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ADVANCED COAL GASIFICATION SYSTEM FOR ELECTRIC POWER GENERATION

SECOND QUARTERLY PROGRESS REPORT
FY-1979

Period January 1 to March 31, 1979

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SECTION 1.0

OBJECTIVE AND SCOPE OF WORK

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

1.1 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 de-caking and devolatilizing fresh coal feedstocks. Process feasibility of the devolatilizer was demonstrated through a series of tests with a variety of coal feedstocks, including 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 will be followed by evaluation of the integrated system consisting of the devolatilizer and gasifier-agglomerator.

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

1.2 LABORATORY SUPPORT STUDIES (Task 3)

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, develop process models for scale-up, and understand process phenomena to achieve reliable operation. Work was 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. Work accomplished and planned is summarized in Section 3.5.

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

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

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

converted to an auxiliary coal feed system. In addition, the pilot air and propane flow control loops for the F-110 synthesis gas generators were rebuilt, and maintenance and corrective work was performed on the char drawoff leg.

2.1.5 PDU Process and Design Engineering

Work performed in this area encompassed a considerable variety of activities. Accomplishments included design engineering and analysis of process, piping and equipment modifications for integrated operation, design of a new multi-thermocouple array for the upper ash annulus, revision of the gasifier heat and material balance computer program, instrumentation upgrading, and product characterization studies.

In product characterization, Subsection 3.3.2, work accomplished included modifying and developing sample apparatus to improve measurement techniques, and analyzing and evaluating chemical and physical property data of samples from tests TP-018-4, TP-018-5, and TP-019-1, -2 and -3. Solids, product gas and liquids analyses are included.

As part of the environmental safety and health program, chemical storage and equipment safety reviews were conducted, as well as industrial first aid classes.

2.2 LABORATORY SUPPORT STUDIES (Task 3)

2.2.1 Cold Flow and Analytical Modeling

The planned experiments on the momentum dissipation of and the gas entrainment into a gas-solid two-phase jet were completed at three different nominal jet velocities and with three different solid loadings at each jet velocity. Regular movies were taken around the jet region to follow the particle movement around the jet and high-speed movies were also taken at 2000 frames/second to chart the solid particle trajectory inside the jet for both pure gas jets and gas-solid two-phase jets. The rate of solid entrainment into the jet at different jet velocities will then be determined from these movies. This concluded the experimental phase of the studies on jet phenomena in a fluidized bed, but the experimental data will continue to be analyzed. The semicircular unit is now being modified for carrying out experiments on simulation of continuous char-ash separation in the annular char-ash separator.

Tests to explore operation with multiple draft tubes continued. The focus was on investigation of performance during simulated upset conditions, that is, allowing a draft tube to plug. Diagnostic techniques were studied for monitoring performance.

2.2.2 Coal Behavior

Documents are being prepared to report the results on char reactivity studies and surface area measurements.

SECTION 2.0

TECHNICAL PROGRESS SUMMARY

2.1 OPERATION AND MAINTENANCE OF THE PDU (Task 1)

2.1.1 Gasifier Tests

Single-stage gasifier testing was concluded in December 1978, and no additional testing was conducted during January, February and March 1979, since during this period, maintenance and modification of the gasifier was performed to prepare the PDU for integrated operation. In addition to this maintenance activity, analyses of test data from PDU gasifier tests conducted during the latter portion of 1978 were completed.

2.1.2 Integrated Tests

In preparation for integrated operation, the test plan for shakedown test TP-020 was completed and reviewed, training sessions for engineers and operating technicians were conducted, and projected heat and material balances were reviewed. The burner control logic was rebuilt and operability flow tests, using CO_2 in place of propane, were conducted by each operating crew. Also, maintenance and modification of existing and additional devolatilizer hardware was accomplished, as discussed in detail in Subsection 3.1.2.2.

2.1.3 PDU Modifications for Improved Operation

During this quarter, the C-119 cyclone barrel refractory was recast, major pumps in the quench water system were removed, inspected and reinstalled, and modifications in support of the integrated PDU shakedown test, TP-020, were performed, as discussed in Section 3.2.1.

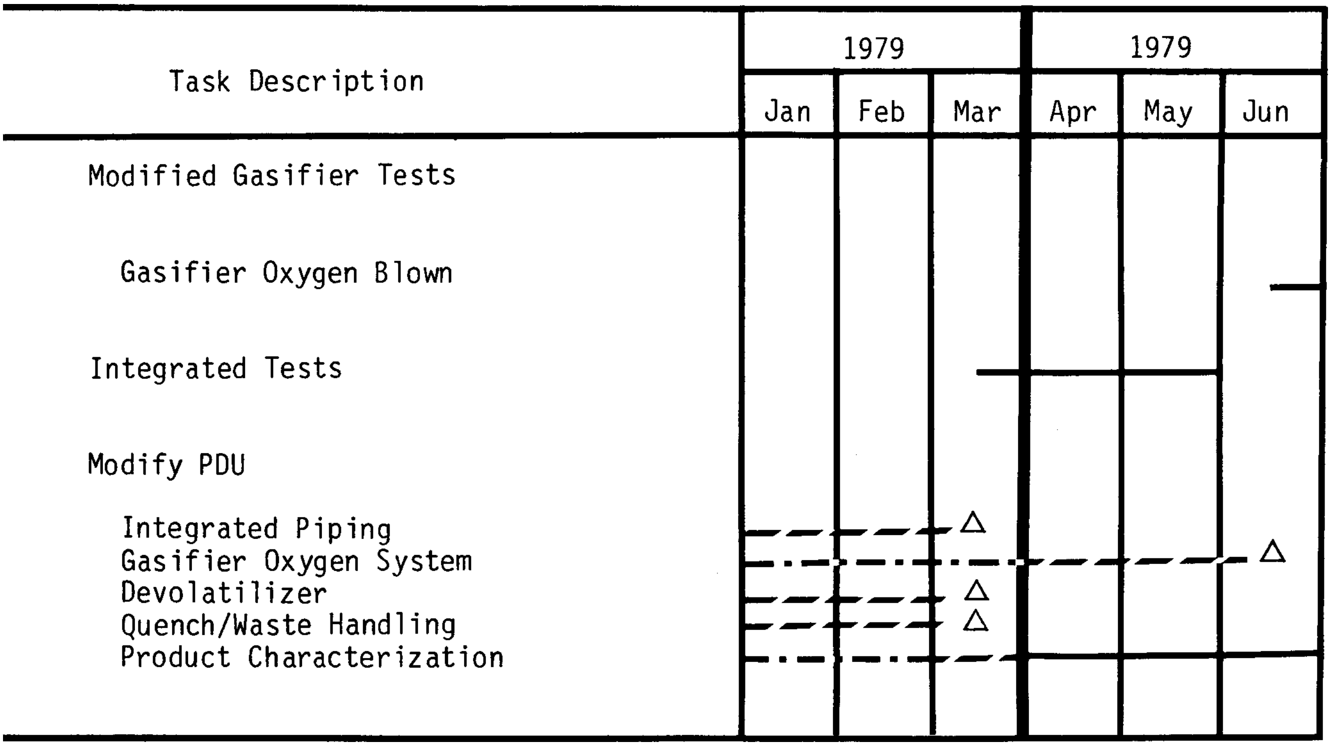
Quotations were solicited for the coal crusher/dryer unit, an evaluation of costs and advantages of a 15-day versus a 30-day long-duration test was submitted to Pullman Kellogg, who recommended a 15-day run, and an evaluation of PDU power usage from actual test measurement data was performed, indicating a need for additional site power.

2.1.4 PDU Modifications for Integrated Operation

Major efforts this report period were placed on construction and modification tasks to prepare the PDU for integrated testing. The gasifier was reoriented, devolatilizer refractory work was completed, field fitting of refractory-lined piping was performed and the out-of-service Dolomite lockhoppers were

2.3 SUMMARY SCHEDULES

2.3.1 Operation and Maintenance of the PDU (Task 1)



LEGEND:

Task Complete △

Test ———

Design/Approval ....

Procurement —·—·—

Construction/
Modification — — —

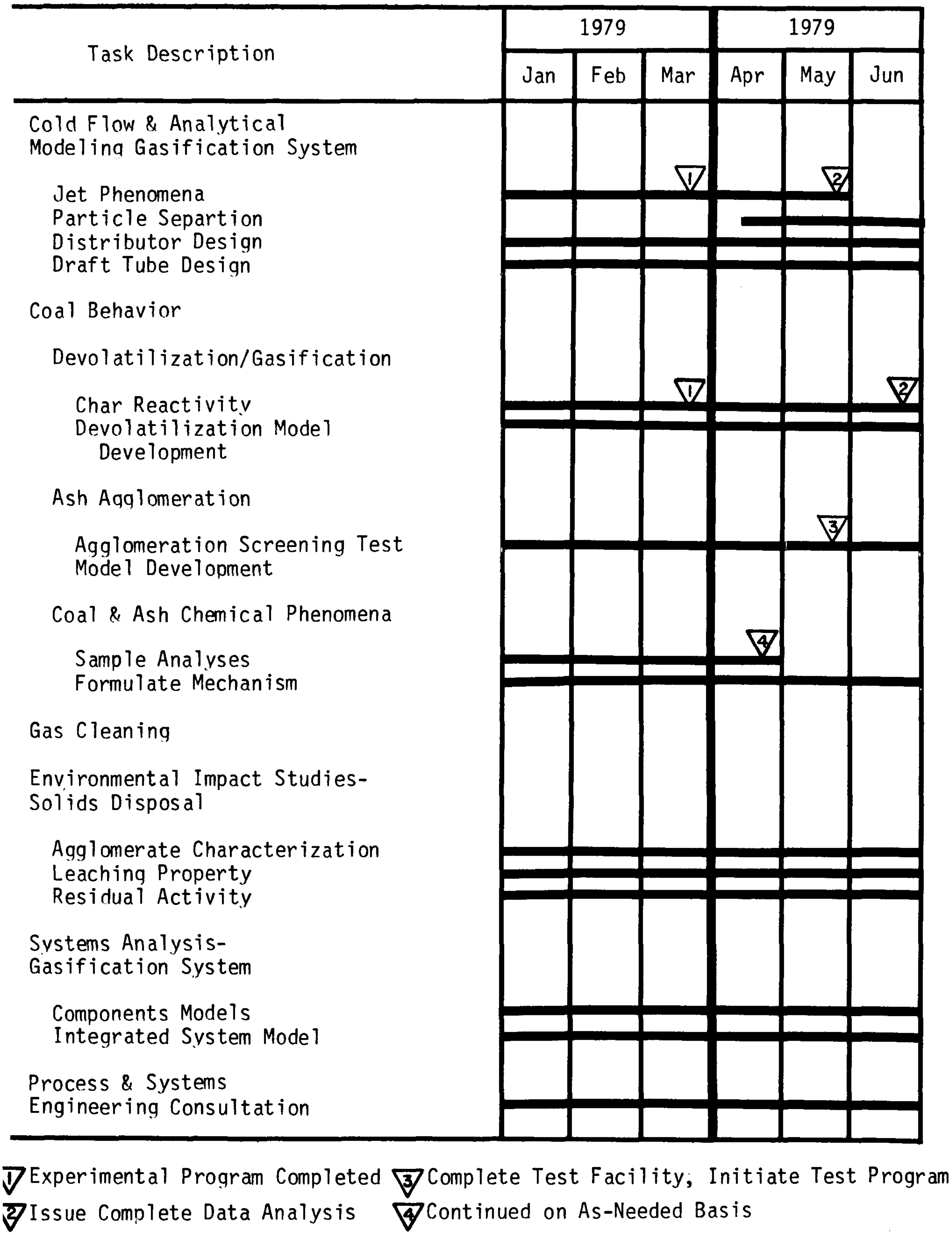
Installation of the ash agglomeration unit is in progress. Several design and operational features of the unit have been substantially improved. Cold flow tests were completed to determine design and operating parameters.

Efforts to isolate and define the binding matrix in ash deposits and agglomerates continue. A spot-test analysis, which involved reactions with zinc chloride and sodium tetraphenyl-boron, showed the presence of potassium in the glassy particles collected manually from a ground sample of wall deposit, under the microscope at a magnification of 200X. Gravity fractionation was also used to isolate the binding material from the bulk of deposits and agglomerates. The various sink and float fractions in carbon tetrachloride, 1, 2-dibromoethane and bromoform were analyzed using DTA (differential thermal analyses) to determine their melting characteristics.

2.2.3 Environmental Impact Studies

Characterization of ash agglomerates from test TP-018-2 (oxygen-blown, coke breeze and Pittsburgh seam coal feed) and investigation of their leaching properties continued. Leachates with a deionized water medium pass drinking water standards. Leaching with an acetate buffer increased leachate concentrations, as expected. The RCRA (Resource Conservation and Recovery Act) test for toxicity, EP (extraction procedure), as proposed by the Environmental Protection Agency, has been performed. Analyses will be completed next quarter and will provide two bases for assessing the classification of ash agglomerates from the Westinghouse process. Preliminary data indicate the agglomerates will not be hazardous.

2.3.2 Laboratory Support Studies (Task 3)



1 Experimental Program Completed

2 Issue Complete Data Analysis

3 Complete Test Facility, Initiate Test Program

4 Continued on As-Needed Basis

SECTION 3.0

DETAILED DESCRIPTION OF TECHNICAL PROGRESS

3.1 OPERATION AND MAINTENANCE OF THE PDU (Task 1)

3.1.1 Modified Gasifier Operation

With the conclusion of single-stage gasifier testing in December, during this quarter maintenance and modifications were performed to prepare the PDU for integrated operation of both the devolatilizer and the gasifier. In addition, test analyses were completed for PDU gasifier tests conducted during the latter portion of 1978.

3.1.1.1 Work Accomplished - Modified Gasifier Tests

No testing of the modified gasifier system was conducted during January, February and March since construction activities continued in preparation for operation of the integrated system.

Test-related work consisted mainly of summaries and analyses of data. Summaries of test TP-018-4 and test TP-018-5 data were completed, as well as final data reports for tests TP-019-1 and TP-019-2, with the final report for TP-019-3 near completion.

3.1.1.2 Work Accomplished - Maintenance and Modifications

Maintenance and service work completed on the gasifier system in January, February and March included the following:

- Inspection of the gasifier and cyclone internals with cleaning and reassembly where required.
- Removal of pump casings G-101, G-102, G-104, G-114, and G-120A/B from the PDU to prevent damage or freezing during the winter construction period. G-114 and G-104 pumps were rebuilt and reinstalled after being inspected.
- Repair and reinstallation of the F-113 electric heater.
- Field fitting of the replacement gasifier ash annulus section. The original section was returned to the manufacturer to correct deficiencies.
- Field fitting of the interconnecting piping to the new modified gasifier cyclone section, shown in Figure 3.1-1.
- Removal and repair of T-129 starwheel feeder in the ash withdrawal system.

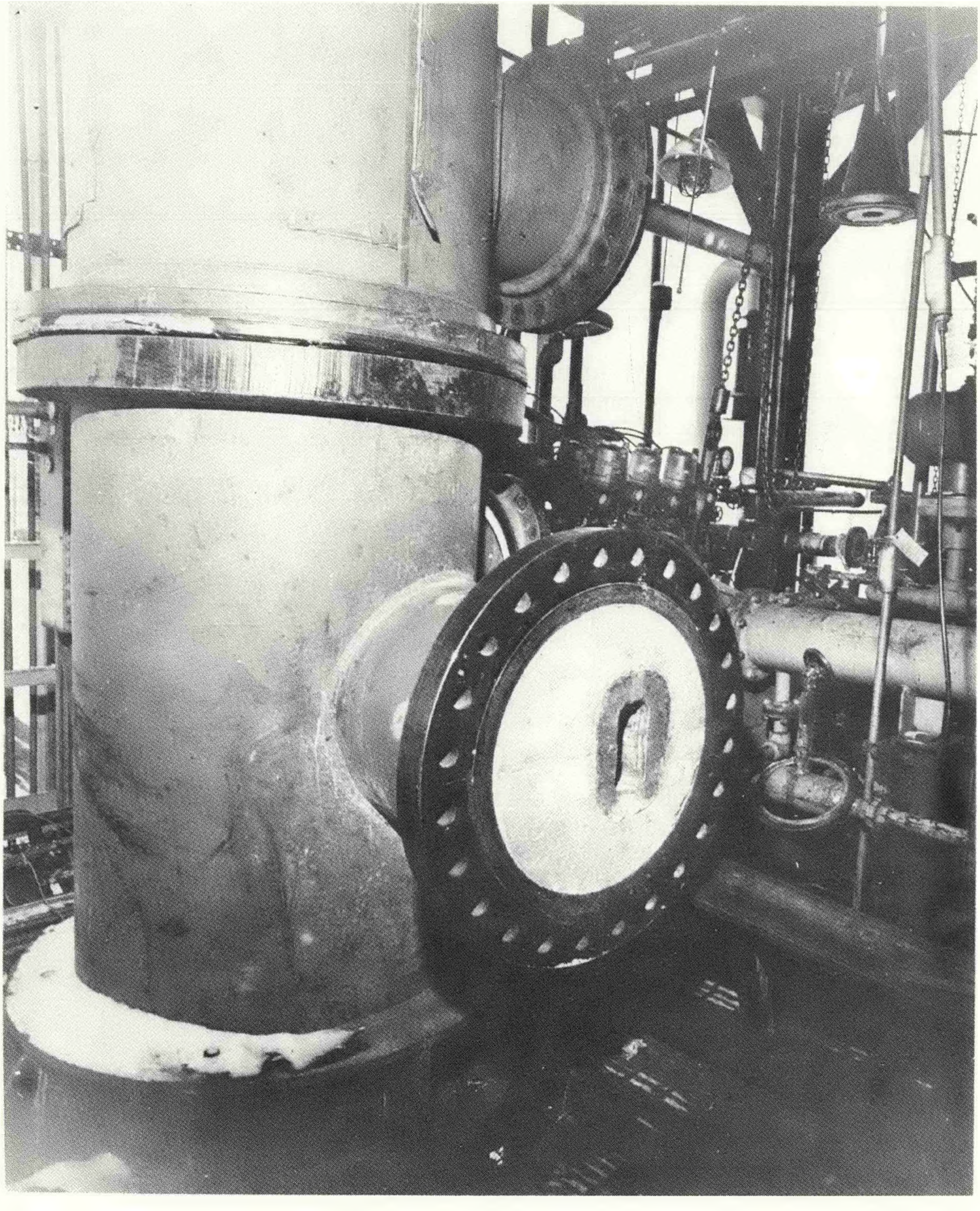


Figure 3.1-1. Inlet Configuration for the Modified Section of the C-119 Gasifier Cyclone

An inspection was completed of the lower sections of the gasifier which included the grid plate assembly and annulus region refractory. This section had been subjected to nearly two and one-half years of testing with over 40 temperature cycles, that is, from cold startup to hot operation, followed by cooldown to ambient. The condition of these sections was found to be inadequate and unacceptable for restart operation of a lengthy test series and repairs were necessary. The grid plate mortar joints were found to be eroded to the point that a new grid plate assembly was installed. The refractory in the annular region where the temperature interface existed during previous PDU tests was found to be moderately spalled and required recasting. The affected refractory area is shown in Figure 3.1-2. The temperature differential across this interface during operation is very large, ranging from 1000-1400°F, and thus movement of this interface over the axial length of the annular region causes large portions of the hardface refractory to alternate between compression and tensile stress. With the additional stress cycles of the numerous startups during the past two and one-half years, small pieces of dense refractory have been found in the ash discharge material, more frequently during the recent test series, and causing sporadic withdrawal problems.

To determine indications of erosion or corrosion that may be taking place in gasifier subsystems such as the product gas cooling system, the feedstock storage and feeder systems and the refractory-lined sections of the gasifier and cyclone, an ultrasonic probe was used to measure wall thicknesses. No specific thickness measurements were identified that would be a matter of concern, but the results will be maintained as a continuing reference for future periodic measurements.

3.1.2 Integrated PDU Operation

3.1.2.1 Work Accomplished - Integrated Tests

The test plan for TP-020, the shakedown test for integrated operation, was reviewed by the operational safety review committee and was conditionally approved with some follow-up assessments required of various items.

TP-020 defines a startup for operating the gasifier system on coke breeze, with product gas and elutriated solids flowing through the integrated piping to the devolatilizer reactor and the cyclone. Fluidized beds will then be established in both reactors with coke breeze. Once transfer of coke breeze from the devolatilizer to the gasifier is demonstrated and circulation around the draft tube is established, coal will be introduced to the devolatilizer, where a change in bed density of 2:1 is expected. Once this change in density has been accomplished, devolatilizer char will be introduced into the gasifier via the standpipe, where a similar bed density transition will take place.

Other preparations for integrated operation included a number of training sessions held in January for engineers and operating technicians. These were essentially a review of the previous devolatilizer tests, subsystem modifications relative to devolatilizer operation and input capacities. In

Figure 3.1-2. Gasifier Annulus Section Following Two and One-Half Years of Severe Operating Conditions with Over 40 Temperature Cycles. (Post-Test TP-019-3 Inspection)

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addition, the intended testing philosophy, projected heat and material balances, based on integrated operation with Pittsburgh seam coal as the feedstock, were reviewed.

Operability flow of the synthesis gas generator control logic was checked with each operating crew conducting a flow test using CO_2 in place of propane.

All real-time data acquisition system programs were reviewed and modified as required for use in integrated operation, and new CRT displays were created to facilitate monitoring during the test.

3.1.2.2 Work Accomplished - Maintenance and Modifications

A limited amount of maintenance and modification work was accomplished relative to existing devolatilizer hardware, mainly to assure readiness and compatibility with the new integrated system. The C-110 devolatilizer cyclone was cleaned, a carbon dioxide line was connected to the cyclone sparger, the G-117 glycol feed pump for the devolatilizer coal feed tube was inspected and cleaned, and all devolatilizer system pressure safety valves were removed and recalibrated for integrated operation.

Process heaters F-119 and F-120 were reinstalled, as were the sample pots for the devolatilizer. Heat sensors were also installed on the devolatilizer, along with temperature indicating paint, and the field wiring for the F-110 synthesis gas generator was reconnected.

Additional items completed this quarter included fabrication and installation of the pressure safety valve assembly for the devolatilizer, the isokinetic TCA*/miniscrubber sampling train to the devolatilizer outlet gas line and the C-101 devolatilizer coal feed tube. Installation of the F-110 synthesis gas generator, generator view ports, generator flow loops, glycol cooling lines and G-128 glycol cooling pump for the burner was completed, along with fabrication of personnel protection on the F-110 generator. The spool pieces from C-101 to the C-104 alternate char drawoff and from C-101 to the C-110 devolatilizer cyclone, spring supports on the char drawoff leg (seventh level), pumps G-120A and B, and a second gas chromatograph system were also installed.

Also, completion of the T-124 and T-125 starwheel feeder assemblies, the char feed transport line to the C-115 gasifier, and ultrasonic thickness measurements of the recycle gas and quench water system was accomplished.

The plant water system piping was cleaned with Oakite 32 descaling solution, inspected, flushed and reassembled for the initial test for 1979.

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*Total condensables analyzer

3.1.3 Feedstock Procurement

A requisition was placed for 60 tons of Pittsburgh seam coal, but startup problems encountered at the grinding facility as a result of frozen and wet coal delayed delivery. An alternate means of obtaining the required tonnage is being explored. In addition, 60 tons of Ohio #9 coal cannot be ground off-site until late spring. Offsite services for grinding and air drying of feedstock at the site continue to be a problem for PDU operation, both in logistics of preparation and delivery of wet material, causing feedline plugs during operation.

3.2 MODIFICATIONS TO THE PDU (TASK 2)

3.2.1 Modifications for Improved Operation

Work accomplished in support of the integrated PDU shakedown test included several engineering design tasks for improved operations. The first involved modification of the lower section of the gasifier pressure vessel to incorporate six additional axial-spaced instrumentation nozzles for thermocouples and one nozzle for a sample drawoff line. A new steam distribution ring for the gasifier grid was also designed and was imbedded within the transition grid. This design should improve the steam distribution patterns in the grid region. The old design featured a conical segmented grid which distributed the steam through holes formed by adjacent refractory segments. In addition, the angular configuration of the grid was changed to improve the patterns for solids recirculation and ash withdrawal.

Two major refractory casting jobs were completed this quarter, the new C-119 cyclone section and the ash annulus section of the gasifier. The C-119 cyclone barrel was cast with two layers of castable refractory. The innermost refractory is Castolast "G," a highly abrasion-resistant material made by Harbison-Walker. The outer refractory is an intermediate density, castable LW-26, also made by Harbison-Walker. The form design, manufacture, refractory pouring and cure were performed on site by Westinghouse personnel, and similar refractory work was performed on the gasifier/cyclone spool piece. The spool piece provides a circular-to-rectangular transition inlet to the cyclone, which was modified in an attempt to reduce solids deposition on the refractory wall and to marginally increase overall mass collection efficiency.

Following test TP-019-3, the condition of the top portion of the ash annulus refractory was badly cracked, showing indications of local spalling in some areas, as shown in Figure 3.1-2. As a result of this condition, all of the refractory in this section was replaced. During this replacement, the radial thickness dimensions of the hardface refractory was changed from 5 to 4 inches in an attempt to reduce the effects of spalling caused by high thermal stresses in this region. With additional thermocouples located in this zone for better temperature interface control and the thickness reduction of the refractory, increased service life of the refractory is expected. The sparger ring in this section was also redesigned to reorient the 6 holes that formerly pointed outward at a slight angle into a direct downward position. This should eliminate the erosion experienced on the vessel walls as a result of the past year's testing.

Other hardware modifications made to improve reliability performance consisted of changing the type of valve used in the recycle transport gas system of the C-110 cyclone and in the electrical feedthrough of the F-114 recycle gas heater. The previously oversized split body plug valve used to control the recycle gas return downstream of the C-108A lockhopper cyclone was replaced by a rotary valve to improve the transport and control of fines from the C-110 cyclone.

The F-114 recycle gas heater used to heat fines transport gas during both integrated and gasifier operation was also modified to incorporate a new sealing arrangement for the electrical feedthrough. A Teflon seal inside a ceramic sleeve was installed on the electrode to prevent moisture and fines in the recycle gas from contacting the electrode, causing internal shorting across the feedthrough flange.

The C-111 quench scrubber was inspected and cleaned, and a flow test and a dye penetrant test were performed on the water box.

All steam lines were inspected to ensure a rust- and scale-free condition; the devolatilizer, C-110 cyclone and intermediate product gas line were painted with heat sensitive paint; the CO_2 purge rotameters were cleaned and repaired; subsystem procedures for integrated operation were reviewed and updated; and the pressurization and leak test of the integrated system was initiated for the first integrated test, TP-020.

In other activity, the purchasing-design specification package for the coal crusher/dryer unit for future tests was submitted for quotation requests.

And finally, an evaluation of the power usage for the PDU was made using actual test measurement data. The need for additional site power to accommodate equipment planned for upgrading the PDU was identified from the study, as were peak load requirements for the integrated test series and other future additions.

Preparations for the long-duration test were limited to evaluation studies to determine the best test duration period for the PDU. An evaluation of costs and technical advantages of a 15-day versus a 30-day test was submitted to Pullman Kellogg, and their recommendation was in favor of a 15-day run.

3.2.2 Modifications for Integrated Operation

During this period, a major effort was placed on construction and modification tasks which were needed to prepare the PDU for integrated operation of both the devolatilizer and the gasifier reactor systems.

The first phase involved reorienting the gasifier by rotating the outlet section 90 degrees to connect with the integrated piping between the gasifier and the devolatilizer. Expanded sections of the devolatilizer were then rotated, plumbed and installed in permanent position with the gasifier, as shown in Figure 3.2.1.

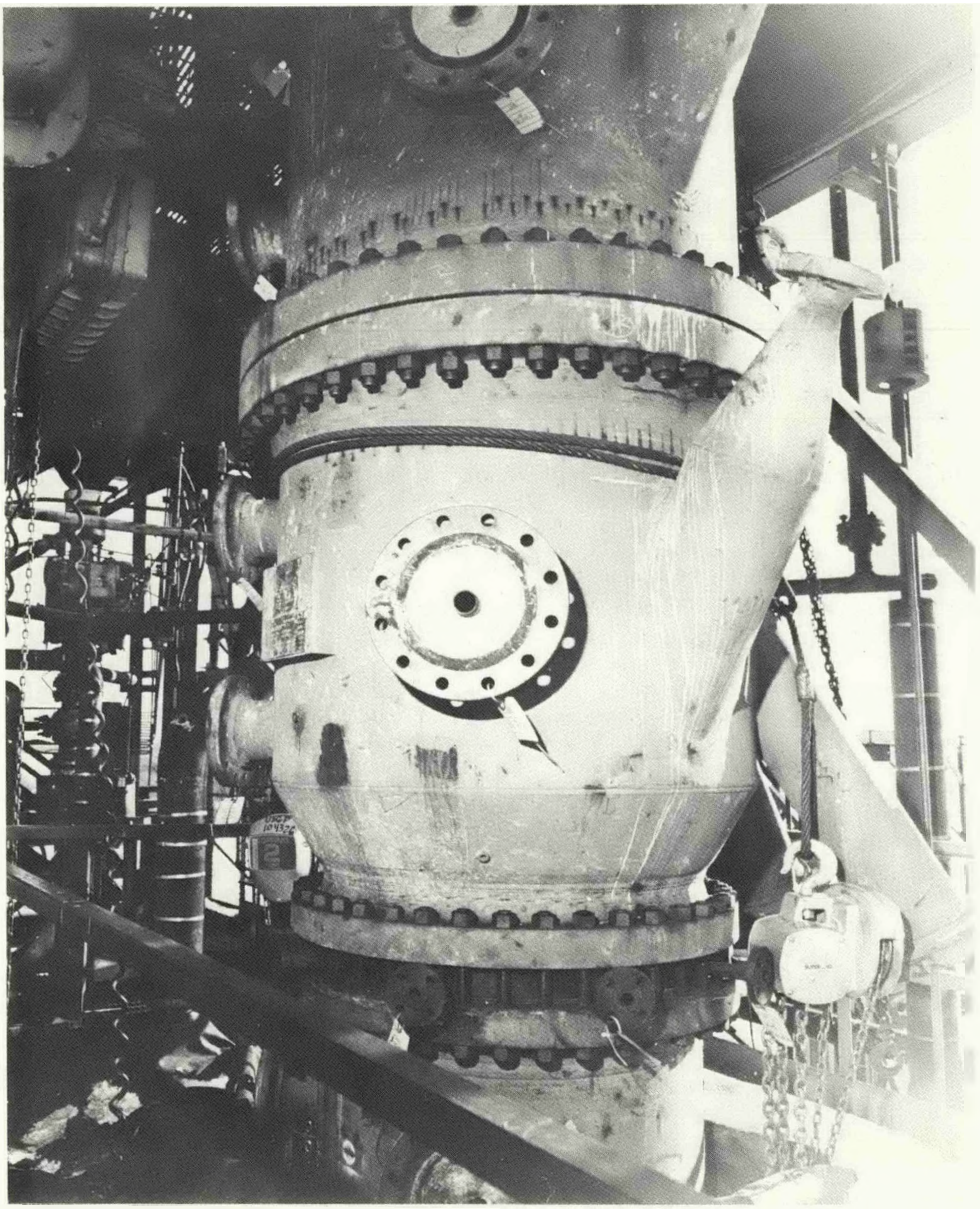

Figure 3.2-1. New Expanded Section of the C-101 Devolatilizer

Next, the bottom section of the devolatilizer was lowered and supported to allow casting of the refractory. A layer of insulating brick was followed with a layer of abrasive-resistant arched bricks, all of which surround the plenum of the coal feed tube. On the top of the grid plate, conical bricks were then installed. Following came the draft tube assembly consisting of the lower draft tube support wheel, five sections of the draft tube, the center draft tube support and the remaining four sections of the tube and associated top support section. A four-day hot-air heatup of the refractory was performed prior to bolting the two bottom sections of the reactor together.

In reactivating the F-110 synthesis gas generator, which is used as an auxiliary heat source for the integrated test to make up for excessive heat loss, modifications to the flow loops and rebuilding of the burner assembly were required.

Modifications were made to the flow loops to improve operating characteristics. The F-110 pilot air and propane flow control loops were rebuilt to eliminate excessively corroded external sections and to upgrade the piping from threaded Schedule 40 fittings to welded Schedule 80 carbon steel. During the devolatilizer test series, even though the 1-inch flow control valves on the CO_2 lines (FV-69) and the propane line (FV-51) were operated with the smallest sized trims for the valve bodies available, automatic control was still hindered by minimum valve opening. To remedy this, the valves were replaced by 1/2-inch control valves with suitably sized trims. A minor change was also made in the F-110 synthesis gas generator control logic to allow the operator to use automatic control of the CO_2 flow valve (FV-69) during the "pilot-only" mode of operation. Previously, a hand valve bypass was used in the pilot-mode operation. This logic change will allow removal of the manual bypass valve (HV-1299) on the CO_2 line.

The F-110 burner face was recast with refractory and the assembled burner face and chamber were installed on the bottom section of the devolatilizer. Also, the C-101 devolatilizer coal feed tube was reworked, recast with Harbison-Walker Castolast "G" and reinserted into the devolatilizer.

Once the devolatilizer was positioned, field fitting of several sections of refractory-lined piping were completed. These sections included:

- Devolatilizer-to-devolatilizer cyclone spool piece.
- Devolatilizer char drawoff spool piece.
- Devolatilizer alternate char withdrawal line.
- Gasifier outlet to the new gasifier cyclone barrel inlet.

The conversion of the out-of-service dolomite lockhoppers into a feed system to supply coal to the devolatilizer during integrated operation was completed. This involved reassembly work from the exit of the T-108 bucket elevator to the inlet of the C-109B lockhopper, rebuilding of the T-125 starwheel feeder under C-109B, and the installation of the 1-inch Incoloy feedline from C-109B to the C-101 devolatilizer.

Instrumentation on the char drawoff leg was partially installed along with the pressure tap carbon dioxide purge lines. During this installation, it was discovered that two of the instrument nozzles were incorrectly cast by the subcontractor and were blocked by refractory. These were repaired by the subcontractor, who also completed installation of the transport gas supply line up to the char pickup transition point. An automatic flow control loop was designed to aid the operation of this standpipe. This will replace the existing manual rotometer control design supplied as part of the integrated package.

During a pressure leak test at 150 psig, a number of major leaks appeared on the subcontracted char drawoff flanged piping installation. The leaks were attributed to the line touching structural members in at least two locations. A detailed analysis of the piping, supports, reactor nozzle loading and springing was initiated to determine the fixes necessary for cold and hot operation of the drawoff line.

3.3 PDU PROCESS AND DESIGN ENGINEERING (Task 1)

3.3.1 Work Accomplished - Process and System Analysis and Design

In support of the upcoming integrated tests, the heat and material balance computer program for the gasifier was revised to incorporate configuration changes for integrated operation. These revisions include a net addition of four major process streams.

An analysis of the ash annulus operation has been completed, with the results defining the nominal operating ranges for the upcoming PDU integrated tests. In addition to providing further information on combustion kinetics, the analysis has given indications of the sensitivity of the operating performance of this section to the configuration and the local fluid dynamics around both the combustion and ash withdrawal zones. The effects and the extent of this sensitivity will be the subject of a more in-depth study in the test program planned for the scale-up model, and subsequent PDU tests

As a part of instrumentation upgrading, specifications for an in-process pH probe/recorder were completed and submitted to possible vendors for quotation. This monitoring probe will permit continuous analysis and adjustment of the quench water pH to reduce the corrosion potential in this system. The current method of extracting samples and awaiting laboratory analysis results is labor intensive and results in unsatisfactory lag times for data evaluation.

Work was initiated to determine the feasibility and effort required to demonstrate computer supervisory control concepts. The initial studies involve automated control of the plant pressurization ramp by computer supervisory control of the system back pressure control valve, PIC-15.

A sensitivity analysis is also under way to determine the effect of input variables on predicted heating values. Specifically, the changes in higher heating values relative to incremental changes in shift constants and methanation constants will be analyzed.

3.3.2 Work Accomplished - Product Characterization

A variety of work was accomplished this quarter under the product characterization task. Product characterization data from the TP-019 test series were compiled this quarter, a summary of which is reported herein. Included are chemical and physical property and size distribution data for tests TP-019, -2 and -3, characterizing the solids in the feedstock, reactor and those penetrating the cyclone.

In addition, trace elements in these solids streams were identified. Data from the analysis of the miniscrubber liquid and quench water samples were obtained and tabulated for further analyses and correlations. These data will be published in future progress reports.

Special analyses were performed to determine trace constituents in the product gas by mass spectrometric techniques and to identify iron and sulfur levels in the samples from cyclone deposits obtained in tests TP-018-4 and -5. In Figure 3.3-1, the sample streams for the single-stage gasifier system are identified. Table 3.3-1 summarizes operational information pertinent to product characterization.

The installation and functional checkout of the laboratory gas chromatograph was completed. Trace hydrocarbons in the gas samples from the gas sampling cylinders can now be analyzed by the laboratory gas chromatograph (GC) during PDU test runs with a flame ionization detector. An additional flame photometric detector unit for the laboratory GC and necessary columns to analyze sulfur compounds such as hydrogen sulfide, carbonyl sulfide, mercaptans and carbon disulfide in the product gas has been ordered.

In addition, work is continuing on the on-line gas calorimeter and the miniscrubber train for the product gas line and on evaluation of an on-line ash measuring device. The existing miniscrubber gas train on the product gas was modified by immersing the heat exchanger coil in the miniscrubber to maximize ammonia absorption in the cold water.

Preliminary feasibility studies of an X-ray absorption technique using a Columbia Scientific, Inc. Model 720 analyzer to rapidly measure ash content in coals, chars and ash samples appears promising. This device is one of the candidates being evaluated as a potential on-line ash content measuring device.

3.3.2.1 Tests TP-019-1 Through TP-019-3 Product Characterization Data

Solids characterization data for feedstocks and reactor solids were obtained for each set point of the TP-019-1 through TP-019-3 oxygen-blown gasifier tests. The raw data characterizing solids are reported in Tables 3.3-2 through 3.3-4. Figures 3.3-2 through 3.3-6 provide the range of mean size distribution of the feedstock and reactor solids for all set points obtained

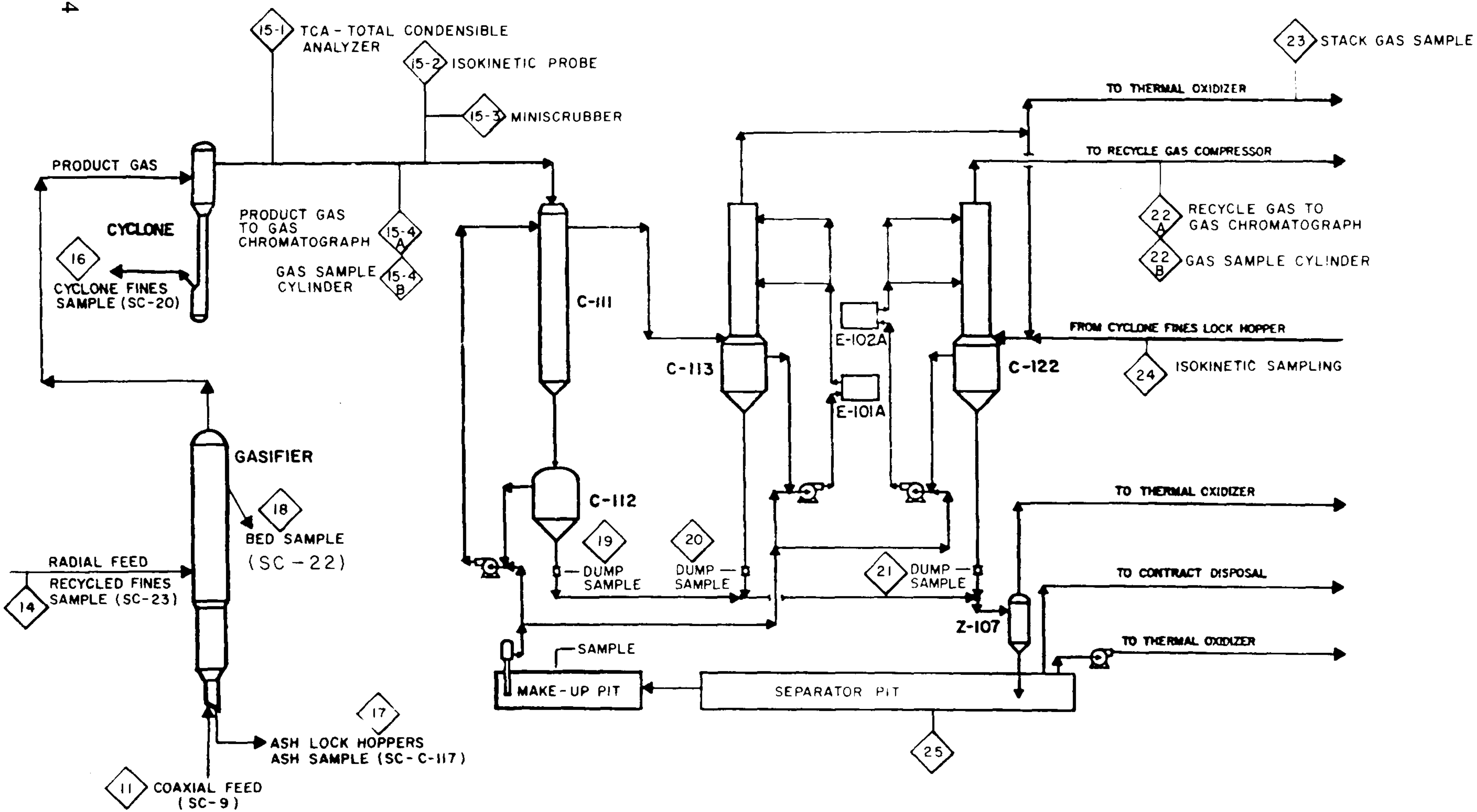

Figure 3.3-1. PDU Gasifier Process Schematic for Solids, Liquids, Gas and Particulate Sampling Locations

TABLE 3.3-1

SUMMARY OF SELECTED OPERATING DATA FOR TESTS TP-019-1, TP-019-2 AND TP-019-3

	Oxygen-Blown Test TP-019-1						Oxygen-Blown Test TP-019-3			
Set Points	1	2A	2B	2C	2D	4	1A	1B	1C	1D
Freeboard Temperature (^{o}F)	1495	1540	1515	1458	1502	1709	1790	1779	1808	1799
Coaxial Feedstock	Rosebud Coal	Rosebud Coal	Rosebud Coal	Rosebud Coal	Rosebud Coal	Indiana Coal	Western Kentucky Coal	Western Kentucky Coal	Western Kentucky Coal	Western Kentucky Coal
Radial Feedstock	No Recycled Fines	Recycled Gasifier Fines	Recycled Gasifier Fines	Recycled Gasifier Fines	Recycled Gasifier Fines	No Recycled Fines	Recycled Gasifier Fines	Recycled Gasifier Fines	Recycled Gasifier Fines	Recycled Gasifier Fines
Bed Ash Content As-Received Basis (%)	16.06	20.06	--	21.97	26.62	22.86	21.58*	26.43*	31.33*	31.80*
Withdrawal Ash Content As-Received* Basis (%)	37.99	41.53	67.34	65.4	77.83	36.09	50.44	48.59	57.23	39.19

	Oxygen-Blown Test TP-019-2						
Set Points	1	2	2A	2B	4A	4B	4C
Freeboard Temperature (^{o}F)	1721	1740	1737	1717	1759	1767	1766
Coaxial Feedstock	Indiana #7 Coal	Indiana #7 Coal	Indiana #7 Coal	Indiana #7 Coal	Western Kentucky Coal	Western Kentucky Coal	Western Kentucky Coal
Radial Feedstock	Recycled Gasifier Fines	Recycled Gasifier Fines	Recycled Gasifier Fines	Recycled Gasifier Fines	Recycled Gasifier Fines	Recycled Gasifier Fines	Recycled Gasifier Fines
Bed Ash Content As-Received Basis (%)	30.84	21.82	24.49	30.11	26.75	26.44	31.64
Withdrawal Ash Content As-Received* Basis (%)	37.04	34.04	42.21	32.74	39.74	46.13	45.14

*Average of 2 to 5 ash analyses.

TABLE 3.3-2

FEEDSTOCKS AND REACTOR SOLIDS PRODUCT CHARACTERIZATION DATA (AS RECEIVED)
GASIFIER TEST TP-019-1*

	Set Point 1					Set Point 2A				
Sample Stream No.**	11	14	18	16	17	11	14	18	16	17
Sample Station	SC-9 Coaxial	SC-23 Radial	SC-22 Bed	SC-20 Fines Carryover	C-117 Ash Lockhopper (Av.+)	SC-9 Coaxial	SC-23 Radial	SC-22 Bed	SC-20 Fines Carryover	C-117 Ash Lockhopper (Av.)
Proximate (%)										
Moisture	22.17	No Recycled Fines	0.54	1.11	0.55	22.17	1.26	0.70	1.26	0.31
Volatile Matter	43.58		1.47	2.54	5.25	43.58	4.57	1.60	4.57	5.47
Fixed Carbon	26.16		81.93	76.76	56.20	26.16	63.94	77.64	63.94	52.72
Ash	8.09		16.06	19.59	37.99	8.09	30.23	20.06	30.24	41.53
Ultimate %										
Carbon	53.98		80.73	76.76	59.43	53.98	68.19	79.02	68.19	56.69
Hydrogen	6.01		0.38	0.27	0.37	6.01	0.79	0.49	0.79	0.43
Oxygen	30.44		1.39	1.63	0.00	30.44	0.0	0.0	0.0	0.0
Nitrogen	0.85		0.42	0.74	0.44	0.85	0.49	0.13	0.49	0.51
Sulfur	0.63		1.02	1.01	3.24	0.63	1.17	0.96	0.17	2.95
Ash	8.09		16.06	19.59	37.99	8.09	30.23	20.06	30.23	41.53
Miscellaneous Analysis										
Bulk Density (lb/ft^3)	37.5	35.8	31.8	35.8	36.7	37.5	27.0	28.1	27.0	39.9
	Set Point 2B					Set Point 2C				
Proximate (%)										
Moisture	21.35	1.73	Samples not collected	1.73	0.39	21.60	1.05	0.78	1.05	0.38
Volatile Matter	45.46	4.60		4.60	5.94	44.52	4.53	2.78	4.53	6.21
Fixed Carbon	25.52	65.85		65.85	26.33	25.84	59.78	74.47	59.78	28.00
Ash	7.67	27.82		27.82	67.34	7.88	34.64	21.97	34.64	65.40
Ultimate %										
Carbon	55.21	68.73		68.73	31.22	54.59	63.23	76.32	63.23	33.43
Hydrogen	5.88	0.69		0.69	0.32	5.94	0.58	0.62	0.58	0.38
Oxygen	29.87	1.32		1.32	0.0	30.16	0.0	0.0	0.0	0.0
Nitrogen	0.85	0.41		0.41	0.33	0.85	0.45	0.53	0.45	0.29
Sulfur	0.52	1.03		1.03	4.30	0.57	1.16	0.76	1.16	3.69
Ash	7.67	27.82		27.82	67.34	7.88	34.64	21.97	34.64	65.40
Miscellaneous Analysis										
Bulk Density (lb/ft^3)	39.5	26.3		26.3	47.1	36.2	29.6	29.1	29.6	48.7

*Montana-Rosebud coal with recyled fines, oxygen-blown, calorific value Btu/lb 11,496 to 12,292.
**Sample locations are shown in Figure 3.3-1.
+Av = Average of analyses from 2 to 5 samples

TABLE 3.3-2 (Continued)

	Set Point 2D					Set Point 4*				
Sample Stream No.**	11	14	18	16	17	11	14	18	16	17
Sample Station	SC-9 Coaxial	SC-23 Radial	SC-22 Bed	SC-20 Fines Carryover	C-117 Ash Lockhopper (Av.$^{+}$)	SC-9 Coaxial	SC-23 Radial	SC-22 Bed	SC-20 Fines Carryover	C-117 Ash Lockhopper (Av.$^{+}$)
Proximate (%)										
Moisture	21.76	1.53	0.80	1.53	0.15	14.79	0.82	0.71	0.82	0.53
Volatile Matter	44.52	4.98	2.49	4.98	5.23	31.89	1.32	0.99	1.32	0.74
Fixed Carbon	25.84	55.21	70.09	55.21	16.80	43.34	66.99	75.44	66.99	62.64
Ash	7.88	38.28	26.62	38.28	77.83	10.06	30.87	22.86	30.87	36.09
Ultimate %										
Carbon	54.59	58.87	72.07	58.87	21.93	61.10	66.79	74.53	66.79	62.14
Hydrogen	5.95	0.74	0.58	0.74	0.2	5.88	0.41	0.34	0.41	0.26
Oxygen	30.16	0.29	0.0	0.29	0.0	21.52	0.83	0.84	0.83	0.21
Nitrogen	0.85	0.35	0.45	0.35	0.14	1.30	0.60	0.67	0.60	0.49
Sulfur	0.57	1.47	1.14	1.47	3.89	0.43	1.50	0.76	0.50	0.82
Ash	7.88	38.28	26.62	38.28	77.83	10.06	30.87	22.86	30.87	36.09
Miscellaneous Analysis										
Bulk Density (lb/ft^3)	38.4	27.5	28.4	27.5	41.7	38.6	19.6	27.0	19.6	37.9

*Indiana #7 coal was used in set point 4, calorific value Btu/lb 10,988 to 11,577.

**Sample locations are shown in Figure 3.3-1.

+Av = Average of analyses from 2 to 5 samples.

TABLE 3.3-3

FEEDSTOCKS AND REACTOR SOLIDS PRODUCT CHARACTERIZATION DATA (AS RECEIVED)
GASIFIER TEST TP-019-2*

	Set Point 1					Set Point 2				
Sample Stream No.**	11	14	18	16	17	11	14	18	16	17
Sample Station	SC-9 Coaxial	SC-23 Radial	SC-22 Bed	SC-20 Fines Carryover	C-117 Ash Lockhopper (Av.$^+$)	SC-9 Coaxial	SC-23 Radial	SC-22 Bed (Av.$^+$)	SC-20 Fines Carryover	C-117 Ash Lockhopper (Av.$^+$)
Proximate (%)										
Moisture	13.47	0.97	0.99	0.97	0.78	12.67	1.10	1.06	1.10	0.93
Volatile Matter	27.73	0.59	0.46	0.59	0.94	29.62	0.58	0.61	0.58	1.38
Fixed Carbon	48.82	78.51	67.71	78.51	61.24	48.68	78.64	75.08	78.64	63.65
Ash	9.98	19.93	30.84	19.93	37.04	9.03	19.68	23.26	19.68	34.04
Ultimate %										
Carbon	62.09	77.34	66.36	77.34	60.50	63.41	77.24	74.08	77.24	63.24
Hydrogen	5.52	0.40	0.26	0.40	0.29	5.42	0.49	0.44	0.49	0.41
Oxygen	20.65	1.24	1.64	1.24	0.91	20.35	1.54	1.18	1.54	1.21
Nitrogen	1.38	0.64	0.58	0.64	0.63	1.46	0.63	0.72	0.63	0.54
Sulfur	0.38	0.45	0.32	0.45	0.63	0.33	0.42	0.33	0.42	0.56
Ash	9.98	19.93	30.84	19.93	37.04	9.03	19.68	23.26	19.68	34.36
Miscellaneous Analysis										
Bulk Density (lb/ft^3)	34.8	19.7	21.6	19.7	36.4	39.4	23.8	25.2	23.8	35.2
	Set Point 2A					Set Point 2B				
Proximate (%)										
Moisture	12.79	0.75	1.15	0.75	0.79	9.87	0.86	0.98	0.86	1.09
Volatile Matter	28.86	0.43	0.62	0.43	1.05	30.01	0.61	0.71	0.61	1.19
Fixed Carbon	49.07	80.93	73.74	80.93	55.95	50.76	75.67	69.14	75.67	64.97
Ash	9.28	17.89	24.49	17.89	42.21	9.36	22.86	29.18	22.86	32.74
Ultimate %										
Carbon	64.34	79.64	72.27	79.64	53.59	66.66	74.88	68.42	74.86	64.04
Hydrogen	5.14	0.33	0.45	0.33	0.34	5.07	0.34	0.4	0.34	0.48
Oxygen	19.47	1.08	1.71	1.08	2.86	17.08	0.75	0.93	0.75	1.46
Nitrogen	1.40	0.57	0.80	0.57	0.53	1.47	0.68	0.77	0.68	0.91
Sulfur	0.37	0.49	0.28	0.49	0.47	0.36	0.49	0.32	0.49	0.38
Ash	9.28	17.89	24.49	17.89	42.21	9.36	22.86	29.18	22.86	32.74
Miscellaneous Analysis										
Bulk Density (lb/ft^3)	33.8	26.1	22.5	26.1	32.90	39.5	25.2	22.3	25.2	29.5

*Indiana #7 coal with recycled fines, oxygen-blown, calorific value Btu/lb 10,988 to 11,577.

**Sample locations are shown in Figure 3.3-1.

+Av = Average of analyses from 2 to 5 samples

TABLE 3.3-3 (Continued)

	Set Point 4A*					Set Point 4B*				
Sample Stream No.**	11	14	18	16	17	11	14	18	16	17
Sample Station	SC-9 Coaxial	SC-23 Radial	SC-22 Bed (Av.$^+$)	SC-20 Fines Carryover	C-117 Ash Lockhopper (Av.$^+$)	SC-9 Coaxial	SC-23 Radial	SC-22 Bed	SC-20 Fines Carryover	C-117 Ash Lockhopper (Av.$^+$)
Proximate (%)										
Moisture	6.68	0.73	0.72	0.73	0.75	6.68	0.99	0.69	0.99	0.93
Volatile Matter	31.98	0.94	0.85	0.94	0.54	35.26	0.45	0.70	0.45	0.65
Fixed Carbon	49.10	71.58	70.16	71.58	54.75	48.63	79.1	65.74	79.1	52.3
Ash	12.24	26.75	28.28	26.75	43.96	9.43	19.46	32.87	19.46	46.13
Ultimate %										
Carbon	66.46	70.52	68.97	70.52	54.14	67.72	76.86	65.67	76.86	51.26
Hydrogen	4.92	0.34	0.33	0.34	0.13	5.29	0.43	0.36	0.43	0.34
Oxygen	12.38	0.21	0.27	0.21	0.0	13.59	0.98	0.04	0.98	0.0
Nitrogen	1.45	0.55	0.58	0.55	0.5	1.40	0.60	0.56	0.60	0.59
Sulfur	2.55	1.63	1.72	1.63	2.46	2.57	1.67	0.64	1.67	2.79
Ash	12.24	26.75	28.28	26.75	43.96	9.43	19.46	32.87	19.46	46.13
Miscellaneous Analysis										
Bulk Density (lb/ft^3)	38.2	28.8	26.7	28.8	38.26	37.3	23.0	23.1	23.0	36.2

	Set Point 4C*				
Proximate (%)					
Moisture	6.69	0.85	0.85	0.85	1.02
Volatile Matter	33.75	0.69	0.37	0.69	0.73
Fixed Carbon	49.06	74.65	65.69	74.65	53.11
Ash	10.50	23.81	33.09	23.81	45.14
Ultimate %					
Carbon	66.82	72.57	63.55	72.57	52.52
Hydrogen	5.28	0.47	0.33	0.47	0.34
Oxygen	13.42	0.67	0.62	0.67	0.0
Nitrogen	1.42	0.56	0.57	0.56	0.51
Sulfur	2.56	1.92	1.85	1.92	2.68
Ash	10.50	23.81	33.09	23.81	45.14
Miscellaneous Analysis					
Bulk Density (lb/ft^3)	38.0	23.8	26.9	23.8	42.5

*Western Kentucky coal with recycled fines, oxygen-blown, calorific value Btu/lb 11,858 to 12,180.
**Sample locations are shown in Figure 3.3-1.
+Av = Average of analyses from 2 to 5 samples

TABLE 3.3-4

FEEDSTOCKS AND REACTOR SOLIDS PRODUCT CHARACTERIZATION DATA (AS RECEIVED)
GASIFIER TEST TP-019-3*

	Set Point 1A					Set Point 1B				
Sample Stream No.**	11	14	18	16	17	11	14	18	16	17
Sample Station	SC-9 Coaxial	SC-23 Radial	SC-22 Bed (Av.+)	SC-20 Fines Carryover	C-117 Ash Lockhopper (Av.+)	SC-9 Coaxial	SC-23 Radial	SC-22 Bed (Av.+)	SC-20 Fines Carryover	C-117 Ash Lockhopper (Av.+)
Proximate (%)										
Moisture	5.69	1.29	0.48	1.29	0.37	6.26	1.00	0.64	1.00	0.71
Volatile Matter	32.04	1.82	0.69	1.82	0.76	33.73	3.79	1.25	3.79	1.19
Fixed Carbon	51.65	77.39	77.25	77.39	48.43	49.57	76.39	71.48	76.39	49.51
Ash	10.62	19.50	21.58	19.50	50.44	10.44	18.82	26.63	18.82	48.59
Ultimate %										
Carbon	68.42	77.50	75.77	77.50	47.81	67.87	76.27	70.37	76.27	48.52
Hydrogen	4.72	0.47	0.33	0.47	0.21	5.09	0.84	0.46	0.84	0.38
Oxygen	12.45	0.0	0.17	0.0	0.0	12.63	1.14	0.0	1.14	0.0
Nitrogen	1.35	0.6	0.6	0.6	0.42	1.38	0.73	0.73	0.73	0.57
Sulfur	2.44	1.94	1.55	1.94	2.31	2.59	2.20	20.3	2.20	3.02
Ash	10.62	19.50	21.58	19.50	50.44	10.44	18.82	26.63	18.82	48.59
Miscellaneous Analysis										
Bulk Density (lb/ft^3)	38.3	35.2	29.9	35.2	38.6	41.2	24.3	23.1	24.3	33.0
	Set Point 1C					Set Point 1D				
Proximate (%)										
Moisture	6.63	0.88	0.59	0.88	0.53	5.44	0.62	0.55	0.62	0.69
Volatile Matter	30.66	2.72	0.86	2.72	1.07	32.34	0.91	1.01	0.91	1.34
Fixed Carbon	48.94	74.53	67.21	74.53	41.17	47.87	75.56	66.63	75.51	58.78
Ash	13.77	21.87	31.33	21.87	57.23	14.35	22.91	31.80	22.91	39.19
Ultimate %										
Carbon	65.08	74.08	66.50	74.08	41.39	65.04	74.60	66.22	74.60	57.87
Hydrogen	4.72	0.70	0.35	0.70	0.34	4.75	0.40	0.65	0.40	0.44
Oxygen	12.53	0.53	0.0	0.53	0.0	11.84	0.0	0.0	0.0	0.0
Nitrogen	1.30	0.68	0.65	0.68	0.55	1.35	0.73	0.63	0.73	0.79
Sulfur	2.60	2.14	2.09	2.14	3.04	2.67	2.06	1.93	2.06	3.04
Ash	13.77	21.87	31.33	21.87	57.23	14.35	22.91	31.80	22.91	39.19
Miscellaneous Analysis										
Bulk Density (lb/ft^3)	40.5	21.6	20.9	21.6	34.7	40.4	21.1	21.3	21.1	31.9

*W. Kentucky coal with recycled fines, oxygen-blown, calorific value Btu/lb 11,858 to 12,180.

**Sample locations are shown in Figure 3.3-1.

+Av = Average of analyses from individual samples.

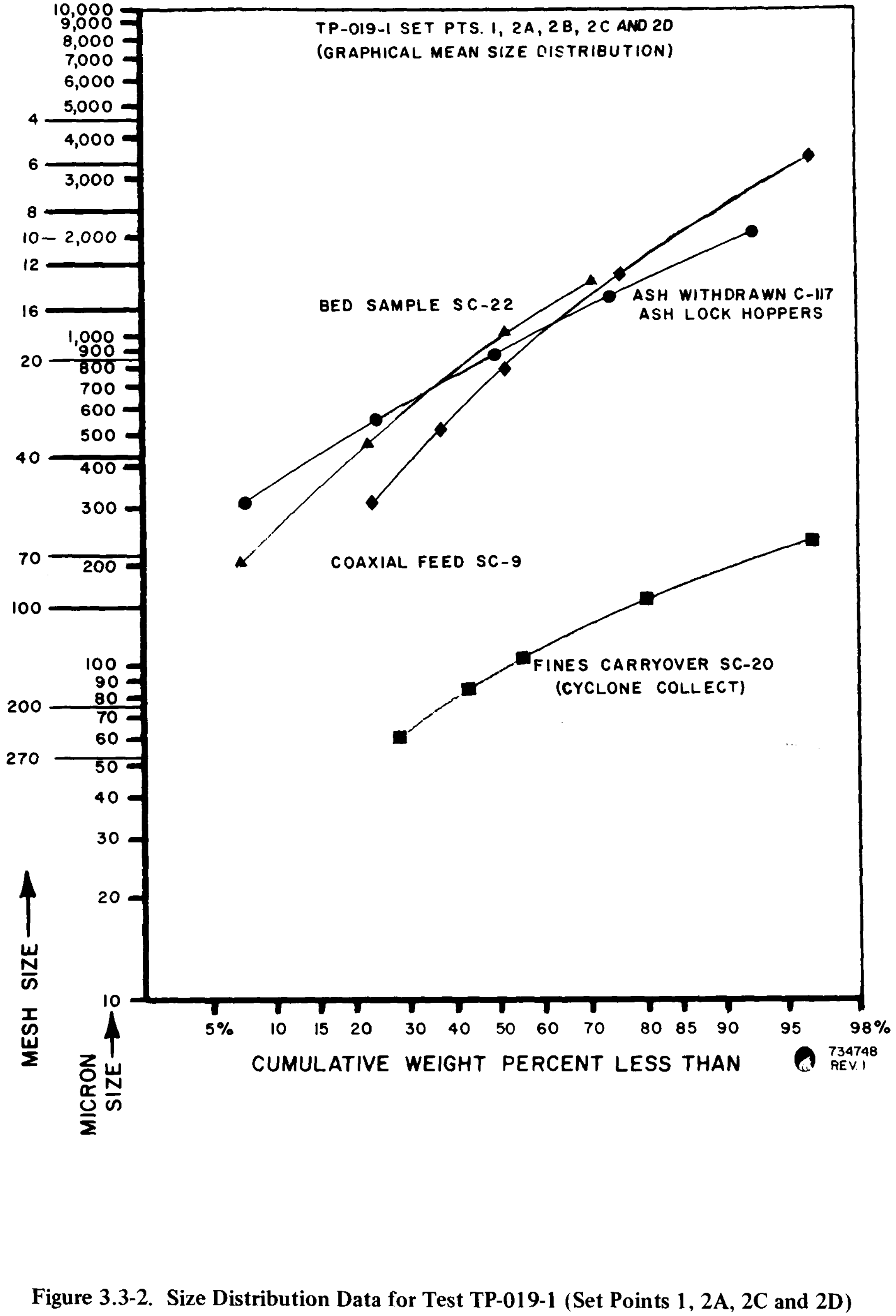

Figure 3.3-2. Size Distribution Data for Test TP-019-1 (Set Points 1, 2A, 2C and 2D) Feedstocks and Products

2243-7

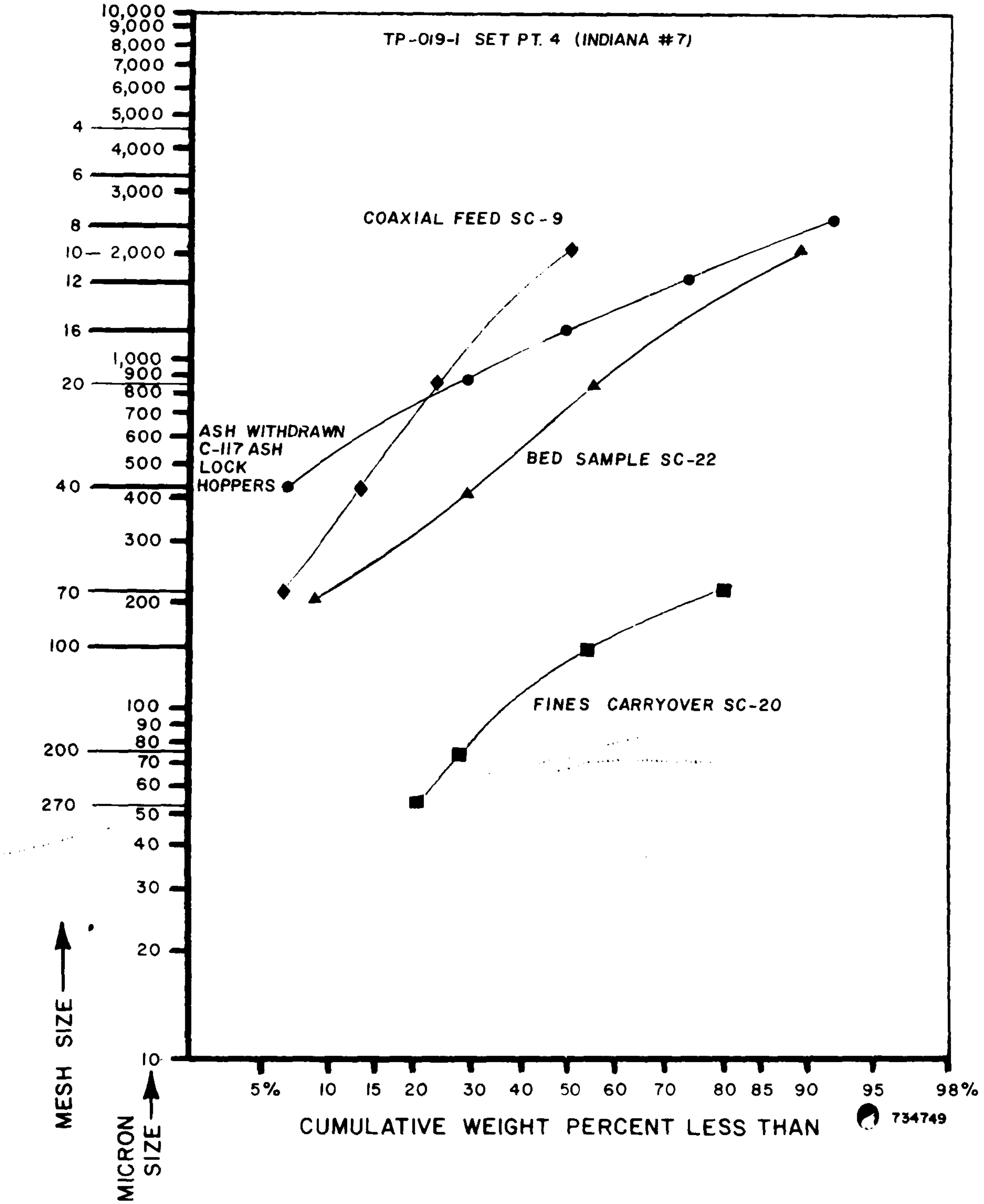

Figure 3.3-3. Size Distribution Data for Test TP-019-1 (Set Point 4) Feedstocks and Products

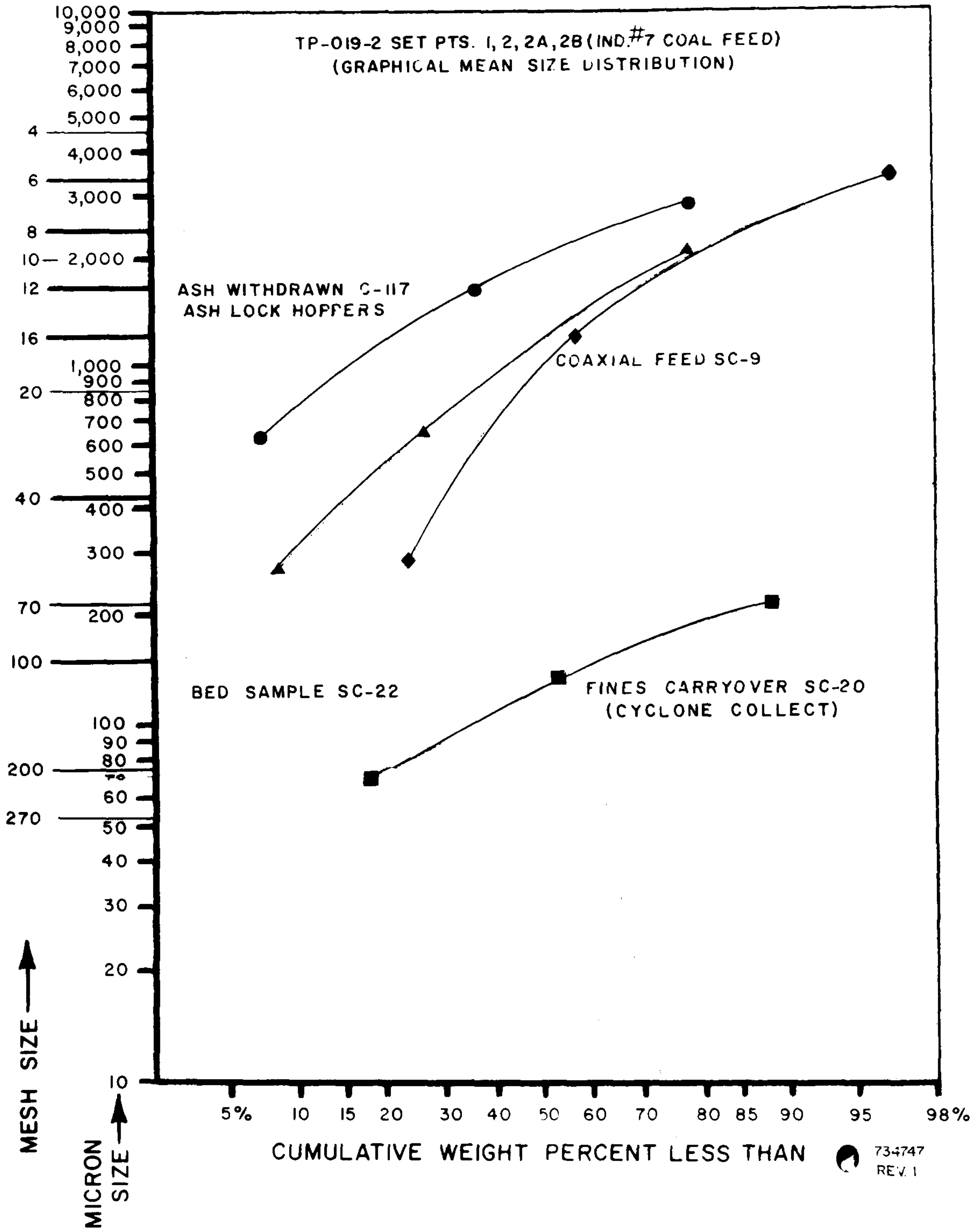

Figure 3.3-4. Size Distribution Data for Test TP-019-2 (Set Points 1, 2, 2A and 2B) Feedstocks and Products

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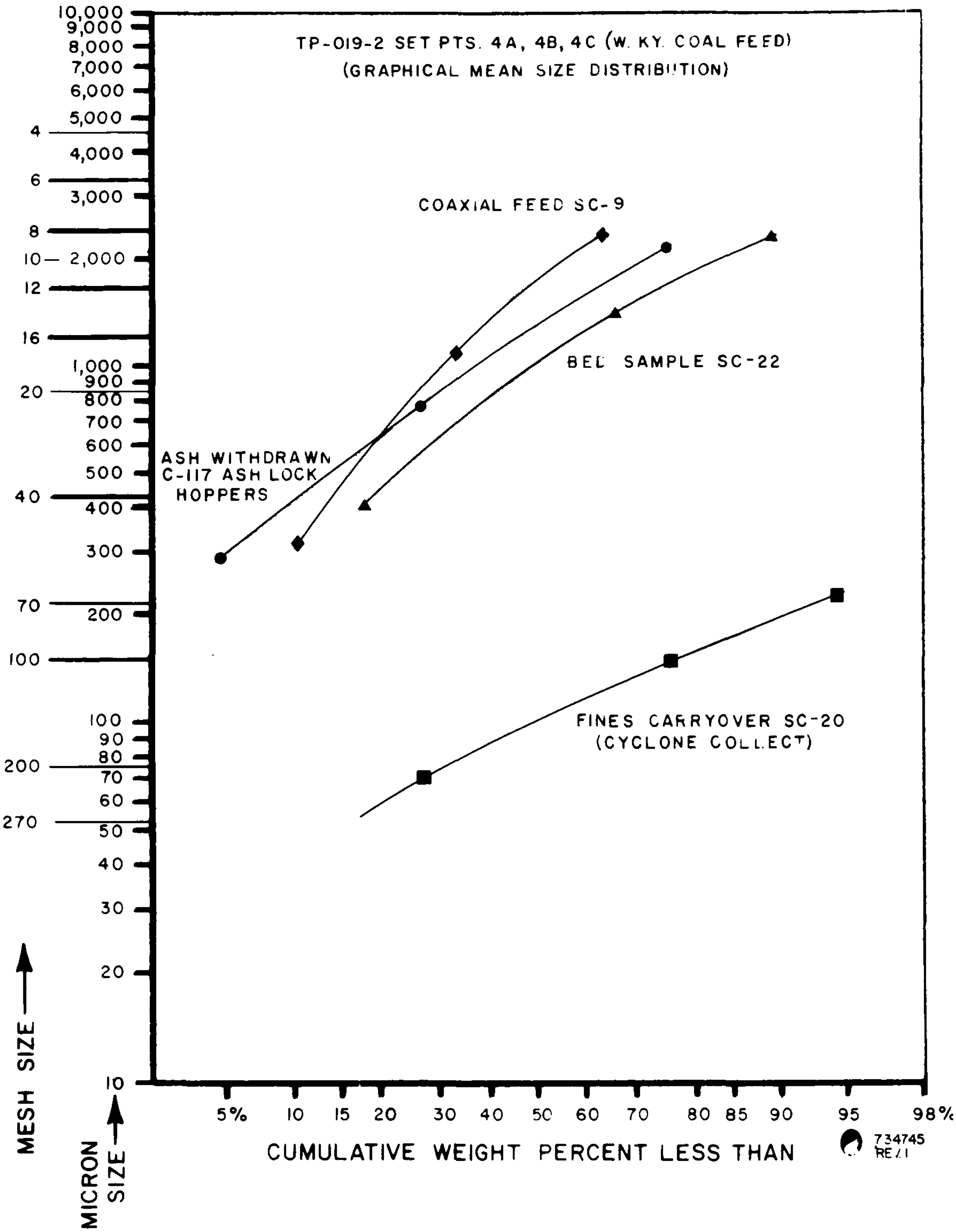

Figure 3.3-5. Size Distribution Data for Test TP-019-2 (Set Points 4A, 4B, and 4C) Feedstocks and Products

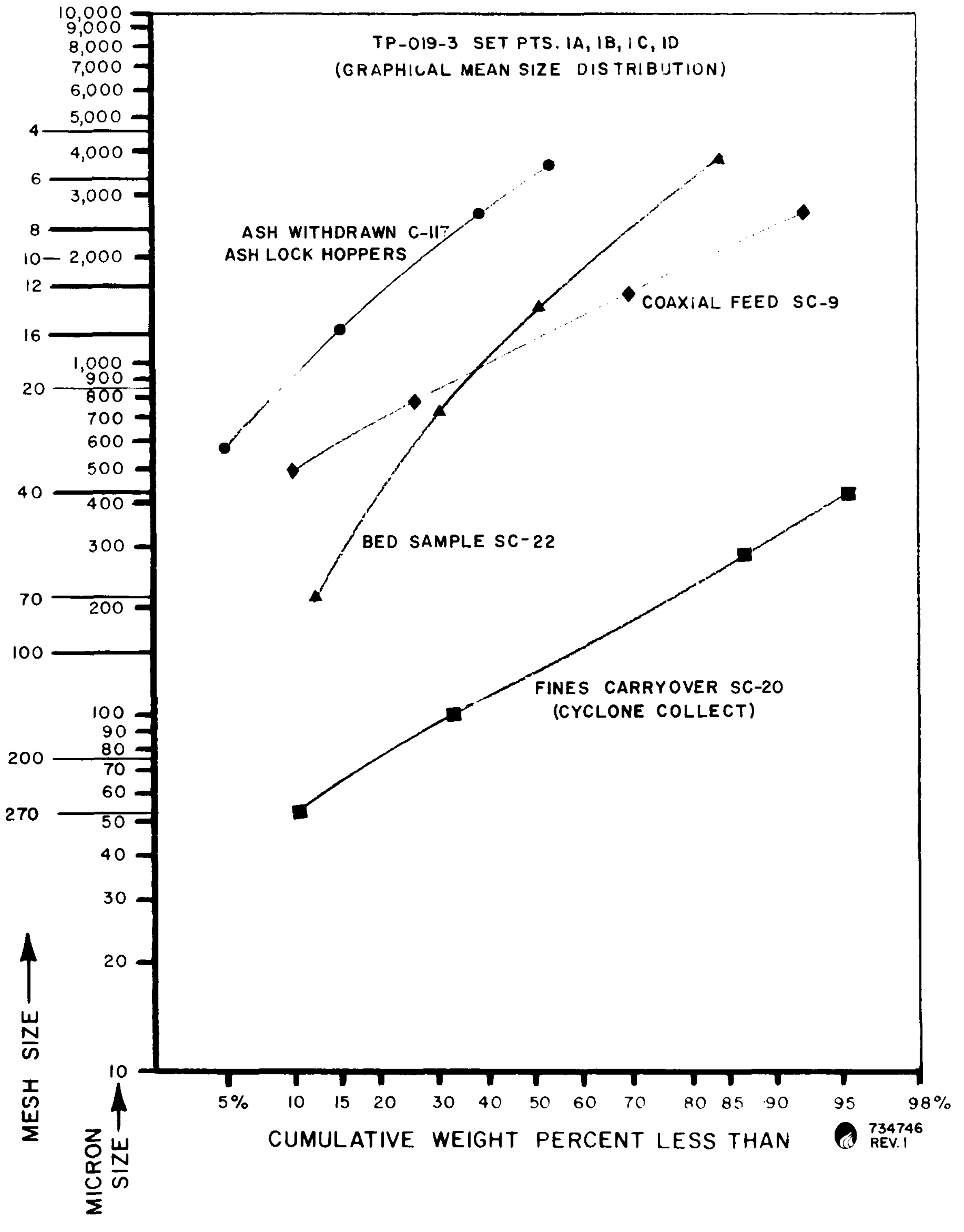

Figure 3.3-6. Size Distribution Data for Test TP-019-3 (Set Points 1A, 1B, 1C and 1D) Feedstocks and Products

during predefined steady states in tests TP-019-1 through TP-019-3. Raw data for ash withdrawal material from the C-117 ash lockhoppers represent an average of two to five analyses of samples collected during the steady state periods.

A summary of the characteristics of the cyclone penetration particulates for oxygen-blown gasifier tests TP-019-1 through TP-019-3 are given in Table 3.3-5, and Figures 3.3-7, -8, and -9 represent the size distribution of the cyclone escape particulates using the Coulter counter technique.

Trace elements in selected solid streams from a single steady state point in each of tests TP-019-1 through TP-019-3 were analyzed using an X-ray fluorescence technique. Table 3.3-6 lists the results of these analyses.

The on-line gas chromatograph data for CO, CO_2, H_2, CH_4, N_2 and O_2 contents in the product gas and recycle gas streams were averaged over steady state periods for heat and material balances. The results of the on-line gas chromatograph data for TP-019-1, TP-019-2, and TP-019-3 are reported in FE-1514-97, "Quarterly Progress Report, First Quarter, Fiscal Year 1979, October 1 to December 31, 1978." Trace hydrocarbons and sulfur compounds were obtained by mass spectrometer measurements of the gas collected in the sample cylinders. The data for TP-019-1 through TP-019-3 are reported in Table 3.3-7.

Product gas characterization by miniscrubber gas sampling train for water-soluble compounds such as ammonia, trace metals, chlorides, cyanides and phenols are described in Table 3.3-8 for tests TP-019-1 through TP-019-3. The results presented in this table are as-measured values with measurement uncertainties commensurate with early-stage development of equipment and sampling techniques. At this time, these data should be considered only as rough estimates.

A composite sample was prepared from dump liquid samples collected from each vessel during steady state periods of set points of tests TP-019-1 through TP-019-3. The results are tabulated in Table 3.3-9. There were no visible "tars and oils" detected in the liquid samples in any of the gasifier tests, nor were there any adsorbed acetone extractable hydrocarbons (tars) on the solids present in the quench water samples.

3.3.2.2 Cyclone Deposit Analysis

Chemical analyses of cyclone deposits from tests TP-018-4 and TP-018-5 have been completed. The ash content of the deposit samples ranged from 91 to 93 percent for test TP-018-4 and from 81 to 94 percent for test TP-018-5. The ash content of the coal feed for these tests was 9 percent, and the ash content of the collected cyclone fines ranged from 11 to 14 percent. The data also indicated enrichment of iron and sulfur in the deposit samples, supplementing the similar findings from analysis of cyclone deposits found after test TP-018-3. X-ray and microprobe analyses on cyclone deposits identified $Fe_{1-x}S$ as a major phase and predominance of iron and sulfur in the deposit sample, respectively.

A comparison of the iron and sulfur analyses for these tests are shown in Table 3.3-10.

TABLE 3.3-5

SUMMARY OF CHARACTERISTICS OF CYCLONE PENETRATION PARTICULATES FOR OXYGEN-BLOWN GASIFIER TESTS TP-019-1 THROUGH TP-019-3

	Test		
Test Operating Data	TP-019-1	TP-019-2	TP-019-3
Freeboard (°F) Temperature Range	1458-1709	1717-1767	1779-1808
Freeboard Velocities (ft/s) 30" section	0.76-0.97	1.20-1.60	1.53-1.77
Feedstock Material Used for Gasifier	Rosebud and Indiana Coals	Indiana and W. Kentucky Coals	W. Kentucky Coal
Mean Diameter of Particulate (50% by Wt) (μm)	19	20	21
Particulates greater than 10 μm (Wt. %)	84	84	86
<u>Chemical Characteristics (As Received)</u>*			
<u>Proximate (%)</u>			
Moisture	1.27	3.92	3.22
Volatile Matter	6.06	0.0	3.98
Fixed Carbon	35.43	71.67	66.33
Ash	57.24	24.40	26.57
Calorific Value (Btu/lb)	9030	--	9901.7
<u>Ultimate (%)</u>			
Carbon	61.21	68.82	65.86
Hydrogen	0.63	0.83	0.50
Oxygen	0.92	4.20	35.91
Nitrogen	0.59	0.57	0.69
Sulfur	1.22	1.17	2.45
Ash	35.43	24.41	26.57

*Average value from analyses of composite samples of TCA and isokinetic sampling streams 15-1 and 15-2.

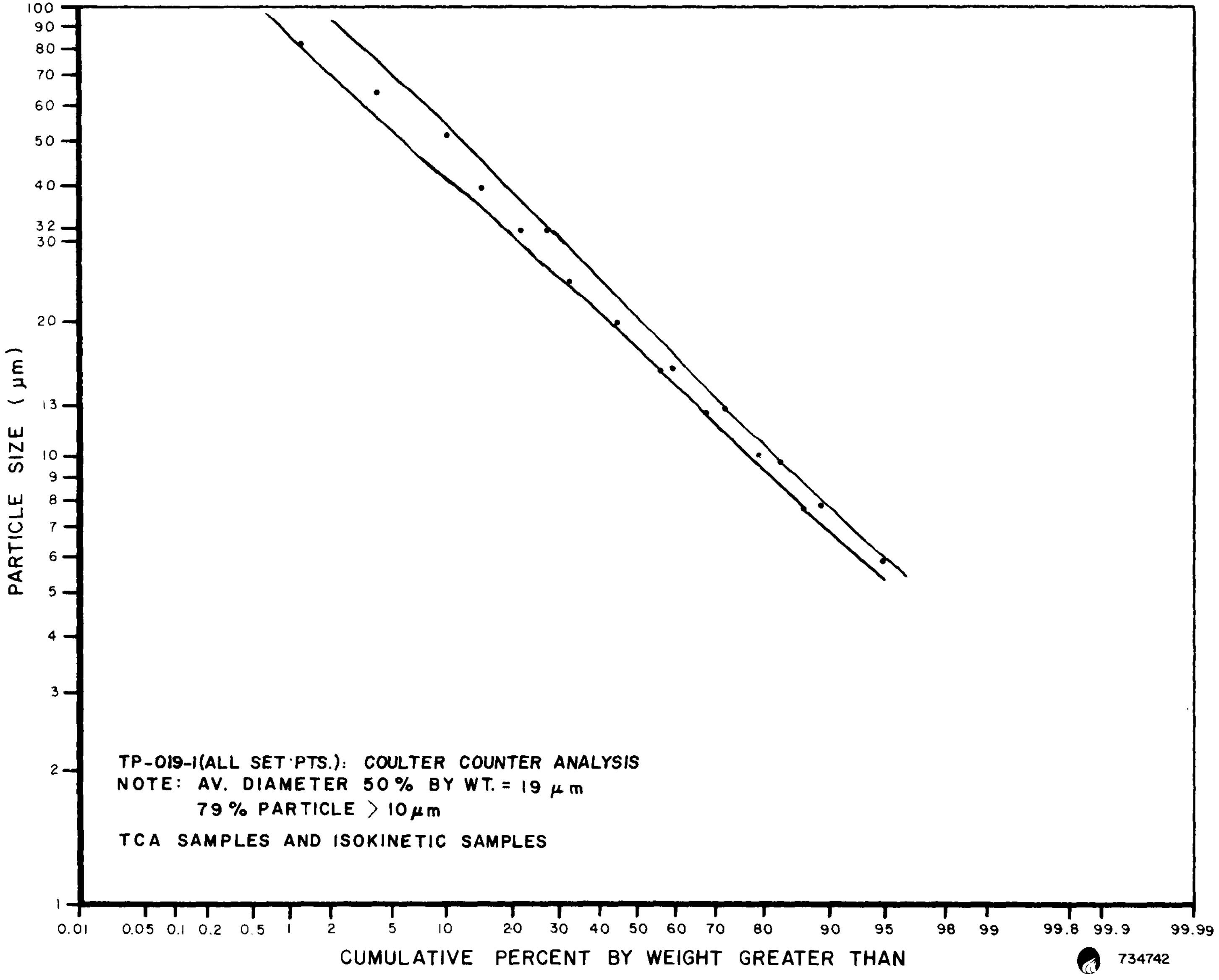

Figure 3.3-7. Cyclone Penetration Particulate Size Distribution Data (Coulter Counter Analysis), Test TP-019-1 (All Set Points)

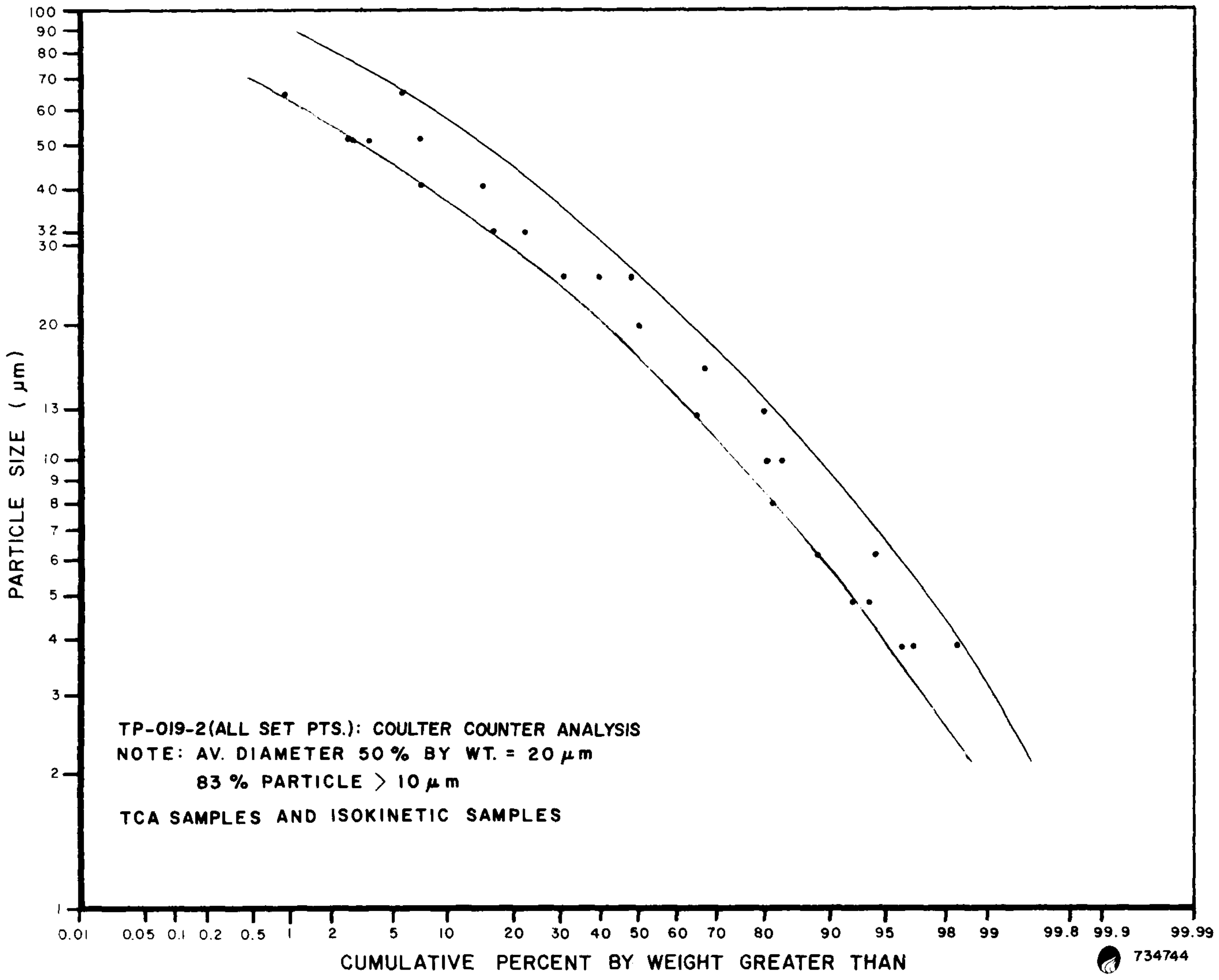

Figure 3.3-8. Cyclone Penetration Particulate Size Distribution Data (Coulter Counter Analysis), Test TP-019-2 (All Set Points)

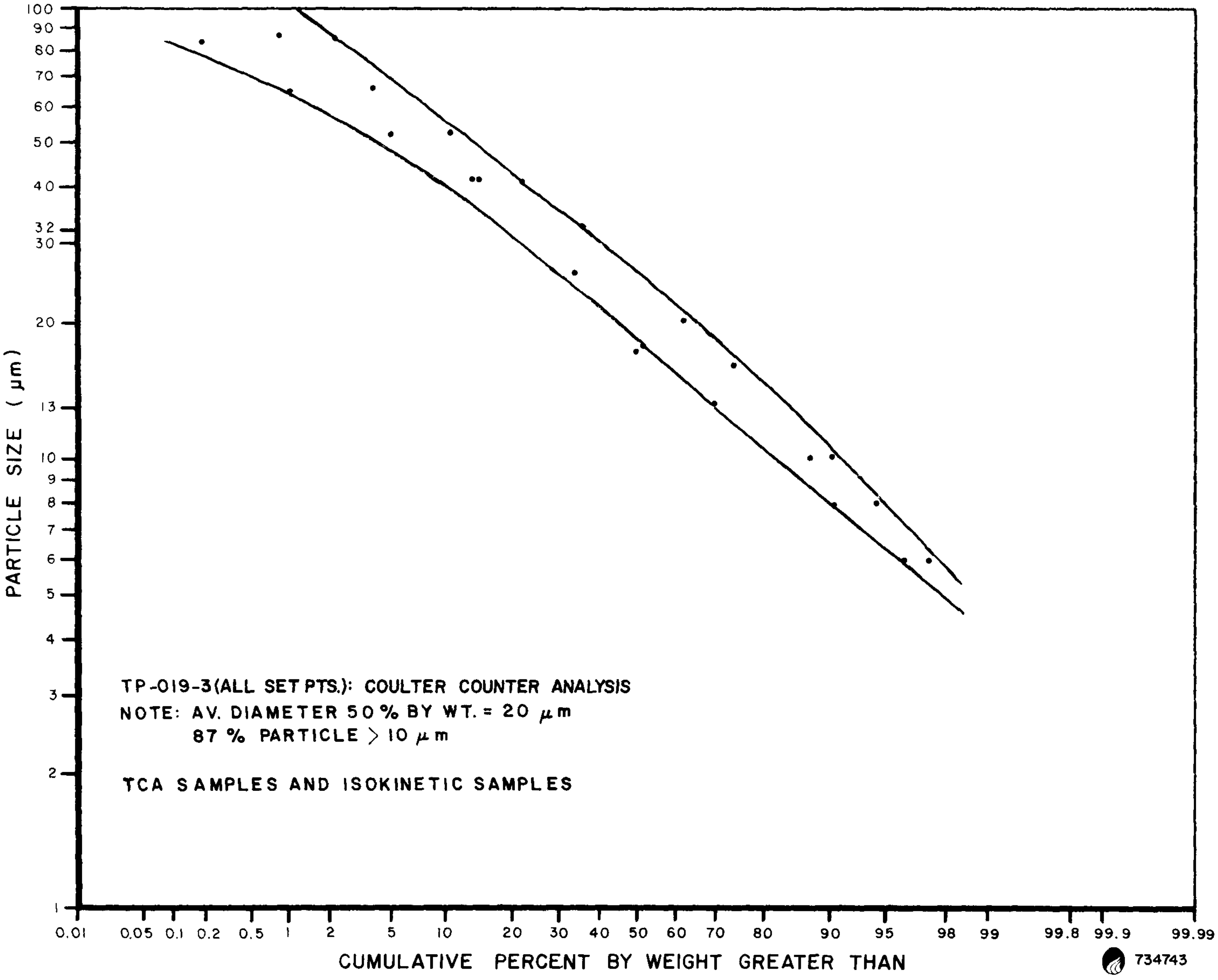

Figure 3.3-9. Cyclone Penetration Particulate Size Distribution Data (Coulter Counter Analysis), Test TP-019-3 (All Set Points)

TABLE 3.3-6

CHARACTERISTICS OF SELECTED TRACE ELEMENTS IN SOLIDS STREAMS IN OXYGEN-BLOWN GASIFIER TESTS (PERCENT BY WEIGHT IN AS-SAMPLED MATERIAL)

	Set Point 2B, TP-019-1 (Rosebud Coal Feed)					Set Point 4, TP-019-1 (Indiana Coal Feed)				
Sample Stream No.*	11	18	17	16	15-1-2	11	18	17	16	15-1-2
Sample Station	SC-9 Feed	SC-22 Bed	C-117 Ash Lockhopper	SC-20 Cyclone Collect	TCA/ISOK Cyclone Escape	SC-9 Feed	SC-22 Bed	C-117 Ash Lockhopper	SC-20 Cyclone Collect	TCA/ISOK Cyclone Escape
Aluminum, Al	3.97	3.28	2.85	2.45	1.61	3.60	2.44	3.09	2.60	2.38
Arsenic, As	<0.05	<0.05	<0.05	<0.05	<0.5	<0.05	<0.05	0.10	<0.5	<0.5
Calcium, Ca	2.27	3.72	3.26	0.85	3.51	0.79	0.53	0.81	0.85	5.44
Chromium, Cr	<0.002	<0.002	0.011	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Iron, Fe	<0.005	0.11	2.58	1.03	<1.91	0.005	1.44	0.76	0.77	0.36
Potassium, K	1.4	1.99	1.74	0.76	1.76	0.79	0.64	0.79	0.78	2.78
Sodium, Na	0.30	0.27	0.068	0.51	0.35	0.52	0.59	0.37	0.40	0.18
Lead, Pb	0.085	0.054	<0.01	0.16	0.15	0.29	0.11	0.014	0.12	0.03
Vanadium, V	<0.02	<0.02	<0.02	<0.02	<0.82	<0.02	<0.02	<0.02	<0.02	<0.02
	Set Point 2, TP-019-2 (Indiana Coal Feed)					Set Point 1A, TP-019-3				
Aluminum, Al	3.74	3.24	2.60	3.23	2.86	3.10	2.55	1.73	2.50	1.10
Arsenic, As	<0.05	<0.05	0.099	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Calcium, Ca	0.59	0.51	0.54	0.61	0.62	0.76	0.82	2.06	1.05	1.04
Chromium, Cr	<0.002	<0.002	<0.002	<0.002	<0.002	0.069	0.036	0.058	0.024	0.062
Iron, Fe	<0.005	0.52	1.49	0.60	0.44	1.86	3.30	5.97	4.73	6.77
Potassium, K	0.72	0.67	0.66	0.70	0.69	0.81	0.79	1.18	0.87	0.81
Sodium, Na	0.42	0.43	0.45	0.39	0.62	0.81	0.30	0.39	0.28	0.39
Lead, Pb	0.11	0.069	0.044	0.13	0.28	0.39	0.051	0.025	0.054	0.089
Vandium, V	<0.02	<0.02	<0.02	<0.02	<0.02	0.021	<0.002	0.022	<0.02	0.022

*Sample locations are shown in Figure 3.3-1.

TABLE 3.3-7

PRODUCT GAS ANALYSIS (DRY BASIS) OF TRACE CONSTITUENTS BY LABORATORY MASS SPECTROMETER FOR OXYGEN-BLOWN GASIFIER TESTS TP-019-1 THROUGH TP-019-3

Sample Stream No.*		GS-78-0135	GS-78-0130
Test & Setpoint	TP-019-2 Set Point 2B	TP-019-3 Set Point 1C	TP-019-3 Set Point 1D
Feedstock (% Volume)	Indiana #7 Coal	W. Kentucky Coal	W. Kentucky Coal
Hydrogen Sulfide, H_2S	0.07	.07	.89
Carbonyl Sulfide, COS	---	---	---
Methane, CH_4	1.96	2.75	2.93
Ethylene, C_2H_4	---	---	---
Ethane, C_2H_6	---	0.12	0.04
Propylene, C_3H_6	---	---	---
Acetylene, C_2H_2	---	---	---

*Sample locations are shown in Figure 3.3-1.

---Not detectable.

TABLE 3.3-8

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

Coal Feed	Test	Ammonia (NH_3)	Chloride (Cl)	Cyanide (Cn)	Sodium (Na)	Potassium (K)	Phenols	Arsenic (As)	Lead (Pb)	Vanadium (V)	pH
Rosebud	TP-019-1 Set Point 2A	194	13.7	5.6	0.66	0.51	0.190	<0.400	<0.0240	---	7.5
Rosebud	TP-019-1 Set Point 2B	994	17.8	2.8	0.61	0.41	0.130	<0.230	<0.0140	---	7.6
Rosebud	TP-019-1 Set Point 2C	680	9.0	4.1	0.28	0.15	0.180	<0.190	<0.0110	---	7.6
Indiana #7	TP-019-1 Set Point 4	633	43.4	55.2	0.45	1.30	0.003	<0.160	<0.0097	---	7.6
Indiana #7	TP-019-2 Set Point 1	206	167.2	15.0	0.21	0.18	0.110	<0.025	0.0900	<0.067	---
Indiana #7	TP-019-2 Set Point 2	322	128.7	10.9	0.52	1.70	0.040	<0.050	0.0500	<0.040	---
W. Kentucky	TP-019-3 Set Point 1B	370	342.0	52.8	2.40	3.00	0.013	0.013	< .0130	< .035	7.1
W. Kentucky	TP-019-3 Set Point 1C	345	107.4	15.4	0.14	0.30	0.140	<1.320	< .0100	< .030	6.4

*Water-soluble compounds only.
As-measured data.

TABLE 3.3-9

QUENCH SCRUBBER WATER SAMPLE ANALYSIS

Set Point	Solids (% Wt/Wt)	Tars & Oils Acetone Extractibles (% Wt/Wt)	pH	Total NH_3 (mg/L)	Total Alkalinity as $CaCO_3$ (mg/L)	Total Cyanide, CN (mg/L)	Total Sulfur, S (mg/L)	Total Sulphate, SO_4" (mg/L)	Total Sulfide, S (mg/L)	Total Thio-Sulfates, S_2O_3" (mg/L)	Total Chloride, Cl" (mg/L)	Total Phenols (mg/L)	* COD (mg/L)	** BOD (mg/L)	Filterable Total Dissolved Solids (mg/L)
Oxygen Blown Test TP-019-1															
1	1.57	NEMA+	8.8	1753	5600	0.48	92	100	<0.02	1525	26	0.04	150	48	493
2A	0.02	NEMA	8.0	2229	3560	0.55	113	145	<0.02	1790	32	<0.01	190	75	527
2B	0.05	NEMA	8.8	935	4160	4.3	64	100	<0.02	1075	22	<0.01	170	38	260
2C	--	NEMA	---	1176	3000	14	52	80	<0.02	1275	7	<0.01	160	< 1	261
Oxygen-Blown Test TP-019-2															
1	1.6	NEMA	8.8	2100	7080	38	96	170	<0.02	1635	32	0.02	240	62	---
2A	0.51	NEMA	8.7	840	2770	33	40	54	<0.02	1187	37	0.02	118	21	---
2B	1.1	NEMA	8.8	1300	4280	16	46	70	<0.02	1254	5	0.01	133	63	---
4C	1.7	NEMA	7.4	320	820	0.37	66	110	<0.02	784	12	0.02	98	48	---
Oxygen-Blown Test TP-019-3															
1A	0.39	NEMA	8.4	390	870	1.3	1.98	180	<0.02	1030	75	0.03	252	140	---
1B	0.20	NEMA	8.1	240	274	0.29	90	82	<0.02	403	403	0.04	158	48	---
1C	1.29	NEMA	8.1	780	1410	0.37	1004	180	<0.02	1658	52	0.03	507	130	---

*COD - Chemical oxygen demand.
**BOD - Biological oxygen demand.
+NEMA - No extractible material with acetone.
--- - Not measured.

TABLE 3.3-10

CHARACTERISTICS OF CYCLONE DEPOSITS COMPARED WITH FEEDS AND SOLIDS PRODUCTS

	Test					
	TP-018-3		TP-018-4		TP-018-5	
Freeboard Temperature (°F)	1749-1779		1747-1778		1780-1835	
	% Wt. in the Unashed Sample		% Wt. in the Unashed Sample		% Wt. in the Unashed Sample	
Elements	Fe	S	Fe	S	Fe	S
Deposit Material	33-48	9-18	50-68	15-29	30-44	4-14
Feedstock (Pittsburgh Coal)	1.7	2.1	1.7	2.1	1.7	2.1
Cyclone Fines (Collect)	2.4	1.1	2.3	1.3	1.3	1.0
Ash Withdrawal Material from the Bottom of Gasifier	8.4	1.3	3.2	1.1	8.6	1.5

3.3.3 Environment, Safety and Health

Work accomplished this quarter included a review of new Environmental Protection Agency standards for polychlorinated biphenyl (PCB) and discharge of hazardous substances and a review of the Kay-Ray bed level measurement system for the devolatilizer. A design change was initiated to incorporate the system, and the Institute of Gas Technology Kay-Ray system, which is available for Westinghouse use, was evaluated but is unsuitable for use on the devolatilizer because of collimetric restrictions. In addition, a review of the PDU elevator design was conducted relative to the problems experienced during winter operation. To prevent snow and ice from affecting safe operation, three sides of the elevator will be enclosed. A load test and functional check of the elevator were satisfactory.

Also during this quarter, chemicals on site were identified and labeled for use and exposure, the plant process piping wall thickness was measured for potential corrosion or erosion, the flammable storage building was revamped, with all materials placed on drum tilt racks with safety vents, nozzles and drip cans, and the site respiratory protection plan was updated to include recent OSHA requirements. Industrial first aid classes for 36 engineers and technicians and a class in cardiopulmonary resuscitation (CPR) for 13 site personnel were conducted, and a report on the physiological and psychological effects of night and shift work was evaluated relative to PDU operation. From the survey, it was concluded that no change in PDU operation is warranted.

3.3.4 Work Forecast for Next Quarter

Process and design engineering work planned for next quarter is as follows:

- Complete the laboratory data for solids, liquids and gaseous products for integrated operation.
- Review the miniscrubber data for water-soluble products such as ammonia, alkali and chlorides in the product gas.
- Evaluate the feasibility of a portable X-ray analyzer for rapid analysis of the ash contents of feedstocks and solids products.
- Perform functional checkout of the on-line gas calorimeter.
- Write specifications, and obtain and evaluate bids for on-line analyzers to measure water, ammonia and sulfur compounds in the product gas.
- Modify the existing gas sampling train (total condensable analyzer) to improve measurement of water in the product gas.

3.4 SCALE-UP MODEL (Task 1)

3.4.1 Design and Development

Scale-up test facility design and development efforts continued during this quarter. Specifications were prepared for the weather enclosures of the model and air supply utilities and for the computer data logging system. Also, analyses were performed for the design of the ash withdrawal section of the gasifier model, for the stress evaluation of the pressure containment sections of the model, and for the control valve sizing requirements of both the 15- and 20-psig air supply systems.

Other work accomplished includes the specifications for the model and compressor enclosures and associated bid package drawings, which are now ready for approval. A stress evaluation for all model sections was initiated, and to date includes only minor structural changes. It was determined that the components meet the code rules selected for this application. A change in the specification was made for the starter for the 600-hp compressor unit drive motor to limit the starting current surge to approximately 50 percent of locked rotor current.

3.4.2 Procurement

Bids for control valves, rotary feeders and the weigh cell systems were reviewed, change notices were prepared to purchase these items, and bids for the process control instrumentation were received and are being reviewed.

3.5 LABORATORY SUPPORT STUDIES (Task 3)

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, develop process models for scale-up, and understand process phenomena to achieve reliable operation. Work was 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. Work accomplished and planned is summarized in the following sections.

3.5.1 Cold Flow and Analytical Modeling

3.5.1.1 Work Accomplished - Jet Phenomena

Gas Entrainment into a Pure Gas Jet Inside a Fluidized Bed

Gas entrainment into a pure gas jet inside a fluidized bed was studied by two different techniques. A two-dimensional directional pitot tube was used to measure the gas velocity profiles inside the jet at various jet cross sections. Through integration of those gas velocity profiles, quantitative information on gas entrainment into the jet could be obtained. A gas tracer (helium) was also injected into different gas streams (jet, annular flow from char-ash separator, and conical flow from the conical grid) to investigate the movement of gas inside the reactor. This will provide information for selecting the optimal location to inject steam to promote gasification in the reactor. The gas velocity profiles have been reported previously in FE-1514-93, "Quarterly Progress Report, Fourth Quarter, Fiscal Year 1978, July 1 to September 30, 1978." The concentration profiles of the gas tracer across the bed at different locations are summarized here. To aid the interpretation of the data, the relative dimensions and locations of the jet nozzle, the char-ash separator and the conical plate are shown in Figure 3.5-1.

The jet nozzle was located higher than the top of the conical grid so that the jet could be visually observed and high-speed movies could be used to study the solid entrainment into the jet. The flow conditions in all the runs are summarized in Table 3.5-1.

The tracer gas concentration expressed as the tracer concentration at any given point in the fluidized bed (C) over that in the original flow (Co) is plotted in Figures 3.5-2 through 3.5-9 against the distance from the front plate. From the results of the study on velocity profiles, it was found that the jet degenerated much faster when the conical grid flow was absent. The finding is collaborated by the tracer gas study as shown in Figure 3.5-2 (Run GJ 159-163). If there were no leakage of gas out from the jet, the tracer gas concentration (C/Co) should be 1.0 at a distance of 3.4 cm or larger from the front plate for all sample locations. Large dilution of tracer gas flow is evident in Figure 3.5-2, indicating leakage of jet flow along the entire jet length. The jet boundary at 1.7 cm above the jet nozzle is between 1.0 and 4.5 cm from the front plate based on the velocity profile reported earlier. If this is the case, Figure 3.5-2 clearly shows that the gas entrained into the jet stays very close to the jet boundary. The entrained gas is subsequently expelled from the jet at higher distances above the jet nozzle because the jet core shows very little tracer gas. An increase in the jet flow does not seem to affect the concentration profiles, as shown in Figure 3.5-3 (Run GJ 179-183). The plateau on the concentration profile at 1.7 cm above the jet nozzle and between 4.5 to 6 cm from the front plate may be an indication of a localized vortex or gas recirculation. This was only observed for the runs without the conical grid flow.

When the conical grid flow is present, the gas leakage from the jet decreases, as seen in Figure 3.5-4 (Run GJ 169-173) and the tracer gas does penetrate into the core of the jet. Comparable profiles at a higher jet velocity are shown in Figure 3.5-5 (Run GJ 189-193).

A gas tracer was also injected into the conical grid flow and gas samples were taken at different bed locations. Figure 3.5-6 (Run GJ 194-198) shows that very little tracer gas was actually entrained into the jet at a lower jet velocity (31.37 m/s). At a higher jet velocity (50.72 m/s), the penetration improves but not substantially, as shown in Figure 3.5-7 (Run GJ 204-208). At higher conical grid flows and higher jet velocities, somewhat larger entrainment of conical grid flow into the jet was observed (Figure 3.5-8, Run GJ 199-203, and Figure 3.5-9, Run GJ 209-213). But this is still small compared to the entrainment of annular flow (for char-ash separator) into the

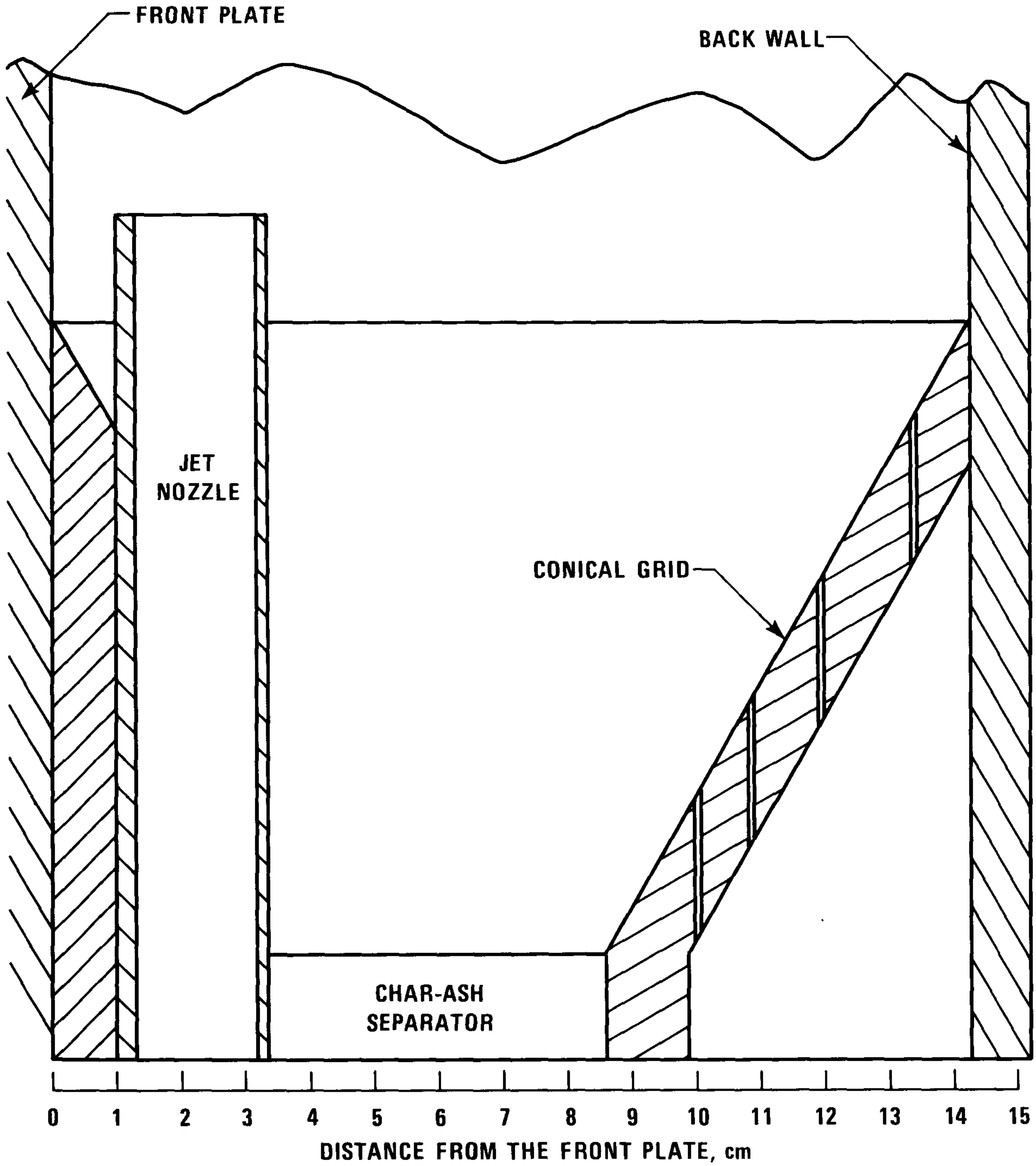

Figure 3.5-1. Relative Dimensions and Locations of the Jet Nozzle, Char-Ash Separator and Conical Grid

2243-11

TABLE 3.5-1

SUMMARY OF EXPERIMENTAL CONDITIONS

I. Tracer Injection through Char-Ash Separator Flow

Run No.	Jet Velocity (m/s)	Char-Ash Separator Flow (m^3/min)	Conical Grid Flow (m^3/min)
GJ159-163	30.96	0.65	None
GJ164-168	30.96	0.65	0.69
GJ169-173	31.37	0.65	1.20
GJ174-178	36.20	0.65	None
GJ179-183	41.56	0.65	None
GJ184-188	50.12	0.64	0.70
GJ189-193	50.72	0.58	1.20

II. Tracer Injection through Conical Grid Flow

Run No.	Jet Velocity (m/s)	Char-Ash Separator Flow (m^3/min)	Conical Grid Flow (m^3/min)
GJ194-198	31.37	0.66	0.69
GJ199-203	31.37	0.66	1.20
GJ204-208	50.72	0.66	0.70
GJ209-213	50.72	0.58	1.21

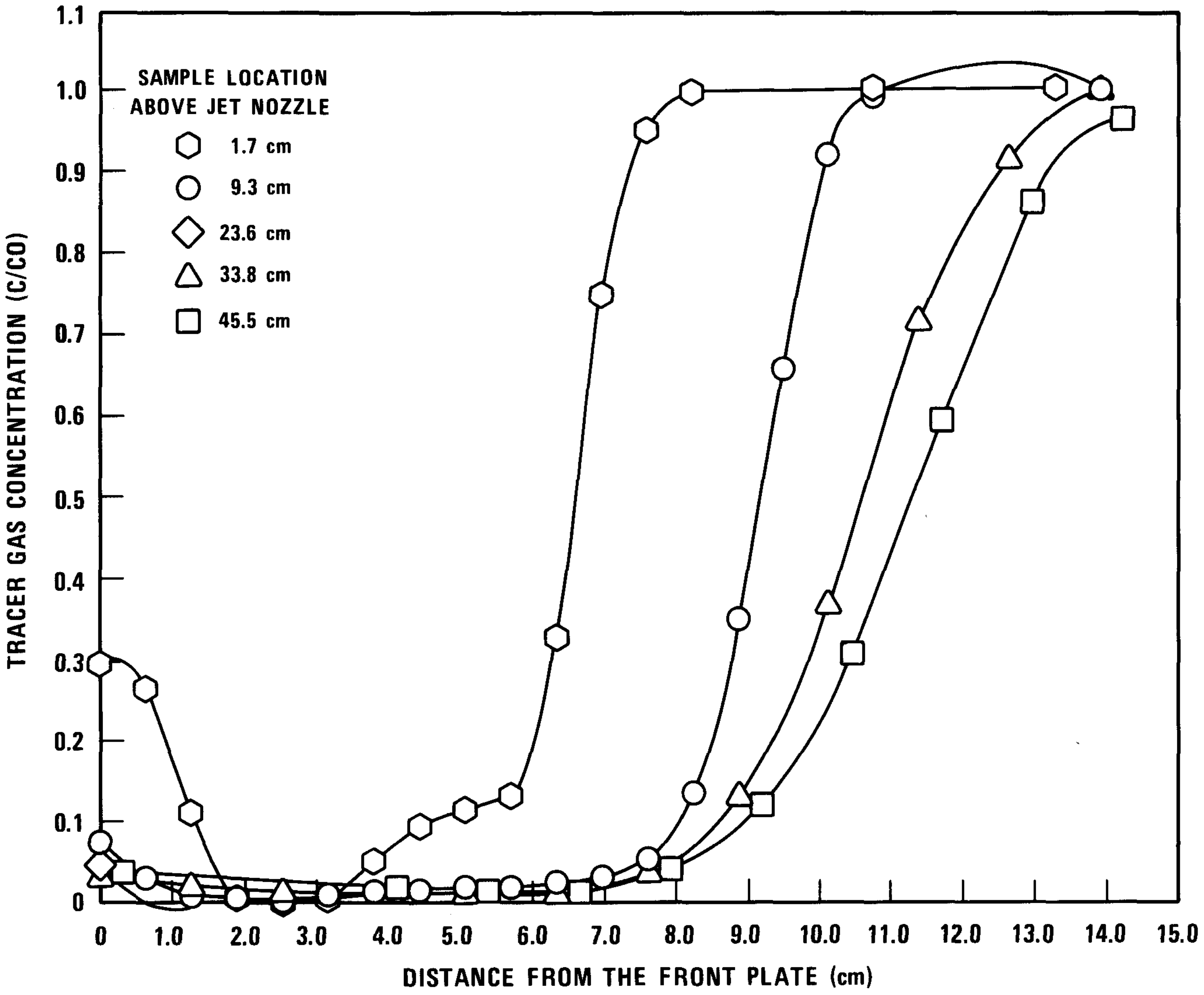

Figure 3.5-2. Tracer Gas Concentration Profile – Run GJ 159-163

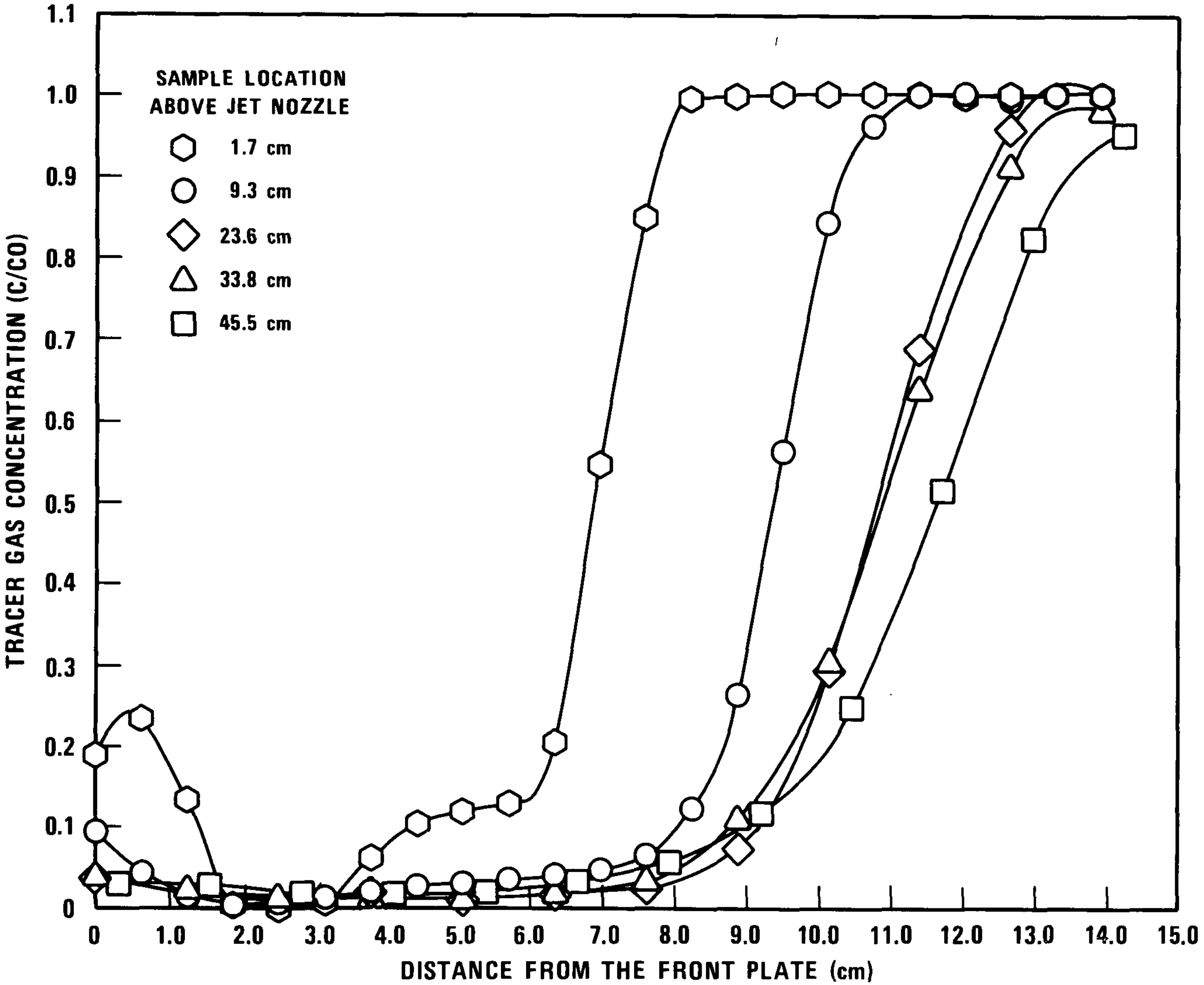

Figure 3.5-3. Tracer Gas Concentration Profile – Run CJ 179-183

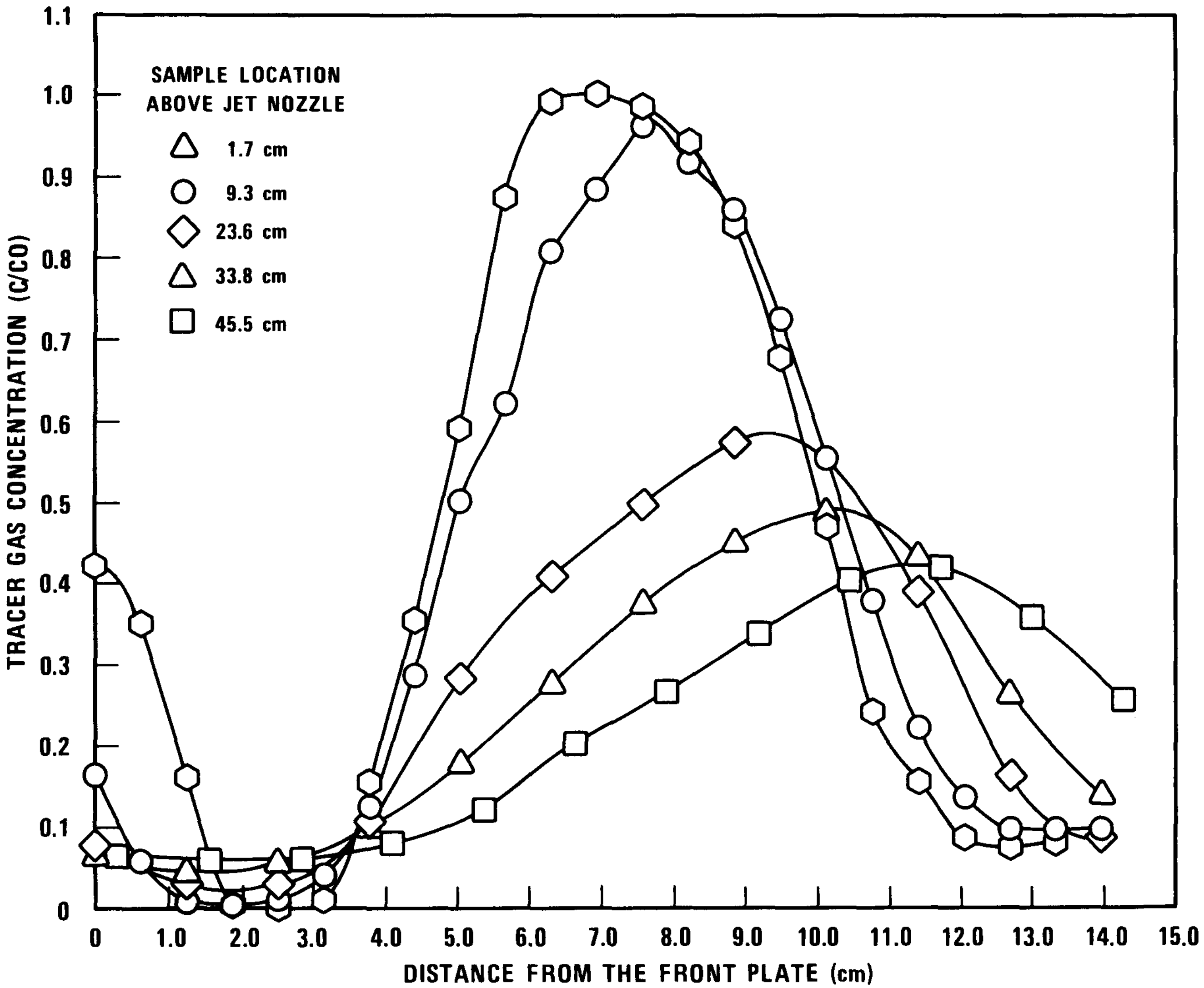

Figure 3.5-4. Tracer Gas Concentration Profile – Run CJ 169-173

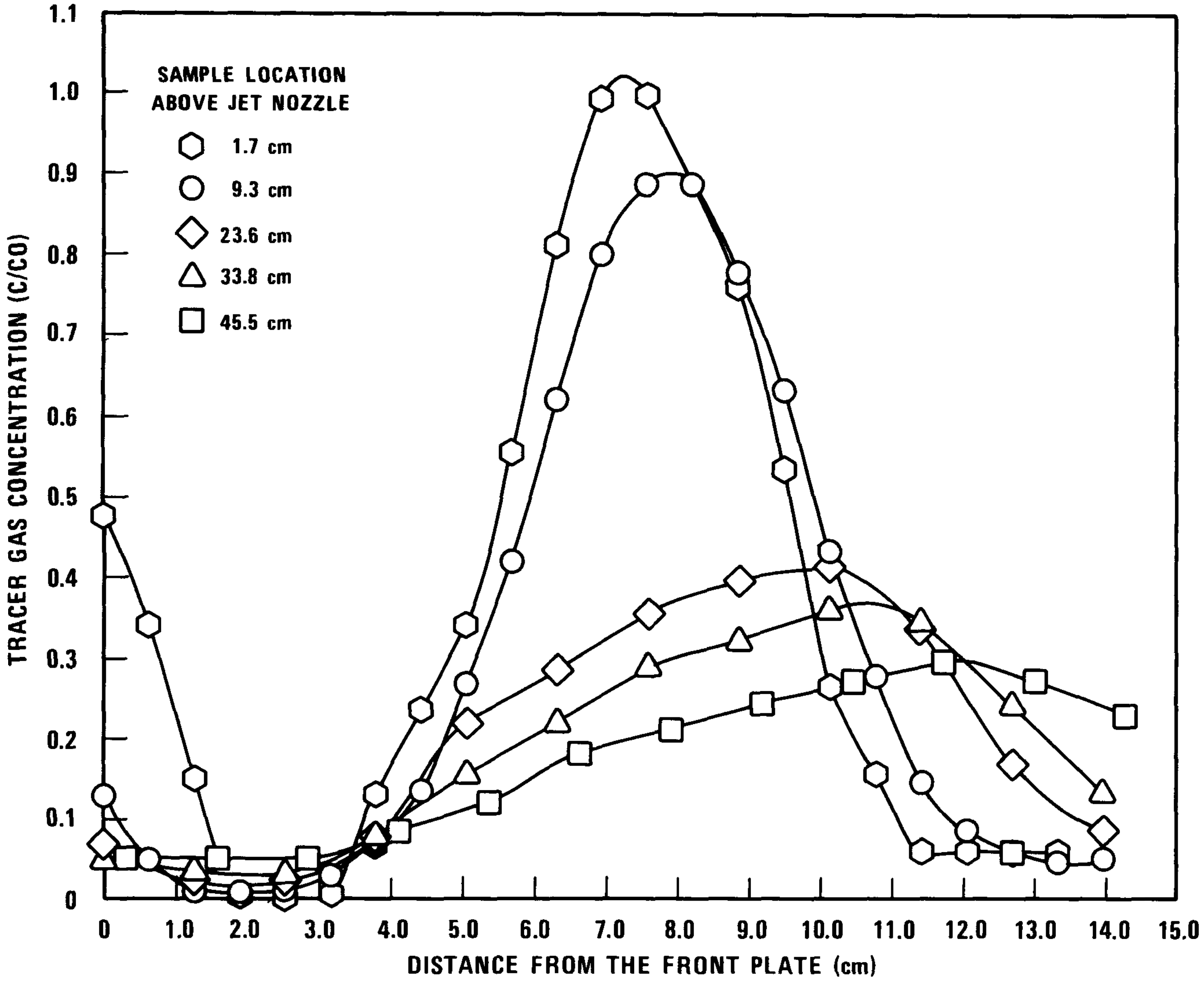

Figure 3.5-5. Tracer Gas Concentration Profile – Run GJ 189-193

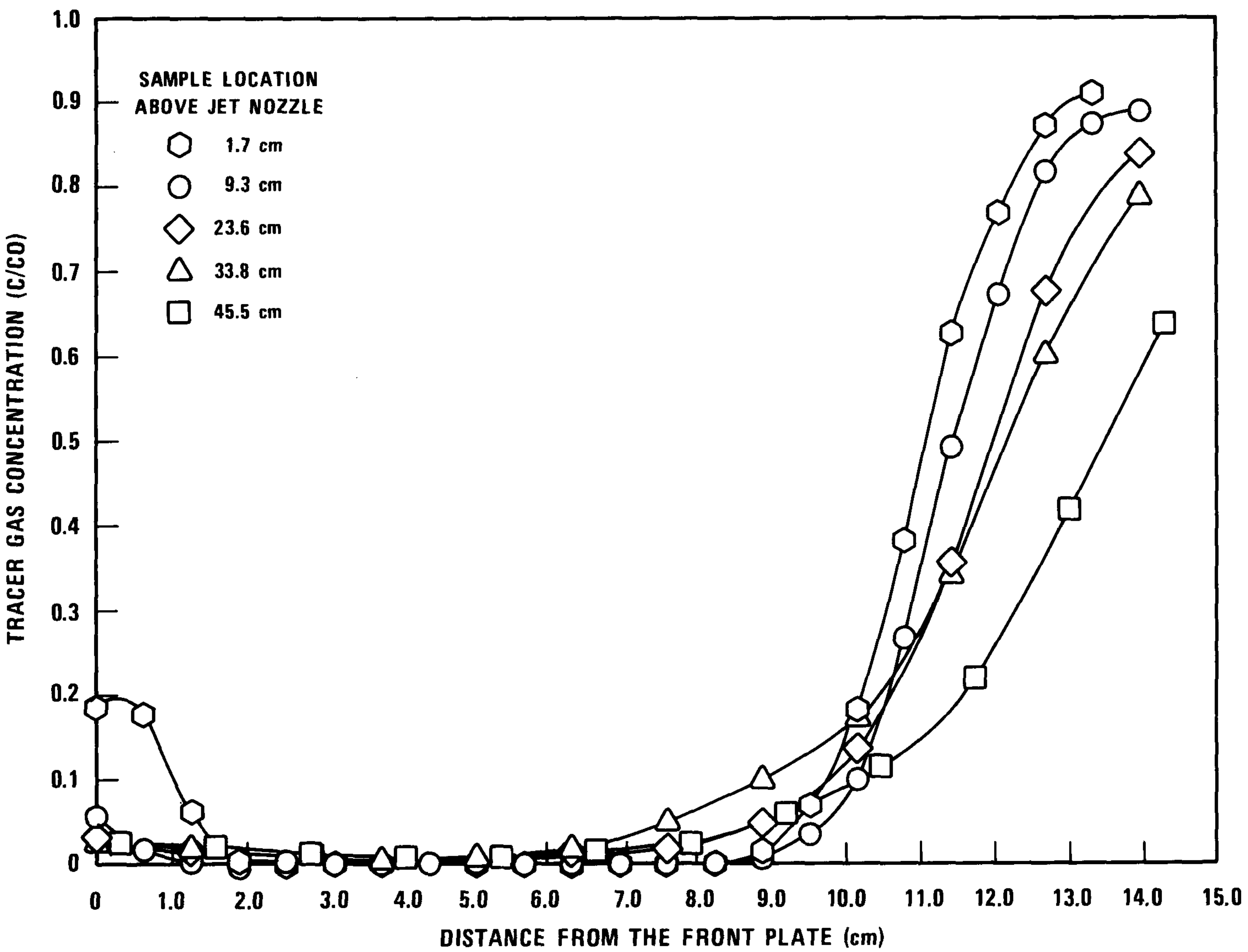

Figure 3.5-6. Tracer Gas Concentration Profile – Run GJ 194-198

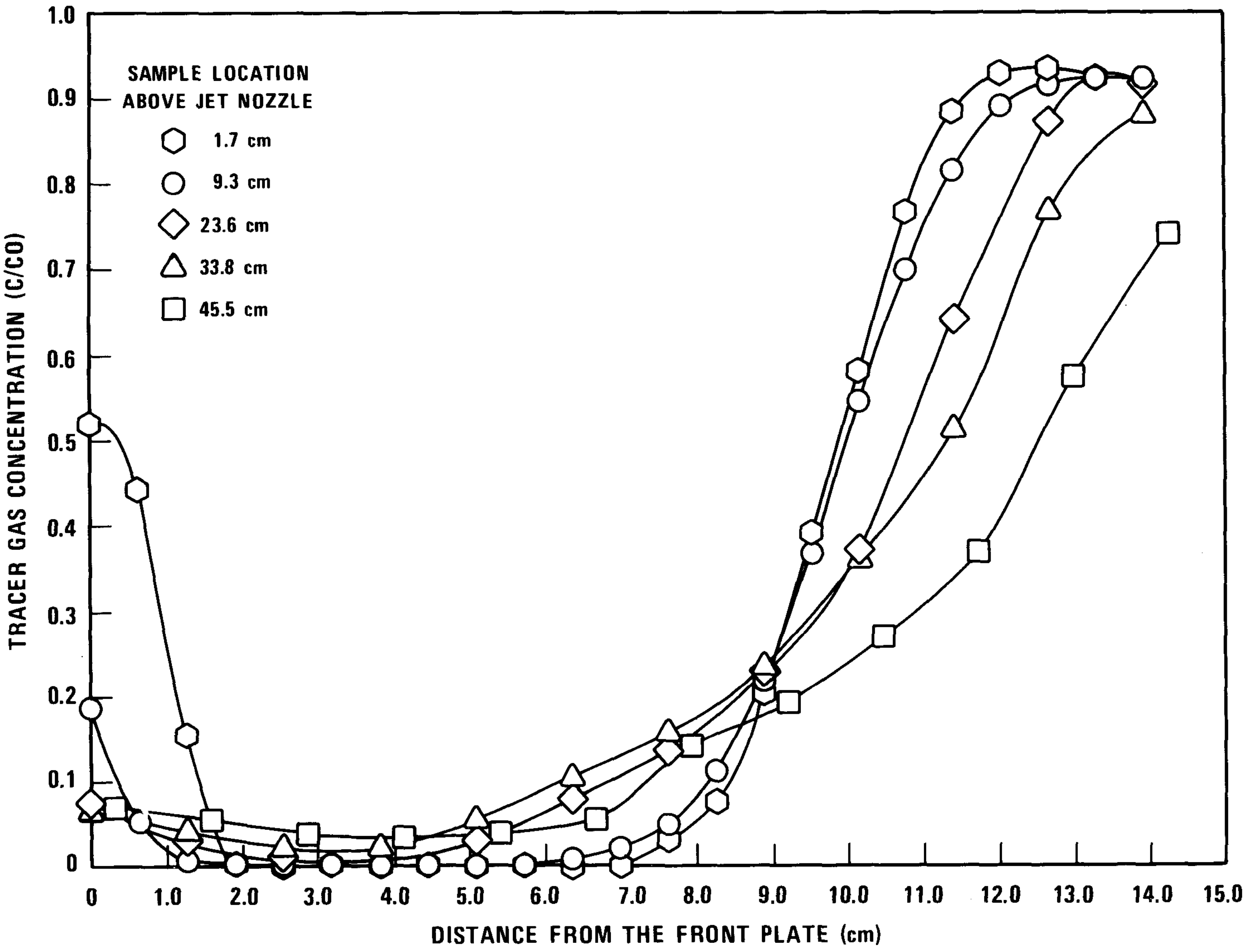

Figure 3.5-8. Tracer Gas Concentration Profile – Run GJ 199-203

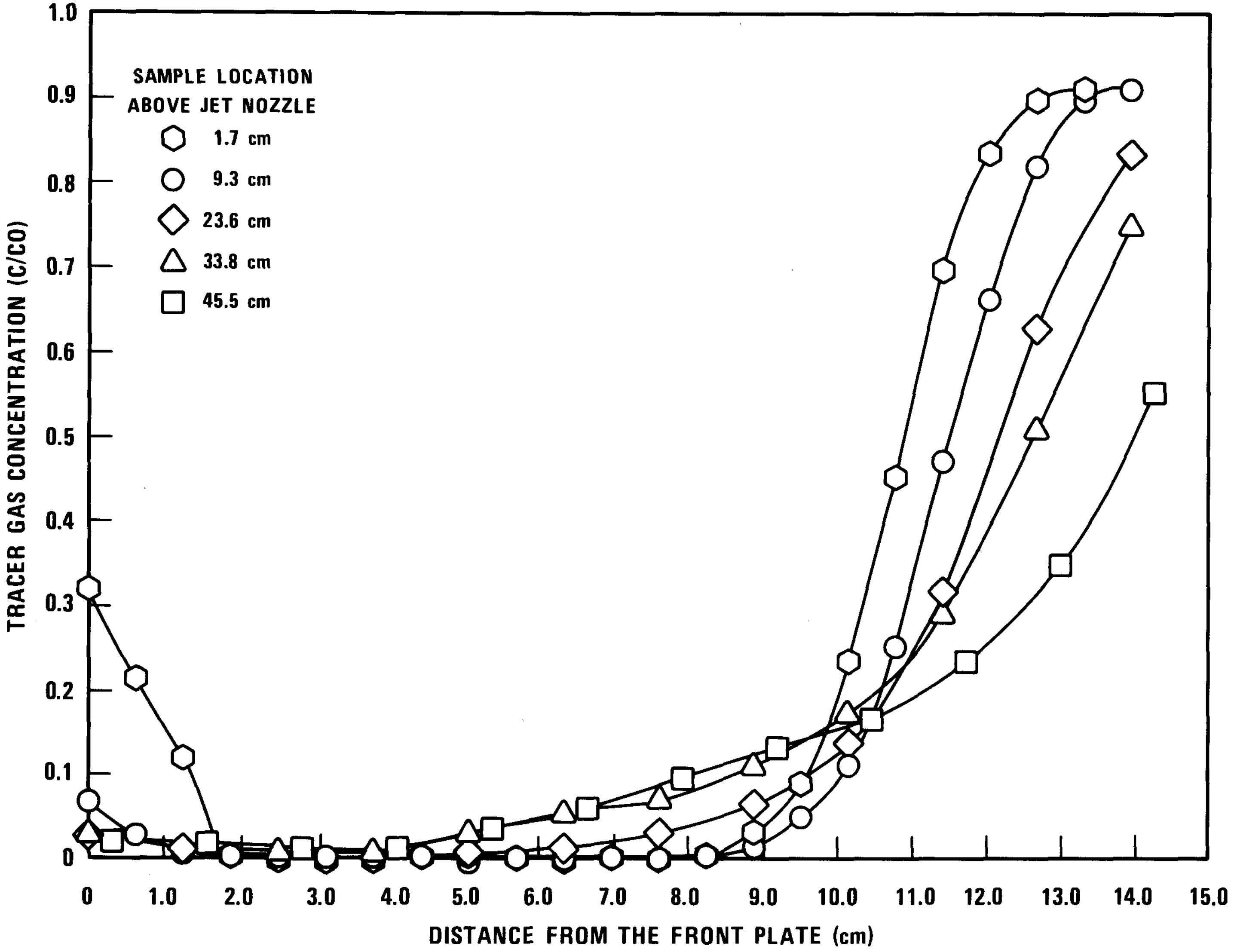

Figure 3.5-7. Tracer Gas Concentration Profile – Run GJ 204-208

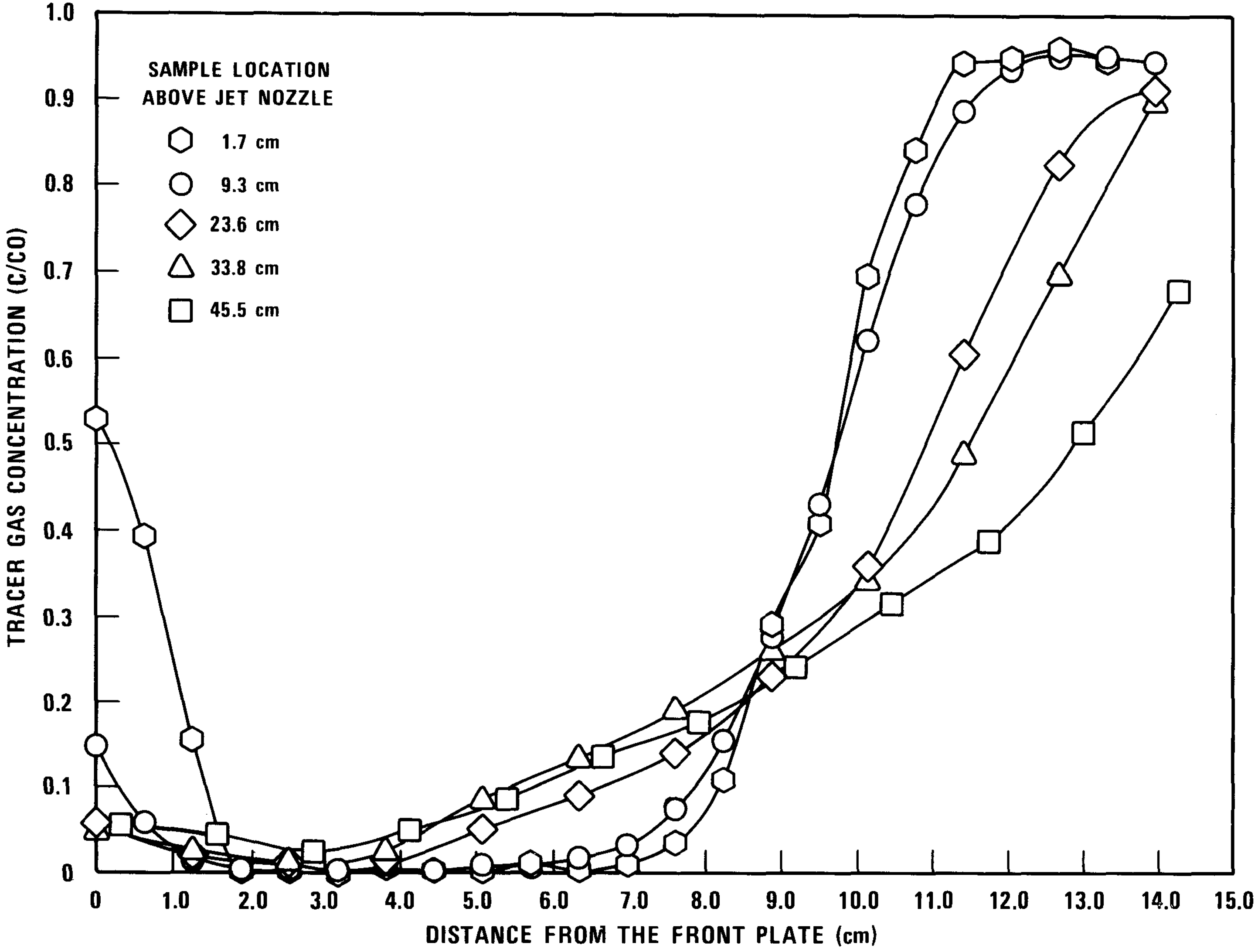

Figure 3.5-9. Tracer Gas Concentration Profile – Run GJ 209-213

jet under similar operating conditions. It is concluded that if it is beneficial for the steam to be entrained into the jet, the steam should be fed through the char-ash separator. Otherwise, the steam should be fed through the conical grid.

Momentum Dissipation of and Gas Entrainment into a Gas-Solid Two-Phase Jet

Gas velocity profiles in a gas-solid two-phase jet inside a fluidized bed were determined at five different horizontal planes (1.7, 9.3, 23.6, 33.8, and 45.5 cm from the top of the jet nozzle) perpendicular to jet direction using a 0.6 cm diameter two-dimensional directional pitot tube. The experiments were conducted at three nominal jet velocities (29, 40, and 51 m/s) and with solid loadings (weight of solid/weight of gas) ranged from 0 to 3.

Preliminary analysis of the results indicated that jets with higher solid loadings did dissipate slower than that with lower loadings as expected. In other words, the jets with higher solid loadings penetrated more deeply into the fluidized bed. The jet boundary, however, changed little with respect to changes in solid loading. The velocity profiles at 1.7 cm from the jet nozzle were almost identical for all test conditions with different solid loadings. This indicated that the rate of gas entrainment into the jet was not affected by the amount of solids present in the jet and only depended on the jet velocity. The data are being analyzed, and results will be reported in the next quarterly report.

3.5.1.2 Work Accomplished - Draft Tube Design

Upset operating conditions were purposely created in the two-dimensional unit with multiple draft tubes by allowing one of the three draft tubes to be plugged or to become a downcomer. The pressure drops across each downcomer and each draft tube were measured as usual. It was found that the pressure drop across the plugged draft tube or across the draft tube which became a downcomer was usually higher than the rest of the draft tubes by at least 30 percent. The pressure drop across different draft tubes in a normally operated bed was usually less than 10 percent (see FE-1514-93). Hence, the draft tube pressure drop may be employed as a diagnostic tool in the event of operational upset.

Cork particles (-8 + 12 mesh and particle density = 15 lb/ft^3) were introduced into the two-dimensional unit as the bed material. Though the bed could be started with recirculation of bed material up through the draft tube and down in the downcomer, the operation was not very smooth due to excessive adherence of particles on the walls. If the cork particles were sprayed with the antistatic agent before introduction into the bed, the operation of the bed improved but lasted only about 30 minutes. After that, the effect of static electricity increased and the operation of the bed became poor again. Cork particles will be tried in the three-dimensional semicircular unit to see whether a unit of larger dimensions will help the situation.

3.5.1.3 Work Accomplished - Distributor Design

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

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

Experimental work with the cold model was started. In the first stage of the experiments only gas, that is, no fine solids, is introduced through the plenum. No weeping into the annulus of the bed material was observed at gas velocities above approximately 9.8 ft/s (3 m/s). The terminal velocity of the bed solids is 4.3 ft/s (1.3 m/s). As the velocity is decreased, small amounts of particles tend to fall into the annulus. At even lower velocities, the annulus acts like a vigorously fluidized bed. The "shoulder" in the plenum, just below the annulus, seems to effectively prevent the bed material from falling into the bottom of the plenum at low gas flow rates and during shutdown. However, it was observed that during startup with the column full, there is a danger of blowback of the bed material into the plenum. A startup sequence will be recommended to prevent this particle blowback.

3.5.1.4 Work Forecast for Next Quarter

- Initiate the study on char-ash separation by using different materials of different characteristics to simulate char and ash particles.
- Continue analysis of the data on gas and solids entrainment into a pure gas jet and a gas-solids two-phase jet.
- Conduct experiments in the two-dimensional unit with multiple draft tubes using a different bed material and different distances between the distributor plate and the draft tube inlet.
- Initiate a test program to study devolatilizer distributor/plenum performance.

3.5.2 Coal Behavior Studies

3.5.2.1 Work Accomplished - Gasification

The reactivities of Montour and Utah chars were determined. The variation of the reaction rate with carbon conversion was studied for both of these chars. A document is being prepared on the reactivities of chars and their possible relationship with surface areas. This information will be published as available.

3.5.2.2 Work Accomplished - Ash Agglomeration

Fabrication of the ash agglomeration reactor has been completed, and installation of the reactor is in progress. The support structure and air tube assembly were fabricated. Since this reactor is much larger than the previous reactor, the layout of the test facility, that is, the position of the cyclone, ash discharge section, gas preheaters, and so on, is different and much of the plumbing connecting the various pieces of the equipment is being rerouted.

A natural gas burner system was considered to heat the reactor overnight during a test series, but was found to be complex and unsuitable. Instead, electrical heaters were designed to preheat the nitrogen used to heat the reactor to the desired temperature level. The same heaters will be used to preheat all the inlet gas streams during testing. Materials necessary for the fabrication of the heaters, such as heating elements, sample cylinders and packing, were ordered and received, and temperature controllers to control the temperatures of various gases and the reactor will be installed. Bed temperature control will be accomplished through the use of a solenoid valve to cut off the oxygen supply and restore the nitrogen supply. The present experimental setup and procedure are more refined and considerably more complex than in the past.

Experiments on the cold model were continued to determine the optimum range of annuluar velocity for the separation of ash agglomerates from the bed material in the char-ash separator section at minimum jet and grid flows for satisfactory fluidization. A booster flow was introduced through a distributor approximately 5 inches below the air tube top, and ash agglomerates were fed above the bed surface. The following operating conditions and materials were used for these studies:

Bed Material: Coke Breeze (-1.7 + 0.5 mm)

Minimum Fluidization Velocity of Agglomerates (U_{mf}): 2.9 ft/s

Jet Velocity: 99 ft/s

Grid Flow: 2.4 scfm

Annular Velocity: 0.9 U_{mf} to 1.2 U_{mf}

The separation of agglomerates from the bed material was poor outside the limits of 0.9 U_{mf} to 1.2 U_{mf} for the annular velocity. The rate of separation was observed to be lower at an annular velocity of 0.9 U_{mf} than at higher velocities. The cold model experiments were thus useful in establishing the desirable ranges of flow in addition to the visual observation of the bed and operator training.

3.5.2.3 Work Accomplished - Coal and Ash Chemical Phenomena

Efforts to isolate and define the binding matrix in ash deposits and agglomerates continue. Under the microscope, at a magnification of 200X, particles of a glassy transparent material, believed to be part of the binding matrix, have been separated from a ground sample of wall deposit (PDU test P-012-3). A spot-test analysis, which involved reactions with zinc chloride and tetraphenyl-boron, showed the presence of potassium in the glassy particles collected. However, this result has not as yet been reproduced because manual separation of the glassy particles is very time consuming. Another separation technique, involving gravity fractionalism (classification of particles as sink or float fractions in liquids of various specific gravities) was used to isolate the binding material from the bulk of deposits and agglomerates. Samples of wall deposits, ground to -40 mesh size -425 µ), were separated into sink and float fractions in carbon etrachloride (density = 1.584), in 1.2 = dibromoethane (density = 2.169) and n bromoform (density = 2.865). All of the particles sank in carbon etrachloride; about one percent floated in dibromoethane and 62 percent which sank in dibromoethane) floated in bromoform. The remaining 37 percent omprised the sink fraction in bromoform. The various sink and float ractions were analyzed, using DTA (differential thermal analyses) to etermine their melting characteristics. Preliminary DTA results showed that he majority of the samples did not change chemically or physically in air, rgon or hydrogen, in the temperature range 250°C to 1200°C (482°F to 192°F). One very small endothermic reaction, possibly a melting, was egistered at 902°C (1656°F) in air, for the fraction "sink in ibromoethane - float in bromoform." Also, two strong exothermic reactions, ossibly oxidation reactions, were observed at 346°C (655°F) and 741°C 1366°F) in air, for the fraction "float in dibromoethane."

.5.2.4 Work Forecast for Next Quarter

- No work is planned on char reactivity studies.
- Complete installation and testing of the new reactor in the ash agglomeration test facility and continue ash behavior study.
- Continue to update the gasification model for design purposes.
- Continue an experimental program to isolate and characterize the binding matrix in ash deposits and agglomerates.

3.5.3 Environmental Impact Studies

3.5.3.1 Work Accomplished - Solids Disposal

Characterization of ash agglomerates from oxygen-blown test TP-018-2 (coke breeze and Pittsburgh seam coal feed) and investigation of their leaching properties continued. Table 3.5-2 summarizes the chemical compositions of two TP-018-2 test samples and typical flyash from a conventional coal-fired power plant. The latter underwent parallel leaching tests to provide a comparison with a conventional coal ash. Noticeable differences exist in the percent of unburnt carbon and total sulfur content among the samples.

Examination by scanning electron microscopy (SEM) and energy dispersive X-ray analysis (EDAX) revealed the morphological characteristics with corresponding chemical compositions for test TP-018-2 coke breeze agglomerates shown in Figure 3.5-10(a) to (c); test TP-018-2 Pittsburgh coal agglomerates, shown in (d) to (f); and Duquesne fly ash, shown in (g) to (i). Two phases on each SEM were scanned by EDAX to identify their elemental composition, that is, EDAX spectra at points A and B shown in Figure 3.5-10(a) are shown in (b) and (c) for test TP-018-2 coke breeze samples. Differences in minor elements (Fe, Ca S) are clearly seen among various samples and phases, although the major ash elements (Si, Al) remain similarly high at all sites. It is interesting to note that TP-018-2 coke breeze agglomerates have a higher Fe content, as seen in Figure 3.5-10(b) and (c), than the agglomerates with coal feed, shown in (e) and (f), as well as the presence of spherical particles which are most likely cenospheres. The correlation has been previously observed. Both samples were produced from a similar temperature range. Also worth nothing i the higher S content in the coal feed agglomerates shown in Figure 3.5-10(e) and (f) than the coke breeze agglomerates. Chemical analysis of the solids shown in Tables 3.5-2 and 3.5-3 confirms this observation. However, the sulfur species in the ash agglomerates do not seem to be soluble in water or acetate buffer (pH = 4.5), which will be discussed in leaching test results. Duquesne fly ash consists of varying sizes of cenospheres as well as a non-spherical phase, as seen in Figure 3.5-10(g), and consists of Si, Al, Fe, K, S, Ca and Ti typical of a conventional coal ash.

Leaching studies, partially reported in the previous quarterly report (FE-1514-97), have been completed on TP-018-2 test samples. Table 3.5-3 summarizes the chemical characteristics of solids and leachates (in water and pH = 4.5 buffer media) of two TP-018-2 agglomerates. Results of parallel tests on Duquesne fly ash are also summarized to provide a reference leachate from a conventional coal ash. Drinking water standards (DWS) are listed to provide a perspective for leachate quality; those that exceed the DWS and those that are ten times the DWS are cross-hatched and double-cross-hatched for ease of comparison. Close examination of Table 3.5-3 indicates the following:

- Leachates, with a deionized water medium, of both TP-018-2 samples pass the DWS. The deionized water leachate of Duquesne fly ash has higher concentrations of dissolved species such that As, Se and SO_4 exceed the DWS.

TABLE 3.5-2

CHEMICAL CHARACTERIZATION OF TP-018-2 ASH AGGLOMERATES AND DUQUESNE FLYASH

	TP-018-2 Coke Breeze (Wt.%)	TP-018-2 Pittsburgh Coal (Wt.%)	Flyash (Wt.%)
SiO_2	37.8	24.2	47.0
Al_2O_3	19.1	11.6	22.2
Fe_2O_3	11.2	6.7	13.2
SO_3 (total S)	4.1	7.2	1.84
CaO	2.6	0.56	2.6
Na_2O	0.33	0.25	0.84
K_2O	1.3	0.59	1.9
Free C	30-40	50-55	$\sim$10

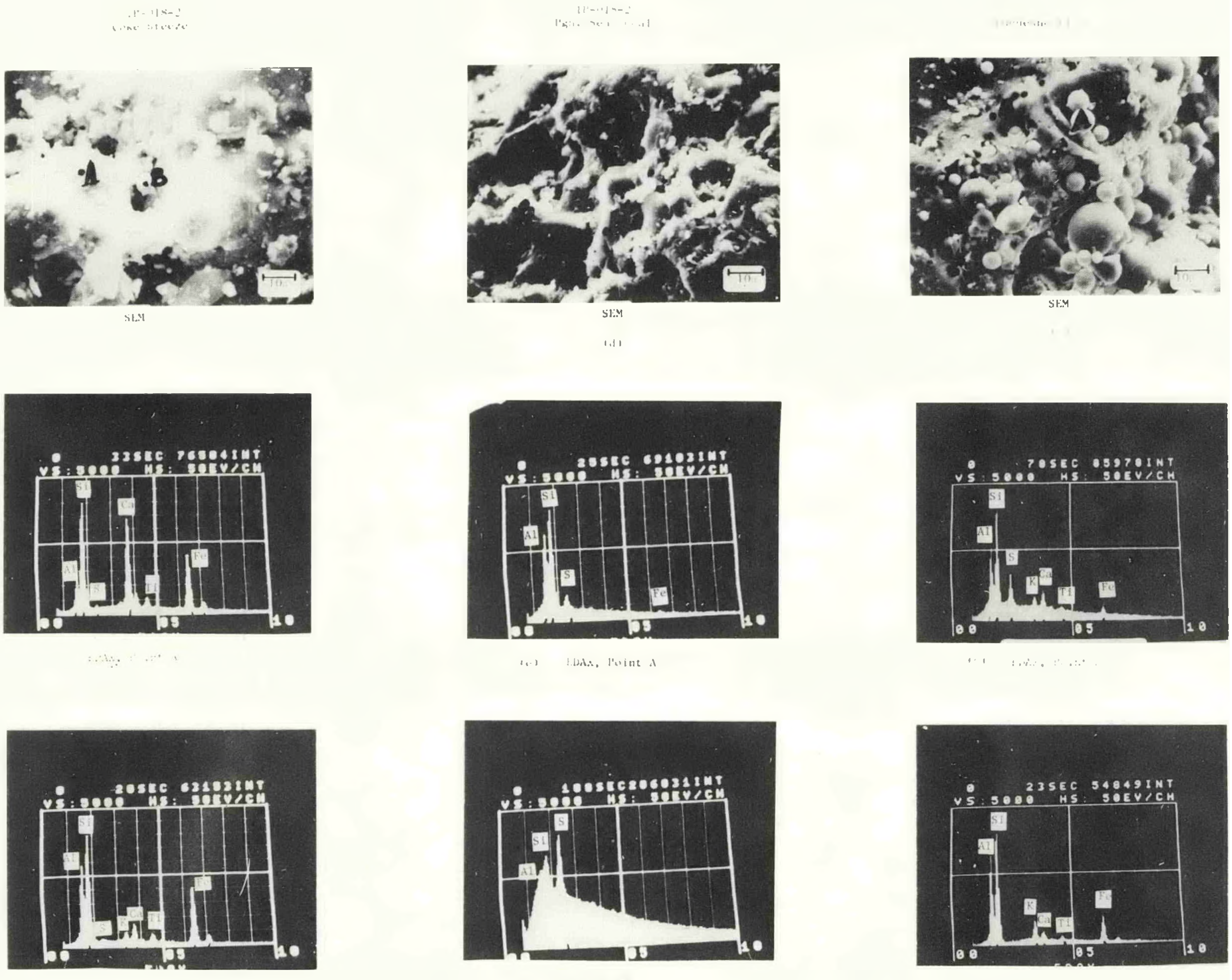

Figure 3.5-10. Scanning Electron Photomicrographs and Energy Dispersive X-Ray Analysis of TP-018-2 Ash Agglomerates and Duquesne Flyash

TABLE 3.5-3

SUMMARY OF LEACH TEST RESULTS

Dwg. 2622C20

Substance	TP018-2 Coke Breeze			TP018-2 Pgh. Seam Coal			Conventional Coal Flyash			DWS (mg/ℓ)
	Solid (ppm)	Leachate Deionized H_2O (mg/ℓ)	Leachate Acetate Buffer (mg/ℓ)	Solid (ppm)	Leachate Deionized H_2O (mg/ℓ)	Leachate Acetate Buffer (mg/ℓ)	Solid (ppm)	Leachate Deionized H_2O (mg/ℓ)	Leachate Acetate Buffer (mg/ℓ)	
Al	10.1%	<.1	.5	6.2%	<.1	14	11.8%	.2	3	
Ag	<1	<.01	<.01	<1	<.01	<.01	<1	<.02	<.02	0.05
As		.004	.001		<.001	<.002		▨ .174	▨ .13	0.05
B	100	1	2	80	.1	2	150	5	25	
Ba	600	<1	<1	300	<1	<1	600	<1	<1	1.0
Be	3	<.01	.01	1	<.01	.01	3	<.01	<.01	
Bi	<10	<.01	<.01	<10	<.01	<.01	<10	<.01	<.01	
Ca	1.8%	12	▨ 584	0.4%	8	192	1.8%	192	▨ 696	200
Cd	<5	<.01	<.01	<5	<.01	<.01	<5	<.005	<.005	0.01
Co	<10	<.01	.2	<10	<.01	.07	<10	<.02	<.02	
Cr	150	<.01	<.02	50	<.01	▨ .07	150	<.02	<.02	0.05
Cu	100	<.1	<.1	30	<.1	<.4	100	<.1	<.1	1.0
Fe	7.7%	<.1	.2	4.7%	<.1	▩ >8	9.2%	.02	<.3	0.3
Ge	<5			<5			5			
Hg		.001	.0007		.001	.0008		.0009	.0009	0.002
Li	150			100			300			
K	1.1%			0.49			1.6%			
Mg	.432%	7.2	81.6	>1000	2.4	28.2	.096%	4.8	52.8	150
Mn	1000	<.01	▩ >.5	100	.02	▩ >.8	1000	<.01	▩ 3	0.05
Mo	30	.02	<.05	20	<.02	.07	30	.1	.8	
Na	0.24%	1	Major	0.19%	(10)	Major	0.62%	>1	Major	
Ni	50	<.01	▨ 3	50	<.01	2	80	<.05	.08	2.0
Pb	10	<.02	<.2	10	<.02	▨ .07	50	<.04	<.04	0.05
Sb	<50	<.05	<.05	<50	<.05	<.07	<50	<.1	<.1	
Se		<.001	<.001		<.001	<.002		▨ .03	▨ .02	0.01
Si	24.2%	>2	>5	15.4%	>2	>5	30.1%	2	<10	
Sn	<10	<.05	<.05	<10	<.05	<.07	<10	<.1	<.1	1.0
Sr		<.2	5		2	1		>1	>10	
Ti	>1000	<.1	<.1	>1000	<.1	<.1	>1000	<.1	<.1	
V	50	.2	.02	50	<.01	.07	50	.02	.08	
Zn	30	<1	<1	10	<1	<1	100	<1	2	5.0
Zr	200	<.2	<.2	100	<.2	<.2	300	<.5	<.5	
SO_3	3.2%			5.1%			1.3%			
SO_4	0.84%	8.5	27.9	0.44%	11.6	8.5	0.65%	▨ 489	▨ 457	250
$S^{=}$	.2%	0	0	1.66%	0	0	.0416%	0	0	
F		<1	<1		<1	<1		<1	<1	2.4
Cl		<1	<1		<1	<1		2	<1	250
Br		<1	<1		<1	<1		<1	<1	
NO_3 (As N)		<1	1		<1	1		<1	<1	10
PO_4		<1	<1		<1	<1		<1	<1	
Free C	30 - 40%			50 - 55%			~10%			
TOC		<10			<10			<10		
pH		8.6	▨ 4.85		8.18	▨ 4.78		7.88	▨ 5	6.5 to 9.2
SC (μmhos/cm)		125	▨ 5120		115	▨ 3,970		▨ 800	▨ 5,870	~750

DWS - NIPDWR, USPHS and WHO Drinking Water Standards

▨ Exceeds DWS

▩ Exceeds 10 X DWS

- The effect of acetate leaching on leachate concentrations was more than additive. An increased leachability of Al, B, Ca, Co, Cr, Fe, Mg, Mn, Mo, Na, Ni, Pb, Si, Sr and total dissolved solids (TDS) were found with an acetate buffer medium. This effect is consistent with that observed in the TP-014 test agglomerates (FE-1514-88, "Quarterly Progress Report, Fiscal Year 1978, April 1 to June 30, 1978").

- Leaching with an acetate buffer (pH = 4.5; specific conductance = 3.31 milimhos/cm) resulted in TP-018-2 leachates of pH ≤ 5 and several trace elements (Ca, Cr, Fe, Mn, Ni, Pb) exceeding the DWS. Similarly, acidic leaching resulted in an increased number of trace elements exceeding the DWS in the leachate of conventional coal ash.

- The DWS is used here to provide a reference point of safe drinking water quality. In reality, a ten-fold dilution would be a conservative factor and has been proposed by the Environmental Protection Agency (Federal Register, December 18, 1978) as the criterion for hazardous waste identification in association with the EPA-proposed extraction procedure (EP) test. Those exceeding 10XDWS are double-cross-hatched (Mn, Fe) in Table 3.5-3.

The impact of the RCRA of 1976 as the guidelines and regulations proposed by the EPA is carefully monitored with respect to PDU solid waste disposal. The recently proposed guidelines and regulations for hazardous waste in the Federal Register, December 18, 1978, under the RCRA, Subtitle C, Section 3001, 3002, and 3004, have been reviewed. According to the proposed regulations under Section 3004, the utility waste--"flue gas desulfurization waste, bottom ash waste and fly ash waste, which is generated by steam power plants solely from the use of fossil fuels"--is among the six wastes under the special waste category. Should they be found to be hazardous according to the proposed identification criteria under Section 3001, a set of less stringent regulations are to be followed than would be required for the non-special hazardous wastes.

The RCRA test for toxicity, EP (as proposed in the December 18 Federal Register), is a modified procedure from the previously EPA-drafted TEP test), and has been carried out on test TP-018-2 solids. The analyses are expected to be completed by the next report period. The up-to-date results indicated that the PDU ash agglomerates would not be hazardous and therefore would be subjected to the non-hazardous waste disposal regulations to be promulgated under the RCRA, Subtitle D, Section 4004 (Federal Register, February 6, 1978).

3.5.3.2 Work Forecast for Next Quarter

The impact of the RCRA on PDU solids disposal will be assessed based on EP test results. Characterization and environmental impact investigation of test TP-018 solids will be continued.

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