
August 16	0001	Pressurization and leak check completed.
August 18	1645	Begin hot-air heatup.
August 19	0535	Begin coke breeze feed to build bed.
	1730	Achieved autogenous combustion of coke breeze.
August 20	0145	Initiated steam flow to oxidant tube.
	0600	Air flow stopped. Operation achieved with mixture of oxygen and steam.
	1110	Started coal feed (Pittsburgh Seam Coal).
	1230	Achieved Set Point Number 1 conditions.
August 21	1300	Achieved Set Point Number 2 conditions.
	1645	To increase the ash content in the withdrawal, annular flow was reduced. In response the ash withdrawal on automatic control increased from 100 to 150 lb/hr.
August 22	2350 to 0400	Increased Annular Flow in response to differential pressure indication of stagnation in annulus.
	0425 to 1325	Pulsed reactor with CO_2 from C-117 lockhoppers three times to eliminate stagnation. Good ash withdrawal achieved.
	1730	Achieved Set Point Number 3 conditions.
August 23	0100	Pick-up rate on C-119 decreased, indicating cyclone plugging.
	0130	PDT-84, across the C-119 cyclone, increased to beyond the maximum span of the transmitter (7 psi).
	0810	Initiated shutdown.

TABLE 3.1-16

SUMMARY OF OPERATING DATA FOR MODIFIED GASIFIER TEST TP-018-3

SET POINT		1	2	3
TEST RUN DATE AND TIME (1978)	Unit	8-20 Hours 1310/1630	8-22 Hours 0630/0830	8-23 Hours 0305/0600
MEASURED GASIFIER PARAMETERS				
TE-504-4 Freeboard Temperature	°F	1749	1779	1757
TE-507-3 Gasifier Bed Temperature	°F	1816	1841	1805
TE-504-10 Ash Annulus Temperature	°F	300	388	402
Average Bed Height	feet	24.68	24.61	26.01
System Pressure	psig	130.0	130.0	128.0
Average Gasifier Bed Density	lb/ft^3	23.30	16.36	11.5
Average Ash Annulus Density	lb/ft^3	22.25	25.37	21.28
Freeboard Gas Velocity	fps	1.12	1.12	1.12
Oxidant Tube Velocity		124.0	147.0	103.0
Coal Feed Material		Pgh. Seam Coal	Pgh. Seam Coal	Pgh. Seam Coal
Coal Feed Rate, WR-27	lb/hr	418	555	557
Fines Feed Material		Recycled Fines	Recycled Fines	Recycled Fines
Fines Feed Rate, WR-14	lb/hr	100	300	154
Cyclone Collection Rate, WR-19	lb/hr	113	430	286
Carryover to Water System*	lb/hr	66	97	105
Ash Withdrawal Rate	lb/hr	111	80	30
PRODUCT GAS ANALYSIS, DRY BASIS				
Carbon Monoxide	%	31.50	37.77	41.01
Carbon Dioxide	%	45.41	38.98	35.21
Methane	%	2.73	2.49	2.49
Nitrogen	%	0.0	0.0	0.0
Oxygen	%	0.0	0.0	0.0
Hydrogen	%	20.34	20.76	20.74
HHV, Dry Basis (Gas Chromatograph)	Btu/scf	195.2	214.3	224.7
OVERALL PROCESS RATES				
Steam/Coal Ratio, MAF**	lb/lb	2.10	1.59	1.14
Oxygen/Coal Ratio, MAF	lb/lb	1.27	1.32	1.11
Total Moisture/Coal Ratio, MAF	lb/lb	2.13	1.61	1.16
SOLIDS ANALYSIS				
Ash Content - Fines	%	16.04	14.43	17.30
Ash Content - Feedstock	%	9.03	9.03	9.03
Ash Content - Bed	%	15.43	22.50	32.25
Ash Content - Agglomerate	%	26.13	45.35	60.24

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

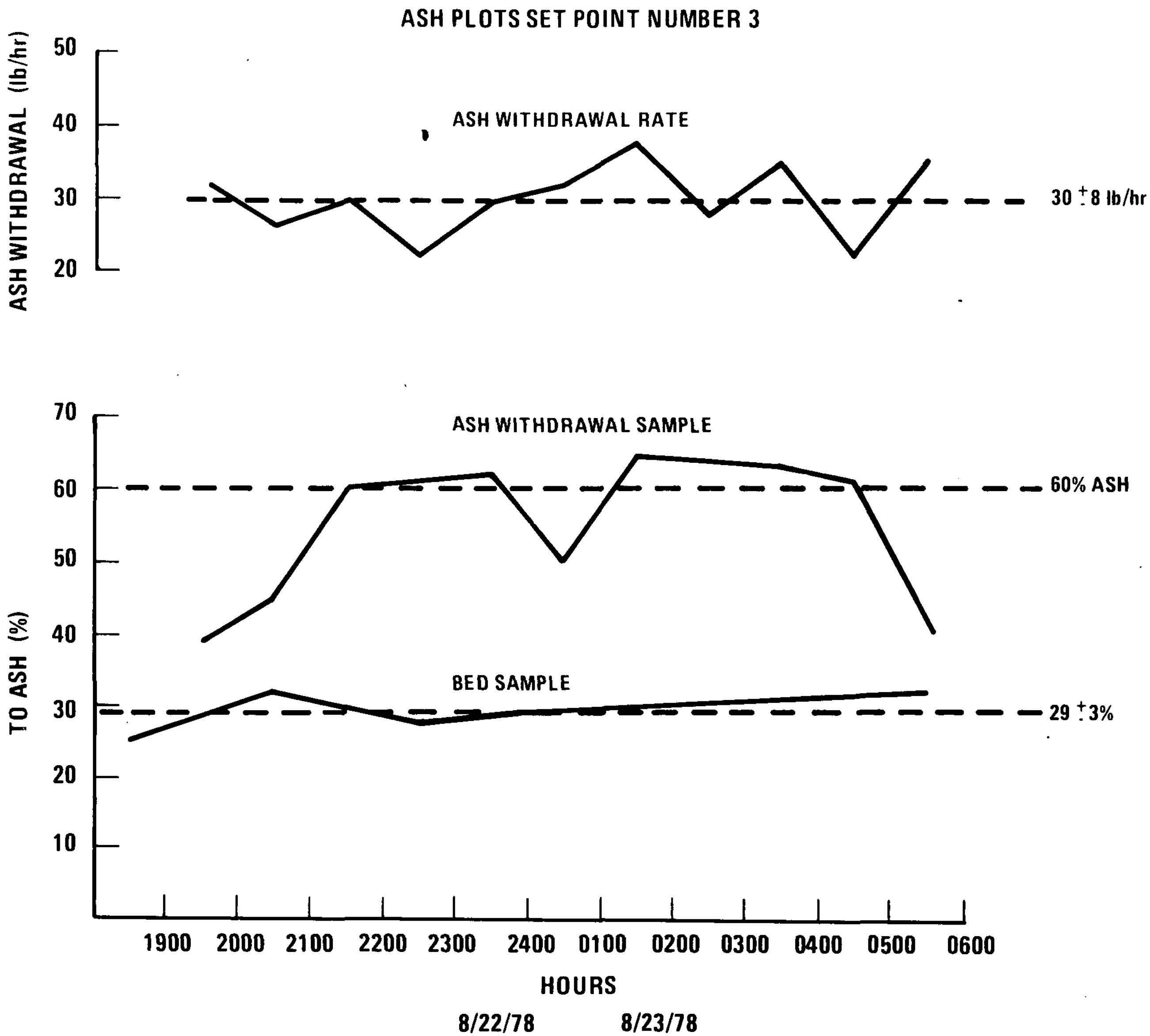


Figure 3.1-3. Ash Discharge Plot for Test TP-018-3

was 29 percent ± 3 percent, and the ash content of the withdrawal was between 60 and 65 percent for the entire period, with the exception of one sample where the ash content dropped to 50 percent. This high ash condition was not maintained beyond 0600 on August 24 because reactor conditions were upset in various attempts to clear the developing plug in the C-119 cyclone.

Flow streams for TP-018-3 are shown in Figure 3.1-2 and heat and material balance data are given in Tables 3.1-18, -19 and -20.

TABLE 3.1-17
ASH CHARACTERISTICS
TEST TP-018-3

Set Point	1	2	3
Ash Content	26	45	60
Avg. Size μ	1000	1000	1000
Particle Shape	ANG**	ANG	ANG
Bulk Density	35	38	41
Particle Density*	60	66	71
Ash Fusion Temp.	←	Not Determined	→

*Particle density was not measured. Values shown assume .42 voidage of sample. **ANG = Angular.

3.1.1.4 Work Accomplished - Gasifier Test TP-018-4

Test TP-018-4 was conducted from September 12 through September 18 and was designed principally to measure the effects of steam flow and reactor temperature on the gasification of Pittsburgh seam coal using oxygen and steam as the gasifying media. Specific plans called for:

- Operating the gasifier with oxidant tube concentrations increased progressively from 36 to 60 percent oxygen content by lowering steam input to the tube.

- Exploring changes in gasification rate and gasifier temperature as the result of lowering steam input to the oxidant tube.

- Experimentally testing the effect of reduced and unreacted steam in the product gas as it affected gasification of a stagnant region of fines in the external cyclone, a condition that had created blockages in the cyclone during tests TP-018-2 and -3. (The gasification referred to was thought to have produced a high-ash deposit--analyses from TP-018-2 and -3 showed ash contents as high as 95 percent--that becomes sticky at the gasifier exit temperature and causes progressively larger amounts of material to collect in the stagnant regions of the cyclone.)

TABLE 3.1-18

GASIFIER HEAT AND MATERIAL BALANCES
TEST TP-018-3 - SET POINT 1

TEST NO. :TP-018-3　　DATE :8-20-78　　ISSUED BY :J. PAVEL　　DATE :
POINT NO. :SET POINT #1　　TIME :1310 TO 1630　　COMPLETED BY :　　DATE :

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	302.00	492.00	0.00	0.00	305.00	0.00	433.00	355.02	717.23	114.92
TEMPERATURE F	503.0	526.0	0.0	0.0	118.0	174.0	598.0	174.0	174.0	210.0
GAS LB/HR	302.00	492.00	0.00	0.00	305.00	0.00	433.00	355.02	717.23	114.92
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	29.479	29.479	29.479	29.479	29.479
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	31.64	31.64	31.64	31.64	31.64
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	44.72	44.72	44.72	44.72	44.72
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	20.44	20.44	20.44	20.44	20.44
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	2.76	2.76	2.76	2.76	2.76
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	0.00	0.00	0.00	0.00	0.00
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	0.44	0.44	0.44	0.44	0.44
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	83.237	0.000	139.585	114.447	231.209	37.046
HYDROGEN LB/HR	33.794	55.055	0.000	0.000	0.000	0.000	7.816	6.409	12.947	2.074
OXYGEN LB/HR	268.206	436.945	0.000	0.000	221.763	0.000	285.601	234.166	473.070	75.799
NITROGEN LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	58.892	101.353	0.000	0.000	2.618	0.000	1155.903	903.538	1825.355	293.628

(continued)

TABLE 3.1-18 (Continued)

TEST NO. :TP-018-3 DATE :8-20-78 ISSUED BY :J. PAVEL DATE :
POINT NO. :SET POINT #1 TIME :1310 TO 1630 COMPLETED BY : DATE :

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	715.56	481.00	0.00	430.40	2947.32	1181.14	111.00	6.50	0.00	2.30
TEMPERATURE F	200.0	519.0	519.0	288.0	1376.0	320.0	389.0	1795.0	0.0	0.0
GAS LB/HR	297.56	481.00	0.00	330.40	2881.32	1068.14	0.00	0.00	0.00	0.00
SOLID LB/HR	418.00	0.00	0.00	100.00	66.00	113.00	111.00	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	29.479	32.000	44.011	29.479	25.815	29.479	0.000	0.000	0.000	0.000
CO VOLUME %	31.64	0.00	0.00	31.64	21.10	31.64	0.00	0.00	0.00	0.00
CO2 VOLUME %	44.72	0.00	100.00	44.72	30.42	44.72	0.00	0.00	0.00	0.00
H2 VOLUME %	20.44	0.00	0.00	20.44	13.63	20.44	0.00	0.00	0.00	0.00
CH4 VOLUME %	2.76	0.00	0.00	2.76	1.83	2.76	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	0.00	0.00	0.00	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 %	0.44	0.00	0.00	0.44	33.00	0.44	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	412.976	0.000	0.000	187.348	768.669	435.681	79.753	5.292	0.000	-6.928
HYDROGEN LB/HR	27.191	0.000	0.000	6.494	113.499	19.880	0.466	0.053	0.000	11.782
OXYGEN LB/HR	222.726	481.000	0.000	218.873	2053.479	705.602	0.022	0.000	0.000	5.450
NITROGEN LB/HR	6.186	0.000	0.000	0.690	0.455	0.780	0.511	0.036	0.000	74.084
SULFUR LB/HR	8.736	0.000	0.000	0.950	0.627	1.073	1.276	0.116	0.000	68.071
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	37.745	0.000	0.000	16.040	10.586	18.125	29.004	1.003	0.000	-9.172
HEAT CONTENT KBTU/HR	6559.372	48.224	0.000	2033.554	7651.363	4099.076	1172.181	81.986	425.000	-3.444

TABLE 3.1-19

GASIFIER HEAT AND MATERIAL BALANCES
TEST TP-018-3 - SET POINT 2

TEST NO. :TP-018-3 DATE :8-22-78 ISSUED BY :J. PAVEL DATE :
POINT NO. :SET POINT 2 TIME :0630 TO 0830 COMPLETED BY : DATE :

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	301.00	493.00	0.00	0.00	305.00	0.00	681.62	413.80	690.68	105.72
TEMPERATURE F	509.0	527.0	0.0	0.0	117.0	175.0	599.0	175.0	175.0	239.0
GAS LB/HR	301.00	493.00	0.00	0.00	305.00	0.00	681.62	413.80	690.68	105.72
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	28.383	28.383	28.383	28.383	28.383
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	37.68	37.68	37.68	37.68	37.68
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	38.46	38.46	38.46	38.46	38.46
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	20.92	20.92	20.92	20.92	20.92
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	2.64	2.64	2.64	2.64	2.64
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	0.00	0.00	0.00	0.00	0.00
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	0.31	0.31	0.31	0.31	0.31
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	83.237	0.000	227.241	137.955	230.261	35.244
HYDROGEN LB/HR	33.682	55.167	0.000	0.000	0.000	0.000	12.840	7.795	13.011	1.991
OXYGEN LB/HR	267.318	437.833	0.000	0.000	221.763	0.000	441.538	268.053	447.408	68.481
NITROGEN LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	59.559	101.795	0.000	0.000	2.553	0.000	2067.791	1203.114	2008.117	309.291

(continued)

TABLE 3.1-19 (Continued)

TEST NO. :TP-018-3 DATE :8-22-78 ISSUED BY :J. PAVEL DATE :
POINT NO. :SET POINT 2 TIME :0630 TO 0830 COMPLETED BY : DATE :

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	848.99	660.00	0.00	625.20	3308.83	1292.85	80.00	6.50	0.00	8.52
TEMPERATURE F	188.0	579.0	579.0	275.0	1478.0	459.0	404.0	1782.0	0.0	0.0
GAS LB/HR	293.99	660.00	0.00	325.20	3211.83	862.85	0.00	0.00	0.00	0.00
SOLID LB/HR	555.00	0.00	0.00	300.00	97.00	430.00	80.00	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	28.383	32.000	44.011	28.383	27.413	28.383	0.000	0.000	0.000	0.000
CO VOLUME %	37.68	0.00	0.00	37.68	33.68	37.68	0.00	0.00	0.00	0.00
CO2 VOLUME %	38.46	0.00	100.00	38.46	34.76	38.46	0.00	0.00	0.00	0.00
H2 VOLUME %	20.92	0.00	0.00	20.92	18.51	20.92	0.00	0.00	0.00	0.00
CH4 VOLUME %	2.64	0.00	0.00	2.64	2.22	2.64	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	0.00	0.00	0.00	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 %	0.31	0.00	0.00	0.31	10.82	0.31	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	518.980	0.000	0.000	356.848	1074.780	643.742	41.776	4.906	0.000	-11.035
HYDROGEN LB/HR	34.509	0.000	0.000	7.656	80.272	18.447	0.288	0.052	0.000	40.559
OXYGEN LB/HR	225.573	660.000	0.000	213.270	2138.438	562.674	0.328	0.000	0.000	16.910
NITROGEN LB/HR	8.214	0.000	0.000	1.320	0.427	1.892	0.304	0.039	0.000	72.081
SULFUR LB/HR	11.599	0.000	0.000	2.820	0.912	4.042	1.024	0.041	0.000	58.260
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	50.116	0.000	0.000	43.290	13.997	62.049	36.280	1.462	0.000	-21.821
HEAT CONTENT KBTU/HR	8555.421	75.577	0.000	4581.320	11167.823	7795.056	618.524	76.019	425.000	-5.895

TABLE 3.1-20

GASIFIER HEAT AND MATERIAL BALANCES
TEST TP-018-3 - SET POINT 3

TEST NO. :TP-018-3　　DATE :8-23-78　　ISSUED BY :J. PAVEL　　DATE :
POINT NO. :SET PT 3　　TIME :0305 TO 0600　　COMPLETED BY :　　DATE :

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	259.00	315.00	0.00	0.00	305.00	0.00	689.67	203.61	683.68	103.80
TEMPERATURE F	497.0	511.0	0.0	0.0	115.0	177.0	595.0	177.0	177.0	240.0
GAS LB/HR	259.00	315.00	0.00	0.00	305.00	0.00	689.67	203.61	683.68	103.80
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	27.892	27.892	27.892	27.892	27.892
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	41.50	41.50	41.50	41.50	41.50
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	34.56	34.56	34.56	34.56	34.56
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	20.69	20.69	20.69	20.69	20.69
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	2.44	2.44	2.44	2.44	2.44
H2S VOLUME %	0.00	0.00	0.00	0.00	0.00	0.53	0.53	0.53	0.53	0.53
N2 VOLUME %	0.00	0.00	0.00	78.06	0.00	0.00	0.00	0.00	0.00	0.00
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	0.37	0.37	0.37	0.37	0.37
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	83.237	0.000	233.152	68.832	231.128	35.091
HYDROGEN LB/HR	28.982	35.249	0.000	0.000	0.000	0.000	13.197	3.896	13.083	1.986
OXYGEN LB/HR	230.018	279.751	0.000	0.000	221.763	0.000	439.133	129.643	435.320	66.092
NITROGEN LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	4.186	1.236	4.150	0.630
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	49.766	62.630	0.000	0.000	2.424	0.000	2247.312	638.050	2142.473	327.152

(continued)

TABLE 3.1-20 (Continued)

TEST NO. :TP-018-3 DATE :8-23-78 ISSUED BY :J. PAVEL DATE :
POINT NO. :SET PT 3 TIME :0305 TO 0600 COMPLETED BY : DATE :

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	854.43	556.00	0.00	479.37	3110.38	1299.04	30.00	6.50	0.00	0.08
TEMPERATURE F	207.0	0.0	0.0	341.0	1426.0	362.0	407.0	1775.0	0.0	0.0
GAS LB/HR	297.43	556.00	0.00	325.37	3005.38	1013.04	0.00	0.00	0.00	0.00
SOLID LB/HR	557.00	0.00	0.00	154.00	105.00	286.00	30.00	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	27.892	32.000	44.011	27.892	26.784	27.892	0.000	0.000	0.000	0.000
CO VOLUME %	41.50	0.00	0.00	41.50	36.06	41.50	0.00	0.00	0.00	0.00
CO2 VOLUME %	34.56	0.00	100.00	34.56	30.96	34.56	0.00	0.00	0.00	0.00
H2 VOLUME %	20.69	0.00	0.00	20.69	18.23	20.69	0.00	0.00	0.00	0.00
CH4 VOLUME %	2.44	0.00	0.00	2.44	2.19	2.44	0.00	0.00	0.00	0.00
H2S VOLUME %	0.53	0.00	0.00	0.53	0.48	0.53	0.00	0.00	0.00	0.00
N2 VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	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 %	0.37	0.00	0.00	0.37	12.08	0.37	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	523.033	0.000	0.000	232.704	1016.322	570.358	11.256	4.250	0.000	-13.858
HYDROGEN LB/HR	34.767	0.000	0.000	6.858	80.004	20.558	0.111	0.024	0.000	27.041
OXYGEN LB/HR	224.638	556.000	0.000	208.899	1976.931	648.239	0.000	0.014	0.000	5.950
NITROGEN LB/HR	8.244	0.000	0.000	0.601	0.410	1.115	0.126	0.031	0.000	80.988
SULFUR LB/HR	13.447	0.000	0.000	3.669	18.553	9.295	0.561	0.084	0.000	-4.304
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	50.297	0.000	0.000	26.642	18.165	49.478	18.072	2.096	0.000	-14.131
HEAT CONTENT KBTU/HR	8663.947	-9.104	0.000	2819.860	11115.596	6544.891	171.350	65.072	425.000	-8.129

- Evaluating the effect of increasing gas inlet velocity to the cyclone as a means of eliminating formation of deposits in the cyclone observed in previous tests. A velocity increase by a factor of approximately two was achieved by installing a refractory insert in the cyclone inlet.

The set point 1 conditions achieved for TP-018-4 were a repeat of conditions used previously during tests TP-018-2 and -3 as shown in Table 3.1-21.

In addition to exploring gasification sensitivity to changes in steam flow rates and reactor temperatures, a slight change was made in the gasifier boot operation. Instead of withdrawing ash at the maximum rate during start-up, the rate was reduced to a level that balanced the net ash input with a 70 percent concentration in the withdrawal stream. Annular velocities were also minimized by setting a low velocity after ignition and then increasing it whenever larger agglomerates were produced.

The results of these operating changes were significant and somewhat dramatic as shown in Figure 3.1-4. Ash content of the withdrawal stream increased steadily over a 14-hour period from less than 30 percent to more than 80 percent. The annular velocities used during this set point were significantly lower than those used during TP-018-3 where the char-ash interface was conservatively controlled low within the gasifier annulus. During this set point the interface was maintained higher in the gasifier annulus on a less conservative basis.

While operating the oxidant tube with steam at an oxygen concentration of 47 percent, frequent loss of material withdrawal was noted. The ash withdrawal was regained by momentarily increasing the flow in the annular region. Once withdrawal was regained, the ash discharge was inspected for sources of blockage of the starwheel feeder or the outlet pipe. Two types of material were observed: sintered material characteristic of the combustion zone, and wall/thermocouple ash deposition from the gasifier bed region.

The use of the lower steam inputs and higher cyclone inlet velocities were found to have no measurable effect on the overall operating characteristics of the cyclone.

Accomplishments of this test included:

- Achieved an ash content in the discharge material of 68 to 81 percent during set point 2.

- For set point 2 an oxygen concentration for the oxidant tube of 47 percent was tested for a sustained period of time with no major effects on overall plant operation.

- Achievement of a product gas heating value of 235 Btu/scf, dry basis.

TABLE 3.1-21

EXPERIMENT TEST GRID, TP-018 SERIES TEST*
USING PITTSBURGH #8 COAL

		All Steam Flow to Oxidant Tube	Steam Split Between Grid and Oxidant Tube	Steam Split Between Booster and Oxidant Tube
LOW OXYGEN FLOW RATE	Low Steam Flow 350-450 Lb/h			
	Med. Steam Flow 500-600 Lb/h		TP-018-3 (S.P. #3)**	
	High Steam Flow 700-800 Lb/h	TP-018-2 (S.P. #5)	TP-018-2 (S.P. #4) TP-018-3 (S.P. #1) TP-018-4 (S.P. #1) 1750°F 213 HHV†	
MEDIUM OXYGEN FLOW RATE	Low Steam			
	Medium Steam			
	High Steam		TP-018-3 (S.P. #2) TP-018-4 (S.P. #2) 1780°F 235 HHV	
HIGH OXYGEN FLOW RATE	Low Steam	Not Planned for Gasifier Testing since Reactor Temperature Would Exceed 1900°F		
	Medium Steam			
	High Steam	TP-018-2 (S.P. #6)		

*Includes TP-018-2, -3 and -4.
**S.P. = Set Point.
†HHV = Higher Heating Value

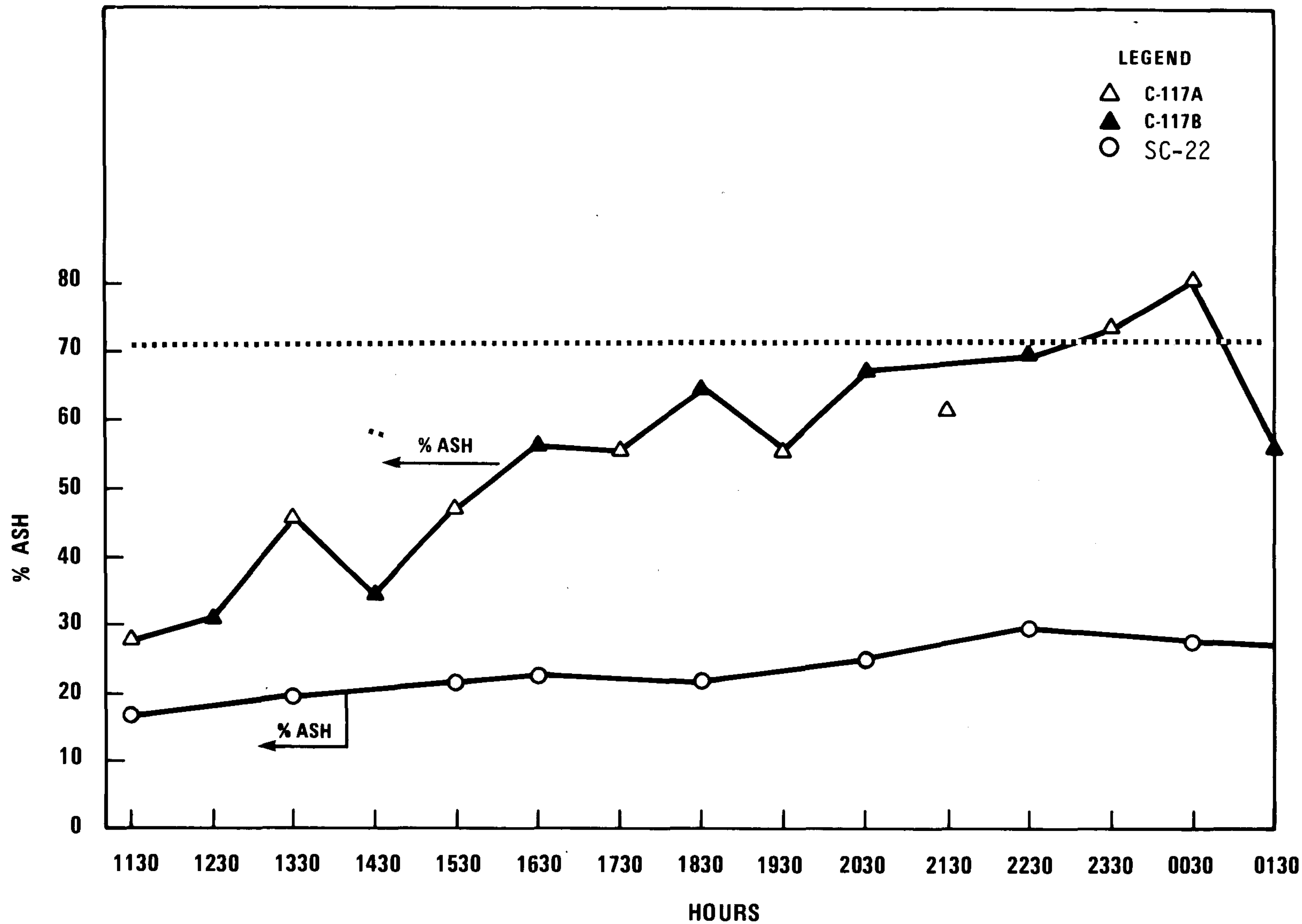


Figure 3.1-4. Temporal Plot of Bed and Withdrawal Ash, Test TP-018-4.

A chronological summary of the test is presented in Table 3.1-22 and steady state data for the two set points of TP-018-4 are given in Table 3.1-23. A flow diagram for the test is shown in Figure 3.1-2 and the heat and material balance data for these steady state conditions are presented in Tables 3.1-24, 3.1-25 and 3.1-26.

3.1.1.5 Work Forecast for Next Quarter

Tests to be run next quarter will include a final test with Pittsburgh coal to explore the range of gasifier oxygen-blown operation with this coal. Modifications proposed for the oxidant tube configuration will be tried at an oxygen concentration in excess of 50 percent.

Characterization of various coal feedstocks will continue with TP-019 series of tests. Rosebud coal from Montana, Indiana #7, Western Kentucky #9 and Ohio #9 coals are planned for gasifier testing.

PDU systems analysis will continue with emphasis on correlating the carbon-steam and methane formation data from PDU tests.

3.1.2 PDU Modifications for Integrated Operation

Because of the expanded series of gasifier tests, modification, assembly and installation work on the process development unit for integrated operation this quarter continued on a reduced basis. Work was limited to field construction during downtime periods and shop construction during gasifier operation. Work accomplished included the completion of designs and procurement of major hardware components. Specific work accomplished included the following:

- Installation of the 12-inch diameter refractory-lined pipe for interconnecting the gasifier and the devolatilizer
- Installation of the 10-inch diameter refractory-lined pipe for the devolatilizer draw-off leg
- Initiating assembly and casting of the refractory in the bottom section of the devolatilizer
- Updating the process and instrumentation drawing to include changes consistent with the revised start-up philosophy.

Progress was also made on the design and fabrication of PDU component modifications, with the work, including fabrication, being performed by plant personnel. A summary of the current status shows:

TABLE 3.1-22

CHRONOLOGY OF EVENTS, TEST TP-018-4

Date	Time	Event
September 12	0110	Began pressure leak test of system.
September 13	0015	Started hot air heatup.
September 14	1720	System depressurized to remove a thermocouple assembly.
	2340	System repressurized to 130 psig.
September 15	0200 -0215	Started coke breeze feed via C-103B and C-102B.
	0615	Achieved autogenous ignition of coke breeze.
	1645	Started oxygen flow to gasifier.
September 16	0045	Started coal feed to gasifier.
	0415	Achieved Set Point Number 1 conditions.
	1200	Terminated Set Point Number 1.
	1600	Achieved Set Point Number 2 conditions.
	1800	Terminated Set Point Number 2.
	1930	Achieved Set Point Number 3 conditions.
September 17	0001 -0830	Restored lost ash withdrawal four times.
	0830 -1030	Cyclone pressure drop gradually increased to greater than 5 psid.
	1330	Initiated a controlled shutdown.

TABLE 3.1-23

SUMMARY OF OPERATING DATA FOR MODIFIED GASIFIER TEST TP-018-4

SET POINT		1	2	3
TEST RUN DATE AND TIME (1978)	Unit	9-16 Hours 0415-0950	9-16 Hours 1415-1800	9-16, 17 Hours 1940-0130
MEASURED GASIFIER PARAMETERS				
TE-504-4 Freeboard Temperature	°F	1750	1747	1778
TE-507-3 Gasifier Bed Temperature	°F	1808	1774	1803
TE-504-10 Ash Annulus Temperature	°F	358	355	396
Average Bed Height	feet	24.0	24.0	24.0
System Pressure	psig	132.0	132.0	132.0
Average Gasifier Bed Density	lb/ft^3	18.10	11.81	11.19
Average Ash Annulus Density	lb/ft^3	21.02	26.60	26.03
Freeboard Gas Velocity	fps	1.02	1.08	0.94
Oxidant Tube Velocity		120.0	125.0	123.0
Coal Feed Material		Pgh. Seam Coal	Pgh. Seam Coal	Pgh. Seam Coal
Coal Feed Rate, WR-27	lb/hr	457	493	690
Fines Feed Material		--	Recycled Fines	Recycled Fines
Fines Feed Rate, WR-14	lb/hr	0	177	171
Cyclone Collection Rate, WR-19	lb/hr	70	193	326
Carryover to Water System*	lb/hr	30	67	90
Ash Withdrawal Rate	lb/hr	37	27	28
PRODUCT GAS ANALYSIS, DRY BASIS				
Carbon Monoxide	%	38.01	38.15	44.92
Carbon Dioxide	%	40.43	40.27	32.15
Methane	%	2.52	2.44	2.28
Nitrogen	%	0.0	0.0	0.0
Oxygen	%	0.0	0.0	0.0
Hydrogen	%	19.04	19.14	20.65
HHV, Dry Basis (Gas Chromatograph)	Bru/scf	210.0	210.0	235.0
OVERALL PROCESS RATES				
Steam/Coal Ratio, MAF**	lb/lb	1.88	1.75	1.15
Oxygen/Coal Ratio, MAF	lb/lb	1.22	1.25	1.03
Total Moisture/Coal Ratio, MAF	lb/lb	1.90	1.77	1.17
SOLIDS ANALYSIS				
Ash Content - Fines	%	--	17.56	20.08
Ash Content - Feedstock	%	8.5	8.5	8.5
Ash Content - Bed	%	13.2	22.55	25.36
Ash Content - Agglomerate	%	30.08	41.93	65.71

*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-018-4 - SET POINT 1

TEST NO. :TP018-4 DATE :9/19/78 ISSUED BY :J PAVEL DATE : 12/26/78
POINT NO. : SET POINT 1 TIME :4:15 - 9:50 COMPLETED BY :DMC DATE :

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	297.00	472.00	0.00	0.00	305.00	0.00	513.53	324.93	714.43	83.03
TEMPERATURE F	491.0	515.0	0.0	0.0	134.0	180.0	600.0	180.0	180.0	217.0
GAS LB/HR	297.00	472.00	0.00	0.00	305.00	0.00	513.53	324.93	714.43	83.03
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	29.418	29.418	29.418	29.418	29.418
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	37.35	37.35	37.35	37.35	37.35
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	41.20	41.20	41.20	41.20	41.20
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	18.71	18.71	18.71	18.71	18.71
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	2.47	2.47	2.47	2.47	2.47
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	0.00	0.00	0.00	0.00	0.00
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	169.901	107.502	236.369	27.469
HYDROGEN LB/HR	33.234	52.817	0.000	0.000	0.000	0.000	8.416	5.325	11.708	1.361
OXYGEN LB/HR	263.766	419.183	0.000	0.000	221.763	0.000	335.214	212.101	466.355	54.196
NITROGEN LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	56.219	94.748	0.000	0.000	3.652	0.000	1438.238	870.415	1913.814	223.257

(continued)

TABLE 3.1-24 (Continued)

TEST NO. :TP018-4   DATE :9/19/78   ISSUED BY :J PAVEL   DATE : 12/26/78

POINT NO. : SET POINT 1   TIME :4:15 - 9:50   COMPLETED BY :DMC   DATE :

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	802.43	500.00	0.00	335.18	3130.49	759.83	37.00	6.00	0.00	9.53
TEMPERATURE F	213.0	515.0	515.0	365.0	1375.0	139.0	409.0	1811.0	0.0	0.0
GAS LB/HR	345.43	500.00	0.00	335.18	3100.49	689.83	0.00	0.00	0.00	0.00
SOLID LB/HR	457.00	0.00	0.00	0.00	30.00	70.00	37.00	6.00	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	29.418	32.000	44.011	29.418	26.994	29.418	0.000	0.000	0.000	0.000
CO VOLUME %	37.35	0.00	0.00	37.35	30.43	37.35	0.00	0.00	0.00	0.00
CO2 VOLUME %	41.20	0.00	100.00	41.20	32.37	41.20	0.00	0.00	0.00	0.00
H2 VOLUME %	18.71	0.00	0.00	18.71	15.25	18.71	0.00	0.00	0.00	0.00
CH4 VOLUME %	2.47	0.00	0.00	2.47	2.02	2.47	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	0.00	0.00	0.00	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	19.93	0.25	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	460.233	0.000	0.000	110.893	919.554	287.163	25.234	5.051	0.000	-3.462
HYDROGEN LB/HR	26.363	0.000	0.000	5.493	90.881	11.508	0.052	0.017	0.000	29.201
OXYGEN LB/HR	262.089	500.000	0.000	218.792	2115.693	450.983	0.000	0.059	0.000	13.094
NITROGEN LB/HR	6.764	0.000	0.000	0.000	0.174	0.406	0.159	0.035	0.000	88.558
SULFUR LB/HR	8.135	0.000	0.000	0.000	0.228	0.532	0.426	0.046	0.000	84.866
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	38.845	0.000	0.000	0.000	3.960	9.240	11.130	0.792	0.000	35.329
HEAT CONTENT KBTU/HR	6993.611	49.656	0.000	915.349	9022.061	2687.252	365.152	75.387	425.000	-0.127

TABLE 3.1-25

GASIFIER HEAT AND MATERIAL BALANCES
TEST TP-018-4 - SET POINT 2

TEST NO. :TP-018-4
POINT NO. :SET POINT 2

DATE : 9/16/78
TIME :14:15 TO 18:00

ISSUED BY : J PAVEL
COMPLETED BY : DMC

DATE : 12/26/78
DATE :

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	300.00	473.00	0.00	0.00	305.00	0.00	568.72	336.53	774.32	74.67
TEMPERATURE F	481.0	516.0	0.0	0.0	139.0	190.0	600.0	190.0	190.0	187.0
GAS LB/HR	300.00	473.00	0.00	0.00	305.00	0.00	568.72	336.53	774.32	74.67
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	29.296	29.296	29.296	29.296	29.296
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	37.95	37.95	37.95	37.95	37.95
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	40.53	40.53	40.53	40.53	40.53
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	18.80	18.80	18.80	18.80	18.80
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	2.27	2.27	2.27	2.27	2.27
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	0.00	0.00	0.00	0.00	0.00
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	0.47	0.47	0.47	0.47	0.47
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	83.237	0.000	188.288	111.415	256.357	24.721
HYDROGEN LB/HR	33.570	52.929	0.000	0.000	0.000	0.000	9.317	5.513	12.686	1.223
OXYGEN LB/HR	266.430	420.071	0.000	0.000	221.763	0.000	371.112	219.597	505.273	48.725
NITROGEN LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	55.360	95.175	0.000	0.000	3.977	0.000	1600.255	906.774	2086.407	201.137

(continued)

TABLE 3.1-25 (Continued)

TEST NO. :TP-018-4 DATE : 9/16/78 ISSUED BY : J PAVEL DATE : 12/26/78
POINT NO. :SET POINT 2 TIME :14:15 TO 18:00 COMPLETED BY : DMC DATE :

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	835.66	554.00	0.00	509.43	3326.56	939.70	27.00	6.00	0.00	9.13
TEMPERATURE	F	194.0	516.0	516.0	305.0	1402.0	180.0	377.0	1783.0	0.0	0.0
GAS	LB/HR	342.66	554.00	0.00	332.43	3259.56	746.70	0.00	0.00	0.00	0.00
SOLID	LB/HR	493.00	0.00	0.00	177.00	67.00	193.00	27.00	6.00	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		29.296	32.000	44.011	29.296	27.075	29.296	0.000	0.000	0.000	0.000
CO	VOLUME %	37.95	0.00	0.00	37.95	30.94	37.95	0.00	0.00	0.00	0.00
CO2	VOLUME %	40.53	0.00	100.00	40.53	32.66	40.53	0.00	0.00	0.00	0.00
H2	VOLUME %	18.80	0.00	0.00	18.80	15.52	18.80	0.00	0.00	0.00	0.00
CH4	VOLUME %	2.27	0.00	0.00	2.27	1.98	2.27	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	0.00	0.00	0.00	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 %	0.47	0.00	0.00	0.47	18.90	0.47	0.00	0.00	0.00	0.00
ELEMENTS											
CARBON	LB/HR	486.648	0.000	0.000	250.351	1001.341	400.185	15.023	4.539	0.000	-1.433
HYDROGEN	LB/HR	27.947	0.000	0.000	6.951	93.719	13.874	0.041	0.016	0.000	28.299
OXYGEN	LB/HR	263.091	554.000	0.000	217.529	2218.401	487.908	0.000	0.000	0.000	12.349
NITROGEN	LB/HR	7.296	0.000	0.000	1.274	0.482	1.390	0.097	0.031	0.000	76.660
SULFUR	LB/HR	8.775	0.000	0.000	2.248	0.851	2.451	0.516	0.061	0.000	64.812
ARGON	LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH	LB/HR	41.905	0.000	0.000	31.081	11.765	33.891	11.321	1.353	0.000	20.081
HEAT CONTENT	KBTU/HR	7464.799	55.150	0.000	3005.168	10008.605	4293.599	219.533	68.357	425.000	2.967

TABLE 3.1-26

GASIFIER HEAT AND MATERIAL BALANCES
TEST TP-018-4 - SET POINT 3

TEST NO. :TP018-4
POINT NO. :SET POINT 3

DATE :9/16/78 9/17/78
TIME : 19:40 1:30

ISSUED BY : J PAVEL
COMPLETED BY : DMC

DATE : 12/26/78
DATE :

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	303.00	407.00	0.00	0.00	305.00	0.00	586.97	325.32	850.60	82.57
TEMPERATURE F	471.0	518.0	0.0	0.0	136.0	189.0	600.0	189.0	189.0	205.0
GAS LB/HR	303.00	407.00	0.00	0.00	305.00	0.00	586.97	325.32	850.60	82.57
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	27.713	27.713	27.713	27.713	27.713
CO VOLUME %	0.00	0.00	0.00	0.00	0.00	44.44	44.44	44.44	44.44	44.44
CO2 VOLUME %	0.00	0.00	0.00	0.00	100.00	32.72	32.72	32.72	32.72	32.72
H2 VOLUME %	0.00	0.00	0.00	0.00	0.00	20.12	20.12	20.12	20.12	20.12
CH4 VOLUME %	0.00	0.00	0.00	0.00	0.00	2.38	2.38	2.38	2.38	2.38
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	0.00	0.00	0.00	0.00	0.00
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	0.43	0.43	0.43	0.43	0.43
ELEMENTS										
CARBON LB/HR	0.000	0.000	0.000	0.000	83.237	0.000	202.347	112.148	293.231	28.466
HYDROGEN LB/HR	33.906	45.544	0.000	0.000	0.000	0.000	10.807	5.990	15.661	1.520
OXYGEN LB/HR	269.094	361.456	0.000	0.000	221.763	0.000	373.811	207.180	541.710	52.587
NITROGEN LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SULFUR LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HEAT CONTENT KBTU/HR	54.476	82.284	0.000	0.000	3.782	0.000	1954.021	1043.077	2727.311	265.133

(continued)

TABLE 3.1-26 (Continued)

TEST NO. :TP018-4 DATE :9/16/78 9/17/78 ISSUED BY : J PAVEL DATE : 12/26/78
POINT NO. :SET POINT 3 TIME : 19:40 1:30 COMPLETED BY : DMC DATE :

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	1025.27	640.00	0.00	494.33	3453.21	1225.35	28.00	6.00	0.00	6.13
TEMPERATURE F	154.0	518.0	518.0	321.0	1439.0	241.0	380.0	1810.0	0.0	0.0
GAS LB/HR	335.27	640.00	0.00	323.33	3363.21	899.35	0.00	0.00	0.00	0.00
SOLID LB/HR	690.00	0.00	0.00	171.00	90.00	326.00	28.00	6.00	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	27.713	32.000	44.011	27.713	26.290	27.713	0.000	0.000	0.000	0.000
CO VOLUME %	44.44	0.00	0.00	44.44	39.13	44.44	0.00	0.00	0.00	0.00
CO2 VOLUME %	32.72	0.00	100.00	32.72	28.01	32.72	0.00	0.00	0.00	0.00
H2 VOLUME %	20.12	0.00	0.00	20.12	17.99	20.12	0.00	0.00	0.00	0.00
CH4 VOLUME %	2.38	0.00	0.00	2.38	1.99	2.38	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 %	0.00	0.00	0.00	0.00	0.00	0.00	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 %	0.43	0.00	0.00	0.43	12.89	0.43	0.00	0.00	0.00	0.00
ELEMENTS										
CARBON LB/HR	637.908	0.000	0.000	243.765	1131.719	562.262	8.666	4.366	0.000	-6.615
HYDROGEN LB/HR	37.430	0.000	0.000	6.740	90.294	18.058	0.036	0.010	0.000	31.218
OXYGEN LB/HR	268.785	640.000	0.000	206.785	2211.700	574.418	0.000	0.000	0.000	11.360
NITROGEN LB/HR	10.212	0.000	0.000	1.026	0.540	1.956	0.067	0.031	0.000	76.919
SULFUR LB/HR	12.282	0.000	0.000	1.676	0.882	3.195	0.832	0.071	0.000	64.322
ARGON LB/HR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH LB/HR	58.650	0.000	0.000	34.337	18.072	65.461	18.399	1.522	0.000	-11.256
HEAT CONTENT KBTU/HR	10221.332	64.013	0.000	2984.268	12480.448	6581.147	131.025	65.678	425.000	-1.462

- Hardware fabricated and available
  - 60 degree conical grid plate
  - Refractory bricks for instrumentation rings
  - Plenum filler bricks. (Purpose of these bricks is to maintain exit gas velocity in the plenum to prevent saltation and buildup of fines elutriated from the gasifier.)
- Hardware to be fabricated
  - Refractory plug for manway in plenum
  - Syngas generator refractory lining.
- Hardware to be designed
  - Coal feed nozzle. To include details relative to extension of the coal feed nozzle above the grid plate, along with cooling and erosion protection of the extension.
- Hardware procured
  - Inspection of the Edens separator at the vendor's shop by Westinghouse representatives occurred in August. It has since been received on site and is scheduled to be installed during the next quarter. The separator is designed to remove fines from the recirculating product gas cooling water on a continuous basis.

3.1.2.1 Work Forecast for Next Quarter

Work planned for next quarter will be conducted between the scheduled gasifier tests:

- Continue to rebuild the subassemblies for the devolatilizer in preparation for final assembly.
- Complete final installation and mounting of refractory-lined pipe
- Continue to mount instrumentation and electrical hardware in preparation for final installation and checkout
- Expedite completion of subcontractor tasks.

3.1.3 PDU Modifications for Operation with Oxygen

Following the initial oxygen shakedown test TP-018-1, modifications to the oxygen supply system for PDU gasifier operation was accomplished. Post-operational modifications and repairs to the oxygen supply piping and control system were completed in July, concluding the construction phase of this project task.

The supply system flange, which caused a premature termination of test TP-018-1, was repaired by AIRCO personnel under the supervision of Westinghouse. A multiple number of cooling and thawing cycles were imposed on the vaporizer inlet flange over a period of one week to assure the integrity of the repair and to qualify it for service. During this qualification test, a number of oxygen service valves developed leaks at the stem. These were repaired by thawing the valve and tightening the stem packing gland. An evaluation of the valve construction and packing is underway to determine whether improvements can be incorporated to increase the reliability of the system.

Minor modifications were made to the oxygen control interlock logic. The change allowed automatic opening of the CO_2 main flow block valve in event the steam block valve was closed. Also, the CO_2 purge block valve was modified to open as soon as the oxygen supply valve was opened.

During gasifier test TP-018-2 the operational characteristics of the oxygen supply and control system were functionally checked. Performance was satisfactory with the exception of minor problems with the oxygen supply pressure regulator system. During a shutdown between test points, the pressure building coil regulator stuck open, and the pressure in the tank increased to the level that oxygen was vented from the system. The regulator was checked by both AIRCO and Westinghouse personnel and cause of the malfunction was attributed to ice or foreign matter lodging in the regulator.

3.1.3.1 Work Forecast for Next Quarter

Work planned for next quarter will include reviewing operating performance of the oxygen supply system and implementing a maintenance and service schedule. Effective with the October 1978 Monthly Progress Report, improvements and developments of this basic system will be described under "Modifications for Improved Operation."

3.1.4 PDU Process and Design Engineering

Process and design engineering work was performed in support of PDU gasifier tests, in analyzing experimental test and equipment performance data, in developing heat and material balance computer models for analyzing and predicting PDU process and design data, in product characterization studies, in design of the scale-up model, and in administrating the PDU Environmental, Safety and Health Program.

In addition the cost estimate for the Rapid City Program prepared by Bechtel for Westinghouse Research & Development Center was received, reviewed and approved, thus terminating this support phase of the Rapid City Program.

3.1.4.1 Work Accomplished - PDU General Engineering

Process evaluation and design engineering tasks encompassed a broad range of activities this quarter. To improve water balance measurements and water sampling techniques, an electronic water flow totalizer and a recirculating sampling and mixer loop continued to be evaluated. An on-line calibration of the makeup water flow totalizer circuit was conducted prior to TP-018-2. The calibration entrailed measuring the amount of water collected (volume change) in the separator pit over a period of time (about 4 hours) and comparing this volume to the totalizer output. Accuracy obtained was about 0.6 percent.

The recirculating sampling scheme for providing a more representative sample for the quench water waste system was successfully demonstrated during TP-018-2 test. As an integral part of this measurement scheme, the flow totalizer was also used to provide a measurement of the total quantity of dumped wastewater. Once the accuracy of these measurmements is demonstrated, they will permit a simple and reliable determination of solids loading into the quench system, thereby providing a significant input to the overall water balance determination.

Various pieces of process equipment in service during the gasifier tests were evaluated on a performance basis before being removed for repair and/or interim inspection. Included in the evaluation were a solids flow measurement device and the water balance equipment. An in-line solids flow measurement device is being experimentally evaluated to investigate and develop a technique for direct measurement of solids circulated through the char draw-off line during integrated tests. This device, which has been tested in situ during the gasifier tests, uses a modified thermal mass flow measuring technique. Preliminary evaluation of the test data shows promising results. Calculated solids flowrate from temperature measurements are consistent and follow the weight rates from lockhopper load cell measurements satisfactorily. Efforts are being made to improve the accuracy of the device. Different locations of the downstream thermocouple and effects of recycle gas flow and temperature are being investigated.

An evaluation of the effects of medium Btu-gas on hydrogen and embrittlement of the carbon steel vessel was completed and showed no adverse effects on the vessel construction material for the operating conditions planned in the gasifier test series.

A design review of the modified gasifier ash annulus was held to complete the design of the ash withdrawal section of the gasifier. This section adds the capability of an in-line delumper for the withdrawal system. After incorporating changes to provide instrumentation mounting hardware, the design was released for purchase.

As a result of deposit build-up in the barrel of the gasifier off-gas cyclone, several conceptual hardware designs were developed to modify the external fines collection device. To accommodate these modifications, a spare interchangeable shell section for the cyclone was designed with an oversized inlet pipe and an order was released for construction. To resolve the problem of restrictions forming in the entrance of the cyclone, some modifications have been undertaken. As the result of a design review meeting between

Westinghouse engineers and representatives of the Ducon Company and their consultant, corrective action was taken in test TP-018-3. This consisted of a refractory insert sleeve designed to redirect the gas flow as it enters the cyclone and to increase gas velocity. Subsequent action is contingent upon post-test review of the performance of this modification and the results of an operating data analysis of cyclone performance.

A study to enable a long-duration PDU continuous test was started in September. A task force was formed to evaluate the frequency of all component breakdowns and to determine ways to assure continuous operation. A history and frequency record on PDU test anomalies for the period of March 1977 through September 1978 was compiled and studied. From this study a list has been compiled of possible critical problem areas. Resolution is expected to require definition of design changes and requirements for backup systems and spare parts ordering. In general it is believed that a 30-day downtime period immediately preceding the long-duration test will be necessary to carry out maintenance and upgrading of PDU equipment. The test is tentatively planned for mid-1979.

In July, three feedstocks were procured for PDU gasifier tests: Indiana #7, Pittsburgh seam and Rosebud coal. The Rosebud coal is from the bi-gas plant at Homer City, Pennsylvania. A review of the bi-gas coal grinding capabilities was made which included a tour of the facilities and a review of grinding performance. Based on the information received, it was determined that the grind from the Homer City facility would provide an acceptable size distribution for the initial feedstock evaluation test.

Western Kentucky coals were also reviewed for their application in PDU gasifier tests. Coals with the lowest sulfur contents, approximately 2.5 percent by weight, were identified as Western Kentucky #4 and #6 seam. Initial purchase inquiries regarding the availability of these coals were solicited. These coals were not readily available and were tentatively dropped as potential candidates for the subsequent gasifier feedstock tests. However, Western Kentucky #9 coal was found to be available and acceptable. Purchase requisitions were released to purchase 75 tons of Western Kentucky #9 coal for a feedstock characterization test.

To facilitate feedstock procurement logistics for future feedstock characterization tests, the need for a grinding and possibly a drying facility was identified. A quotation for a PDU grinding facility to size 5 tons per hour of hard Pittsburgh coal was solicited. The facility could include a roll-type mill and screening equipment. Preliminary cost estimates of equipment and installation were set at $25,000.

Following TP-018-1 gasifier test, a distortion of the superheater shell in the steam generator was discovered. An analysis of test events was conducted in an effort to determine the cause. The distortion was attributed to off-design operation of the steam generation system related to instrumentation and control devices. The operational control devices were readjusted following installation of a new superheater shell, a functional checkout of the subsystem was conducted and operating procedures modified in preparation for test TP-018-2.

Several components from the water system were examined, repaired or rebuilt.

An examination of the nickel chrome boron coating on the shaft sleeve of the G-101 recirculating pump was made. Findings show a significant increase in wear resistance compared to the 316 stainless steel shaft sleeves previously used.

In August, the G-120B make-up pit pump was examined for erosion on the impeller hubs. Severe wear was evident as a result of the high fines concentrations in the make-up water during the initial portion of test TP-015. Wear rings were machined to match the bowl wear rings with a factory-recommended 0.019-inch clearance. Additional Gould's parts or modifications of existing parts were procured and the pump was reassembled for test TP-018-3.

In September, the G-120B water make-up pump was rebuilt with new replacement components. New bowls made of CD4MCU stainless steel and machined impeller wear rings made of ASTM A312, 316 stainless steel were installed using a factory-recommended 0.019-inch clearance. The pump performed satisfactorily during test TP-018-4, and depending upon continued performance, the G-120A spare pump will also be rebuilt to the same specifications.

Other service components evaluated during this period were the steam generator superheater, electric gas heaters and the gasifier cyclone.

During the initial oxygen-blown gasifier test TP-018-1, problems occurred in the gas heaters when the heating elements to the heater casings shorted. Apparently the increased moisture content in the gas streams during oxygen service caused a breakdown of the Saureisen cement seal between the electrodes and the heater end-plate flanges. Upon review of alternate materials Teflon was selected as the new seal material and the new arrangement was installed in heaters F-113 and F-130 prior to test TP-018-4. With the new seal material and design, performance is satisfactory and the operating life of the gas heaters has been significantly improved. However, based on post-test spot inspection of the seal arrangements, a better mounting seal and assembly technique is necessary and evaluation of the material will continue.

3.1.4.2 Work Accomplished - Product Characterization

Work accomplished this quarter under the product characterization subtask included: (1) continuation of modifying and developing the sample apparatus to improve measurement techniques, and (2) evaluation of chemical and physical property data of samples analyzed for the air-blown gasifier tests TP-016 and TP-017. The current status of the product characterization analyses of the minimum requirements adopted as a standard for each test is shown in Table 3.1-27. In addition, the chemical and X-ray analyses of the build-up deposit found in the barrel of the fines collection cyclone after the oxygen-blown gasifier test TP-018-3 have been initiated. The results of these analyses are are reported in the following subsections.

3.1.4.2.1 Gas Sampling Apparatus Modification

During the initial checkout of the on-line product gas sampling apparatus, several operational problems were experienced, with modifications subsequently

TABLE 3.1-27

PRODUCT CHARACTERIZATION STATUS SUMMARY

Test No.	Test Description	Product Characterization *Analysis
TP-015	Air-blown gasifier expanded reactor shakedown and feedstock characterization test with coke breeze, W. Ky. FMC char and Wyoming sub-C coal.	C
TP-016	Air-blown gasifier process evaluation test with Pittsburgh Seam, Adamsburg mine coal.	C
TP-017	Air-blown gasifier process evaluation and demonstration test with Pittsburgh Seam, Adamsburg mine coal.	C
TP-018-2	Oxygen-blown gasifier process evaluation test with Pittsburgh Seam, Champion facility coal.	P
TP-018-3	Oxygen-blown gasifier process evaluation test with Pittsburgh Seam, Champion facility coal.	I
TP-018-4	Oxygen-blown gasifier feedstock characterization test with Pittsburgh Seam (Champion) and Rosebud coal.	I
TP-018-5	Oxygen-blown gasifier process evaluation test with Pittsburgh Seam (Champion) and Rosebud coal.	I

C - Complete
P - Partially complete
I - In progress

*Standard adopted minimum requirements

being made. The sampling apparatus consisted of an isokinetic sampling probe specially designed for the PDU, a minicyclone, a miniscrubber system, and a flow measuring and control system. Some of the problems experienced during the tests included:

- Water in the miniscrubber was carried over to the downstream equipment. This problem was corrected by modifying the operating procedure for sampling.
- Gas leaked from the sampling lines as a result of erosion at a 90 degree bend in the tubing run connecting the minicyclone. Gas leaks also occurred through the O-ring seal in the catch pot screwed closure head.
- Heater failures in the cyclone isothermal insulator box were attributed to local overheating.

The following modifications were made to the sampling train for hot product gas.

- For test TP-016-1, the miniscrubber was relocated downstream of the minicyclone. The heater box for the minicyclone was close-coupled to the reactor piping and high-temperature block valves were added between the minicyclone and the isokinetic probe.
- For test TP-017, a larger sample catch pot was constructed and installed.
- For test TP-018-3, the heater box was removed and the catch pot was modified to incorporate an in-line mechanical connector to facilitate disassembling and reassembling the catch pot. This modification was made to eliminate the potential hazard of a gas leak through the O-ring used in the original catch pot design.
- For test TP-018-4, the internal heat exchanger for the isokinetic probe was eliminated and an external one added.

3.1.4.2.2 TP-016 and TP-017 Product Characterization Data

Completed this quarter was the compilation of product characterization data for the two air-blown gasifier tests TP-016 and TP-017. Process and sampling streams for the gasifier test system are shown in Figure 3.1-5. Table 3.1-28 summarizes the operating conditions for each of these tests and the data are reported in Tables 3.1-29 through 3.1-37.

Solids characterization data of the feedstock and product solids were performed for each set point of TP-016 and -017. Tables 3.1-29 and -30 define the results of the proximate and ultimate analyses for these points. In Tables 3.1-31 and -32, the size distribution of the solids are listed. The data represent only the as-defined steady state conditions for each of the set points. Equal quantities from various solids samples collected during the steady state time periods were composited to provide a single representative sample for the analyses.

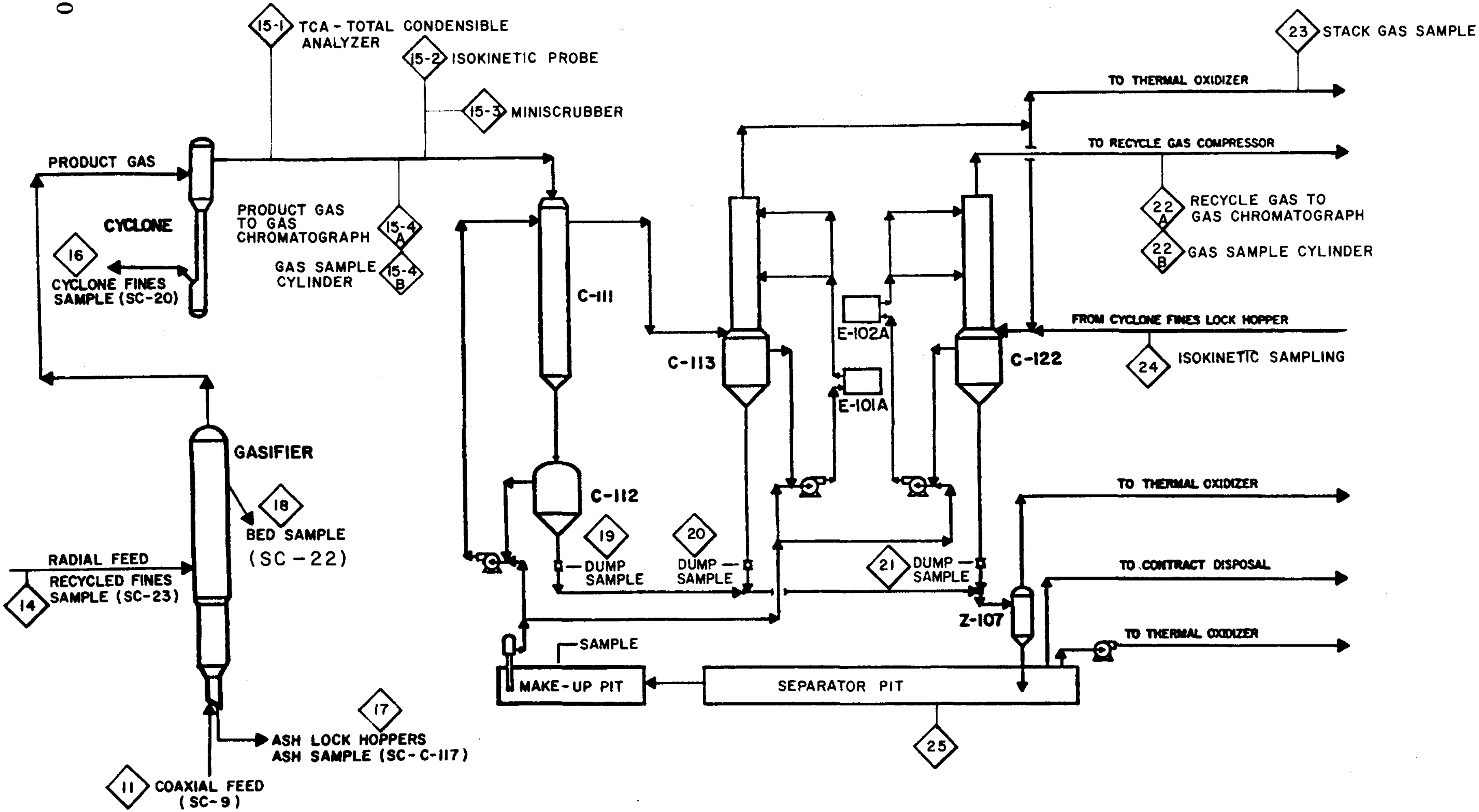


Figure 3.1-5. PDU Gasifier Process Schematic for Solids, Liquids, Gas and Particulate Sampling Locations

TABLE 3.1-28

SUMMARY OF OPERATING DATA FOR TP-016 AND TP-017 TESTS

	Air-blown TP-016 Test				Air-blown TP-017 Test				
Set Points	1	2	3	4	1	2	3	4	5
Freeboard Temperature °F	1807	1796	1867	1743	1716	1753	1847	1651	1852
Coaxial Feed Stock	← Pittsburgh Coal Adamsburg Mine →				← Pittsburgh Coal Adamsburg Mine →				
Radial Feed Stock	← Recycled Gasifier Fines →				← Recycled Gasifier Fines →				
Bed Ash Content Dry Basis (%)	21.43	23.29	19.83	26.58	23.8	27.54	34.23	24.75	18.40
Withdrawal Ash Content Dry Basis (%)	51.45	47.02	48.32	51.84	42.4	48.0	71.1	34.0	38.3

TABLE 3.1-29

FEEDSTOCKS AND REACTOR SOLIDS
PRODUCT CHARACTERIZATION DATA (AS RECEIVED)
*PITTSBURGH SEAM COAL (ADAMSBURG MINE) WITH RECYCLED FINES
AIR-BLOWN GASIFIER TEST TP-016

	Set Point 1					Set Point 2				
Sample Stream No.**	11	14	18	16	17	11	14	18	16	17
Proximate (%)	SC-9 Coaxial	SC-23 Radial	SC-22 Bed	SC-20 Fines Carryover	C-117 Ash Lockhopper	SC-9 Coaxial	SC-23 Radial	SC-22 Bed	SC-20 Fines Carryover	C-117 Ash Lockhopper
Moisture	2.05	1.53	0.56	1.53	0.46	2.05	1.48	0.46	1.48	0.51
Volatile Matter	34.82	2.69	0.73	2.69	0.64	34.82	1.52	0.56	1.52	1.44
Fixed Carbon	53.68	80.35	77.39	80.35	47.69	53.68	78.63	75.79	78.63	51.27
Ash	9.45	15.43	21.32	15.43	51.21	9.45	18.37	23.19	18.37	46.78
Ultimate (%)										
Carbon	74.81	80.46	75.67	80.46	45.59	74.81	77.28	74.32	77.28	50.24
Hydrogen	5.42	0.73	0.69	0.73	0.45	5.42	0.68	0.61	0.68	0.47
Oxygen	7.29	1.53	0.75	1.53	0.67	7.29	1.90	0.24	1.90	0.64
Nitrogen	1.54	0.72	0.77	0.72	0.50	1.54	0.72	0.74	0.72	0.58
Sulfur	1.49	1.13	0.80	1.13	1.56	1.49	1.05	0.90	1.05	1.29
Ash	9.45	15.43	21.32	15.43	51.21	9.45	18.37	23.19	18.37	46.78
Miscellaneous Analysis										
Bulk Density (lb/ft^3)										
	Set Point 3					Set Point 4				
Proximate (%)										
Moisture	2.05	1.54	0.46	1.54	0.26	2.05	1.03	0.77	1.03	0.45
Volatile Matter	34.82	1.49	0.75	1.49	1.06	34.82	2.43	1.06	2.43	0.94
Fixed Carbon	53.68	77.17	79.05	77.17	50.48	53.68	74.25	71.08	74.25	47.31
Ash	9.45	19.80	19.74	19.80	48.20	9.45	22.29	26.37	22.29	51.30
Ultimate (%)										
Carbon	74.81	75.93	78.79	75.93	51.27	74.81	74.46	70.57	74.46	45.99
Hydrogen	5.42	0.64	0.49	0.64	0.30	5.42	0.45	0.57	0.45	0.45
Oxygen	7.29	1.99	0.0	1.99	0.0	7.29	0.83	0.59	0.83	0.0
Nitrogen	1.54	0.70	0.71	0.70	0.48	1.54	0.70	0.64	0.70	0.48
Sulfur	1.49	0.94	0.79	0.94	1.01	1.49	1.27	1.31	1.27	2.13
Ash	9.45	19.80	19.74	19.80	48.20	9.45	22.29	26.37	22.29	51.30
Miscellaneous Analysis										
Bulk Density (lb/ft^3)										

*Calorific Value Btu/lb 13,889
Free Swelling Index 7-1/2
Giesler plasticity (DDPM) 31,000
**Sample locations are shown in Figure 3.1-5

TABLE 3.1-30

FEEDSTOCKS AND REACTOR SOLIDS
PRODUCT CHARACTERIZATION DATA (AS RECEIVED)
*PITTSBURGH SEAM COAL (ADAMSBURG MINE) WITH RECYCLED FINES
AIR-BLOWN GASIFIER TEST TP-017

	Set Point 1					Set Point 2				
Sample Stream No.**	11	14	18	16	17	11	14	18	16	17
	SC-9 Coaxial	SC-23 Radial	SC-22 Bed	SC-20 Fines Carryover	C-117 Ash Lockhopper	SC-9 Coaxial	SC-23 Radial	SC-22 Bed	SC-20 Fines Carryover	C-117 Ash Lockhopper
Proximate (%)										
Moisture	3.24	1.48	0.41	1.48	0.37	3.24	1.38	0.33	1.38	0.50
Volatile Matter	30.03	2.80	1.03	2.80	0.97	30.03	3.76	1.82	3.76	1.23
Fixed Carbon	57.65	74.34	76.26	74.34	56.71	57.65	73.20	73.19	73.20	49.83
Ash	9.08	21.38	22.30	21.38	41.95	9.08	21.66	24.66	21.66	48.44
Ultimate (%)										
Carbon	73.77	74.59	74.99	74.59	56.28	73.77	73.56	72.35	73.56	49.70
Hydrogen	5.15	0.63	0.46	0.63	0.37	5.15	1.04	0.66	1.04	0.44
Oxygen	9.09	1.18	0.55	1.18	0.0	9.09	1.43	0.54	1.43	0.00
Nitrogen	1.39	0.61	0.63	0.61	0.53	1.39	0.75	0.71	0.75	0.55
Sulfur	1.52	1.61	1.07	1.61	1.90	1.52	1.56	1.08	1.56	1.80
Ash	9.08	21.38	22.30	21.38	41.95	9.08	21.66	24.66	21.66	48.44
Miscellaneous Analysis										
Bulk Density (lb/ft^3)										
	Set Point 3					Set Point 4				
Proximate (%)										
Moisture	3.24	0.59	0.38	0.59	0.09	3.24	0.62	0.36	0.62	0.53
Volatile Matter	30.03	1.04	0.72	1.64	0.77	30.03	1.53	1.48	1.53	1.29
Fixed Carbon	57.65	76.08	69.66	76.08	28.29	57.65	76.56	78.06	76.56	55.16
Ash	9.08	21.69	29.44	21.69	70.85	9.08	21.29	20.10	21.29	43.02
Ultimate (%)										
Carbon	73.77	74.69	68.57	74.69	28.94	73.77	75.91	76.43	75.91	54.67
Hydrogen	5.15	0.63	0.43	0.63	0.25	5.15	0.50	0.56	0.50	0.55
Oxygen	9.09	0.76	0.0	0.76	0.0	9.09	0.13	0.30	0.13	0.0
Nitrogen	1.39	0.69	0.73	0.69	0.32	1.39	0.69	0.97	0.69	0.74
Sulfur	1.52	1.54	1.32	1.54	2.63	1.52	1.48	1.64	1.48	1.87
Ash	9.08	21.69	29.24	21.69	70.91	9.09	21.29	20.10	21.29	43.02
Miscellaneous Analysis										
Bulk Density (lb/ft^3)	38.9	15.35	-	15.35	31.15					

(Continued)

TABLE 3.1-30 (Continued)

	Set Point 5				
Sample Stream No.†	11	14	18	16	17
Proximate (%)	SC-9 Coaxial	SC-23† Radial	SC-22 Bed	SC-20† Fines Carryover	C-117 Ash Lockhopper
Moisture	3.24	-	0.38	-	0.26
Volatile Matter	30.03	-	1.40	-	1.42
Fixed Carbon	57.65	-	77.87	-	69.21
Ash	9.08	-	20.35	-	29.11
Ultimate (%)					
Carbon	73.77	-	77.72	-	68.59
Hydrogen	5.15	-	0.56	-	0.50
Oxygen	9.09	-	0.0	-	0.0
Nitrogen	1.39	-	0.78	-	0.85
Sulfur	1.52	-	0.86	-	1.07
Ash	9.08	-	20.35	-	29.11
Miscellaneous Analysis					
Bulk Density (lb/ft^3)		38.9		16.2	28.1

* Calorific Value Btu/lb 13,889
Free Swelling Index 7-1/2
Giesler plasticity (DDPM) 31,000
** Sample locations are shown in Figure 3.1-5
† Samples not available

TABLE 3.1-31

FEEDSTOCK AND SOLIDS PRODUCT SIZE DISTRIBUTION DATA PITTSBURGH (ADAMSBURG) COAL WITH RECYCLED FINES FEED AIR-BLOWN GASIFIER TEST TP-016

Set Point 1

Sample Stream No.*	11 SC-9 (Coaxial feed)	18 SC-22 (Bed Sample)	16 and 14 SC-20 (Fines Carryover) and SC-23 (Radial Feedstock)		17 C-117 (Ash Lockhoppers)	
Mesh	Wt. %	Wt. %	Mesh	Wt. %	Mesh	Wt. %
+6	0.34	1.04	+40	1.27	+8	12.20
-6 +10	15.73	26.39	-40 +50	4.58	-8 +12	46.36
-10 +20	44.39	60.97	-50 +70	10.03	-12 +16	22.30
-20 +40	20.73	9.06	-70 +100	23.17	-16 +20	9.34
-40 +70	10.33	1.35	-100 +200	33.40	-20 +40	6.43
-70 +100	3.10	0.24	-200 +270	8.86	-40 +70	0.85
-100	5.40	0.95	-270	18.70	-70	2.51

Set Point 2

Sample Stream No.*	11 SC-9 (Coaxial Feed)	18 SC-22 (Bed Sample)	16 and 14 SC-20 (Fines Carryover) and SC-23 (Radial Feedstock)		17 C-117 (Ash Lockhoppers)	
Mesh	Wt. %	Wt. %	Mesh	Wt. %	Mesh	Wt. %
+6	0.34	0.48	+40	1.60	+8	9.40
-6 +10	15.73	27.76	-40 +50	6.15	-8 +12	35.08
-10 +20	44.39	53.44	-50 +70	11.17	-12 +16	22.19
-20 +40	20.73	10.56	-70 +100	19.15	-16 +20	13.04
-40 +70	10.33	3.36	-100 +200	32.00	-20 +40	11.79
-70 +100	3.10	0.88	-200 +270	9.58	-40 +70	2.95
-100	5.40	3.52	-270	20.35	-70	5.55

Set Point 3

Mesh	Wt. %	Wt. %	Mesh	Wt. %	Mesh	Wt. %
+6	0.34	0.05	+40	2.84	+8	2.74
-6 +10	15.73	10.91	-40 +50	9.24	-8 +12	21.94
-10 +20	44.39	45.45	-50 +70	15.03	-12 +16	32.67
-20 +40	20.73	23.77	-70 +100	22.87	-16 +20	20.87
-40 +70	10.33	12.26	-100 +200	31.32	-20 +40	11.45
-70 +100	3.10	3.55	-200 +270	6.25	-40 +70	3.04
-100	5.40	4.00	-270	12.43	-70	7.29

Set Point 4

Mesh	Wt. %	Wt. %	Mesh	Wt. %	Mesh	Wt. %
+6	0.34	0	+40	1.13	+8	7.22
-6 +10	15.73	7.08	-40 +50	5.66	-8 +12	26.79
-10 +20	44.39	43.36	-50 +70	11.52	-12 +16	23.16
-20 +40	20.73	19.31	-70 +100	26.56	-16 +20	13.60
-40 +70	10.33	14.00	-100 +200	39.48	-20 +40	13.84
-70 +100	3.10	5.47	-200 +270	6.19	-40 +70	7.82
-100	5.40	10.78	-270	9.45	-70	7.57

*Sample locations are shown in Figure 3.1-5

TABLE 3.1-32

FEEDSTOCK AND SOLIDS PRODUCT SIZE DISTRIBUTION DATA
PITTSBURGH (ADAMSBURG) COAL WITH RECYCLED FINES FEED
AIR-BLOWN GASIFIER TEST TP-017

Set Point 1

Sample Stream No.*	11 SC-9 (Coaxial feed)	18 SC-22 (Bed Sample)	16 and 14 SC-20 (Fines Carryover) and SC-23 (Radial Feedstock)		17 C-117 (Ash Lockhoppers)	
Mesh	Wt. %	Wt. %	Mesh	Wt. %	Mesh	Wt. %
+6	1.49	0.33	+20	-	+8	6.88
-6 +10	12.35	7.67	-20 +40	0.29	-8 +12	26.82
-10 +20	34.21	35.47	-40 +70	11.06	-12 +16	29.68
-20 +40	21.59	17.20	-70 +100	25.63	-16 +20	17.48
-40 +70	14.18	16.67	-100 +200	13.37	-20 +40	14.11
-70 +100	4.88	9.67	-200 +270	16.38	-40 +70	3.87
-100	10.96	13.0	-270	33.27	-70	1.16

Set Point 2

Sample Stream No.*	11 SC-9 (Coaxial Feed)	18 SC-22 (Bed Sample)	16 and 14 SC-20 (Fines Carryover) and SC-23 (Radial Feedstock)		17 C-117 (Ash Lockhoppers)	
Mesh	Wt. %	Wt. %	Mesh	Wt. %	Mesh	Wt. %
+6	1.49	-	+20	-	+8	6.28
-6 +10	12.35	14.16	-20 +40	8.20	-8 +12	23.75
-10 +20	34.21	65.84	-40 +70	36.17	-12 +16	20.37
-20 +40	21.59	10.89	-70 +100	17.77	-16 +20	13.89
-40 +70	14.18	4.45	-100 +200	22.67	-20 +40	18.23
-70 +100	4.88	1.09	-200 +270	3.86	-40 +70	7.92
-100	10.96	3.07	-270	11.33	-70	9.56

Set Point 3

Mesh	Wt. %	Wt. %	Mesh	Wt. %	Mesh	Wt. %
+6	1.49	1.78	+20	-	+8	5.86
-6 +10	12.35	15.15	-20 +40	2.97	-8 +12	21.04
-10 +20	34.21	29.50	-40 +70	26.33	-12 +16	24.27
-20 +40	21.59	17.13	-70 +100	20.17	-16 +20	19.33
-40 +70	14.18	6.93	-100 +200	28.66	-20 +40	19.73
-70 +100	4.88	2.38	-200 +270	5.10	-40 +70	3.99
-100	10.96	7.13	-270	16.77	-70	5.78

Set Point 4

Mesh	Wt. %	Wt. %	Mesh	Wt. %	Mesh	Wt. %
+6	1.49	0.90	+20	-	+8	13.41
-6 +10	12.35	15.93	-20 +40	2.69	-8 +12	28.81
-10 +20	34.21	37.68	-40 +70	25.10	-12 +16	18.34
-20 +40	21.59	14.33	-70 +100	21.22	-16 +20	11.96
-40 +70	14.18	13.53	-100 +200	32.07	-20 +40	13.71
-70 +100	4.88	5.51	-200 +270	5.28	-40 +70	4.24
-100	10.96	12.12	-270	13.65	-70	9.52

*Sample locations are shown in Figure 3.1-5

(Continued)

TABLE 3.1-32 (Continued)

Set Point 5						
Sample Stream No.*	11 SC-9 (Coaxial feed)	18 SC-22 (Bed Sample)	16 and 14 SC-20 (Fines Carryover) and SC-23 (Radial Feedstock)		17 C-117 (Ash Lockhoppers)	
Mesh	Wt. %	Wt. %	Mesh	Wt. %	Mesh	Wt. %
+6	8.07	0.50	+40	NA	+8	11.47
-6 +10	18.57	8.64	-40 +50	NA	-8 +12	37.48
-10 +20	34.36	45.68	-50 +70	NA	-12 +16	23.50
-20 +40	13.69	21.85	-70 +100	NA	-16 +20	11.33
-40 +70	8.20	10.13	-100 +200	NA	-20 +40	8.78
-70 +100	3.89	2.88	-200 +270	NA	-40 +70	1.65
-100	13.25	10.33	-270	NA	-70	5.59

*Sample locations are shown in Figure 3.1-5

TABLE 3.1-33

SELECTED TRACE ELEMENTS CHARACTERISTICS
OF SOLID STREAMS IN GASIFIER TEST TP-017
(% By Weight In As-Sampled Material)

Stream Elements	11* SC-9 Feed	18* SC-22 Bed	17* C-117 Ash Lockhopper	16* SC-20 Cyclone Collect	15-1/2* TCA/ISOK Cyclone Escape
Al	3.4	2.4	2.7	2.7	2.7
As	<0.05	<0.05	<0.05	<0.05	<0.05
Ca	0.41	0.46	0.56	0.49	0.49
Cr	0.023	0.007	<0.002	0.011	<0.015
Fe	1.3	1.7	1.7	1.6	1.6
K	0.8	0.72	0.78	0.75	0.75
Na	1.4	1.4	1.3	1.4	1.5
Pb	0.10	0.038	0.055	0.038	0.042
V	<0.02	<0.02	<0.02	<0.02	<0.02

*Sample locations are shown in Figure 3.1-5

TABLE 3.1-34

CYCLONE-ESCAPE PARTICULATES CHARACTERISTIC
FOR AIR-BLOWN GASIFIER TESTS TP-016 AND TP-017

	TP-016	TP-017
Freeboard °F (Temperature Range)	1743 to 1807	1651 to 1852
Freeboard Velocities (ft/s) 30" section	1.96 to 2.08	0.91 to 1.70
Feedstock Material Used for Gasifier	Pittsburgh Seam Coal (Adamsburg Mine)	Pittsburgh Seam Coal (Adamsburg Mine)
Mean Diameter of Particulate (50 percent by wt.)	27 μm	27 μm
Greater than 10 μm (by wt. %)	75	82
Ash Content Range (Wt. %) (As Received Basis)	15.44 to 22.76 (5 samples)	18.12 (1 sample)
Calorific Value (Btu/lb)	10044 to 11328 (5 samples)	11263 (1 sample)
Composite Sample Analysis (As received basis)		
Proximate Analysis (Wt. %)		
Moisture	1.95	2.39
Volatile Matter	--	3.35
Fixed Carbon	--	75.55
Ash	--	18.71
Ultimate Analysis (Wt. %)		
Carbon	73.51	75.00
Hydrogen	1.03	0.77
Oxygen	--	2.71
Nitrogen	0.88	0.92
Sulfur	--	1.89
Ash	--	18.71
Calorific Value (Btu/lb.)	--	11,360

--Not determined, insufficient quantity

TABLE 3.1-35

PRODUCT GAS ANALYSIS OF TRACE CONSTITUENTS
BY LABORATORY MASS SPECTROMETER

TP-016

Sample Stream No.*	15-4B	15-4B	15-4B	15-4B
	Set Point 1 Volume % (Dry Basis)	Set Point 2 Volume % (Dry Basis)	Set Point 3 Volume % (Dry Basis)	Set Point 4 Volume % (Dry Basis)
Hydrogen Sulfide H_2S	ND	--	0.13	ND
Carbonyl Sulfide COS	0.03	--	0.03	0.16
Methane CH_4	0.80	0.59**	0.85	1.20
Ethylene C_2H_4	0.01	--	ND	ND
Ethane C_2H_6	0.01	--	0.03	0.06
Propylene C_3H_6	ND	--	ND	ND
Acetylene C_2H_2	ND	--	ND	ND
Ammonia NH_3	ND	--	ND	ND

TP-017

	15-4B	15-4B	15-4B	15-4B
	Set Point 1 Volume % (Dry Basis)	Set Point 2 Volume % (Dry Basis)	Set Point 3 Volume % (Dry Basis)	Set Point 4 Volume % (Dry Basis)
Hydrogen Sulfide H_2S	--	ND	ND	ND
Carbonyl Sulfide COS	--	0.05	ND	ND
Methane CH_4	0.75**	0.92	0.44	0.52
Ethylene C_2H_4	--	ND	ND	ND
Ethane C_2H_6	--	ND	ND	ND
Propylene C_3H_6	--	ND	ND	ND
Acetyline C_2H_2	--	ND	ND	ND
Ammonia NH_3	--	ND	ND	ND

* Sample locations are shown in Figure 3.1-5
** Analysis by Gc (field)
-- Not measured
ND Not detectable

TABLE 3.1-36

MINISCRUBBER ANALYSIS OF RAW GAS*
(PPM BY WEIGHT IN RAW GAS)

Test	Ammonia NH_3 (ppm by Wt.)	Chloride Cl (ppm by Wt.)	Cyanide Cn (ppm by Wt.)	Sodium Na (ppm by Wt.)	Potassium K (ppm by Wt.)	Phenols (ppm by Wt.)
TP-016	194	34.5	33.6	1.0	1.3	<.002
TP-017	100	--	7.2	--	--	--

*Water soluble compounds only.

-- Not measured.

TABLE 3.1-37

QUENCH SCRUBBER WATER SAMPLE ANALYSIS

Set Point	Solids % Wt/Wt	Tars & Oils Acetone Extractibles % Wt/Wt	PH	Total NH_3 mg/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 mg/L
Air-Blown Test TP-016 - Pittsburgh Coal (Adamsburg)															
1	0.84	NEMA†		250	820	4.3	--	125	<.02	830	15	<.01	105	9.6	233
2	-- ††	NEMA		280	822	0.48	--	125	<.02	1010	19	<.01	211	18	272
3	1.1	NEMA		210	758	2.6	--	105	<.02	900	10	<.01	175	23	258
4	0.96	NEMA		420	1520	2.2	--	115	<.02	1725	16	<.01	348	35	571
Air-Blown Test TP-017 - Pittsburgh Coal (Adamsburg)															
1	0.41	NEMA	8.4	320	--	14.0	--	--	--	--	21.0	0.01	--	--	--
2	--	NEMA	7.2	330	--	17.0	--	--	--	--	38.0	0.08	--	--	--
3	1.18	NEMA	8.1	190	--	0.12	--	--	--	--	11.0	0.02	--	--	--
4	--	NEMA	7.1	240	--	0.10	--	--	--	--	153.0	0.02	--	--	--
5	0.88	NEMA	8.4	410	--	16.0	--	--	--	--	220.0	0.02	--	--	--

*COD - Chemical Oxygen Demand.

**BOD - Biological Oxygen Demand.

†NEMA - No extractible material with acetone.

††-- - Not measured.

To identify trace elements in the solids, samples from TP-017 test were selected and characterized. Table 3.1-33 lists the results of these data. In order to study the release characteristic of the trace elements into the gas phase, X-ray fluorescence methods will be attempted, and a material balance within the accuracy of solids mass flow measurements will be made. The results of the study should be available by the next reporting period.

The size distribution for the particulates escaping the roughing cyclone were sampled with the isokinetic probe-minicyclone apparatus and measured by Coulter Counter techniques. The results of these analyses for TP-016 and TP-017 gasifier tests are graphically shown in Figures 3.1-6 and -7.

In Table 3.1-34, the particulates escaping the cyclone for TP-016 and TP-017 are characterized.

In addition to the product and recycle gas measurements made with the on-line gas chromatograph to determine CO, H_2, CH_4, CO_2, H_2 and O_2 contents, trace hydrocarbons and sulfur compounds were obtained by laboratory mass spectrometer measurements of the gas collected in sample cylinders. The data for TP-016 and TP-017 are reported in Table 3.1-35. The on-line gas chromatograph data were reported last quarter in the operating data summary sheets (see Quarterly Progress Report, FE-1514-88).

Other product gas constituents were measured from analyzing the water sample from the miniscrubber. The data are given in Table 3.1-36.

The quench scrubber water was sampled from each vessel. A composite sample was prepared from equal quantities of several dump samples collected during the defined steady state periods for TP-016 and TP-017 tests. In addition to the various scrubbed chemical components, solids, acetone extractable tar and oils, and pH were determined. The results for TP-016 and TP-017 tests are shown in Table 3.1-37.

Chemical analysis of the cyclone deposit found after TP-018-3 test were initiated. The ash content of the deposit samples was found to range from 90 to 94 percent. Ash content of the coal feedstock was about 9 percent for this test and the fines collected by the cyclone ranged from 14 to 17 percent. These data imply that the residence time of the deposit was relatively longer than the residence time of the fines collected by the cyclone. In addition, the data indicate an enrichment of iron, nickel, and sulfur concentration. Preliminary results of this analysis are described below.

	Fe In Ashed Sample (Wt. %)	Ni In Ashed Sample (Wt. %)	Sulfur (Total) In Unashed Sample (Wt. %)
Cyclone Deposit (wall side to gas side)	36-54	0.054-0.13	9-18
Feed (Pgh coal)	20	0.02	2
Cyclone Fines	15	0-10	1.09

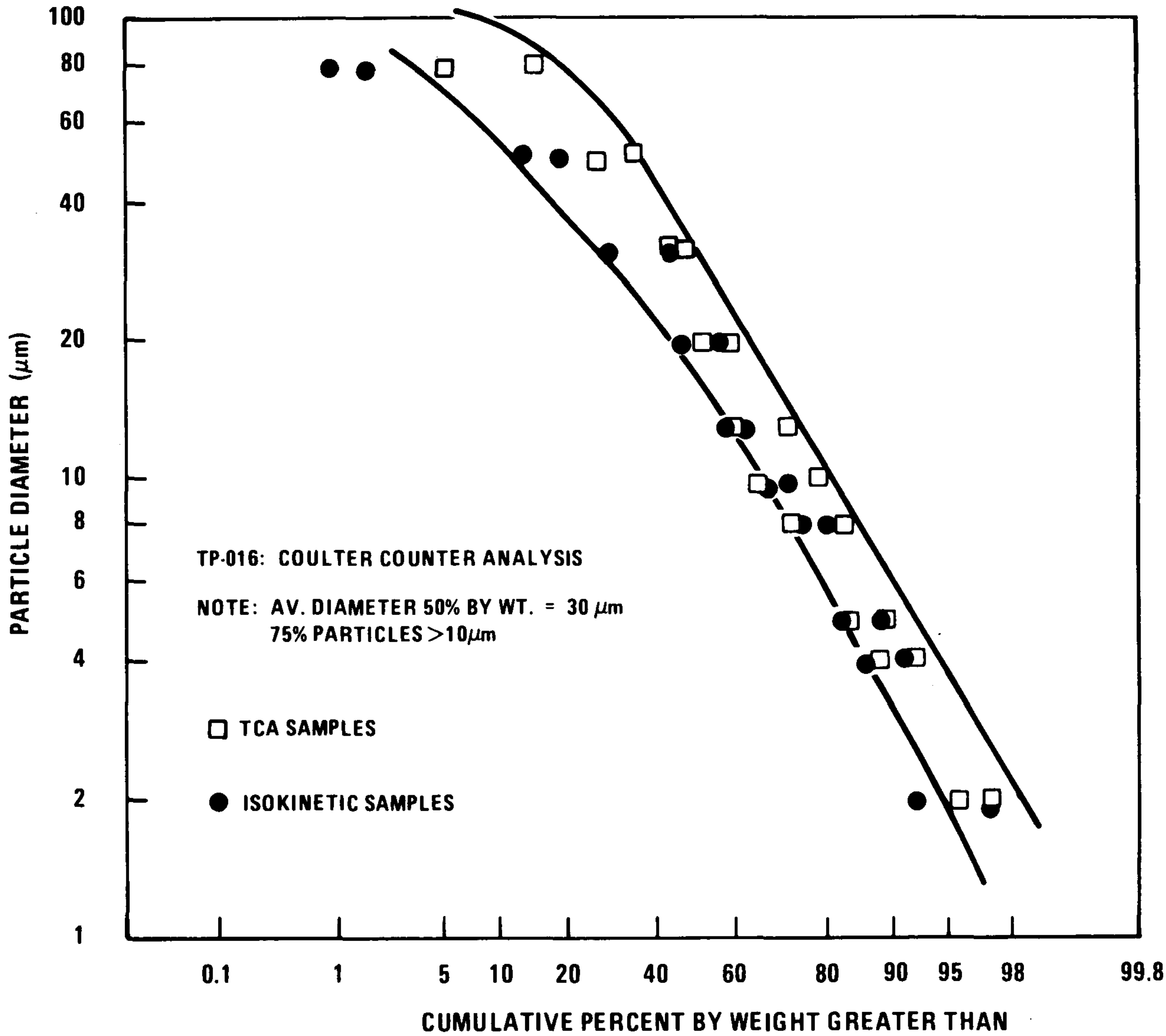


Figure 3.1-6. Cyclone Penetration Particulate Size Distribution Data (Coulter Counter Analysis) Test TP-016.

1363-3

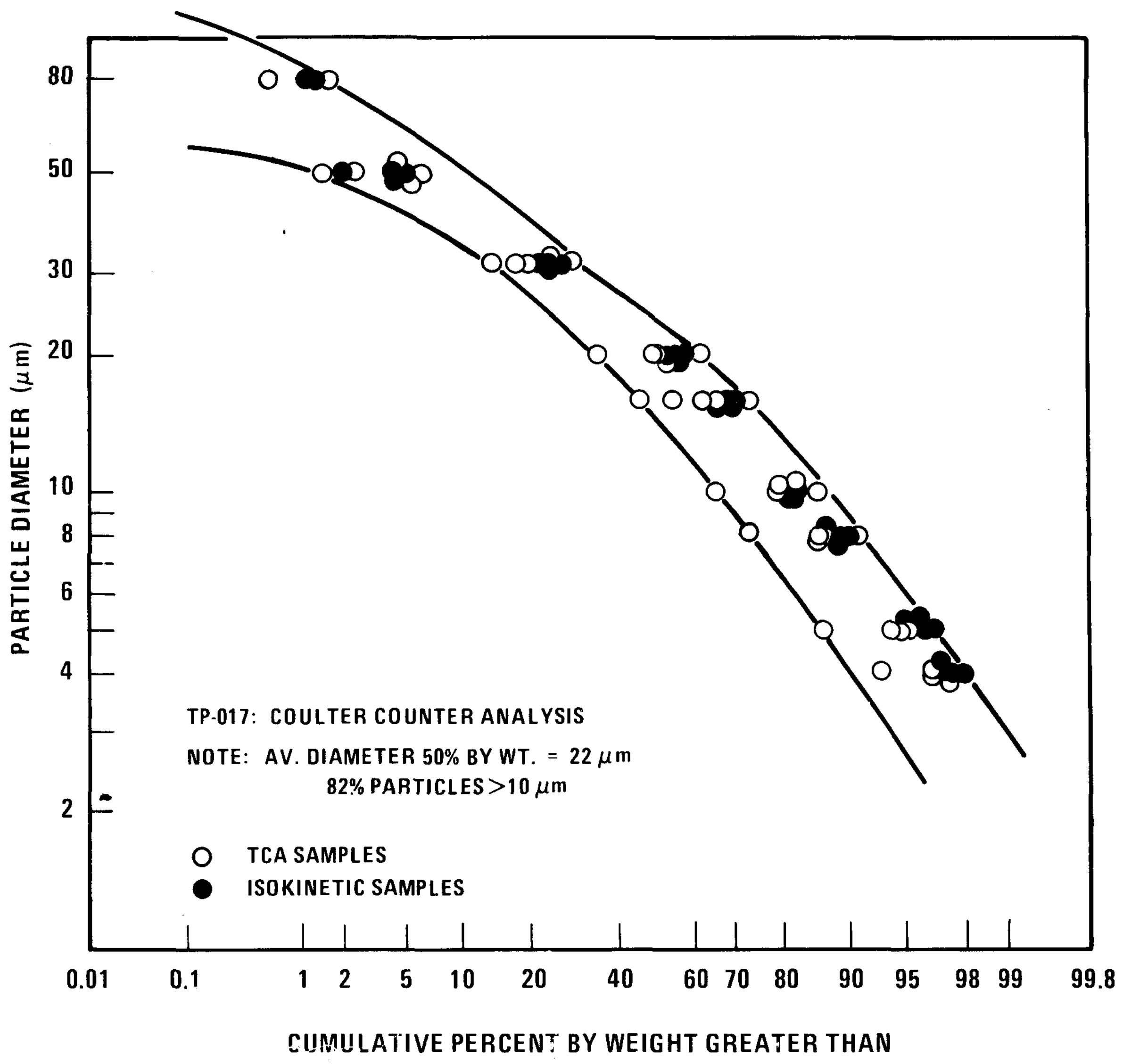


Figure 3.1-7 Cyclone Penetration Particulate Size Distribution Data (Coulter Counter Analysis) Test TP-017.

1363-4

Further studies of this build-up are being conducted by the Westinghouse R&D Center under the Laboratory Support program described in Subsection 3.2.

3.1.4.3 Work Accomplished - Environmental, Safety and Health

On August 4, the newly installed water spray deluge system, protecting the 33,000 gallon liquid propane tank, underwent an initial checkout test. Response time between sensor activation and full flow of water proved to be 10 seconds.

Figures 3.1-8 and 3.1-9 show the system following construction and during the functional checkout test. The system is equipped with 72 three-eighth inch nozzles that can spray 1300 gallons of water per minute at 130 psig onto the tank surface and the delivery vehicle area adjacent to the tank. When activated, the system provides a density greater than 0.3 gpm/ft^2 of tank surface which meets the National Fire Prevention Association (NFPA) specifications. Water feed lines are maintained in a dry state when not in use, and the feeder valve is located in a heated building for protection in cold weather.

The activation system consists of 14 combination rate-of-rise and set-temperature (160^{o}F) sensors. A cylinder of compressed nitrogen is used to maintain the sensor lines between 2200 and 500 psig, and system alarms are activated in event of low pressure or heater failure.

With the deluge system in place, the possibility of a boiling liquid-expansion vapor explosion (BLEVE) is greatly lessened since the cooling spray will serve to deter a rapid liquid-vapor transition.

3.1.4.4 Work Forecast for Next Quarter

Process and design engineering work planned for the next quarter includes:

- Completing the evaluation of product characterization analyses for oxygen-blown gasifier tests TP-018-2, -3 and -4.
- Completing design and procurement of test hardware for the delumper system.
- Obtaining approvals for the operating permits.

Figure 3.1-8. PDU Propane Storage Tank and Newly-Installed Deluge System

Figure 3.1-9. Propane Storage Tank Deluge System Undergoing Initial Checkout Test

3.2 PHASE I, TASK 3 - LABORATORY SUPPORT STUDIES

Work has been conducted in the following areas during the fourth quarter: cold flow and analytical modeling, coal behavior and ash agglomeration studies, studies of coal and ash chemical phenomena, environmental impact studies and systems analysis.

3.2.1 Cold Flow and Analytical Modeling

3.2.1.1 Work Accomplished - Jet Phenomena

Gas velocity profiles in a jet within a fluidized bed were determined at five different horizontal planes perpendicular to the jet direction by using a 0.6-cm (0.2 inch) diameter two-dimensional directional pitot tube. The wedge shaped sensing head with three separate probe holes permits measurement of yaw angle, total pressure, and static pressure of a moving gas. The two side holes on the wedge are 0.57 mm in diameter and the middle hole is 0.41 mm in diameter. Because of the smallness of the probe holes, it is believed that the velocity profiles obtained are those of interstitial gas. Inside the jet region where the solid particle concentration is small, the gas velocity profiles obtained should be accurate representations of the actual ones.

The experiments were conducted at three different nominal jet velocities, i.e., 32.6, 42.1, and 50.7 m/s (10.7, 13.8 and 16.6 ft/s), and eight different fluidized bed operating conditions. The velocity profiles were obtained at horizontal planes perpendicular to the jet direction 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) from the top of the jet nozzle. The resulting velocity profiles are presented in Figures 3.2-1 through 3.2-8 and the run conditions are given in Table 3.2-1. The peak velocity at 1.7 cm (0.66 inch) from the jet nozzle is usually 10 to 20 percent higher than the average jet velocity. This is because of the existence of the velocity profile inside the jet nozzle. It was also observed that the jet degenerated faster when the No. 3 flow was absent (see callouts in Figures 3.2-1 through 3.2-8 for designation of flow streams). The velocity measured outside the jet region, i.e., inside the fluidized bed, was usually larger than the calculated interstitial fluidization velocity. This slight discrepancy is the result of two factors. First, because of the low velocities to be measured inside the fluidized bed, the absolute magnitude of the impact pressures measured by the pitot tube approached the accuracy limit of the inclined manometer used. Second, the momentum of solid particles might contribute to some of the impact pressure measured by the pitot tube as the result of the higher concentration of solid particles in a fluidized bed.

The velocity profiles reported were those obtained from the pitot tube and calculated from the pitot tube equation with a coefficient of one. The velocity profiles were not corrected for the solids concentration in the jet. Solids entrainment into the jet will be studied separately by high speed movies and the results combined with the gas entrainment studies to give a complete description of jetting phenomenon inside a fluidized bed.

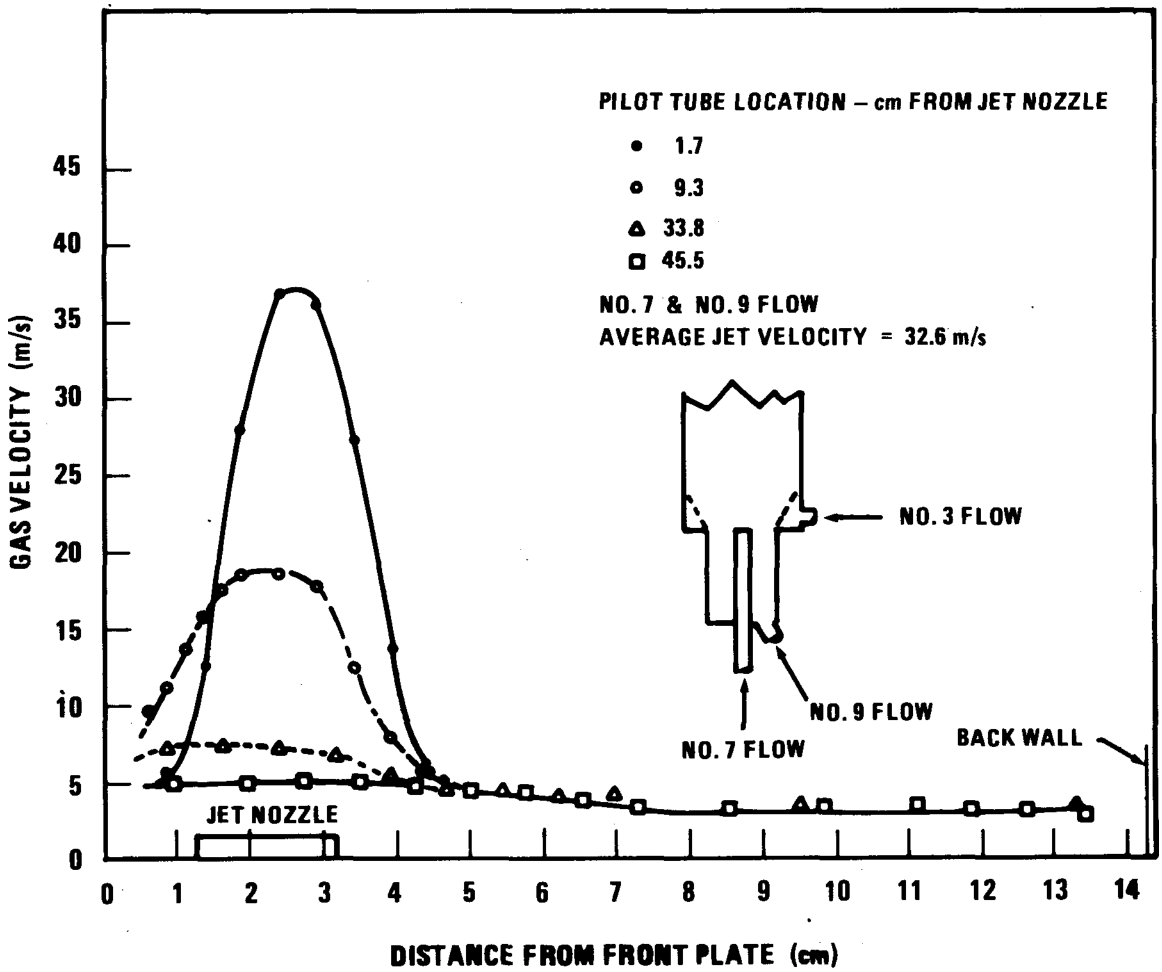


Figure 3.2-1. Jet Velocity Profiles for Run GJ114

1363-6

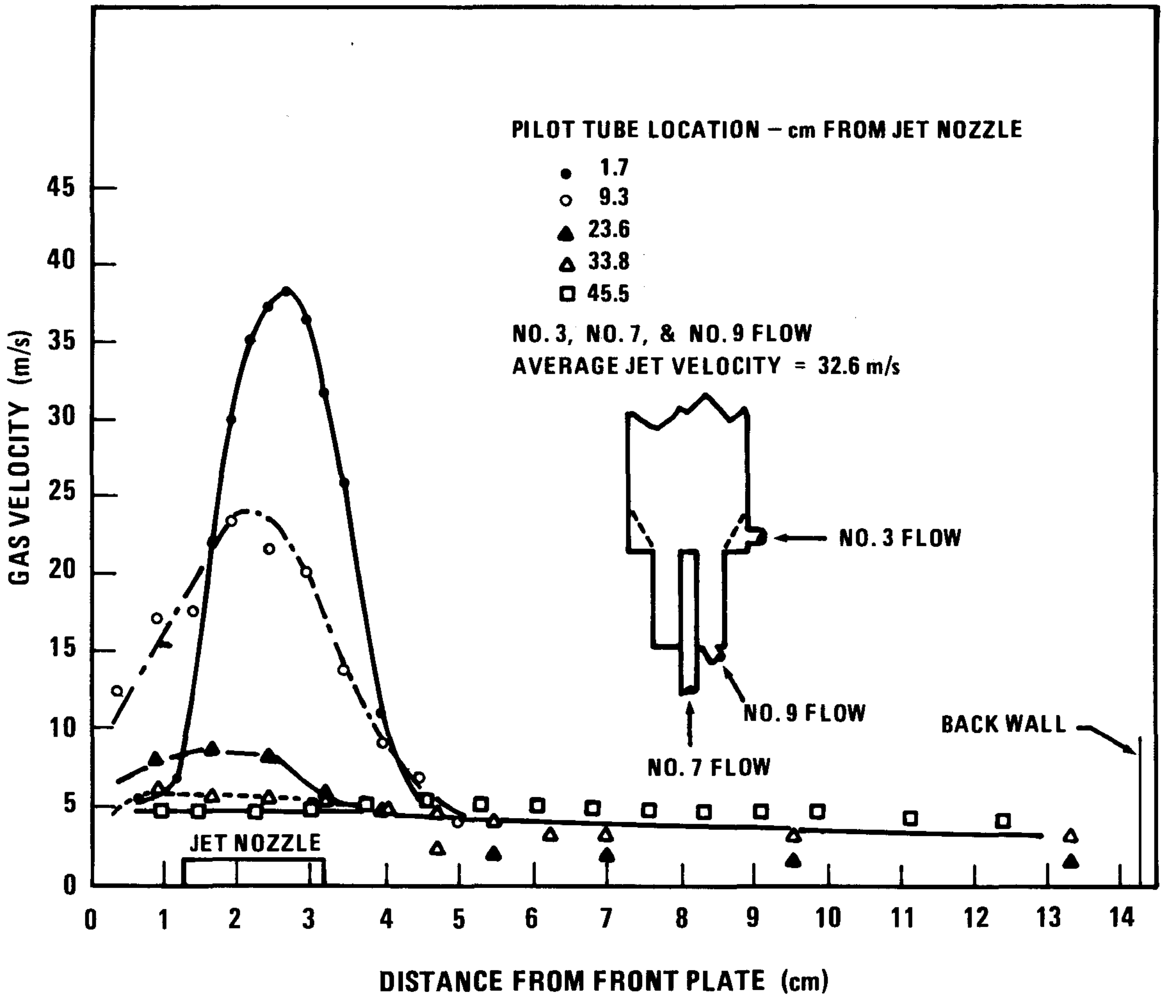


Figure 3.2-2. Jet Velocity Profiles for Run GJ115

1363-4

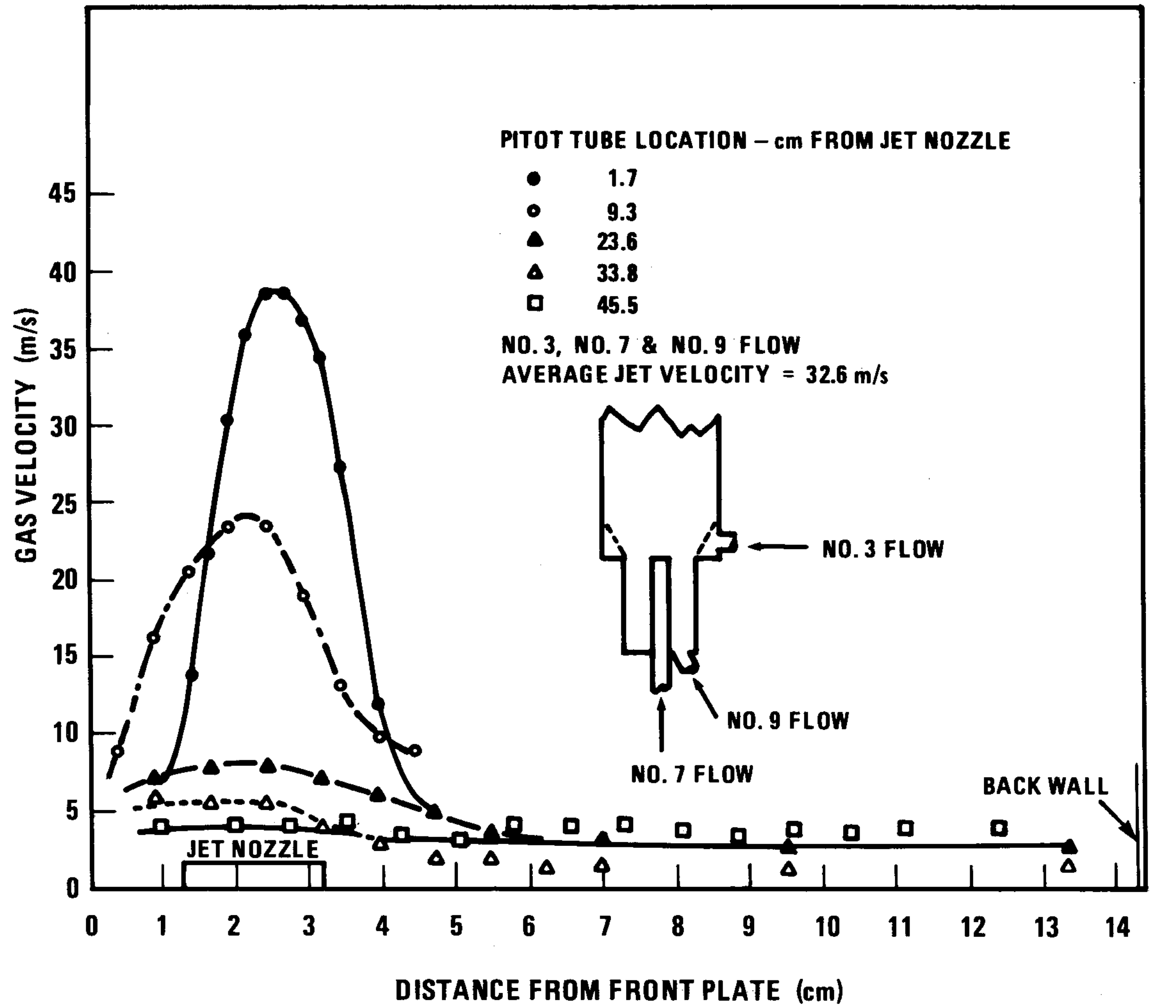


Figure 3.2-3. Jet Velocity Profiles for Run GJ116

1363-8

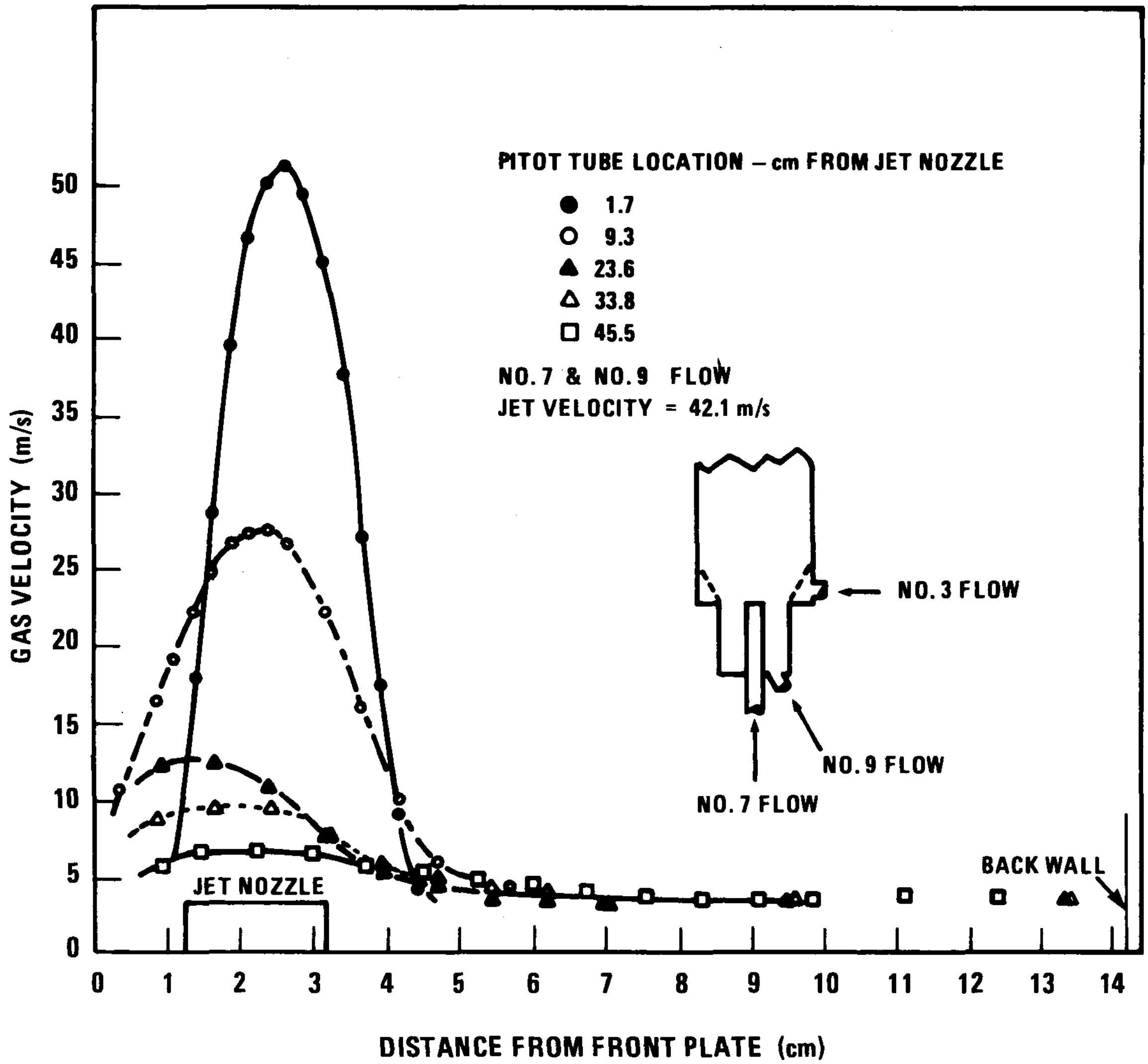


Figure 3.2-4. Jet Velocity Profiles for Run GJ118

1363-7

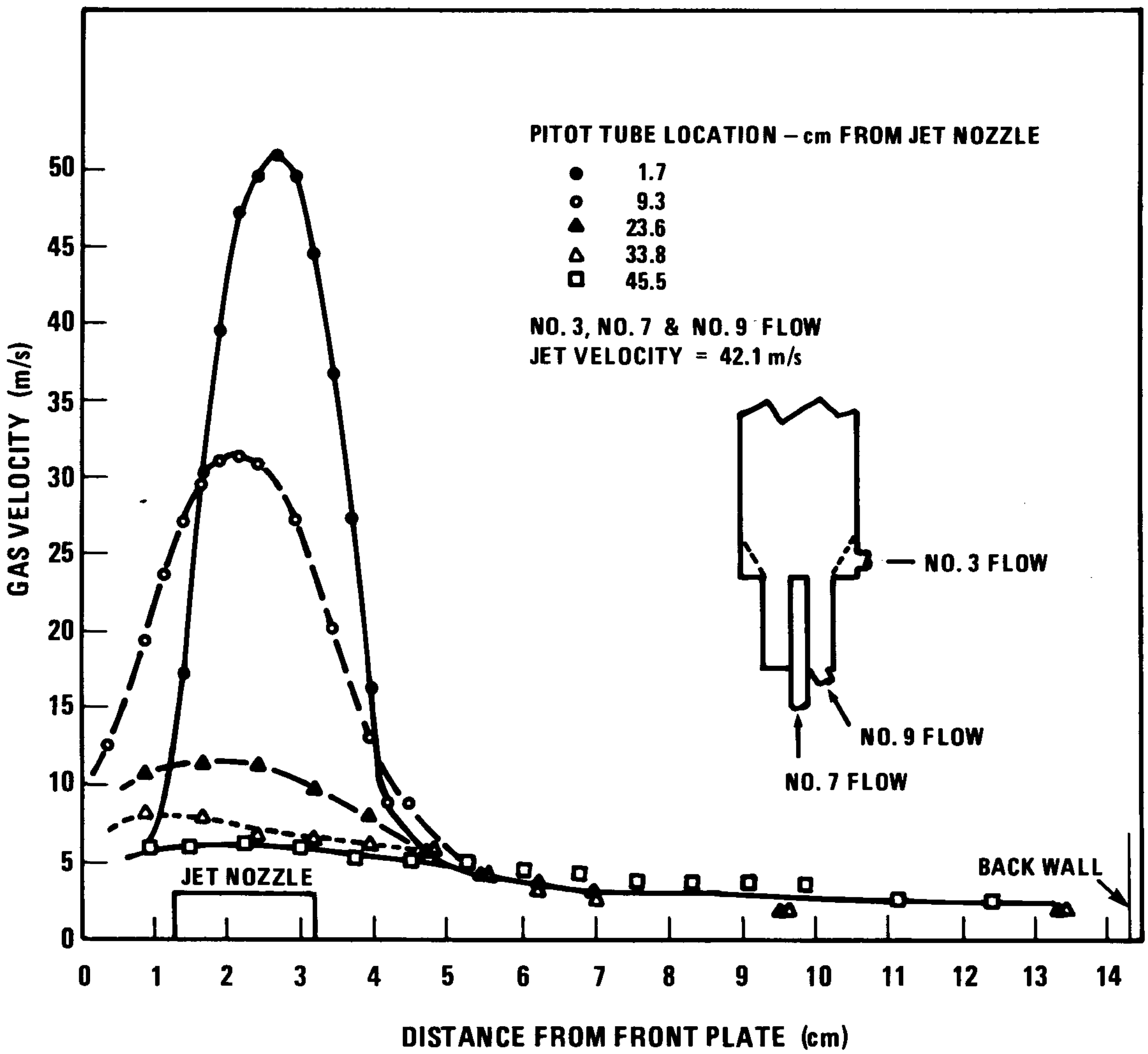


Figure 3.2-5. Jet Velocity Profiles for Run GJ119

1363-9

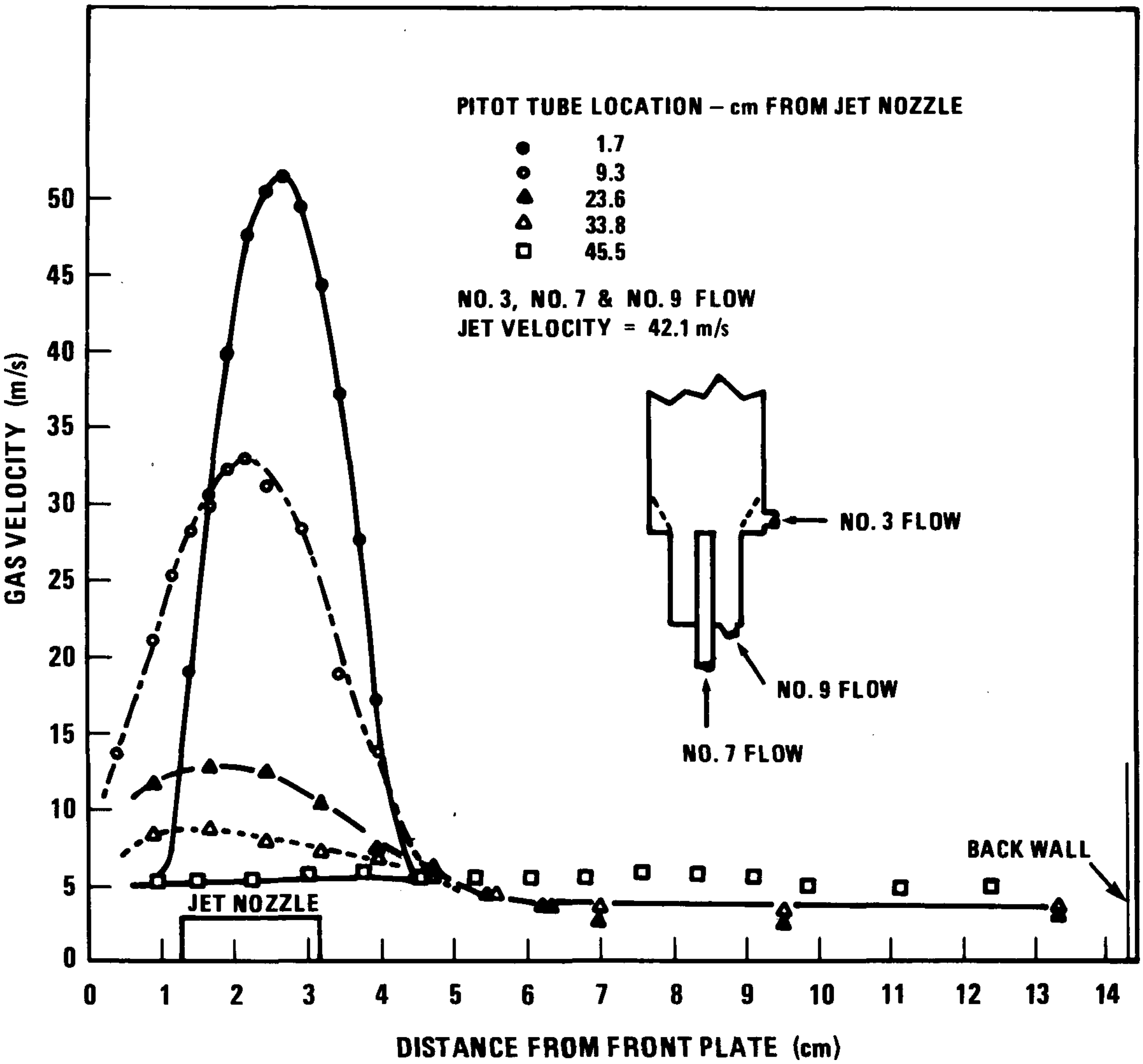


Figure 3.2-6. Jet Velocity Profiles for Run GJ120

1363-11

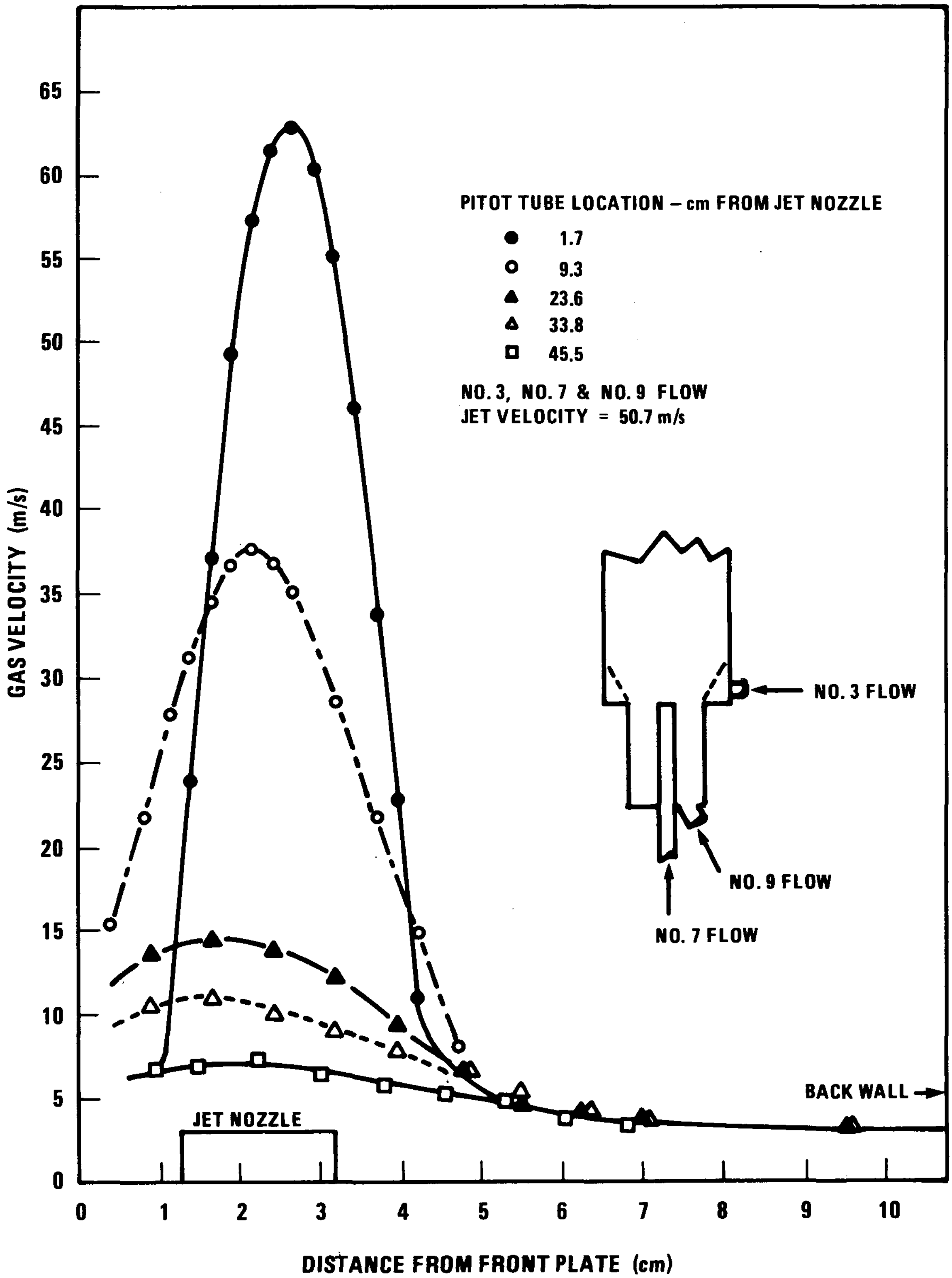


Figure 3.2-7. Jet Velocity Profiles for Run GJ121

1363-10

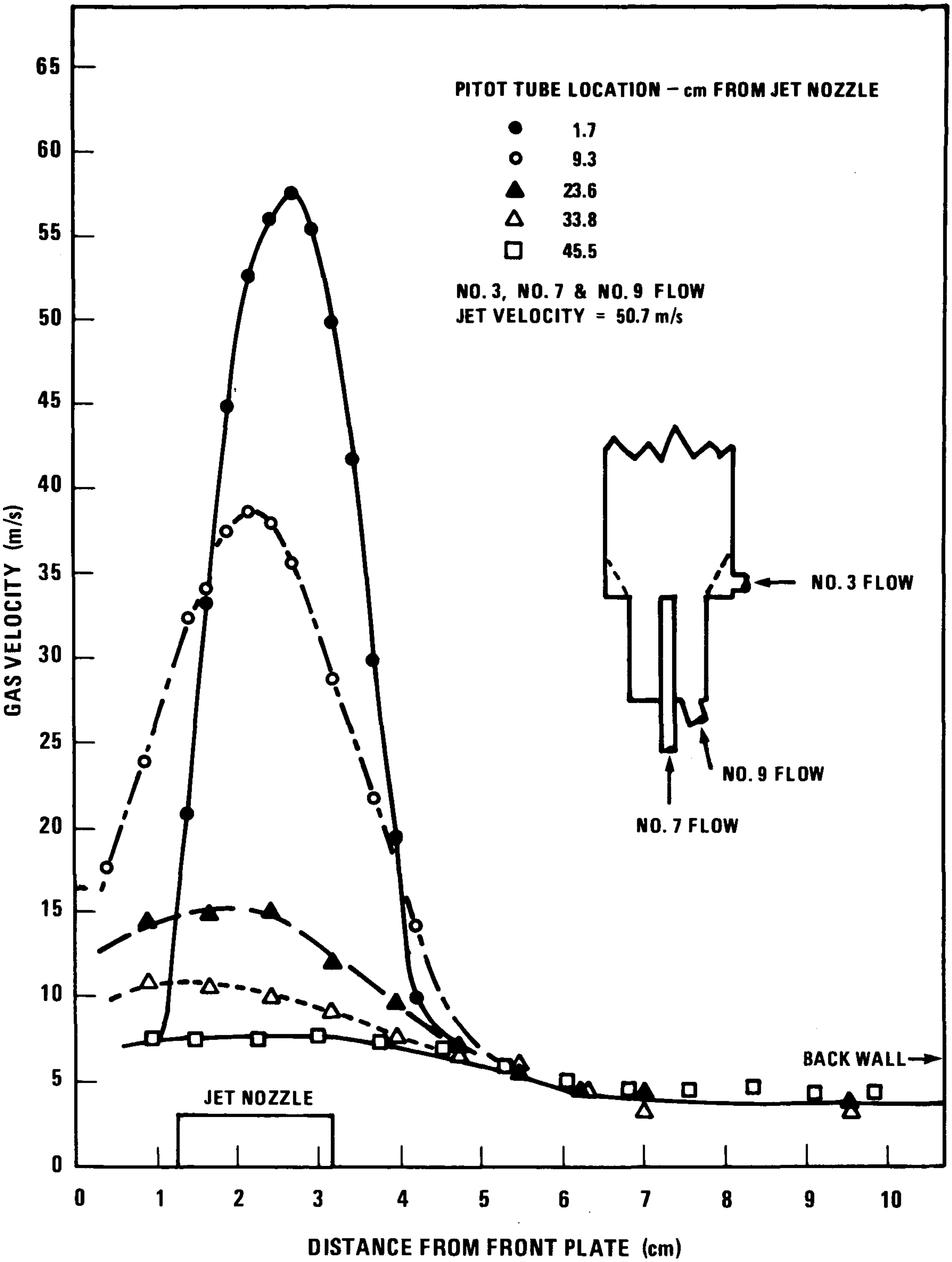


Figure 3.2-8. Jet Velocity Profiles for Run GJ122

1363-12

TABLE 3.2-1

OPERATING CONDITIONS OF THE FLUIDIZED BED DURING STUDIES OF GAS ENTRAINMENT

Run No.	No. 3 Flow (m^3/min)*	No. 7 Flow (m^3/min)	Nominal Jet Velocity (m/s)	No. 9 Flow (m^3/min)
GJ114	0	1.06	32.6	0.66
GJ115	0.69	1.06	32.6	0.66
GJ116	1.20	1.07	32.6	0.66
GJ118	0	1.42	42.1	0.67
GJ119	0.69	1.44	42.1	0.66
GJ120	1.20	1.46	42.1	0.67
GJ121	0.70	1.74	50.7	0.66
GJ122	1.20	1.74	50.7	0.58

*The flow is calculated at 14.7 psia (100 KPa) and 70°F (20°C).

The jet nozzle, being semicircular in cross section, presented some difficulties in analyzing the data. From an examination of the velocity profiles, it was found that they were basically symmetric with respect to the peak velocity, though the location of the peak velocity shifted from inside the bed at lower jet height toward the front plate at higher jet height. The symmetry in velocity profiles suggested that the velocity profiles obtained might be more representative of an imaginary circular jet as shown in Figure 3.2-9, rather than of the original semicircular jet. The data were analyzed by assuming that the velocity profiles were typical of an imaginary circular jet.

Another difficulty encountered during analysis of the data was the determination of the exact jet boundaries. The point at which the velocity profile suddenly leveled off was picked as the jet boundary at that particular location. These boundaries usually occurred at a gas velocity of around 5.5 m/s (18 f/s) which was smaller than the calculated terminal velocity of the bed particles at around 8 m/s (26 f/s). The gas velocity at 5.5 m/s represented the outer boundary of a transition zone where the voidage changed gradually from that of a fluidized bed to that of a jet.

The velocity profiles in Figures 3.2-1 through 3.2-8 were integrated graphically using a K&E 4242 compensating polar planimeter. The results of the gas entrainment at different jet velocities and different operating conditions are summarized in Table 3.2-2. Several preliminary conclusions can be drawn:

1. Gas entrainment into a jet occurs primarily at the top of the jet nozzle. The gas is then expelled from the jet along the entire jet length. The rate of the gas leakage from the jet can be calculated once the jet boundary is determined.

2. The jet degenerates quicker without No. 3 flow, that is the gas leakage rate from the jet is faster for runs without No. 3 flow. This occurs primarily at lower jet height.

3. The gas entrained into the jet comes primarily from the No. 9 flow. Doubling the No. 3 flow did not alter the amount of gas entrainment substantially. Experiments are now being conducted by injecting tracer gas into No. 3 and No. 9 flows.

4. The absolute amount of gas entrainment into the jet is directly proportional to the jet velocity.

3.2.1.2 Work Accomplished - Draft Tube Design

Experiments were performed in the two-dimensional unit with three separate draft tubes during the quarter. The preliminary results showed that the solid particle downward velocities in the central two downcomers were consistently higher than that at the two outer downcomers at similar gas velocities in all three draft tubes. Under certain operating conditions, the particle velocities could be different by more than a factor of two. However, the

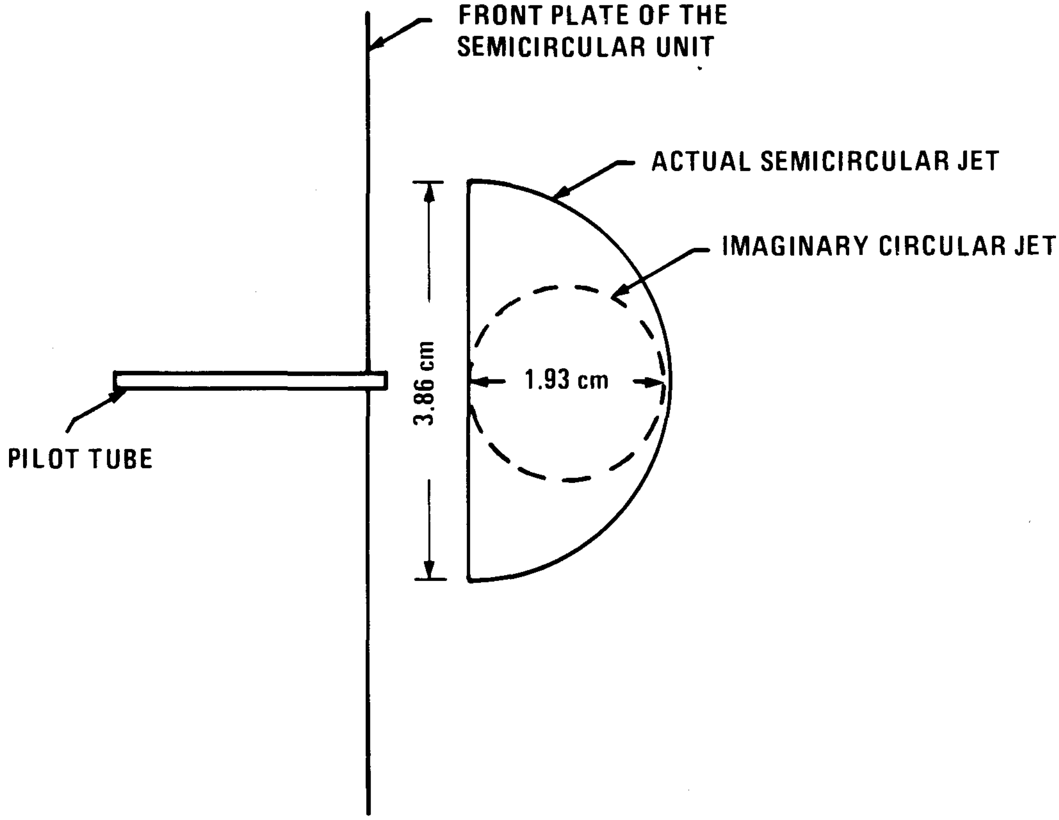


Figure 3.2-9. Scheme of Semicircular Unit and Imaginary Circular Jet Used for Data Analysis.

1363-5

TABLE 3.2-2

GAS ENTRAINMENT INTO THE JET UNDER DIFFERENT OPERATING CONDITIONS*

	Distance From the Jet Nozzle				
Run No.	1.7 cm	9.3 cm	23.6 cm	33.8 cm	45.5 cm
GJ114	1.39*	0.96	--	0.42	--
GJ115	1.36	1.22	0.39	0.30	--
GJ116	1.42	1.18	0.48	0.34	--
GJ118	1.36	1.08	0.62	0.43	0.21
GJ119	1.41	1.27	0.66	0.44	0.23
GJ120	1.37	1.25	0.77	0.61	--
GJ121	1.45	1.24	0.70	0.62	0.32
GJ122	1.35	1.28	0.76	0.71	0.42

*Ratio of gas flow inside the jet at the perpendicular horizontal plane divided by the total gas flow supplied through the jet nozzle.

pressure drop across each downcomer was essentially the same. Apparently, there was a self-regulating mechanism to adjust the amount of gas bypassing to keep the pressure drops across the draft tubes and the downcomers the same. A tracer gas injection scheme is being devised in an attempt to determine the cause.

Experiments are being continued by operating the draft tubes at different velocities to purposely create the unbalanced conditions to simulate upsets during operation.

3.2.1.3 Work Accomplished - Distributor Design

A scaled-down model of the PDU devolatilizer gas and solids inlet system has been fabricated and assembled together with the semicircular column. The apparatus is constructed and will be operated so as to simulate the gas and solids inlet conditions to the devolatilizer during integrated operation. The outer shell of the devolatilizer entrance is made of plexiglass to enable observing the fines flow during operation. A storage hopper will be fabricated to connect all the gas and solids feed lines.

Hollow microspheres with a mean diameter of about 500 microns and a density of 400 kg/m^3 will be used as bed material. These particles were chosen so that the solids-gas density ratio in the column is the same as in the PDU. To simulate the fines char carryover from the gasifier, hollow glass spheres of 100 micron mean diameter will be blown in through the annulus around the concentric solids feeder.

The smaller size particles as received contain a considerable amount of fines, and therefore are very cohesive. To alleviate the problem of cohesion, some of the fines in this batch of particles are being sieved out. Should the problem persist, ground cork particles may be used as an alternative. It has also been decided to purchase a screw feeder to measure feed these particles into the gas stream entering the devolatilizer.

3.2.1.4 Work Forecast For Next Quarter

In work planned for next quarter, the experimental test program on gas entrainment into a jet in a fluidized bed will be completed; experiments in the two-dimensional unit to evaluate the performance of multiple draft tubes will be continued; experiments on jet penetration with a solids-gas, two phase jet will be initiated, and preparation for plenum tests with the devolatilizer conical grid will continue.

3.2.2 Coal Behavior Studies

3.2.2.1 Work Accomplished - Devolatilization-Gasification

Surface area measurements on several chars were completed using carbon dioxide as the adsorbate on a micromeritics model 2100 surface area analyzer. Sample holders have an outer jacket for circulating water at a constant temperature to maintain the sample temperature at about 75°F (298 K). An equilibration time of 30 minutes was allowed for each adsorption point. A total of six to seven adsorption points were obtained in the pressure range of 40 to 1400 psi (20 to 700 mmHg).

The Dubinin-Polanyi equation was applied for the evaluation of surface areas. The D-P equation is given as:

$$\log V_a = \log V_o - D' \log^2 (P_o/P_2)$$

where

V_a = amount of CO_2 adsorbed at equilibrium pressure P_2

V_o = micropore capacity

P_o = saturation vapor pressure of adsorbate at adsorption temperature

D' = constant.

A plot of log V versus $\log^2 (P_o/P)$ yields the value of $\log V_o$ from which the specific surface area of the sample can be calculated.

Dubinin-Polanyi plots for FMC Western Kentucky, Utah and Synthane chars are shown in Figures 3.2-10, -11 and -12, respectively. Note the excellent linearity in these plots. The surface areas for these chars were estimated to be 118, 153 and 90 m^2/g, respectively. The molecular area of carbon dioxide at 298 K was taken as 25.3 $\mathring{A}^2$. Surface area measurements on several other chars were performed, with verification of results to be completed.

The scanning electron microscope (SEM) pictures of various unreacted chars are shown in Figures 3.2-13 and -14. The differences in the pore structure between the reactive chars and coke breeze are quite marked and can be clearly seen with the exception of the Synthane char. The reactive chars are more porous than coke breeze. The reactivities of FMC Western Kentucky, Minnehaha and Synthane chars are about the same. Renton char is much less reactive compared to these chars. The structure of FMC Western Kentucky char is somewhat different from others in that it appears as a cluster of particles. Regarding the structure of Synthane char, it is possible that a representative sample was not used in obtaining the pictures, or that the char develops its pore surface area after a certain amount of carbon conversion takes place. SEM pictures of reacted coke breeze and Minnehaha char samples were also taken but were found to be unsatisfactory since a representative sample was not available. These photos will be taken again at a later stage.

3.2.2.2 Work Accomplished - Ash Agglomeration

The design of the new reactor was completed and construction is underway. Fabrication of the shell was completed and machining of the transition piece connecting the reactor and the pipe leading to the cyclone has begun.

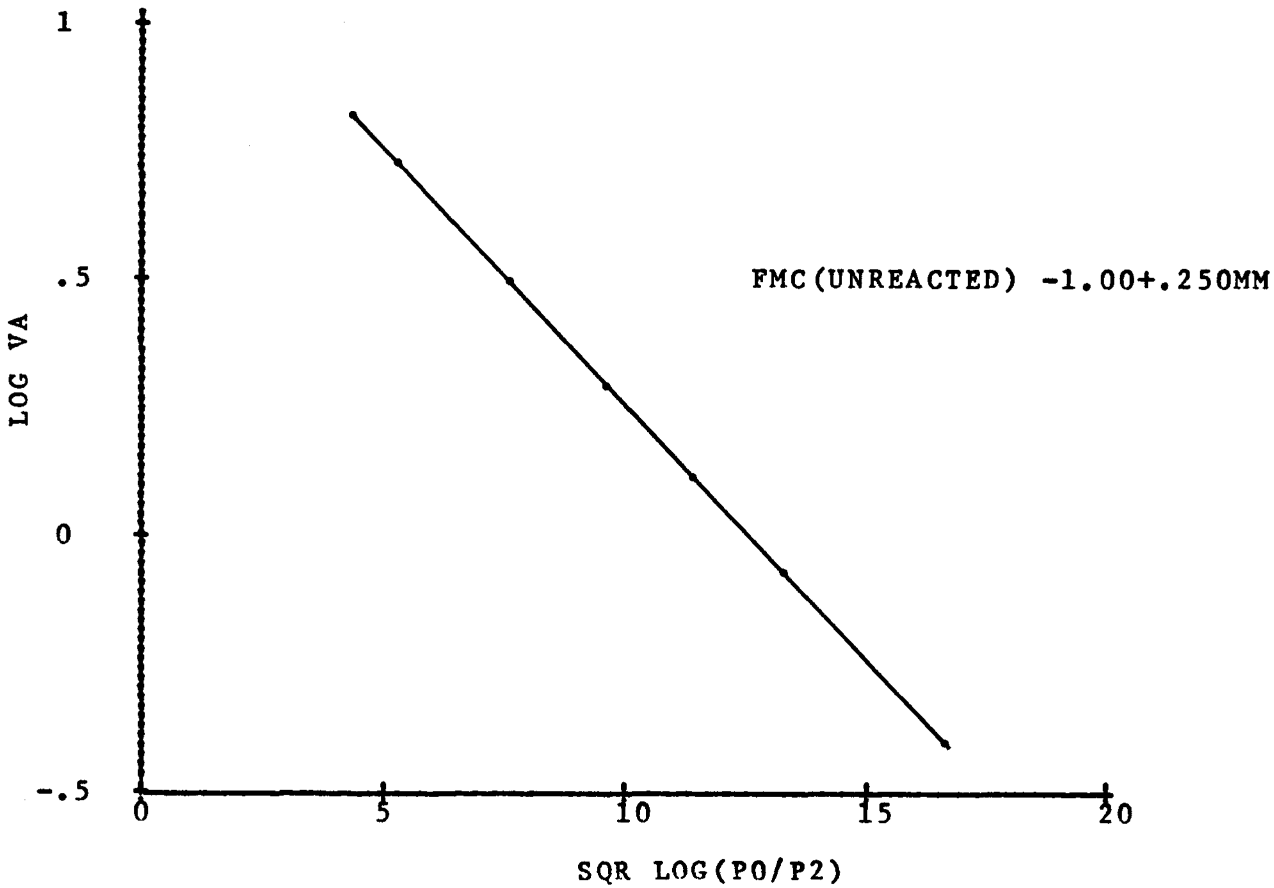


Figure 3.2-10. Dubinin-Polanyi Plot for FMC Western Kentucky Char

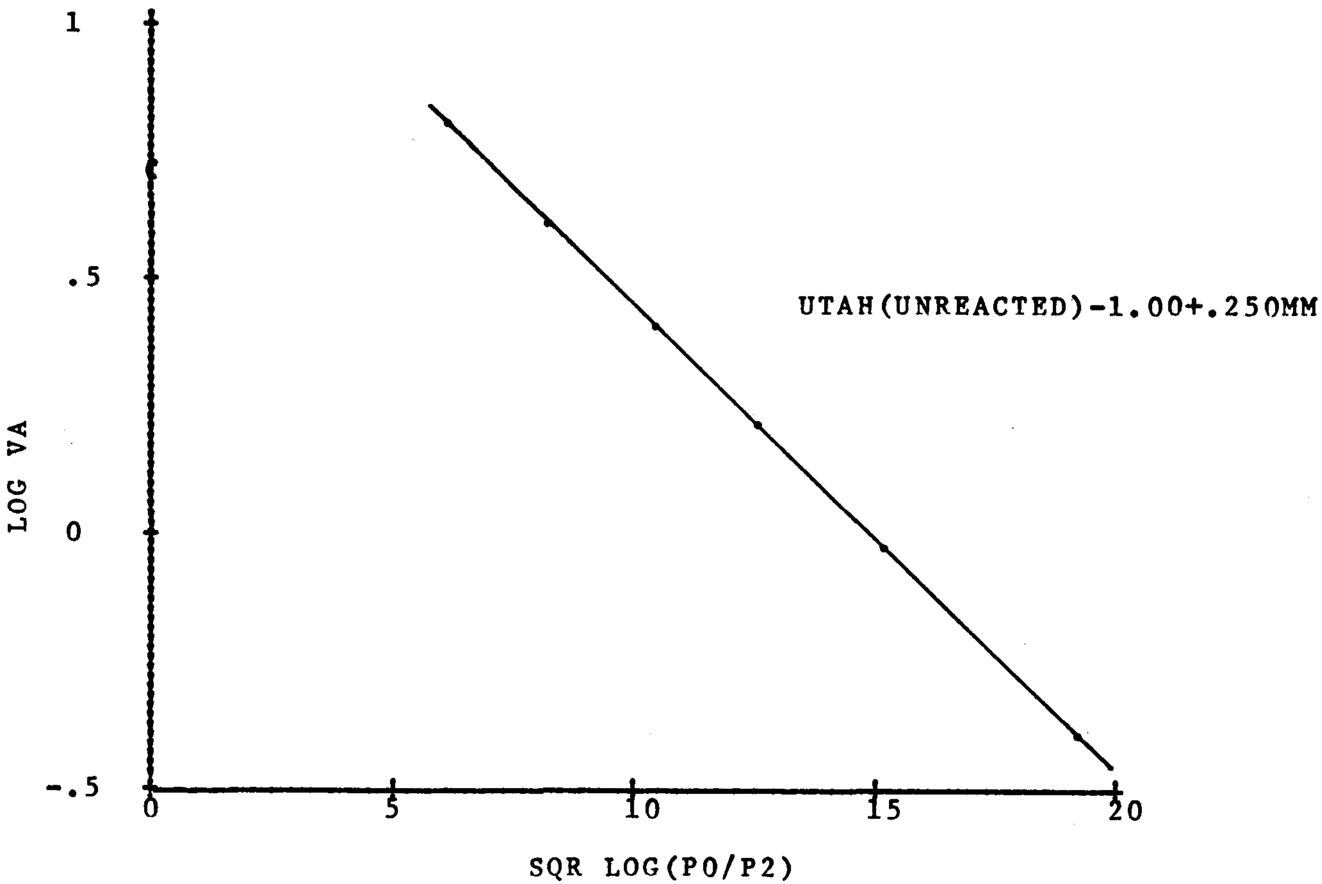


Figure 3.2-11. Dubinin-Polanyi Plot for Utah Char

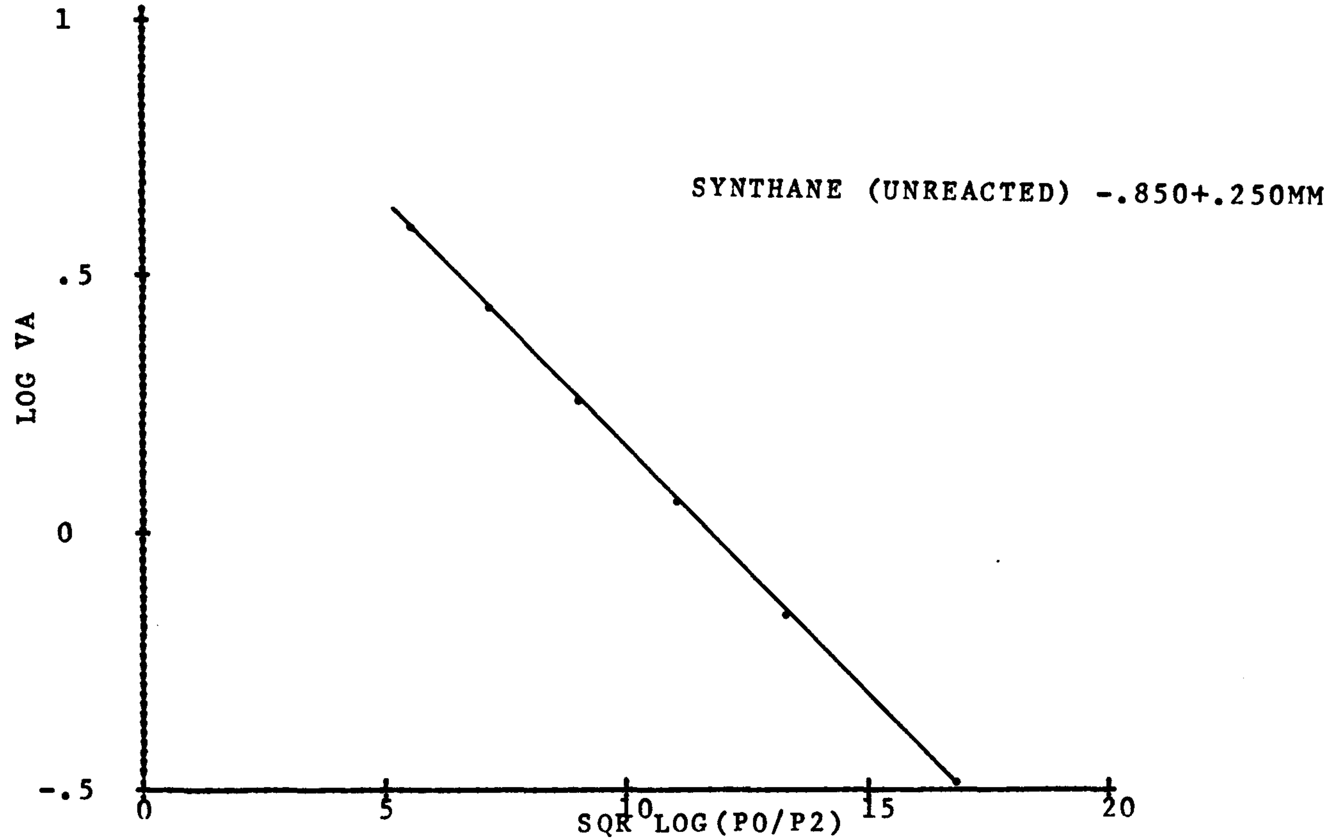


Figure 3.2-12. Dubinin-Polanyi Plot for Synthane Char

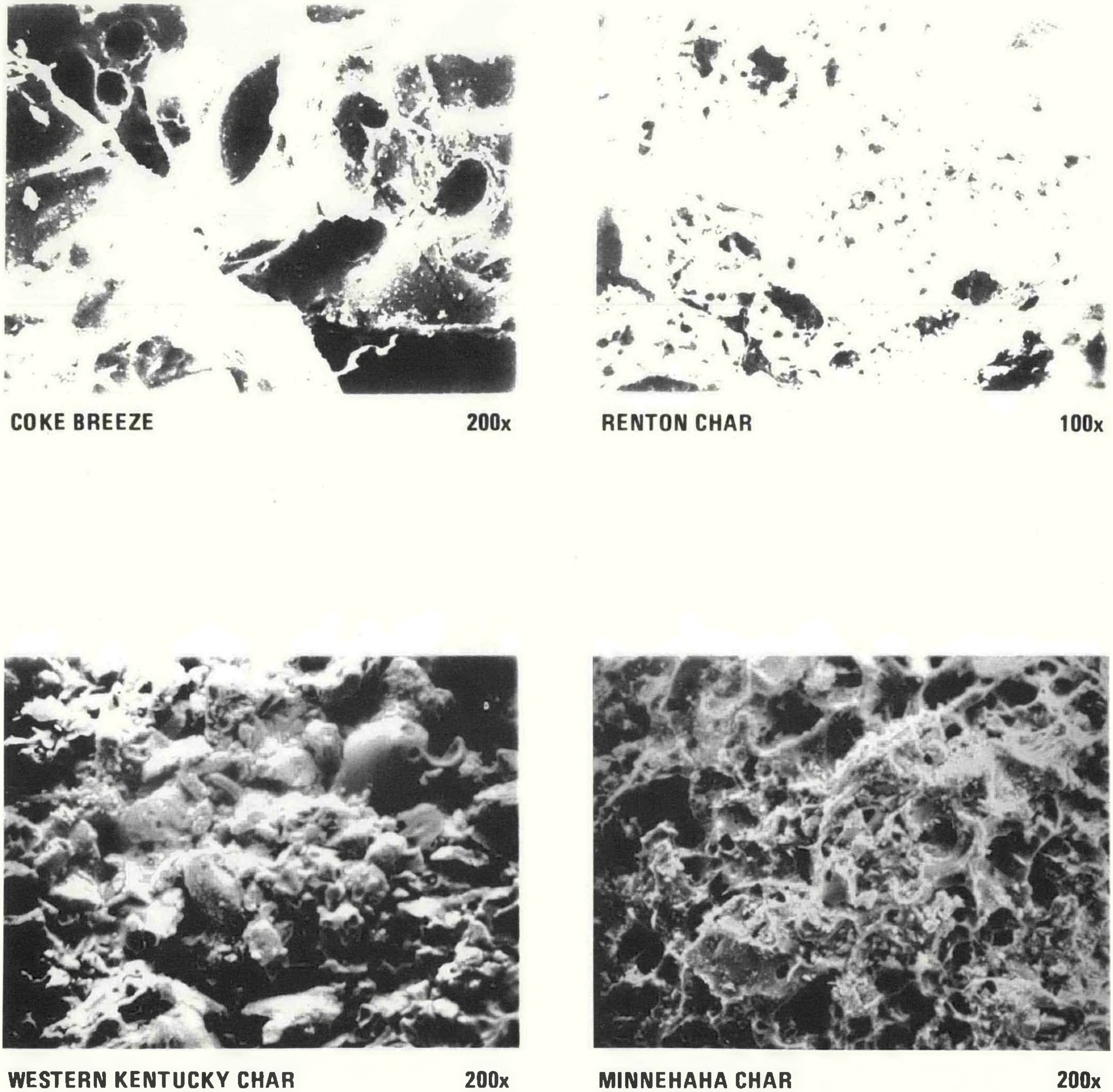
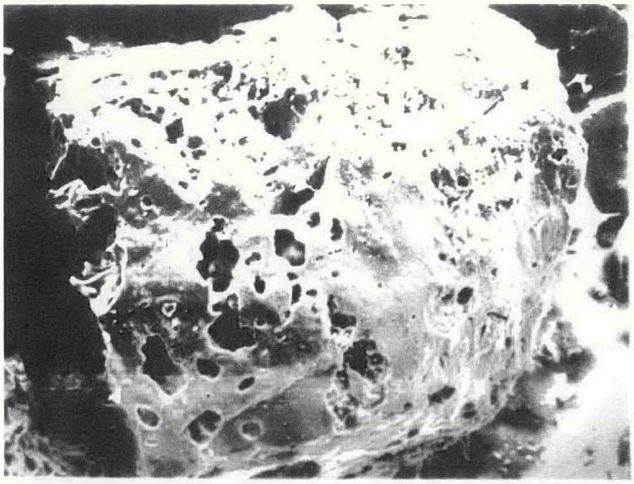
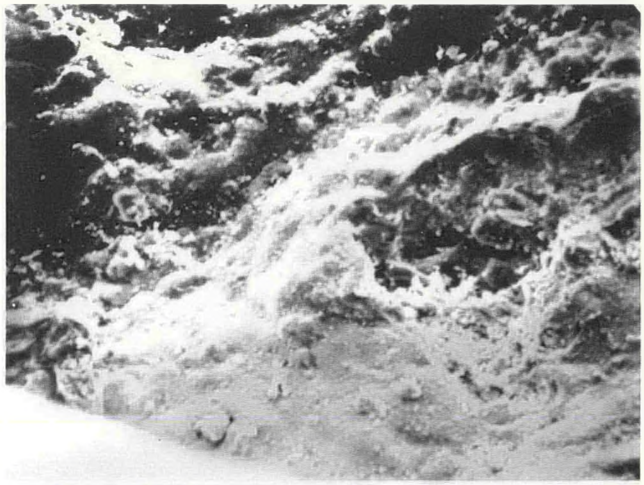


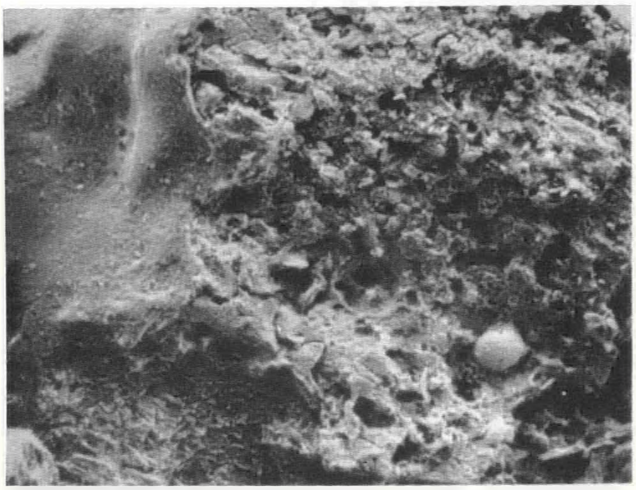
Figure 3.2-13. Scanning Electron Microscope (SEM) Photos of Unreacted Chars, Showing Coke Breeze, Renton, Western Kentucky and Minnehaha Chars.



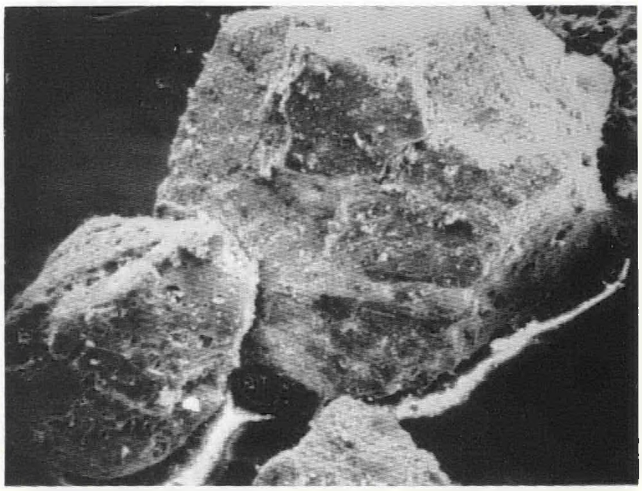
UTAH CHAR 100x



IGT COKE BREEZE 200x



MONTOUR CHAR 100x



SYNTHANE CHAR 100x

Figure 3.2-14. Scanning Electron Microscope (SEM) Photos of Unreacted Chars Showing Utah Char, IGT Coke Breeze, Montour and Synthane Chars.

1363-2

Castable refractory material was received and the refractory liners will soon be cast. Preparations are being made to erect a suitable structure for supporting the reactor.

A cold model made of plexiglass was set up to visualize the operation and to obtain data which will be helpful in the operation of the ash agglomeration test facility.

3.2.2.3 Work Accomplished - Coal and Ash Chemical Phenomena

Thermodynamic calculations have been used to study the effects of temperature, gasifier bed-ash content, and steam flow to the grid plate on the chemical compounds formed in the gasifier and their relative amounts at equilibrium. The mineral compounds, predicted by thermodynamics, in the solid or liquid phases included:

$Al_6 Si_2O_{13}$, $Al_2 SiO_5$, $CaO.Al_2O_3.2SiO_2$, $Al_2O_3.TiO_2$, $FeO.Al_2O_3$, $MgAl_2O_4$,

K_2SiO_3 and SiO_2.

Only potassium (K_2SiO_3) and iron ($FeO.Al_2O_3$) were shown to be affected by changes in the gasifier operating conditions. The conditions studied were:

Gasifier bed temperatures	= 1500; 1700; 1800; 1900 and 2100°F
Pressure	= 16 atmospheres
Bed ash content	= 10, 15 and 25 percent
Steam flow to the grid plate	= 25, 100, 200 and 400 lb/h

It was assumed that the total material held-up in the gasifier was 552 pounds and the char transport gas flow was 470 lb/hr. Also, all the gases formed in the combustor were input into the gasifier.

As temperature increased from 1500°F to 2100°F, K_2SiO_3, in the solid or liquid phase, reacted with steam and (HCN) gas to form (KOH) gas and (KCN) gas. The amount of KCN formed is, however, very small in the temperature range studied. The majority of the potassium (90 to 99 percent) was tied-up as ($K_2 SiO_3$) in the gasifier, in comparison with the combustor which had 30 to 70 percent of the potassium as (K_2SiO_3) and 0 to 30 percent as (K_2SO_4) solid/liquid. Since K_2SiO_3 melts at 1789°F (976°C) and has a low melting eutectic at 1368°F (742°C), it may have acted as a binding matrix for ash deposits and ash agglomerates. The amount of (K_2SiO_3) liquid which decomposed into (KOH) gas and (KCN) gas increased with increasing bed temperatures, increasing steam flow to the grid plate and decreasing bed ash content, as shown in Figures 3.2-15 and 16. However, the effects of these parameters on the decomposition of K_2SiO_3 were not as significant in the gasifier as they were in the combustor. Results on thermodynamic projections of the operation of the combustor were reported in the previous Quarterly Progress Report, FE-1514-88. Thermodynamic

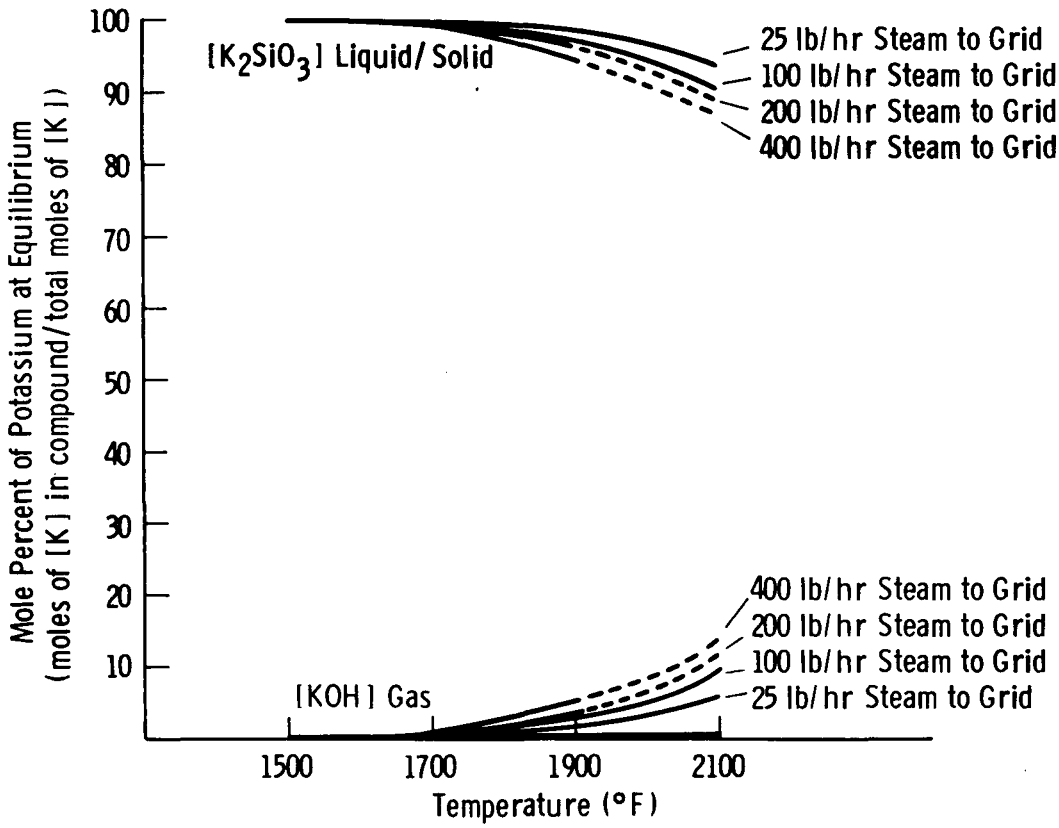


Figure 3.2-15. Effect of Steam Flow to the Grid Plate on the Distribution of Potassium in the Gasifier at Equilibrium. (Gasifier Ash Content = 15%; Operating Pressure = 16 atm)

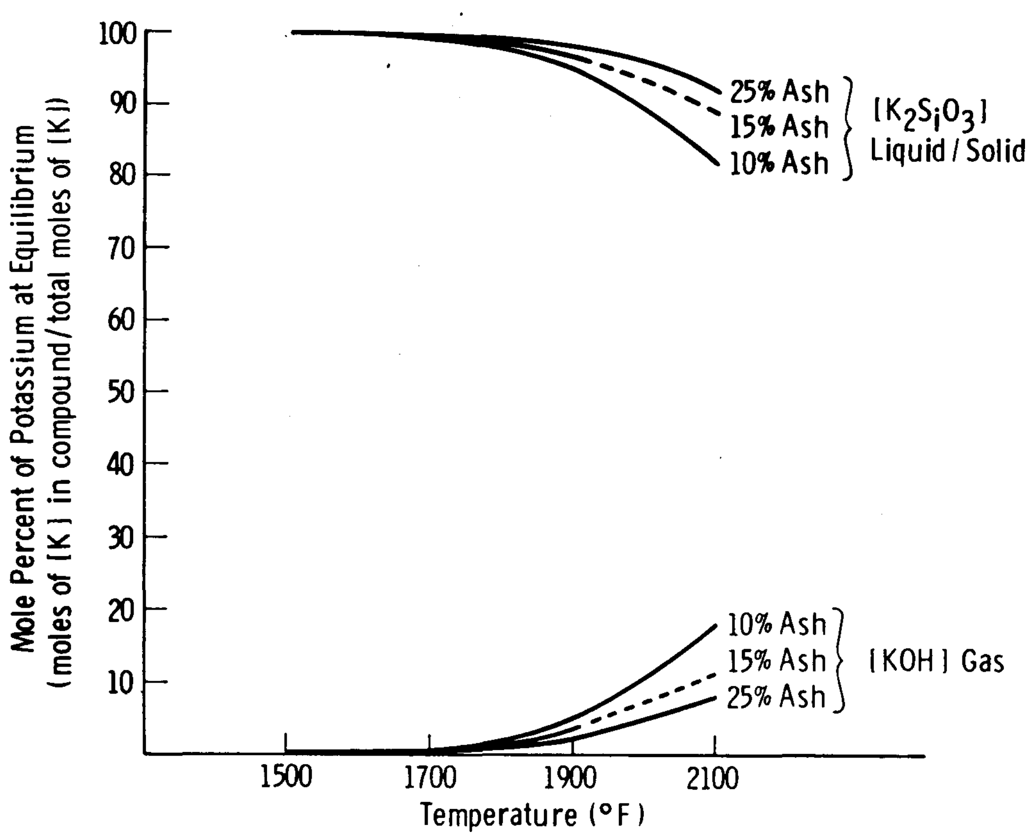


Figure 3.2-16. Effect of Gasifier Bed Ash Content on the Distribution of Potassium in the Gasifier at Equilibrium. (Steam Flow to Grid Plate = 200 lb/hr; Operating Pressure = 16 atm)

calculations also showed that the potassium which was evolved as (K_2SO_4) gas and (KOH) gas from the combustor, was incorporated in (K_2SiO_3) solid/liquid, in the gasifier as shown in Table 3.2-3.

Iron, which was stable as $FeO.Al_2O_3$, reacted with steam at high temperatures to form $Fe(OH)_2$ gas. Increasing steam flow to the grid plate increased the formation of $Fe(OH_2)$ gas. However, $FeO.Al_2O_3$, which melts at 3092°F (1700°C) with a low melting eutectic at 2426°F (1330°C), was in the solid phase at the operating temperature of the gasifier and may not have been part of the binding matrix. Also, the amount of $Fe(OH)_2$ gas formed is insignificant in the temperature range studied.

3.2.2.4 Work Forecast for Next Quarter

Coal behavior studies work for the next quarter includes the following projections.

- Surface area measurements on chars will be completed, and reactivity studies on various chars in a laboratory fluidized bed will be initiated.
- Fabrication, installation and testing of the ash agglomeration facility will be completed.
- An experimental program which will help in determining the binding matrix in ash deposits and ash agglomerates will be developed and a study to examine the mechanism for deposition in the cyclone will be conducted.

3.2.3 Environmental Impact Studies

3.2.3.1 Work Accomplished - Solids Disposal

Ash agglomerate from gasifier test TP-016 has been tested for environmental impact from disposal. The purpose of TP-016 was to evaluate gasifier performance with a highly caking coal feedstock. Pittsburgh seam coal was fed directly to the gasifier operating at 1800°F without the benefit of pretreatment on devolatilization. Ash content of the agglomerates was 67 percent. Silica quartz and amorphous phase were the major species found by X-ray diffraction.

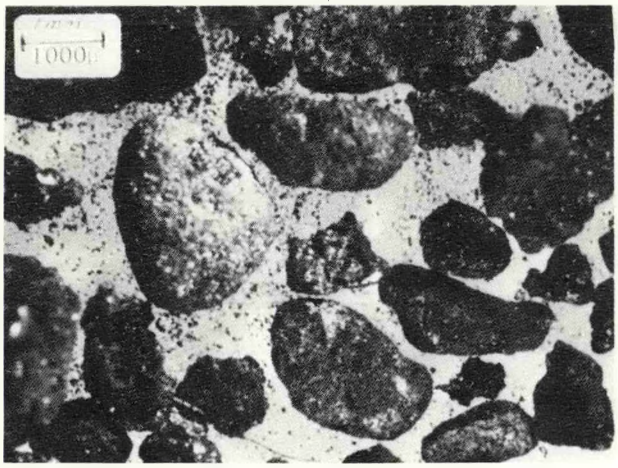
Figure 3.2-17 shows photomicrographs by light and scanning electron microscopy (SEM). A typical coal ash composition is shown by EDAX. Most of the TP-016 agglomerates ranged in particle size from 0.5 to 3 mm. A small amount of fines, <<0.5 mm, was also present. SEM analysis reveals that the average pores were larger in the interior than on the surface of the agglomerated ash particles, and that no cenospheres were present, which was the case with TP-014 agglomerates that were also produced at approximately 1800°F.

TABLE 3.2-3

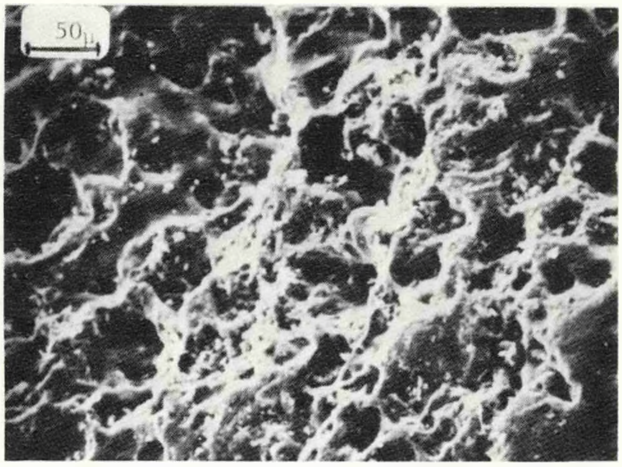
DISTRIBUTION OF POTASSIUM*

(K) From the Combustor ((Moles of Potassium)	(K) In Gasifier (Moles of Potassium Tiedup within)		
	(K_2SiO_3)	(KOH)	(KCN)
0.0142	0.0142	0.0000	0.0000
0.0050	0.0050	0.0000	0.0000
0.0019	0.0019	0.0000	0.0000

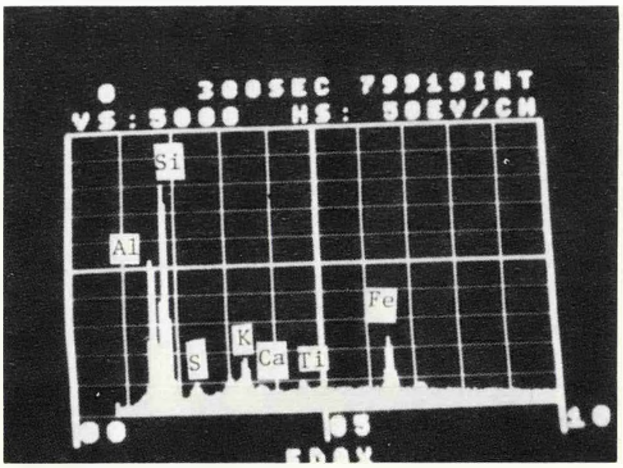
*Evolved from the combustor, between the various gas/liquid/solid phases in the gasifier.



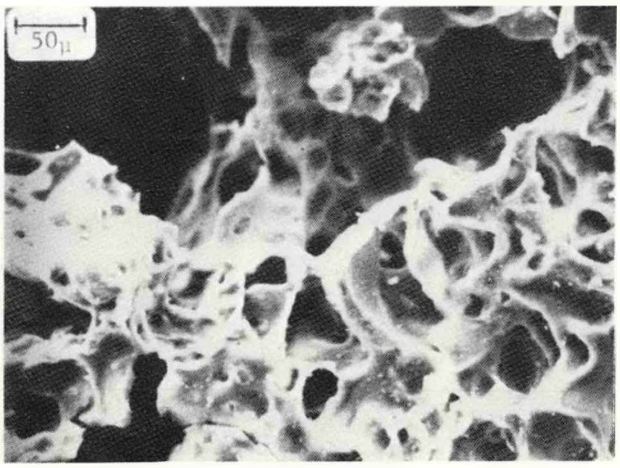
LIGHT PHOTOMICROGRAPH



SEM, PARTICLE SURFACE



TYPICAL EDAX



SEM, FRACTURED SURFACE

Figure 3.2-17. Typical Photomicrographs and EDAX From Test TP-016

1363-1

Leaching property was investigated by the continuous shake method. Table 3.2-4 shows the chemical composition of TP-016 solids and results of the 200 hour, aerobic leachate. It can be seen that the TP-016 leachate compares satisfactorily with the drinking water standards (DWS).

Regulations and criteria on solid waste disposal have been reviewed with special attention given to the US Environmental Protection Agnecy (EPA) current developments under the authority of the Resource Conservation and Recovery Act (RCRA, PL94-580, 1976).

Under the initial implementation strategy, EPA is focusing primary emphasis on three provisions: identification of hazardous waste characteristics; listing of hazardous wastes; and preparation of guidelines for handling and disposition.(1) Subtitle C of RCRA covers hazardous waste management and deals with identification and listing of hazardous waste. Under the authority of Section 3001, EPA is currently developing criteria and tentative identification methods for hazardous waste which may be one or more of the following wastes: ignitable, corrosive, infectious, reactive, radioactive or toxic.(2) Subtitle C Section 3002 to 3004 of RCRA also requires EPA to promulgate standards for generation, handling, treatment, storage and disposal of such waste within 18 months after enactment.(3) If the residue were not hazardous, it would still be subject to any restrictions developed by the individual states, under their respective management plans, within the guidelines established by EPA as required by the RCRA.

A draft has been written by the EPA Hazardous Management Office entitled "Hazardous Waste Guidelines and Regulations -- Criteria, Identification, and Listing of Hazardous Waste" which proposes leach test (toxic extraction procedure -- TEP). Preliminary testing of TEP is being carried out using PDU ash agglomerates.

The March 24, 1978 Draft of Sec. 3001 states that the "toxicant extraction" procedure is as follows:

1 - Weigh a representative sample of the waste to be tested. Separate sample into liquid and solid phases by either centrifugation, followed by filtration of the liquid through a 0.4 - 0.5 micron filter media, or by pressure filtration using a 0.4 - 0.5 micron filter having a surface area of at least 0.5 cm sq. per gram of sample. Save the liquid for further use.

2 - Grind the solid material, if necessary, to pass through a 9.5 mm (3/8") standard sieve.

3 - The solid material is taken and added to 8 times its weight of deionized water. The pH of the solution is then adjusted to pH 5 with 1:1 acetic acid or 1N sodium hydroxide. Samples are to be agitated during pH adjustment. pH measurements are to be determined electrometrically following standard calibration procedures.

TABLE 3.2-4

CHEMICAL CHARACTERISTICS OF ASH AGGLOMERATE
TEST TP-016 AND LEACHATE

Substance	Solid (ppm)	Leachate (200 hr aerobic, mg/l) Uncrushed	Crushed	DWS (mg/l)
Al	major	1	1	
Ag	< 1	<.01	0.01	0.05
As		<.001	<.001	0.05
B	100	2	2	
Ba	300	<1	<1	1.0
Be	1	<.002	<.002	
Bi	< 1	<.01	<.01	
Ca	>>1000	<20	<20	200
Cd	< 3	<.01	<.01	0.01
Co	10	<.02	<.02	
Cr	100	<.02	<.02	0.05
Cu	10	<.5	<.5	1.0
Fe	major	<.2	<.2	0.3
Hg		0.0006	0.0008	0.002
Mg	> 1000	5	5	150
Mn	100	0.01	<.01	0.05
Mo	10	0.02	<.02	
Na	1000	2	5	
Ni	30	<.02	<.02	2.0
Pb	< 10	<.02	<.02	0.05
Sb	< 50	<.1	<.1	
Se		<.002	<.002	0.01
Si	major	>5	>5	
Sn	< 10	<.05	<.05	1.0
Sr	100			
Ti	>>1000	<1	<1	
V	100	<.02	<.02	
Zn		<1	<1	5.0
Zr	1000	<1	<1	
SO_3		<1	<1	
S		<10	<10	
SO_4	0.1%	10	33	250
F		<1	<1	2.4
CI		<1	<1	250
Br		<1	<1	
NO_2		<1	<1	
NO_3(as N)		<1	<1	10
free C	33%			
TOC		<20	<20	
pH		7.8	9.0	6.5-9.2
S.C.(μmhos/cm)*		100	120	~750
TDS (Approx.)		<100	<100	500

DWS - NIPDWR, USPHS, and WHO Drinking Water Standards
Exceed DWS
*S.C. = Specific Conductance

4 - Samples are to be maintained at room temperature during extraction. Samples are to be agitated for a period of 24 $\pm$ 0.5 hours with pH to be maintained during leaching within the range 4.9 to 5.2. The preferred method of maintaining pH is with automatic titration. If the necessary equipment is not available, manual procedures can be employed.

5 - At the end of the 24 hour extraction period the solution is filtered as in step 1. The filtrate is then adjusted with deionized water so that its volume is 10 times the initial weight of solid sample (v(cc)/w(gm)). The liquid is combined with the original liquid phase and the solid reextracted with fresh extractant as in steps 3 and 4.

6 - At the end of the second extraction period the mixture is filtered; the concentration adjusted as in step 5, and the liquid phase combined with that from the previous separations. This combined liquid, and any precipitate that later forms, is designated as the Toxicant Extraction Procedure eluate.

Ash agglomerate TP-014-1 was tested according to this procedure. Since the agitation mode is not specified in the draft procedure, a magnetic stir was used for ease of continuous titration. Elutriate produced by this test was then analyzed for these chemical species for which tentative criteria exist, that is, ten times the primary drinking water standards according to the draft. Table 3.2-5 summarizes the results and compares them with the tentative criteria. It can be seen that the Cr in TP-014-1 elutriate exceeds the current tentative criteria and therefore should be given special attention in future tests.

Since many uncertainties exist in the present draft procedure, (for example, agitation mode, since leachate is a function of degree of agitation) and many changes and improvements of the current method are to be expected,(4) the above results will serve only as a preliminary indication of areas that might cause environmental concern.

3.2.3.2 Work Forecast for Next Quarter

Ash agglomerate samples of oxygen-blown gasifier test TP-018 will be obtained and tested for the environmental impact of disposal. New developments of regulations and test procedures of Resource Conservation and Recovery Act will be reviewed as related to the disposal of solid waste from the Westinghouse coal gasification process.

TABLE 3.2-5

CHEMICAL CHARACTERISTICS OF TEP*-ELUTRIATE OF PDU
ASH AGGLOMERATE TP-014-1

Substance	TEP Elutriate (ppm)	10 x DWS** (ppm)
Ag	<0.03	10 x 0.05
As	0.001	10 x 0.05
Ba	<1	10 x 1.0
Cd	0.007	10 x 0.01
Cr	0.86†	10 x 0.05
F	To be determined	10 x 2.4
Hg	0.0013	10 x 0.002
NO_3 (as N)	3	10 x 10
Pb	0.03	10 x 0.05
Se	0.002	10 x 0.01
pH	5.0	None
Specific Conductance (µmhos/cm)	730	None

*Toxic Extraction Procedure

**DWS - National Interim Primary Drinking Water Regulations, (NIPDWR), 1976.

† - Exceed 10 x NIPDWR/DWS

3.2.4 References

1. "Strategy for the Implementation of the Resource Conservation and Recovery Act of 1976 (Draft)", U.S. Environmental Protection Agency, December 5, 1977.

2. "Hazardous Waste Guidelines and Regulations -- Criteria, Identification, and Listing of Hazardous Waste", U.S. Environmental Protection Agency, 40 CFR 250 (Draft), March 24, 1978.

3. "Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities (Draft)", U.S. Environmental Protection Agency, March 24, 1978.

4. Corson, A., Friedman, D., and Viviani, D., U.S. Environmental Protection Agency, Hazardous Waste Management Office, Private Communication, March to September, 1978.