

ADVANCED COAL GASIFICATION SYSTEM
FOR ELECTRIC POWER GENERATION

FIRST QUARTERLY PROGRESS REPORT
FY-1980

Period October 1 to December 31, 1979

Program Manager:

L. A. Salvador

Contributors:

H. K. Altiner
M. J. Arthurs
E. J. Chelen
P. Cherish
Z. F. Hudson
S. Katta
D. L. Keairns
L. K. Rath
N. D. Rohatgi
M. B. Smith
C. C. Sun
E. J. Vidt
W. C. Yang

Date Published: January 25, 1980

Prepared For:

U.S. DEPARTMENT OF ENERGY
DIVISION OF FOSSIL FUEL PROCESSING
WASHINGTON, D. C. 20545

CONTRACT EF-77-C-01-1514

WESTINGHOUSE ELECTRIC CORPORATION
ADVANCED COAL CONVERSION DEPARTMENT
BOX 158, MADISON, PENNSYLVANIA 15663

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

TABLE OF CONTENTS

	<u>Page</u>
1.0 OBJECTIVE AND SCOPE OF WORK	1
1.1 Operation and Maintenance of the PDU	1
1.2 Laboratory Support Studies	2
2.0 TECHNICAL PROGRESS SUMMARY	3
2.1 Operation and Maintenance of the PDU	3
2.1.1 Gasifier Test TP-025-1	3
2.1.2 Gasifier Test TP-025-2	4
2.1.3 Gasifier Test TP-023-3	4
2.2 Process Analysis and Design	5
2.3 Process and Component Engineering and Design	5
2.4 Scale-Up Model	6
2.5 Laboratory Support Studies	6
2.5.1 Cold Flow and Analytical Modeling	6
2.5.2 Coal/Ash Behavior	7
2.5.3 Environmental Impact Studies	7
2.6 Summary Schedules	8
2.6.1 Operation and Maintenance of the PDU	8
2.6.2 Laboratory Support Studies	9
3.0 PDU TEST OPERATIONS AND RESULTS	10
3.1 Gasifier Operation	10
3.1.1 Gasifier Test TP-025-1	10
3.1.2 Gasifier Test TP-025-2	11
3.1.3 Gasifier Test TP-023-3	31
3.2 Product Characterization	31
3.2.1 Solids Analyses	31
3.2.2 Liquids Analyses	31
3.2.3 Gas Analyses	38
3.3 Environmental, Safety and Health Programs	38
4.0 PROCESS ANALYSIS AND DESIGN	39

TABLE OF CONTENTS (Continued)

	<u>Page</u>
5.0 PROCESS AND COMPONENT ENGINEERING AND DESIGN	46
5.1 Oxygen System Upgrade	46
5.2 Fines Recycle and Utilization	46
5.3 Heat Recovery	47
5.4 Product Gas Scrubbing/Cooling Upgrade	47
5.5 Electrical and Instrumentation Upgrade	47
6.0 SCALE-UP MODEL	48
7.0 LABORATORY SUPPORT STUDIES	50
7.1 Cold Flow and Analytical Modeling	50
7.1.1 Jet Phenomena	50
7.1.2 Particle Separation	50
7.1.3 Distributor/Plenum Design	56
7.2 Coal Behavior Studies	56
7.2.1 Gasification	56
7.2.2 Ash Agglomeration	56
7.2.3 Coal and Ash Chemical Phenomena	59
7.3 Environmental Impact Studies	59

LIST OF ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
3.2-1	PDU Gasifier Process Schematic for Solids, Liquids, Gas and Particulate Sampling Locations	33
3.2-2	Typical Size Distribution of Feedstock and Reactor Solids, Test TP-025-1, Set Point 2B	36
4.0-1	Scanning Micrographs of a Sample of Cyclone Buildup, Test TP-023-1	40
4.0-2	Spherical Glassy Particles from a Sample of Cyclone Buildup	41
4.0-3	Scanning Micrographs of Glassy, Clear and Transparent Particles	42
4.0-4	Scanning Micrographs of Glassy, Colored and Shiny Particles	43
4.0-5	Effect of Water Spray in the Freeboard Area of the Gasifier	44
6.0-1	Cold Flow Scale-up Facility Takes Shape	49
7.1-1	Rate of Particle Separation at a Velocity of 25 cm/s	52
7.1-2	Rate of Particle Separation at a Velocity of 42 cm/s	53
7.1-3	Rate of Particle Separation at a Velocity of 71 cm/s	54
7.1-4	Rate of Particle Separation at a Velocity of 103 cm/s	55
7.2-1	Reactivity of Coke Breeze Fines	57
7.2-2	Reactivity of Coke Breeze Fines	58
7.2-3	Schematic Diagram of Ash Agglomeration Test Facility	60
7.2-4	Ash Agglomeration Reactor	61
7.3-1	SEM and EDX of Test TP-020-2	65

LIST OF TABLES

<u>Table</u>	<u>Page</u>
3.1-1 Chronology of Significant Events, Test TP-025-1	12
3.1-2 Summary of Operating Data for Single-Stage Air-Blown Gasifier Test TP-025-1	13
3.1-3 Gasifier Heat and Material Balances, Test TP-025-1, Set Point 1	14
3.1-4 Gasifier Heat and Material Balances, Test TP-025-1, Set Point 2A	16
3.1-5 Gasifier Heat and Material Balances, Test TP-025-1, Set Point 2B	18
3.1-6 Gasifier Heat and Material Balances, Test TP-025-1, Set Point 2C	20
3.1-7 Gasifier Heat and Material Balances, Test TP-025-1, Set Point 3A	22
3.1-8 Gasifier Heat and Material Balances, Test TP-025-1, Set Point 3B	24
3.1-9 Gasifier Heat and Material Balances, Test TP-025-1, Set Point 4	26
3.1-10 Chronology of Significant Events, Test TP-025-2	29
3.1-11 Summary of Nominal Hourly Average Operating Data for Single-Stage Oxygen-Blown Gasifier Test TP-025-2	30
3.1-12 Chronology of Significant Events, Test TP-023-3	32
3.2-1 Feedstocks and Reactor Solids Product Characterization Data (As Received), Air-Blown Gasifier Test TP-025-1	34
3.2-2 Quench Scrubber Water Analysis, Test TP-025-1	37
7.3-1 Particle Size Distribution by Sieve Analysis Test TP-020-2	62
7.3-2 Particle Size Distribution by TV Image Analysis, Test TP-020-2	63
7.3-3 Leachate Characteristics of Test TP-020-2 Ash Agglomerates by 200-Hour Continuous Shake Test	66
7.3-4 Leachate Characteristics of Test TP-020-2	67
7.3-5 Leachate Characteristics from RCRA/EP Test of PDU and Conventional Coal Ash	68

SECTION 1.0

OBJECTIVE AND SCOPE OF WORK

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

1.1 OPERATION AND MAINTENANCE OF THE PDU (Task 1)

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

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

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

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

Under Task 2, present work involves the modification and upgrading of the PDU to achieve better performance as dictated by the results of prior testing efforts. One subtask includes modification to upgrade the high-pressure oxygen system to support the testing program. Specifically, this work involves the oxygen supply, process piping, flow controls, instrumentation and

related process hardware. The PDU will also be modified to provide the capability of evaluating the equipment and subsystems necessary for heat recovery and fines recycle tests using the PDU-derived fuel gas. Modifications to both the PDU and the Test and Development Center are planned to permit combustion evaluation tests of medium and low-Btu gas from the PDU.

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

1.2 LABORATORY SUPPORT STUDIES (Task 3)

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

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

For the Laboratory Support experimental program, test facilities include:

- Two flexible 1-foot diameter semicircular units which operate at atmospheric pressure and ambient temperature for fluidization studies.
- A fluidized bed test unit, operating at design temperature and pressure, for devolatilization and gasification investigations.
- An atmospheric pressure fluidized bed agglomerator, operating at design temperatures.
- A pressurized thermo-gravimetric analysis system, differential thermal analysis and a pressurized high-temperature fluidized bed test unit to conduct investigations in gas cleaning and gasification.

SECTION 2.0

TECHNICAL PROGRESS SUMMARY

2.1 OPERATION AND MAINTENANCE OF THE PDU (Task 1)

Three single-stage gasifier tests, TP-025-1, TP-025-2 and TP-023-3, were completed this quarter. A summary description of these tests follows.

2.1.1 Gasifier Test TP-025-1

The objectives of TP-025-1, a single-stage, air-blown gasifier test, were to (1) determine the operational characteristics of the modified (shortened and reduced-diameter) gasifier annulus and the effect of the new geometry on ash separation efficiency, (2) demonstrate operation with air transport of coal through the axial feed tube, (3) evaluate product gas composition and process efficiency as a function of recycle gas-to-coal ratio, and (4) evaluate performance of a pipeline delumper which was installed in the ash withdrawal subsystem.

Accomplishments of test TP-025-1 are as follows:

- Four set points were conducted, including one reference set point using coke breeze. A total of 234 hours of operation was achieved, with approximately 62 tons of Indiana #7 coal processed in 146 hours of coal operation.
- Operability and automatic temperature control of the modified gasifier annulus was successfully demonstrated. Ash concentrations of 60 percent or greater were obtained in the withdrawal during all steady-state periods with coal feed.
- Air was successfully utilized as the transport medium for the axial coal feed system. Use of air in place of recycle gas for this purpose permitted the gasifier to operate with a recycle gas-to-coal ratio of 1.5 and resulted in a significant improvement in the product gas heating value.
- The in-line delumper that was installed in the ash withdrawal system was replaced during the test with a pipe spool section. Initial evaluation indicated that, with minor modifications in the seal area and additional run-in adjustments, the delumper could be operated reliably in subsequent tests.

2.1.2 Gasifier Test TP-025-2

Test TP-025-2 was a single-stage, air-blown, gasifier feedstock characterization test. Modifications that were evaluated during the test included a reduced L/D ash withdrawal section and a single multifeed system with three feed pickup points. The objectives of test TP-025-2 were to (1) characterize gasifier performance with Indiana #7, Ohio #9 and Upper Freeport coals, (2) evaluate operational performance of the modified L/D ash withdrawal configuration and the distributor in the booster at higher booster-to-sparger flow ratios, (3) evaluate the operational performance and process enhancement of the single multifeed on reduction of recycle gas usage and fines consumption, (4) evaluate computer control of pressurization and depressurization rates, (5) evaluate water quench of the product gas to study cyclone deposition and temperature effects, and (6) evaluate operational performance of the rebuilt in-line delumper in the ash withdrawal system.

The following accomplishments were achieved during test TP-025-2:

- A total of 115 hours of hot operation was achieved, including 56 hours of operation with Indiana #7 coal, while processing 30 tons of the feedstock. One data point with Indiana #7 coal was achieved at set point conditions, and three steady-state periods of 11, 6 and 5 hours were achieved during this set point.
- Multi-pickup feed testing with coke breeze at cold flow conditions was successfully completed.
- Computer control of pressurization and depressurization rates was successfully performed.
- During delumper operation, repeated belt failures initially caused withdrawal problems. A chain drive was adapted to the delumper and proved satisfactory until metal pieces sheared from the struts supporting the annulus liner and jammed the rotor. An interim shutdown resulted. Following repair of the delumper, no further incidents occurred and satisfactory performance was achieved throughout the remainder of the test.

2.1.3 Gasifier Test TP-023-3

Test TP-023-3 continued the series of feedstock characterization tests intended to evaluate the feasibility of producing medium Btu gas in the single-stage oxygen/steam-blown gasifier. This test was designed to use Upper Freeport and Texas lignite coals as the feedstocks. The major goal of this test was the evaluation of a developmental oxidant feed tube. The objectives of test TP-023-3 also included: (1) demonstration of the operability of the gasifier with an oxygen concentration range of 47 to 65 percent with a modified oxidant tube, (2) continued evaluation of the gasifier product gas water quench as a method of reducing cyclone buildup, (3) continued evaluation of the multifeed system that was installed for test TP-025-2, and (4) a functional checkout and shakedown of the heat recovery test apparatus.

A chronological summary of significant events is listed in Section 3.0. Further information on the results of this test will be reported at a later date.

2.2 PROCESS ANALYSIS AND DESIGN

A review of the data and the effect of various modifications on cyclone deposits was conducted this quarter. Based on this review, it is tentatively concluded that the mechanism of deposit formation is the result of sticky particles or liquid droplets out of the combustion and/or gasification zone impacting on the hot refractory cyclone walls as a result of change in direction of flow. Also, there must be different "glue" generated from Ohio #9 coal as compared with Pittsburgh seam coal. Chemical, X-ray and microprobe analyses of the deposits in the TP-018 test series with Pittsburgh seam coal showed the presence of $Fe_{1-x}S$ compound as the predominant phase. However, with Ohio #9 coal in test TP-020-2, FeS was absent as a major phase and Fe_2O_3 and SiO_2 were present as major compounds.

The most effective modification to date for alleviating cyclone deposits has been a water spray nozzle which was installed in the freeboard area of the gasifier to quench particles with a liquid film and render them nonsticky. During test TP-025-2, with 8 hours of Ohio #9 coal and 50 hours of Indiana #7 coal, water spray in the freeboard area of the gasifier was used to cool the gas and particles from 1800°F to 1300°F. At this temperature, the deposit was practically eliminated. However, long-duration tests with Pittsburgh seam and Ohio #9 coals are necessary before any firm conclusions can be drawn about the effect of water spray.

2.3 PROCESS AND COMPONENT ENGINEERING AND DESIGN

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

- The high-pressure oxygen supply tank was installed, connected and leak checked.
- A new superheater, boiler heating elements, and miscellaneous electrical hardware were requisitioned for the PDU steam system.
- The preliminary system design for fines recycle and utilization was completed.
- An investigation of the efficiency of the existing cyclone was initiated.
- Installation and system checkout of the heat recovery test apparatus were completed.

- Purchase requisitions for fabrication and product characterization equipment were issued for the new total condensables analyzer (TCA), and drawings are being finalized for the TCA sampling system, sample cooler and internals, and cyclone.
- A new pH analyzer was installed in the makeup/supply water pit.
- The Phase I evaluation study of the PDU power upgrade was completed.

2.4 SCALE-UP MODEL

During this report period, significant progress was made in the construction of the cold-flow scale-up facility:

- The compressor building shell was erected, the insulation and inside panels were installed, and the cooling water system was leak-checked and connected. Also, the gas supply line to the compressor building was installed.
- The model foundation forms were installed, the floor slab was poured and the steel framework for the model enclosure was delivered to the construction site.
- Installation of the storm sewer system was completed, and work was initiated on the miscellaneous pads and foundations around the outside of the model and compressor building.
- All utilities to the site were delivered and final grading has begun.
- The final concrete work for the baghouse support and loading bins was completed.
- The subcontract with the Architect-Engineer for structural design and component and piping layouts was completed.
- Piping and plant layout drawings were issued for construction purposes.

2.5 LABORATORY SUPPORT STUDIES (Task 3)

2.5.1 Cold Flow and Analytical Modeling

Tests were completed on the semicircular column to investigate mass transfer of gases through jets and between the jet and the emulsion phase. The tests simulate the PDU oxidant feed system. Experiments were completed to extend previous char-ash separation tests to simulate particle density relationships obtained in the PDU tests. Previous operating velocity recommendations are

supported by the tests and indicate the practical operating velocity range to achieve a desired separation may be relatively large. The time required to achieve the separation was $\sqrt{15}$ seconds and was found to be independent of the operating velocity.

2.5.2 Coal/Ash Behavior

Reactivities of several chars were studied in the laboratory fluidized bed. Tests were performed on a thermogravimetric analyzer to investigate the effect of sample weight and gas flow rate on the rate of carbon-steam reaction.

A shakedown test was successfully conducted on the ash agglomeration test facility with coke breeze as the feedstock.

The injection of water in the freeboard region of the gasifier reduced the ash buildup to a thin layer on the cyclone wall. X-ray and microprobe analyses of a sample of this deposit did not indicate the presence of FeS. The injection of water, in cooling the exit gas from the gasifier, changed the FeS liquid droplets into FeS solid particles which no longer selectively deposited on the cyclone wall. To identify the binding material in deposits, particles that appeared, under the microscope, to have exited in a molten state were isolated from a sample of cyclone deposit. Microprobe analysis showed that those particles were made of compounds of the K-Al-Si and Fe-K-Al-Si systems. It appears that these compounds may be part of the binding material in ash deposits.

2.5.3 Environmental Impact Studies

Environmental impact studies on ash agglomerates from test TP-020-2 were completed using Westinghouse standard leach tests. Tests with acidic acetate buffer resulted in leachate, manganese and iron exceeding 10 times the drinking water standard, which are being proposed as the leachate criteria. All samples were non-hazardous according to the proposed RCRA criteria.

2.6 SUMMARY SCHEDULES

2.6.1 Operation and Maintenance of the PDU (Task 1)

Task Description	FY 1980			FY 1980		
	OCT	NOV	DEC	JAN	FEB	MAR
<u>Modified Gasifier Tests</u>						
Gasifier Oxygen-Blown		—————				
Gasifier Air-Blown	—————					
Maintenance and Test Modification				-----	-----	
<u>PDU Plant Modifications</u>						
Gas Characterization Upgrading					-----	-----
Heat Recovery Phase I	-----	-----	▲			
Oxygen System Upgrading	-----	-----	-----	-----	-----	-----
Coal Preparation	-----	-----	-----	-----	-----	-----
Power Distribution Modification	-----	-----	-----	-----	-----	-----
Fines Collection and Recycle	-----	-----	-----	-----	-----	-----
Structure Modifications	-----	-----	-----	-----	-----	-----
PDU/TDC Pipeline	-----	-----	-----	-----	-----	-----
CFSF Model	-----	-----	-----	-----	-----	-----

LEGEND:

- Task Complete ▲
- Test —————
- Design/Approval ········
- Procurement - · - · - ·
- Construction/
Modification - / - / - /

2.6.2 Laboratory Support Studies (Task 3)

Task Description	FY 1980			FY 1980		
	OCT	NOV	DEC	JAN	FEB	MAR
Cold Flow & Analytical Modeling Gasification System						
Jet Phenomena						
Particle Separation						
Distributor Design						
Coal Behavior						
Devolatilization/Gasification						
Coal Characterization Tests						
Gasification Model						
Ash Agglomeration						
Reactor Tests						
Model Development						
Coal & Ash Chemical Phenomena						
Formulate Mechanism						
Deposit Prevention						
Gas Cleaning						
Environmental Impact Studies-Solids Disposal						
Agglomerate Characterization						
Leaching Property						
Residual Activity						
Systems Analysis-Gasification System						
Component Models						
Integrated System Model						
Process & Systems Engineering Consultation						

SECTION 3.0

PDU TEST OPERATIONS AND RESULTS

3.1 GASIFIER OPERATION

3.1.1 Gasifier Test TP-025-1

An air-blown reactor characterization and design test, TP-025-1, was conducted the latter half of September. Several modifications to the single-stage gasifier system were implemented, including a revised annulus, a pipeline delumper located in the ash withdrawal subsystem, and pneumatic transport of the coal employing air as the conveying medium. The objectives of test TP-025-1 were to: (1) determine the operational characteristics of the modified (shortened and reduced-diameter) gasifier annulus and the effect of the new geometry on ash separation efficiency, (2) demonstrate operation with air transport of coal through the axial feed tube, and (3) evaluate product gas composition and process performance as a function of recycle gas-to-coal ratio.

During the first few days of the test period, the pressure leak check and hot air dryout proceeded normally until packing problems on the delumper occurred. The packing was replaced and run in per the manufacturer's instructions only to fail two days later. Since this was the first attempt to operate the delumper at system pressure and temperature, it was decided to remove it from the system pending an evaluation of the shaft seal design.

Set point 1 was to be a functional checkout and evaluation of the revised annulus using coke breeze as the feedstock. The set point was conducted as planned except that the cyclone was operated in the negative ΔP mode. Throughout the duration of this set point, the ash withdrawal starwheel was controlled automatically to maintain the desired annular temperature profile.

Set point 2 was planned to provide a base case for air-blown Indiana #7 coal operation. Operating conditions were very close to those planned with only two exceptions: steam flow to the grid was slightly higher (20 percent), and the gasifier freeboard temperature was lowered from 1850°F to 1820°F since the feed system capacity was insufficient to maintain the bed at the higher temperature. This set point was terminated after 45 hours of operation.

Set point 3 was run at conditions similar to those of set point 2 but utilized air transport of the coal feed through the axial feed tube. This set point was disrupted by an electrical fault which rendered almost one-half of the PDU control panel inoperable for a 7-hour period and by four feedline plugs which were attributed to wet feedstock. Between the disruptions, two steady-state periods were recorded while operating in the air transport mode at the desired recycle gas-to-coal ratio of approximately 1.5. This set point demonstrated air transport to be a safe and reliable alternative to recycle gas transport of feed material.

Throughout set points 2 and 3, the product gas cooling system had been accumulating solids as a result of a combination of the high carryover through the cyclone and mechanical problems with the water makeup pumps. To alleviate this operating problem, coke breeze was fed following set point 3 and the gasifier was idled for 12 hours while the product gas cooling system was purged.

Set point 4 was planned to utilize air transport of Indiana #7 coal at a lower steam rate to investigate possible kinetic effects at different gasifier bed levels. The gasifier operated for 12 hours at set point conditions before ash withdrawal problems were experienced, causing shutdown. Post-test inspection revealed that the annulus was blocked with large chunks of material which had built up on several thermowells near the combustion zone. These few thermowells had been installed at a greater insertion depth than normally used. The usual depth is 2 inches and these were inserted 6 to 8 inches into the bed.

A chronology of test events is shown in Table 3.1-1 and a summary of nominal operating data is presented in Table 3.1-2. Heat and material balances are presented in Tables 3.1-3 to 3.1-9.

Notable accomplishments of test TP-025-1 are as follows:

- A total of 234 hours of hot operation was logged during the test, including 146 hours with coal feed, while processing 62 tons of coal.
- Operability and automatic temperature control of the modified gasifier annulus was successfully demonstrated. Ash concentrations of 60 percent or greater were obtained in the withdrawal during all steady-state periods with coal feed.
- Air was successfully utilized as the transport medium for the axial coal feed system. Use of air in place of recycle gas for this purpose permitted the gasifier to operate with a recycle gas-to-coal ratio of 1.5 and resulted in a significant improvement in the product gas heating value.

3.1.2 Gasifier Test TP-025-2

A single-stage, air-blown, gasifier feedstock characterization test, TP-025-2, was conducted from October 27 to November 11, 1979. A reduced L/D ash withdrawal section and a single feed system with three feed pickup points were the two modifications that were evaluated during this test. The objectives of test TP-025-2 were to (1) characterize gasifier performance with Indiana #7, Ohio #9 and Upper Freeport coals, (2) evaluate operational performance of the modified L/D ash withdrawal configuration and the spread multihole distributor in the booster at higher booster-to-sparger flow ratios, (3) evaluate the operational and process performance enhancement of the single multifeed on reduction of recycle gas usage and fines consumption, (4) evaluate computer

TABLE 3.1-1

CHRONOLOGY OF SIGNIFICANT EVENTS, TEST TP-025-1

Date	Time	Event
Sept. 11	1335	Pre-test plant readiness check completed. System pressure leak test initiated.
Sept. 12	1315	Completed pressure leak check; initiated hot air heatup.
Sept. 13	2130	Completed hot air heatup.
Sept. 14	0510	Initiated coke breeze feed to build bed in gasifier.
Sept. 17	0545	Autogenous ignition of coke breeze achieved.
	1847/ 1920	Seal packing failure on delumper - replaced delumper with pipe spool.
Sept. 19	1825	Initiated coke breeze feed to build bed in gasifier.
Sept. 20	0110	Autogenous ignition of coke breeze achieved.
	2355	Initiated fines recycle to gasifier.
Sept. 21	0030	<u>Achieved Set Point 1 test conditions.</u>
	1845	Initiated Indiana #7 coal feed to gasifier.
Sept. 22	0315	<u>Achieved Set Point 2 test conditions.</u>
Sept. 24	0535	Initiated air transport of coal.
	1415/ 2140	Experienced loss of electrical power to ash withdrawal, fines recycle and water quench systems. Repaired electrical systems and functionally checked out operating systems.
Sept. 25	1730	<u>Achieved Set Point 3 modified test conditions.</u>
Sept. 26/ Sept. 27	0730/ 0260	Experienced two feedline plugs; replaced makeup water pump G-120A.
Sept. 28	0730	Initiated transition to set point 4 test conditions, ash withdrawal rates erratic.
	1800	<u>Achieved Set Point 4 test conditions.</u>
Sept. 29	0600	Terminated test TP-025-1 and initiated shutdown sequence.

TABLE 3.1-2

SUMMARY OF OPERATING DATA FOR SINGLE-STAGE AIR-BLOWN GASIFIER TEST TP-025-1

SET POINT		1	2A	2B	2C	3A	3B	4
TEST RUN DATE AND TIME (1979)	Unit	9-21 Hours 0730 to 1510	9-22 Hours 0330 to 0800	9-22/23 Hours 0900 to 1700	9-23 Hours 1800 to 2400	9-25/26 Hours 1900 to 0300	9-27 Hours 0030 to 0730	9-27/28 Hours 1730 to 2330
<u>MEASURED GASIFIER PARAMETERS</u>								
Freeboard Temperature	OF	1808	1845	1818	1817	1828	1811	1806
Gasifier Bed Temperature	OF	1890	1913	1889	1892	1885	1895	1898
Ash Annulus Temperature	OF	364	406	410	482	402	452	411
Average Bed Height*	feet	10.35	10.0	9.9	9.6	10.1	9.5	8.7
System Pressure	psig	231	231	231	231	221	221	221
Average Gasifier Bed Density	lb/ft ³	24.43	14.38	13.62	14.36	12.70	11.90	9.44
Average Annulus Density	lb/ft ³	24.28	14.56	13.81	13.77	13.28	14.48	10.78
Freeboard Gas Velocity	fps	.818	1.603	1.524	1.489	1.432	1.488	1.416
Air Tube Velocity	fps	49.08	93	87	88	82.69	83.55	78.22
Coal Feed Material		L-60 Coke Breeze	Indiana #7 Coal	Indiana #7 Coal	Indiana #7 Coal	Indiana #7 Coal	Indiana #7 Coal	Indiana #7 Coal
Coal Feed Rate	lb/hr	317	1075	996	1010	1070	1082	987
Fines Feed Material		Recycled Fines	Recycled Fines	Recycled Fines	Recycled Fines	Recycled Fines	Recycled Fines	Recycled Fines
Fines Feed Rate	lb/hr	273	127	261	265	232	244	247
Carryover to Water System**	lb/hr	223	114.6	205	180	100	100	100
Ash Withdrawal Rate	lb/hr	111	75	85	94	108	89	102
<u>PRODUCT GAS ANALYSIS, DRY BASIS</u>								
Carbon Monoxide	%	7.73	17.18	15.57	16.20	17.22	16.35	16.77
Carbon Dioxide	%	18.74	10.07	12.38	11.50	10.90	15.35	17.92
Methane	%	0	.29	.31	.31	.53	.51	.38
Nitrogen	%	70.59	62.76	61.58	61.75	59.65	57.65	56.05
Oxygen	%	0	0	0.0	0.0	0.0	0.0	0.0
Hydrogen	%	2.94	11.39	10.59	10.38	11.70	10.14	8.89
HHV, Dry Basis (Gas Chromatograph)	Btu/scf	34.62	94.15	86.49	86.48	98.49	91.10	86.29
<u>OVERALL PROCESS RATES</u>								
Steam/Coal Ratio, MAF+	lb/lb	---	.35	.42	.42	.30	.38	.27
Oxygen/Coal Ratio, MAF	lb/lb	---	---	---	---	---	---	---
Total Moisture/Coal Ratio, MAF	lb/lb	---	.51	.58	.58	.53	.53	.43
Recycle Gas/Coal Ratio, MAF	lb/lb	---	2.64	2.65	2.55	1.80	1.96	2.06
<u>SOLIDS ANALYSIS</u>								
Ash Content - Fines	%	26.68	13.47	27.30	29.86	27.51	35.74	23.38
Ash Content - Feedstock	%	13.15	8.56	8.56	8.56	9.51	9.51	8.44
Ash Content - Bed	%	17.05	33.39	28.90	45.19	31.60	39.60	38.97
Ash Content - Agglomerate	%	40.26	66.90	64.98	68.01	67.90	76.47	59.17

* From jet inlet to top of bed.

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

+ Moisture and ash free.

TABLE 3.1-3

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

STREAM NO.		1	2	3	4	5	6	7	8	9	10
STREAM DESCRIPTION		STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING FLOW	BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-61)
TOTAL	LB/HR	254.00	0.00	0.00	1912.00	154.00	0.00	527.50	395.37	718.94	0.00
TEMPERATURE	F	424.0	0.0	0.0	1004.0	98.0	158.0	596.0	158.0	158.0	0.0
GAS	LB/HR	254.00	0.00	0.00	1912.00	154.00	0.00	527.50	395.37	718.94	0.00
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	30.310	30.310	30.310	30.310	30.310
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	7.89	7.89	7.89	7.89	7.89
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	19.10	19.10	19.10	19.10	19.10
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	2.82	2.82	2.82	2.82	2.82
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	69.91	69.91	69.91	69.91	69.91
O2	VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	100.00	100.00	100.00	0.00	0.00	0.29	0.29	0.29	0.29	0.29
ELEMENTS											
CARBON	LB/HR	0.000	0.000	0.000	0.000	42.028	0.000	56.422	42.289	76.899	0.000
HYDROGEN	LB/HR	28.423	0.000	0.000	0.000	0.000	0.000	1.091	0.818	1.407	0.000
OXYGEN	LB/HR	225.577	0.000	0.000	443.619	111.972	0.000	129.160	96.806	176.035	0.000
NITROGEN	LB/HR	0.000	0.000	0.000	1443.592	0.000	0.000	340.829	255.454	464.523	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	24.789	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	40.028	0.000	0.000	443.163	0.674	0.000	296.490	178.262	324.155	0.000

(Continued)

TABLE 3.1-3 (Continued)

STREAM NO.		11	12	13	14	15	16	17	18		
STREAM DESCRIPTION		COAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	FINE FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS. G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	907.97	0.00	0.00	664.21	4139.95	1132.16	114.00	2.00	0.00	2.64
TEMPERATURE	F	237.0	0.0	0.0	300.0	1642.0	461.0	427.0	1850.0	0.0	0.0
GAS	LB/HR	590.97	0.00	0.00	391.21	4117.65	853.16	0.00	0.00	0.00	0.00
SOLID	LB/HR	317.00	0.00	0.00	273.00	22.30	279.00	114.00	2.00	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		30.310	32.000	44.011	30.310	29.019	30.310	0.000	0.000	0.000	0.000
CO	VOLUME %	7.89	0.00	0.00	7.89	6.95	7.89	0.00	0.00	0.00	0.00
CO2	VOLUME %	19.10	0.00	100.00	19.10	16.86	19.10	0.00	0.00	0.00	0.00
H2	VOLUME %	2.82	0.00	0.00	2.82	2.64	2.82	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 %	69.91	0.00	0.00	69.91	63.50	69.91	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.29	0.00	0.00	0.29	10.04	0.29	0.00	0.00	0.00	0.00
ELEMENTS											
CARBON	LB/HR	326.004	0.000	0.000	239.386	421.968	293.139	66.622	1.608	0.000	-0.039
HYDROGEN	LB/HR	3.029	0.000	0.000	1.355	36.331	2.323	0.137	0.004	0.000	-7.158
OXYGEN	LB/HR	149.011	0.000	0.000	95.787	1151.290	208.898	0.000	0.016	0.000	4.745
NITROGEN	LB/HR	384.848	0.000	0.000	254.731	2524.404	553.251	0.821	0.015	0.000	2.083
SULFUR	LB/HR	3.392	0.000	0.000	2.402	0.196	2.455	0.752	0.016	0.000	40.979
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	41.685	0.000	0.000	72.836	5.950	74.437	45.896	0.341	0.000	-10.568
HEAT CONTENT											
	KBTU/HR	4117.176	0.000	0.000	3045.583	3750.558	3377.263	963.603	24.008	425.000	-1.124

TABLE 3.1-4

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

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	0.00	0.00	4402.00	160.00	0.00	685.39	436.42	965.60	0.00
TEMPERATURE	F	411.0	0.0	0.0	749.0	105.0	160.0	596.0	160.0	160.0	0.0
GAS	LB/HR	297.00	0.00	0.00	4402.00	160.00	0.00	685.39	436.42	965.60	0.00
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	26.691	26.691	26.691	26.691	26.691
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	17.09	17.09	17.09	17.09	17.09
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	10.46	10.46	10.46	10.46	10.46
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	11.23	11.23	11.23	11.23	11.23
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.30	0.30	0.30	0.30	0.30
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	60.52	60.52	60.52	60.52	60.52
O2	VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	100.00	100.00	100.00	0.00	0.00	0.39	0.39	0.39	0.39	0.39
ELEMENTS											
CARBON	LB/HR	0.000	0.000	0.000	0.000	43.665	0.000	85.903	54.699	121.023	0.000
HYDROGEN	LB/HR	33.234	0.000	0.000	0.000	0.000	0.000	6.322	4.025	8.906	0.000
OXYGEN	LB/HR	263.766	0.000	0.000	1021.344	116.335	0.000	157.770	100.460	222.271	0.000
NITROGEN	LB/HR	0.000	0.000	0.000	3323.583	0.000	0.000	435.396	277.240	613.400	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	57.072	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	44.991	0.000	0.000	728.872	0.935	0.000	1016.805	594.549	1315.456	0.000

(Continued)

TABLE 3.1-4 (Continued)

STREAM NO.		11	12	13	14	15	16	17	18		
STREAM DESCRIPTION		COAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	FINE FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	1641.28	0.00	0.00	496.06	7485.61	1450.92	75.00	2.00	0.00	0.77
TEMPERATURE	F	123.0	0.0	0.0	313.0	1744.0	453.0	445.0	1850.0	0.0	0.0
GAS	LB/HR	566.28	0.00	0.00	369.06	7371.01	1034.92	0.00	0.00	0.00	0.00
SOLID	LB/HR	1075.00	0.00	0.00	127.00	114.60	416.00	75.00	2.00	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		26.691	32.000	44.011	26.691	26.052	26.691	0.000	0.000	0.000	0.000
CO	VOLUME %	17.09	0.00	0.00	17.09	15.72	17.09	0.00	0.00	0.00	0.00
CO2	VOLUME %	10.46	0.00	100.00	10.46	9.22	10.46	0.00	0.00	0.00	0.00
H2	VOLUME %	11.23	0.00	0.00	11.23	10.43	11.23	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.30	0.00	0.00	0.30	0.27	0.30	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 %	60.52	0.00	0.00	60.52	57.45	60.52	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.39	0.00	0.00	0.39	6.90	0.39	0.00	0.00	0.00	0.00
ELEMENTS											
CARBON	LB/HR	761.339	0.000	0.000	150.522	950.845	471.247	23.768	1.270	0.000	-18.895
HYDROGEN	LB/HR	65.961	0.000	0.000	3.887	102.348	11.126	0.135	0.006	0.000	7.128
OXYGEN	LB/HR	339.331	0.000	0.000	88.331	1861.720	249.294	0.172	0.034	0.000	8.590
NITROGEN	LB/HR	375.962	0.000	0.000	235.397	4554.523	660.556	0.135	0.014	0.000	0.870
SULFUR	LB/HR	6.665	0.000	0.000	0.813	0.733	2.662	0.487	0.008	0.000	47.964
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	92.020	0.000	0.000	17.107	15.437	56.035	50.303	0.668	0.000	-12.202
HEAT CONTENT											
	KBTU/HR	13125.073	0.000	0.000	2016.589	14499.384	6413.975	352.190	19.183	425.000	-15.212

TABLE 3.1-5

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

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	331.00	0.00	0.00	4150.00	186.00	0.00	701.47	440.14	976.56	0.00
TEMPERATURE	F	411.0	0.0	0.0	749.0	107.0	157.0	596.0	157.0	157.0	0.0
GAS	LB/HR	331.00	0.00	0.00	4150.00	186.00	0.00	701.47	440.14	976.56	0.00
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	27.026	27.026	27.026	27.026	27.026
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	15.84	15.84	15.84	15.84	15.84
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	11.45	11.45	11.45	11.45	11.45
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	10.55	10.55	10.55	10.55	10.55
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.32	0.32	0.32	0.32	0.32
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	0.00	0.00	78.06	0.00	61.52	61.52	61.52	61.52	61.52
O2	VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	100.00	100.00	100.00	0.00	0.00	0.29	0.29	0.29	0.29	0.29
ELEMENTS											
CARBON	LB/HR	0.000	0.000	0.000	0.000	50.761	0.000	86.070	54.004	119.022	0.000
HYDROGEN	LB/HR	37.039	0.000	0.000	0.000	0.000	0.000	6.000	3.770	8.364	0.000
OXYGEN	LB/HR	293.961	0.000	0.000	964.732	135.239	0.000	162.086	101.701	225.649	0.000
NITROGEN	LB/HR	0.000	0.000	0.000	3139.359	0.000	0.000	447.309	280.665	622.724	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	53.909	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	50.142	0.000	0.000	688.471	1.165	0.000	969.010	554.746	1230.843	0.000

(Continued)

TABLE 3.1-5 (Continued)

STREAM NO.		11	12	13	14	15	16	17	18		
STREAM DESCRIPTION		COAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	FINE FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	1567.79	0.00	0.00	630.40	7437.22	1369.47	85.00	2.00	0.00	1.09
TEMPERATURE	F	125.0	0.0	0.0	285.0	1722.0	453.0	0.0	1827.0	0.0	0.0
GAS	LB/HR	571.79	0.00	0.00	369.40	7232.22	1037.47	0.00	0.00	0.00	0.00
SOLID	LB/HR	996.00	0.00	0.00	261.00	205.00	332.00	85.00	2.00	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		27.026	32.0000	44.011	27.026	26.613	27.026	0.0000	0.0000	0.0000	0.0000
CO	VOLUME %	15.84	0.00	0.00	15.84	14.50	15.84	0.00	0.00	0.00	0.00
CO2	VOLUME %	11.45	0.00	100.00	11.45	11.53	11.45	0.00	0.00	0.00	0.00
H2	VOLUME %	10.55	0.00	0.00	10.55	9.86	10.55	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.32	0.00	0.00	0.32	0.29	0.32	0.00	0.00	0.00	0.00
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	VOLUME %	61.52	0.00	0.00	61.52	57.38	61.52	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.29	0.00	0.00	0.29	6.43	0.29	0.00	0.00	0.00	0.00
ELEMENTS											
CARBON	LB/HR	709.789	0.0000	0.0000	224.971	1000.225	355.812	28.509	1.364	0.0000	-11.281
HYDROGEN	LB/HR	61.171	0.0000	0.0000	4.495	93.481	10.579	0.204	0.0000	0.0000	13.715
OXYGEN	LB/HR	325.743	0.0000	0.0000	91.046	1917.114	246.962	0.723	0.027	0.0000	5.884
NITROGEN	LB/HR	379.653	0.0000	0.0000	237.437	4369.491	663.957	0.281	0.015	0.0000	1.437
SULFUR	LB/HR	6.175	0.0000	0.0000	1.201	0.943	1.527	0.501	0.0000	0.0000	59.607
ARGON	LB/HR	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	100.0000
ASH	LB/HR	85.258	0.0000	0.0000	71.253	55.965	90.636	55.233	0.578	0.0000	-29.328
HEAT CONTENT	KBTU/HR	12167.160	0.0000	0.0000	3091.874	14136.953	4727.645	414.206	20.672	425.0000	-5.178

TABLE 3.1-6

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

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	331.00	0.00	0.00	4021.00	205.00	0.00	656.81	435.90	1005.93	0.00
TEMPERATURE	F	411.0	0.0	0.0	749.0	110.0	173.0	596.0	173.0	173.0	0.0
GAS	LB/HR	331.00	0.00	0.00	4021.00	205.00	0.00	656.81	435.90	1005.93	0.00
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	27.233	27.233	27.233	27.233	27.233
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	15.96	15.96	15.96	15.96	15.96
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	12.11	12.11	12.11	12.11	12.11
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	10.23	10.23	10.23	10.23	10.23
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.29	0.29	0.29	0.29	0.29
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	0.00	0.00	78.06	0.00	61.18	61.18	61.18	61.18	61.18
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	0.22	0.22	0.22	0.22	0.22
ELEMENTS											
CARBON	LB/HR	0.000	0.000	0.000	0.000	55.946	0.000	82.177	54.538	125.857	0.000
HYDROGEN	LB/HR	37.039	0.000	0.000	0.000	0.000	0.000	5.361	3.558	8.210	0.000
OXYGEN	LB/HR	293.961	0.000	0.000	932.945	149.054	0.000	155.944	103.494	238.833	0.000
NITROGEN	LB/HR	0.000	0.000	0.000	3035.922	0.000	0.000	413.333	274.314	633.033	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	52.133	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	50.142	0.000	0.000	665.787	1.413	0.000	891.970	541.320	1249.200	0.000

20

(Continued)

TABLE 3.1-6 (Continued)

STREAM NO.		11	12	13	14	15	16	17	18		
STREAM DESCRIPTION		COAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	FINE FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	1576.08	0.00	0.00	630.88	7252.66	1311.46	94.00	2.00	0.00	2.26
TEMPERATURE	F	124.0	0.0	0.0	291.0	1720.0	434.0	469.0	1826.0	0.0	0.0
GAS	LB/HR	566.08	0.00	0.00	365.88	7072.66	1039.46	0.00	0.00	0.00	0.00
SOLID	LB/HR	1010.00	0.00	0.00	265.00	180.00	272.00	94.00	2.00	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		27.233	32.000	44.011	27.233	26.529	27.233	0.000	0.000	0.000	0.000
CO	VOLUME %	15.96	0.00	0.00	15.96	15.13	15.96	0.00	0.00	0.00	0.00
CO2	VOLUME %	12.11	0.00	100.00	12.11	10.74	12.11	0.00	0.00	0.00	0.00
H2	VOLUME %	10.23	0.00	0.00	10.23	9.69	10.23	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.29	0.00	0.00	0.29	0.29	0.29	0.00	0.00	0.00	0.00
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	VOLUME %	61.18	0.00	0.00	61.18	57.70	61.18	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 %	0.22	0.00	0.00	0.22	6.43	0.22	0.00	0.00	0.00	0.00
ELEMENTS											
CARBON	LB/HR	719.447	0.000	0.000	222.214	957.599	311.149	28.012	1.056	0.000	-2.907
HYDROGEN	LB/HR	61.685	0.000	0.000	4.364	90.715	9.899	0.188	0.007	0.000	16.145
OXYGEN	LB/HR	330.746	0.000	0.000	91.984	1839.573	252.043	1.166	0.016	0.000	8.808
NITROGEN	LB/HR	371.487	0.000	0.000	232.079	4310.271	656.011	0.301	0.011	0.000	-0.100
SULFUR	LB/HR	6.262	0.000	0.000	1.113	0.756	1.142	0.404	0.006	0.000	68.697
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	86.456	0.000	0.000	79.129	53.748	81.219	63.929	0.904	0.000	-20.663
HEAT CONTENT											
	KBTU/HR	12307.767	0.000	0.000	3040.255	13723.579	4014.932	411.652	16.291	425.000	0.834

TABLE 3.1-7

GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-025-1, SET POINT 3A

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	317.00	0.00	0.00	3935.00	182.00	0.00	677.24	428.40	929.98	0.00
TEMPERATURE	F	411.0	0.0	0.0	812.7	97.0	183.0	596.0	183.0	183.0	0.0
GAS	LB/HR	317.00	0.00	0.00	3935.00	182.00	0.00	677.24	428.40	929.98	0.00
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	26.664	26.664	26.664	26.664	26.664
CO	VOLUME X	0.00	0.00	0.00	0.00	0.00	17.35	17.35	17.35	17.35	17.35
CO2	VOLUME X	0.00	0.00	0.00	0.00	100.00	10.81	10.81	10.81	10.81	10.81
H2	VOLUME X	0.00	0.00	0.00	0.00	0.00	11.51	11.51	11.51	11.51	11.51
CH4	VOLUME X	0.00	0.00	0.00	0.00	0.00	0.53	0.53	0.53	0.53	0.53
H2S	VOLUME X	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	VOLUME X	0.00	0.00	0.00	78.06	0.00	59.56	59.56	59.56	59.56	59.56
O2	VOLUME X	0.00	0.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	VOLUME X	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME X	100.00	100.00	100.00	0.00	0.00	0.23	0.23	0.23	0.23	0.23
ELEMENTS											
CARBON	LB/HR	0.000	0.000	0.000	0.000	49.669	0.000	87.532	55.370	120.199	0.000
HYDROGEN	LB/HR	35.472	0.000	0.000	0.000	0.000	0.000	6.557	4.148	9.004	0.000
OXYGEN	LB/HR	281.528	0.000	0.000	912.992	132.331	0.000	159.358	100.804	218.830	0.000
NITROGEN	LB/HR	0.000	0.000	0.000	2970.991	0.000	0.000	423.788	268.074	581.946	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	51.018	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	48.021	0.000	0.000	715.992	0.758	0.000	1045.223	611.715	1327.938	0.000

(Continued)

TABLE 3.1-7 (Continued)

STREAM NO.		11	12	13	14	15	16	17	18		
STREAM DESCRIPTION		COAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	FINE FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS. G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	1070.00	0.00	0.00	640.88	6463.07	1381.47	00.00	2.00	0.00	2.76
TEMPERATURE	F	93.0	0.0	0.0	301.0	1721.0	504.0	0.0	1838.0	0.0	0.0
GAS	LB/HR	0.00	0.00	0.00	408.88	6363.07	1031.47	0.00	0.00	0.00	0.00
SOLID	LB/HR	1070.00	0.00	0.00	232.00	100.00	350.00	100.00	2.00	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		26.664	32.000	44.011	26.664	26.154	26.664	0.000	0.000	0.000	0.000
CO	VOLUME %	17.35	0.00	0.00	17.35	16.23	17.35	0.00	0.00	0.00	0.00
CO2	VOLUME %	10.81	0.00	100.00	10.81	10.27	10.81	0.00	0.00	0.00	0.00
H2	VOLUME %	11.51	0.00	0.00	11.51	11.02	11.51	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.53	0.00	0.00	0.53	0.50	0.53	0.00	0.00	0.00	0.00
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	VOLUME %	59.56	0.00	0.00	59.56	56.21	59.56	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 %	0.23	0.00	0.00	0.23	5.77	0.23	0.00	0.00	0.00	0.00
ELEMENTS											
CARBON	LB/HR	692.076	0.000	0.000	211.535	857.310	372.716	32.670	1.329	0.000	-3.917
HYDROGEN	LB/HR	57.245	0.000	0.000	5.142	87.786	11.772	0.248	0.000	0.000	15.101
OXYGEN	LB/HR	196.238	0.000	0.000	101.060	1650.002	250.026	0.572	0.010	0.000	9.250
NITROGEN	LB/HR	16.157	0.000	0.000	257.879	3031.046	640.498	0.454	0.014	0.000	0.841
SULFUR	LB/HR	6.527	0.000	0.000	1.438	0.620	2.170	0.724	0.000	0.000	55.794
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	101.757	0.000	0.000	63.823	27.510	96.285	73.332	0.632	0.000	-19.434
HEAT CONTENT											
	KBTU/HR	12244.631	0.000	0.000	2909.861	12811.699	5069.191	477.543	20.289	425.000	0.531

TABLE 3.1-8

GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-025-1, SET POINT 3B

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	320.00	0.00	0.00	3979.00	221.00	0.00	720.66	483.43	938.95	0.00
TEMPERATURE	F	411.0	0.0	0.0	812.0	122.0	184.0	596.0	184.0	184.0	0.0
GAS	LB/HR	320.00	0.00	0.00	3979.00	221.00	0.00	720.66	483.43	938.95	0.00
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	27.819	27.819	27.819	27.819	27.819
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	16.26	16.26	16.26	16.26	16.26
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	15.59	15.59	15.59	15.59	15.59
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	10.02	10.02	10.02	10.02	10.02
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.53	0.53	0.53	0.53	0.53
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	0.00	0.00	78.06	0.00	57.37	57.37	57.37	57.37	57.37
O2	VOLUME %	0.00	0.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	100.00	100.00	100.00	0.00	0.00	0.24	0.24	0.24	0.24	0.24
ELEMENTS											
CARBON	LB/HR	0.000	0.000	0.000	0.000	60.313	0.000	100.753	67.587	131.272	0.000
HYDROGEN	LB/HR	35.808	0.000	0.000	0.000	0.000	0.000	5.910	3.964	7.700	0.000
OXYGEN	LB/HR	284.192	0.000	0.000	923.201	160.687	0.000	197.656	132.591	257.527	0.000
NITROGEN	LB/HR	0.000	0.000	0.000	3004.211	0.000	0.000	416.342	279.289	542.454	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	51.588	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		48.475	0.000	0.000	723.280	2.084	0.000	986.002	606.916	1178.794	0.000

(Continued)

TABLE 3.1-8 (Continued)

STREAM NO.		11	12	13	14	15	16	17	18	HEAT LOSS	TOTAL CLOSURE
STREAM DESCRIPTION		COAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	FINE FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)		
TOTAL	LB/HR	1082.00	0.00	0.00	702.51	7031.78	1329.62	89.00	2.00	0.00	-0.06
TEMPERATURE	F	91.0	0.0	0.0	288.0	1642.0	511.0	454.0	1830.0	0.0	0.0
GAS	LB/HR	0.00	0.00	0.00	458.51	6931.78	1040.62	0.00	0.00	0.00	0.00
SOLID	LB/HR	1082.00	0.00	0.00	244.00	100.00	289.00	89.00	2.00	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		27.819	32.000	44.011	27.819	27.186	27.819	0.000	0.000	0.000	0.000
CO	VOLUME %	16.26	0.00	0.00	16.26	15.37	16.26	0.00	0.00	0.00	0.00
CO2	VOLUME %	15.59	0.00	100.00	15.59	14.43	15.59	0.00	0.00	0.00	0.00
H2	VOLUME %	10.02	0.00	0.00	10.02	9.53	10.02	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.53	0.00	0.00	0.53	0.48	0.53	0.00	0.00	0.00	0.00
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	VOLUME %	57.37	0.00	0.00	57.37	54.19	57.37	0.00	0.00	0.00	0.00
O2	VOLUME %	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	VOLUME %	0.24	0.00	0.00	0.24	6.00	0.24	0.00	0.00	0.00	0.00
ELEMENTS											
CARBON	LB/HR	699.838	0.000	0.000	213.236	988.356	322.123	19.892	1.157	0.000	-4.598
HYDROGEN	LB/HR	57.887	0.000	0.000	4.736	85.165	9.689	0.169	0.008	0.000	18.080
OXYGEN	LB/HR	198.439	0.000	0.000	129.197	2050.446	289.487	0.000	0.036	0.000	-2.473
NITROGEN	LB/HR	16.338	0.000	0.000	266.625	3871.456	603.243	0.240	0.012	0.000	1.112
SULFUR	LB/HR	6.600	0.000	0.000	1.464	0.600	1.734	0.000	0.006	0.000	62.926
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	102.898	0.000	0.000	87.206	35.740	103.289	68.058	0.792	0.000	-9.350
HEAT CONTENT											
	KBTU/HR	12381.564	0.000	0.000	2760.456	12411.756	3985.419	302.492	17.677	425.000	8.269

TABLE 3.1-9

GASIFIER HEAT AND MATERIAL BALANCES, TEST TP-025-1, SET POINT 4

STREAM NO.		1	2	3	4	5	6	7	8	9	10
STREAM DESCRIPTION		STEAM TO GRID	STEAM TO AIR TUBE	BOOSTER STEAM	AIR	CO2 PURGE	GRID GAS	SPARGER RING FLOW	BOOSTER GAS	TRANSPORT GAS (FV-33)	TRANSPORT GAS (FV-61)
TOTAL	LB/HR	212.00	0.00	0.00	3738.00	248.00	0.00	690.25	448.06	954.64	0.00
TEMPERATURE	F	411.0	0.0	0.0	827.2	129.0	180.0	597.0	180.0	180.0	0.0
GAS	LB/HR	212.00	0.00	0.00	3738.00	248.00	0.00	690.25	448.06	954.64	0.00
SOLID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		18.016	18.016	18.016	28.963	44.011	28.514	28.514	28.514	28.514	28.514
CO	VOLUME %	0.00	0.00	0.00	0.00	0.00	16.98	16.98	16.98	16.98	16.98
CO2	VOLUME %	0.00	0.00	0.00	0.00	100.00	17.74	17.74	17.74	17.74	17.74
H2	VOLUME %	0.00	0.00	0.00	0.00	0.00	8.72	8.72	8.72	8.72	8.72
CH4	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.34	0.34	0.34	0.34	0.34
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	VOLUME %	0.00	0.00	0.00	78.06	0.00	55.90	55.90	55.90	55.90	55.90
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	0.33	0.33	0.33	0.33	0.33
ELEMENTS											
CARBON	LB/HR	0.000	0.000	0.000	0.000	67.681	0.000	101.955	66.181	141.008	0.000
HYDROGEN	LB/HR	23.723	0.000	0.000	0.000	0.000	0.000	4.746	3.081	6.564	0.000
OXYGEN	LB/HR	188.277	0.000	0.000	867.284	180.319	0.000	204.481	132.733	282.805	0.000
NITROGEN	LB/HR	0.000	0.000	0.000	2822.252	0.000	0.000	379.068	246.062	524.266	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	48.464	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	32.115	0.000	0.000	694.139	2.706	0.000	887.518	525.800	1120.285	0.000

(Continued)

TABLE 3.1-9 (Continued)

STREAM NO.		11	12	13	14	15	16	17	18		
STREAM DESCRIPTION		COAL FEED & TRANS. G.	OXYGEN TO TUBE	CO2 TO TUBE	FINE FEED & TRANS. G.	PRODUCT GAS	CYCLONE FINES & TRANS.G.	ASH WITH-DRAWAL	BED SAMPLE (SC-22)	HEAT LOSS	TOTAL CLOSURE
TOTAL	LB/HR	987.00	0.00	0.00	712.21	6840.82	1337.73	102.00	2.00	0.00	-3.66
TEMPERATURE	F	0.0	0.0	0.0	291.0	1600.0	511.0	460.0	1848.0	0.0	0.0
GAS	LB/HR	0.00	0.00	0.00	465.21	6740.82	1074.73	0.00	0.00	0.00	0.00
SOLID	LB/HR	987.00	0.00	0.00	247.00	100.00	263.00	102.00	2.00	0.00	0.00
LIQUID	LB/HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLECULAR WEIGHT		28.514	32.000	44.011	28.514	27.921	28.514	0.000	0.000	0.000	0.000
CO	VOLUME %	16.98	0.00	0.00	16.98	15.80	16.98	0.00	0.00	0.00	0.00
CO2	VOLUME %	17.74	0.00	100.00	17.74	16.89	17.74	0.00	0.00	0.00	0.00
H2	VOLUME %	8.72	0.00	0.00	8.72	8.38	8.72	0.00	0.00	0.00	0.00
CH4	VOLUME %	0.34	0.00	0.00	0.34	0.36	0.34	0.00	0.00	0.00	0.00
H2S	VOLUME %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	VOLUME %	55.90	0.00	0.00	55.90	52.82	55.90	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 %	0.33	0.00	0.00	0.33	5.76	0.33	0.00	0.00	0.00	0.00
ELEMENTS											
CARBON	LB/HR	637.701	0.000	0.000	246.407	1030.312	347.948	40.086	1.175	0.000	-12.577
HYDROGEN	LB/HR	55.667	0.000	0.000	4.668	72.892	8.954	0.255	0.007	0.000	16.597
OXYGEN	LB/HR	189.504	0.000	0.000	144.620	2140.424	325.626	0.031	0.019	0.000	-12.606
NITROGEN	LB/HR	14.805	0.000	0.000	257.508	3573.302	592.372	0.734	0.013	0.000	1.827
SULFUR	LB/HR	6.021	0.000	0.000	1.260	0.510	1.341	0.541	0.007	0.000	67.055
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	83.303	0.000	0.000	57.749	23.300	61.489	60.353	0.779	0.000	-3.510
HEAT CONTENT											
	KBTU/HR	11391.268	0.000	0.000	3148.035	11576.379	4124.944	594.188	17.976	425.000	5.973

control of pressurization and depressurization rates, (5) evaluate water quench of the product gas to study cyclone deposition and temperature effects, and (6) evaluate operational performance of the rebuilt in-line delumper in the ash withdrawal system.

A computer program was written to provide supervisory control of PDU pressurization. The program is capable of controlling the setpoint on a pressure control indicator in order to pressurize or depressurize the gasifier at a programmed rate. After overcoming a few initial problems, this system of computer control performed successfully. Achieving this milestone opens the way to exploring other areas in the process which could be computer controlled.

A multifeed system was installed for this test. This arrangement enables the coal and recycled fines to be fed axially through a single feed line into the gasifier. The objectives of this new configuration were two fold: higher coal feed capacity to the gasifier and reduced recycle gas transport flow. Multi-pickup single-feed capacity testing with coke breeze at cold flow conditions was successfully demonstrated before proceeding to the hot test. Preliminary results show that 3400 pounds per hour of dry coke breeze feed can be transported through the single feed system at velocities as low as 25 feet per second. Plugging of the line occurred when the velocity was decreased to between 16 and 20 feet per second. These early results give favorable outlooks for reduced recycle gas-to-coal ratios in future tests. More detailed analysis of this feed system will be performed from the data obtained from this and subsequent tests.

The chronology of events for test TP-025-2 is listed in Table 3.1-10 and a summary of nominal operating data is given in Table 3.1-11. The chemical analysis of the solids samples collected during this test is still being performed. Therefore, the heat and materials balances will be presented in the next quarterly report.

From a preliminary review of the test data, the following accomplishments were achieved:

- A total of 115 hours of hot operation was achieved, including 56 hours of operation with Indiana #7 coal, while processing 30 tons of the feedstock. One set point with Indiana #7 coal was achieved at test conditions, and three steady-state periods of 11, 6 and 5 hours were identified during this set point.
- Observations during tests TP-025-1 and TP-025-2 show that, for the PDU L/D configuration, the booster/sparger flow ratio must be greater than 40/60 but less than 60/40.
- Multi-pickup single-feed capacity testing with coke breeze at cold flow conditons was successfully conducted.
- Computer control of pressurization and depressurization rates was successfully demonstrated.

TABLE 3.1-10

CHRONOLOGY OF SIGNIFICANT EVENTS, TEST TP-025-2

Date	Time	Events
Oct. 27	1240	System pressure leak test initiated.
Oct. 29	0930	Completed pressure leak check and initiated hot air heatup.
Oct. 30	1600	Completed hot air heatup.
	2200	Initiated cold flow multifeed test with coke breeze.
Nov. 1	2100	Completed multifeed test; several problems were encountered with the operation of the delumper during the multifeed test.
Nov. 1	2315	Autogenous ignition of coke breeze achieved.
Nov. 2	1418	Initiated fines recycle to gasifier.
	1630	<u>Achieved Set Point 1 test conditions</u> with coke breeze.
Nov. 3	0430	Initiated coal feed to gasifier.
	2130	Initiated shutdown as a result of intermittent loss of ash withdrawal. Post-shutdown inspection showed the problem was caused by liner support tabs that had sheared off, jammed the delumper, preventing solids flow.
Nov. 6	1830	Initiated pressure leak test.
Nov. 8	0330	Completed hot air heatup.
	0930	Initiated coke breeze feed to build bed.
	1715	Autogenous ignition of coke breeze achieved.
Nov. 9	0400	Initiated Indiana #7 coal feed to gasifier.
	0500	Initiated fines recycle to gasifier.
	1300	<u>Achieved Set Point 2A test conditions.</u>
Nov. 10	0000	Problems with quality of coal feedstock - oversized and wet material caused several feed line plugs.
Nov. 11	1135	Initiated transition to Set Point 2B test conditions.
	1355	Leak on quench water vessel inlet flange detected. Initiated normal shutdown. Test TP-025-2 terminated.

TABLE 3.1-11

SUMMARY OF NOMINAL HOURLY AVERAGE OPERATING DATA
FOR SINGLE-STAGE OXYGEN-BLOWN GASIFIER TEST TP-025-2

SET POINT		1	2A-1	2A-2	2A-3
TEST RUN DATE AND TIME (1979)	Unit	11-2/3 Hours 1630 to 0430	11-10 Hours 0945 to 2030	11-10/11 Hours 2130 to 0430	11-11 Hours 0630 to 1130
<u>MEASURED GASIFIER PARAMETERS</u>					
TE-504-4 Freeboard Temperature	°F	1805	1792	1809	1803
TE-507-3 Gasifier Bed Temperature	°F	1914	1829	1848	1843
TE-504-10 Ash Annulus Temperature	°F	875	289	298	290
Average Bed Height*	feet	11.8	14.4	11.2	12.1
System Pressure	psig	231	229	230	229
Average Gasifier Bed Density	lb/ft ³	32.35	11.24	9.94	10.29
Average Annulus Density	lb/ft ³	24.16	11.62	11.20	10.92
Freeboard Gas Velocity	fps	.79	1.41	1.39	1.38
Fines Feed Material		Recycled Fines	Recycled Fines	Recycled Fines	Recycled Fines
Fines Feed Rate, WR-14	lb/hr	160	213	302	370
Coal Feed Material		L-60 Coke Breeze	Indiana #7 Coal	Indiana #7 Coal	Indiana #7 Coal
Coal Feed Rate, WR-27	lb/hr	199	1239	1094	1135
Carryover to Water System**	lb/hr	11	120	114	114
Ash Withdrawal Rate	lb/hr	84	128	114	134
HHV, Dry Basis (Gas Chromatograph)	Btu/scf	43.58	96.94	96.98	94.65
<u>SOLIDS ANALYSIS</u>					
Ash Content - Fines	%	11	22.57	26.14	24.70
Ash Content - Feedstock	%	11.24	10.44	12.13	10.46
Ash Content - Bed	%	23	24.98	32.44	31.30
Ash Content - Agglomerate	%	46	49.04	58.24	48.81

* From jet inlet to top of bed.

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

- During the initial delumper operational checkout phase, repeated belt failures caused withdrawal problems. A chain drive was adapted to the delumper and proved satisfactory until metal pieces that sheared from the struts supporting the annulus liner migrated and jammed the rotor. An interim shutdown resulted. Following repair of the delumper, no further incidents occurred and satisfactory performance was achieved throughout the remainder of the test.

3.1.3 Gasifier Test TP-023-3

Test TP-023-3 continued the series of oxygen-blown, feedstock characterization tests intended to evaluate the feasibility of producing medium-Btu gas in the single-stage gasifier. This test was designed to use Upper Freeport and Texas lignite coals as the feedstocks. The major goal of this test was the evaluation of the new higher oxygen concentration oxidant/feed tube. The objectives of test TP-023-3 also included: (1) demonstration of the operability of the gasifier with an oxygen concentration range of 47 to 65 percent with the higher oxygen concentration oxidant tube, (2) continued evaluation of the gasifier product gas water quench as a method of reducing cyclone buildup, (3) continued evaluation of the multifeed system loop that was installed for test TP-025-2, and (4) a functional checkout and initial shakedown test of the heat recovery loop.

A chronological summary of significant events is listed in Table 3.1-12. Further information on the results of this test will be reported at a later date.

3.2 PRODUCT CHARACTERIZATION

Analytical work on the samples collected in test TP-025-1 was completed during this quarter. The results for the seven steady-state periods of that test are included in this report.

Figure 3.2-1 shows the process sampling streams for the gasifier test system.

3.2.1 Solid Analyses

Characterization analyses were performed on the feedstock and reactor solids samples from test TP-025-1. The results of the proximate and ultimate analyses and the bulk density determinations are summarized by steady-state period in Table 3.2-1. Figure 3.2-2 shows the typical size distribution of the feedstock and reactor solids for a steady-state period during set point 2B.

3.2.2 Liquids Analyses

Samples were obtained regularly from each of the quench scrubber vessels and the water makeup pit during test TP-025-1. Composite samples were prepared for each steady-state period and were analyzed. The results of these analyses are detailed in Table 3.2-2.

TABLE 3.1-12
CHRONOLOGY OF SIGNIFICANT EVENTS, TEST TP-023-3

Date	Time	Event
Dec 7	1245	Initiated pressurization and pressure leak test.
Dec 9	1410	Achieved acceptable leak rate, began ramping temperatures.
Dec 10	0430	Began 12-hour hot air dryout, holding at 500 ⁰ F.
	1430	Ran heat recovery loop flow test.
	1630	Completed 12-hour hot air dryout.
	2140	Initiated coke breeze feed to gasifier.
Dec 11	0820	Achieved autogenous ignition.
Dec 12	0230	Experienced intermittent problems with delumper.
	0300	Recycle gas compressor shut down.
	1050	Initiated feeding Freeport coal to the gasifier.
	1400	Initiated recycle fines feed to the gasifier.
	1600-2300	Experienced problems in transferring wet feedstock from storage bins to lockhoppers.
Dec 13	0400	<u>Achieved Set Point 1</u> conditions.
	0645	Started feeding coke breeze to gasifier as the result of difficulty in transferring wet coal.
	1500	Started feeding Pittsburgh Seam coal through C-109 lockhopper to the gasifier.
	2015	Initiated recycle fines feed to gasifier.
	2200	Started heat recovery system.
Dec 14	0300	<u>Achieved Heat Recovery Set Point</u> conditions.
	0630	<u>Achieved modified Set Point 2</u> test conditions. Same nominal operating conditions as Set Point 1 except for coal type.
Dec 16	0320	<u>Achieved modified Set Point 3</u> conditions.
	1030	Pressure drop increasing rapidly, indicating restriction between gasifier and quench scrubber.
	1115	Initiated shutdown.
	1120	Lost oxygen flow as the result of pressure buildup in gasifier. Switched to air/steam. Terminated test TP-023-3.

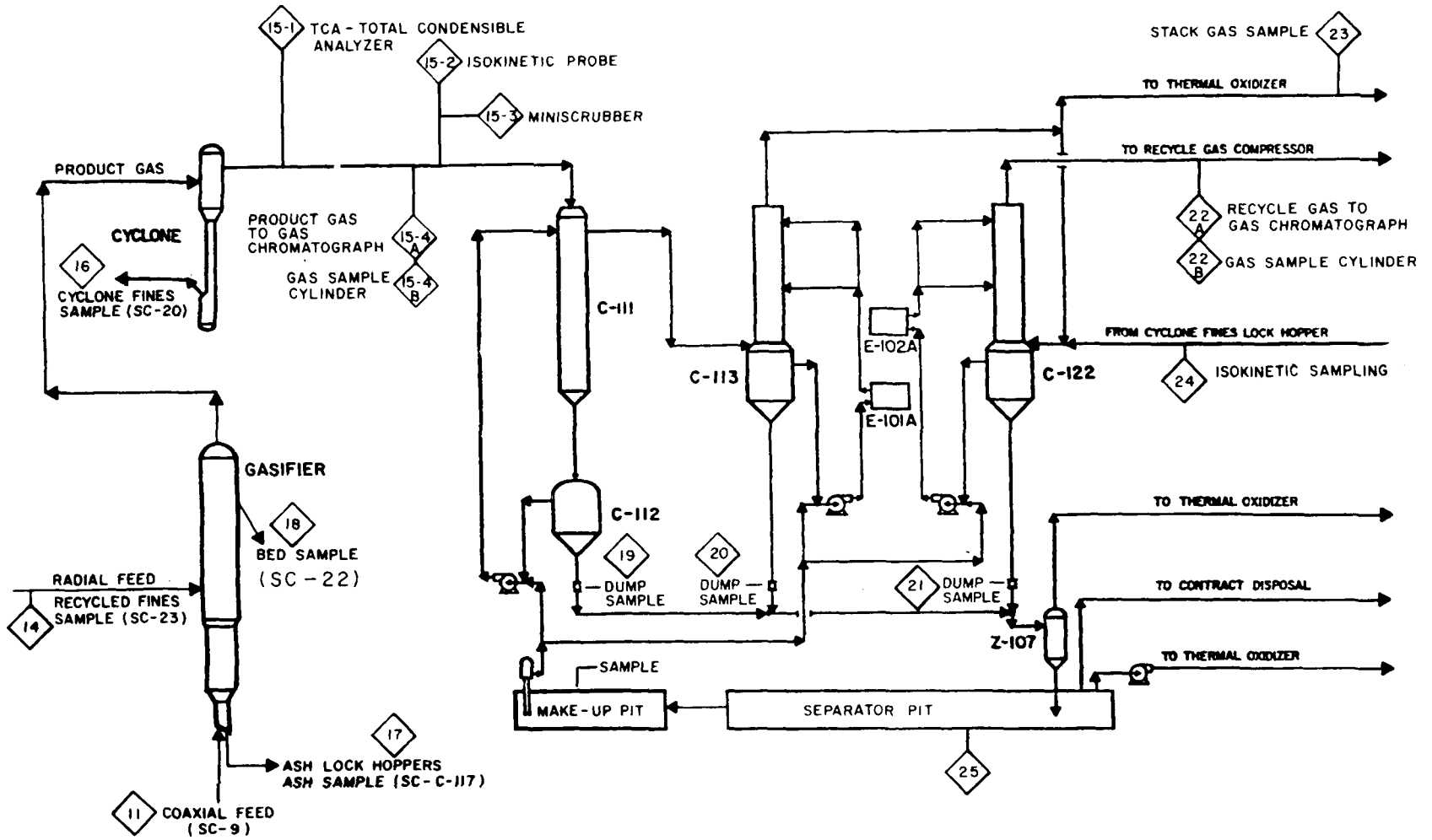


Figure 3.2-1. PDU Gasifier Process Schematic for Solids, Liquids, Gas and Particulate Sampling Locations

TABLE 3.2-1

FEEDSTOCKS AND REACTOR SOLIDS PRODUCT CHARACTERIZATION DATA (AS RECEIVED)
AIR-BLOWN GASIFIER TEST TP-025-1*

Sample Stream No.**	Set Point 1				Set Point 2A			
	11	18	16	17	11	18	16	17
	SC-9 Coaxial	SC-22 Bed	SC-20 Fines Carryover	C-117 Ash Lockhopper	SC-9 Coaxial	SC-22 Bed	SC-20 Fines Carryover	C-117 Ash Lockhopper
<u>Proximate (%)</u>								
Moisture	0.98	0.42	0.85	0.47	12.69	1.33	1.55	0.92
Volatile Matter	2.78	1.15	1.35	0.28	31.00	1.25	1.13	0.52
Fixed Carbon	83.09	81.19	71.12	58.98	47.75	64.03	83.85	31.50
Ash	13.15	17.05	20.26	40.27	8.56	33.39	13.47	67.07
<u>Ultimate (%)</u>								
Carbon	82.90	80.40	77.40	58.23	64.22	63.51	82.10	31.69
Hydrogen	0.57	0.21	0.26	0.12	5.65	0.29	0.38	0.18
Oxygen	1.36	0.78	0.83	0.00	19.44	1.72	2.66	0.23
Nitrogen	0.95	0.76	0.77	0.72	1.51	0.70	0.75	0.18
Sulfur	1.07	0.80	0.41	0.66	0.62	0.39	0.64	0.65
Ash	13.15	17.05	20.26	40.27	8.56	33.39	13.47	67.07
<u>Miscellaneous Analysis</u>								
Bulk Density (lb/ft ³)	34.4	35.3	34.7	39.3	45.5	18.8	24.8	30.4
	Set Point 2B				Set Point 2C			
<u>Proximate (%)</u>								
Moisture	12.69	1.08	1.74	0.88	12.69	1.19	1.71	1.00
Volatile Matter	31.00	1.20	1.67	0.76	31.00	0.69	1.56	0.54
Fixed Carbon	47.75	68.87	69.30	35.25	47.75	52.93	66.87	30.45
Ash	8.56	28.85	27.29	63.11	8.56	45.19	29.86	68.01
<u>Ultimate (%)</u>								
Carbon	64.22	68.21	68.83	35.40	64.22	52.81	66.58	29.80
Hydrogen	5.65	0.41	0.51	0.24	5.65	0.34	0.52	0.20
Oxygen	19.44	1.40	2.19	0.29	19.44	0.80	1.93	1.22
Nitrogen	1.51	0.75	0.72	0.37	1.51	0.56	0.69	0.33
Sulfur	0.62	0.38	0.46	0.59	0.62	0.30	0.42	0.44
Ash	8.56	28.85	27.29	63.11	8.56	45.19	29.86	68.01
<u>Miscellaneous Analysis</u>								
Bulk Density (lb/ft ³)	45.5	18.8	16.3	28.1	45.5	22.4	17.7	25.9

* Indiana #7 coal, with L-60 coke breeze in Set Point 1

** Sample locations are shown in Figure 3.2-1.

TABLE 3.2-1 (Continued)*

Sample Stream No.**	Set Point 3A				Set Point 3B			
	11	18	16	17	11	18	16	17
<u>Proximate (%)</u>	SC-9 Coaxial	SC-22 Bed	SC-20 Fines Carryover	C-117 Ash Lockhopper	SC-9 Coaxial	SC-22 Bed	SC-20 Fines Carryover	C-117 Ash Lockhopper
Moisture	11.89	1.41	1.61	0.79	11.89	1.47		0.63
Volatile Matter	29.46	1.46	3.20	0.78	29.46	1.15		0.80
Fixed Carbon	49.14	65.53	67.68	30.48	49.14	58.36		22.10
Ash	9.51	31.60	27.51	67.97	9.51	39.02		76.47
<u>Ultimate (%)</u>							No Sample	
Carbon	64.68	66.43	68.39	30.47	64.68	57.86	Taken	22.35
Hydrogen	5.35	0.41	0.51	0.23	5.35	0.39		0.19
Oxygen	18.34	0.48	2.09	0.26	18.34	1.82		0.00
Nitrogen	1.51	0.70	0.88	0.42	1.51	0.61		0.27
Sulfur	0.61	0.38	0.63	0.67	0.61	0.30		0.73
Ash	9.51	31.60	27.51	67.97	9.51	39.02		76.47
<u>Miscellaneous Analysis</u>								
Bulk Density (lb/ft ³)	44.2	18.2	22.6	27.2	44.2	20.0		31.8
	Set Point 4							
<u>Proximate (%)</u>								
Moisture	12.68	0.98	2.77	0.88				
Volatile Matt	31.11	1.04	1.60	0.75				
Fixed Carbon	47.77	59.01	72.26	39.20				
Ash	8.44	38.97	23.38	59.17				
<u>Ultimate (%)</u>								
Carbon	64.61	58.95	72.14	39.30				
Hydrogen	5.64	0.34	0.60	0.25				
Oxygen	19.20	0.95	2.55	0.01				
Nitrogen	1.50	0.66	0.82	0.74				
Sulfur	0.61	0.33	0.51	0.53				
Ash	8.44	38.97	23.38	59.17				
<u>Miscellaneous Analysis</u>								
Bulk Density (lb/ft ³)	45.7	19.2	16.0	24.4				

* Indiana #7 coal, with L-60 coke breeze in Set Point 1.

** Sample locations are shown in Figure 3.2-1.

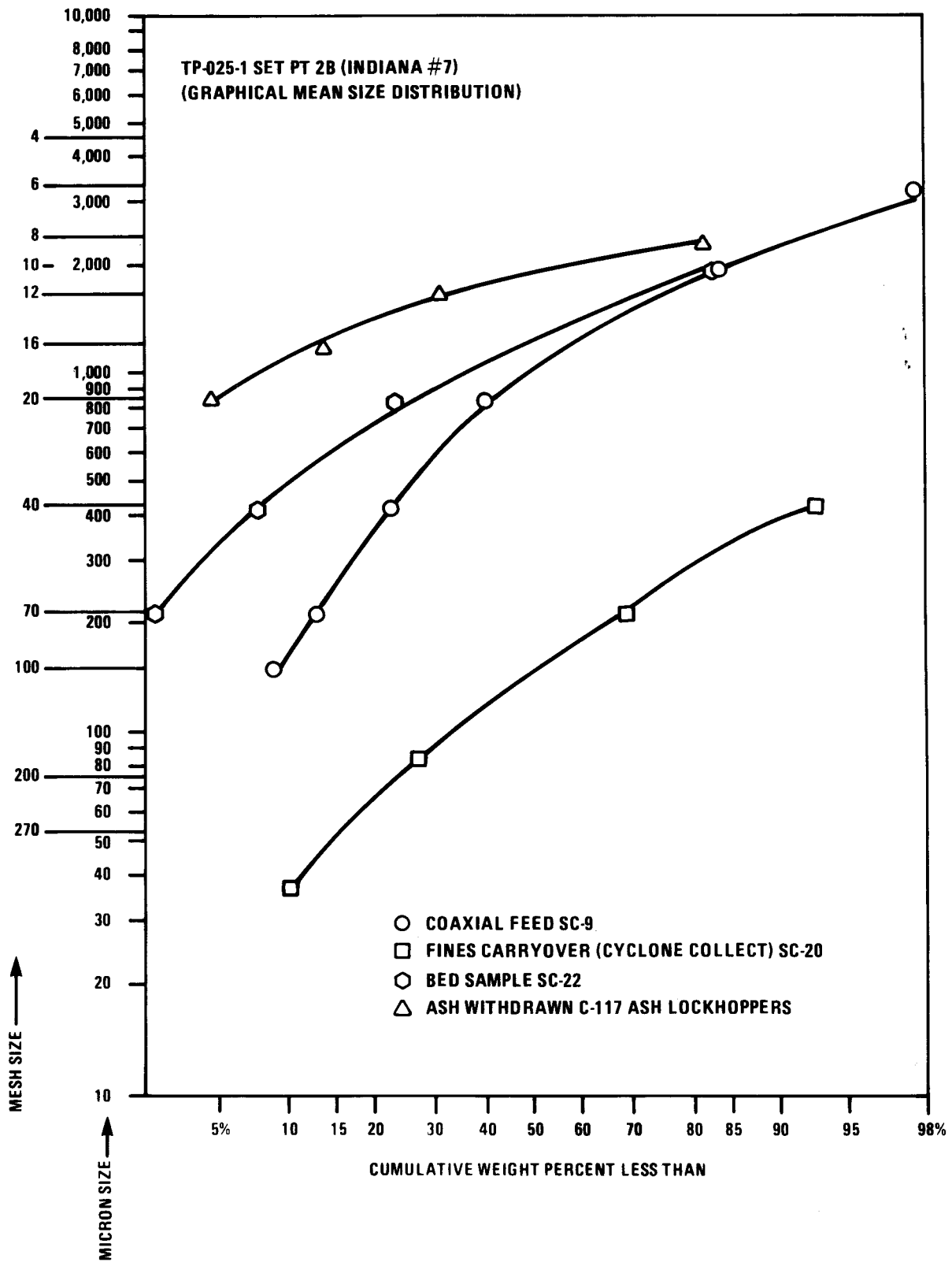


Figure 3.2-2. Typical Size Distribution of Feedstock and Reactor Solids, Test TP-025-1, Set Point 2B

TABLE 3.2-2

QUENCH SCRUBBER WATER ANALYSIS
TEST TP-025-1

AIR-BLOWN GASIFIER TEST TP-025-1 WITH INDIANA #7 COAL*															
Set Point	Solids Wt.-%	Acetone Extractables Wt.-% of Solids**	pH	Total Alkalinity mg/L	Total Ammonia mg/L	Total Chloride mg/L	Total Cyanide mg/L	Total Thio-Cyanate mg/L	Total Sulfur mg/L	Total Sulfate mg/L	Total Sulfide mg/L	Total Thio-Sulfate mg/L	BOD+ mg/L	COD++ mg/L	Phenol mg/L
1	0.11	--	7.0	123	102	70	0.38	22	103	116	0.03	112	55	94	0.18
2A	0.01	00	8.6	1190	400	170	13	--	64	102	0.19	940	19	132	<0.01
2B	Trace	--	8.5	1790	563	152	16	--	57	98	1.3	1283	13	165	<0.01
2C	0.96	--	8.8	1650	502	105	2.4	--	28	105	0.13	1100	60	109	<0.01
3A ^Δ	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
3B ^Δ	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4	0.02	--	8.1	1540	420	90	16	47	41	9	<0.02	850	14	64	0.26

* Coke breeze was used in Set Point 1.

** Analysis incomplete.

+ BOD = biological oxygen demand.

++ COD = chemical oxygen demand.

Δ No samples taken for this set point.

3.2.3 Gas Analyses

The composition of the product and recycle gases was monitored by on-line gas chromatography throughout test TP-025-1. The average analysis for each period is reported in Section 3.1, Tables 3.1-3 to 3.1-9.

3.3 ENVIRONMENTAL, SAFETY AND HEALTH PROGRAMS

The results of the air survey taken during test TP-023-1 were received and analyzed. Samples were taken for naphthalene, lead, total dust, respirable dust and aromatic hydrocarbons. Two of 24 samples taken for total dust indicated overexposure relative to OSHA standards. All other results were less than the permissible exposure limits.

Safety evaluations were performed on a burner for coal drying equipment and on the discharge of once-through cooling water from a heat exchanger being developed for use on the PDU.

Purchase orders were written to review possible contractors for the disposal of process quench water effluent.

SECTION 4.0

PROCESS ANALYSIS AND DESIGN

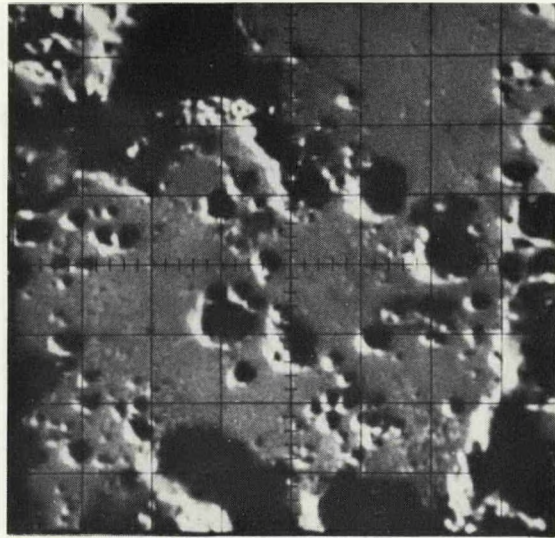
A review of the data on cyclone deposits, which resulted in many premature shutdowns of gasifier tests during 1978 and 1979, was conducted. Data accumulated during this period is as follows. Cyclone deposition became significant during the oxygen-blown TP-018 test series with Pittsburgh seam coal. During these tests, buildup at the cyclone inlet throat resulted in a flow impedance of the product gas. To resolve the problem of restrictions in the inlet of the cyclone, a ceramic sleeve was installed during test TP-018-4 to increase the gas velocity from 35 to 70 feet/second. However, no significant improvement in the deposition problem was achieved with this modification.

In the TP-019 series of gasifier tests, during which widely different feestocks such as Rosebud, Indiana #7 and Western Kentucky coals were used, there was no problem with buildup in the spool piece which joins the gasifier and the cyclone. In the TP-022 test series with Ohio #9 and Pittsburgh seam coals, a modified gasifier cyclone with a rectangular duct inlet and a reduced flow area was utilized to increase inlet velocity and improve collection efficiency. However, buildup was again present in the spool piece.

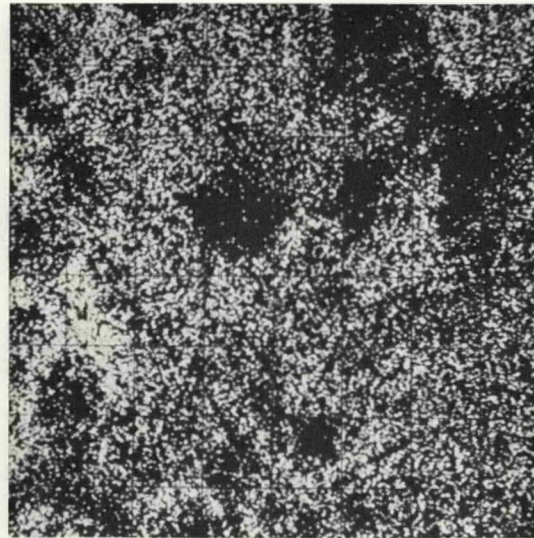
To identify the binding material in deposits, samples of the cyclone ash buildup from test TP-022-2 were observed under the stereomicroscope. Among the loosely bonded ash particles that appeared on the deposit surface close to the wall, spherical particles of a glassy material were noticed (Figure 4.0-2). These particles appeared to have existed in a molten state in the gasifier or in the cyclone. They were small, around 70 microns in diameter, and were well dispersed among other ash particles in the deposit. A number of these glassy particles appeared clear and transparent while other particles were colored and shiny. Both types of particles were isolated by hand from the deposit and were mounted on a glass plate for microprobe analysis. The resulting micrographs showed that the transparent particles were made of compounds of the K-Al-Si system (Figure 4.0-3) and the shiny particles were made of compounds of the Fe-K-Al-Si system (Figure 4.0-4). It was thought that these compounds may be part of the binding material in the ash deposit.

For gasifier test TP-023 with Ohio #9 coal, a water spray nozzle was installed in the freeboard area of the gasifier to quench the particles with a liquid film to render them nonsticky. Post-test inspection of the cyclone and spool piece showed only 1/8- to 1/2-inch thick deposits. The deposit was not the same powdery texture as previously obtained in test TP-022 with the same coal. With water spray cooling of the particles, the texture of this deposit was hard and crusty.

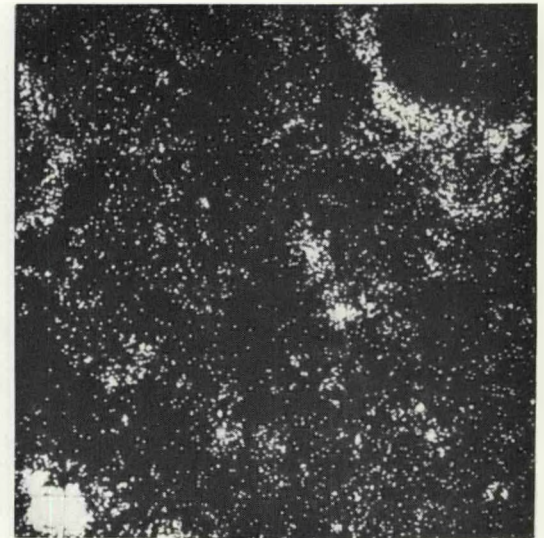
X-ray analysis of a sample of this deposit did not show the presence of FeS hematite (Fe_2O_3) and quartz (SiO_2) were found as the major phases while fayalite (FeSiO_4) and ringwoodite ($\text{MgFe}_2\text{SiO}_4$) were the minor phases. Microprobe analysis also did not show FeS particles. In the resulting micrographs (Figure 4.0-1), the patterns for Fe and for S did not coincide



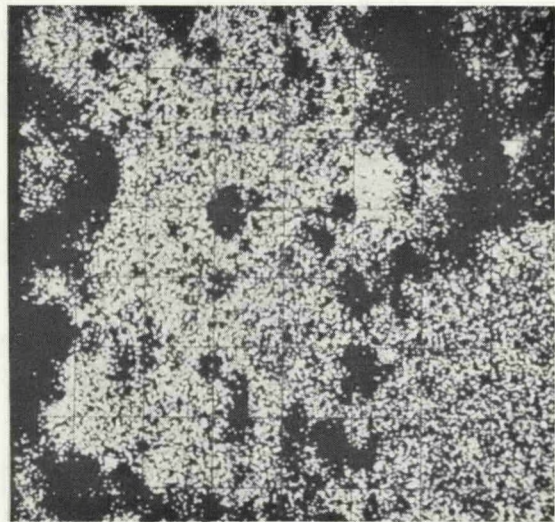
AREA SCANNED



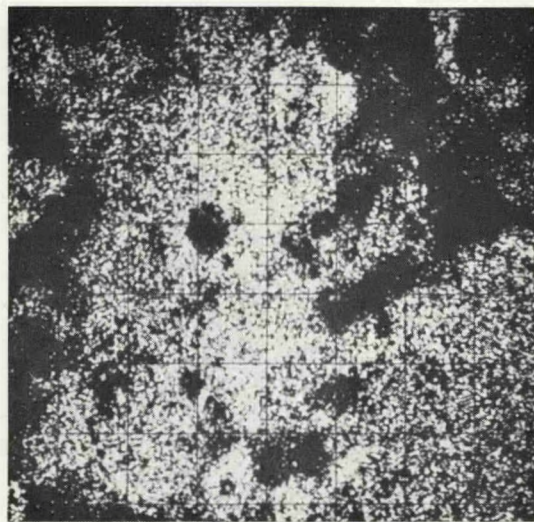
IRON



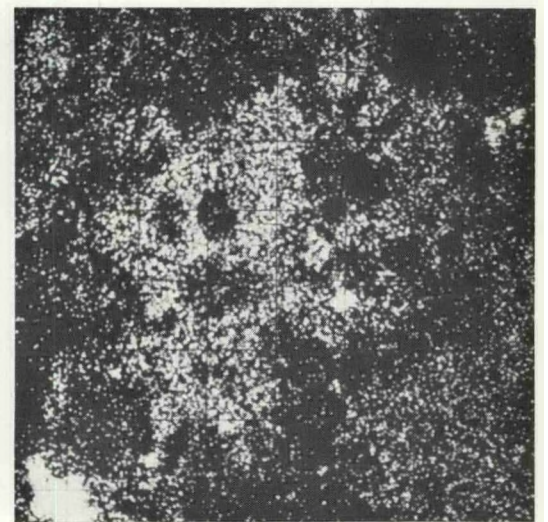
SULFUR



SILICON



ALUMINUM



POTASSIUM

Figure 4.0-1. Scanning Micrographs of a Sample of Cyclone Build-up, Test TP-023-1 (Area scanned was in the middle of the sample.)



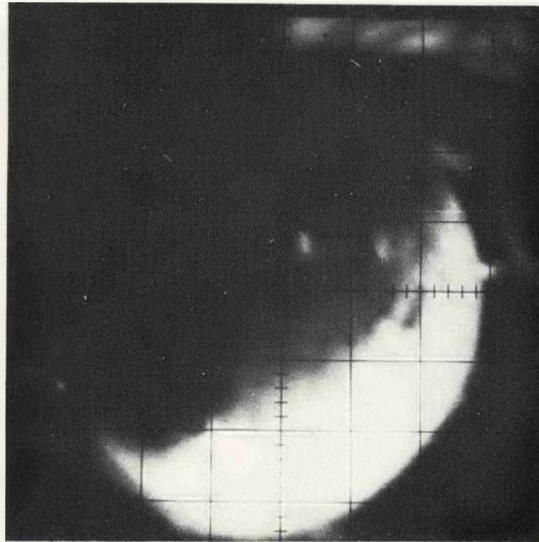
(a)



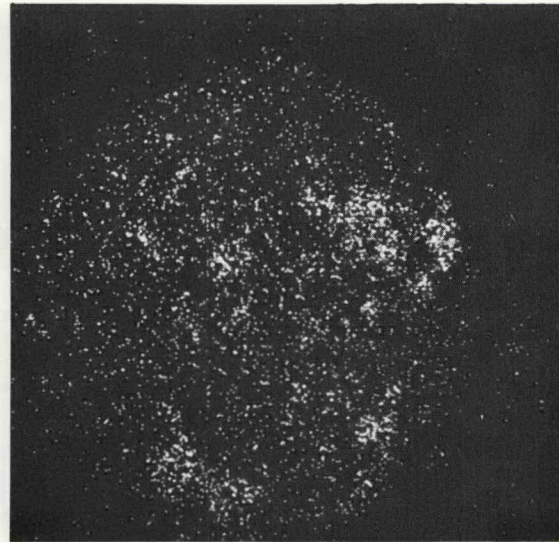
(b)

Figure 4.0-2. Spherical Glassy Particles from a Sample of Cyclone Build-up
(a) Dispersed Among Other Ash Material
(b) Isolated for Analysis

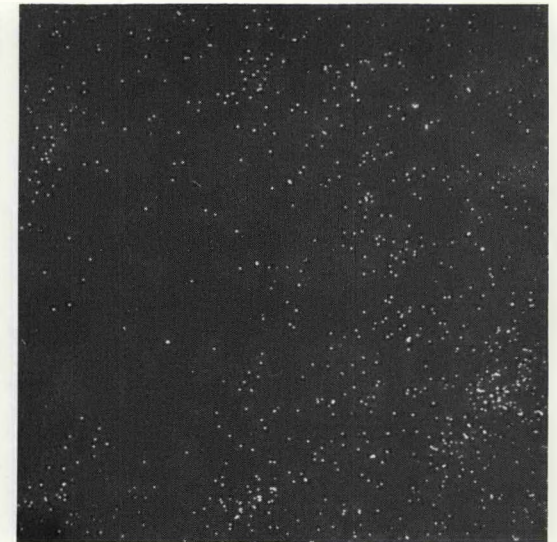
1363-24



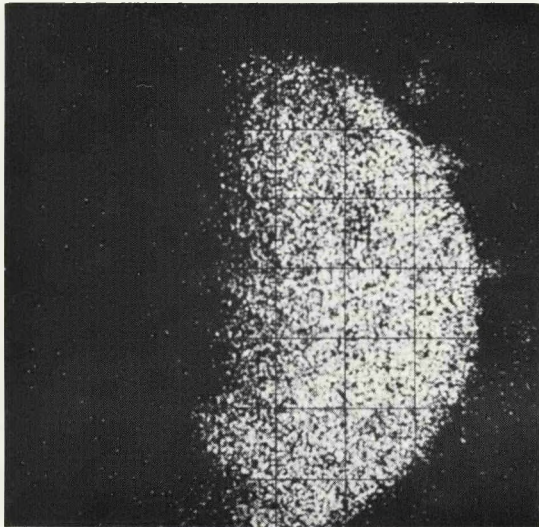
AREA SCANNED



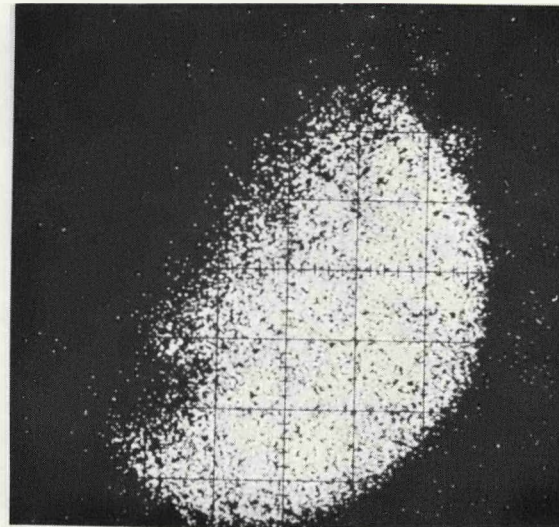
IRON



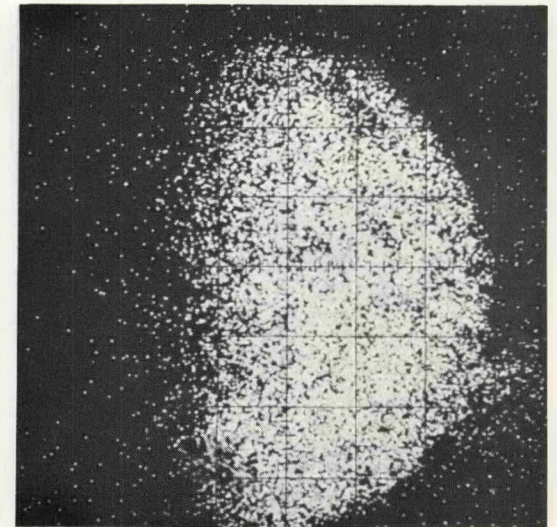
SULFUR



SILICON

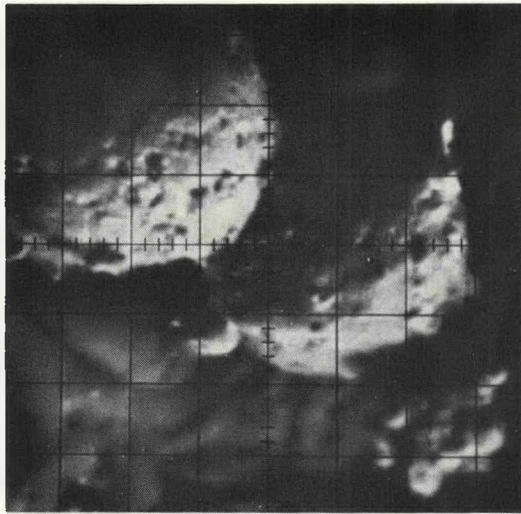


ALUMINUM

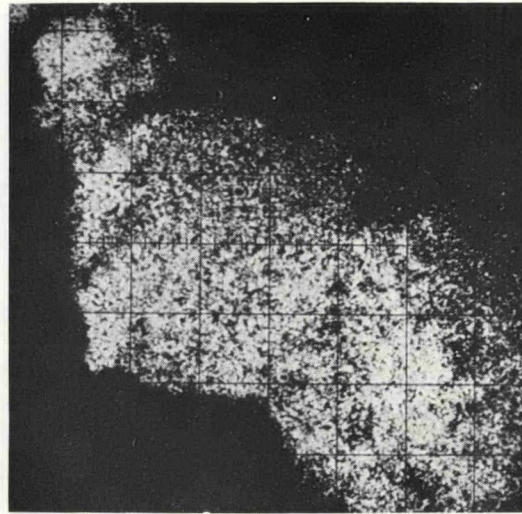


POTASSIUM

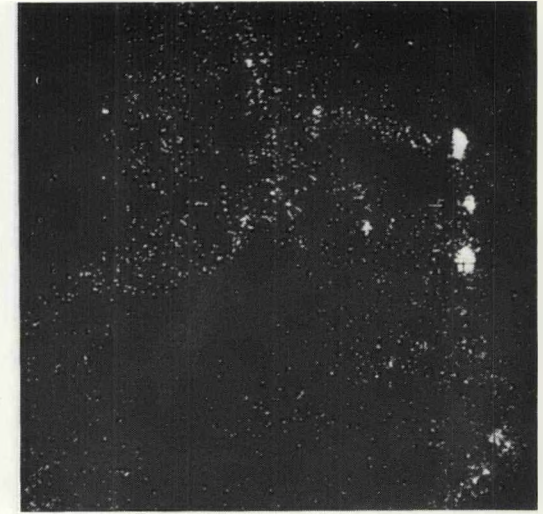
Figure 4.0-3. Scanning Micrographs of Glassy, Clear and Transparent Particles



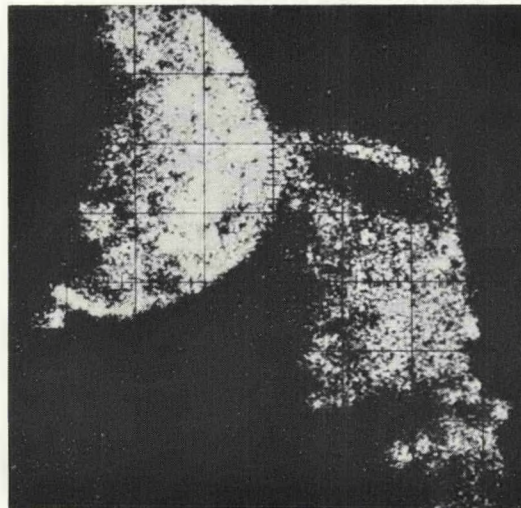
AREA SCANNED



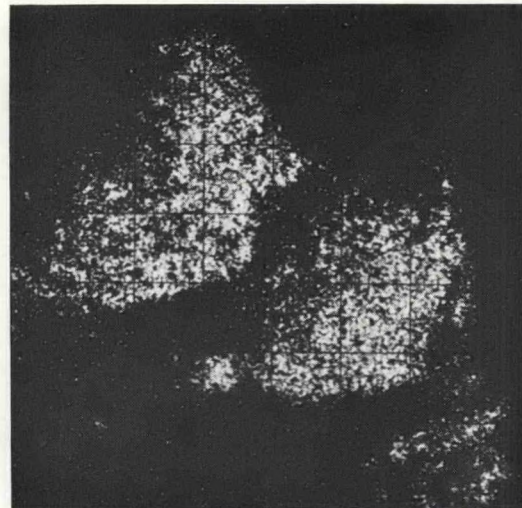
IRON



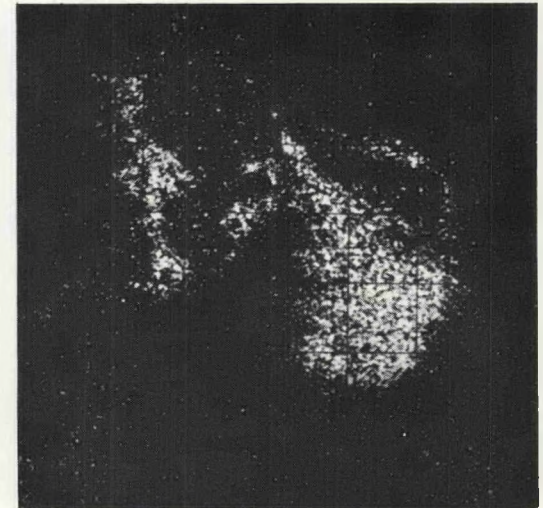
SULFUR



SILICON



ALUMINUM



POTASSIUM

Figure 4.0-4. Scanning Micrographs of Glassy, Colored and Shiny Particles

with each other. The absence of FeS distinguished this deposit from previous cyclone deposits (tests TP-018 and TP-022), and may have been caused by the water injection into the gasifier freeboard. Water cooled the exit gas from the gasifier and changed the FeS liquid droplets into FeS solid particles which no longer selectively deposited on the cyclone wall. The absence of FeS liquid droplets, which were thought to be part of the binding material in the deposit, may explain the small thickness of the deposit in test TP-023-1.

TP-025-1, an air-blown gasifier test with Indiana #7 coal without water spray, was a long-duration test of 146 hours and resulted in a very light, approximately 1/4-inch thick buildup of material in the cyclone. TP-025-2, an air-blown gasifier test with Ohio #9 and Indiana #7 coals, was performed with water spray in the freeboard area, and the deposit was a very light dust which was easily brushed off.

It is tentatively concluded that the mechanism of deposit formation is due to sticky particles or liquid droplets out of the combustion and/or gasification zone, and the change in direction of flow results in these particles impacting on the hot refractory cyclone walls. Chemical analysis, X-ray and microprobe analyses of the deposits in the TP-018 test series with Pittsburgh seam coal showed the presence of $Fe_{1-x}S$ compound as the predominant phase. However, with Ohio #9 coal, in test TP-022-2 the absence of FeS as a major phase and the presence of Fe_2O_3 and SiO_2 as major compounds leads to another hypothesis that there must be different "glue" generated from Ohio #9 coal as compared with Pittsburgh seam coal. During test TP-025-2, with 8 hours of Ohio #9 coal and 50 hours of Indiana #7 coal, water spray in the freeboard area of the gasifier was used to cool the gas and particles from 1800°F to 1300°F. At this temperature, the deposit was practically eliminated. The water cooling effect is shown in Figure 4.0-5. The gas was cooled to 1300°F before the water was shut off at the end of the test. However, long-duration tests with Pittsburgh seam, and Ohio #9 coals are necessary before any firm conclusion can be drawn about the effect of water spray. The tests with Indiana #7 coal, which is a low sulfur and low iron coal, did not pose any problems with cyclone deposits, but test TP-023-1 with Ohio #9 coal and water spray was run for only 30 hours. The analysis of the chemical compositions of the deposits are still in progress and will be reported at a later date.

SECTION 5.0

PROCESS AND COMPONENT ENGINEERING AND DESIGN

5.1 OXYGEN SYSTEM UPGRADE

The high-pressure oxygen supply tank was installed and connected to the existing vaporizer. The tank was then filled and vacuum measurements were taken to check for internal leaks.

Efforts to upgrade PDU steam system capacity were finalized this quarter: alternate designs were considered, a cost analysis was performed, and competitive bids were reviewed. Also, a new 4-inch steam supply line for this modification was designed. Purchase requisitions were then issued for a new superheater, boiler heating elements, and miscellaneous electrical hardware. In addition, a subcontract order was released for vendor installation services.

5.2 FINES RECYCLE AND UTILIZATION

During this past quarter, with the preliminary system design completed, two major decisions were made regarding the type of fines recycle system to be installed at the PDU:

- A single pressure vessel will be installed between the existing cyclone and the quench water system. Within this pressure vessel various types of fines collection devices, of either Westinghouse or outside vendor design, will be installed and tested. As a minimum, provision will be made for testing a single-barrel high-efficiency cyclone, a tornado-type cyclone, a multi-tube cyclone, and ceramic bag filters.
- The system designed to convey the collected fines back to the gasifier will be of sufficient flexibility to allow testing of various schemes, including a fluidized standpipe with either a mechanical or non-mechanical valve for solid metering, and a direct rotary feeder system for metering the fines from the cyclone to a transport line without intermediate lockhoppers.

Also during this quarter, a preliminary investigation of the efficiency of the existing cyclone was initiated to provide design and operating information for future modifications to the PDU.

During the next quarter, the secondary fines collection pressure vessel, the fines cooler, and the extended cyclone dipleg will be designed.

5.3 HEAT RECOVERY

The Phase I heat recovery test loop was completed this quarter. During December the loop was installed in the PDU, and prior to operation during test TP-023-3, the test plan was approved and issued, training sessions were presented to operations personnel, and installation and system checkout was completed. In addition, the component drawings for the isokinetic sample system of the Phase I test loop were completed.

During the next quarter, the results of the initial shakedown test of the loop will be evaluated, heat recovery test setups for 1980 will be formulated, and preliminary design for advance heat recovery testing beyond the Phase I slipstream arrangement will be completed.

5.4 PRODUCT GAS SCRUBBING/COOLING UPGRADE

Design and purchasing activities for a new, larger capacity total condensables analyzer (TCA) sampling system are progressing. Drawings for the TCA sampling system, the TCA sample cooler and internals, and the TCA cyclone are being finalized. The purchase order for the fabrication of the cyclone was issued. TCA internals will be shop-fabricated at Westinghouse. Purchase requisitions for other product characterization equipment requirements were released. These included the gas chromatograph and infrared analyzer for direct water measurements, and TCA piping hardware including the gas pressure regulators, high temperature ball valves for the TCA cyclone, metering valves and flow switches.

5.5 ELECTRICAL AND INSTRUMENTATION UPGRADE

During this quarter, the following work was accomplished under this task:

- The new pH analyzer, supplied by Great Lakes Instruments, Inc., was installed in the makeup/supply water pit.
- The Phase I evaluation study of the PDU power upgrade, initiated in August, was completed upon receipt and review of the Hornfeck Engineering evaluation report. Based on the results of this report, a work scope was prepared and a request for quotation was submitted for the design of the system, including procurement specifications for the equipment.
- Power feeder circuits were designed for the 25 hp oxygen truck unloading pump and the coal crushing/drying unit.

SECTION 6.0

SCALE-UP MODEL

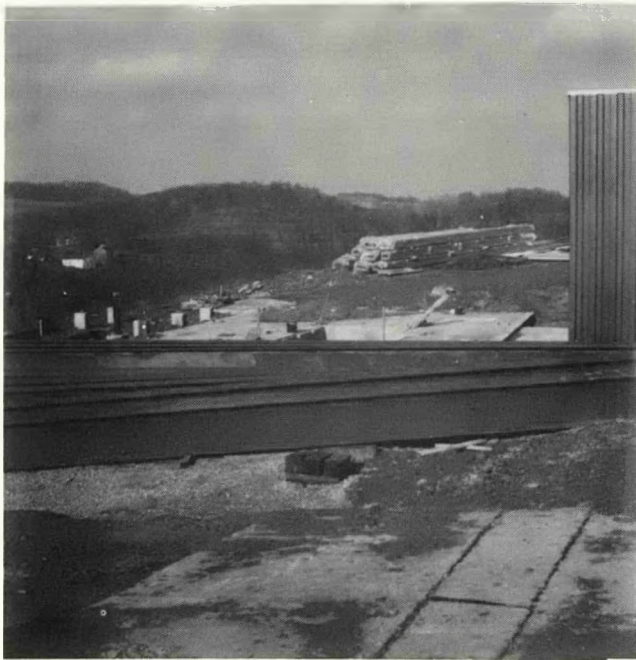
During this report period, significant progress was made in the construction of the cold-flow scale-up facility:

- The compressor building shell was erected, the insulation and inside panels were installed, and the cooling water system was leak-checked and connected. Also, the gas supply line to the compressor building was installed.
- The model foundation forms were installed, the floor slab was poured, and the steel framework for the model enclosure was delivered to the construction site.
- Installation of the storm sewer system was completed, and work was initiated on the miscellaneous pads and foundations around the outside of the model and compressor building.
- All utilities to the site were delivered and final grading has begun.
- The final concrete work for the baghouse support and loading bins was completed.
- The subcontract with the Architect-Engineer for structural design and component and piping layout was completed.
- Piping and plant layout drawings were issued for construction purposes

In the procurement effort, the vibrators, compressor cooling system relief valves, and the waste bins were ordered, as well as the compressor cooling water regulator, flow orifice plates, tubing, pressure and temperature indicators and the control cable and steel trough. Requests for quotation were issued for the viewing platform and the baghouse and loading bin support structure. Work was initiated on the piping installation procurement package, anchoring of major components for the air supply system and fabrication of the storage bins, weigh bins and cyclones.

During the next report period, building fabrication will be completed; the weigh bins, storage bins, baghouse support structure, baghouse, waste bin, and unloading bin and support structure will be installed; and work on the piping installation for the compressor building will be initiated. In addition, the main air supply compressors will be aligned and grouted.

(Right) Compressor Building Shell Erected and Foundation Forms in Place for the Model Structure



(Left) Main Steel Framework Members Receive on Site with Concrete Work Complete

(Right) Erection of Model Structure Begins with Steel Framework which Dwarfs the Smaller Compressor Structure



Figure 6.0-1. Cold Flow Scale - Up Facility Takes Shape

SECTION 7.0

LABORATORY SUPPORT STUDIES

Support work on fuel processing was conducted to investigate operating conditions for the PDU test program, provide troubleshooting capability for PDU operation, obtain data for PDU modifications, analyze and interpret results from PDU operation and develop information for future process development. Work was conducted in the areas of cold flow and analytical modeling, coal behavior (gasification, ash agglomeration, and coal and ash phenomena) and environmental impact studies. Work accomplished and planned is summarized as follows.

7.1 COLD FLOW AND ANALYTICAL MODELING

7.1.1 Jet Phenomena

The semicircular column was modified to accept a semicircular jet nozzle to simulate the coal feeding nozzle in the PDU. Experiments were initiated to study the mass transfer of gases through the jet and between the jet and the emulsion phase by injecting helium into the jet to simulate oxygen or air in the PDU operation. Tracer gas concentration profiles were mapped by taking gas samples at seven vertical planes perpendicular to the jet direction for three different jet velocities. The gas velocity profiles will be similarly mapped to gain an understanding of momentum dissipation of, and gas and solids entrainment into, the jet.

The jet experiments were temporarily suspended after the above series of experiments to meet PDU test program needs. The jet nozzle is being further modified to simulate the new oxidant tube design to be employed in the next PDU test.

7.1.2 Particle Separation

Experiments were performed in a 7-cm diameter fluidized bed to study the rate of particle separation. The materials used were -20 mesh + 70 mesh crushed acrylic particles to simulate the char particle and -12 mesh + 20 mesh crushed dolomite particles to simulate the ash particles. The series of experiments for the mixture with 20 percent dolomite by weight were completed and the results are reported here. Experiments are being carried out for the mixture with 40 percent dolomite by weight.

The experiments were carried out at five different fluidizing velocities, i.e., 0.47 ft/s (0.14 m/s), 0.81 (0.25), 1.38 (0.42), 2.34 (0.71), and 3.37 (1.03) and at test durations ranging from 3 to 25 seconds. The minimum fluidization velocities for pure acrylic, pure dolomite, and the mixture of both with 20 percent dolomite by weight were experimentally found to be 0.35

ft/s (0.11 m/s), 2.45 (0.75), and 0.45 (0.14), respectively. To start an experiment, the mixture with 20 percent dolomite by weight was first passed through a Riffle Sampler at least four times to obtain a uniform distribution of dolomite in acrylic. The mixture was then placed in the 7-cm fluidized bed and a predetermined amount of fluidization air was started for a predetermined length of time through an air line controlled by two solenoid valves. After shutdown, the bed material was vacuumed out layer by layer and their compositions were determined by sieving.

The results of particle separation for a mixture with 20 percent dolomite by weight are presented in Figures 7.1-1 through 7.1-4. No substantial separation was observed for the case with a 0.47 ft/s (0.14 m/s) fluidizing velocity, which is very close to the minimum fluidizing velocity of the 20 percent dolomite mixture, 0.45 ft/s (0.14 m/s). At a fluidizing velocity of 0.81 ft/s (0.25 m/s), the acrylic-dolomite separation was almost complete in the top 3 inches of bed after 20 seconds (Figure 7.1-1). However, the bottom layer had only a dolomite concentration of about 58 percent. Operation longer than 20 seconds will not improve the dolomite concentration in the bottom layer because the bottom layer is essentially a packed bed with a mixture whose minimum fluidization velocity is comparable to that of operating a fluidizing velocity. The same argument holds true for the separation at a velocity of 1.38 ft/s (0.42 m/s). Because of a higher operating velocity, the dolomite concentration in the bottom is correspondingly higher (Figure 7.1-2). Note that the separation is essentially complete after 15 seconds.

At a velocity closer to the minimum fluidizing velocity of the dolomite, 2.34 ft/s (0.71 m/s), the dolomite in the bottom layer is enriched to more than 94 percent (Figure 7.1-3). However, the dolomite concentration in the upper bed is also increased due to bubbling action in the bottom layer. The air bubbles generated in the bottom layer are now carrying dolomite in their wake into the upper layer. At an even higher velocity of 3.37 ft/s (1.03 m/s), the mixing between the two layers becomes proportionally higher. The dolomite concentration in the upper layer increases while in the bottom layer it decreases, as shown in Figure 7.1-4. The time required for complete separation is, however, comparable, i.e., about 15 seconds. Thus it can be concluded that if the concentration of the jetsam in the bottom layer is of primary concern, the optimal operating velocity is slightly higher than the minimum fluidization velocity of the jetsam, as previously recommended. The practical operating velocity range can, however, be large. For example, operating at velocities of 1.38 ft/s (0.42 m/s) and 3.37 ft/s (1.03 m/s), which are substantially different from the minimum fluidizing velocity of dolomite, 2.45 ft/s (0.75 m/s), the dolomite concentration in the bottom layer decreases only from 94 percent to 88 percent (see Figure 7.1-2 to 7.1-4).

If the flotsam concentration in the upper layer is of primary concern, an almost pure flotsam layer can be obtained as long as the operating velocity is in between the minimum fluidization velocities of the mixture and the jetsam. However, the optimal operating velocity is one slightly lower than the minimum fluidizing velocity of the jetsam so that only a very small portion of the flotsam can be trapped in the bottom layer.

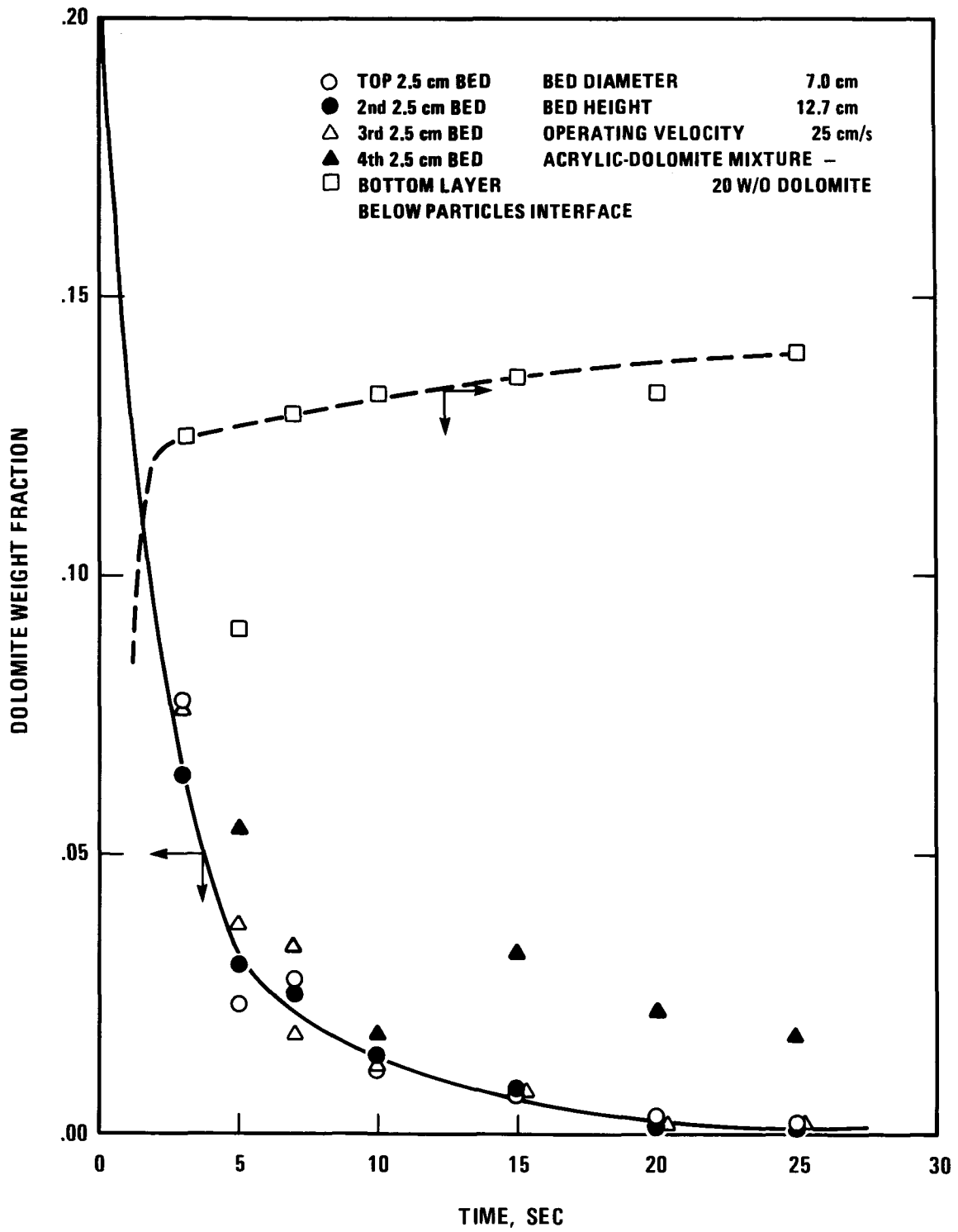


Figure 7.1-1. Rate of Particle Separation at a Velocity of 25 cm/s

1363-35

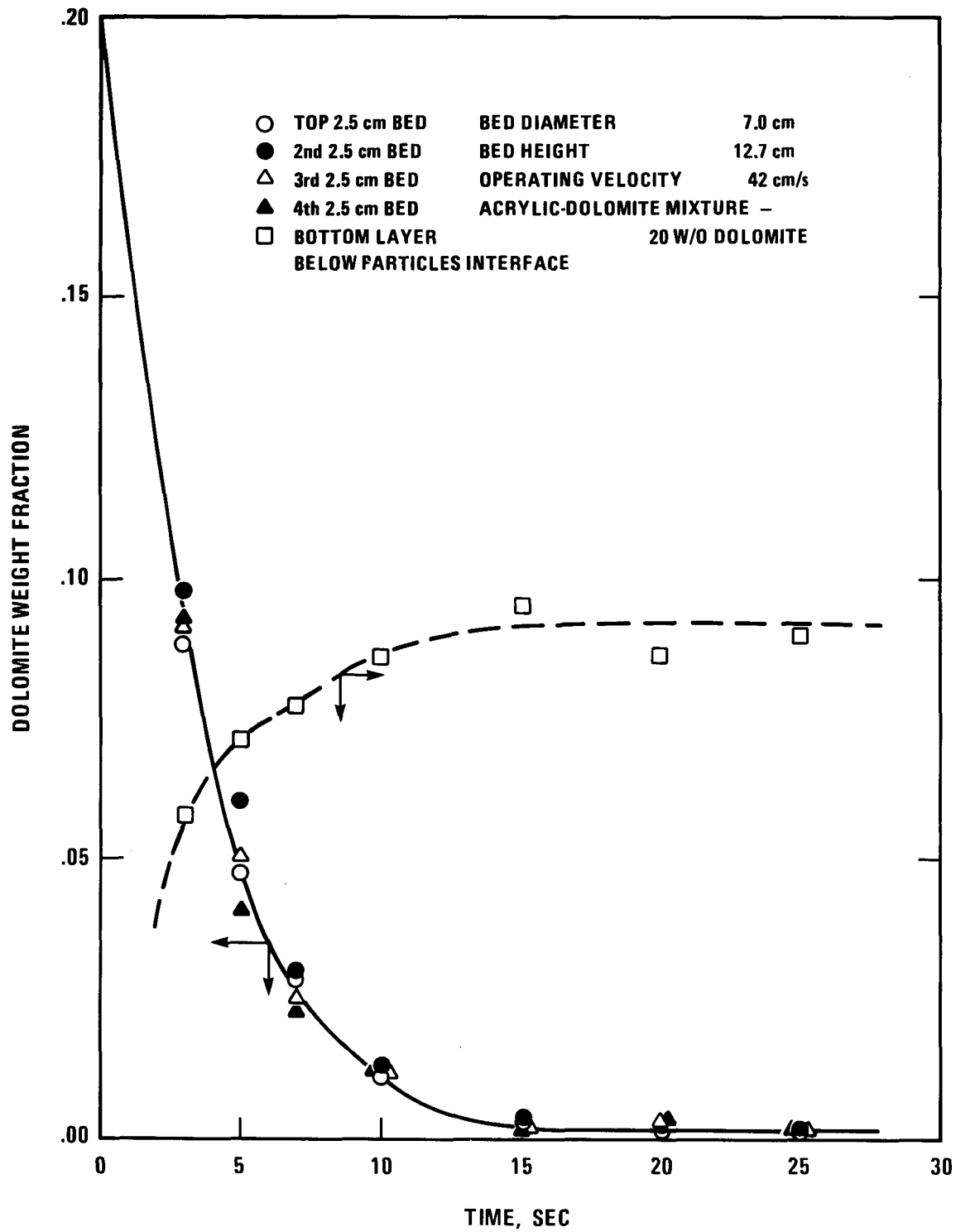


Figure 7.1-2. Rate of Particle Separation at a Velocity of 42 cm/s

1363-36

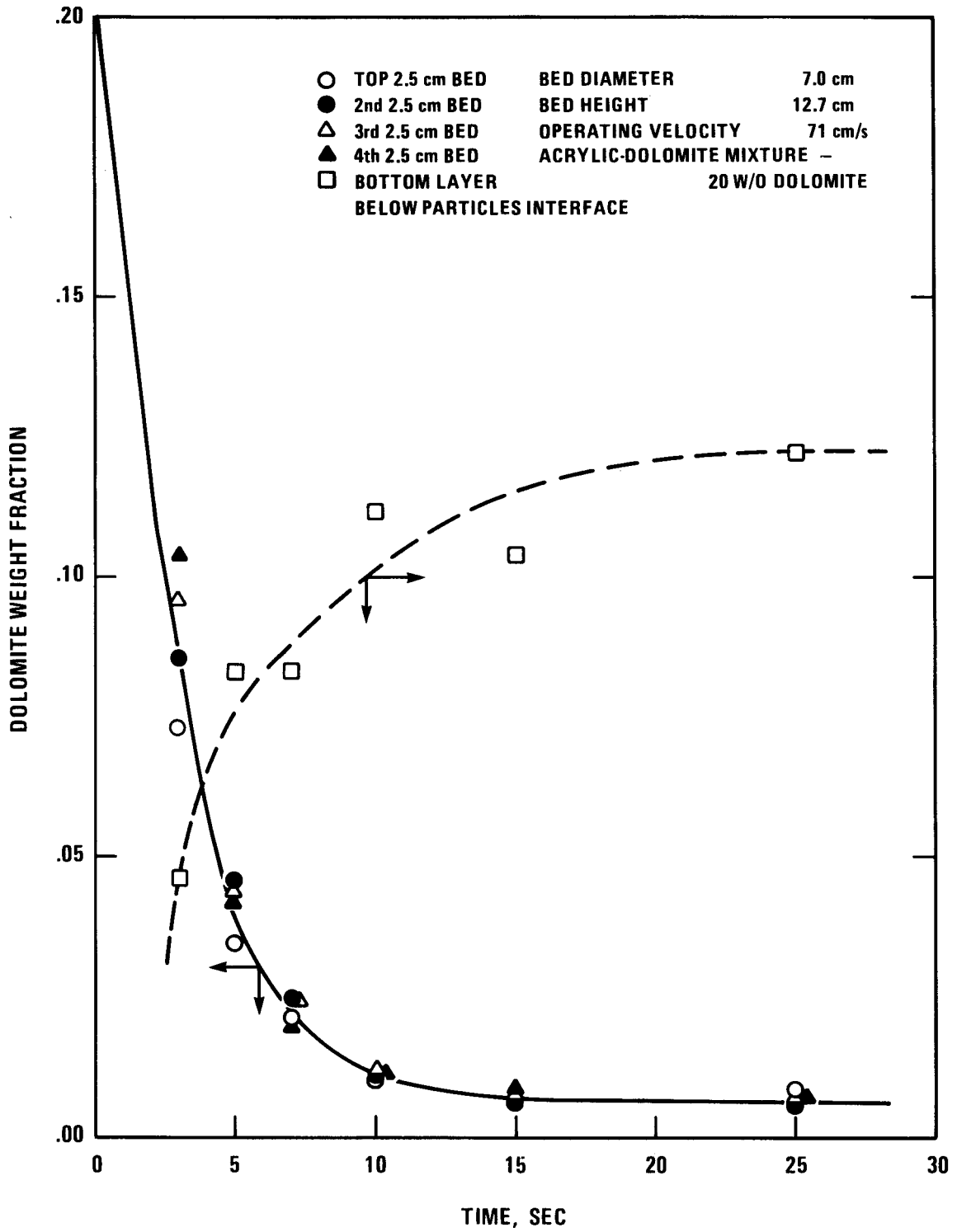


Figure 7.1-3. Rate of Particle Separation at a Velocity of 71 cm/s

1363-37

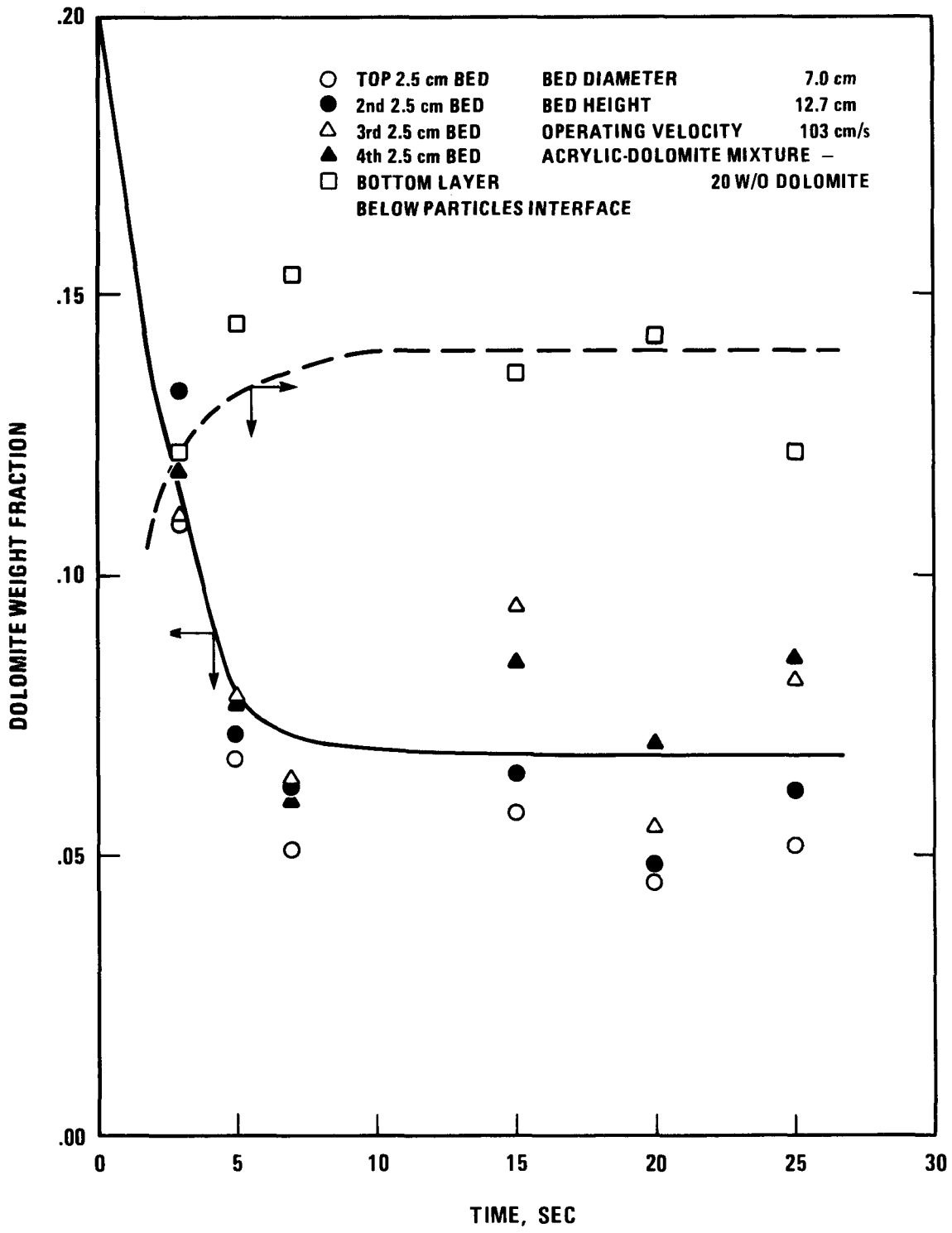


Figure 7.1-4. Rate of Particle Separation at a Velocity of 103 cm/s

1363-38

The time required for complete separation was found to be independent of operating velocity. For the acrylic-dolomite system with 20 percent dolomite by weight, it is about 15 seconds. The experiments are being carried out for a mixture with 40 percent by weight.

7.1.3 Distributor/Plenum Design

The devolatilizer cold model grid and plenum simulation tests were completed.

Work Forecast for Next Quarter

- Complete modification of the semicircular unit to support PDU operation with a similar jet nozzle configuration.
- Continue studies on the rate of particle separation with char and ash particles at different concentrations.
- Prepare a report on devolatilizer grid/plenum design test.

7.2 COAL BEHAVIOR STUDIES

7.2.1 Gasification

Reactivities of chars made from Ohio #9, Illinois #6 and Montana subbituminous coals were studied in a fluidized bed. The reactivity of coke breeze fines collected in the PDU cyclone was studied in the fluidized bed and found to be close to the reactivity of coke breeze of a larger size distribution (-1.0 + 0.25 mm).

Several tests were performed on the thermogravimetric analyzer (TGA) to study the effect of sample weight and gas flow rate on the rate of carbon-steam reaction in order to develop the TGA as a reliable tool for gasification studies. Results are given in Figures 7.2-1 and 7.2-2 to show the effect of sample weight. A comparison will be made of the results obtained in the fluidized bed and the TGA. The effect of rapid heating of coal and the temperature of preparation of char on its reactivity will be studied on the TGA.

7.2.2 Ash Agglomeration

Ignition was achieved with coke breeze in the ash agglomeration test facility and a shakedown test was performed at an operating temperature of 1950°F. All components of the test facility were found to operate as planned. A subsequent test was attempted with coke breeze but the fluidized bed could not be heated up to the desired operating temperature of 1950°F as a result of the failure of the gas preheating furnace. The gas preheaters are being replaced with a more reliable design. Tests with different coals are planned after a successful test with coke breeze is conducted.

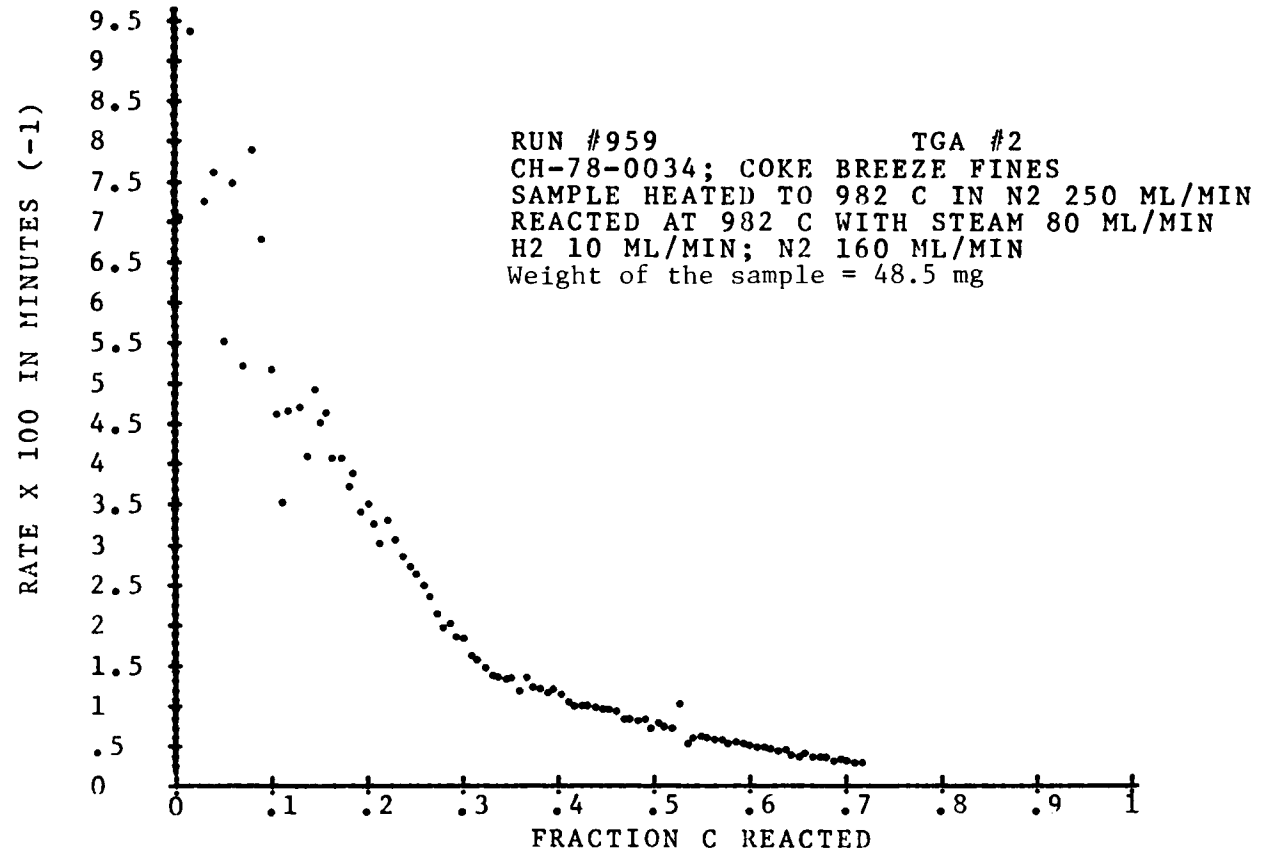


Figure 7.2-1. Reactivity of Coke Breeze Fines

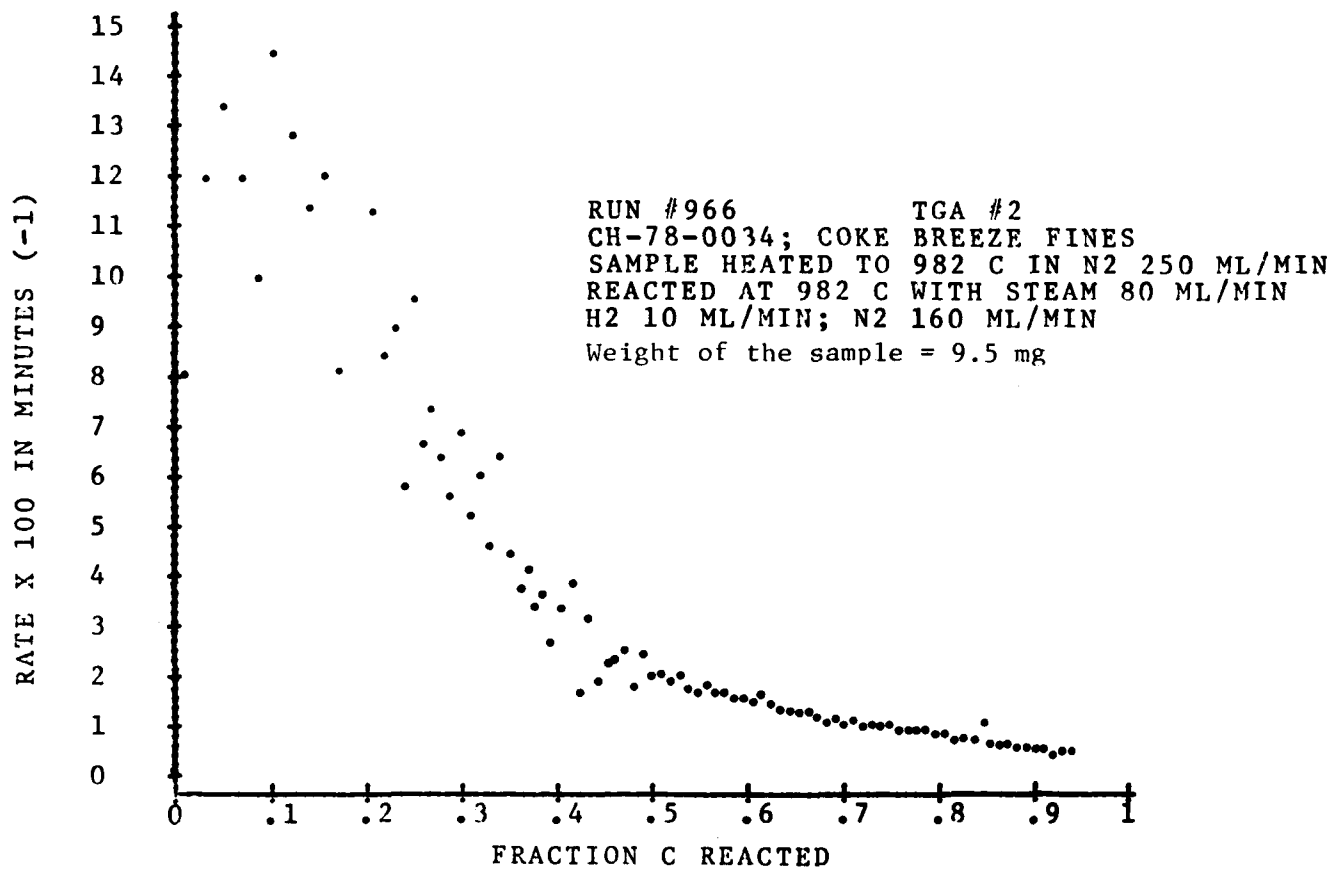


Figure 7.2-2. Reactivity of Coke Breeze Fines

A schematic diagram of the ash agglomeration reactor test facility and a sketch of the reactor are shown in Figures 7.2-3 and 7.2-4, respectively.

7.2.3 Coal and Ash Chemical Phenomena

In support of the PDU test program, analyses of samples of ash build-up to determine the chemical composition and mechanism of formation continued. X-ray analyses of TP-023-1 and stereomicroscope survey of the TP-022-2 samples were completed. These results are reported in Section 4.0 of this report.

Work Forecast for Next Quarter

- Char fines reactivity tests will be continued on the fluidized bed unit and the TGA.
- Tests will be performed with coke breeze during commissioning test. Bituminous coals will then be used in the ash agglomeration unit to develop an understanding of optimal operating conditions.
- Analyses of samples of ash buildup to determine its chemical composition and its mechanism of formation will be continued, along with efforts to identify alternative means of reducing buildup in the cyclone.

7.3 ENVIRONMENTAL IMPACT STUDIES

The environmental impact studies of a composite sample of test TP-020-2 ash agglomerates were completed during this reporting period, including residue characterization, investigation of leaching properties and thermal activity.

Test TP-020-2 was an air-blown, integrated shakedown test which demonstrated the reliable operation of the two-stage fluidized bed design. Pittsburgh seam coal was fed directly to both the devolatilizer and gasifier which operated at temperature ranges of 1510-1610^oF and 1820-1910^oF, respectively. These TP-020-2 agglomerates contained approximately 83 percent ash. The crystalline phases were determined by X-ray diffraction to be a major SiO₂ quartz, minor FeS and trace Fe₂SiO₄ spinel.

The particle size distribution was determined by two methods: sieve analysis and TV image analysis. The results summarized in Tables 7.3-1 and 7.3-2, respectively, indicated that the average particle size was below 1 mm from both methods. The TV image analysis resulted in smaller mean particle size (0.57 mm) because it was based on percent of particle counts and therefore would emphasize the smaller particles which were many per unit weight. Sieve analysis, on the other hand, is based on fractions of weight of particles retained on individual sieves.

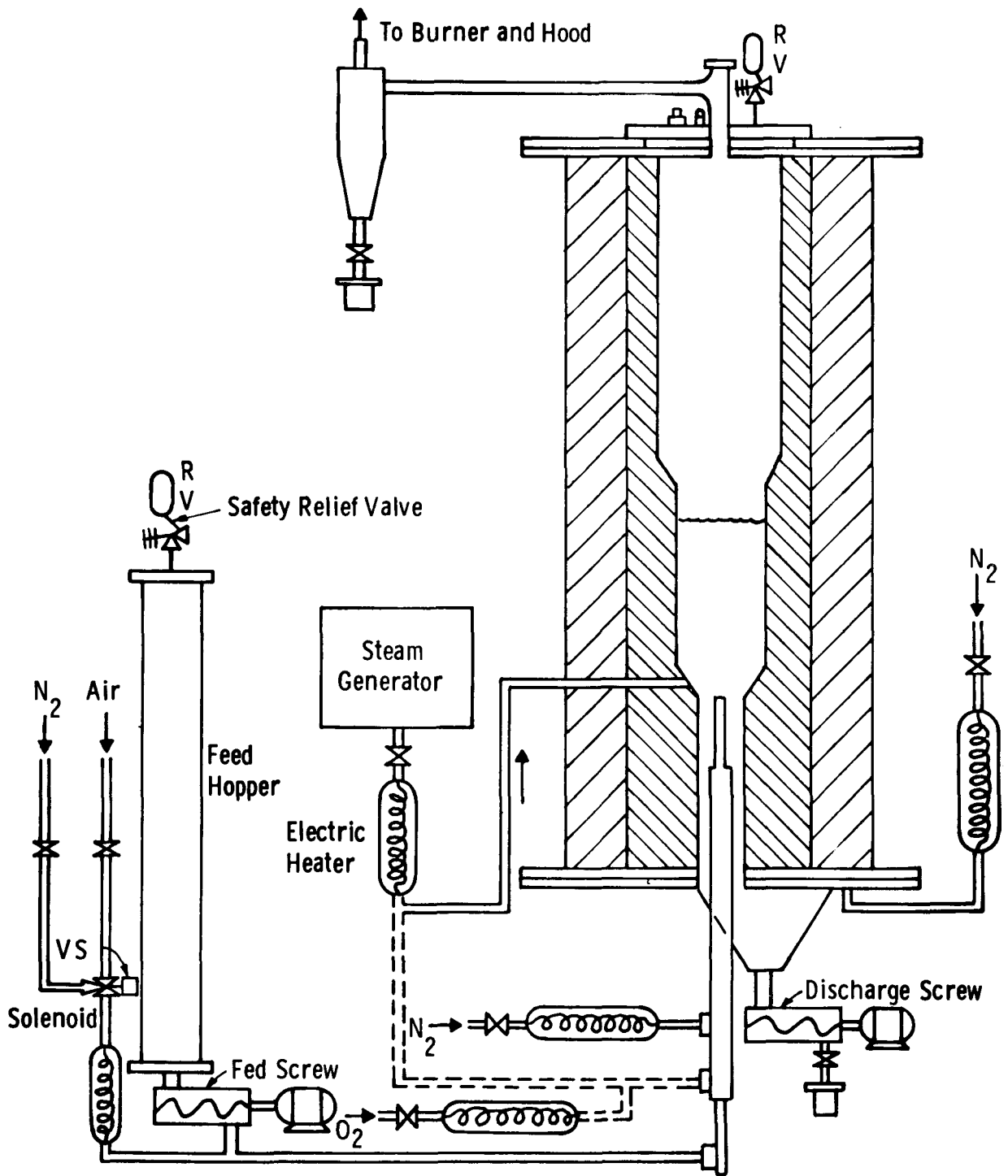


Figure 7.2-3. Schematic Diagram of Ash Agglomeration Test Facility

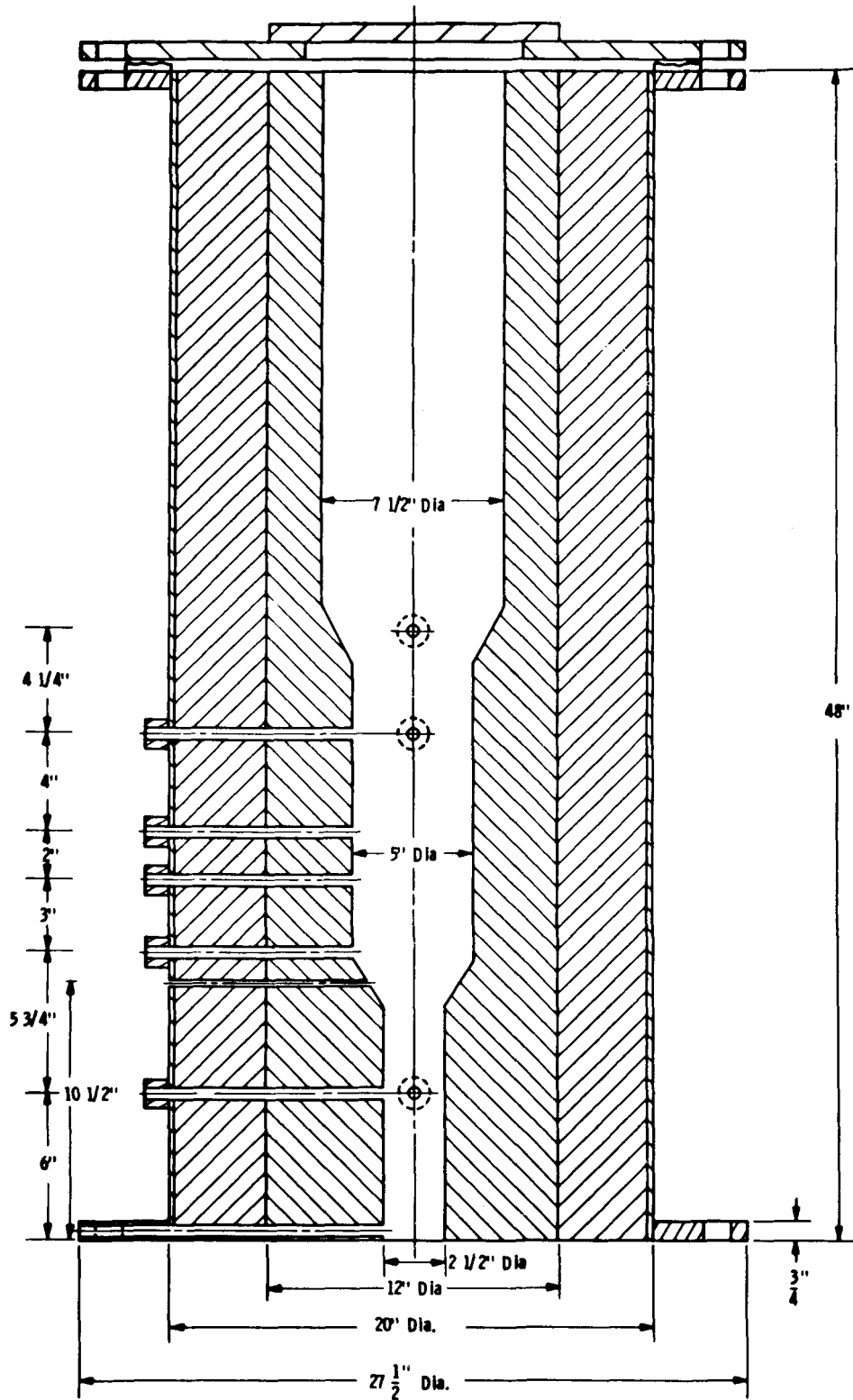


Figure 7.2-4. Ash Agglomeration Reactor

1363

TABLE 7.3-1

PARTICLE SIZE DISTRIBUTION BY SIEVE ANALYSIS, TEST TP-020-2

Size, mm	Wt.-%
+3.35	0.02
-3.35 + 2.36	0.5
-2.36 + 2.0	2.27
-2.0 + 1.7	4.6
-1.7 + 1.4	7.5
-1.4 + 1.18	9.4
-1.18 + 1	13.72
-1 + .6	36.06
-600 + 500 μ	9.33
-500 + 425 μ	5.45
-425 + 150 μ	10.47
-150 + 75 μ	.33
-75 μ	.31
Total	99.96

TABLE 7.3-2

PARTICLE SIZE DISTRIBUTION BY TV IMAGE ANALYSIS, TEST TP-020-2

Size, mm	% Particle Count
0 - 0.15	1.0
0.15 - 0.3	14.3
0.3 - 0.45	22.9
0.45 - 0.6	21.0
0.6 - 0.75	17.1
0.75 - 0.90	11.4
0.90 - 1.05	4.8
1.05 - 1.20	3.8
1.20 - 1.35	1.0
1.35 - 1.50	2.9
>1.50	0
Total Number of Particles Counted	105
Mean Particle Size	0.58

Scanning electron microscopy (SEM) and energy dispersive X-ray (EDX) analysis were employed to examine the TP-020-2 residue. The results shown in Figure 7.3-1 indicate an elemental content of Si, Al, K, Fe, Ca, and S in decreasing order. No cenospheres were observed.

Leachability of test TP-020-2 residue was investigated using two Westinghouse standard leach tests. Table 7.3-3 summarizes the solid and leachate characteristics by a 200-hour continuous shake method using deionized water and an acidic acetate buffer (pH = 4.5) as the leaching media. The deionized water leachate passed all existing Drinking Water Standards (DWS). The total dissolved organic (TOC) was extremely low. No sulfide was detected in the leachate. Leaching with acidic acetate buffer caused increased leachate concentrations of B, Ca, Fe, Mn, Si, Cl and total dissolved solids (TDS). The increase in Fe, Mn and TDS in acetate leachate were especially worth noting because all three exceeded the DWS, and Fe and Mn exceeded 10xDWS, which is being considered by the EPA Office of Solid Waste as the leachate criteria. The leaching behavior in an acidic acetate leachate suggests that siting and designing the disposal facility requires consideration to minimize an acidic environment. Co-disposal with municipal or industrial waste should be avoided because it generally results in acidic leaching conditions. Table 7.3-4 summarizes selected leachate characteristics including pH and conductance (approximating TDS) as a function of a 72-hour intermittent leaching cycle using both media. The improvement with this leaching cycle, i.e., total leachate volume passing the sample and time, is easily noted, except for SO₄ in an acidic acetate leachate which increases with the number of leaching cycles. The leachate characteristics by 200- and 400-hour continuous shakes are also summarized in Table 7.3-4 for comparison. The effect of acidic leaching is again seen.

Leaching properties of test TP-020-2 residue were also investigated using the EPA proposed extraction procedure (EP under RCRA). These results are summarized in Table 7.3-5 together with earlier results from test TP-018-2, conventional ash and EPA-proposed criteria for hazardous waste. All samples tested were non-hazardous according to the proposed definition under the RCRA.

Work Forecast for Next Quarter

The environmental impact studies conducted to date will be summarized. Ash agglomerates characteristics and leaching properties will be compared as a function of feed materials and process conditions. The environmental impact will also be compared with that of conventional ash disposal.

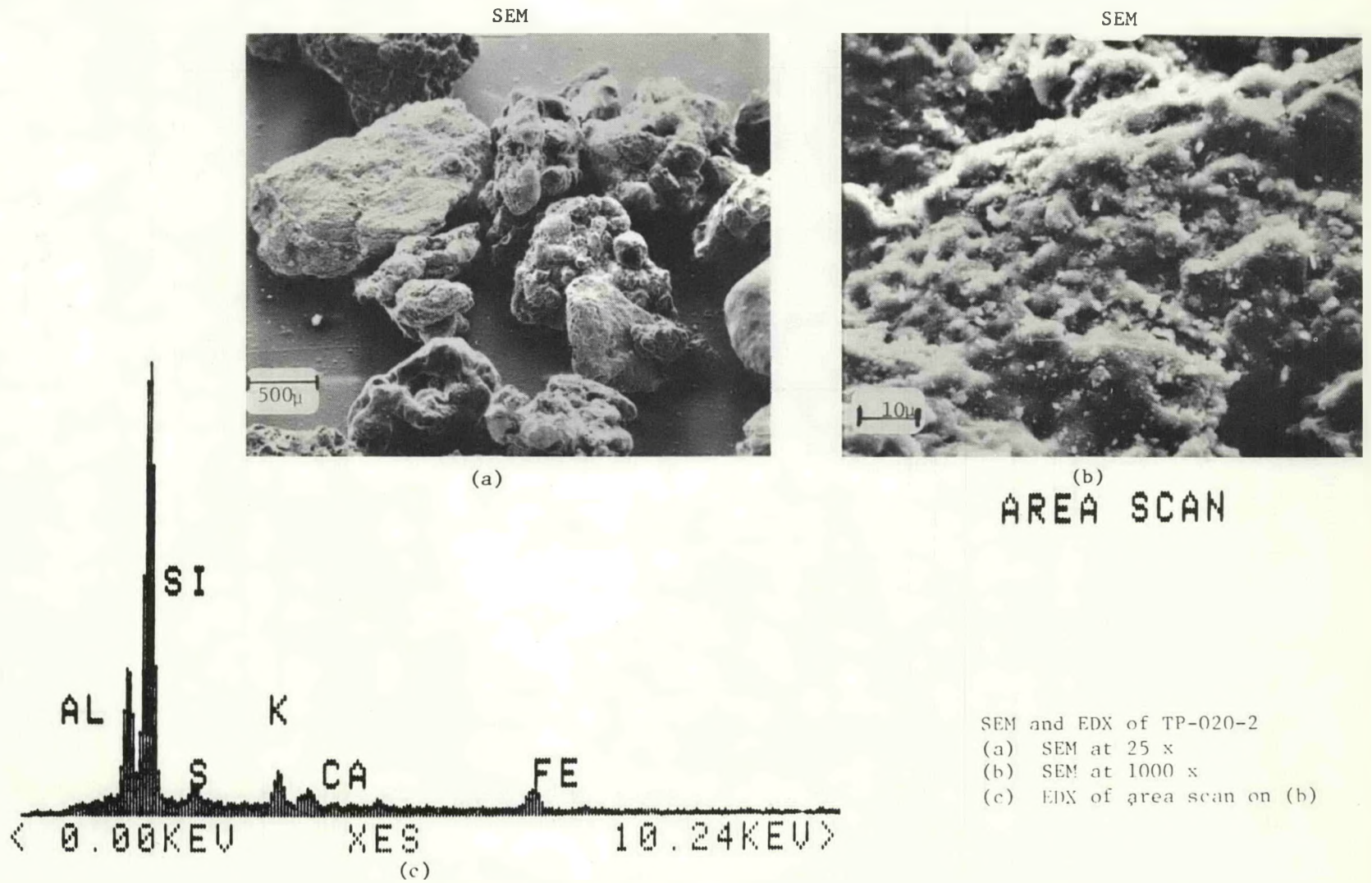


Figure 7.3-1. SEM and EDX of Test TP-020-2 (a) SEM at 25x, (b) SEM at 1000x, (c) EDX of Area Scan on (b)

TABLE 7.3-3

LEACHATE CHARACTERISTICS OF TEST TP-020-2 ASH AGGLOMERATES
BY 200-HOUR CONTINUOUS SHAKE TEST

Substance	Solid, ppm	Leachate Deionized H ₂ O, mg/l	Leachate Acetate Buffer, mg/l	DWS, mg/l
Al	6.66%	< 1	1	
Ag	< 1	< .03	< .03	0.05
As		< .001	< .001	0.05
B	200	5	30	
Ba	500	< 1	< 1	1.0
Be	7	< .03	< .03	
Bi	10	< .1	< .1	
Ca	< .88%	16	192	200
Cd	< 10	< .005	< .005	0.01
Co	30	< .1	< .1	
Cr	100	< .02	< .02	0.05
Cu	33	< 1	< 1	1.0
Fe	10.75%	< .3	> 100	0.3
Ga	30	.5	.5	
Ge	< 10	< .1	< .1	
Hg		.0012	.0013	0.002
K	0.78%			
Mg	0.17%	< 10	< 5	150
Mn	1000	< .03	> 3	0.05
Mo	50	< .1	< .1	
Na	0.17%			
Ni	50	< .1	.1	2.0
Pb	< 10	< .05	< .05	0.05
Sb	< 30	< 1	< 1	
Se		< .002	< .002	0.01
Si	12.4%	10	20	
Sn	< 10	< .1	< .1	1.0
Sr	200	< 5	< 5	
Ti	> 1000	< 1	< 1	
V	100	< .1	< .1	
Zn	200	< 5	< 5	5.0
Zr	200	< 1	< 1	
SO ₄	0.22%	12	< 10	250
S ⁼	3.05%	< 2	< 2	
F		< 1	< 1	2.4
Cl		< 1	170	250
NO ₃ (as N)		< 1	< 1	10
PO ₄		< 1	< 1	
TOC		< 20		
pH		8.28	4.75	6.5 to 9.2
SC, μmho/cm		195	4.960	~750

DWS - NIPDWR, USPHS, and WHO Drinking Water Standards

▨ Exceeds DWS

▩ Exceeds 10 × DWS

TABLE 7.3-4

LEACHATE CHARACTERISTICS OF TEST TP-020-2

Leaching Medium	Chemical Characteristics	Intermittent Shake, No. of 72-Hr Intervals (S/L = 1/3)										Continuous Shake/Hr (S/L = 1/10)	
		1	2	3	4	5	6	7	8	9	10	200	400
Deionized Water pH = 7	pH	8.92	8.7	8.17	7.82	7.71	7.9	7.72	7.7	7.52	7.7	8.28	8.23
	Sp. Conductance, $\mu\text{mho/cm}$	.302	.171	.122	.178	.154	.2	.2	.182	.17	.17	.195	.186
	Ca, mg/l	44	12	12	12	12	12	8	8	12	8	16	12
	Mg, mg/l	0	12	7.2	9.6	7.2	<5	7.2	<5	<5	<5	<10	<10
	$\text{SO}_4^{=}$, mg/l	88	29.2	20.1	34.7	31.8	97.8	56	48.5	41.6	42.4	12	27.9
$\text{S}^{=}$, mg/l	<5	0	-	-	-	-	-	-	-	-	<2	<2	
$\text{NaC}_2\text{H}_3\text{O}_2/\text{HC}_2\text{H}_3\text{O}_2$ Buffer pH = 4.45 Cond = 3.2 $\mu\text{mho/cm}$	pH	4.95	4.73	4.52	4.5	4.5	4.43	4.4	4.42	4.43	4.42	4.75	4.7
	Sp. Conductance, $\mu\text{mho/cm}$	4.71	3.59	3.27	3.63	3.3	36.3	3.38	3.25	3.25	3.32	4.96	4.54
	Ca, mg/l	488	136	64	48	40	40	24	24	<10	<5	192	248
	Mg, mg/l	28.8	14.4	19.2	<5	0	14.4	<5	<5	<5	<10	<5	28.8
	$\text{SO}_4^{=}$, mg/l	27.3	18.2	66.7	85.8	66.7	126.5	103	123.5	105.7	115.5	<10	<10
$\text{SO}^{=}$, mg/l	0	-	-	-	-	-	-	-	-	-	<2	0	

TABLE 7.3-5

LEACHATE CHARACTERISTICS FROM RCRA/EP
TEST OF PDU AND CONVENTIONAL COAL ASH

Substance (ppm)	Test TP-020-2	Test TP-018-2	Conventional Ash	EPA Proposed Criteria for Hazardous Waste, 10X DWS
Ag	<0.02	<0.02	<0.02	0.5
As	<0.001	<0.001	0.065	0.5
Ba	<1	<1	<1	10.0
Cd	<0.01	<0.005	<0.005	0.1
Cr	<0.05	<0.02	<0.02	0.5
Hg	0.0008	0.0008	0.006	0.02
Pb	<0.05	<0.04	<0.04	0.5
Se	<0.001	0.004	0.02	0.1
Ca	44	24	372	None
Mg	<10	0	21	None
SO ₄	<10	10	1010	None
NO ₃	-	<1	<1	None
F	-	<1	<1	None
Total Volume of Acetic Acid Added, ml	8	5	24	None
Final pH	5.2	4.95	5.05	None
Specific Conductance, millimhos/cm	0.51	0.22	1.62	None