

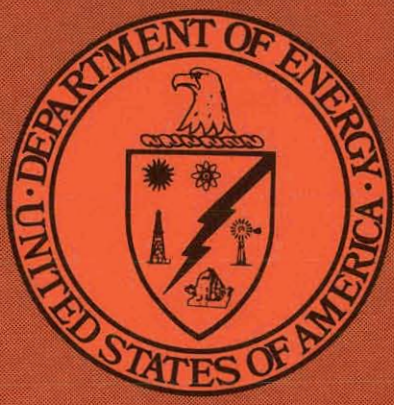
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RIVESVILLE MULTICELL FLUIDIZED-BED BOILER

Annual Technical Progress Report for the Period
July 1979-June 1980

MASTER

Work Performed Under Contract No. AC21-81MC16230

Pope, Evans and Robbins, Incorporated
New York, New York

TECHNICAL INFORMATION CENTER
UNITED STATES DEPARTMENT OF ENERGY

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RIVESVILLE MULTICELL FLUIDIZED-BED BOILER

Prepared by

Pope, Evans and Robbins, Incorporated

Annual Technical Progress Report

For the period July 1979 - June 1980

Prepared for

UNITED STATES DEPARTMENT OF ENERGY
Morgantown Energy Technology Center
Morgantown, West Virginia

Under Contract No. DE-AC21-81MC16230

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ABSTRACT

The objective of this program is to design, construct and test a multicell fluidized-bed boiler, as a pollution-free method of burning high-sulfur or highly corrosive coals. The fluidized-bed boiler produces approximately 300,000 pounds of steam per hour. Steam pressure and temperature conditions were selected to meet requirements of the site at which the boiler was installed.

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INTRODUCTION

General

The Government, in order to implement research and development work on a multicell fluidized-bed boiler operating under utility electric power generation conditions, awarded DOE/ERDA/OCR Contract No. EX-76-C-01-1237 to Pope, Evans and Robbins Incorporated (PER) on October 5, 1972. The work under this contract is a follow-on to work previously performed by PER under OCR Contract No. 14-01-0001-478 as amended, and OCR Contract No. 14-02-0001-1229, which indicated that continued development would have a high probability of success.

Tasks and Phases

The objective of the program covered by DOE/ERDA/OCR Contract No. EX-76-C-01-1237 (E(49-18)-1237) is to test a multicell fluidized-boiler as a pollution-free method of burning high-sulfur coal or highly corrosive coals.

The objective is to be accomplished by designing, constructing and operating a multicell fluidized-bed boiler under utility electric power generation conditions in four technically distinct but chronologically overlapping phases:

- Phase I Boiler and Plant Design: Performance of Experiment to Optimize Certain Boiler Features.
- Phase II Fabrication, Installation and Component Testing
- Phase III Demonstration Operation
- Phase IV Preparation of Atmospheric Fluidized Bed (AFB) Boiler and conceptual design of packaged industrial size AFB boiler.

This Interim Report covers work performed under Phase III and IV of the Contract during the July 1979 through June 1980 time period.

I. SUMMARY

1.1 Work Covered by this Report

This report includes description of work performed under Phases II, III and IV of the contract and includes:

- a) Operation of the boiler and auxiliary systems in hot mode demonstration status to determine performance and emissions characteristics, established operational reliability and commercial operation feasibility.
- b) Conduct approved laboratory test programs to support operation of the Rivesville MFB unit and to continue investigation of the atmospheric fluidized bed combustion process.
- c) Administration and supervision of subcontracted work.

1.2 Review of Significant Events

The following significant events occurred between July 1979 and June 1980.

<u>Event</u>	<u>Date</u>
First lightoff of D cell from C cell	July 1979
53 hours of continuous commercial operation; the longest to date	July 1979
Execution of a two cell, Phase I performance test, Pre-test 5	September 1979
Forced outage due to Monongahela Power's overhaul of No. 7 boiler and No. 5 turbine	September - December 1979
Installation of Fuller-Kinyon feed systems on C cell	September - December 1979
Installation of "nut and bolt" air distributor in B and C cells	September - December 1979
Installation of alternate bed drain valves for B, C and D cells	September - December 1979
Distribution tests of the Fuller-Kinyon splitters	December 1979
Testing of "nut and bolt" gridplate pressure drops	December 1979
Initial operation with Fuller-Kinyon systems	January 1980
First "cold weather" operation	January 1980
132 1/2 hour continuous commercial operation; longest to date	February 1980
200 hours of continuous commercial operation; longest to date	March 1980
Improved performance of the ESP	March 1980
Reduction of Fuller-Kinyon transport and needle velocities	April 1980
Execution of load following tests	April 1980

Event

Date

Modification of DC-1 cyclone to
improve collection efficiency

May 1980

Modification of Fuller-Kinyon
system to allow reduced velocity
operation

May 1980

Operation and testing of flyash
reinjection system

June 1980

1.3 Summary of Activities

1.3.1 General

Substantial progress was made during this reporting period in achieving overall program objectives. Most significant progress was made in on-line operation of the Rivesville MFB. The duration of operation was continuously increased, resulting in increased reliability and higher levels of confidence in unit performance.

Installation and testing of the Fuller-Kinyon feed systems and "nut and bolt" gridplates and completion of 132 and 200 hour commercial operations were the focal points of the period.

Rivesville activities were supported by the Alexandria Laboratory, the New York office engineering and design staff, and various subcontractors.

1.3.2 Laboratory Work at Alexandria, Virginia

Work at the Alexandria fluidized bed combustion laboratory supported operation of the Rivesville Multicell Fluidized Bed Boiler (MFB) and continued development of the atmospheric fluidized bed combustion process. During the reporting period, two major projects were undertaken concerning flyash recycle performance and hot baghouse performance. Summaries of each project follow.

Flyash Recycle Testing

Tests were conducted in the Alexandria laboratory to develop flyash reinjection eductors and gain experience with total flyash recycle. Hardware development efforts were evaluated by performance tests of the PDU system with total recycle.

Based on the hardware development efforts an empirical model was developed to predict the performance of flyash transport eductors using low pressure air.

Operation with total flyash recycle did not significantly improve combustion efficiency over typical non-reinjection PDU test results. Sulfur capture with Grove limestone was better than typical non-recycle results with Greer and Lowellville limestones at low calcium to sulfur molar feed ratios.

Hot Baghouse Testing

Tests were conducted in the Alexandria laboratory to determine the feasibility of collection of fluid bed particulate by means of a hot baghouse. The main objectives of this project were:

- Determine mass collection efficiencies of baghouse.
- Determine outlet emissions in terms of lbs particulate per 10⁶ BTU fired.
- Determine operational characteristics of baghouse.
- Compare baghouse performance in several cleaning modes and at several filtration ratios.
- Evaluate operational problems in the use of fabric filters as final dust collection systems on FBC units.

Conclusion arrived at after evaluation of test data included:

- The baghouse operated with a mass collection efficiency of 99.7%.
- Regardless of variances in air to cloth ratios, inlet dust loading, or chemical composition, the baghouse outlet emissions remained below current EPA standards.

1.3.3 Rivesville MFB Plant Operations

During this reporting period, Rivesville activities were concentrated on several items, including:

- Installation and testing of the Fuller-Kinyon fuel feed systems.
- Installation and testing of the "nut and bolt" air distributor in C and B cells.
- Testing of the flyash reinjection system.
- Improving combustion within individual cells.
- Proving the reliability of the MFB with long commercial runs.

Two successful long-term commercial runs, of 132 and 200 hours respectively, provided considerable data concerning long-term unit performance, ESP performance, Fuller-Kinyon performance and combustion within the cells.

1.3.4 New York Office Engineering and Design Work

Design and engineering work was performed in PER's New York office in support of MFB operations. Various tasks were accomplished to improve performance, increase reliability and alleviate operational problems of the MFB unit.

Work performed at the New York office included:

- Evaluation of a baghouse to augment and/or replace the electrostatic precipitator at the Rivesville MFB.
- Installation drawing for the Fuller-Kinyon feed systems.
- Updating the "as built" drawings of the Rivesville facility.

1.3.5 Subcontractor Activities

The specialized expertise of two organizations was utilized under subcontract arrangements to support MFB unit operation and maintenance activities and AFB technological development.

The two organizations were:

- Foster Wheeler Energy Corporation - MFB unit operative assistance and improvement.
- Stone and Webster Engineering Corporation - plant advisory operations assistance.

II. ALEXANDRIA, VIRGINIA PROCESS DEVELOPMENT UNIT

2.1 Introduction

The Alexandria, Virginia fluidized-bed combustion laboratory serves as the process development facility for the multicell fluidized bed boiler design, construction and test program. Hot model experiments and design verification tests are conducted on a nine square foot bed area process development unit (PDU). The unit is designed to handle 10⁷ BTU/hr heat release feeding 800 lb/hr coal and 400 lb/hr sorbent.

During this reporting period, work at the Alexandria facility concentrated on testing of the flyash recycle and baghouse filtration of fluid bed exhaust gases.

2.2 Flyash Reinjection Test Program

Reinjection of flyash to a fluidized bed combustor offers several attractive features for the industrial scale plant. These are improved combustion efficiency, improved sulfur capture, and elimination of a carbon burn-up cell. A test program was undertaken to operate the Alexandria PDU utilizing this combustion enhancement technique. Objectives of the program were to:

- Operate the PDU with total recycle from the mechanical collector.
- Develop a flyash reinjection system that met process requirements and was energy efficient.

The development program was conducted using primarily Grove limestone, since this sorbent was selected for the Georgetown AFBB. Eductors were selected for the reinjection study due to their low cost, commercial availability, and their application at Georgetown. The use of eductors for injecting flyash into the Rivesville carbon burn-up cell was also being attempted and provided further impetus to the development effort.

Laboratory experience in flyash handling and previously developed design data for coal feed eductors, using low pressure air (less than 15 psig) as a motive force, was the starting point for the development program. Although eductors have been commonly used at the Alexandria lab to pneumatically transport solids in positive pressure systems, selection of an eductor to feed flyash has always been difficult. Since the minimum fluidization velocity of flyash is less than .1 feet per second, blow back of pneumatic transport air into the solids inlet region can result in aeration and suspension of solids and drop-off of flyash feed rates. This application becomes more difficult when feeding flyash into the bottom of a fluidized bed because of the backpressure of the bed.

Feeding out of a dust collector at negative draft also adds to the difficulty. The eductor must overcome the total operating pressure difference between the flyash collector and the bed as it feeds solids. This is accomplished by accelerating the transport air through a converging nozzle which creates a high velocity jet and a reduced pressure at the solids inlet region to induce solids into the transport air.

In the design of an eductor for total recycle, additional problems arise from the following:

- The required flyash feed rate is unknown until the combustion system is tested.
- The air to solids ratio of the eductor can influence carbon burnup.
- The velocity at the feed point can disturb the fluidized bed.
- The hot flyash heats the transport air increasing the velocity through the eductor.

Thus the development effort on hardware can only be evaluated by total system performance.

Based on previous work for coal feed eductors, an eductor was designed and tested reinjecting flyash into the PDU. The results of the initial tests indicated the need for a simultaneous hardware and process development effort consisting of both cold tests and hot tests on progressive system modifications. The first portion of the test program was conducted using a single flyash reinjection point to feed the nine square foot cross section PDU in the following sequence:

- a. Tests on a converging nozzle eductor with and without solids flow.
- b. Tests on a converging nozzle eductor using a pressure recovery section with and without solids flow.
- c. Tests on a converging nozzle eductor with a pressure recovery section using a higher pressure blower with and without solids.

The system used for most of the tests is shown in Exhibit 2.1. The blower for the first tests in the program was a positive displacement rotary blower set up to deliver 67 standard cubic feet per minute of air at up to 8 psig. A simple converging nozzle eductor, Exhibit 2.2, was used to inject the solids into the boiler and the throat diameter of the nozzle was determined using the correlations developed from coal feed eductor testing.

After the tests with the simple converging nozzle, a pressure recovery section was added downstream of the solids inlet to improve performance at the same blower pressure, see Exhibit 2.3. This pressure recovery section (diffuser) was designed as an insert into the feedpipe, which could be adjusted to vary the distance between the solids inlet and diffuser entrance. After the data was collected using the diffuser and compared with the simple nozzle results, the reinjection blower was replaced with a positive displacement rotary blower to provide 90 standard cubic feet per minute of air at pressures up to 14 psig. Once the new blower was installed the eductor/diffuser combination was tested with the same nozzle diameter used in the previous tests, but with blower pressures from 8 psig to 14 psig.

With the successive improvements in eductor performance, hot tests were conducted to evaluate system performance. Performance was measured in terms of maintaining a flyash feed rate with increasing operating bed depths. When the eductor performance was sufficiently improved to maintain flyash feed into the desired PDU operating bed depth (about 24 inches static equivalent), the development effort was directed toward increased flyash feed rates and increased combustion of the flyash.

The first attempts to increase feed rate and combustion involved varying the air-to-fuel ratio in the eductor. This was followed by installing a splitter and dual eductors to feed two points in the bed, Exhibit 2.4. The air-to-fuel ratio was varied by increasing the nozzle diameter on the eductor between tests and by changing the blower pressure for the supply air during tests. Varying the blower pressure from 6 to 14 psig resulted in a change of the air-to-fuel ratio by a factor of 1.5. Combined changes in nozzle diameters and blower pressures resulted in a factor of 2.5 change in air-to-fuel ratio. Once a change was made in the nozzle, hot and cold tests were run at different back pressures to determine how much material could be injected. Then using this data a new design correlation was developed.

The reinjection tests are summarized in Exhibit 2.5. Many of these tests served several purposes. When baghouse testing or limestone testing was conducted, flyash reinjection testing was given second priority in terms of test objectives and data collection.

The data collected during the reinjection tests included:

- Solids inlet pressure and temperature
- Eductor air inlet pressure and temperature.
- Diffuser outlet temperature, back pressure on the system.

- The flyash and transport air feed rates.

There was a significant difference in the results of the solids flow and non-solids flow tests with and without the pressure recovery section (diffuser). When the simple nozzle was used, minus 21 inches w.c. pressure could be developed at the solids inlet as it fed against atmospheric pressure. The same nozzle tested with solids flow could only develop minus 15 inches w.c. pressure, again feeding against atmospheric pressure. Five inches of pressure were lost with solids flow due to the solids transport energy losses. Although the increase in pressure at the solids pick-up was linear with respect to increasing back pressure for both solids and non-solids tests, the difference between the two did not remain constant due to the decrease in solids feed rate. As the back pressure on the system increased, blow back of transport air into the solids pick-up region increased resulting in solids suspension and reduced feed rates. When the tests on the simple nozzle were completed, the diffuser section was added. When the eductor/diffuser combination was used, minus 36 inches w.c. of pressure was developed feeding against atmospheric pressure. This was more efficient than the simple nozzle using the same blower pressure, and the difference between the simple nozzle and the eductor diffuser nozzle remained constant at 15 inches w.c. at all blower pressures.

Problems with using the solids inlet pressure as the only indicator of the efficiency of the reinjection system became apparent when the eductor/diffuser combination was tested with solids. The nozzle/diffuser combination fed a great deal more flyash than the simple nozzle. Because more flyash was being fed through a reduced area in the diffuser the acceleration and friction energy losses increased, resulting in large fluctuations in the solids inlet pressure. With the nozzle/diffuser combination the solids inlet pressure no longer was a function of the solids feed rate. Initially as the back pressure on the eductor/diffuser combination increased, the solids inlet pressure increased which resulted in lower flyash feed rates. However, when the back pressure was increased to 6 in. w.c., the solids inlet pressure leveled off at minus 2 in. w.c. (the dust collector negative draft) and remained at this pressure for subsequent increases in the back pressure. Pressure drop in the nozzle was below the critical pressure ratio and hence leveling of the solids inlet pressure was not influenced by approach to sonic velocity. Similarly, the solids feed rates decreased until the back pressure increased to 6 in. w.c. At this back pressure the solids feed rates leveled off and remained essentially constant for all other changes in back pressure.

Using the eductor/diffuser combination flyash could be fed into the PDU over the range of operating bed depth, but because of the low feed rates, total recycle could not be achieved.

Therefore, further changes were made to the system to improve the recycle rate.

In order to determine how much of an increase in recycle was needed, an accurate method to determine flyash feed rates had to be developed. Since the direct measurement of hot solids flow in pneumatic transport is difficult, a means to measure the feed rate was developed before the solids entered the air stream. A 4 inch diameter Pyrex spool piece was installed under the main dust collector and above the flyash eductor nozzle, Exhibit 2.2. During a data collection period, the time for a known volume of solids to drain was measured. Combining the measured solids velocity with a measured bulk density a mass flow could be calculated. The accuracy of this technique was dependent on the bulk density since the solids must be removed from the flowing stream for measurement. The actual density of the flowing stream may be slightly lower than the measured density but the range of density variation could be determined. The mass velocity measurement technique was calibrated by measuring the time a known weight of material was injected against a set back pressure. This result was then compared to mass velocity measurements at ambient conditions against the same back pressure. The results of the eductor development work are shown in Exhibit 2.6.

During the development effort on the eductor an erosion problem was encountered in the eductor diffuser and reinjection piping. Because of the abrasive nature of the flyash and the high velocity in the eductor, erosion was expected. The erosion pattern in the diffuser was not uniform, however. Inspection showed that wear was occurring primarily at the two o'clock position on the circumference of the diffuser converging section. It was assumed that the flyash was concentrating on the upper portion of the transport air stream. This wear problem was significant even in the short test program because wear in the diffuser reduced the effectiveness of the eductor. Heat treating the diffuser sections of the eductors for hardness was a sufficient solution of the problem for the test program.

During all the flyash reinjection tests there was no significant improvement in combustion efficiency over typical non-reinjection test results. The primary reason for this performance was thought to be insufficient residence time of the flyash in the bed, and of secondary importance was the high limestone attrition rates associated with Grove limestone.

Because of the configuration of the combustor the residence time of the flyash is calculated to be about .7 seconds. Based on an earlier combustion model the flyash at a minimum mean particle diameter of 100 microns requires 1.0 second to burn to completion after reaching the ignition point. If the flyash was channeling through the bed in the bubble phase

of the transport air, it may never have reached ignition temperature. Therefore, the flyash residence time at a combustion temperature was probably insufficient. Flyash recycle then creates a heat load on the combustor which draws heat away from the bed. This problem is compounded by excessive attrition of limestone because of the quantity of noncombustible material which has to cycle through the reinjection loop. More heat is then required to heat the recycle stream to a combustion temperature which results in lower stack oxygen concentrations at a given superficial velocity and bed temperature.

As previously noted, Grove limestone was used in most of the flyash reinjection tests because it was selected for use at Georgetown. This limestone has been found to be less attrition resistant than most other limestones used in the PDU. Because of the higher attrition rates, the heat load of the reinjection stream can become detrimental to combustion efficiency.

Several feeders were tried on the PDU to improve combustion. The first was a single feeder similar in design to the coal feed needle but injected flyash parallel to the top of the air distributor. This feed arrangement did not enhance combustion because at the higher feed rates the bed temperature near the in-bed feed point dropped 150°F. This was believed to be due to the large sensible heat losses incurred when the flyash was heated from 300°F, the equilibrium transport temperature, to bed temperature. A double feeder arrangement shown in Exhibit 4 was also tested. This double feeder reduced the sensible heat loss effect by splitting the solids flow, but did not appear to improve combustion. The next design used the double feeder with a cap at the end, (see Exhibit 2.7) to create a downward flow of flyash in an effort to increase residence time. This appeared to be the most successful design but only qualitative data was obtained in the remaining available test program duration.

Exhibit 2.8 shows a plot of the sulfur capture as a function of Ca/S mole feed ratios. Included in the figure for comparison are points obtained using Greer limestone in the FBC and PDU, points using Lowellville limestone in the PDU and some Grove limestone test points obtained while attempting to simulate the Georgetown plant operation with flyash reinjection. A comparison of these different limestone tests shows that while both Greer and Lowellville perform nearly the same at a Ca/S ratio near 2.0, the Grove limestone with reinjection appears more reactive. As the Ca/S ratio increases the Greer and Lowellville stones appear more efficient.

Sulfur capture is improved by flyash reinjection because the concentration of -40 mesh bed material is increased. Normally, in a once through system this material would be elutriated and discarded after one pass, usually after only

a fraction of the calcium is utilized. Since sulfur capture is a surface reaction with limestone, particles with a high surface area to volume ratio have a greater utilization. Thus, the -40 mesh material recycled through the PDU would increase the rate of capture even at low Ca/S mole ratios.

However, as the Ca/S mole ratio increased more heat was required as coal feed to offset the sensible losses of the recycle solids. In this case the sulfur in the additional fuel may offset the sulfur capture gained by reinjection.

To feed flyash into a fluidized bed, an eductor must develop a low pressure region at the flyash pickup point and have sufficient pressure recovery to overcome the acceleration losses, friction losses, and bed backpressure. Test results showed that the minimum blower pressure adequate to feed into a two foot equivalent static bed depth with a near optimal eductor design was about 12 psig. This can represent a significant horsepower consumption depending on the pounds of eductor air per pound of flyash required for satisfactory combustion. An estimate of this requirement is from one third to one half of the fluidizing air horsepower.

To operate with total flyash recycle, burnup of the carbon or size degradation is required to prevent the recycle stream from becoming too great. With too high a recycle rate, such as with excessive limestone elutriation, the recycle stream can cause adverse effects on bed combustion performance although sulfur capture may be improved. For example, a large quantity of recycle solids injected at a single point can cause a bed temperature drop at that point and hinder carbon burnout. Such a problem was suspected in the PDU from bed temperature readings. When residence time is limited by in-bed cooling surface and a short freeboard, combustion efficiency may not be enhanced by total recycle. This appeared to be the experience in the PDU. To improve combustion efficiency using total flyash recycle, the particle size and resulting recycle quantity should be controlled. This means that dust collector performance for the recycle stream should be integrated in the process design and that flexibility for collecting and reinjecting flyash should be included in the plant design.

Recommendations from this test program include:

1. Additional studies of combined coal and flyash firing to develop performance predictions.
2. Flexibility in design of recycle systems (such as slip streams to disposal of recycle points) to regulate the recycle rate, collectors with changeable efficiency, and alternative recycle streams such as from mechanical or baghouse collectors.
3. Development of low energy flyash reinjection methods suited to the process performance.

Control of particulate emissions from coal fired fluidized bed combustion (FBC) units will be a significant factor in future selection and public acceptability of such plants. The particulate emission limit initially set by the EPA, under provisions of the Clean Air Act of 1970, for large, new coal fired boilers was 0.10 lbs/10⁶ BTU. However, under the Clean Air Act of 1977, EPA promulgated on July 11, 1979, (Federal Register, Vol. 44, Page 33581) a new source performance standard for particulates of 0.03 lbs/10⁶ BTU. These more stringent particulate emission limitations will have a definite impact on the economics and design of future FBC units.

The two primary methods for stack gas particulate removal for FBC systems are fabric filtration and electrostatic precipitators. For many years, electrostatic precipitators have been the dominant particulate collection device because of their relatively low capital and operating costs. However, increasingly stringent emission standards have increased the cost of precipitators sufficiently for fabric filter technology to become a competitive alternative. Although fabric filter performance is generally independent of the quantity, temperature, and chemical composition of the flue gas, blinding can be a problem in high dew point flue gas filtration. Since the fabric filter collects sub-micron particles more effectively than the precipitator, lower stack opacities can be expected for a baghouse installation.

The purpose of this test program was to evaluate the application of a baghouse to an FBC system and provide data to be used in future fabric filter designs. The goals of the program were:

- Determine mass collection efficiencies of baghouse.
- Determine outlet emissions in terms of lbs particulate/10⁶ BTU fired as compared with the New Source Performance Standard of 0.03 lbs/10⁶ BTU.
- Determine bag ΔP and other operating characteristics of the baghouse through data and observation.
- Compare baghouse performance in several cleaning modes and at several filtration ratios.
- Evaluate operational problems in the use of fabric filters as final dust collection systems on FBC units.

The flue gas baghouse test unit was designed and furnished by Buell Emission Control Division, Envirotech Corporation. The baghouse was located downstream of the existing primary induced draft fan and had its own I. D. fan and stack, Exhibit 2.9. Basically, the baghouse consisted of a single 9'L x 5'W x 35'H bag compartment with 60° pyramidal hopper as a stationary base with two interchangeable air casing tops. In this way the three major types of baghouse cleaning modes could be tested:

- High energy cleaning with compressed air (pulse jet).
- Shaker cleaning by mechanical agitation.
- Reverse air cleaning by reverse flexing of bags.

One top, consisting of a shaker motor and assembly, was used to evaluate the reverse air and shake cleaning modes separately and in combination. Thirty-two 8" O.D. x 23' bags were clamped over thimbles on a four bag reach tube sheet inserted between the bag compartment and hopper, see Exhibit 2.10. The bags were then suspended from a shaker mechanism near the roof line and tensioned with a spring loading mechanism for support and to prevent collapse during reverse air cleaning. Bag specifications are given in Exhibit 2.11. Filtration was from the inside outward, i.e., dust laden gas entered below the tube sheet and passed up the inside of the bags. Cleaning was accomplished by gently shaking the formed filter cake from the bags into the disposal hopper. In the reverse air mode filtration remained the same while cleaning was accomplished by isolating the compartment from operation and reversing the air flow through the bags. To obtain hot gas for reverse air flow, three-way poppet valves were arranged as shown in Exhibit 2.12 to pressurize the clean side of the bags by a reverse gas loop tied into the discharge side of the I. D. fan taking air from the dirty side of the bags.

A cleaning cycle consisted of four timed intervals:

- 1) Bypass to atmosphere to isolate the cell
- 2) Reverse air bag flexing
- 3) Bag shaking
- 4) Dust settlement period

The duration of each of these intervals was variable from 0 to 120 seconds. In a reverse air only cleaning mode (no shake) the shake period becomes a settling time and likewise in a shake only mode the reverse air becomes a settling period.

The second top, for pulse jet cleaning, consists of control solenoids, air manifold and compressed air piping, Exhibit 2.13.

In this configuration the lower tube sheet from the shake mode was removed and replaced by a roof level support frame.

Sixty-six bags, 6"O.D. x 10', were pulled over metal cage support liners and top loaded through the support frame forming an air tight seal. Air headers extend from the manifold above the six rows of bags with a small orifice located above each bag, see Section A-A of Exhibit 2.13. Filtration was from the outside inward. Cleaning was accomplished with 100 psig compressed air. A blast of air was directed along the air header through the orifice above each bag creating a shock wave down the bag to release the filter cake. Duration of the air blast was set at 22 milliseconds. Provisions were made during installation to allow continuous or off-line cleaning. Controls allow both selection of the time between cleaning as well as the duration of the cleaning air pulse.

During baghouse operation the following instrumentation was monitored for data collection:

- 1) Pressure gages on the high and low side of baghouse fan.
- 2) Differential pressure gages measuring pressure drop across bags.
- 3) Thermocouples in the inlet and outlet flue gas streams.
- 4) Lear-Siegler model RM-41 transmissometer for measuring optical density of gas outlet steam.

Particulate sampling of baghouse inlet and outlet dust loading was conducted using a Rader high volume isokinetic flue gas sampler.

Initially, the shaker top was installed to allow testing in the shake only, reverse air only and reverse air with shake cleaning modes. However, after six tests comprising more than 235 hours of operation, the baghouse outlet emissions had been equal to or under the new source performance standard of 0.03 lbs particulate/10⁶ BTU in only four of thirty-five sample periods. Additionally, the 99.6% mass collection efficiency expected by the manufacturer was seldomly met. Excessive pressure drop readings across the bags were also experienced. For example, bag ΔP values rose in excess of 8" W.C. within 30 minutes of filtration during some tests.

The cause of these operational problems was a result of the reverse air cleaning phase of the operation. The test unit being a single compartment design used hot gas from the dirty side for reverse air cleaning. A conventional multicompartmental

design isolates the cell to be cleaned and draws hot gases from the clean side of an operating cell for reverse air flexing of the bags in the isolated cell. Limitations of the test unit design thus led to several adverse effects on performance.

First, and most detrimental, was that a substantial dust cake was found on the outside or clean side of the bags. This additional resistance caused excessive bag ΔP values when acting in series with the inside filter cake formed during normal filtration. Additionally, this outside filter cake, which would be subject to reverse air flow during normal filtration operation was subject to removal from the bags to the clean side gas stream. Since the time of formation of the dust cake on the clean side was unknown, pressure drop results for this operating mode were not valid and not reported.

Secondly, the dust blown to the clean air side during reverse air flow that did not collect on the bags accumulated on either the tube sheet around the outside of the bags or remained suspended in the air. These conclusions were supported by the following observations. In going from a reverse air cleaning period to a gas filtration period, an obvious heavy dust plume exited the baghouse outlet stack for approximately 15 seconds indicating that the clean air side of the bags was being purged. On two occasions during extended run times dust accumulated on the tube sheet as much as 8" deep and was found to be smoldering a few days after the unit was shut down. This was believed to be the result of hydration of the calcium oxide in the flyash with moisture in the air, an exothermic reaction. This heated the surrounding flyash to the point where combustion of the carbon soot could begin. Although temperatures as high as 700°F were recorded with a thermocouple, no bags were damaged since the excessive temperatures were confined to the walkway area of the tube sheet.

Testing in the reverse air mode and reverse air combined with shake was therefore abandoned in favor of a shake only test program. With this revised plan, all reverse air bags were removed and replaced with new bags designed for shake only cleaning. Prior to any testing these bags were precoated with minus 200 mesh limestone as prescribed by the manufacturer. All internals were cleaned of dust accumulated during reverse air testing and a blind flange was installed to prevent dirty gas leakage through the reverse air poppet valve.

A total of seven tests totaling 254 hours of operation were run at two air-to-cloth (a/c) ratios and data collected during thirty-four baghouse outlet sampling periods. One test was not completed due to instrumentation problems. A summary of the completed baghouse tests is given in Exhibit 2.14. Tests 704-24 and 704-25 were run with all bags installed to give an a/c of 2.5 ACFM/ft². Tests 704-28 through 704-31 were conducted at an a/c of 4.0 ACFM/ft². Tests 704-28 through 704-31 were conducted at an a/c of 4.0 ACFM/ft² by removing 11 bags or 528 square feet. Air flow rates were measured with

a pitot tube concurrently with baghouse inlet and outlet isokinetic sampling and confirmed by mass balances on flue gas flow into and out of the baghouse.

Conditions for Tests 704-24 and 704-25 were such that the 500°F inlet gas to the baghouse resulted in an a/c of 2.5 ACFM/ft². Exhibit 2.15 gives a typical chemical analysis of the dust collected by the baghouse during operation. Exhibit 2.16 shows the range of flue gas compositions seen by the baghouse from the worst conditions during lightoff to the better conditions seen during steady state boiler operation. Because of the experimental nature of the boiler, the baghouse went through numerous lightoff cycles therefore passing through the acid dewpoint frequently.

Baghouse performance results for the shake only mode at an a/c of 2.5 ACFM/ft² are summarized in Exhibits 2.17 and 2.18. The mass collection efficiencies were 99.7% or better in all cases. However, since mass collection efficiency is dependent on the inlet dust loading, the more significant value is the lbs particulate/10⁶ BTU as compared to the 0.03 new source standard. The data shows that the baghouse emissions were below the standard in all cases. These outlet values remained nearly constant despite the high inlet values of about 3 gr/SCF and its increase in some cases to more than 6.0 gr/SCF.

The same summary of results for baghouse performance at an a/c ratio of 4.0 ACFM/ft² in the shake only mode is shown in Exhibits 2.19-2.21. Again, mass collection efficiencies were 99.7% or better while the lbs particulate/10⁶ BTU values met or fell below the 0.03 performance standard. Noteworthy is the fact that the emissions remained below performance standards despite inlet dust loads of greater than 17 gr/SCF, far more than would even be seen in normal industrial use.

In addition to particulate emissions and collection the baghouse was tested for bag ΔP values. From the theory of fabric filtration, the pressure drop across a bag is the sum of two individual drops taken in series, that due to the fabric and that due to the collected dust cake. The filter cloth pressure drop should essentially be a constant for a given cloth material. Consequently, the over-all pressure drop depends primarily on the ΔP across the filter cake as the particulate layer is deposited. Exhibit 2.22 is a typical plot of bag ΔP vs. time from a shake only test following a cleaning cycle. Note that the curve has three basic regions. Region A is the residual ΔP area where the part of the filter cake not removed by cleaning causes the near instantaneous rise. Region B represents the short time period where the forming dust layer is fairly irregular and the resistance to flow increases rapidly until non-homogeneous regions in the dust layer are filled. From then on the bag ΔP varies linearly with time as shown in Region C. The point of demarcation between Region A and Region B as determined by the departure of Region B from the extrapolation of Region A is known as the clean bag

ΔP value. Bag ΔP vs. time, of course, did vary with inlet dust loading. Typically, however, the clean bag ΔP seen at an a/c of 2.5 was 2.3" w.c. with a value of approximately 4.8" w.c. seen after nearly 60 mins. of filtering. At an a/c of 4.0 the clean bag ΔP rose to about 5.4" w.c. with a value of approximately 4.8" w.c. seen after nearly 60 mins. of filtering. At an a/c of 4.0 the clean bag ΔP rose to about 5.4" w.c. with a value of nearly 8.0" w.c. seen after only 30 mins. Thus, considering the relationship between bag ΔP and a/c ratio by ignoring other conditions which may have varied, the clean bag ΔP varied nearly as the square of the a/c ratio. At the higher a/c ratio, then, baghouse collection efficiency and emission performance remained nearly constant while the time between clean cycles needed to stay below 8" w.c. bag ΔP was reduced by nearly a factor of 4.

Following shake mode testing the pulse jet top was installed and all necessary modifications needed to carry out testing completed. Preliminary filtration testing gave results below expectations. Typically, when brought on line the baghouse performed well with an exit plume of low opacity. However, when on line continuous cleaning was started at a bag ΔP of 6" w.c. visible plumes appeared following the cleaning of each row of bags. Further, after all six rows of bags had cycled the bag ΔP fell to 1.5" w.c. while the stack plume remained readily visible. As the bag ΔP began its rise again, the visible plume decreased with increasing bag ΔP . The plume then reappeared during and following the ensuing pulse cleaning of the bags.

The bags were removed and examined after shutdown. Small pinsized holes were found in a number of bags. Bags with several holes were replaced with new bags such that all on site replacement bags were used. The bags were then reinstalled and their seal to the tube sheet carefully checked. The unit was again operated several days later and the baghouse brought on line. The result was exactly the same as the previous run.

Following this second and a third run with poor baghouse emission performance several bag manufacturers were contacted. The application of the fabric being utilized was thus questioned. Filter fabrics may be felted or woven. Felted fabrics are composed of fibers that are compressed under high pressure and are relatively thick. Thickness of felt provides for maximum dust impingement and greater bag durability. Woven fabrics are composed of twisted yarns that are woven into geometric patterns having various spacings between the yarns, and with specific surface finish that is designed to shed a filter cake. In the pulse jet mode felted bags are generally recommended due to the violent nature of the air pulse and its effect on bag strength and life. Woven fiberglass bags with a 10%

teflon coating were used during this testing due to the desire to operate at baghouse inlet temperatures up to 500°F. At the conclusion of this limited amount of testing the application of woven fiberglass bags with teflon coating for pulse jet cleaning is questionable.

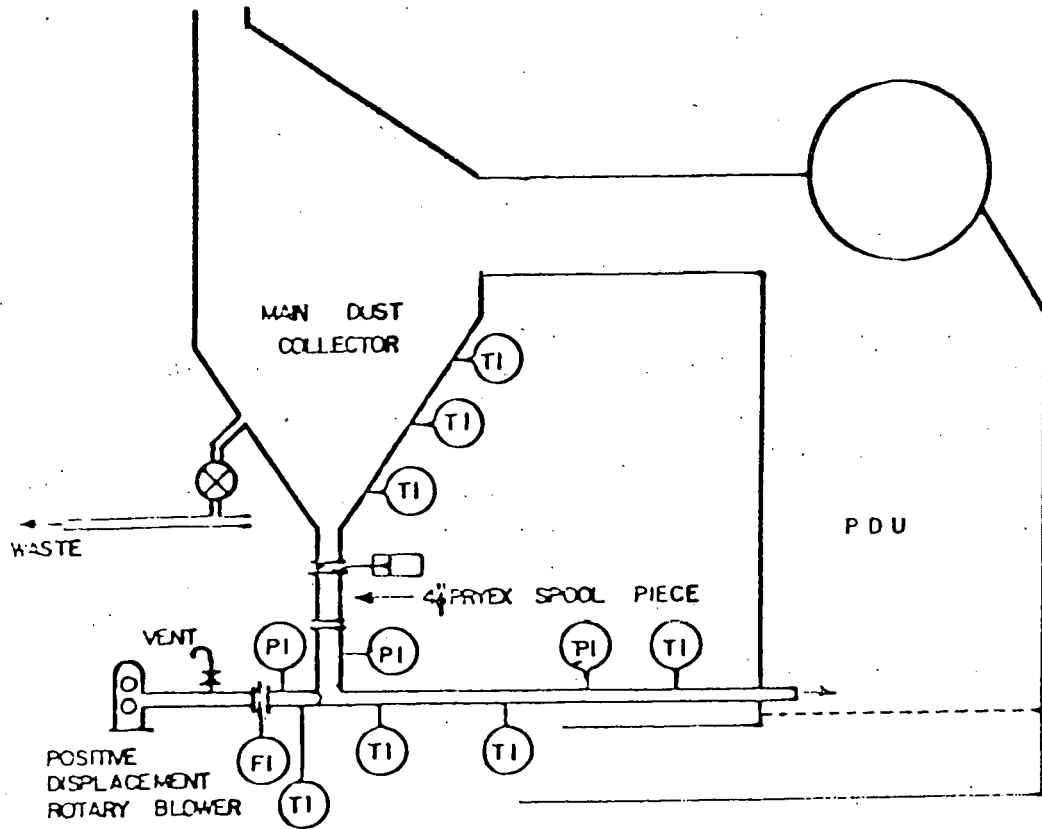
Other difficulties in the test program could also have contributed to poor performance of the baghouse. Installation of the bags and cages from the top of the unit was difficult due to the design of the bag sealing arrangement. It is possible that damage to the bags observed after the initial run was due to the installation difficulty. Alternately, the damage may have been due, to some extent, to the cleaning pulses. The difficulty in installing the bags and cages also suggested that leakage may have occurred around the bag seals.

From this initial testing of fabric filter application to the fluidized bed combustion process the following conclusions are drawn:

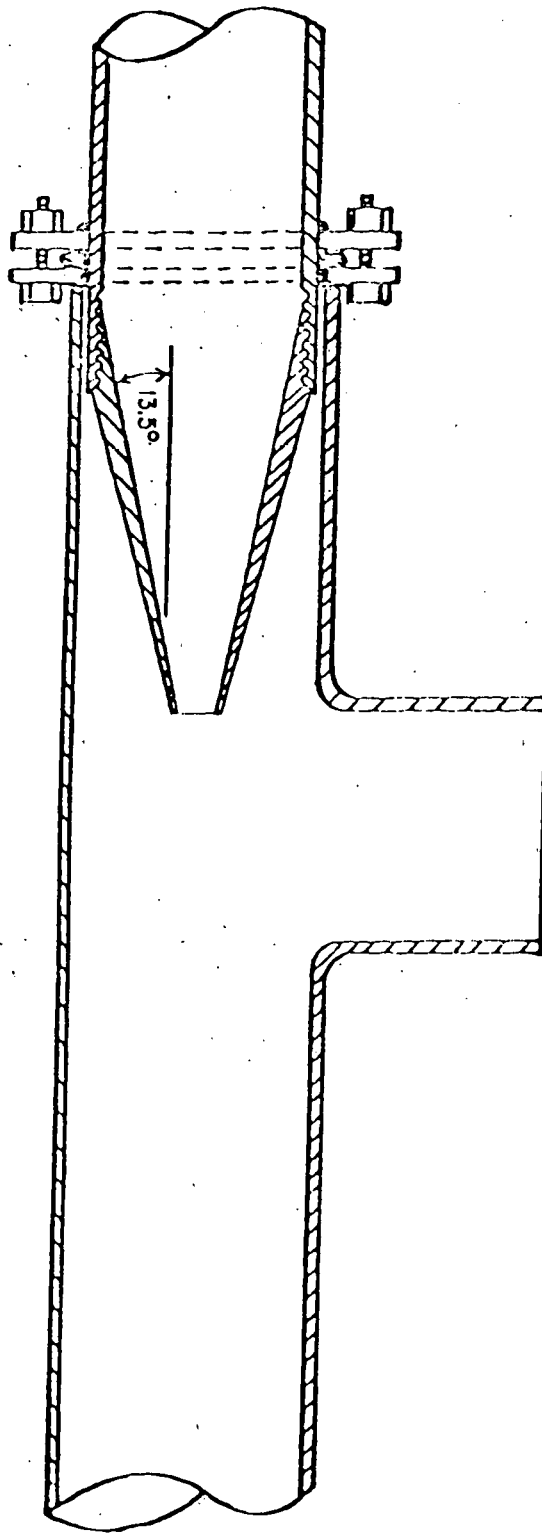
- 1) In the shake only mode the baghouse operated with a mass collection efficiency of 99.7% or better with inlet dust loadings ranging from 2.5 to as great as 17.5 gr/SCF independent of a/c ratio.
- 2) Regardless of variances in a/c ratios or inlet dust loading or chemical composition the baghouse outlet emissions remained constant meeting or surpassing the new EPA source performance standard of 0.03 lbs particulate/10⁶ BTU in every sampling case.
- 3) Although bag ΔP values varied with inlet dust loading, typical bag ΔP values ranged from a starting value of 2.3" w.c. after cleaning to 4.8" w.c. after 60 mins. of filtering at an a/c of 2.5 ACFMft² and from 5.4" w.c. to 8.0" w.c. or more after 30 mins. at an a/c of 4.0.
- 4) Despite the excessive dust loadings and numerous passes through the acid dewpoint during startups the shake only bags performed well. This reflects the care taken to precoat the bags with limestone dust and to minimize the exposure to the acid dewpoint by rapid heat up.

Because of design limitations, no representative testing could be carried out in the reverse air cleaning mode. The pulse jet cleaning mode also presented testing problems. Despite the fact that the pulse jet cleaned the bags well, dropping the bag ΔP from 6" w.c. before cleaning to 1.5" w.c. afterwards, particulate emissions were well above performance standards. This unacceptable performance in the limited pulse jet mode testing was believed due to one or more of the following:

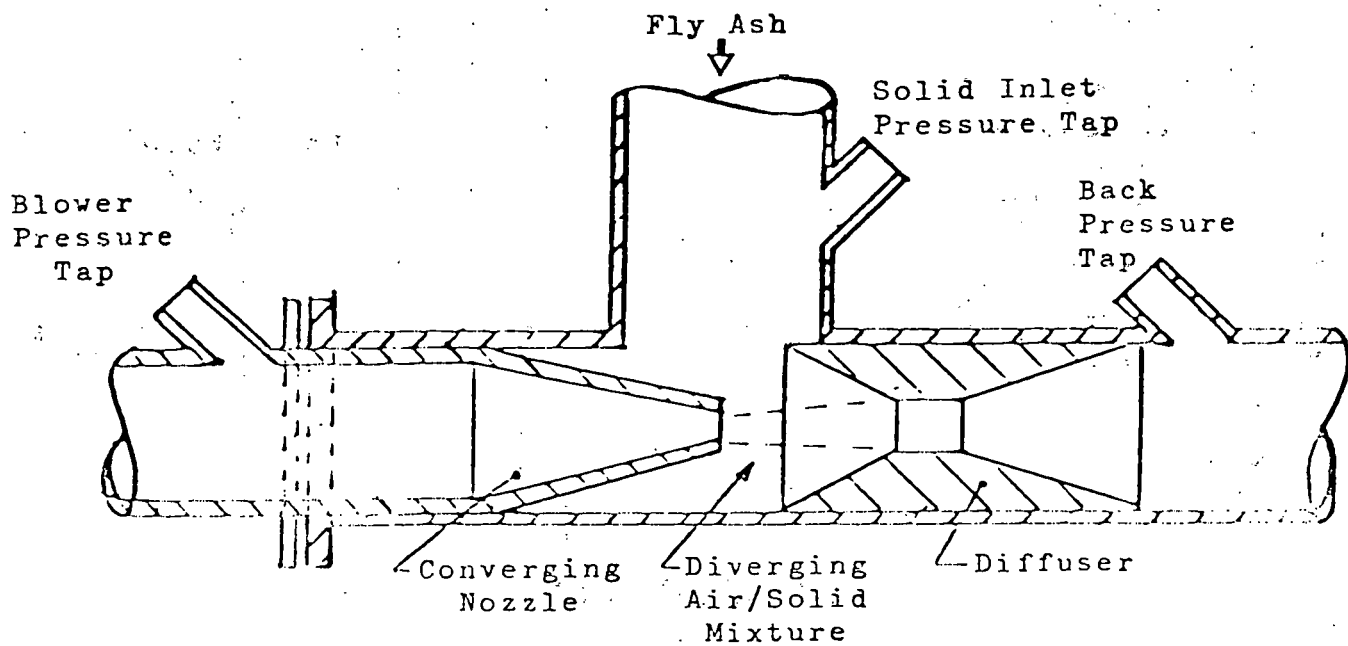
- 1) Fabric not suitable for application.
- 2) Design and/or fabrication of the test unit caused bag damage on installation.
- 3) Design of seals on bags allow leakage of particulate from dirty to clean gas side.



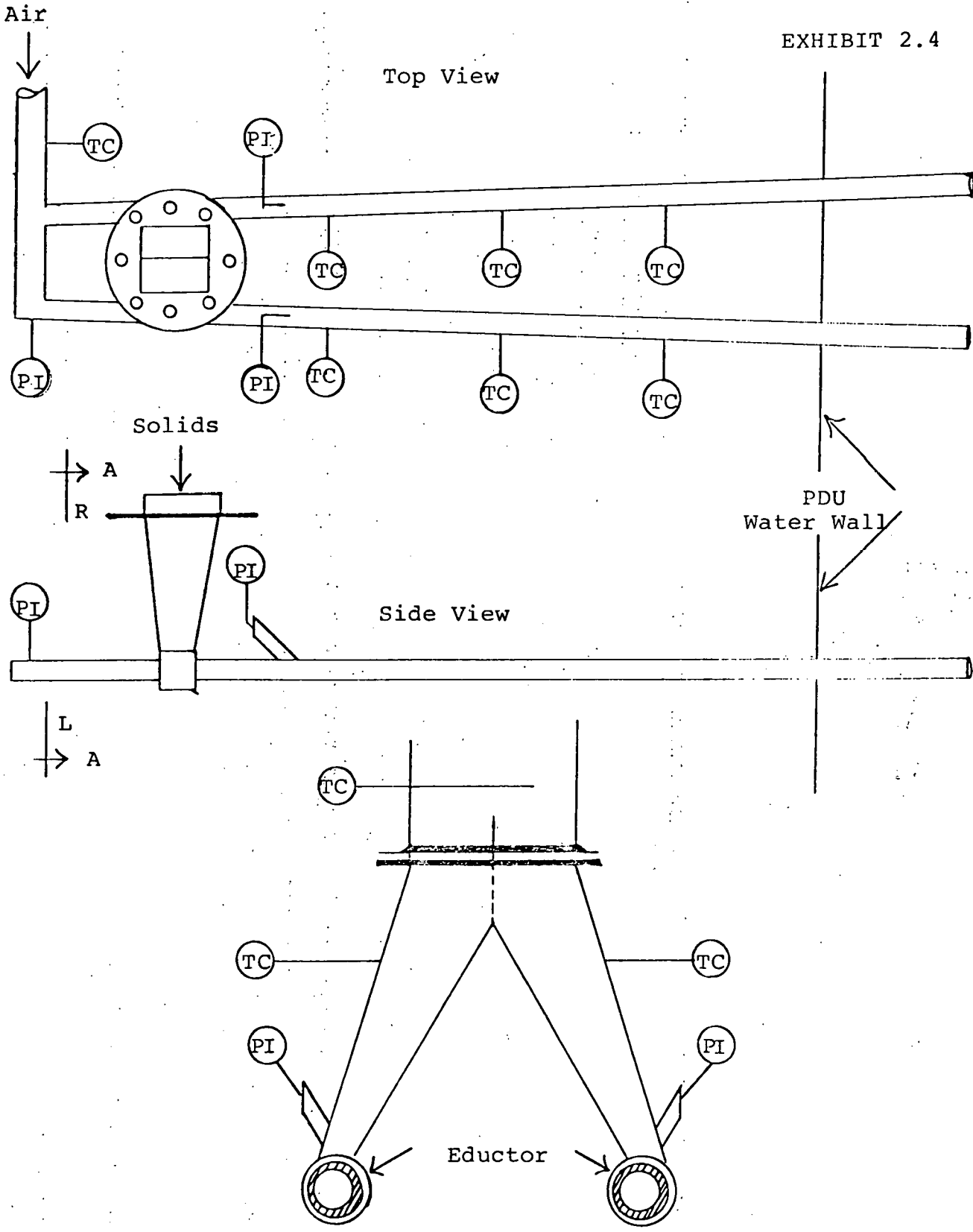
Flyash Eductor Test System



Cross Section of Simple Nozzle Eductor



Eductor with Diffuser



Section A-A
Flyash Splitter With Dual Eductors

SUMMARY OF FLYASH REINJECTION TESTS

<u>Test</u>	<u>Date</u>	<u>Duration</u>	<u>Purpose</u>	<u>Combustion Efficiency</u>	<u>Sulfur Capture</u>
704-3	4/24/79	5.5 hrs	Preliminary reinjection test with a simple nozzle using low sulfur coal and Grove Limestone	-	-
704-4	4/26/79	6.0	Repeat of Test 704-3	-	-
704-5	5/3/79	30	Reinjection test using low sulfur coal and Grove Limestone to determine elutriation rates.	90	78
704-6	5/22/79	20	Repeat of Test 704-5	-	-
704-7	6/1/79	6	Reinjection test using a larger nozzle	-	-
704-8	6/5/79	5.5	Reinjection test with diffuser, high sulfur coal and Grove Limestone for determining elutriation rates	-	-
704-9	6/6/79	8	Reinjection test with diffuser	89	76
704-10	6/18/79	6	Reinjection/baghouse test	81	89
704-11	6/20/79	32	Reinjection/baghouse test with diffuser using Lowellville Limestone	90	84
704-12	6/27/79	56	Reinjection/baghouse test, no diffuser using Lowellville Limestone and high sulfur coal for elutriation rates	89	87
704-14	7/18/79	56	Same as Test 704-12	91	84
704-16	6/8/79	39	Reinjection/baghouse test with diffuser	85	74
709-17	8/14/79	52	Reinjection/baghouse testing with diffuser	82	--
704-18	9/12/79	6	Heat transfer with flyash reinjection	--	--

SUMMARY OF FLYASH REINJECTION TESTS

<u>Test</u>	<u>Date</u>	<u>Duration</u>	<u>Purpose</u>	<u>Combustion Efficiency</u>	<u>Sulfur Capture</u>
704-19	9/20/79	5 hrs	Same as Test 704-18.	--	--
704-20	9/26/79	30	Baghouse testing and reinjection tests with pyrex spool piece Grove Limestone and high sulfur coal	85	78
704-24	10/24/79	56	Reinjection/baghouse test using the double feeder	80	84
704-25	10/31/79	50	Testing with reinjection on and off, baghouse tests	(Reinj.) on 88 off 87	84 86
PDU-7	11/6/79	6	Reinjection shakedown	--	--
704-26	11/8/79	9	Reinjection test run at 1850° bed temperature	96	57
704-27	11/13/79	18	Reinjection rates were measured with several nozzle diameters and blower pressures	--	--
704-28	11/28/79	15	Measure reinjection rates at different blower pressures	89	88
704-29	11/30/79	7.5	Reinjection test with a new nozzle size	--	--
704-30	12/5/79	32	Baghouse/reinjection test	87	82
704-31	12/18/79	33	Baghouse/reinjection test with a new nozzle size	86	88
704-33	2/21/79	6	Reinjection tests with new feeder	--	---
704-34	2/27/79	6	Reinjection test to determine feed rates with new feeder	--	---

TEST DATA ON FLYASH REINJECTION

Nozzle Diameter (in)	Blower Pressure (psig)	Air Flow Rate (#/hr)	Flyash Feed Rate (#/hr) Ambient	Flyash Feed Rate (#/hr) Bed Temperature	Combustion* Efficiency	Sulfur Capture
.265	14	161		660**	88	71
	12.5	155		707**		
	10.0	139		850**		
	8.0	130		942**		
.281	14	202	1895	--	85	85
	12	188	1872	1211**		
	10	175	2347	1015**		
	8	165	1708	984**		
	6	146	1514	--		
.292	14	211	1649	722	88	88
	12	203	1522	641		
	11	197	1596	644		
	10	188	1452	651		
	8	161	1414	635		
	6	112	1292	--		
.297	14	216	1253	795	89	88
	12	210	1115	800		
	11	205	1147	--		
	10	198	1177	825		
	8	183	1186	--		
	6	170	1091	--		

2-22

TEST DATA ON FLYASH REINJECTION

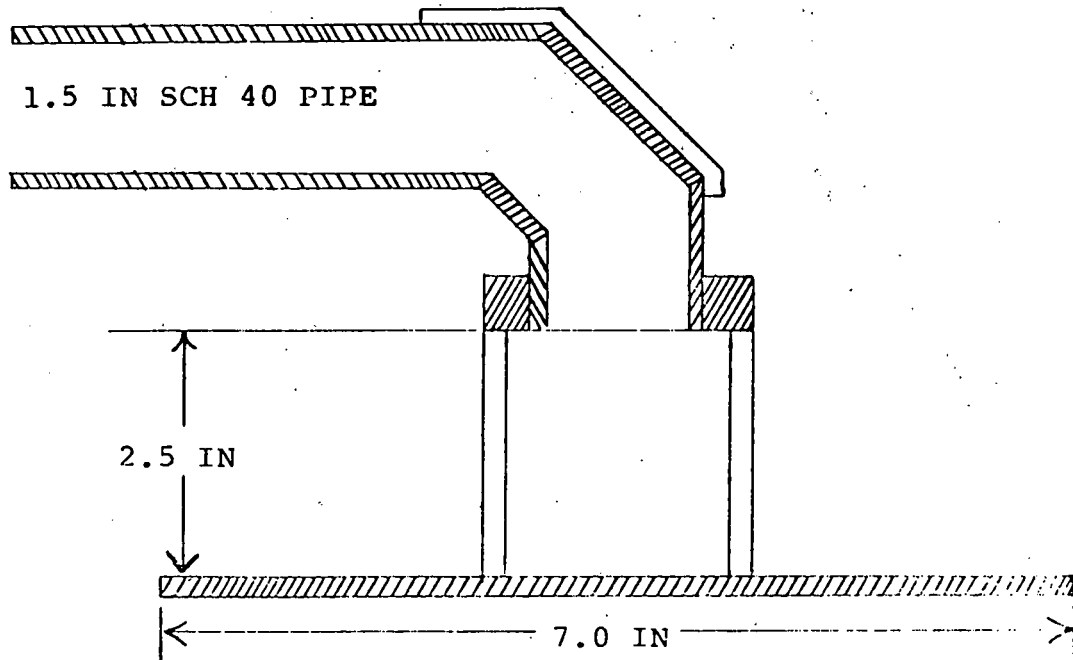
Nozzle Diameter (in)	Blower Pressure (psig)	Air Flow Rate (#/hr)	Flyash Feed Rate (#/hr) Ambient	Flyash Feed Rate (#/hr) Bed Temperature	Combustion* Efficiency	Sulfur Capture
.302	14	220	2200	1274	88	92
	12	206	1862	1224		
	10	201	1766	1187		
	8	186	1700	1112		
	6	175	1625	--		
.3125	14	274	1875	1275	88	
	12	265	1825	1205		

2-23

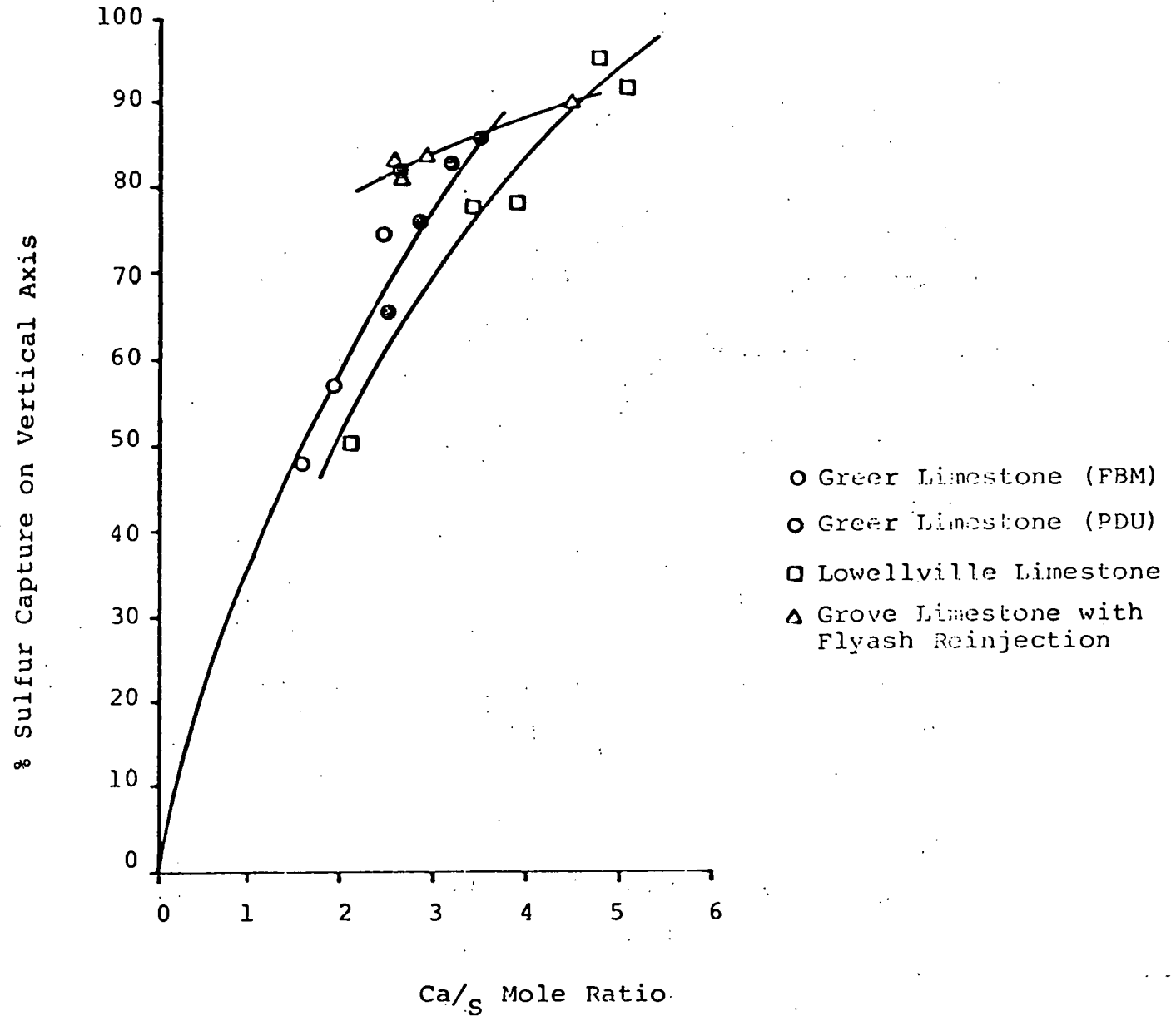
** Due to flow back of transport air into the pyrex spool piece the mass velocity measurements could only be made with the knife gate closed.

- Data could not be taken during test

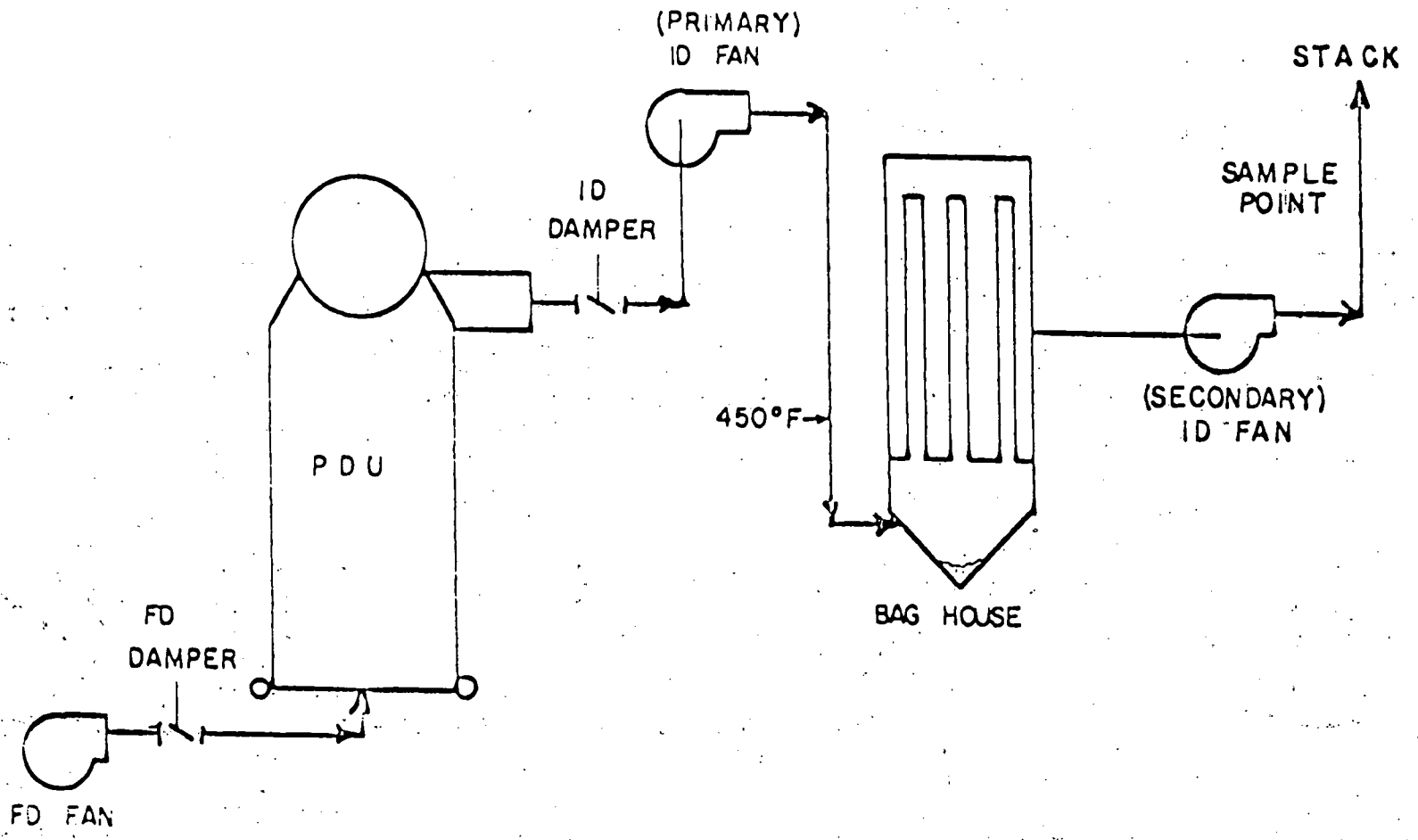
* Average of every test using that nozzle



Flyash Downflow Feeder



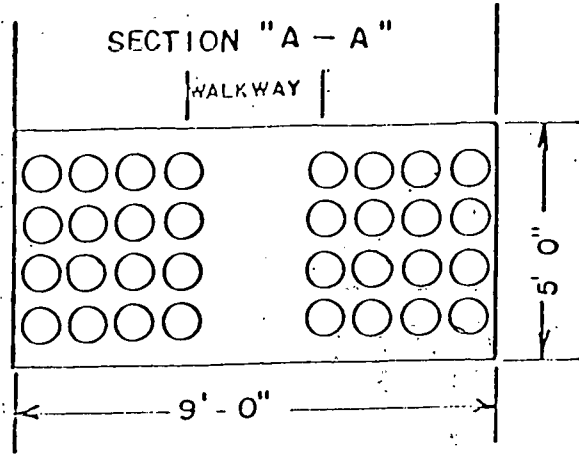
Percent Sulfur Capture Versus Calcium to Sulfur Molar Feed Ratio for Stones Tested



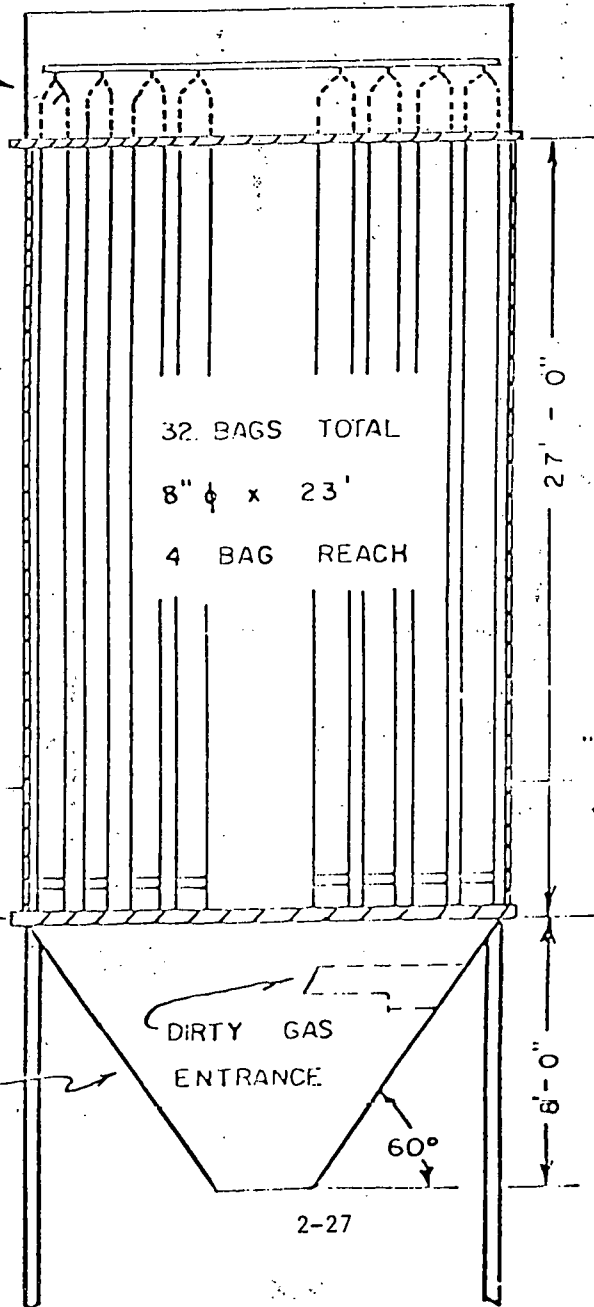
Gas Flow Diagram

SECTION "A - A"

EXHIBIT 2.10



SHAKER TOP



Baghouse Configuration in the Shake Only Clean Mode

TUBE SHEET
w/ THIMBLES

60° PYRAMIDAL
HOPPER

DIRTY GAS
ENTRANCE

2-27

Detailed Specifications of Bags Used in Testing

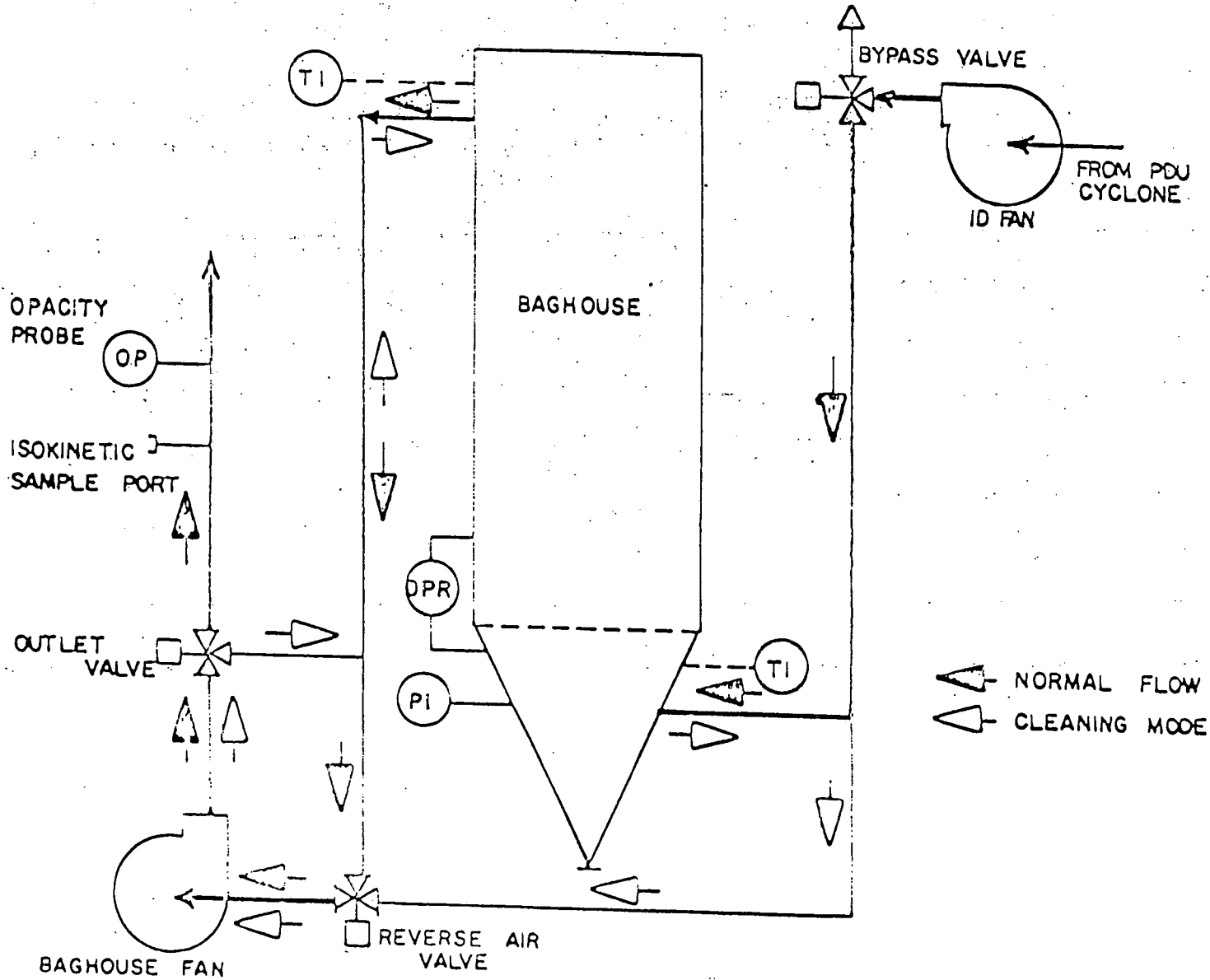
Manufacturer: Norblow Division, Envirotech			
	Pulse Jet	Shaker	Reverse Air
Number	66	32	32
Active Area/Bag	15.7 sq. ft.	48.2 sq. ft	48.2 sq. ft
Fabric	Woven Glass	Woven Glass*	Woven Glass**
Weight	14.5 oz.	10 oz.	10 oz.
Permeability	25-40 FPM @ 0.5" H ₂ O	60-80 FPM @ 0.5" H ₂ O	60 FPM @ 0.5 H ₂ O
Dimensions	6" x 10'	8" x 23"	8" x 23'

* Shaker bags are 9% teflon coated

** Reverse air bags are 9% teflon coated, with 5 rings sewn in

NOTE: For reverse air cleaning the normal flow is reversed as shown by the cleaning mode arrows

For pulse jet cleaning only the normal flow mode is used



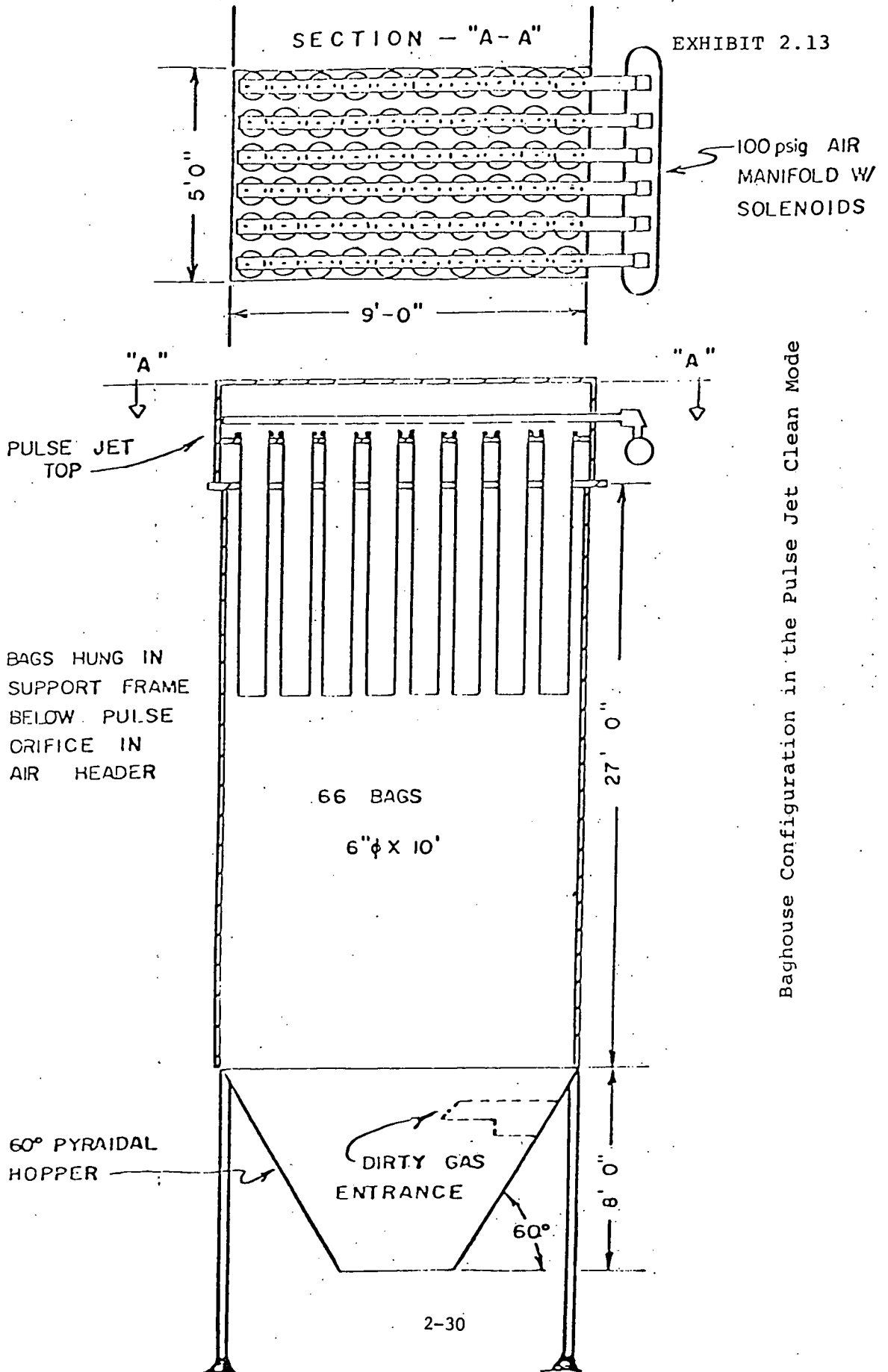
Stack Gas Baghouse Flow Diagram

2-29

EXHIBIT 2.12

SECTION - "A-A"

EXHIBIT 2.13



Baghouse Configuration in the Pulse Jet Clean Mode

Summary of Baghouse Testing
In Shake Only Cleaning Mode
At Alexandria PDU Site

Test	Air-To-Cloth Ratio	Date	Duration
704-24	2.5:1	10/24-26/79	56 hrs.
704-25	2.5:1	10/31/79-11/2/79	50 hrs.
704-28	4.0:1	11/28/79	15 hrs.
704-29	4.0:1	11/30/79	8 hrs.
704-30	4.0:1	12/5-7/79	57 hrs.
704-31	4.0:1	12/18-20/79	57 hrs.
			Total hrs. 243

Typical Composition of Solids
Collected By Baghouse*

Carbon	Hydrogen	Sulfur	Calcium	Ash
18.4	0.4	2.1	20.8	76.2

* % by wt.

Typical Range Flue Gas Composition
Seen by Test Baghouse

Component	Concentration
CO ₂	11-13.7% Vol.
O ₂	3-5% Vol.
NO _x	300-500 ppm
SO ₂	300-1500 ppm
hydrocarbons	20-2000 ppm
CO	500-2500 ppm
H ₂ O	2-6% Vol.

BAGHOUSE PERFORMANCE RESULTS
TEST 704-24

Date/Time	Bag ΔP in. H ₂ O	Inlet Particulate Grains/SCF lb/hr		Outlet Particulate Grains/SCF lb/hr		Col. η	lbs Partic./10 ⁶ BTU
<u>10/24/79+</u> 1530	2.4			.0057	.123	99.9	.012
<u>10/24/79+</u> 1537	2.7	6.01	111.6	.0082	.176	99.8	.018
<u>10/24/79+</u> 1545	3.0			.0082	.176	99.8	.018
<u>10/24/79+</u> 1554	3.3			.0065	.141	99.9	.014
<u>10/24/79+</u> 1602	3.6			.0065	.141	99.7	.017
<u>10/25/79+</u> 1321	2.4			.0106	.211	99.7	.020
<u>10/25/79+</u> 1330	2.7	3.22	64.8	.0124	.246	99.7	.020
<u>10/25/79+</u> 1339	3.0			.0070	.132	99.8	.011
<u>10/25/79++</u> 1530	3.8 to 4.6	3.20	58.0	.0026	.050	99.9	.004
<u>10/25/79+++</u> 1100	1.9 to 3.5	3.45	69.9	.0098	.195	99.7	.016
<u>10/26/79+++</u> 1500	1.9 to 3.0	3.56	73.5	.0023	.044	99.9	.0037
+ Sampled for 5 Minutes		++ Sampled for 30 Minutes		+++ Sampled for 45 Minutes			

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EXHIBIT 2.17

BAGHOUSE PERFORMANCE RESULTS
 TEST 704-25 (10-31--11-2-79)

Date/Time	+ Bag Δ P in. w.c.	Inlet Particulate Grains/SCF lb/hr		Outlet Particulate Grains/SCF lb/hr		Col. %	lbs Partic./10 ⁶ BTU
<u>11/1/79</u> 1000	2.4 to 4.7	5.50	95.1	.0023	.044	99.9	.005
<u>11/1/79</u> 1500	2.4 to 4.8	4.16	77.7	.0080	.154	99.8	.016
<u>11/2/79</u> 0800	2.4 to 4.8	4.02	72.6	.0035	.066	99.9	.006
<u>11/2/79</u> 1125	3.2 to 3.8	2.30	43.7	.0054	.099	99.8	.009

2-35

+ 60 Minute Samples

BAGHOUSE PERFORMANCE RESULTS
 TESTS 704-28 (11-28-79), 704-29 (11-30-79)

Date/Time	Bag Δ P in H ₂ O	Inlet Particulate Grains/SCF lb/hr	Outlet Particulate Grains/SCF lb/hr	Col. %	lbs Partic./10 ⁶ BTU
Test 704-28:					
<u>11/28/79+</u> 0945	5.4"-6.3"	4.10 75	.011 .223	99.7	.021
<u>11/28/79++</u> 1300	5.0"- 8.0"	17.6 325	.018 .342	99.9	.030
Test 704-29:					
<u>11/30/79+</u> 1200	5.8"-7.2"	No inlet tests	.009 .164	----	.017

+ 15 Minutes
 ++ 9 Minutes

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BAGHOUSE PERFORMANCE RESULTS
 TEST 704-30, 12/5-7/1979

Date/Time	Bag ΔP During Sampling "H ₂ O	Inlet Particulate		Outlet Particulate		Mass Collection Efficiency %	lbs Partic./10 ⁶ BTU
		Grains/SCF	lb/hr	Grains/SCF	lb/hr		
<u>12/5/79+</u> 0410	5.4 to 6.7			.010	.094		.010
<u>12/5/79+</u> 0630	5.7 to 6.9			.002	.029		.003
<u>12/5/79+</u> 0745	6.1 to 7.2	3.33	60.2	.002	.044	99.9	.004
<u>12/5/79++</u> 1300	6.4 to 8.0			.015	.281		.028
<u>12/6/79+</u> 1500	4.48 to 8.0	10.16	209.3	.010	.194	99.9	.019
<u>12/6/79+</u> 0250	5.7 to 8.0			.007	.126		.012
<u>12/6/79+</u> 0441	5.4 to 7.8			.004	.073		.007
<u>12/6/79+</u> 0715	5.8 to 8.0	3.77	67.9	.006	.112	99.8	.011
<u>12/6/79+</u> 1330	5.2 to 7.8			.009	.171		.017
<u>12/6/79+</u> 1500	5.3 to 8.0	10.7	196	.014	.261	99.9	.026

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BAGHOUSE PERFORMANCE RESULTS
TEST 704-30, 12/5-7/1979

Date/Time	Bag Δ P	Inlet Particulate		Outlet Particulate		Mass	lbs. Partic./10 ⁶ BTU
	During Sampling "H ₂ O	Grains/SCF	lb/hr	Grains/SCF	lb/hr	Collection Efficiency	
<u>12/7/79+</u> 0230	5.7 to 6.6			.004	.067		.006
<u>12/7/79+</u> 1522	5.4 to 7.8			.005	.082		.007
<u>12/7/79+</u> 0710	5.4 to 8.0	4.34	78.8	.005	.100	99.9	.009

2-38

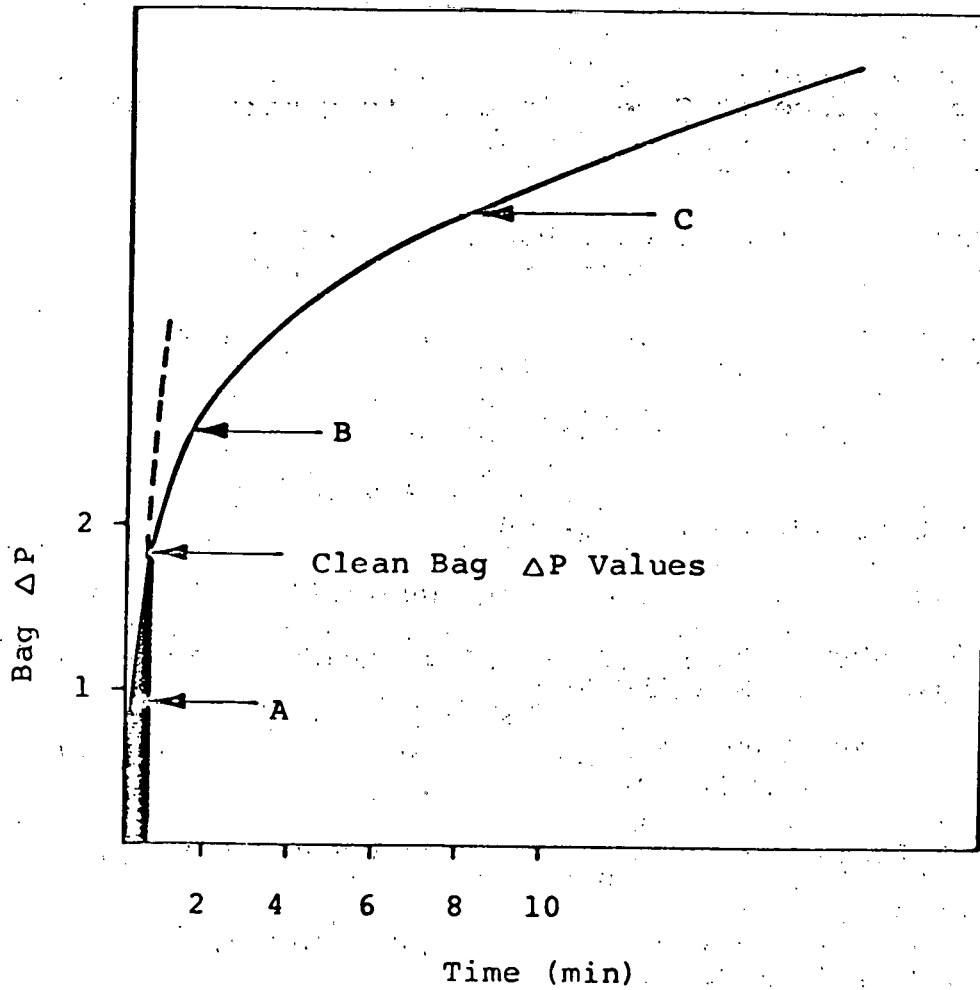
+ 30 Minutes
++ 20 Minutes
+++ 15 Minutes

BAGHOUSE PERFORMANCE RESULTS
 TEST 704-31, 12/18-20/79

Date/Time	Bag Δ P in. w.c.	Inlet Particulate		Outlet Particulate		Col. η	lbs Partic./10 ⁶ BTU
		Grains/SCF	lb/hr	Grains/SCF	lb/hr		
<u>12/18/79+</u> 1510	5.6 to 7.4	5.60	112	.024	.47	99.7	.029
<u>12/19/79+</u> 1000	5.5 to 7.3	5.73	110	.008	.17	99.8	.018
<u>12/19/79++</u> 1330	5.4 to 6.2	6.05	118	.012	.26	99.8	.028

2-39

+ 30 Minutes
 ++ 10 Minutes

Typical Plot of Bag ΔP Versus Time

RIVESVILLE, WEST VIRGINIA, MFB PLANT OPERATIONS

3.1 General

The Multicelled Fluidized Bed Boiler (MFB) facility at Rivesville West Virginia, is a fully operational, commercial fluidized bed boiler. The unit consists of four "cells", A, B, C and D. D cell is the start-up and carbon burnup cell (CBC). Cells A, B and C utilize in-bed and above bed heat transfer surfaces. The in-bed heat transfer surfaces in A and B cells are utilized to produce superheated steam at 1300 psig pressure and 925°F temperature. The in-bed surface of C cell is used to generate saturated steam. The unit is capable of producing 300,000 lb/hr of superheated steam at turbine conditions.

During the reporting period of July 79 to June 80, the activities at the Rivesville MFB were centered around four goals:

- Testing of a new feed system manufactured by the Fuller Company.
- Proving reliable operation of the MFB.
- Testing of flyash reinjection in a carbon burnup cell.
- Improving combustion within the individual cells.

3.2 Summary of Highlights of Period from July 1979 to June 1980

<u>Event</u>	<u>Date</u>
53 hours of continuous commercial operation; the longest to date	July 1979
Performance testing of DC-1	September 1979
Execution of a two cell, Phase I performance test, Pre-test 5	September 1979
Installation of Fuller-Kinyon feed system on C-cell	September - December 1979
Installation of "nut and bolt" air distributor in B and C-cells	September - December 1979
Installation of alternate bed drain valves for B, C and D-cells	September - December 1979
Modification of ESP	December 1979
Distribution tests of the Fuller-Kinyon splitters	December 1979

<u>Event</u>	<u>Date</u>
Testing of pressure drop across new "nut and bolt" gridplate	December 1979
Initial operation with Fuller-Kinyon system	January 1980
132½ hour continuous commercial operation; longest to date	February 1980
Lengthening of fuel feed needles in cells B, C and D	February 1980
200 hours of continuous commercial operation; longest to date	March 1980
Improved performance of the ESP	March 1980
Reduction of Fuller-Kinyon transport and needle velocities	April 1980
Modification of North coal bin to limit amount of fines being fed to C-cell	April 1980
Execution of load following tests	April 1980
Modification of DC-1 cyclone to improve collection efficiency	May 1980
Installation of additional gas traverse ports in cells B, C and D	May 1980
Modification of Fuller-Kinyon system to allow reduced velocity operation	May 1980
Operation and testing of Flyash Reinjection system	June 1980

3.3 Operations

3.3.1 General

A summary of MFB operations is presented in Exhibit 3.1

3.3.2 July 1979

Unit operation in July was intermittent due largely to equipment and control problems.

The unit operation that began on July 3 was aborted due to seal water failure on the west boiler circulating pump. After the seal parts arrived and were installed, the unit was again put into operation on July 6. Late that evening, a capscrew which

had backed out of the west circulating pump jammed between the seating surface of the pump discharge valve. The valve could neither be opened or closed, and this required the unit to be shut down.

On July 11 the unit was back into operation, but was taken out of service on July 13 when the B-cell coal belt feeder would not start.

Problems with B-cell belt feeders continued to plague the unit, until July 17 when stable three-cell operation was sustained and a commercial run began. The commercial operation lasted for 16 hours and ended due to belt feeder problems.

During the period from July 18 to 23, the MFB unit was out of service to conduct necessary equipment repairs.

Operation was reinitiated on July 23 with a coal fire in D-cell. Commercial operation began on July 24 and ended July 26 due to belt feeder problems.

The MFB remained out of service for the remainder of July.

3.3.3 August 1979

Unit start-up was achieved on August 1 with a coal fire in D-cell. Commercial operation began that afternoon but was aborted when the B-cell bed drain rotary feeder broke free of its' supports. The unit was subsequently shutdown.

The unit was again started August 3, but precipitator problems forced another outage which lasted until August 5.

Start-up proceeded smoothly and by August 6, the unit was operating in the three-cell commercial mode in order to conduct excess oxygen/superficial velocity tests.

On August 7, high air preheater gas and air differentials, indicating a plugged preheater, forced the unit out of operation. August 7 was also the day that an initial smoldering problem was observed in coal bunker #2. A fire in the #2 bunker would plague the unit operation for the rest of the month of August.

The air preheater was washed, using the high pressure deluge pump, and subsequently inspected. Unit start-up was delayed until August 10 due to an electrical storm which caused minor damage to the 11 KV transformer which supplies station service power to the MFB.

During the period from August 8-13, several fires were observed and extinguished in the #2 bunker, but the latent heat and noxious

sulfur fumes from the bunker continued indicating a deep smoldering condition still existed.

Unit operation was then executed for the purpose of purging the #2 bunker. On August 14, the unit operation was aborted when smoldering coal burned the D-cell feed belt in half. Attempts at fighting the bunker fire intensified. CO₂, water and attempts at moving the coal were all tried.² The MFB unit operated intermittently during this period under the sole pretense of removing the fouled coal.

By August 20, the bunker fire problem had grown into a major concern requiring the effort of most of the plant personnel. Hot coal bridging in the bins forced the eventual shutdown of the unit on August 21 and the decision was made to manually purge the #2 coal bunker and all bins of coal.

This was accomplished and the unit was out of service for the remainder of August.

3.3.4 September 1979

The MFB unit operation was started on September 5, but quickly aborted due to a tube leak in Monongahela Power's #7 boiler.

Start-up was again initiated on September 7, but plugging problems with coal fines in the vibrating feeder of D-cell forced the unit back out of service. Monongahela Power experienced another tube failure in #7 boiler and the MFB was delayed from operating until September 10.

Start-up proceeded smoothly on September 10 and unit operation continued in order to perform a dust collector performance test. Monongahela Power experienced another tube failure on their #7 boiler and forced the MFB out of service.

On September 17, the MFB unit was again started. The unit was operated in order to conduct a flyash reinjection trial performance. Flyash reinjection was attempted September 18 and sustained for three hours, making this the longest, most successful reinjection attempt to date. Unit operation continued without flyash reinjection until September 19, when another tube leak in the Monongahela Power Company boiler forced the MFB out of service.

On September 24, the MFB officially entered an eight week outage corresponding with the removal of Monongahela Power's #7 boiler from service for an extended overhaul.

3.3.5 October 1979

During the month of October, the Operations Department assisted Maintenance in the performance of clean-up, repair and modifi-

cation tasks pursuant to the accomplishment of the scheduled outage list.

Major tasks include:

1. Installation of new coal feed system (Fuller-Kinyon) to C-cell.
2. Replacement of C and B-cells perforated plate on distributor with "nut and bolt" gridplate.
3. Restoration of boiler bed thermocouples.
4. Installation of main feedwater block valve and flow orifice.
5. Installation of "Kamyr" bed drain valve on C-cell.
6. Repair of precipitator rappers and complete replacement of mild steel emitting wires with stainless steel wire.

3.3.6 November 1979

During the month of November, the Operations Department continued to assist the Maintenance and Construction crews in the performance of clean-up, repair and modification efforts pursuant to the completion of the outage list.

3.3.7 December 1979

Operations performed a hydrostatic test on the boiler in the first week of December and several leaks were detected and repaired.

The outage was officially over on December 7 and preparations were made for complete unit and systems checkout.

Initial start-up occurred on December 13, but had to be aborted when the north start-up burner failed, due to a fractured vaporizer tube.

During the next couple of days while the unit was out of operation, the Fuller-Kinyon feed system was initially operated and debugged. Monongahela Power Company's problems with #7 boiler on December 17 and 18 prevented any operations of the MFB until December 19.

Start-up was attempted on December 19, but failed due to the seizing of one of the boiler circulating pumps. A sleeve bushing in the motor had been installed in an inverted position by Westinghouse. The bushing starved the oiler impeller of lubrication, and this impeller in turn cracked,

causing the pump to seize. Both circulation pump motors were sent to Westinghouse to assess damage and prevent any further occurrence.

By 28 December, the circulating pump motors were installed and back in service, and the unit was prepared for start-up.

On 29 December, the vaporizing tube on the south start-up burner fractured, causing the unit to be taken out of service.

Unit operation was again attempted later on 29 December after the burner tube was replaced.

With a raw limestone bed in initial light-off operation and coal-charging period took a great deal of time. By 30 December, after five successive heavy coal charges had been introduced, the unit was brought out of service when large surface "clinkers" were observed in the bed. These surface agglomerations were partially defluidizing the bed.

The bed was purged of all "clinkers" and relit on 31 December. Shaft collar problems on the fans forced a temporary delay in the start-up, but heavy coal charging and inadequate fluidization were again responsible for large surface agglomerations noticed in the bed.

3.3.8 January 1980

The first coal fire of 1980 in the MFB was achieved on January 7. Unit operation in the first week of January was hampered by a large particle size bed, which made bed fluidization difficult.

On January 8, C-cell coal fire was achieved. This marked the first coal firing operation of the Fuller-Kinyon system since installation. Dust collection problems began occurring, however, on January 9 and by January 10, three of the six precipitator hoppers had high levels in addition to the east hopper of DC-1. The unit was shut down January 10 to examine and clean the dust collection media. A coal fire was reestablished on January 16 and after several fuel interruptions, three cell operation was achieved on January 17 and commercial operation followed.

The next day, however, the unit was brought out of operation due to alarmingly high combustible gas emissions in C-cell and the main flue gas region.

A complete unit inspection was performed on January 21 and no unusual discrepancies or major damage was found.

On January 23, unit start-up was again attempted, but quickly aborted when Monongahela Power Company lost their #7 boiler due to a fuel trip.

Intermittent one and two cell operation was accomplished during the remainder of January. A leaky drain header under the boiler and a massive "clinker" formation in C-cell were primarily the cause of the inconsistent operation.

3.3.9 February 1980

Unit operation began on February 2 with a coal fire in D-cell, and commercial operation was achieved on February 3. The commercial run lasted 6½ hours and was discontinued when high air preheater differentials could not be diminished. D-cell was maintained until February 4 when a city water outage forced the instrument air compressors to be shut down, thus requiring the MFB to be out of service.

Intermittent one and two cell operation followed this first week period due to electrostatic precipitator problems. A broken wire was detected in the outlet section of the ESP and later removed. This wire had disabled two of the precipitator cabinets. The rapping frequency on the precipitator was also intensified in an attempt to keep the collector plates free of ash buildup.

The precipitator problems were remedied and the unit was ready for operation by February 18. A coal fire in D-cell was established on February 10 and by February 21, the MFB was operating in the three cell commercial mode. The Rivesville MFB operated continuously in this commercial generating mode for 132.5 hours, over twice as long as any previous commercial operation. During the course of the run, the MFB unit operated flawlessly and turbine quality steam conditions were maintained. Exhibit 3.2 shows operating parameters throughout the run.

Commercial operation ceased at 1930 hours on February 26 and the unit was subsequently shut down for inspection of the effects of extended operation.

The unit was out of service for the remainder of February.

3.3.10 March 1980

Preparations were completed during the first week of March for unit operation with the new needle extensions in C and B-cells

Unit operation began on March 9 with a coal fire in D-cell. Commercial three-cell operation was achieved on March 10, but lasted only 26 hours due to a malfunction in the C-cell north Fuller-Kinyon interlock circuitry, which interrupted fuel feed. D-cell operation was maintained throughout the week while an intensive investigation of the Fuller-Kinyon circuitry was conducted.

On March 16, while in D-cell operation, a boiler circulating pump seal water header leak developed which forced the unit out of operation on March 17.

The leak was repaired and unit operation resumed on March 20. The MFB unit achieved commercial mode operation at 1530 hours on March 23 and operated continuously for 200 hours in the three-cell mode. Commercial operation was interrupted for about 4 hours during the 200 hours run to test the steam pressure control valve to atmosphere (HPSV-3), which was leaking excessively.

Commercial operation resumed and was continued until the scheduled 200 hours of operation were achieved at 2330 hours on March 28. Exhibit 3.3 shows operating parameters throughout the run. The MFB unit was subsequently shut down, as planned, for scheduled outage work which occupied the remainder of the month of March.

3.3.11 April 1980

For the first two weeks of April, the MFB was out of operational service on a scheduled outage. This period was used to conduct extensive examinations of the boiler and associated equipment following the extended run in March, and to proceed with the unit repairs and modifications.

Initial firing of the unit began on April 20 following simulated operational distribution testing on the Fuller-Kinyon system which occurred on April 17.

On April 21, C-cell operation was initiated with the Fuller-Kinyon feed system operating under a reduced needle velocity (55 fps). After 2.5 hours of operation, the south side feed system to C-cell plugged solidly forcing a shut down of C-cell. The unit was brought out of service and the fuel feed systems were cleaned and checked.

The unit was restarted on April 23 and C-cell operation with greater needle velocity (80 fps) was initiated. This endeavor was successful and the run proceeded without incident.

On April 25, preliminary load following tests were conducted on the MFB while in two-cell operation. Load change rate, rate of stable recovery and range of operation were observed. This preliminary test was conducted in preparation for a more extensive three-cell load following test to be conducted later in the month.

On April 30, an extensive load following test was conducted in three-cell operation. Data was obtained at five steady-state conditions, at various superficial velocities corresponding to different load ranges. After five hours of testing, the MFB was brought out of service for an extended outage.

3.3.12 May 1980

The Rivesville MFB was out of operational service for the entire month of May for major equipment modifications and inspections in anticipation of major unit testing during the summer months. Cold flow velocity distribution tests were conducted during May on the electrostatic precipitator and on the air distributor in C-cell. The Operations Department assisted the Maintenance group in servicing and repairing auxiliary and boiler equipment.

3.3.13 June 1980

Preparations were completed during the first weeks of June to resume operation of the Rivesville MFB. Operational equipment checks were completed and a full pre-light off check list was accomplished to determine operational worthiness.

The MFB unit was started on June 9 with a coal fire in D-cell. By June 10, the unit was operating in the three-cell mode, but commercial operation could not be attempted because of minor B-cell coal feed problems and a major precipitator hopper collection problem. The precipitator hopper problem was caused by two access doors inadvertently left off the mechanical collectors in the main flue gas circuit. This rendered the dust collectors inoperative and thus the precipitator suffered a heavier than design inlet dust loading. With the collector doors secured, the unit remained in operation to attempt a drain of the ash buildup in the precipitator hoppers. The attempt was unsuccessful and the MFB unit was brought out of operation on June 10.

The unit was cleaned, hopper levels evacuated, and worthy for operation by June 13.

On June 16, the unit was restarted and preparations were made to accomplish a three-fold test objective:

- Traverses of C and B-cells
- Flyash reinjection at 2000°F in D-cell
- Precipitator isokinetic evaluation

The MFB unit operated successfully in the three-cell commercial mode throughout the week of June 16-20 and the unit performance testing proceeded smoothly. The unit was taken out of service on June 20, and remained out of service for the rest of the month for planned outage activities.

3.4 MFB Plant Modifications/Improvements

3.4.1 Relocation of Belt Feeder Integrators

The Autoweigh belt feeder solid-state intergrator modules were removed from locations near their respective feeders and placed in the room adjacent to the MFB control room. This not only allowed all of the modules to be placed in one central location for easy access, but the relocation also provided a relatively dust and vibration-free atmosphere for better operation. The performance of the solid-state modules has improved markedly with the change.

3.4.2 Installation of "Nut and Bolt" Air Distributor

A new air distributor utilizing a drilled bolt protruding through and extending 1 3/4" above a 1/4" steel plate with an attached locking nut was installed in C and B-cells to replace the thin perforated-plate air distributor. (See Exhibit 3.6) The new distributor not only provides less resistance to air flow measured as less gridplate pressure drop, but also provides a substantial insulation layer of stagnant material between the plate and bolt aperture that prevents erosion of the gridplate surface. No adverse heat erosion of the gridplate surface has yet occurred in any cell.

3.4.3 Installation of Fuller-Kinyon System

The Fuller-Kinyon fuel feed system was installed in C-cell, replacing the vibrating feeder table, to test an alternate in-bed coal feed system.

The primary objectives of the test installation were to check system reliability, durability and its effects on fluidized bed combustion. See Section 3.5.4.

3.4.4 Mit-Dump Valve, Kamyr Ball Valve, 2 1/2" Self Cleaning Valve Installation

The "Mit-Dump" valve was installed in B-cell to prevent hydrated bed material from settling over the rotary dump valve and thus disabling the bed drain system in that cell. (See Exhibit 3.7)

The valve was unsuccessful due to the length of the actuator arm and susceptibility of the housing to the formation of agglomerates.

The actuator arm traversed the width of the entire cell encased in a metal sleeve near the floor of the air distributor. The hot bed caused the arm to warp and bind within the sleeve. The box constructed over the dump port also created a stagnant zone which contributed to the formation of large agglomerations. The valve was later removed.

The Kamyrr ball valve, on loan from METC, was installed in the spare bed material drain leg of C-cell. (See Exhibit 3.8) This valve proved unsuccessful due to expansion of the ball within the seating chamber once the ball had pivoted open to pass hot bed material. The expansion of the pivoted ball caused the mechanism to seize and the valve could not be closed. The valve was later removed and returned to Morgantown.

The 2 1/2" self-cleaning valve installed on D-cell has proven moderately successful. (See Exhibit 3.9) We are in general agreement, however, that the exit aperture is too small. The valve has to be exercised frequently (preferably on automatic timer) to prevent a hydrated core of bed material from settling above the valve. A continuous agitation mechanism is under investigation as is fluidizing air.

3.4.5 Lengthened Fuel Feed Needles in All Cells

The fuel feed needles in B, C and D-cells were lengthened to improve combustion characteristics within the cells. See Section 3.5.2 page 3.15.

The effect of the needle extensions was less than dramatic. Before and after cell traverses indicate basically identical combustion patterns with localized gas concentrations moving closer to the center of the cell which coincides with the lengthening of the needle exit point. More testing is necessary, but preliminary results seem to indicate the modification had negligible effects.

3.4.6 Bed Material Drain System Modification

The bed material drain system was modified, (See Exhibit 3.10), so that the T-42 single-volute cyclone collectors could operate in series from one vacuum transport line in an attempt to eliminate excessive carryover into the flue gas stream. Initial observations indicate the system achieves better collection, but demonstrable data needs to be produced.

3.4.7 Thermocouple and Thermowell Replacement

With the installation of the new air distributors, new thermocouples were installed in suspension above the bed in C and B-cells

supported with U-bolts from the tube bundle rather than bottom-supported from the gridplate as was previously done. This eliminated the need for any large perforations in the new air distributor. The above-bed holding framework has been severely warped, however, and required replacement once already this year. The Inconel thermowells proved unsatisfactory in high-temperature corrosive environments due to their sensitivity to sulfur attack. Sulfidation destroyed or severely eroded all of the Inconel thermowells in B and C cells after several hundred hours of operation and consequently destroyed many of the thermocouples. 310 stainless steel wells replaced the Inconel and their durability is at this point matchless.

3.4.8 Installation of Additional Gas Traverses Points in D, C and B Cells

Originally a single traverse point was available in C and B cells to determine cell combustion characteristics. 4 additional ports were installed in B-cell, 3 in C-cell, and 1 in D-cell to improve the combustion profile analysis throughout the entire cell. See Section 3.5.2.

3.4.9 Modifications to Electrostatic Precipitator and Dust Collector

These equipment modifications are detailed in Sections 3.5.5 and 3.5.6.

3.4.10 Flyash Reinjection System Modifications

Major modifications to this system are detailed in Section 3.5.7.

3.5 Testing and Results

3.5.1 General

During the reporting period, test emphasis on the Rivesville MFB centered upon individual systems and equipment optimization first and unit performance second.

Utilizing new techniques of sampling, significant data has been collected concerning combustion performance.

Seven sub-sections are listed here, detailing the test achievements made during this period. The sub-sections are:

- Cell gas traverses
- Main uptake gas traverses
- Fuller-Kinyon feed system
- Dust collector performance
- ESP performance
- Flyash reinjection
- Load following

3.5.2 Cell Gas Traverses

A technique was devised during August 1979 at Rivesville to obtain an analysis of flue gas at various above-bed points within the cell.

A sample port was installed approximately 14 feet above the air distributor in both B and C-cells. Originally a single traverse point was available in C and B-cells, but in May 1980, an additional four ports were installed in B-cell and three ports in C-cell. These

ports were designed to provide information both directly above and between fuel feed needles. Exhibits 3.11 and 3.12 show relative locations of gas traverse points for C and B cells, respectively.

The gas traverse probe, Exhibit 3.13, consisted of 1/2" stainless steel tubing with a sintered metal filter on one end. An internal thermocouple ran the entire length of the probe to provide gas temperatures at each sample point. The sample probe was connected to the A cell channel of the Beckman gas analysis package.

The first gas traverses, taken in August 1979, revealed poor areas of combustion above the feed needle discharges in both cells. C cell traverses (Exhibit 3.14) showed extremely high concentrations of CO and hydrocarbons on the north side. B cell's traverses showed high concentrations of CO and hydrocarbons along both the north and south walls. Further investigation showed severe cracks in the gridplates of both cells, which was stated to be the cause of the poor combustion.

After the installation of the Fuller-Kinyon fuel feed (F-K) system to C cell and the "nut and bolt" air distributors in C and B cells, gas traverses were again performed. These traverses showed considerable differences between C and B cells. B cell's traverses (Exhibit 3.15) had become relatively flat, indicating good combustion across the cell. C cell's traverses (Exhibit 3.16) had also improved, but to a lesser degree. There still existed areas of high concentrations of CO and hydrocarbons. The results of these gas traverses prompted a study of all factors of combustion on C cell.

Results of the study yielded some significant combustion problem areas, some of which were:

- A large amount of fines were being generated by the newly installed Fuller-Kinyon feed system.
- The needle velocities of the Fuller-Kinyon feed system were too high.
- Size segregation was occurring in the coal bin, causing more fines to be fed to one side.
- Significant amounts of freeboard burning were occurring.
- The two belt feeders were not feeding equal amounts.

Discussions concerning problems with the Fuller-Kinyon systems are presented in Section 3.5.4 of this report.

To solve the problem of size segregation in the north coal bin, a baffle plate, Exhibit 3.17, was installed at the coal

inlet. The purpose of this baffle was to provide a better distribution of coal to all sections of the bin.

The problem with freeboard burning was discovered when temperature traverses of B and C cells, at similar conditions, were compared. Exhibits 3.18 and 3.19 show an example of these temperature traverses and cell operating conditions. At similar operating conditions, B cell's freeboard temperature was lower than C cell's around the edges. C cell's temperature would decrease towards the middle, matching B cell's at that point. This problem was linked to the fines produced by the F-K system, the high needle velocities and a quenching effect of the above bed tube bundle. In order to reduce the amount of freeboard burning, the feed needles were extended farther into the bed. The needle tips were, thereby, reduced from about 9 to 4 inches above the air distributor in B and C cells. This would be expected to increase residence time of coal fines in the bed which should result in improved combustion.

In May of 1980, additional traverse ports were installed in B, C and D cells in order to obtain more information on combustion in each cell. Exhibits 3.11 and 3.12 show locations of gas traverse points. Exhibits 3.20 and 3.21 show gas traverses with the new ports. These results indicate areas of poor combustion within the cells.

Additional information obtained from gas traverses included:

- Combustion characteristics with a low operating bed depth.
- The progress of an agglomeration during operation.
- Determination of the validity of gas sampling points within the cells.

While performing gas traverses of C cell on 17 January 1980, extremely high values of CO and hydrocarbons were observed. Bed height indicators showed a 13" static bed, but visual observation and gas analysis seemed to indicate a deep bed. Airflow was increased to yield a superficial velocity of 11 fps. C cell was again traversed and the results showed a deterioration in combustion. Again the bed appeared to be acting as a very deep bed. After unit shut down, the bed was physically measured and found to be 13". Apparently what was observed was the flame front of the bed and not the bed itself. With such a low bed depth, the coal was burning above the bed. It appears that with this Fuller-Kinyon feed system, a minimum bed depth of 16" static must be maintained for stable operation.

Also, on 17 January, while traversing B cell, a large reducing zone was observed. Good combustion was observed throughout the cell, with the exception of a few feet on the south side. Subsequent traverses revealed the area of poor combustion to

be spreading until twelve hours later, the unit was shut down due to dangerous combustion conditions existing in B cell. Upon unit inspection, it was observed that an agglomeration of sintered bed material had formed in the southwest corner of B cell over the spare dump port. The agglomeration extended three to four feet into the bed. This agglomeration was not detected on other instrumentation. The agglomeration was attributed to an experimental bed dump valve.

From previous experience, it was noted that an increase of CO and hydrocarbons occurred apparently in the freeboard region between the cells and the main uptake. Based on gas traverse analysis, it appears that the gas samples obtained from the probes within B and C cells are not representative of the mean gas concentration. In particular the sample ports, located away from the walls of the cells, are missing significant amounts of CO and hydrocarbons which are rising along the water walls. This problem has been noted for future reference and is part of the continuing study of CO and hydrocarbon emissions.

Continuing studies utilizing gas traverses are planned for the upcoming year. These studies will help determine optimum operating conditions on this and other fluidized bed units.

3.5.3 Main Uptake Gas Traverses

During several operational periods, there appeared to be an increase in the concentrations of CO₂, CO and hydrocarbons from the main uptake to the gas inlet of the air preheater. It was not known if this was an actual occurrence or a sampling problem.

In February 1980, a series of three tests were conducted to determine the validity of the main uptake gas analysis. A gas traverse probe similar to the ones used in the cell traverses (section 3.5.3) was constructed. The DC-1 inlet isokinetic sampling ports were used as gas sampling ports. Two tests were conducted during two cell operation. Gas traverses of B and/or C cell were conducted at the same time.

The results of the gas traverses showed a definite stratification of gas concentrations. High concentrations of combustion gases (CO₂, CO, SO₂, and hydrocarbons as shown in Exhibits 3.22-3.25) were found near the bottom of the ducts, with high concentrations of O₂ (Exhibits 3.26-3.27) near the top. This was expected due to air leakage through combustion air dampers of unused cells.

The test results from the main uptake traverses were compared to velocity traverses obtained during isokinetic sampling runs at similar conditions. This comparison showed areas of high combustion gas concentrations were also areas of low velocity.

Averaged values of the main uptakes traverses were then compared with readings at the air preheater gas inlet and the main uptake. These are shown in Exhibit 3.28. It appears that the main uptake sample is valid and the generation of CO₂, CO and hydrocarbons is a true indication. From previous unit inspections, it appears that this generation of CO₂, CO and hydrocarbons is occurring within the ESP.

3.5.4 Fuller-Kinyon Feed System

During the outage from September to December 1979, an alternative fuel feed system was installed to feed C-cell. This system, designed and built by the Fuller Company of Bethlehem, Pennsylvania, was to be tested at the Rivesville facility.

The Fuller system, shown in Exhibit 3.29, receives the discharge of the coal belt feeder and limestone rotary feeder through a constant speed rotary feeder. The material passes through the constant speed rotary feeder, which acts as a surge preventer, and is fed into a screw pump where it is compressed to overcome a weighted flapper valve. The coal and limestone mixture then passes into a fluidizing chamber, where it is "pumped" to a mechanical splitter. The splitter splits the coal-limestone air mixture into six feed points by means of a conical separator and six orifices around the perimeter of the the splitters. Material exits the splitter and enters the boiler feed needles into the combustion zone.

Prior to operation, PER personnel met with Fuller representatives in order to develop a test plan for evaluating the new feed system. The primary objectives of the Fuller feed system test plan were:

- System reliability and performance
- System durability
- Effects on fluid bed operation

A study of system reliability and performance would contain the following items:

- Start up and general operation of the system, based on actual performance at the Rivesville site.
- Identification of system derived problems such as frequency of needle pluggages, material bridging and loss of air seal.
- Air leakage to belt feeders and/or rotary feeders.
- Performance of the mechanical splitter; the ability to provide an equal fuel distribution.

The section on system durability deals with the amount of degradation of the screw pump, feed tubes and splitter due to erosion and/or corrosion over extended operational periods. In order to accomplish this, pump and splitter internal measurements will be made prior to and at the end of the test period. Feed tube measurements will be made periodically to determine wear.

Considerations in the study of the effects of the new feed system on fluid bed operation are:

- Combustion efficiency
- Amount of fines generation
- Sulfur capture

Each of these will be studied in the manner put forth in the formal test plan of the Rivesville project.

In December 1979, prior to any boiler operation with the Fuller-Kinyon feed system, the mechanical splitters were tested for feed distribution. In order to do this, splitter discharge was directed into six vented barrels, as shown in Exhibit 3.30. Pressure taps on each splitter discharge point and the splitter inlet were installed in order to obtain the pressure drop for each discharge point. This would then be correlated with fuel distribution attained. The barrels were weighed prior to and at the conclusion of each test run. Test runs were made at 4,000, 6,000 and 8,000 pounds per hour as indicated by control settings. Samples were taken from the feed bin and each barrel for size analysis.

Distribution results from the splitter tests are shown in Exhibits 3.31 and 3.32. From these results, it can be said that both north and south side splitters performed within acceptable limits. The distribution could be improved; however, since the distribution was well within limits of the vibrating feeder table distribution, the splitter configuration was left as is.

Results of the size analysis of the splitter discharge are shown in Exhibit 3.33. From these results it can be seen that the feedstock undergoes a considerable size degradation, reducing the mean particle size by about 50%. Also, considerable amounts of fines (-20 mesh) were generated, as much as 40%. With this amount of fines, combustion problems were anticipated.

Prior to boiler operation, the pump and splitter internals were measured by micrometer for comparison at a future date.

The Rivesville MFB began operation of the Fuller-Kinyon feed system in January 1980. Except for start up problems, the feed system performed in a reliable manner.

During February and March two long term runs, of 132 and 200 hours respectively, were accomplished. Testing during this time frame consisted mainly of gas traverses of C cell (section 3.5.2) to help optimize the operation of C cell.

During the 200 hour turbine run, after an excess of 300 total hours of operation on the Fuller-Kinyon system, the carbon steel transport lines and feed elbows of both sides of the Fuller system started to wear through. On-line repairs were accomplished, but this situation prompted a study of the transport velocities. The study revealed excessive needle velocities of 140 fps (80 fps was originally specified). This high velocity was attributed as the cause of rapid transport line wear. In order to correct the excessive velocities, a manually adjusted blow-off valve was installed on the discharge piping of each compressor. By modulating this valve, velocities could be varied in order to optimize operation.

Needle velocities were then lowered to the specified 80 fps and gas traverses of C cell conducted. The traverses revealed an improvement in combustion due to lengthening of the feed needles which resulted in a longer residence time for fine particles and the reduction in needle velocity. Both sides of the Fuller system operated satisfactorily at this condition.

At the request of DOE and TVA the needle velocity was lowered to 55 fps, the design velocity of the TVA 20 MWe unit. After a couple of hours of operation, the south feed system began operating under "slug-flow" conditions. Soon afterward, a high torque on the south screw feeder caused the drive belts to fail. Following unit shut down, inspection revealed coal solidly packed in the screw flights, in the exit from the flapper valve and well along the 5" horizontal run. All six needles on the south side were coked, indicating a loss of transport air.

In order to operate at 55 fps, the transport system had to be modified. With a 55 fps needle velocity the velocity in the 6" vertical riser was insufficient to transport the larger particles, therefore the "slug-flow" and plugging conditions. The transport lines were reduced to 4" sch 80 pipe, thereby permitting higher transport velocities at lower needle velocities. The system was then operated at 55 fps with no problems.

After the repair of the transport lines, ultrasonic measurements of all feed tubes and lines were made, as baseline data. Additional ultrasonic tests will continue to be run at later dates to determine the wear on the transport lines. Test results to date show little or no wear in the straight sections of transport and needle piping. Severe wear is indicated at all short radius bends and elbows.

Testing on the Fuller system is continuing with optimization runs and combustion efficiency tests scheduled for the fall of 1980. Comparison testing with a vibrating feeder table, both with and without eductors, is also scheduled for the upcoming year.

3.5.5 Dust Collector Performance

During the latter part of May 1980, a series of tests were conducted on the two multi-clone dust collectors, DC-1 and DC-2, in order to determine their collection efficiencies. Test results, shown in Exhibit 3.34, indicate that both dust collectors are performing below their design efficiencies. Explanations for the low collection efficiencies were sought.

The dust collector serving cells A, B, and C, DC-1, was designed for all three main cells in operation. Because of steam limitations imposed by Monongahela Power Company, cell A is never operated. This causes the gas flow rate to decrease and the pressure drop across the dust collector also decreases, thereby affecting the performance of the dust collector.

An isolation damper was installed in December 1978 on the east side of the dust collector, but this was not effective. During the outage of May 1980, a portion of the DC-1 cyclones was physically blocked off. Exhibit 3.35 shows the cyclones which were blocked off. The selection of cyclones to be blocked was dictated by two factors:

- The location of the bed material transport vent line just above DC-1 on the north side of the collector. It is undesirable to have bed material accumulate over inactive cyclones in case bed material should enter through the vent line.
- To prevent excessive cell draft in the event that the east isolation damper would be closed.

During a flyash reinjection test in June 1980, the dust collector, DC-1, was reevaluated (Exhibit 3.36). Test results revealed an 80% collection efficiency. This is still below the design specification, but represents an increase of about 10% from previous data.

Studies conducted on the dust collector serving D cell, DC-2, revealed some possible causes for its low collection efficiency. These were:

- Inlet loadings are at least 50% greater than design.
- Certain areas of the cyclone are being overloaded with excessive quantities of flyash.

- The inlet particle size is smaller than was expected
- The preliminary data obtained indicated that a certain size band, 40-60 microns, has low collection efficiency. This size band is also the most heavily loaded.

Further studies are being conducted in order to improve the dust collector efficiencies.

Another factor which would be affecting dust collector performance is the bed material transport system. These have been conducted and modifications made in order to improve the system. It is felt that once the bed material transport is made more efficient, less carryover will enter the dust collector through the vent, thereby increasing dust collector performance.

3.5.6 ESP Performance

ESP performance has been an on-going study at the Rivesville facility for several years. During this reporting period, in an effort to fully optimize ESP performance, a vendor's representative has been on site.

Based on the results of previous short-term tests, several modifications were made to the ESP in November and December to improve performance. These modifications were:

- Installation of side rappers.
- Installation of stainless steel emitting wires.
- Improvement of existing wire rappers.

In the reconstruction of the ESP after the fire of August, 1978, the bolts connecting the rapper arm on each wire rapper were improperly torqued. This error caused a gap between the striking plate and rapping arm, thereby not allowing a full rapping force to be transmitted to the wires. This could have resulted in improper cleaning of the wires. All bolts have been correctly reinstalled and secured in place.

In March 1980, during the 200 hour commercial run, The ESP was closely monitored for the first time since the modifications were made. Two complete sets of isokinetic samples, one from the ESP inlet and one from the stack discharge, were made. Test results are shown in Exhibit 3.37. The measured collection efficiency of the ESP was 98.8%. This produced an emitting dust loading of 0.895 lbs particulate per 10⁶ Btu

heat input. This collection efficiency is slightly less than design (98.8% vs 99%), but much improved over previous results and within experimental error. Exhibit 3.38 shows a comparison of design conditions and ESP performance results before and after the recent modifications.

From Exhibit 3.38 two facts are evident:

- Under nearly identical conditions the ESP collection efficiency significantly improved after the modification.
- The ESP is currently operating at inlet loading conditions that are significantly above design. If the cyclone collectors were operating at their design efficiencies, it could be expected that the ESP collection efficiency would meet design specifications, even at lower than design temperatures. More studies will be required to inclusively evaluate these effects.

Also, during the 200 hour run, it was observed that corona voltages increased and back corona effects totally disappeared. This is a very favorable sign concerning ESP performance.

During operational runs after the 200 hour run, it was observed that corona voltages were low during periods of start-up and cell transfer. It was thought that this situation was caused by unequal thermal expansion caused by the rapid change of temperatures occurring during start up and cell transfer. In order to study this situation a series of six (6) thermocouples was installed on the skin of the ESP along the north and south sides. Also, distance measurements of the ESP were obtained during start up and cell transfer. Test results showed higher temperatures on the north side than on the south, and greater expansion on the north side than the south side. This corresponds with ESP inlet data showing higher flowrates and temperatures on the north side.

As a possible solution, it was thought that removal of the anti-sway insulators would allow the emitting wires to grow without shorting out the control cabinet. In June 1980, the anti-sway insulators were removed from the "A" (inlet) section of the ESP. This proved to be unsuccessful as the emitting wires began to sway and short out the control cabinet. ESP collection efficiency dropped considerably. After the run was finished, the anti-sway bars were reinstalled.

It appears that during long term operation the ESP can achieve approximately design collection efficiency. However, during start up periods collection efficiency deteriorates due to uneven thermal expansion. Further testing needs to be conducted to find possible solutions. The practice currently applied is to allow the ESP to heat up for 24 hours before attempting two and three cell operation.

3.5.7

Flyash Reinjection Testing

During the reporting period, the majority of flyash reinjection testing was spent in modifying the reinjection system. The flyash reinjection system, Exhibit 3.39, received flyash from the two hoppers of DC-1, through a variable speed rotary feeder and then into a screw feeder where it was pneumatically transported to the boiler. This system had numerous operational and design problems, some of which were:

- Improper nozzle design
- Excessive wear on shaft bearings
- Jamming up of the screw feeder

The problems were solved and in September 1979, the system was tried and worked for a period of two hours. The system had to be shut down due to high hopper levels in DC-1. Further investigation revealed that the rotary valve was not feeding enough to keep the hoppers empty. This prompted further study of the system. The results of this study showed that the flyash reinjection system, as built, would not handle the full amount of flyash collected in DC-1.

In late March 1980, a redesigned flyash reinjection system, Exhibit 3.40, was installed and tested. This system involved diverting the ash silo line into the flyash reinjection line, totally bypassing the screw feeder. This system was found to be able to transport sufficient quantities of flyash to keep DC-1's hoppers clear.

With the system now operating, a new problem arose with DC-2. It seems that with flyash reinjection in service, the flyash handling system serving both the DC-2 and the ESP hoppers could not keep the DC-2 hopper empty. This was because the system alternated between DC-2 and the ESP hoppers. If the system was on DC-2, the ESP hoppers would fill up, and vice versa. To solve this problem a modification was initiated to put DC-2 and the ESP hoppers on separate removal systems. This system is scheduled to be completely installed by the end of the 1980 summer.

Initial flyash reinjection testing on the new feed system was performed in June 1980. The conditions in D cell prior to reinjection were:

- 1550^oF bed temperature
- 26" static bed height
- 9.0 fps superficial velocity

Bed temperature was then increased to 1880^oF, using coal. Flyash reinjection began shortly afterward with bed temperature climbing to 2000^oF. At the same time, the bed height began to drop off rapidly, due to bed elutriation at high temperatures. Conditions finally stabilized out at 20" static bed depth, 1980^oF bed temperature, 9.5 fps superficial velocity and 4% flue

gas oxygen. Coal feed was backed off, from 4000 lb/hr to 1970 lb/hr, to maintain bed temperature. After several hours of steady operation samples of DC-1 East and West lock hoppers were taken to examine the chemical composition of the flyash being reinjected to D-cell. A similar sample was taken from the DC-2 lock hopper and an identical analysis performed to examine the composition of flyash leaving D-cell. The carbon-hydrogen content of the composite flyash sample and of the various particle size cuts was determined. These results are shown in Exhibit 3.41 in tabular form and graphically in Exhibit 3.42. The particle size distributions found were typical of earlier studies and of Alexandria PDU studies. It is evident that the -50 + 120 mesh size (213) contains both most of the flyash and unburned carbon entering and leaving the CBC.

Exhibit 3.42 shows carbon burn-up as a function of flyash particle size. There is a relatively large amount of burn-up in the particles below 200 microns. In order for a particle to burn out, its burn-up time must be less than its residence time in the combustion zone. It is possible that for particles below 200 microns, their burn-out time is less than the residence time in the CBC. Particles over 300 microns, which elutriate, tend to have long hot gas residence time in the freeboard since the Stokes' Law setting velocity approximates the superficial velocity. Therefore, these particles tend to burn more completely.

As part of the data collected during this run, four isokinetic samples were taken: DC-1 inlet, DC-2 inlet, DC-2 outlet and ESP inlet. A mass balance was then performed around the unit. The mass balance is shown in Exhibit 3.43. The results of this mass balance yielded an 83.7% carbon burn-up in D cell.

Based on results from an in-bed heat balance computer program, it was determined that the fraction of in-bed burning was less than 80%. Since combustion occurs both in the bed and in the freeboard region, the amount of in-bed burning will reduce the amount of coal required to maintain bed temperature.

It is believed that combustion efficiencies can be increased by increasing the residence time of flyash particles in the bed. This may be accomplished by operating at reduced superficial velocities and/or much deeper beds. Ideally, high bed temperatures should be maintained, but this presents two problems:

- Bed elutriation which results in shallow beds.
- Decay of sulfur capture effectiveness.

Further testing of flyash reinjection is planned at various bed heights, bed temperatures, and superficial velocities in order to determine the optimum operating conditions for both combustion and sulfur capture.

3.5.8 Load Following Tests

In April 1980, load following simulation tests were conducted while the MFB was in three-cell operation. In order to avoid creating an upset condition during turbine operation, steam was vented to atmosphere. Data was obtained at various steady state conditions, at various load levels.

After data was collected at initial steady state conditions, air flow and coal feed were quickly increased to determine the maximum load response rate of the MFB. Maximum load change typical data is shown in Exhibit 3.44. In terms of full load changes, this corresponds to an average of 7.8% of load per minute. The tube bundles are designed such that loads in B and C-cells can be changed at constant temperature and excess O₂ with no changes in bed mass with static bed depths of about 18 inches. Furthermore, the pressure drop versus air flow relationship of the drilled bolt air distributor allows greater turndown than anticipated. With proper limestone size selection, the MFB can be operated with a 3:1 ratio (4 to 12 ft/sec) without exceeding design gridplate differentials in cell operation.

Summary of 1979-80 Operating Hours

		0	D	C	B	A	Turbine
July	79	14.8	126	115	80.8	0	71.6
Aug.	79	25.7	130	58.5	38.2	0	30.4
Sept.	79	16.9	108.0	22.8	3.5	0	0
Oct.	79	0	0	0	0	0	0
Nov.	79	0	0	0	0	0	0
Dec.	79	42.1	0	0	0	0	0
Jan.	80	57.0	208.6	71.7	27.2	0	23.8
Feb.	80	11.4	304.7	214.6	144.8	0	138.9
March	80	26.2	456.8	284.6	255.8	0	245.5
April	80	7.9	181.2	97.6	22.6	0	16.9
May	80	0	32.2	21.8	21.7	0	21.0
June	80	8	139.4	123.9	92.0	0	76.6
To Date		1848	4432.8	1990.9	1131.6	0	894.2

3-25

EXHIBIT 3.1

Commercial Operation Summary

132 Hour Run

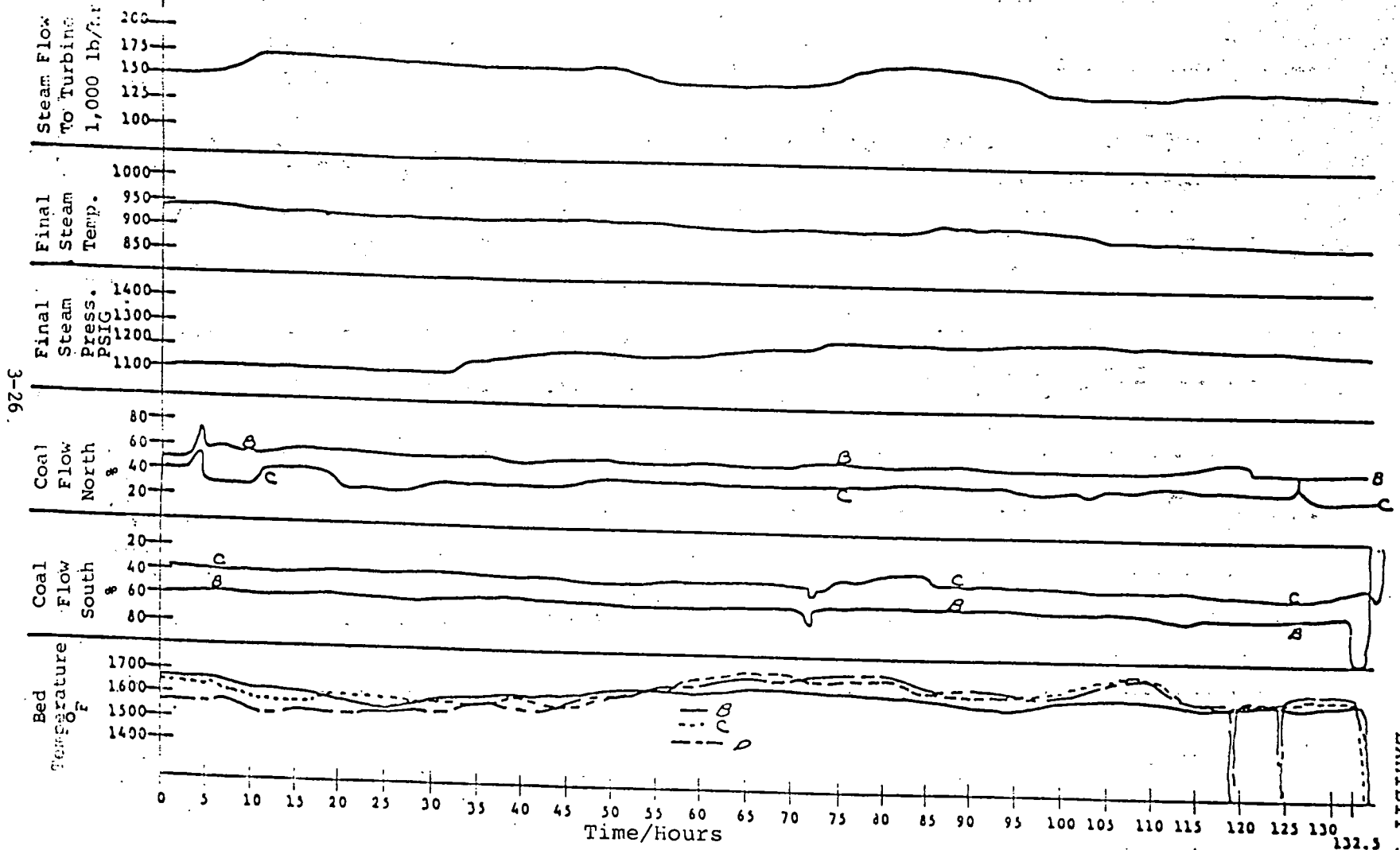
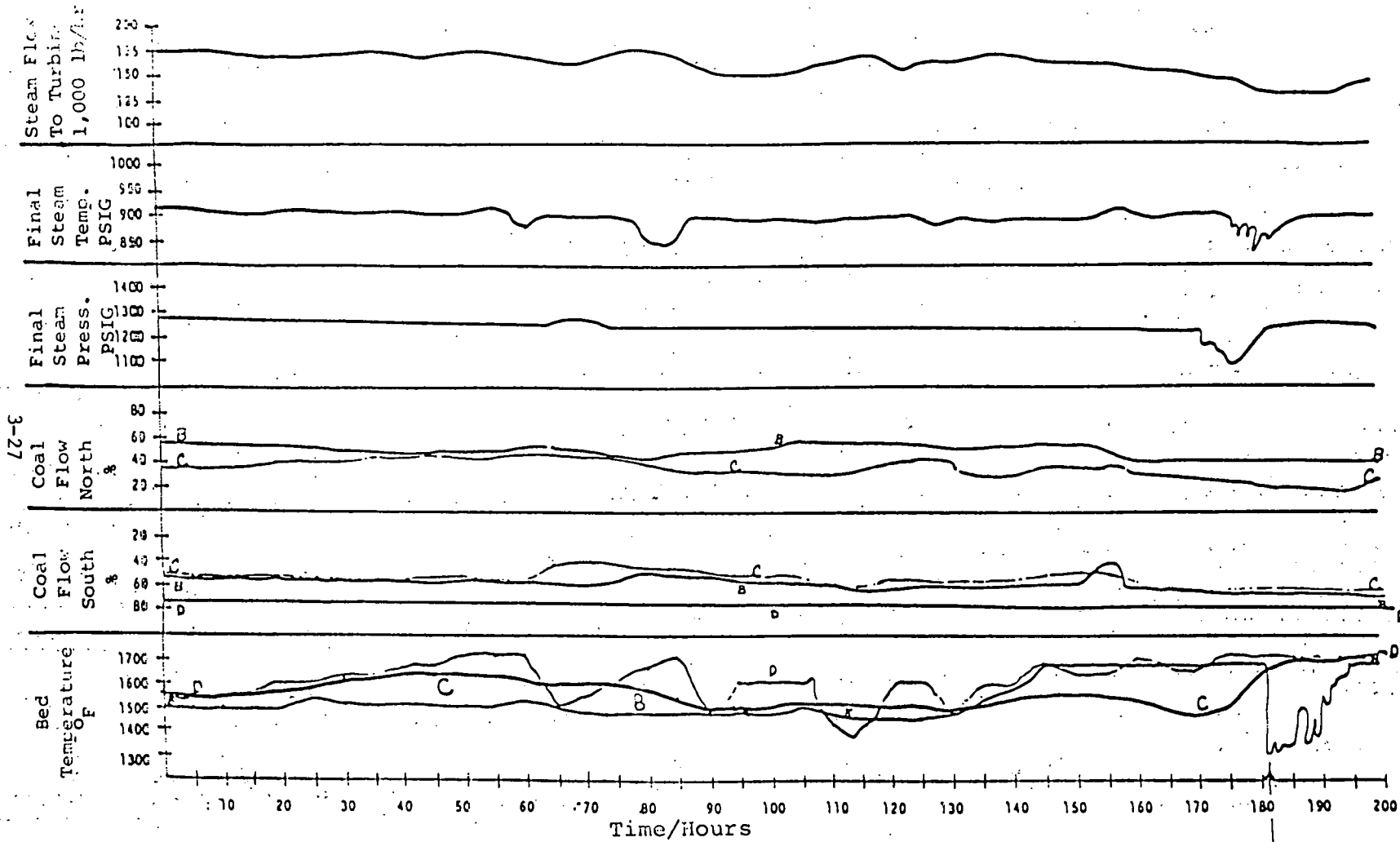


EXHIBIT 3.2

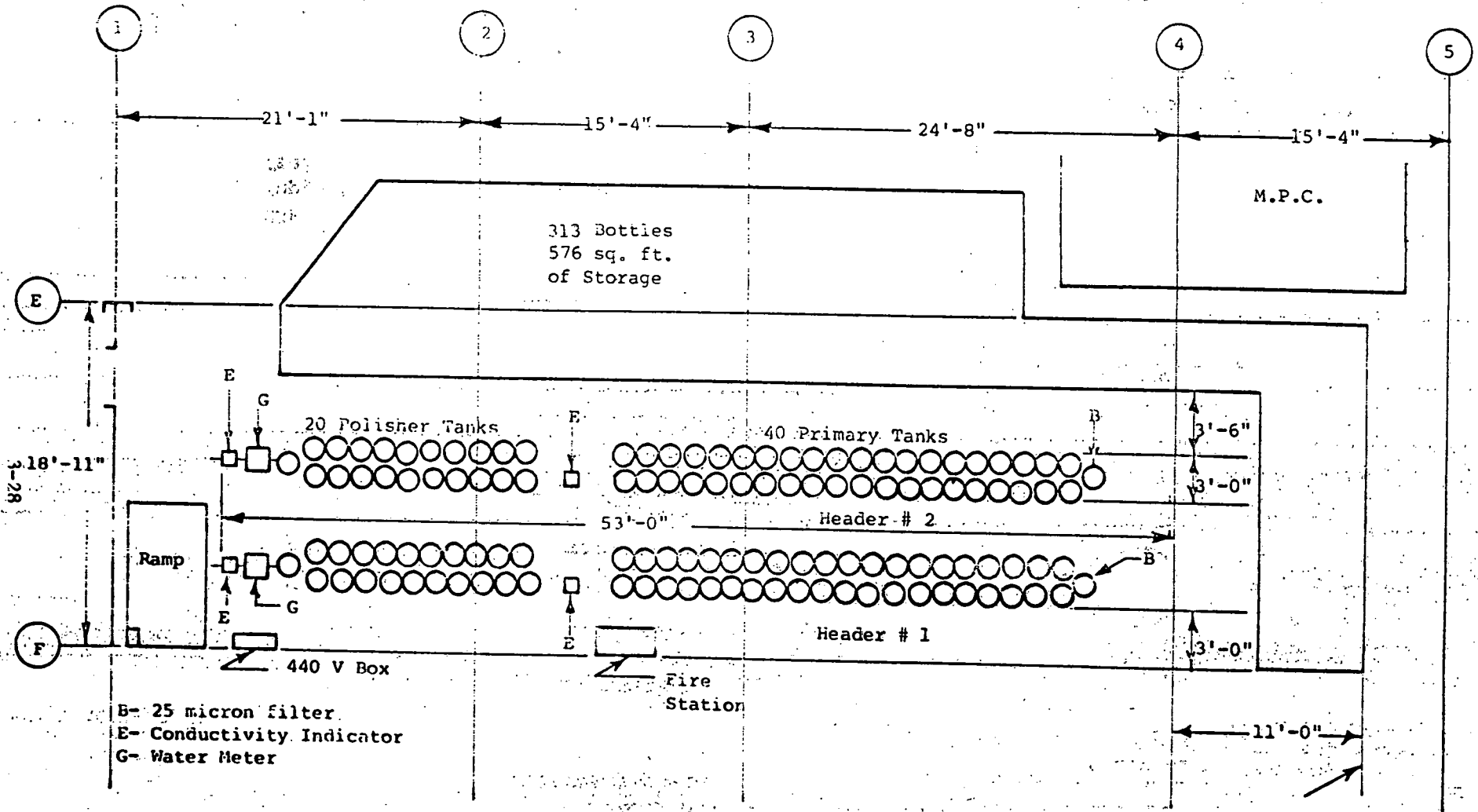
Commercial Operation Summary

200 Hour Run



HPSV-3
Testing

EXHIBIT 3.3



B- 25 micron filter.
 E- Conductivity Indicator
 G- Water Meter

Eciochem Treatment Installation

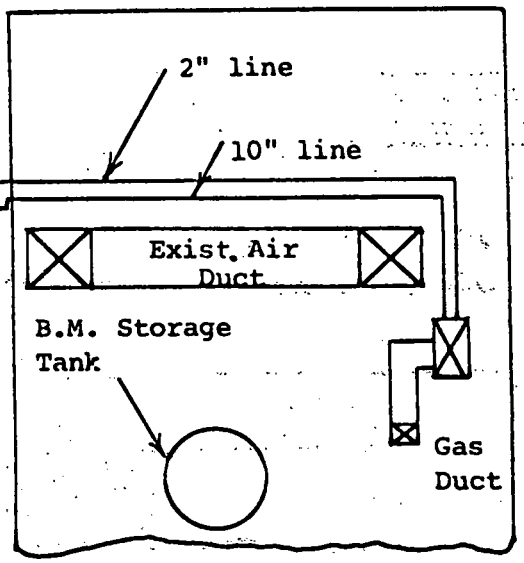
ESP Support Trailer

Baghouse

ESP Trailer

TOP

EPA Piping Arrangement

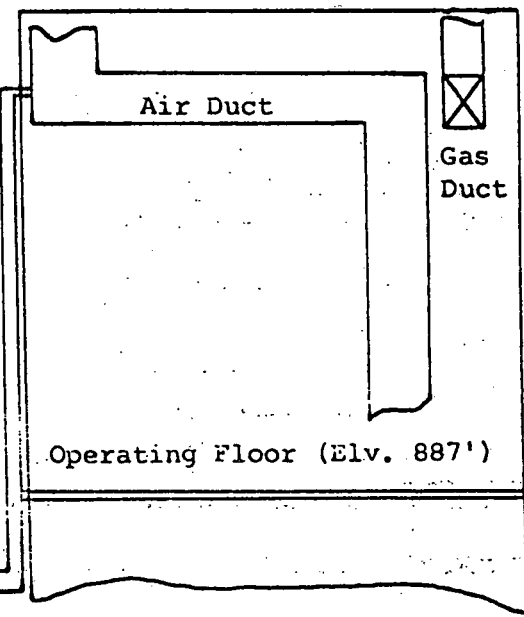
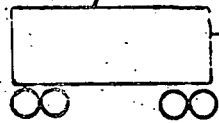
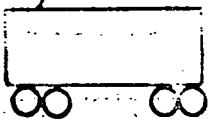


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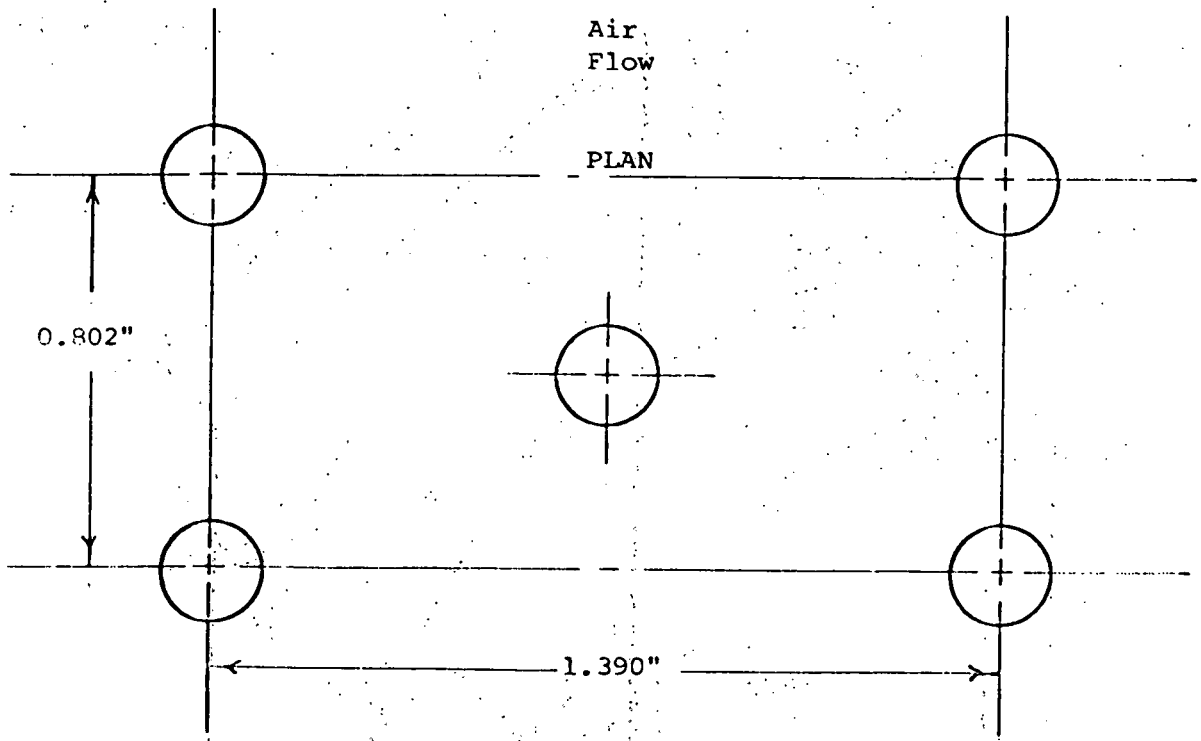
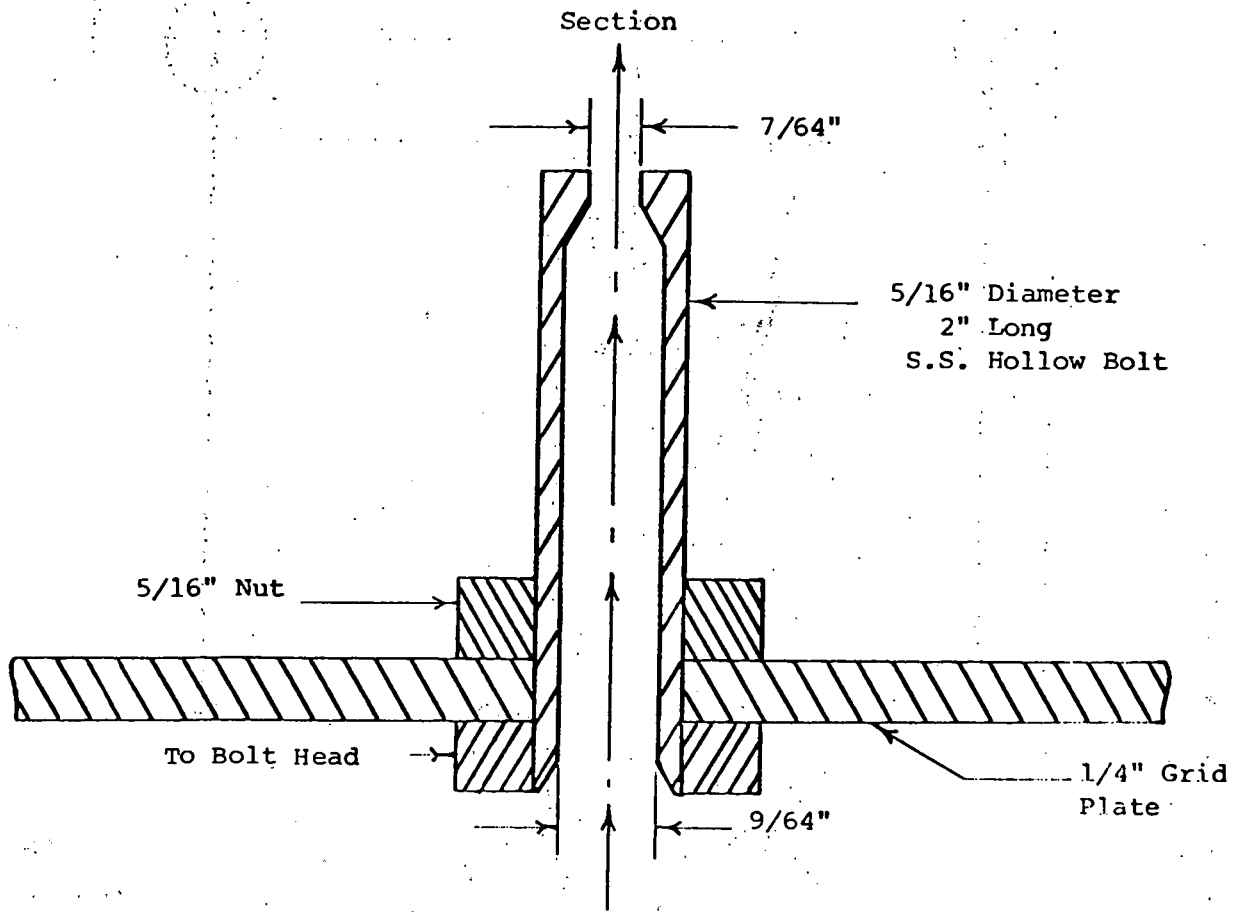
ESP Support Trailer

ESP Trailer

SIDE



"Nut and Bolt" Gridplate



"Middump" Bed Drain Valve
Installed on B Cell

3-31

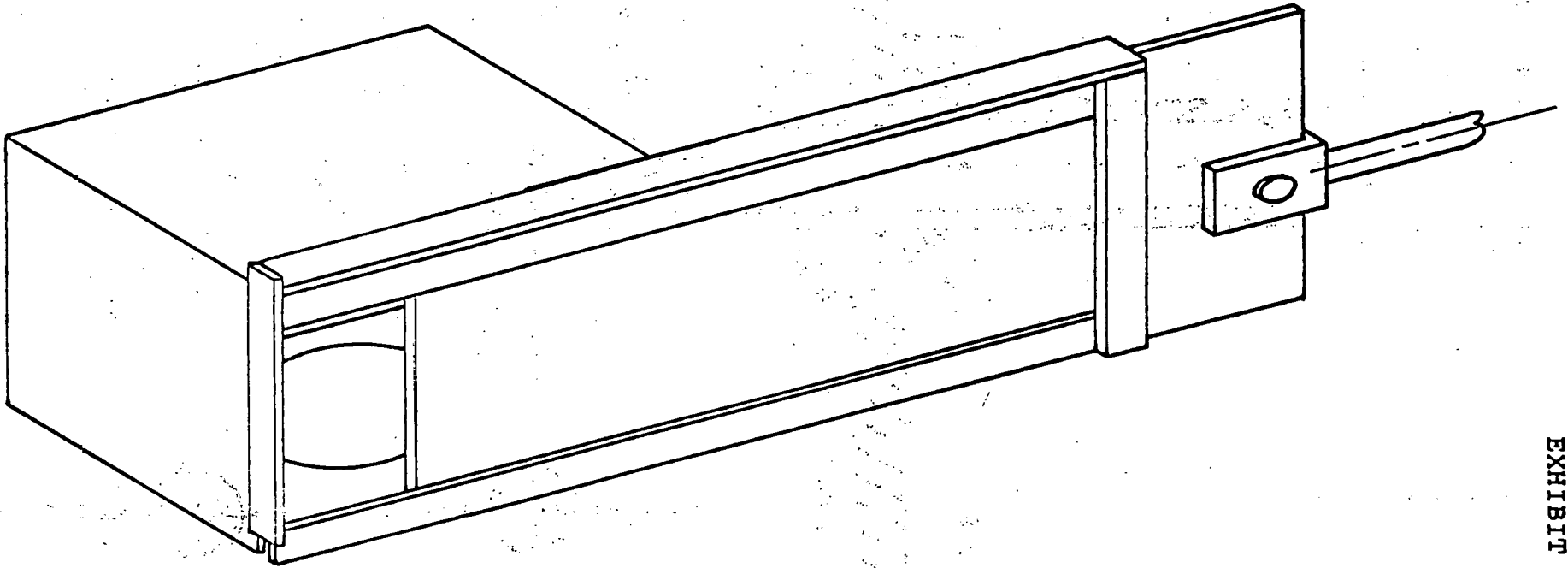
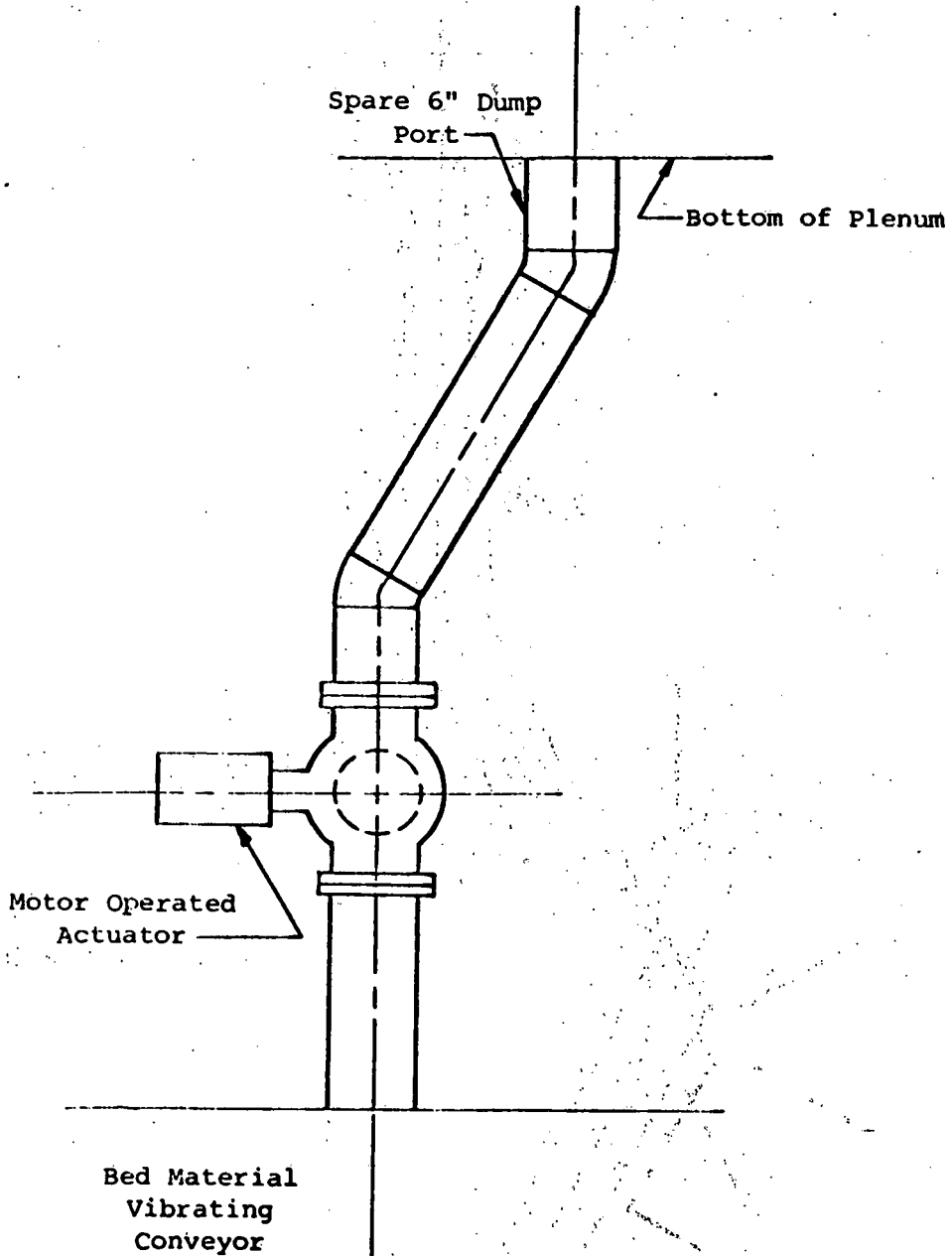
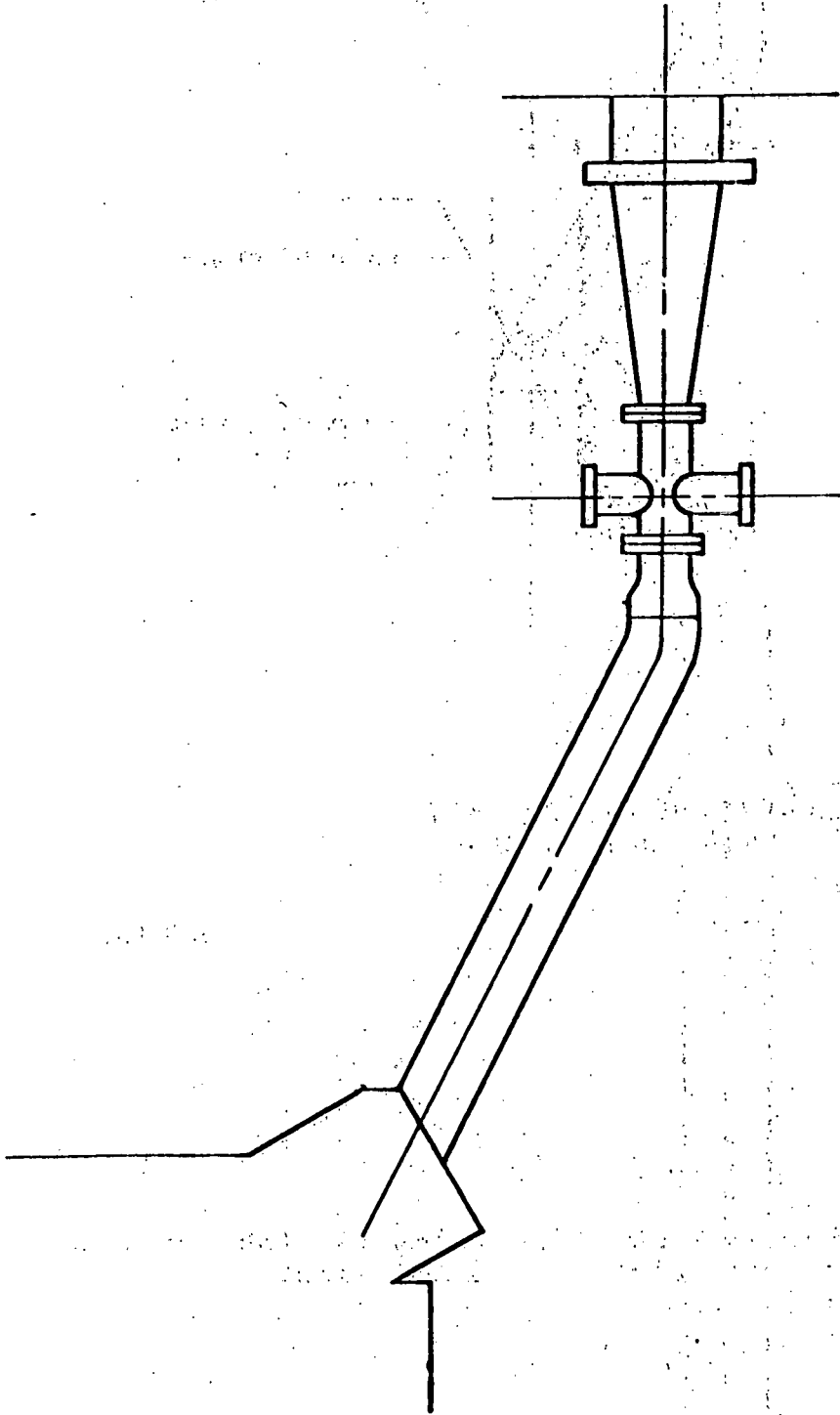


EXHIBIT 3.7

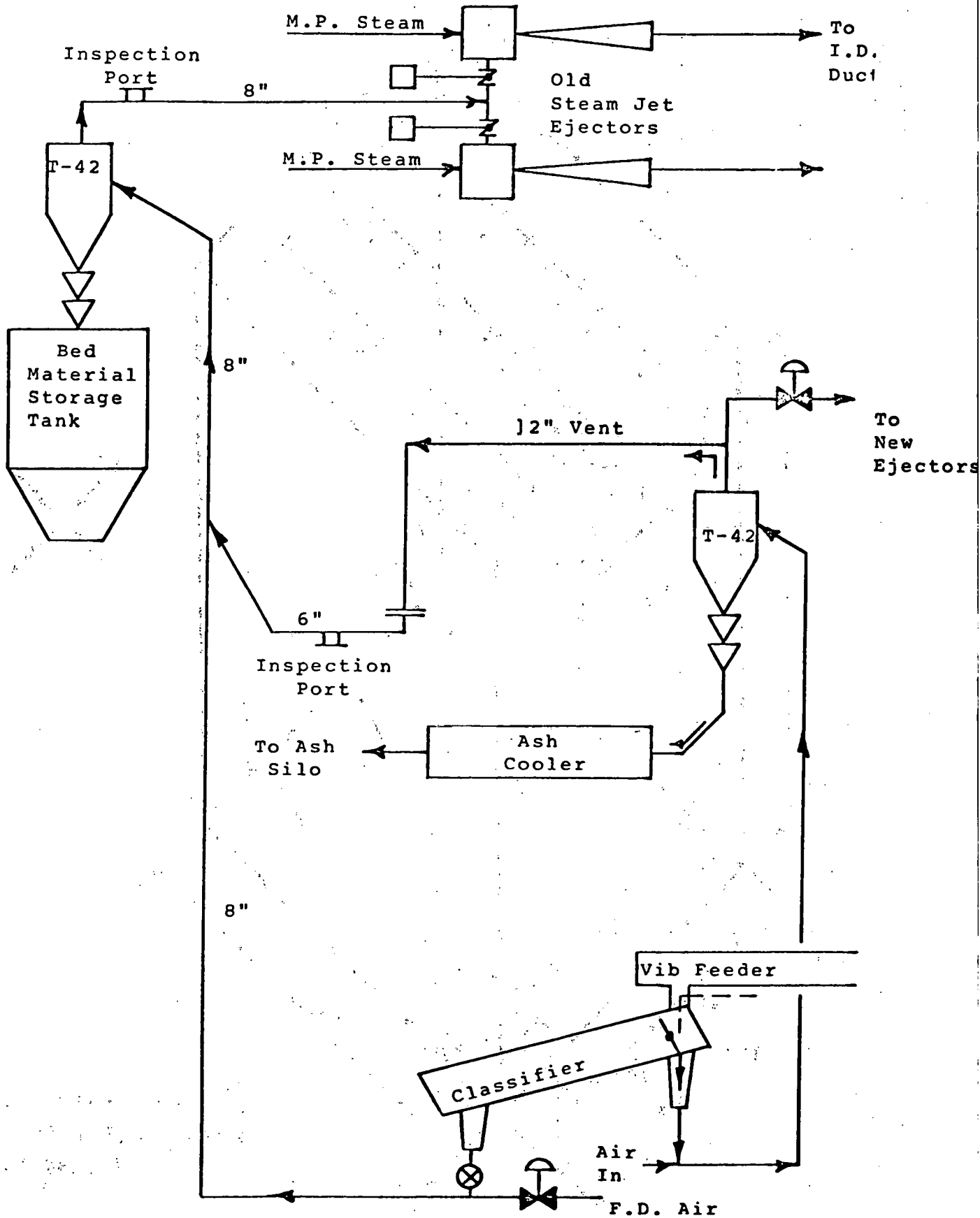
Kamyr Ball Valve
Installed on C Cell



Side View, Self Cleaning Slide Gate Drain Valve
Installed on 'D' Cell

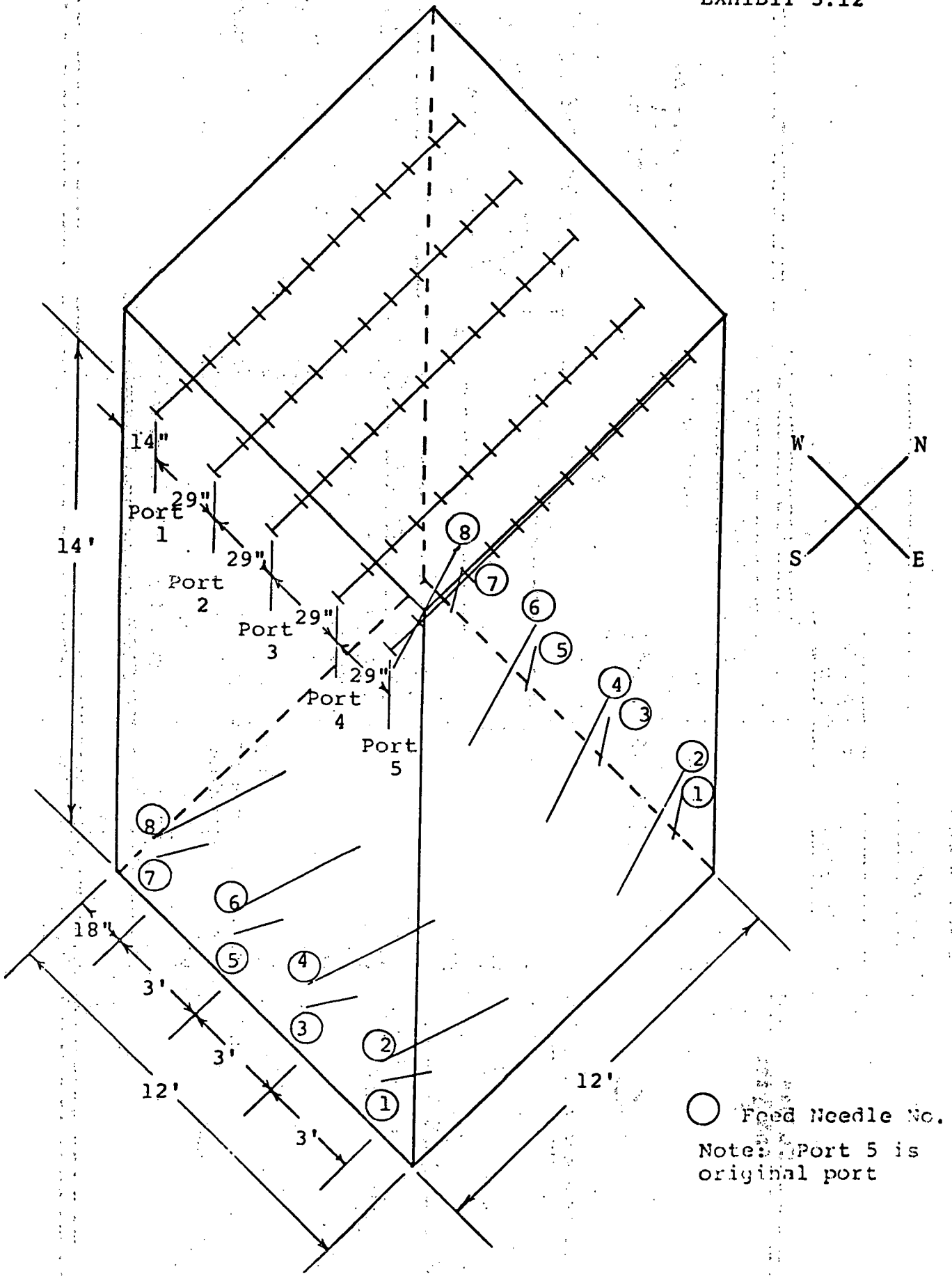


Bed Material Transport Modifications

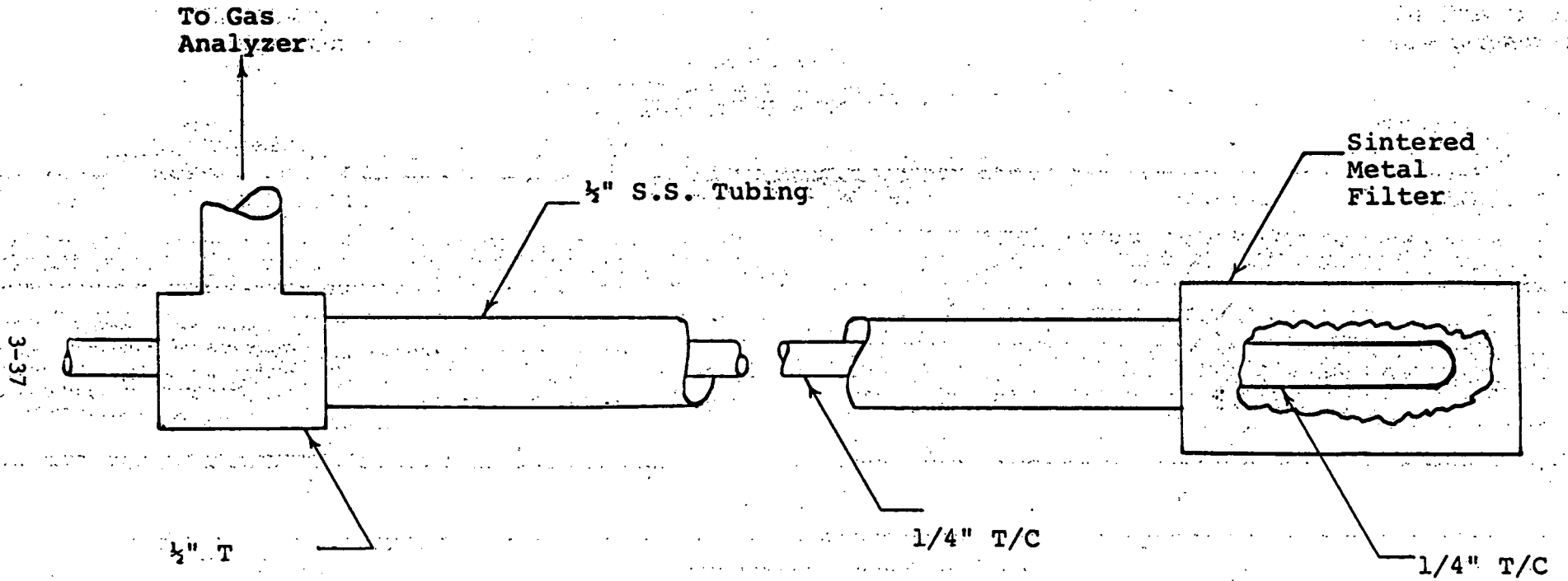


B Cell Gas Traverse Points & Feed Needles

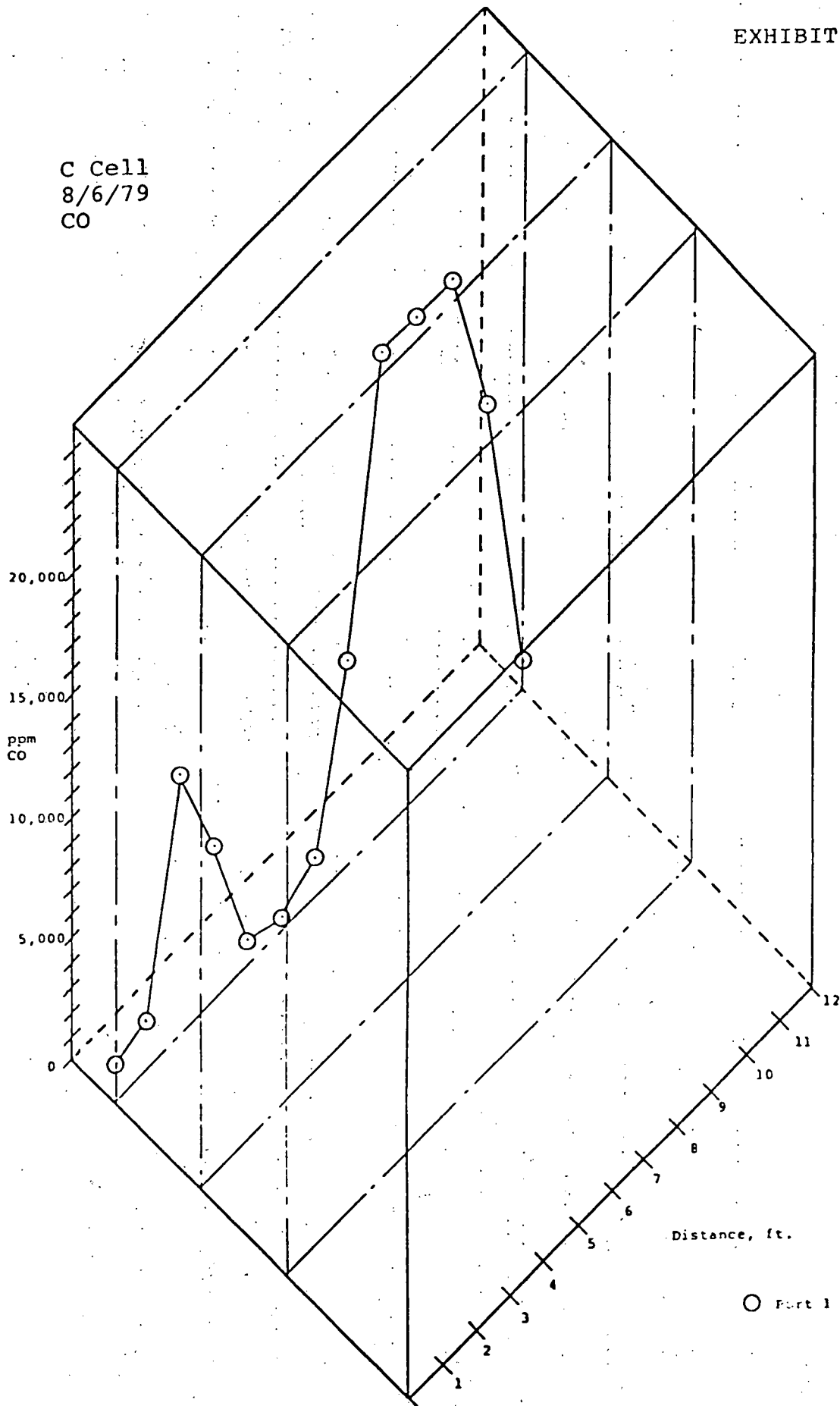
EXHIBIT 3.12



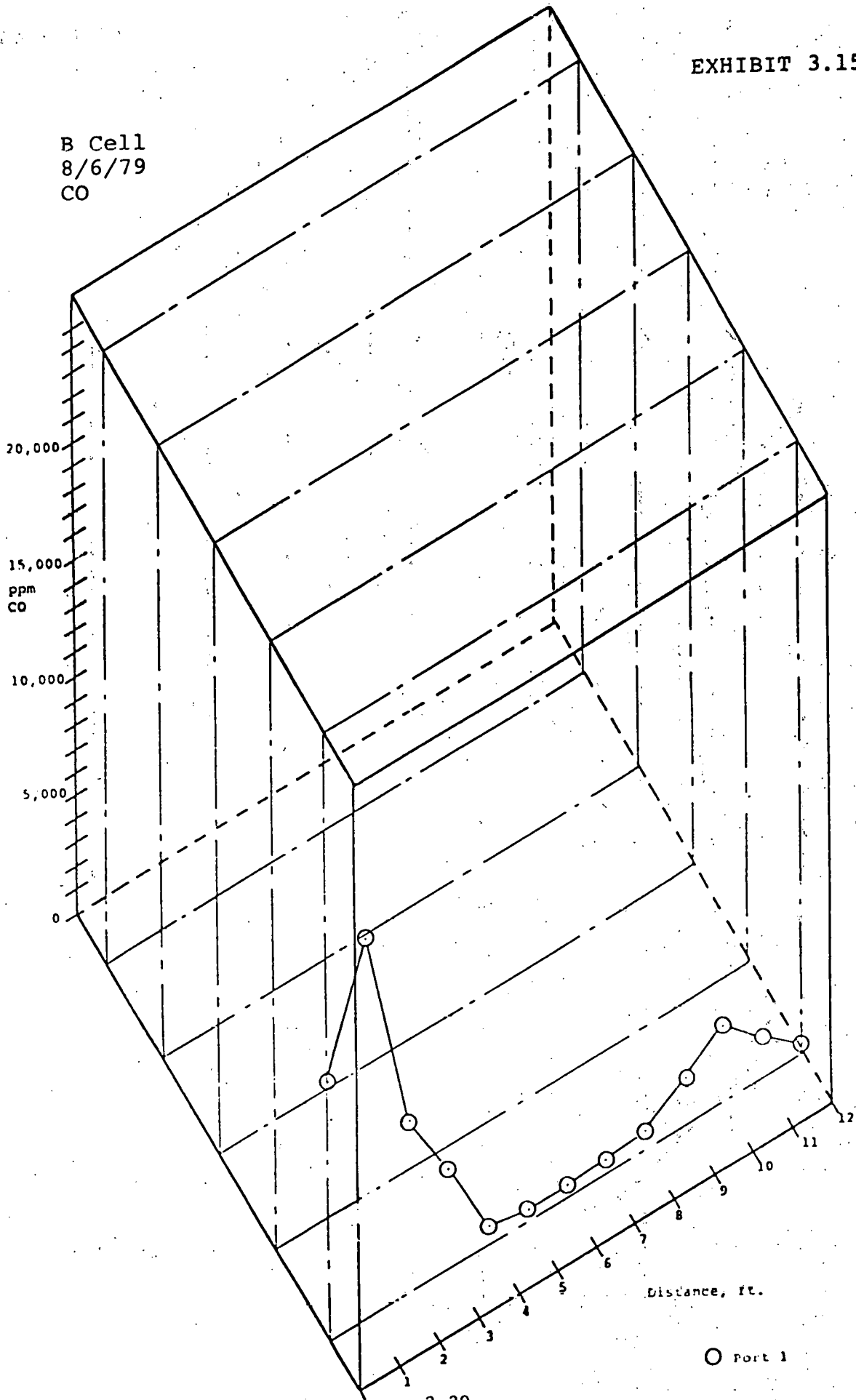
Cell Gas Traverse Probe



C Cell
8/6/79
CO

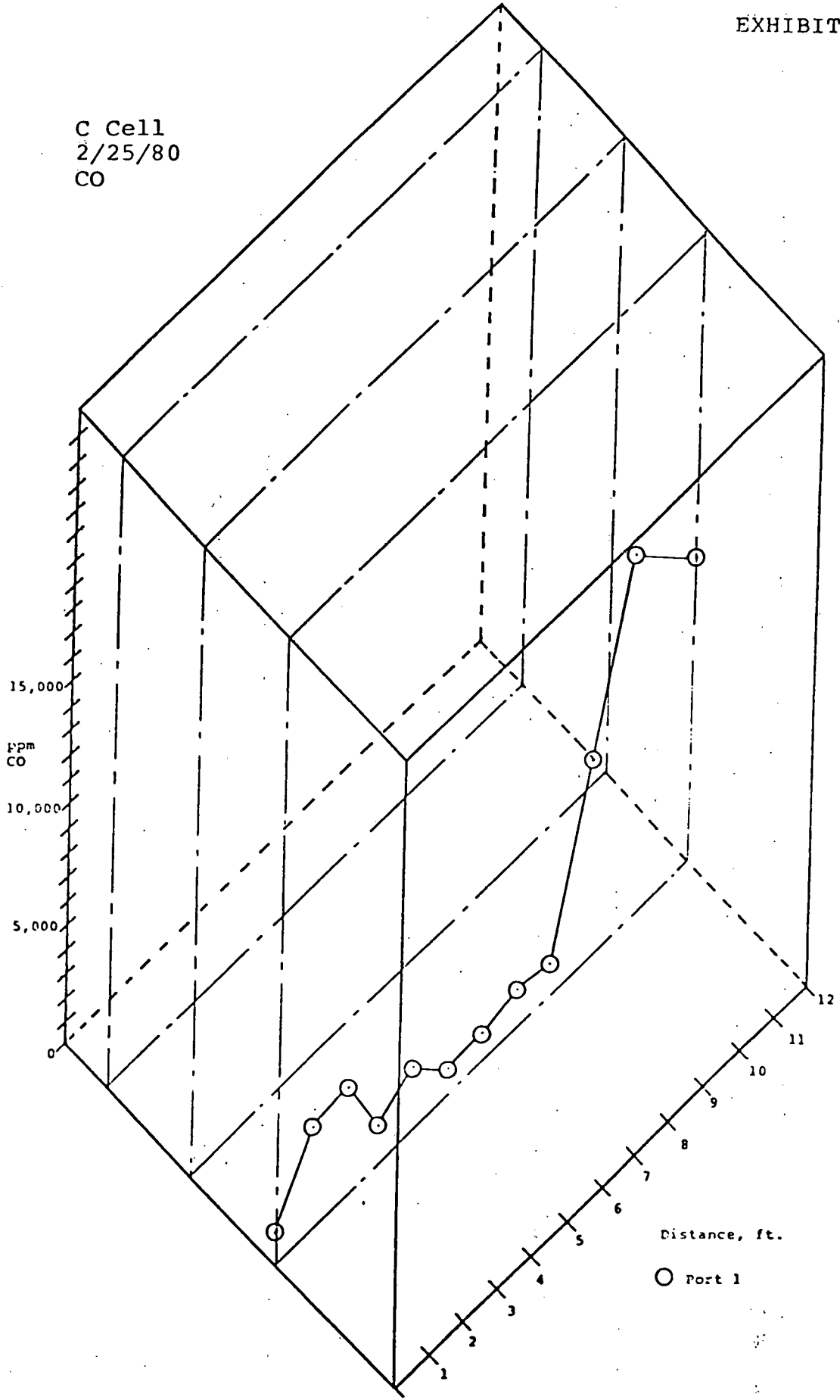


B Cell
8/6/79
CO

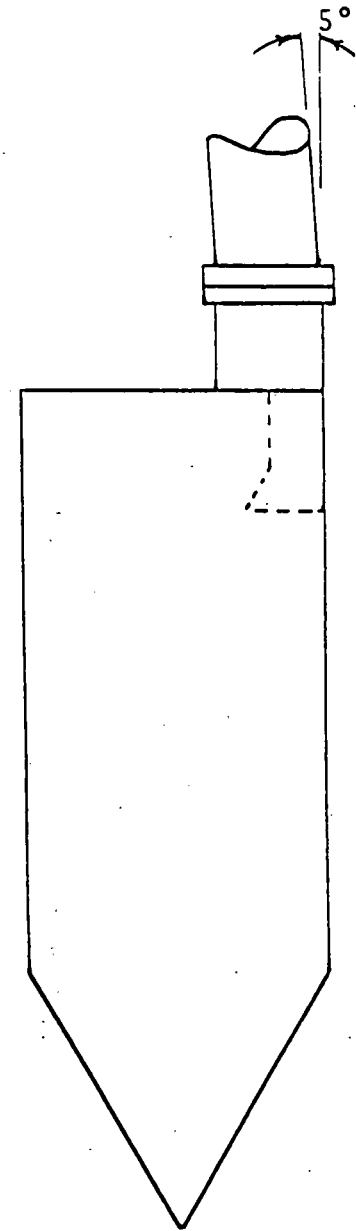
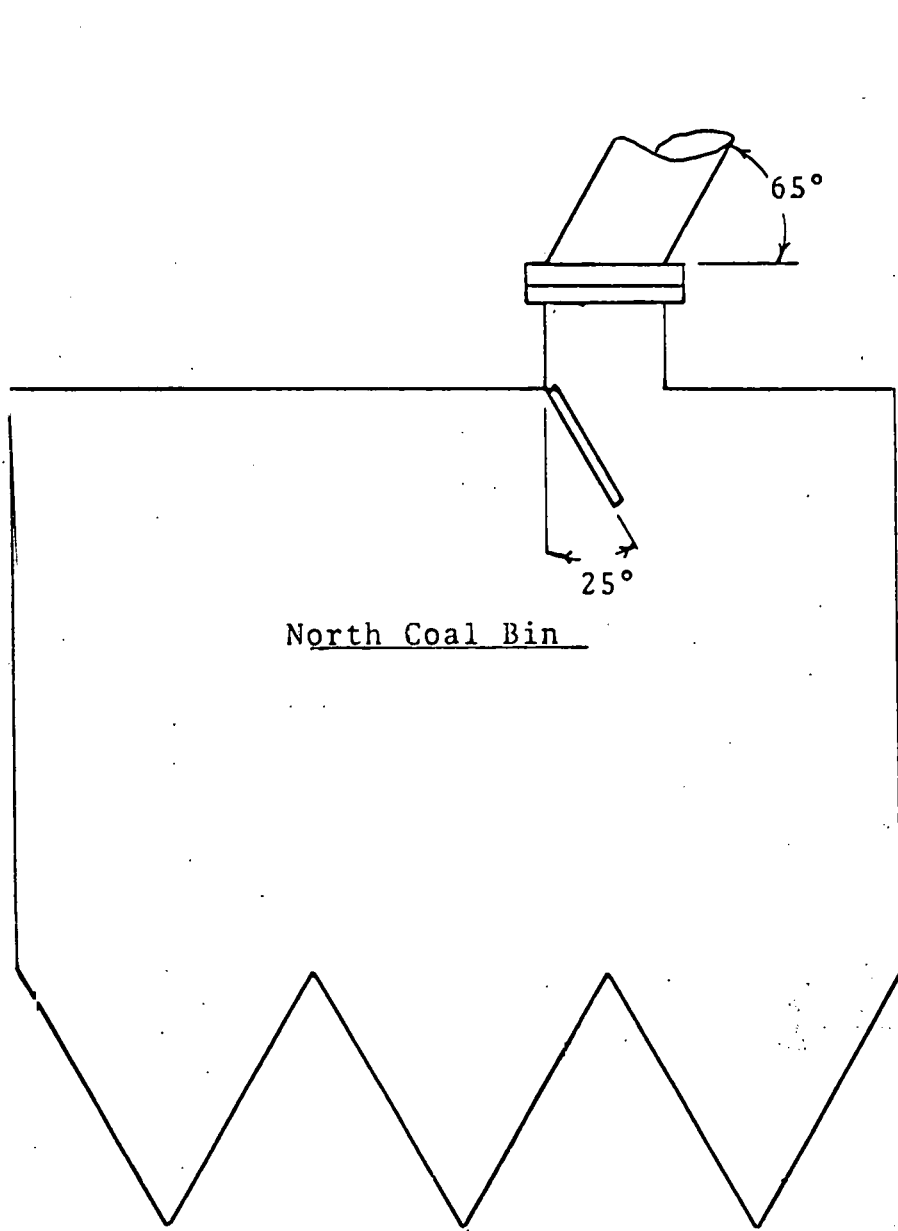


○ Port 1

C Cell
2/25/80
CO

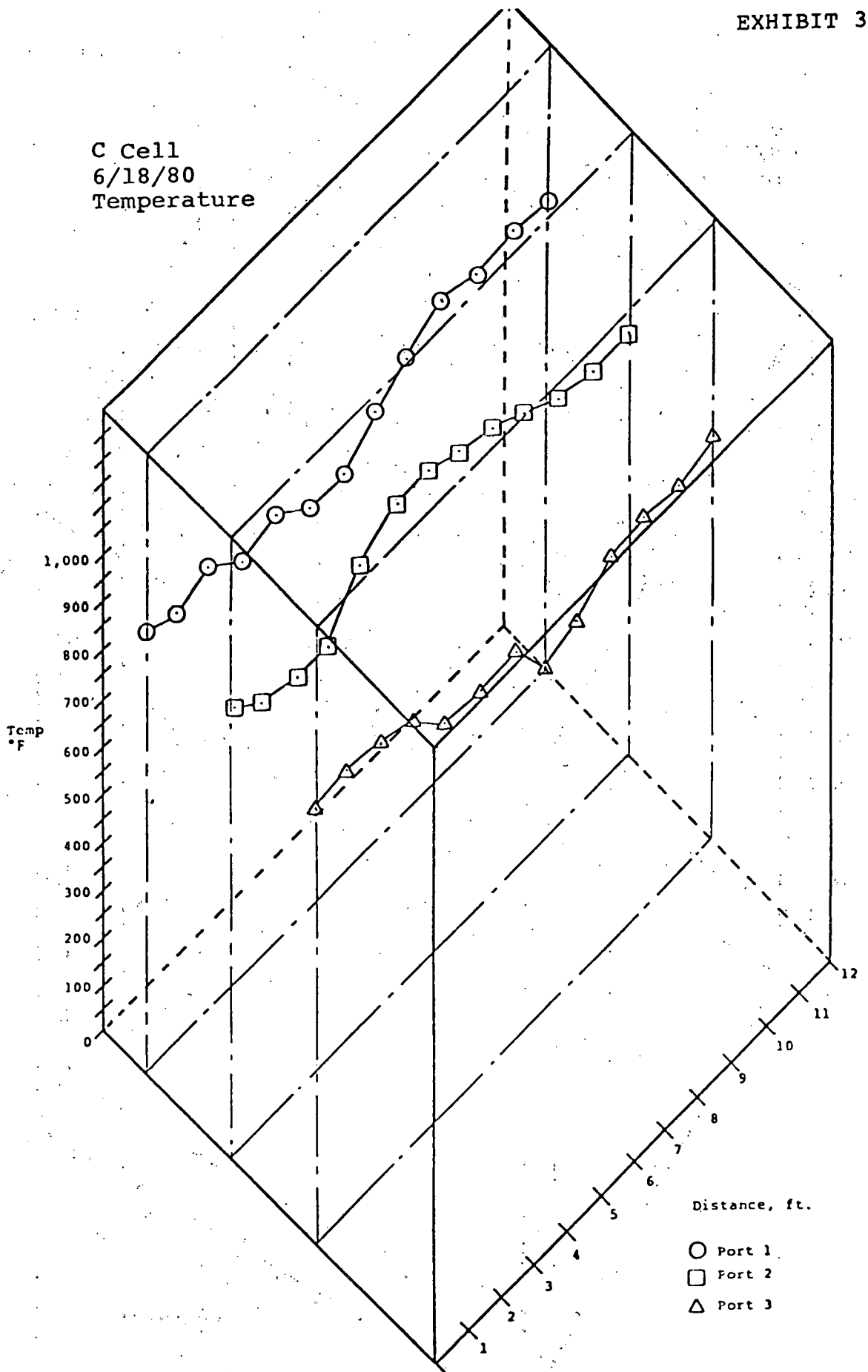


North Coal Bin Baffle Plate Location



3-41

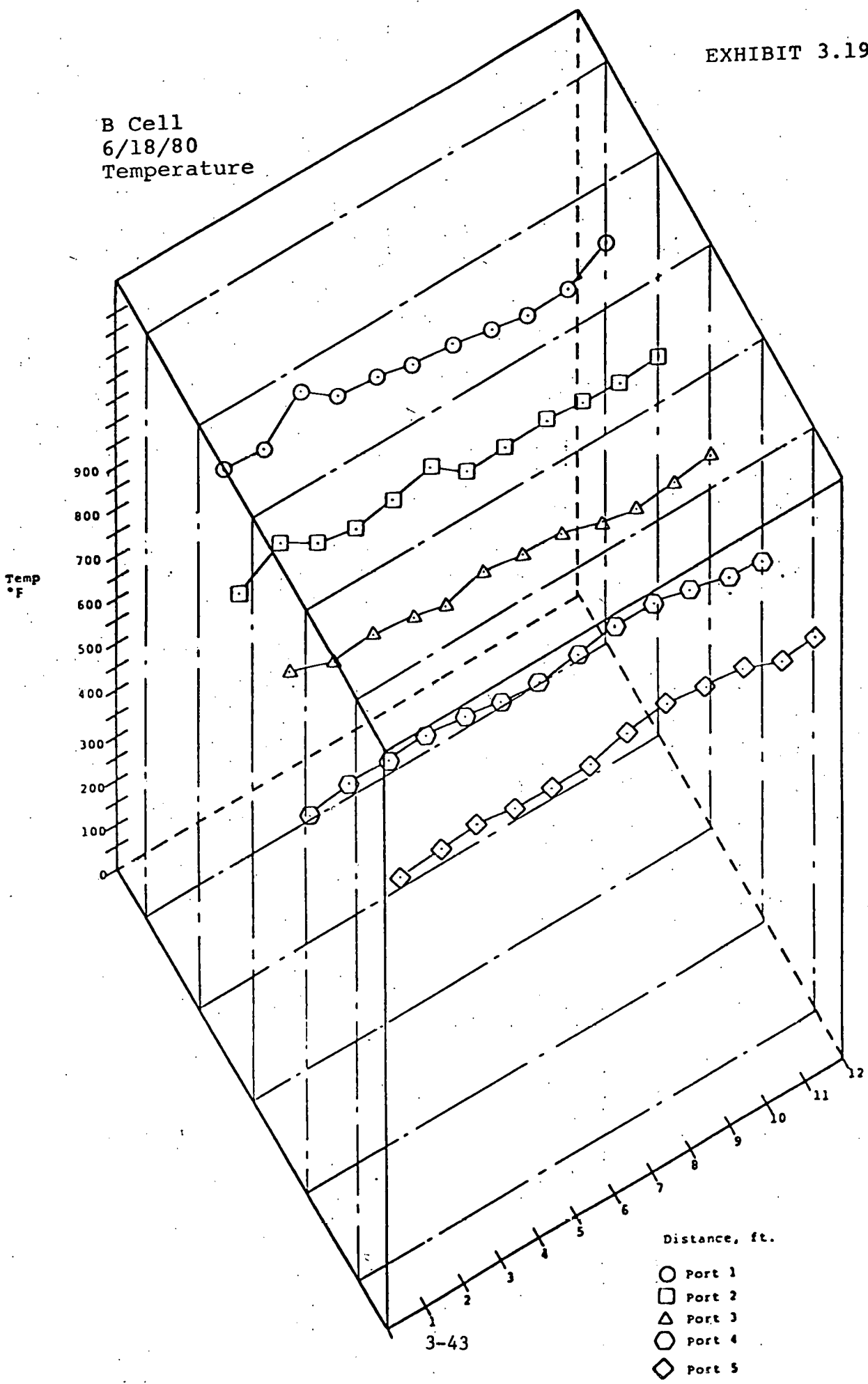
C Cell
6/18/80
Temperature



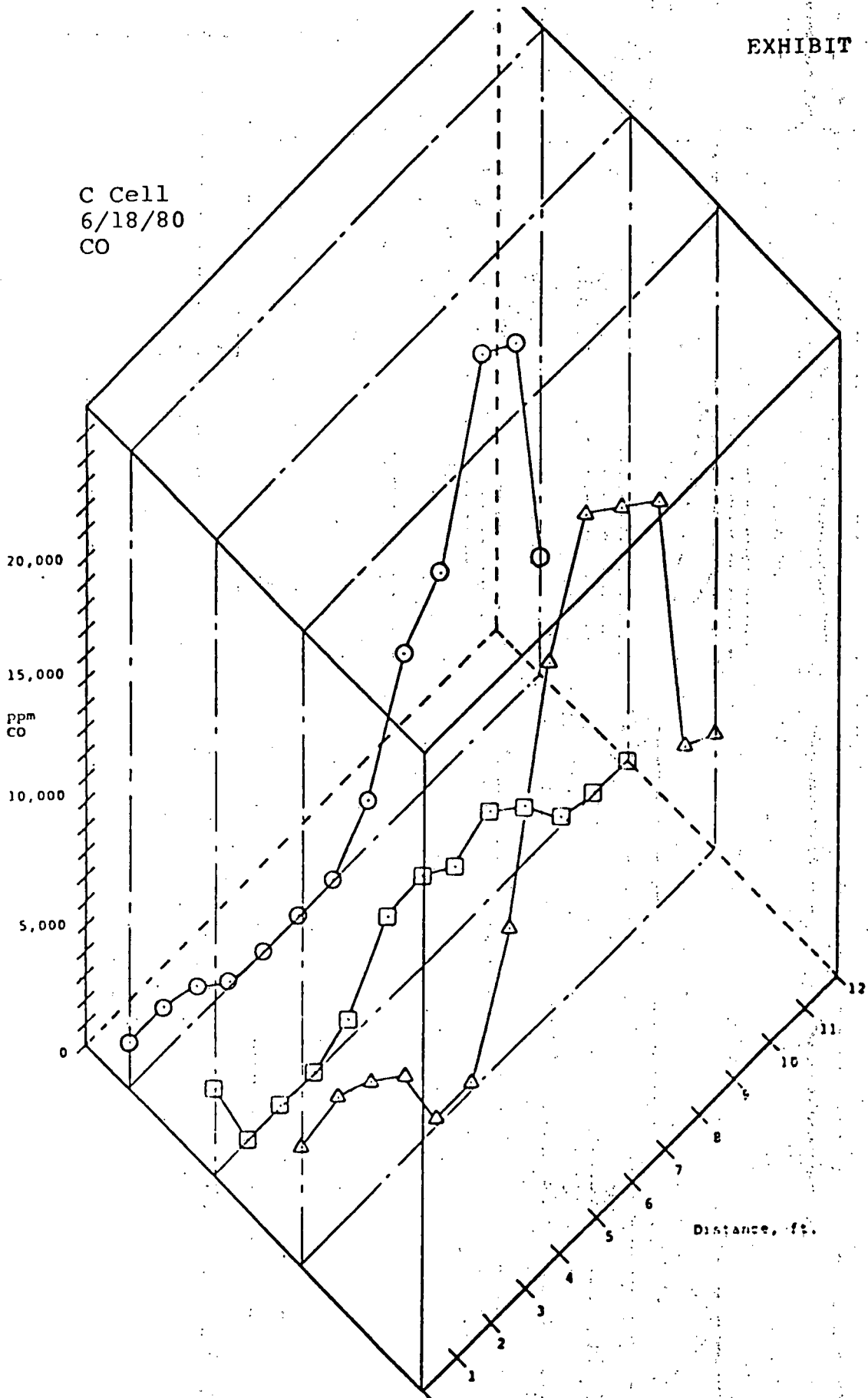
Distance, ft.

- Port 1
- Port 2
- △ Port 3

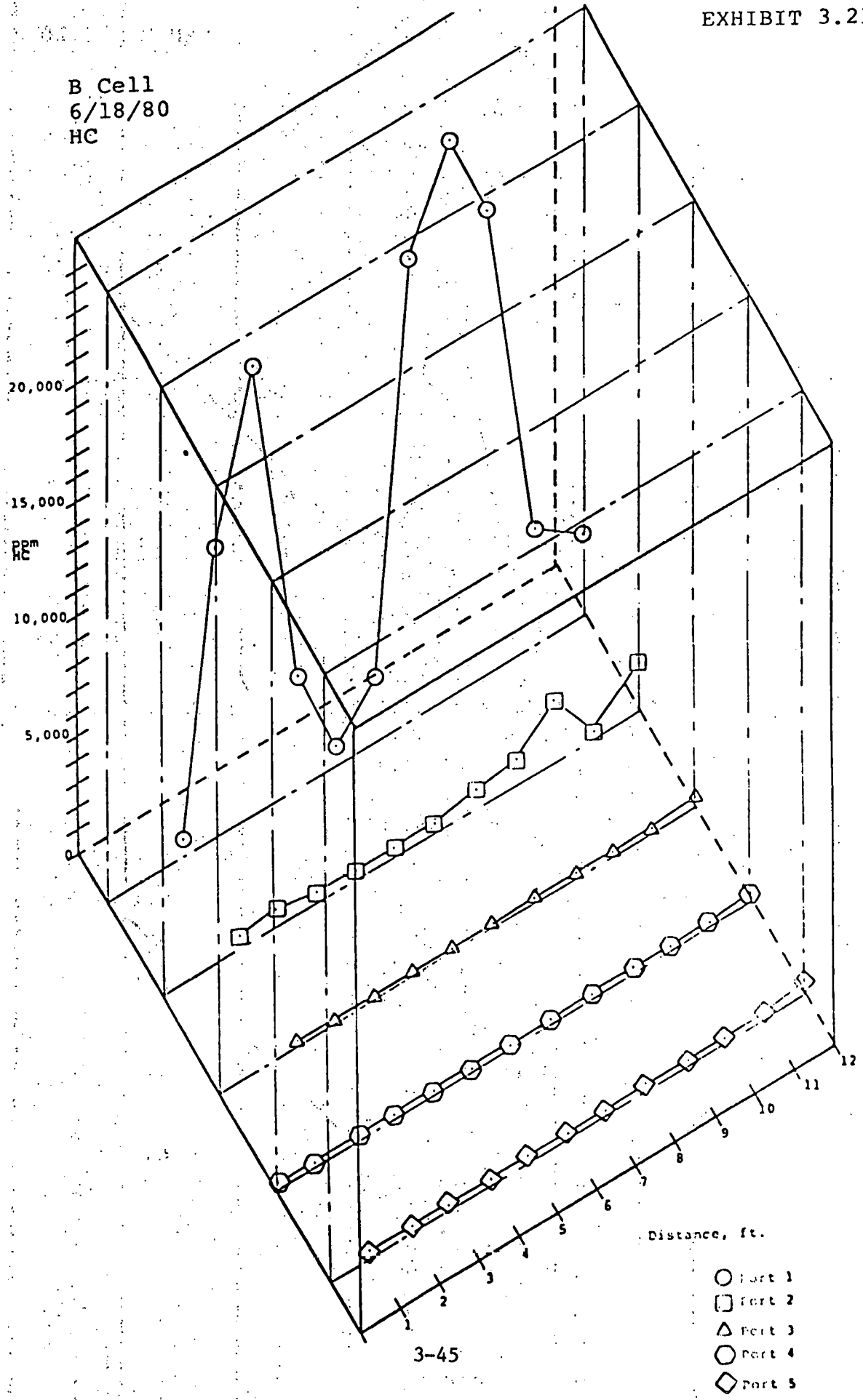
B Cell
6/18/80
Temperature



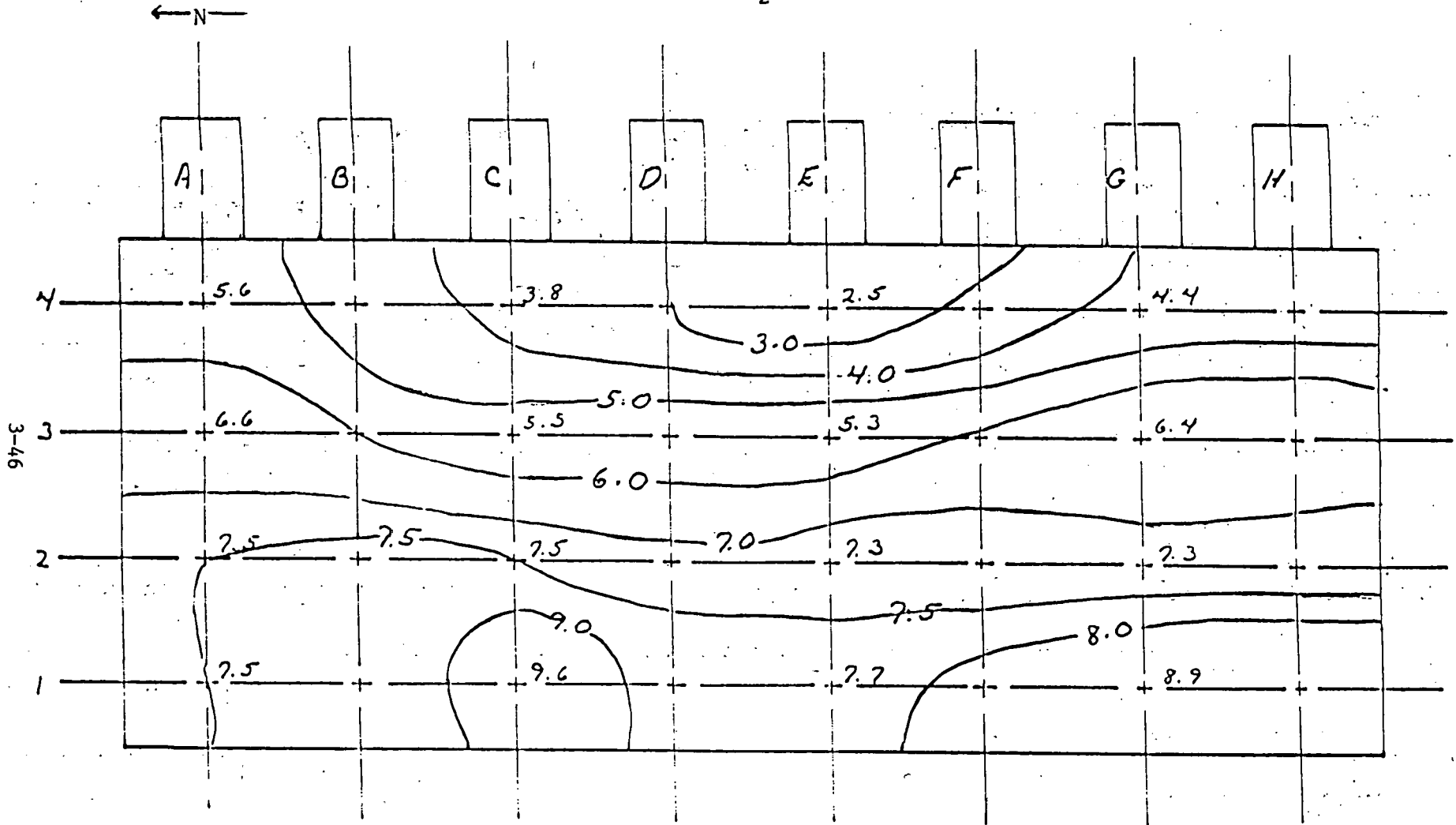
C Cell
6/18/80
CO



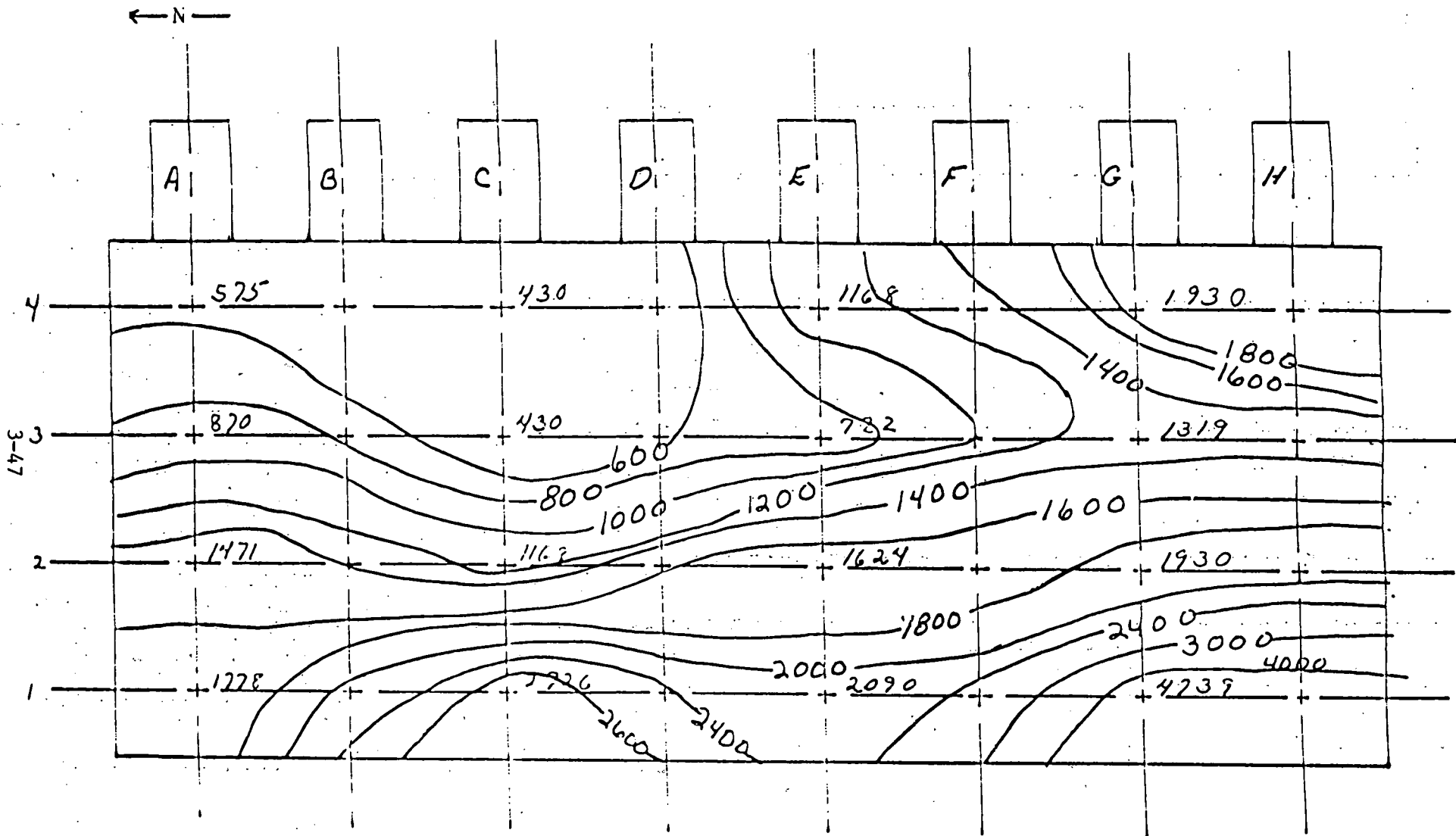
B Cell
6/18/80
HC



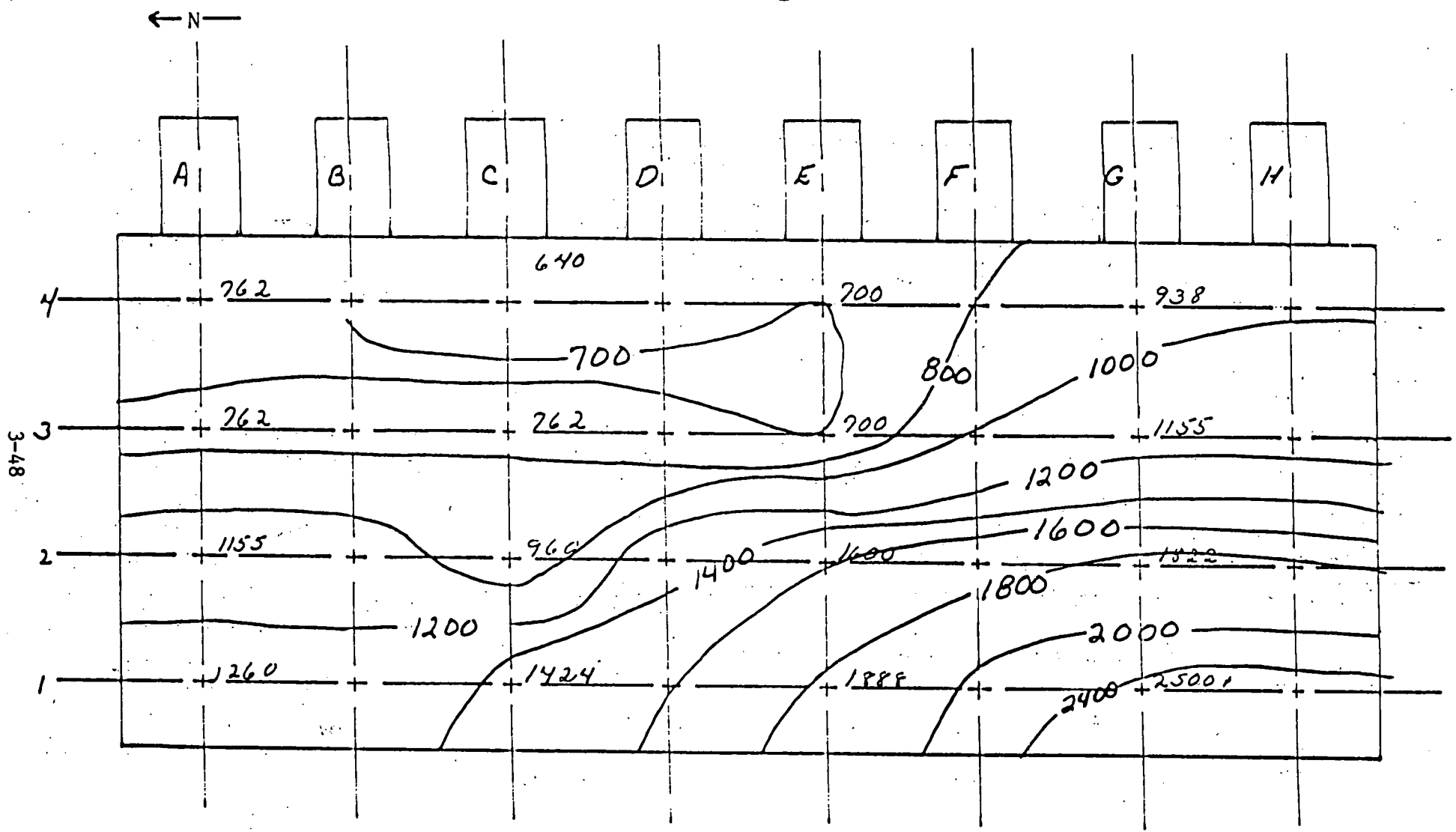
Main Uptake Gas Traverse
% CO₂



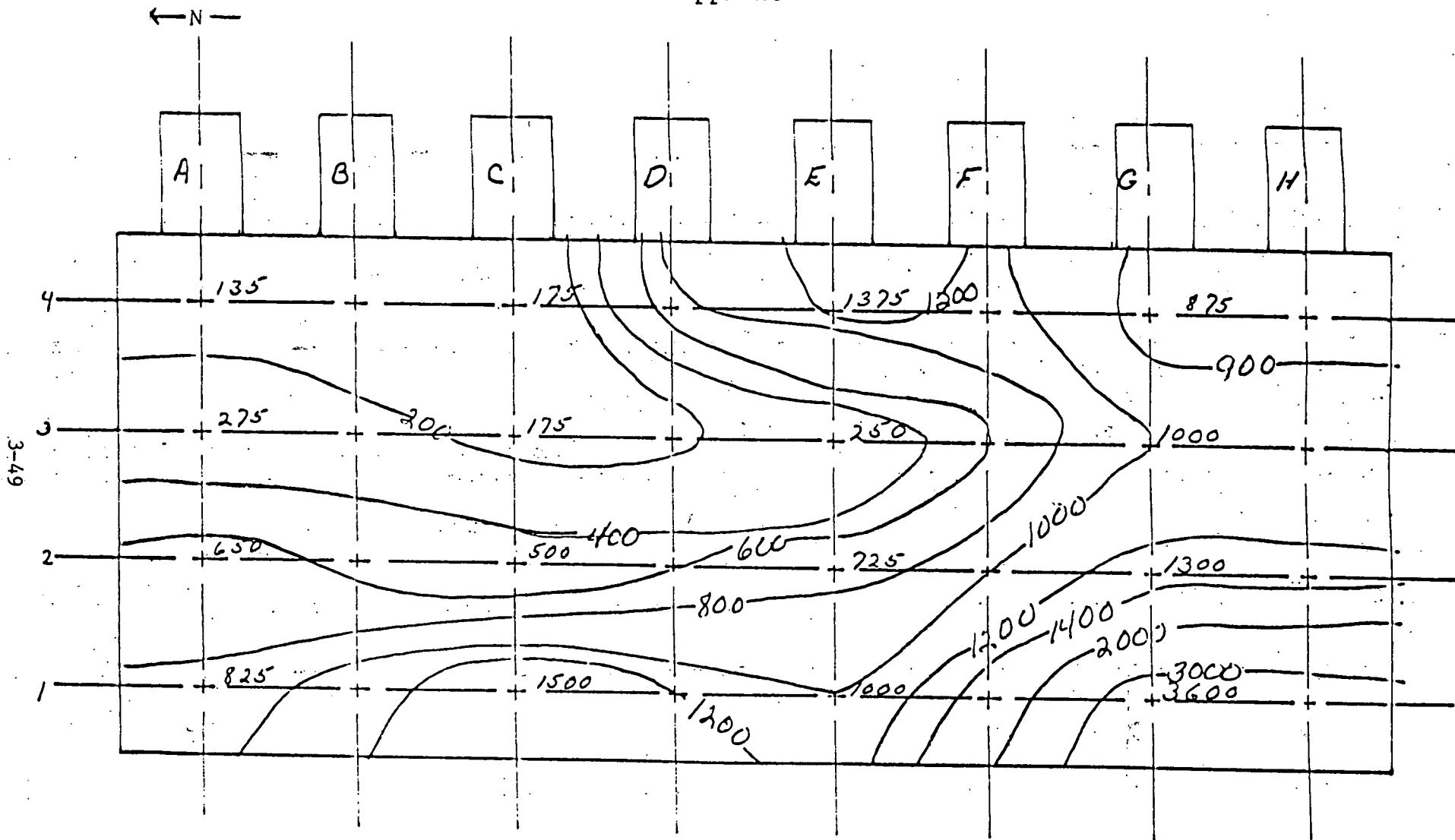
Main Uptake Gas Traverse
ppm CO



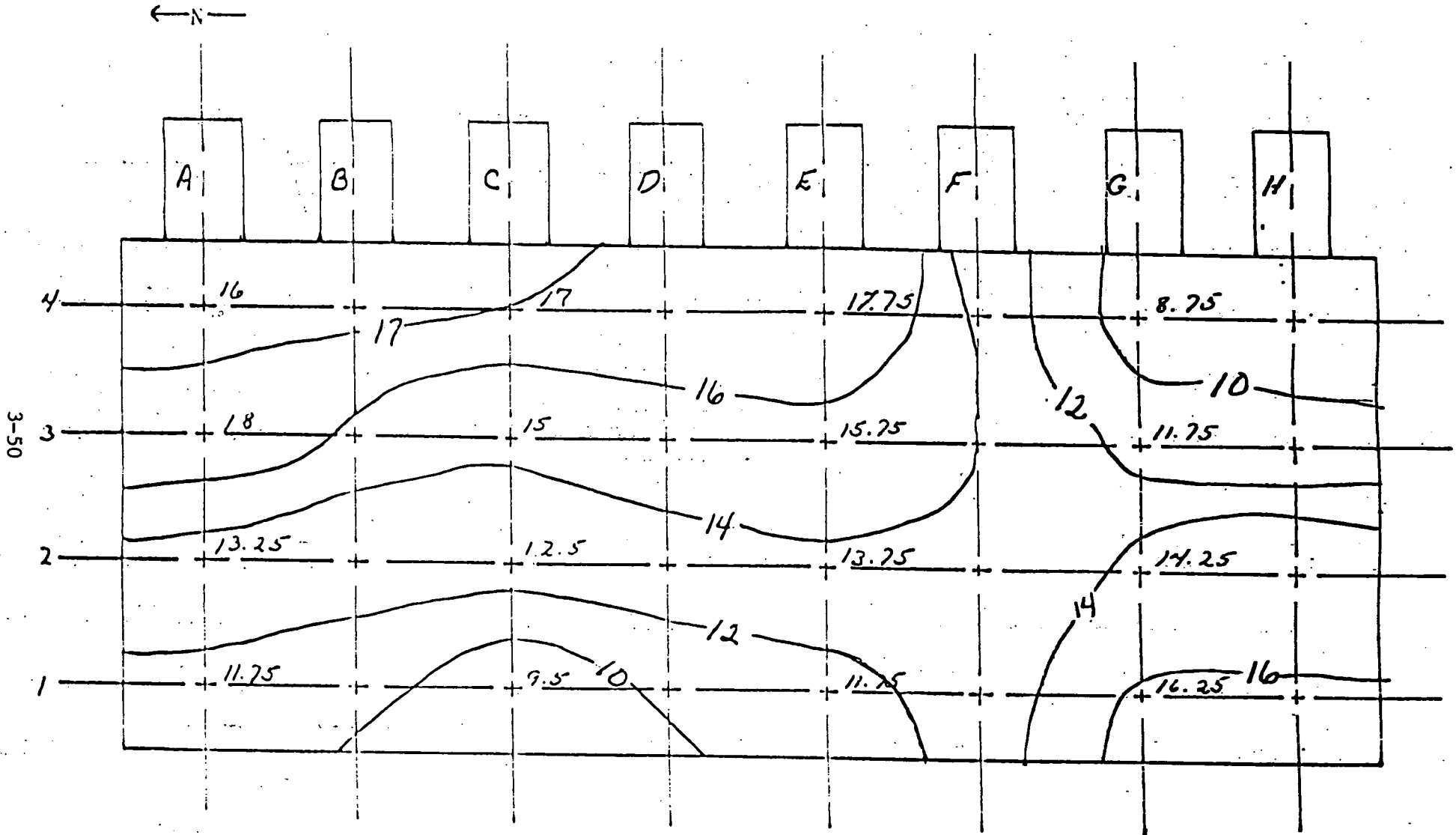
Main Uptake Gas Traverse
ppm SO₂



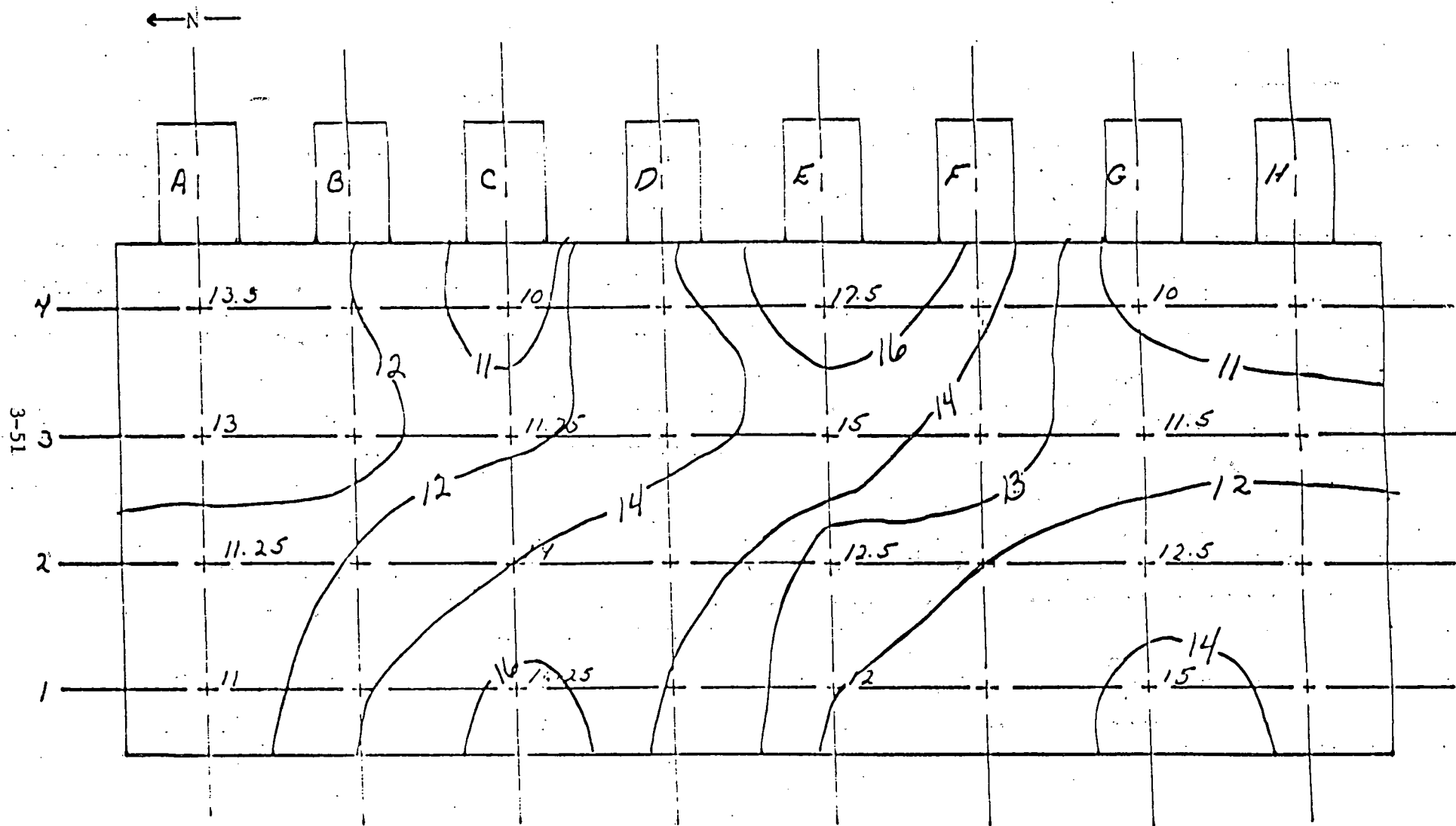
Main Uptake Gas Traverse
ppm HC



Main Uptake Gas Traverse
 % O₂ (Taylor)



Main Uptake Gas Traverse
% O₂ (Beckman)



3-51

Comparison of APH, Main Uptake & Traverse Readings

2/20/80

	CO ₂ %	O ₂ %	SO ₂ ppm	CO ppm	HC ppm
Traverse Averages *					
C Cell	13.42	3.55	1795	11.112	4535
Main Uptake	3.55	12.99	537	1367	1316
Beckman Readings					
Main Uptake	4.3	13.0	762	1778	1400
APH Inlet **	4.9	12.0	680	1933	1600

2/21/80

	CO ₂ %	O ₂ %	SO ₂ ppm	CO ppm	HC ppm
Traverse Averages					
B Cell	9.51	8.1	1286	432	65
C Cell	11.02	5.8	1873	6739	3550
Main Uptake	6.54	12.77	1269	1920	1375
Beckman Readings					
Main Uptake	6.07	12.56	1107	1472	1100
APH Inlet **	7.33	11.25	1170	1702	1325

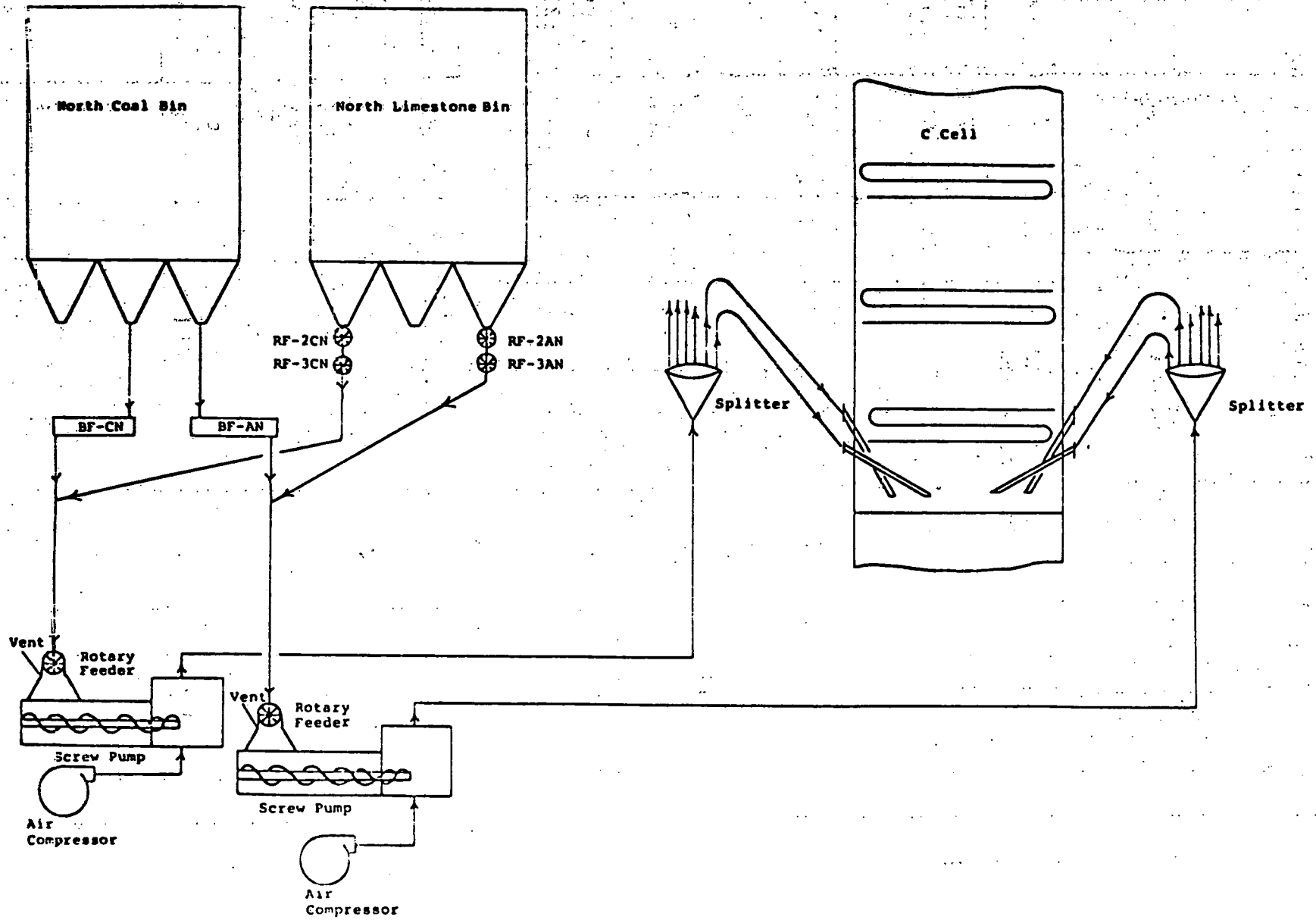
2/25/80

	CO ₂ %	O ₂ %	SO ₂ ppm	CO ppm	HC ppm
Traverse Averages					
B Cell	9.69	8.48	1014	542	19
C Cell	11.05	6.04	1880	5262	1932
Main Uptake	6.46	12.92	1189	1561	960
Beckman Readings					
Main Uptake	6.30	12.19	752	1664	669
APH Inlet **	7.33	12.25	1275	1778	938

* B cell not in operation

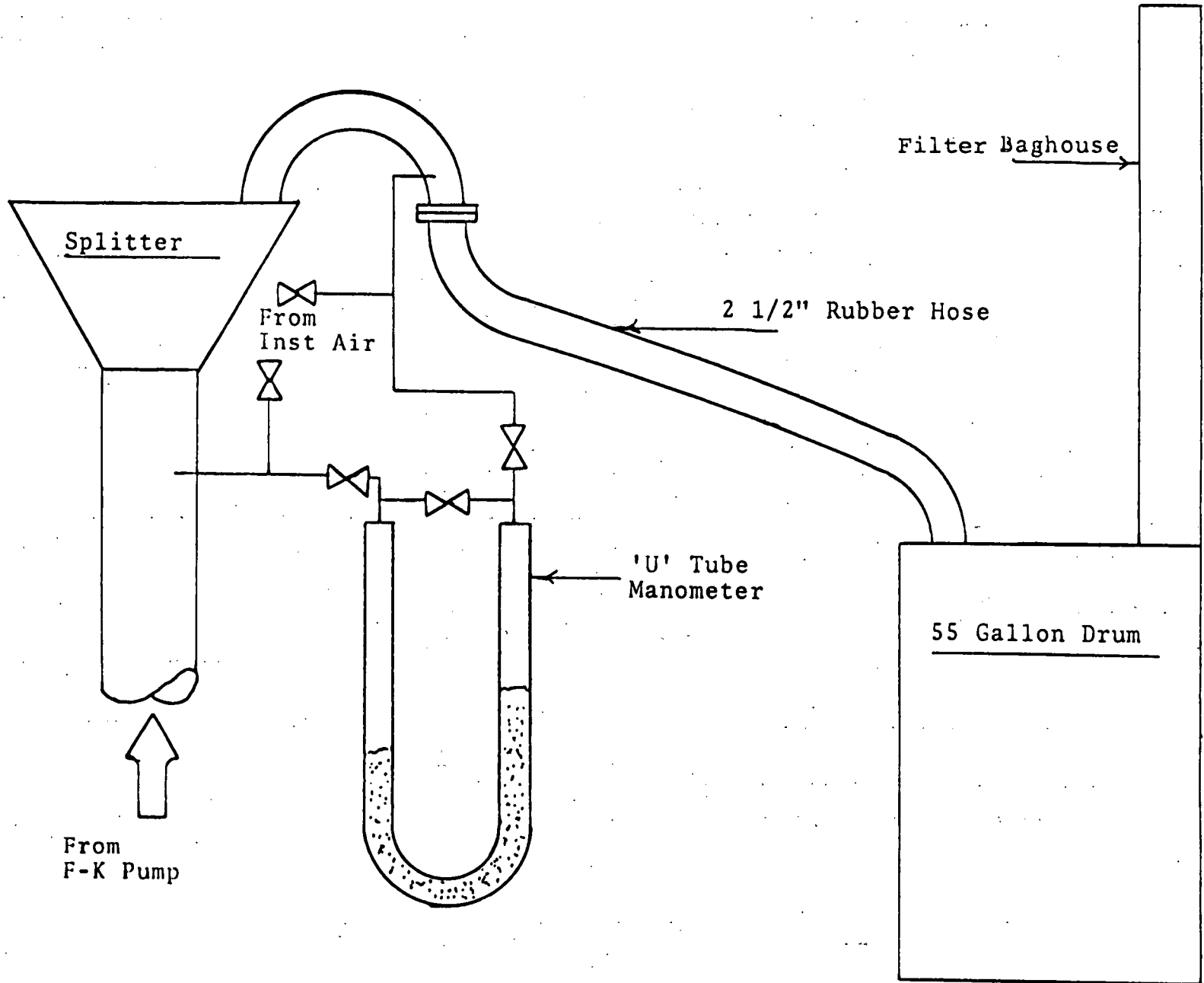
** D cell's contribution to APH inlet neglected

Fuller-Kinyon Feed System



3-53

Fuller-Kinyon Test Arrangement



3-54

EXHIBIT 3.30

C North Fuller-Kinyon System Test Results

Point No.	40% Wt Setting		80% Wt Setting	
	Weight Collected lbs.	% of Total Flow	Weight Collected lbs.	% of Total Flow
1	97.5	15	239	16
2	110.5	17	244	17
3	101.5	16	231.5	16
4	98.0	15	228	15
5	107.0	17	225.5	17
6	120.2	19	278	19
Total Wt, lbs.	635.0		1476.0	
Average Wt, lbs.	105.8		246.0	

C South Fuller-Kinyon System Test Results

Point No.	40% Wt Setting		60% Wt Setting		80% Wt Setting	
	Weight Collected lbs.	% of Total Flow	Weight Collected lbs.	% of Total Flow	Weight Collected lbs.	% of Total Flow
1	97.5	17	160.5	17	211	17
2	103	18	160.0	17	210	17
3	94.0	17	160.0	17	210	17
4	97.5	17	158.5	17	208	17
5	86.0	15	157.0	17	189.5	16
6	89.5	16	152.5	16	194	16
Total Wt., lbs.	567.5		948.5		1222.5	
Avg. Wt., lbs.	94.6		158.1		203.8	

3-56

Size Analysis of Coal Discharging Fuller System

Screen Size	Coal Entering System	Coal Discharging Fuller System					Mean Discharge* of Fuller System	
	N Coal	S 40%	S 60%	S 80%	N 40%	N 80%	MN** W/O S	MN** W/S
+1/2	0.5%	0%	0.5%	0.6%	0.3%	.2%	0.25%	0.32%
-1/2+1/4	43.7%	14.80%	17.9%	16.2%	26.9%	20.7%	23.80%	19.30%
-1/4+5	31.6%	22.1%	25.7%	18.5%	27.7%	26.3%	27.00%	24.06%
-5+10	12.6%	21.40%	21.1%	14.8%	18.5%	19.0%	18.75%	18.96%
-10+12	1.2%	2.7%	2.0%	1.7%	2.1%	2.0%	2.05%	2.10%
-12+20	0.4%	8.2%	5.3%	5.4%	6.0%	6.6%	6.30%	6.30%
-20	6.8%	30.9%	27.6%	42.8%	18.6%	25.2%	21.9%	29.02%
Mean Size μ	2886.4	1060.4	1178.5	852.0	1551.7	1252.5	1402.1	1179.02

* Average of Fuller-Kinyon discharge sizes

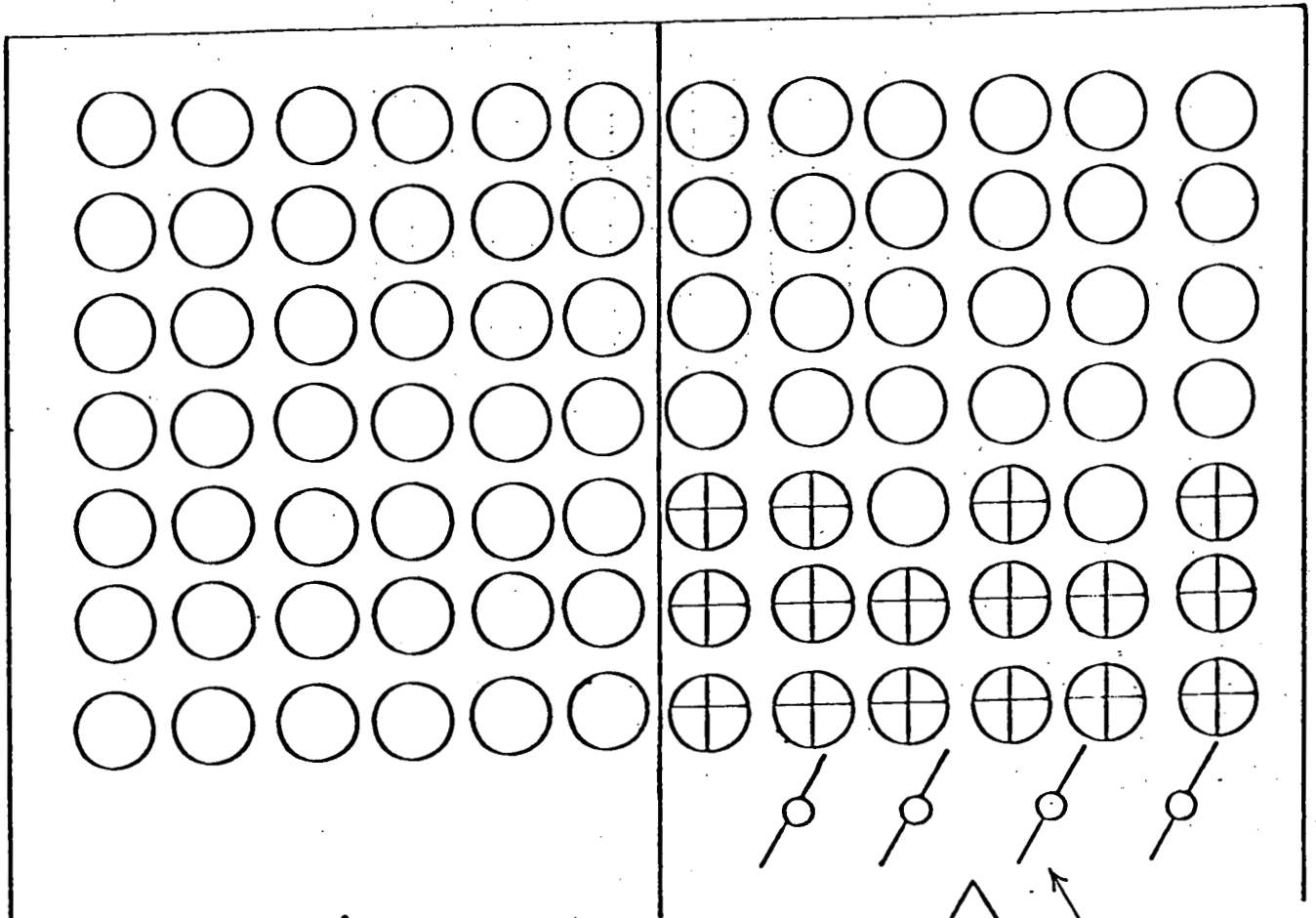
** Average of Fuller-Kinyon discharge disregarding the south side due to possible sample contamination

*** Average of all Fuller-Kinyon discharges

Dust Collector Design Conditions and Test Conditions

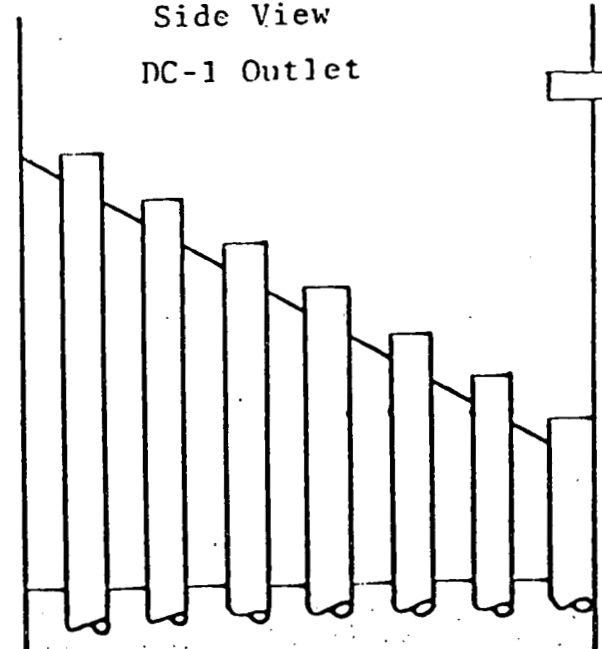
	Design Conditions	5-1-79	5-3-79
DC-1			
flow, acfm	180,000	111,352	136,457
ΔP , "WC	3.6	2.5	2.8
calc ΔP	-	1.5	2.25
% eff.	95	55.8	77.7
DC-2			
flow, acfm	19,800	28,787	27,584
ΔP , "WC	3.4	5.0	4.5
% eff.	95	86.2	74.4

Top View



Isolation
Dampers

Side View
DC-1 Outlet



Red Material
Transport Vent

N

DC-1 Performance
6/19-20/80

Inlet Loading, lb/hr	8265
Outlet Loading, lb/hr	1813
Collector Performance, %	78.1

ESP Performance Results, 200 hr Run

ESP Inlet

Test Date	3-21-80	3-23-80
% Moisture	6.71	5.67
Flow, acfm	146,599	165,533
Flow, dscfm	72,385	73,481
Flow, lb/hr	328,305	333,276
% Isokinetic	90.74	93.3
gr/acf	1.936	1.426
Particulate loading, lb/hr	2482	2023

Stack

Test Date	3-19-80	3-23-80
% Moisture	4.34	4.07
Flow, acfm	150,816	157,402
Flow, dscfm	100,660	105,381
Flow, lb/hr	456,548	477,960
% Isokinetic	102.26	99.33
gr/acf	.02196	.0184
Particulate loading, lb/hr	28.4	24.91
ESP efficiency - calculated	98.81%	98.81%
lb particulate / 10^6 BTU	0.1007	0.0884

3-61

ESP Design Conditions vs Actual Conditions

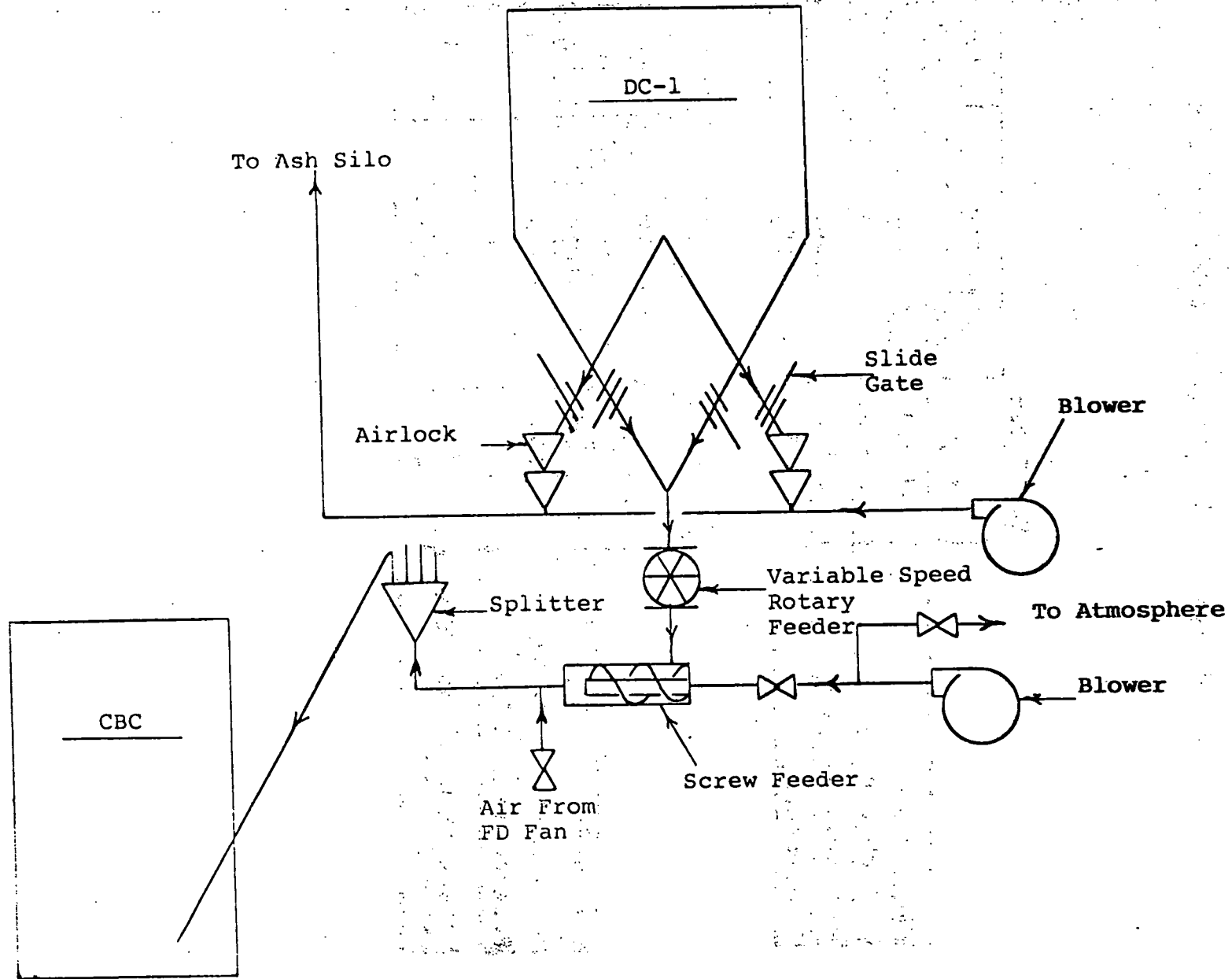
ESP Inlet

	Design	Average	Average
		April-May 1979	March 1980
Flow, acfm	203,000	165,000	156,000
Particulate: gr/acfm	0.875	1.48	1.68
Particulate: lb/hr	1,500	1,966	1,252
Temperature, ..	700	599	606

ESP Outlet

	Design	Average	Average
		April-May 1979	March 1980
Flow, acfm	203,000	165,000	154,000
Particulate: gr/acfm	0.009	0.176	0.020
Particulate: lb/hr	12.0	245	26.65
Particulate: lb/10 ⁶ BTU	0.1	0.89	0.095
ESP efficiency	99.0	87.8	98.8

Flyash Reinjection, New Feeder System



3-63

EXHIBIT 3.39

Flyash Reinjection, Airlock System

3-64

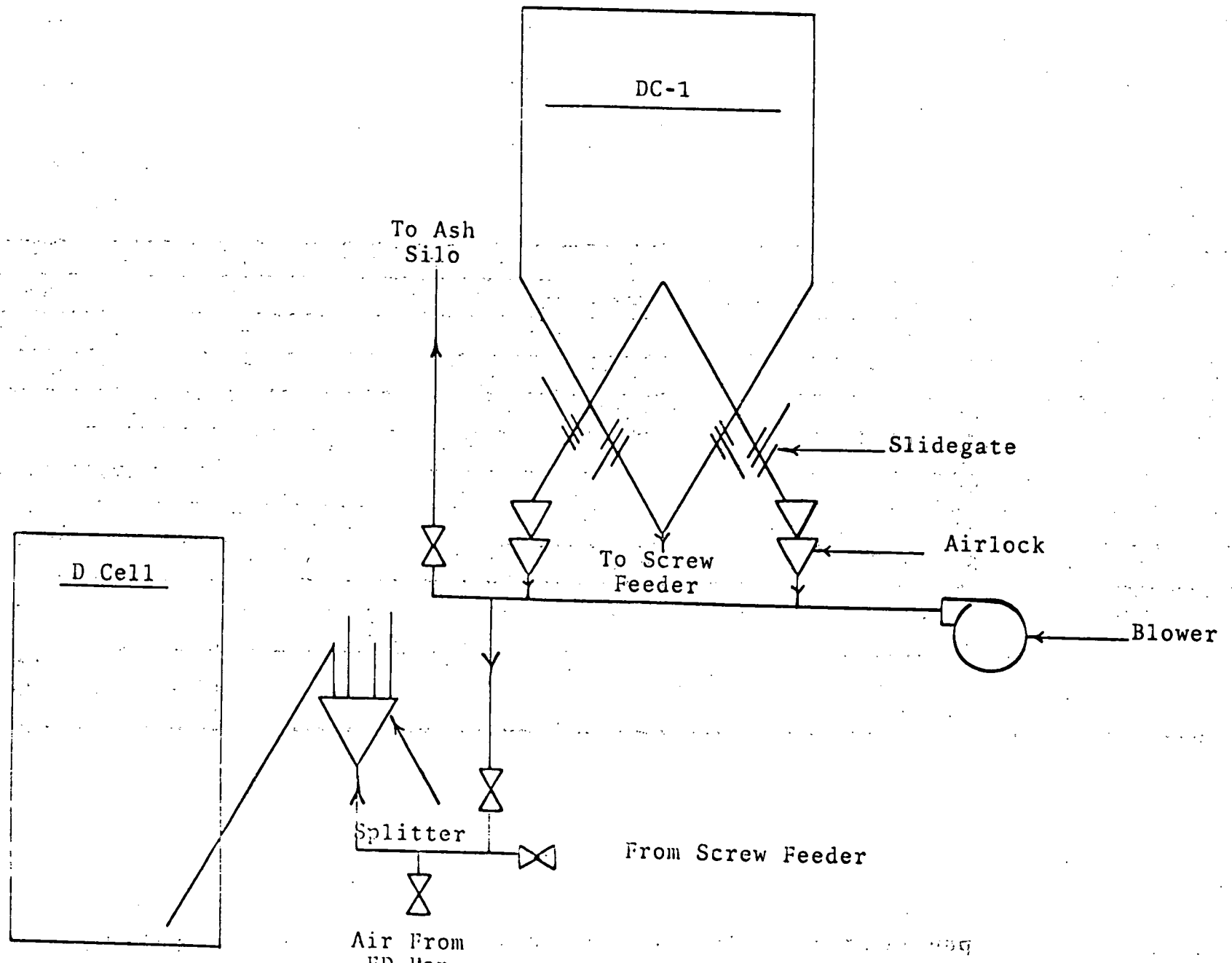


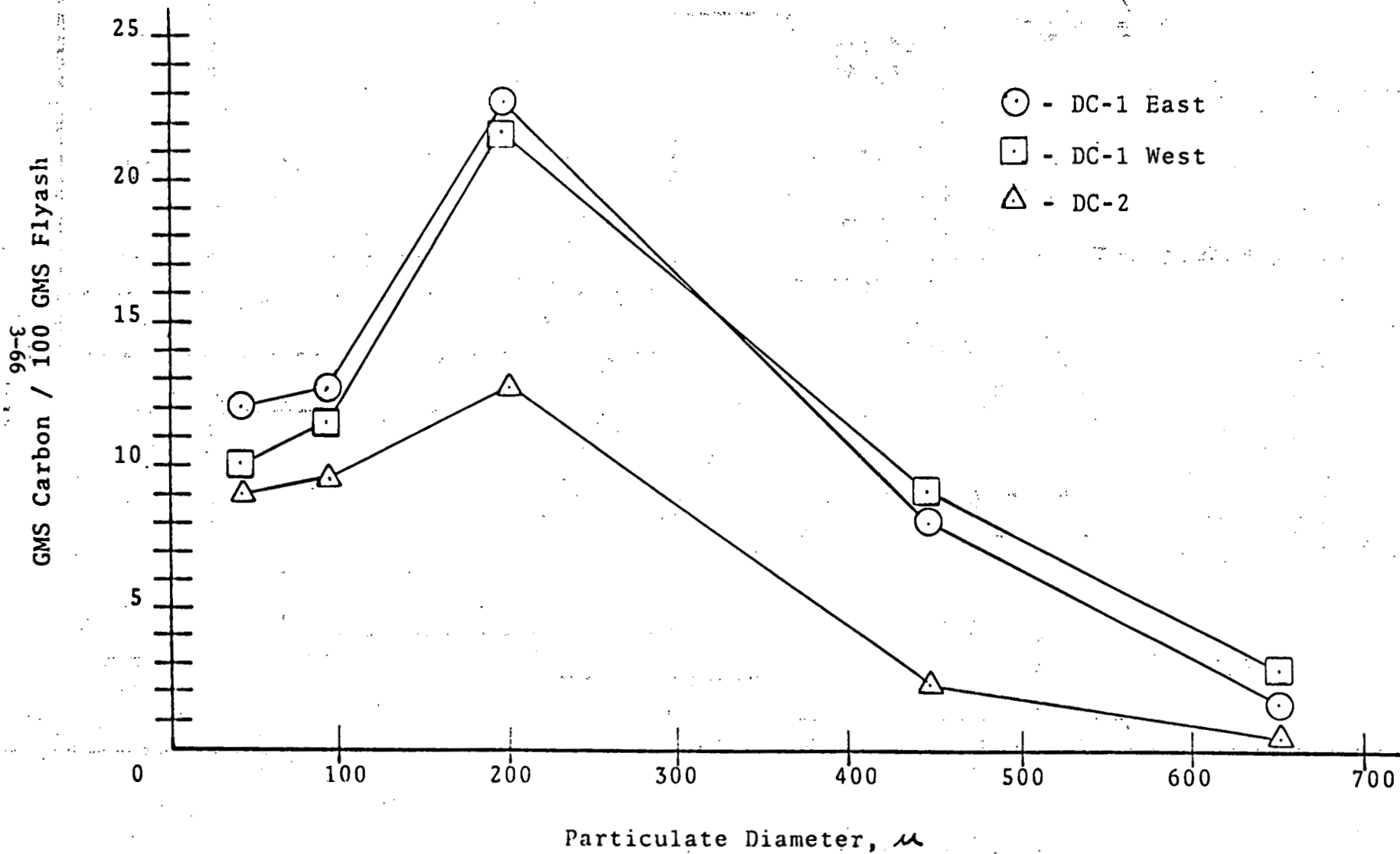
EXHIBIT 3.40

Carbon and Hydrogen as a Function of Size for Flyash Entering and Leaving CBC

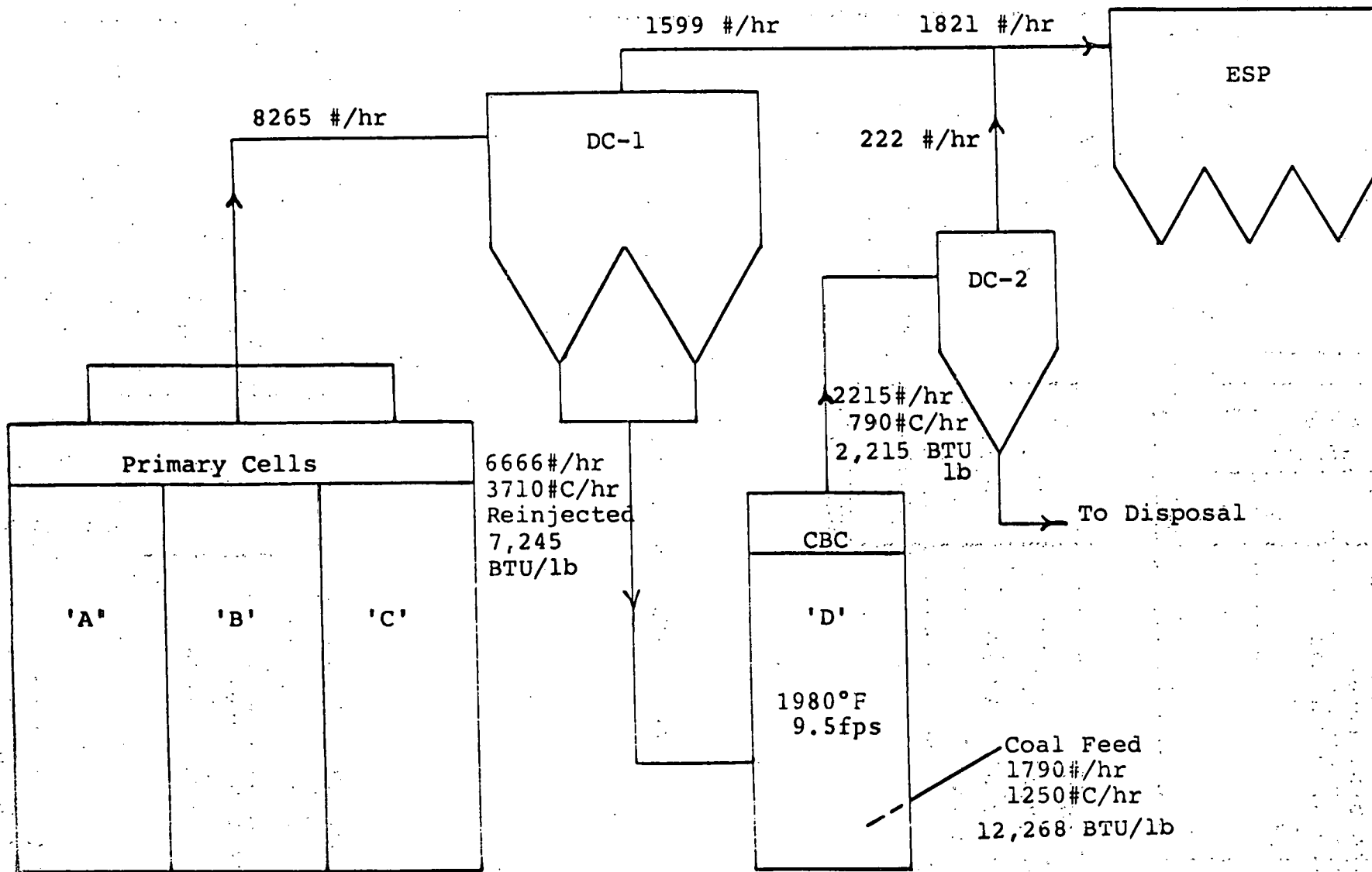
3-65

USS Sieve	Ave Sieve Diam. μ	DC-1 West			DC-1 East			DC-2		
		Mass Fract.	% C	% H	Mass Fract.	% C	% H	Mass Fract.	% C	% H
+30	655	.0386	61.72	0.84	.0182	57.90	0.85	.0096	42.57	0.40
-30+50	450	.1870	47.88	0.76	.1344	62.09	1.08	.1181	16.18	0.17
-50+120	213	.3720	59.18	1.25	.3622	62.44	1.36	.2953	42.12	0.40
-120+200	100	.1931	60.33	1.24	.2164	57.44	1.25	.1882	50.51	0.53
-200	38	.2093	47.83	1.04	.2688	45.23	1.11	.3887	23.27	0.42
Weighted Avg.			55.01	1.10		56.60	1.22		33.31	0.40
Composite Avg.			54.97	1.14		56.33	1.27		35.81	0.40
Composite % Ash			42.90			40.25			66.40	
MN Part Diam. μ		102.7			88.0			71.9		

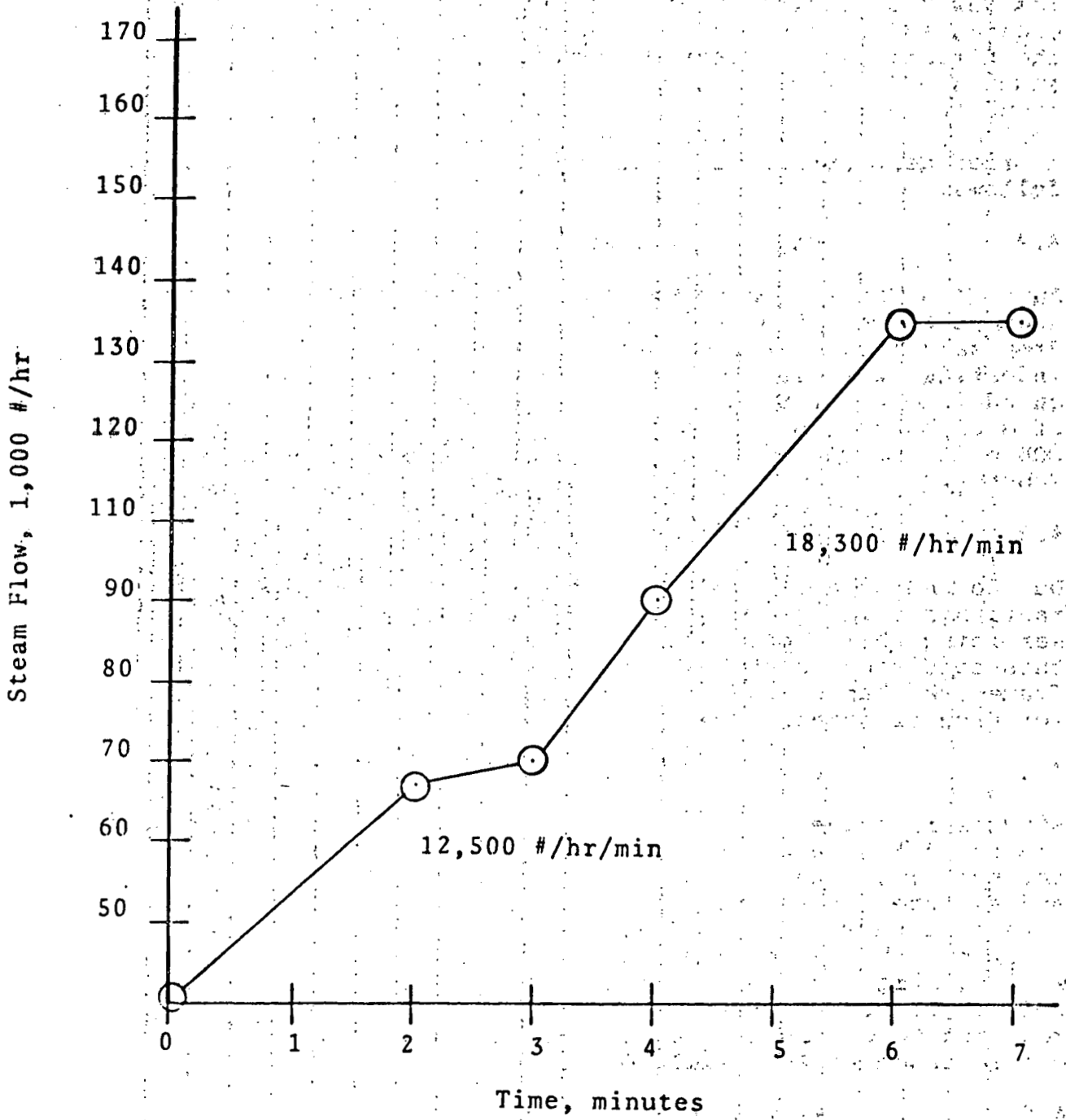
Grams of Carbon per 100gms of Sample Flyash Entering and Leaving CBC



3-67



MFB Load Following Results



IV. DESIGN AND ENGINEERING

4.1 General

The New York Office design and engineering staff has been engaged in various tasks in support of the overall program and the Rivesville MFB Plant Operations. These tasks include studies and evaluations of systems and equipment and modifications to the MFB plant to improve performance and increase reliability based on experience gained from operation. A brief description of their activities during this period follows:

4.2 Baghouse Filter Evaluation

An evaluation was conducted for a fabric filter (baghouse) to augment the electrostatic filter at the Rivesville MFB. Proposals from Standard Haven, Combustion Engineering and Zurn Industries were reviewed together with a study of the impact on additional structural work required to accommodate the offered baghouses. Final recommendations were presented to DOE based on reviews conducted by PER-NY and Stone and Webster.

4.3 Boiler Circulating Pumps

Due to the basement location of the boiler circulating pumps, there has been considerable difficulty in removing and servicing the pumps. During a trip to the site to alleviate this condition, sketches were prepared for a structural framework that would serve to facilitate removal and replacement for ease of maintenance.

4.4 Flyash Removal System

Studies into the use of a vacuum system for flyash transport indicated that a negative pressure of -15" Hg was needed for the system to function properly. An evaluation was conducted and sketches of the necessary modifications to the ash silo were sent to Rivesville Operations for implementation. In addition, the use of a vacuum transport system for bed material was investigated along with utilizing existing No. 4 Dust Collector. Upon investigation of the structural modifications required to withstand the -15" Hg pressure, this information was released to Rivesville Operations.

4.5 Alexandria Ash Silo Support

In order to facilitate loading of collected material, the ash silo structural support system design was modified to raise it sufficiently to permit a truck back-up under the silo.

4.6

Alternate Coal Feed System for C Cell

Design drawings for the Fuller-Kinyon coal feed system, authorized for installation in Cell C on a trial basis by the DOE, were prepared and reviewed by the Fuller-Kinyon Company. The system utilizes compressed air to impinge on the fuel and limestone particles and forces them through a splitter and feed tubes into the boiler bed. Approved drawings for installation were furnished to Rivesville Operations. An updated drawing of the splitter assembly was received and reviewed. Control circuit design sketches for the Fuller equipment were also reviewed. The design was based on manual starting and stopping of the various components from individual push buttons with interlocks provided to prevent operation out of sequence. Prints of the Dracco Model BC air filter were reviewed along with a copy of the installation, operation and maintenance manual.

4.7

Update of "As Built" Drawings

Updating of design analysis and drawing revisions continued, to reflect "as built" conditions. A structural design check was completed for the laboratory second floor slab, as requested by Rivesville Operations, to determine the structural adequacy of storing thirty (30) gas bottles (100 lb each) on the northwest corner of the center room.

4.8

Fuller-Kinyon Expansion Joints

With regard to the Fuller-Kinyon coal injection system, investigated the need for expansion joints on the vertical run to accommodate downward thermal expansion of the boiler. Checked the magnitude of boiler movement and the feed piping from the splitter to the needles and concluded that the system does not require expansion joints.

V. SUBCONTRACTOR ACTIVITIES

5.1 General

In support of development, operation and improvements to the Rivesville MFB unit, the expertise of several major organizations were subcontracted. The more significant subcontracts during this reporting period were with Foster Wheeler Energy Corporation (FWEC) and Stone and Webster Engineering Corporation (S&W). A brief description of their activities follows:

5.2 Foster Wheeler Energy Corporation

FWEC continued to provide subcontract services in support of operation and improvement in performance and reliability of the Rivesville MFB unit, until the early part of 1980. During this reporting period, final design and detailing of the air distributors for cells C and B were completed. The air distributor units were delivered and installed at the Rivesville unit. Engineering evaluation of full load and part load performance of the Rivesville MFB steam generator were conducted.

5.2.1 Phase IX-Systems Evaluation

During this reporting period data on boiler circulation was taken during C and D cell operation. Based on the operating conditions and calculated results, it was determined that the unit circulation was expected and agreed closely with the design mass flow requirements.

5.3 Stone and Webster Engineering Corporation

Stone and Webster activities for the twelve month period, July 1979 through June 1980, concentrated on providing headquarters and on-site engineering and design support to PER for the testing program, operations and specified investigations. Through the twelve months S&W was primarily concerned with operational problems and system performance improvements. S&W assisted PER in the design and testing of the many system modifications and new systems.

At the end of this reporting period, reports have been prepared and submitted to PER on the Auxiliary Steam System Operation, DC-1 Modification, Flyash Reinjection, T-42 Modification, Eductor Blower Test, Ultrasonic Tests performed on the Fuller-Kinyon System and the "B" and "C" cell waterwall tubes and Flyash Recirculation to the Main Beds. Particular attention was supplied to PER for the purchase and installation of the Flyash Reinjection System, the Fuller-Kinyon System, and the Eductor Feed System.

5.3.1 Specific Headquarter Activities

The following Engineering/Design Reports were completed during the period:

EDR-05	"Comments on Buell Report" "Electrostatic Precipitator Operation"
EDR-08	"Vibrating Feeder/Belt Feeder Auxiliary Air" "Flyash Reinjection Equipment Manufacturer Recommendation" "Belt Feeder/Bin Air Leakage"
EDR-10	"Atmospheric Vent Valve" "Turbine Bypass System" "Ash Cooler Transport Ejectors" "Bed Material Storage Tank Transport Ejectors"
EDR-13	"2½" Slide Gate for Bed Letdown DWG. No. BM-12E-1"

5.3.2 Specifications

EDR-10-14	Atmospheric Vent Valve
-----------	------------------------

5.3.3 Specific Activities

The following Field Reports were completed during the period:

FR-39	MPC Boiler Feed Pump #7 Damage
FR-40	FAR Utilizing DV-1 Lockhoppers
FR-41	Sunstrand Eductor Blowers
FR-42	Instrument Air System Review
FR-43	Seal Water Cooling Direct from FBP
FR-44	Auxiliary Steam System Operation
FR-45	Precipitator and Boiler Thermal Growth
FR-46	Fuller-Kinyon System
FR-47	Chemistry Training
FR-48	DC-1 Modification to Cyclones
FR-49	Flyash Reinjection

5.3.4

Results

Stone and Webster assisted PER in developing test plans, performing the tests, and results analysis, particularly for the systems involved in S&W field reports and Engineering/Design Report.

6.0 Rivesville Quarterly Report
(for Period January - March 1980)

6.1 General

The Rivesville MFB operated successfully throughout the reporting period, and sustained several "long term" commercial operating runs. The new fuel feed system in C-cell was tested, fuel feed needles in all three cells were extended farther into the cell during the reporting period, and the electrostatic precipitator equipped with all new stainless steel emitting wires was evaluated.

Performance and test data were collected on the following activities:

- Fuller-Kinyon Fuel Feed
- B and C-cell Air distributor
- Flyash Reinjection System
- C and B-cell Combustion (Cell Traverses)
- Electrostatic Precipitator Performance

6.2 Start-up/Operation Activities

- January 7 Coal fire was established in the MFB for the first time since September 1979 when the unit went into an extended outage phase.
- January 8 Coal fire was transferred to C-cell as the first "hot" operational test of the new Fuller-Kinyon fuel feed system was demonstrated. (See Section 3.5.4 and refer to Exhibit 3.29). C-cell was successfully fired until collection problems in the mechanical cyclones and ESP forced the unit out of service.
- January 16 Unit operation resumed and coal fire was established.
- January 17 Commercial three cell operation initiated. High combustible gas emissions in C-cell forced unit out of service again. At this time, the Fuller-Kinyon needle velocity was suspected of being too high.
- January 23 Unit start-up initiated after a thorough unit inspection revealed no unusual problems or discrepancies in the boiler and flue gas circuit.
- Intermittent one and two cell operation continued throughout the remainder of January. Unit operation was hampered by combustion problems in C-cell as well as

problems within the precipitator.

February 2 Unit start-up proceeded smoothly and by February 3, the unit was in three-cell commercial operation. Poor precipitator collection efficiency caused the air preheater baskets to become fouled and unit was subsequently shutdown.

A broken emitting wire was found and removed from the outlet section of the ESP and the rapping intensity on the precipitator was intensified in an effort to keep the collecting plates free of ash buildup.

February 19 Unit operation resumed with a coal fire in D-cell.

February 21 Three-cell commercial operation was initiated and sustained for 132.5 hours, producing Rivesville's first 100+ hour three-cell operating attempt. The MFB was operated flawlessly producing turbine quality steam with no noticeable stack emissions. Dust collection efficiencies were high and combustion performance within the cells looked good. Exhibit 3.2 of the Interim Report displays the parameters of the extended operation.

February 26 The MFB unit was taken out of service to examine the effects of the extended operation and to lengthen fuel feed needles in B, C and D cells.

The fuel feed needles were lengthened to get a better fuel mix into the center of the bed. Refer to section 3.5.2, page 3.15 in the Annual Report.

March 9 Unit operation began after completion of needle extensions and boiler inspections. Examination of the boiler and associated equipment revealed no severe wear or damage to the unit as a result of the extended run.

March 10 C-cell and B-cell coal fires were initiated with the new feed needle extensions. Commercial operation began and was sustained for 26 hours. A fuel feed interruption caused by a malfunction in the Fuller-Kinyon interlock circuit took the unit out of commercial operation.

March 11-16 D-cell operation continued while the Fuller-Kinyon circuitry was checked. No problems were discovered, but operation could not continue due to a seal water header leak which developed on March 17.

March 20 MFB unit operation was again initiated.

March 20-28 Three-cell commercial operation was achieved and sustained operation in the three-cell mode continued for 200 hours until 2330 hours, March 28 when a planned shutdown was conducted. The 200 hours run established an operation milestone unprecedented in Rivesville's history.

Isokinetic sampling tests and cell traverses were performed during the extended run which confirmed an exceptionally good combustion profile within the cells, and an extremely good collection and stack opacity record were achieved throughout the run. Refer to Exhibit 3.3.

6.3 MFB Modifications, Repair and Retrofit

During the reporting period, the Maintenance Department was responsible for the following major items:

1. Installation of "Mitdump" valve in B-cell to prevent hydrated material from settling over the rotary dump valve. The installation of the Kamyr valve on C-cell and the 2½" self-cleaning valve on D-cell's drain leg to test hot bed material drain performance. (See section 3.4 MFB Plant Modifications/Improvements for more information).
2. Lengthened feed needles in B, C and D-cells to improve residence time of fuel in bed and therefore improve combustion. (See section 3.4, MFB Plant Modifications/Improvements).

6.4 Air Distributor Calibration Tests

After the new "nut and bolt" air distributors were installed, tests were conducted to determine the relationship of airflow to distributor pressure differential with and without a layer of bed material.

Test results show the new air distributors exhibit less resistance to flow than the earlier perforated plate distributors. By referring to Exhibit 6.1, it can be observed that B-cell pressure drop has been decreased by 35%, while C-cell has dropped 20%. (Solid lines represent the new nut and bolt air distributor).

6.5 Cell/Main Uptake Gas Traverses and Gas Analysis

During the reporting period, extensive gas analysis data was accumulated during the operating runs and cell traverses were taken to characterize combustion within the individual cells.

A comparison of combustion profiles in C and B-cells indicates better, more uniform combustion occurring in B-cell than in C-cell. It is suspected that the adverse phenomena occurring in C-cell is attributable to the Fuller-Kinyon fuel feed system. See Sections 3.5.2 through 3.5.4 for more discussion on cell traverses and the Fuller-Kinyon feed system.

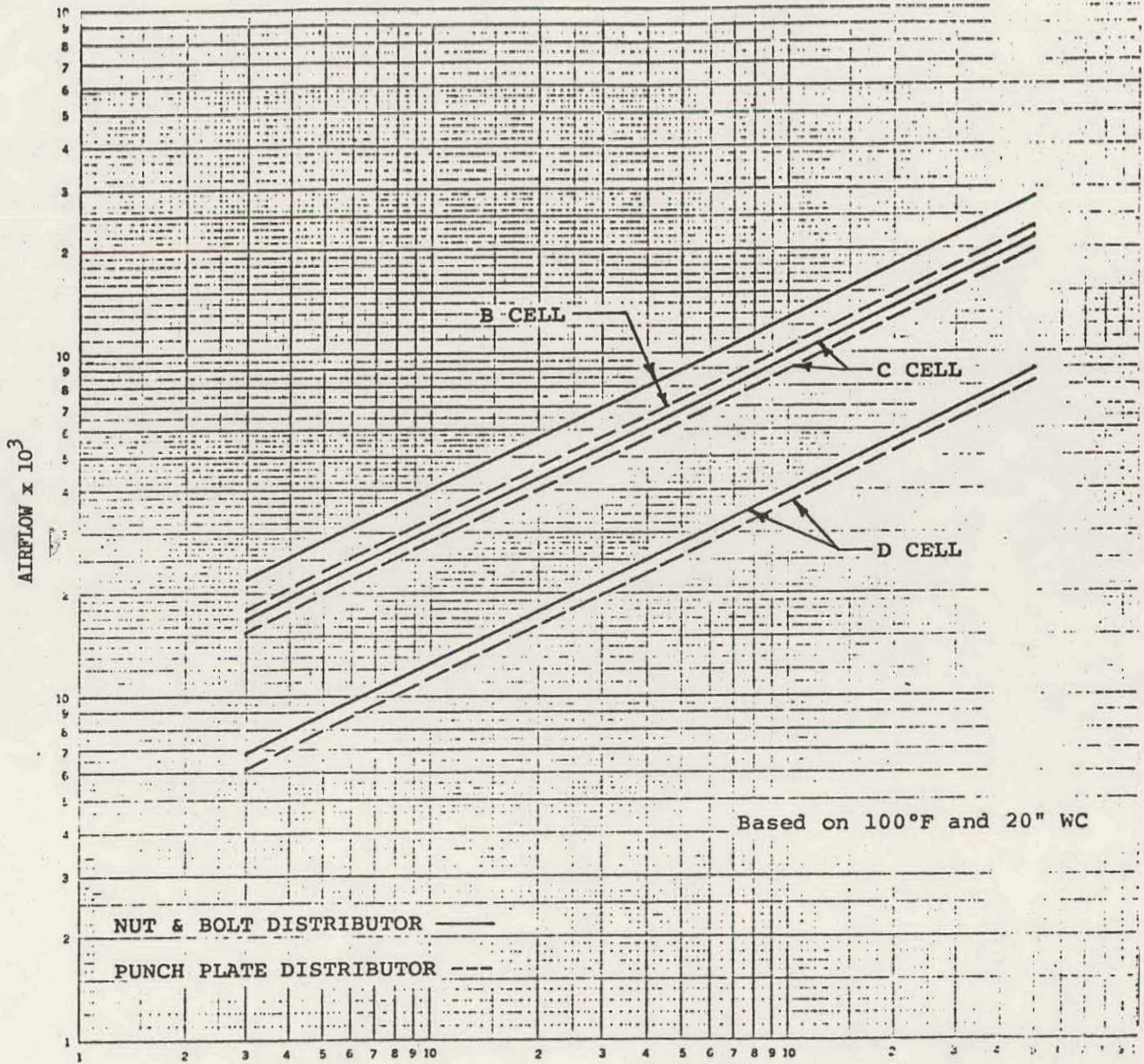
6.6 ESP Testing

Isokinetic sampling of the ESP inlet and outlet, was performed periodically throughout the reporting period in an effort to evaluate electrostatic precipitator performance. See Section 3.5.6

6.7 Feed Needle Extensions

The fuel feed needles in C, B and D-cells were all lengthened during the reporting period in an attempt to improve combustion profiles within the cells by distributing fuel more uniformly throughout the cell. Refer to Section 3.4.5.

COMPARISON OF NUT & BOLT DISTRIBUTOR WITH PUNCH PLATE DISTRIBUTOR



GRID PLATE ΔP IN. WC

EXHIBIT 6.1

7.0 Rivesville MFB Quarterly Report
(for Period April - June 1980)

7.1 General

Following the extended 200 hour run in March, the unit was given a thorough inspection and no major problems were found. Maintenance and repair activities, as well as testing of individual equipment, were undertaken.

Load following tests in three-cell operation were conducted in April. The unit was operated in commercial mode in June to conduct isokinetic sampling tests with flyash reinjection and multiple point cell traverses were conducted in C and B-cells.

7.2 Maintenance, Repair and Retrofit

To improve collection efficiency, 16 of the 84 multiclones were blanked off in DC-1 thus increasing the pressure drop to 6" w.c. Additional gas traverse ports were installed in B and C-cells. The horizontal and vertical risers transporting coal from the Fuller-Kinyon screw pumps were reduced from 5" O.D. to 4" O.D. to permit a lowered needle velocity of 50 ft/sec while maintaining sufficient transport velocity in discharge headers. The design basis for this change was an equation developed from pneumatic transport research at the Energy Research Center in Morgantown, 1970-74. A baffle was added to the north coal bin to provide uniform size-distribution. An annubar was installed in the flyash reinjection system to measure transport rates. Thermocouples were installed to measure flyash rates by conducting a thermal balance.

7.3 Light-off/Operation Activities

April 20 Unit operation began and preparations were made for velocity tests in C-cell. However, at 55 ft/sec needle velocities, the south feed system plugged and the run was aborted.

April 24-30 Unit operation began, but this time, needle velocities were raised to 80 ft/sec and the Fuller-Kinyon feed system operated successfully. Load following tests were conducted on C-cell. Subsequently, load following tests were conducted in three-cell operation with isokinetic data taken at five steady-state conditions.

7.4 Fuller-Kinyon System

The Fuller-Kinyon system operation was satisfactory in this quarter indicating the design calculations to reduce the horizontal and vertical Fuller-Kinyon screw pump risers to 4" O.D. were correct. More detail of the Fuller-Kinyon test is given in Section 3.5.4.

7.5 Dust Collection

In dust collector one, 16 of the 84 multiclones were blanked off to bring cyclone pressure drop closer to design conditions. The efficiency was checked by employing isokinetic testing. Some blockage was noted in outlets. An evaluation and more testing will be conducted in the next quarter.

In the electrostatic precipitator, problems with anti-sway baffles were noted and will be corrected. Temperature stratification will be monitored in upcoming runs and we will try to minimize thermal transients by using bypass air through A and B-cell combustion dampers.

7.6 C-Cell Coal Feed

The Autoweigh belt feeders were sampled for as-fed coal. The mean particle size of the coal being delivered to the north side was found to be 47 percent smaller than that of coal being fed to the south side. A baffle plate was added to the north bin to correct this "fines" problem. Future testing will be necessary to determine if the problem has been resolved.

7.7 Flyash Reinjection (FAR)

Based upon isokinetic data taken at the mechanical dust collectors and the precipitator, and upon flue gas analysis, the combustion efficiency of D-cell seemed to indicate 88 percent. Carbon burnup efficiency for D-cell seemed to be 83.7 percent. More details are given in Section 3.5.7. More testing will be necessary in order to confirm or improve these results.

7.8 Load Following

Preliminary load following data suggests a turndown capability of 3:1 with a 10 percent per minute load change capability. Although positive, the preliminary data will require confirmation and additional tests. See Section 3.5.8 for more details.

7.9 Sub-contractor Activities (Stone & Webster)

During the quarter, Stone & Webster provided general engineering services and backup to the PER staff.

Recommendations were made to improve the flyash reinjection system. A separate transport system from DC-2 to MPC silo was approved. Results of the modification will be reported in subsequent periods.

A recommendation to install a grizzly screen above the transport line from the classifier resulted in successful operation of the bed material system with no plugging due to clinkers.