

MULTICELL FLUIDIZED-BED BOILER  
DESIGN, CONSTRUCTION AND TEST PROGRAM  
QUARTERLY PROGRESS STATUS REPORT

FOR PERIOD JANUARY - MARCH 1977

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COMBUSTION SYSTEMS DIVISION  
POPE, EVANS AND ROBBINS INCORPORATED  
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### ABSTRACT

The objective of the program is to design, construct and test a multicell fluidized-bed boiler as a pollution-free method of burning high-sulphur coal or burning highly corrosive coals without excessive maintenance problems. The fluidized-bed boiler will provide 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 is being 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 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-up 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 ERDA Contract No. EX-76-C-01-1237 is to test a multicell fluidized-bed boiler as a pollution-free method of burning high-sulphur coals or highly corrosive coals without excessive maintenance.

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. MFB Boiler and Plant Design; Performance of Experiments in the Alexandria, Va. Laboratory to Optimize Certain Boiler Features.
- Phase II Fabrication, Installation and Shakedown Status Operation.
- Phase III Demonstration Operation under SO<sub>2</sub> Acceptor Mode.
- Phase IV Preparation of Design and Operation Manuals and the design of largest practical factory-assembled industrial MFB unit.

This Quarterly Report covers work performed under Phases I and II of the contract in the period of January, February and March 1977.

1.0 SUMMARY OF PERFORMED TASKS

1.1 Alexandria, Va. Laboratory Operation

During the January through March 1977 reporting period, work in the Alexandria Laboratory continued to support the design and initial start-up of the Rivesville MFB unit and followed the activity schedule established by the total program cycle.

Work in the following areas is described in this report.

<u>Activity No.</u>	<u>Description</u>
121	Fly Ash Injection System, Cold Tests
407	Carbon-Burnup Cell Tests
709	Evaluation of Instrumentation and Controls
211	Coal Feeder Tests
1106	Light-Off Procedures Study
1116	Process Development Unit
1005	By-Product Study

CBC testing was completed during the quarter. Hot tests conducted during the reporting period include:

<u>Test No.</u>	<u>Date</u>	<u>Description</u>	<u>Duration Hours</u>
644-11	1/27/77	CBC Test/3 and 2 Feeders	7
644-12	2/3/77	CBC Test/1 Feeder	7
644-13	2/8/77	CBC Test/2 Feeders	8
644-14	2/10/77	CBC Test/1 Feeder	8
645-1	1/12/77	Automatic Control Test	6
645-2	1/18/77	Automatic Control Test	6
646-1	3/17/77	Coal Feed Test/Shakedown	3.5
646-2	3/17/77	Coal Feed Test/Overbed Feeders	3.75
646-3	3/24/77	Coal Feed Test/Underbed Tee Feeders	3.75
646-4	3/30/77	Coal Feed Test/Underbed	
647-1	3/22/77	Mushroom Feeder	6.0
647-1	3/22/77	Light-Off Test/Oil Assisted	2
647-2	3/23/77	Light-Off Test/Oil Assisted	1
647-3	3/31/77	Light-Off Test/Reduced Air Flow	3
648-1	2/15 - 18/77	Round the Clock Testing/ Auto Control	77
648-2	2/21 - 25/77	Round the Clock Testing/ Auto Control	86
648-3	3/1/77	Automatic Control Test	7
648-4	3/2/77	Automatic Control Test	7
648-5	3/3/77	Automatic Control Test	7

## 1.2 MFB Plant Operation

During this reporting period, major activities at the Rivesville MFB Plant consisted of operating the boiler unit in various modes and resolving problems arising from sustained operation. Cells D and C were concurrently fired during this period which represented the first firing ever of a multicell fluidized-bed unit.

Construction punch lists and final testing of equipment from the construction subcontractor were completed. Supplemental instrumentation for complete analysis and evaluation of the MFB unit performance was procured and installed.

Preventive maintenance programs for systems and equipment were developed and implemented and the necessary supplies, equipment and tools to support the program were purchased. Outfitting of the Chemistry Laboratory with equipment and supplies was completed. Analyses were performed on treated boiler water and delivered coal.

Operation of the MFB unit was limited during this period as the result of three major equipment failures and lack of boiler feedwater supply due to Monongahela Power Company's system outage for three weeks in March.

Various tests were conducted on the MFB unit and auxiliaries to determine material flows and control settings.

## 1.3 Boiler Design, Fabrication and Erection

All design, fabrication and erection work for the MFB under subcontract to Foster Wheeler Corporation (FWEC) is complete at this time. FWEC, under an extension to their subcontract, is engaged in the design, procurement and installation of test instrumentation for the MFB plant.

During this reporting period, FWEC prepared bid specifications and solicited quotations from qualified vendors for approved instrumentation items and auxiliaries. Quotations were evaluated and orders placed for all items. Miscellaneous hardware items will be field purchased at installation. This completes the Livingston office effort. the remaining effort consists of installation/construction at Rivesville.

## 1.4 MFB Plant Construction

Champion Construction & Engineering Co., Inc. construction subcontractor for the Rivesville MFB Plant and their second tier subcontractors completed all outstanding construction contract items, including amendments and punch list items. At the end of the reporting period, Champion and their subcontractors started demobilization of their field offices and personnel in preparation for moving off the site.

## 1.5 Review of Significant Events

During the October 1972 through March 1977 contract period, the following significant events occurred:

Start of contract	October	1972
Site selection completed	February	1973
Rehabilitation of FBM complete at Alexandria, Virginia laboratory	March	1973
Site selection approved by OCR	March	1973
Evaluation of boiler manufacturers completed	March	1973
Selection of Foster Wheeler Corporation (FWC) and OCR approval	March	1973
Bureau of Mines laboratory tests completed at Alexandria	March	1973
PER boiler design completed	April	1973
FWC boiler evaluation, redesign and cold component testing contract signed	May	1973
Modernization of the Alexandria laboratory completed	June	1973
Monongahela Power Company agreement signed	June	1973
Design verification tests started in the Alexandria laboratory	June	1973
Fluidized bed boiler plant design started	June	1973
Boiler redesign completed and released for bidding	October	1973
Salt tests completed in the Alexandria laboratory	October	1973
Boiler bids submitted by two manufacturers	November	1973
Bid evaluation completed and approved by OCR	December	1973
Notice to Proceed given to FWC for boiler fabrication	December	1973
Cold component testing in the Livingston, New Jersey laboratory started	December	1973
Fluidized bed boiler plant design completed and released for bidding	January	1974
Air distribution plate pre-selection tests in the Livingston laboratory completed	January	1974
Air pollution control permit filed	February	1974
High N <sub>2</sub> content coal NO <sub>x</sub> tests completed in Alexandria	February	1974
Plant construction bids received from three contractors	February	1974
Request for additional funding submitted to OCR	February	1974

Plant construction bids submitted to OCR for evaluation	February	1974
Air pollution control hearing	February	1974
Coal feeder hot tests completed in the Alexandria laboratory	March	1974
Preliminary grid plate tests completed in the Alexandria laboratory	April	1974
Construction Contract No. 1 for Rives- ville boiler support steel work signed	May	1974
Air pollution permit granted by the State	May	1974
Rivesville boiler support steel work started	May	1974
Coal feeder tests started in the Rexnord, Inc., Louisville, Kentucky plant	May	1974
Furnace feed system design completed	June	1974
Combustion control system design com- pleted	June	1974
Fluidized bed boiler plant design package, including furnace feed and combustion control systems released for re-bid	July	1974
Boiler drum and headers delivered to site	July	1974
Construction Contract No. 1 for Rives- ville boiler support steel completed	July	1974
Preparation of Interim Report No. 1 started	July	1974
Design and fabrication of a horizontal tube bundle for the Alexandria FBM started	July	1974
Interim Report No. 1 completed and sub- mitted to OCR	August	1974
Plant construction re-bids received from three contractors and submitted to OCR	August	1974
Request for additional funding resub- mitted to OCR	August	1974
Erection of the 30 MW <sub>e</sub> MFB at Rivesville started	September	1974
General Construction Subcontract signed with Champion Construction & Engineer- ing Co., Inc.	September	1974
Construction of the large cold test model (6'x6') in the Livingston, N.J. labor- atory completed	September	1974
Fabrication of the horizontal tube bundle for the Alexandria FBM completed	September	1974
Purchase of plant equipment by Champion Construction & Engineering Co., Inc. started	October	1974
Additional funding for the project approved by OCR	November	1974

General mobilization by Champion Construction & Engineering Co., Inc. completed	November	1974
Demolition Subcontract work at the Rivesville site started	November	1974
Purchase of major plant equipment by Champion Construction & Engineering Co., Inc. completed	December	1974
Testing of the large cold model with the Rivesville horizontal tube bundle arrangement started	December	1974
Fabrication and delivery of all steam generator parts from the FWEC Dansville, N.Y. and Mountaintop, Pa. plants completed	December	1974
Installation of the horizontal tube bundle in the Alexandria FBM completed	January	1975
Testing of the large cold model with the Rivesville horizontal tube bundle arrangement completed	February	1975
Initial test of the horizontal tube bundle in the Alexandria FBM completed	February	1975
Fuel injection tests in the large cold model started	February	1975
Regeneration Technology Workshop	March	1975
Phase I Erection Sequence of the 30 MW <sub>e</sub> MFB at Rivesville completed	April	1975
Preservation work of the 30 MW <sub>e</sub> MFB at Rivesville completed	April	1975
Developed computer program for heat and material balances for the Alexandria FBM	April	1975
Completed testing in the large cold model	May	1975
Preparation of operation and maintenance manual for the Rivesville, W. Va. MFB started	May	1975
Preparation of a test and instrument program for the Rivesville, W. Va. MFB started	May	1975
Successfully performed test and evaluated the burning of coke-breeze in the Alexandria, Va. FBM	May	1975
Installed pre-selected Rivesville MFB air distribution grid plate in the Alexandria, Va. FBM for final grid performance tests	June	1975
ERDA Technical Audit of PER - July 7 & 8, New York office, July 9 Livingston, N.J., July 10 Rivesville, July 11 Alexandria - completed	July	1975
Started final testing of the selected Rivesville MFB air distribution grid plate in the Alexandria, Va. FBM	July	1975

Preliminary review of the Rivesville, W. Va. MFB instrumentation and test program with ERDA and FWEC	July	1975
Issued Limestone Regenerator Design Report	July	1975
Completed final testing of the selected Rivesville MFB air distributor grid plate in the Alexandria, Va. FBM	August	1975
Issued Final Report for large cold model test work	September	1975
Started detailed horizontal tube bundle heat transfer testing in the Alexandria FBM	October	1975
Design for conversion of the Alexandria FBM to a Carbon Burnup Cell started	November	1975
Modification of the Alexandria FBM facility started	December	1975
Completed preparation of a test and instrumentation program for the Rivesville, W. Va. MFB	January	1976
Completed preparation of an operation and maintenance manual for the Rivesville, W. Va. MFB unit	January	1976
Preparation of an operation and maintenance manual for the Rivesville, W. Va. MFB Plant Auxiliary Systems started	February	1976
Issued Staffing and Training Program for MFB Plant Personnel	March	1976
ERDA review of the Rivesville, W. Va. MFB plant instrumentation and test program at the Plant site	April	1976
Issued Safety Manuals for MFB Plant Operating Personnel	April	1976
Completed design for conversion of the Alexandria FBM to a Carbon Burnup Cell	May	1976
Completed hydrostatic testing of 30 MW <sub>e</sub> MFB and the high pressure steam piping system at Rivesville, W. Va.	June	1976
Completed horizontal tube bundle heat transfer testing in the Alexandria, Va. FBM	June	1976
Completed construction of the Alexandria, Va. FBM facility modifications/minimum equipment improvement	July	1976
Started cold mode operation of the Rivesville, W. Va. MFB Plant systems and equipment	July	1976
Started cold mode operation of the Alexandria, Va. laboratory new systems and equipment	July	1976
Completed chemical cleaning of the Rivesville, W. Va. MFB	July	1976

Completed cold mode operation of the Alexandria, Va. Laboratory new systems and equipment	August	1976
Started hot mode operation of the Alexandria, Va. Laboratory new systems and equipment	September	1976
Fluidized limestone bed in Cell D (CBC) of the Rivesville, W. Va. MFB	September	1976
Fired start-up burners in Cell D (CBC) of the Rivesville, W. Va. MFB	September	1976
Received first shipment of coal at the Rivesville MFB Plant, and placed in No. 5 Storage Bunker	October	1976
Started warm-up of the Rivesville, W. Va. MFB unit by continuous firing of the startup oil burners.	November	1976
Accomplished first lightoff and operation with coal of the Rivesville, W. Va. MFB	December	1976
Operated one cell (CBC) of the Rivesville, W. Va. MFB unit in a continuous mode, burning coal	December	1976
Performed tests for bed material transfer between Cells D (CBC) and C of the Rivesville, W. Va. MFB	January	1977
Accomplished first light-off of Cell C and operation of two Cells (D & C) of the Rivesville, W. Va. MFB unit	February	1977
Initiated coal feeder test and evaluation program at Alexandria Laboratory	March	1977
Performed tests at Alexandria Laboratory to develop alternate light-off procedures for the Rivesville, W. Va. MFB	March	1977
Completed all Rivesville MFB plant auxiliary systems subcontract work	March	1977

## 1.6 Future Planning

The following activities are scheduled for the April, May and June 1977 time period.

- (1) Continue test and evaluation program for alternate light-off procedures at the Alexandria Laboratory.
- (2) Complete coal feeder test and evaluation program at the Alexandria Laboratory.
- (3) Complete design work on replacement FBM unit for the Alexandria Laboratory.
- (4) Continue design, procurement and installation of test instrumentation at the Rivesville MFB Plant.
- (5) Continue coal firing of the Rivesville MFB unit CBC Cell and Cells C and initiate coal firing of Cells B and A.
- (6) Correct equipment deficiencies noted during operation of Cells D and C.
- (7) Complete blowing of steam piping to permit exporting generated steam to Monongahela Power Company's turbine and condenser system.
- (8) Establish, operate and determine combustion characteristics of Rivesville MFB unit at minimum steaming rate.
- (9) Operate and determine combustion characteristics of Rivesville MFB unit at design superheater pressure and temperature.
- (10) Prepare for operation of the Rivesville MFB unit under automatic control.

## 2.0 ALEXANDRIA, VA. LABORATORY RESULTS

### 2.1 Conversion of the FBM to CBC (Activity No. 121)

Cold testing of the Petrocarb, Inc. fly ash injection system with new seal leg internals supplied by Petrocarb continued during the report period. Test results with new internals showed no improvement over the replaced internals. The same problems of plugging in the seal leg discussed in Quarterly Report No. 8 were encountered. All attempts to operate the system proved unsuccessful. As a result, new internals were designed by PER and installed in the seal leg column. Cold test results with these internals indicated that fly ash throughput rates of over 1000 pounds per hour could be achieved with no plugging problems.

The internals designed and installed by PER channel air up the side of the seal legs rather than up the center as designed by Petrocarb. Figure 1 shows PER's internal seal leg aeration design. This arrangement was found to be satisfactory for the range of solid flow rates required.

### 2.2 Carbon-Burnup Cell Tests (Activity No. 407)

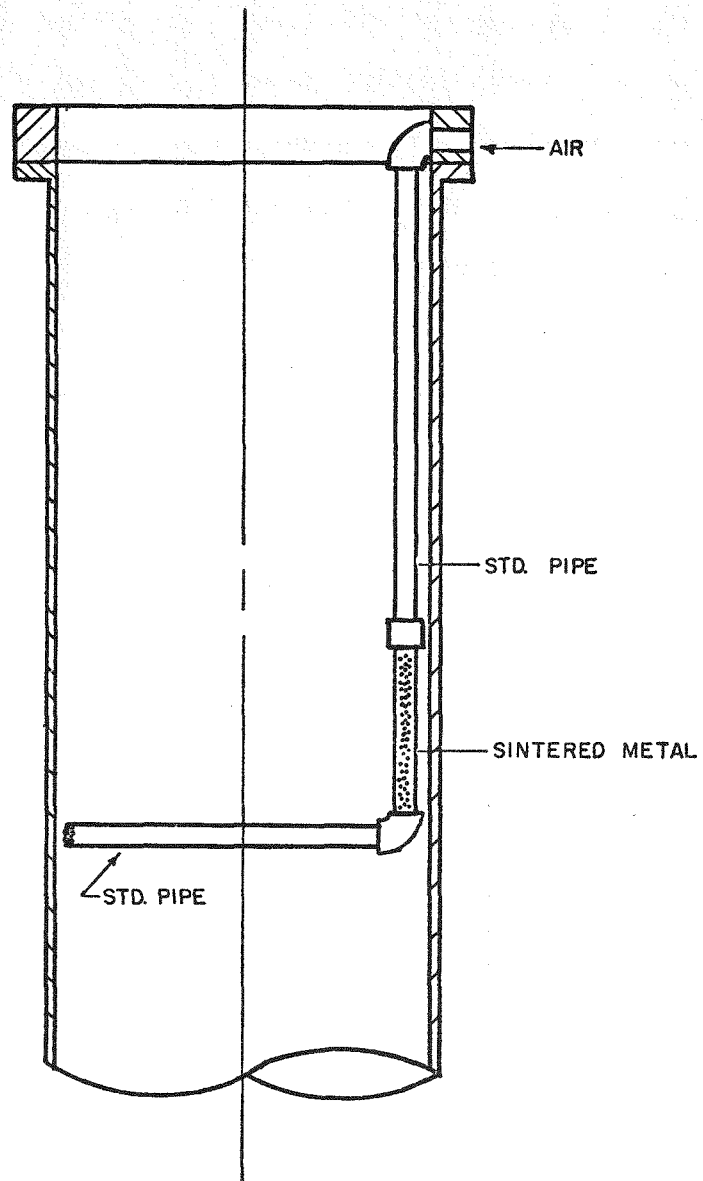
#### 2.2.1 Summary of Test Results

During the reporting period, CBC testing ended with the completion of Test Nos. 644-11 through 644-14. These tests were run with shallow beds ( $\sim$  15 inches static) in order to maintain temperatures of 2000°F and residual oxygen percentages greater than 3 percent. Test No. 644-11 was both a three feeder and two feeder test. Test No. 644-12 was a one feed point experiment. Problems with refractory on the waterwalls and insulation on the bottom of the steam drum prevented the collection of useful data in Test Nos. 644-13 and 644-14.

A summary of CBC test data considered reliable, is shown in Table 1. The range of variables for these tests was as follows:

- . Bed temperature: 1865 to 2030°F,
- . Static bed depth: 12.3 to 22.6 inches,
- . Superficial velocity: 5.6 to 9.8 ft/sec.
- . Residual percent O<sub>2</sub>: 1.0 to 6.7 percent,
- . Fly ash feed rate: 390 to 1050 lb/hr

The observed percent carbon burnup ranged from 78.0 to 96.1 percent. The effect of various operating parameters on carbon-burnup is summarized in the following discussion.



(TYPICAL FOR THREE LOCATIONS)

### SEAL LEG INTERNALS SKETCH

Figure 1

TABLE 1

## Summary of Test Results

Test No.	Time	No. of Feeders	% O <sub>2</sub> in Flue Gas (avg.)	Bed Temperature, °F	Bed Depth, Static inches	Superficial Velocity, Ft/sec	Fly Ash Feed lb/hr	% Carbon Burnup
4	13:00	3	5.4	1895	18.6	7.3	960	87.5
6	13:30	3	3.7	1935	18.5	6.5	900	84.2
	15:00	3	2.3	1930	15.3	6.2	930	86.5
	15:40	3	1.0	1985	12.3	5.6	900	85.4
7	11:30	2	2.9	2010	21.5	8.7	862	90.1
	12:00	2	3.5	1960	22.6	7.2	1050	92.7
	13:00	2	1.7	1898	20.5	6.1	840	78.1
	13:30	2	2.5	1888	18.6	6.5	860	78.7
	14:00	2	2.6	1906	19.2	6.8	1050	84.6
	14:30	2	1.7	1916	17.7	6.9	840	80.1
8	10:00	1	3.0	1955	19.6	6.9	540	88.1
	11:00	1	2.7	1937	19.6	7.3	620	86.8
	12:00	1	2.2	1943	17.7	7.1	650	86.9
	12:30	1	3.2	1940	17.7	6.8	590	87.0
	13:30	1	2.3	1963	17.2	6.6	730	86.8
	14:00	1	2.5	1982	16.7	7.0	660	86.7
	14:30	1	2.8	1975	16.2	6.9	630	86.3
9	12:30	2	3.6	1985	21.6	8.7	850	92.9
	13:00	2	5.6	1865	22.6	7.5	540	89.3
	13:30	2	3.7	1920	21.6	7.9	540	81.8
	14:00	2	4.2	1900	22.1	7.9	780	86.0
10	11:00	1	2.0	1940	21.2	8.8	660	82.2
	11:30	1	2.3	1920	19.7	8.8	900	79.5
	12:00	1	1.7	1970	19.7	8.2	803	78.0
	12:30	1	1.4	1960	19.7	8.0	780	81.0
	13:00	1	1.8	1961	19.7	8.3	940	81.9
	13:30	1	1.8	1950	20.7	8.1	930	85.3
	14:00	1	2.3	1925	20.7	7.5	940	78.8
	15:00	1	2.3	1940	22.2	7.4	960	79.5
11	10:30	3	3.4	2000	16.0	7.1	480	89.3
	11:00	3	6.7	1960	15.5	8.3	390	93.2
	11:30	3	5.3	1940	16.0	7.8	615	89.2
	12:00	3	5.9	2010	16.0	9.6	615	95.0
	12:30	3	4.8	2030	15.5	9.8	615	96.1
	13:00	2	5.2	2030	16.0	9.7	615	94.0
	13:30	2	6.2	2000	15.4	9.6	615	94.6
	14:00	2	3.0	2025	15.5	9.6	615	89.2
	12	11:30	1	1.7	1990	15.9	8.5	405
13:00		1	1.5	1975	15.8	8.4	417	89.2
13:30		1	3.3	1940	16.7	8.3	519	86.8

An important result of the test program was the comparison of carbon-burnup using one, two and three feed points. As can be seen from Table 1, three feeders showed a slight performance improvement over two feeders, and two feeders were generally better than one feeder. Considering operating problems encountered while running with only one feeder and the carbon burnup results, it was concluded that two feeders are necessary for satisfactory operation of the test unit with the feeder type used. It is felt that one feeder has the potential for satisfactory performance with additional development work to optimize feeder design. The three feeder arrangement was concluded to be an overdesign condition since only a marginal improvement resulted over the two feeder configuration.

Bed temperature was observed to have the strongest effect on carbon-burnup. Carbon-burnup efficiencies greater than 90 percent were observed in all but two tests where the bed temperature was above 2000°F. Combustion of the fly ash will be improved by increasing the bed depth. This is due to the longer residence time of the fly ash in the bed. Unfortunately in the Alexandria FBM, a deeper bed resulted in a lower operating temperature due to the extra heat transfer to the water-walls. This limitation prevented simultaneous operation with deep beds and high temperatures.

The superficial velocity also determines the residence time of the fly ash in the bed. Lower superficial velocities favor carbon burn-up by increasing the particle residence time. A more subtle effect of a lower superficial velocity is retention of the fly ash in the bed. The fly ash fuel was generated in FBM, operating usually at 12 ft/sec. The superficial velocity of the CBC ranged between 5.6 and 9.8 ft/sec. Thus, at the lower velocities, the fraction of fly ash fuel whose terminal velocity lies between the CBC operating velocity and 12 ft/sec will remain in the bed and burn.

As a result of differences in superficial velocities between the FBM conditions and the CBC conditions, the mean particle size of the bed was found to decrease during the course of a test. While this effect was not studied to any great extent during these tests, some important observations were made. After a long steady state run (longer than one week), the bed material in the CBC should be within a very narrow range of screen cuts (between 60 and 40 mesh). The screen cut will be a function of the main cell superficial velocity and the CBC superficial velocity. This should improve carbon-burnup because heat transfer from the bed to the fly ash particles should increase. Another advantage from a fine bed will be smaller bubble sizes and better mixing between the bed and the fly ash. A disadvantage that was observed in the Alexandria FBM, was that the finer bed conducts heat to the waterwalls at a higher rate. This made it difficult to maintain bed temperatures as a test progressed.

The residual oxygen in the stack is a function of operating conditions in the furnace. Thus, it is not actually a process variable that can be set by an operator. However, by adjusting the bed depth at a given temperature and superficial velocity, the stack gas oxygen can be adjusted (as in Test No. 644-11 where shallow beds allowed operation at high O<sub>2</sub> percentages and high temperatures). Higher residual oxygen should improve combustion efficiencies. As with any chemical reaction, a higher concentration of the diffusing species (oxygen) will increase the rate of the reaction.

### 2.2.2 Mathematical Modeling of the CBC

In order to predict combustion efficiency in the CBC, the data from the CBC tests has been analyzed using three approaches. The first approach used the statistical correlation reported by PER in 1972 based on tests in a one square foot combustor. The second approach utilized a simple combustion model based on the combustion rate of a single particle. The third approach modeled the combustion process both in the bed and in the freeboard and included the effects of fly ash size distribution, bed size distribution and mixing in the bed.

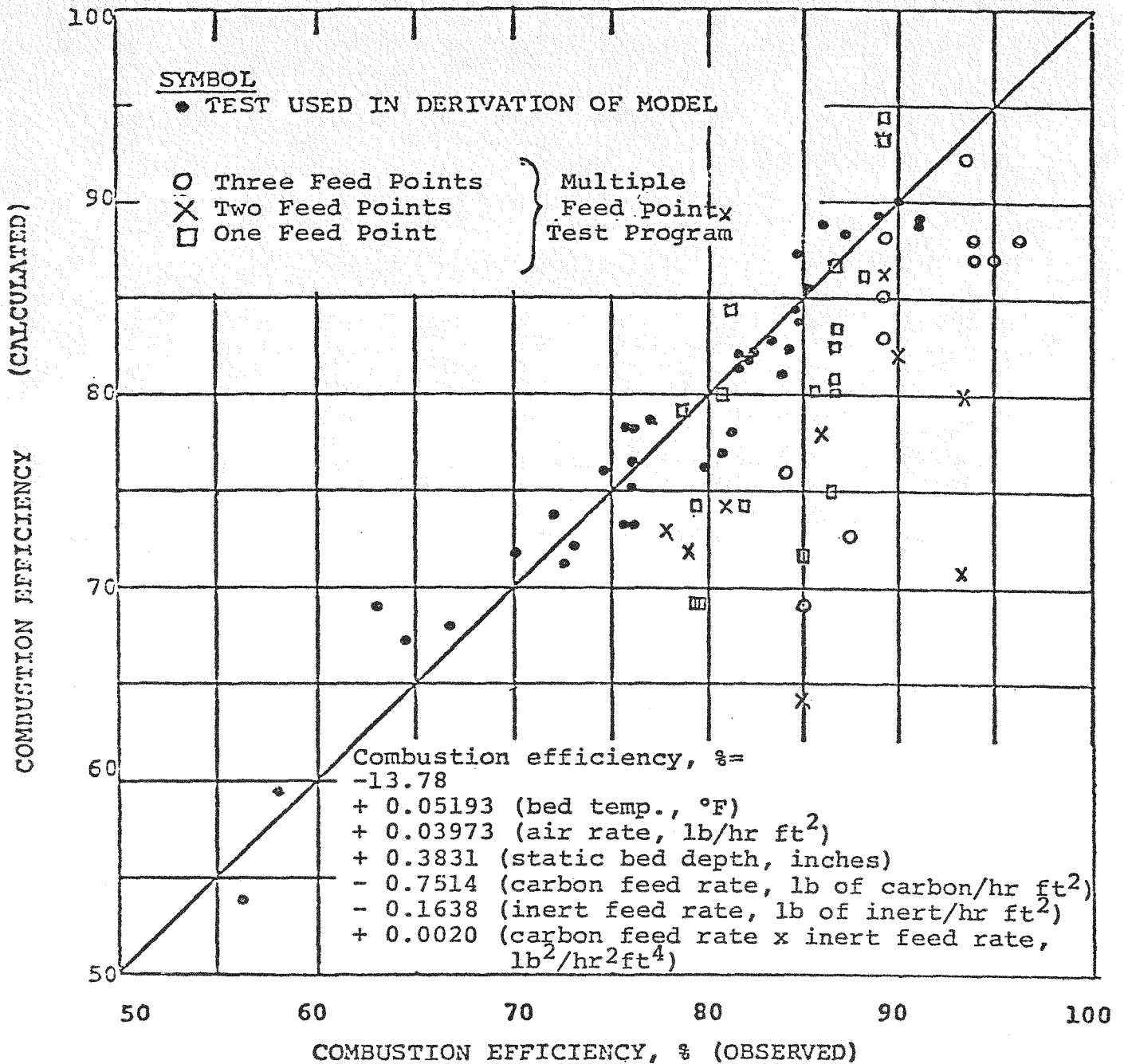
The 1972 CBC report included a statistical correlation of percent combustion efficiency as a function of bed temperature, air rate, bed depth, and carbon and inert feed rates. Data from the present CBC test program was applied to the previously developed correlation for comparison of test results as shown in Figure 2. As noted, the observed combustion efficiencies for the recent tests were greater than the previous correlation would predict. This result was unexpected considering that the area served by each feeder in the recent tests is greater than the area fed by the single feeder in the previous tests.

A preliminary model was developed to predict the theoretical percent carbon-burnup. This model was based on the empirical formula to predict the burn out time  $t_b$  of a given particle:

$$t_b = Kd_o^2 \quad (1)$$

where K is a proportionally constant and  $d_o$  is the initial particle diameter. Equation 1 was used to derive Equation 2, an expression for the fraction of carbon remaining in the particle ( $C/C_o$ ) at any time  $t < t_b$ ;

$$\frac{C}{C_o} = \left( 1 - \frac{t}{t_b} \right)^{\frac{3}{2}} \quad (2)$$



COMPARISON OF OBSERVED AND CALCULATED COMBUSTION EFFICIENCY USING EQUATION FROM PREVIOUS ONE FEEDER TESTS

Figure 2

Equation 1 and 2 are the results obtained from a shrinking particle analysis of coal ash burning in air. The proportionally constant K in Equation 1 is a function of the oxygen concentration  $C_g$ . The shrinking particle model predicts K to be inversely proportional to the oxygen concentration. Furthermore, if the reaction time is assured to be proportional to the ratio of bed depth to superficial velocity (H/V), and that percent carbon-burnup CB is given by:

$$CB = 1 - C/C_o \quad (3)$$

then Equation 1, 2 and 3 can be combined to give:

$$CB = 1 - \left( 1 - \frac{K^1 HC_g}{V d_o} \right)^{\frac{2}{3}} \quad (4)$$

where  $K^1$  is a constant different from K. In Equation 4, the fraction of carbon-burnup for a particle is given as a function of the initial particle diameter. In the current fly ash tests, the size distribution of the fly ash fuel remained fairly constant for all tests. Therefore, the term  $d_o$  can be included in the constant A such that

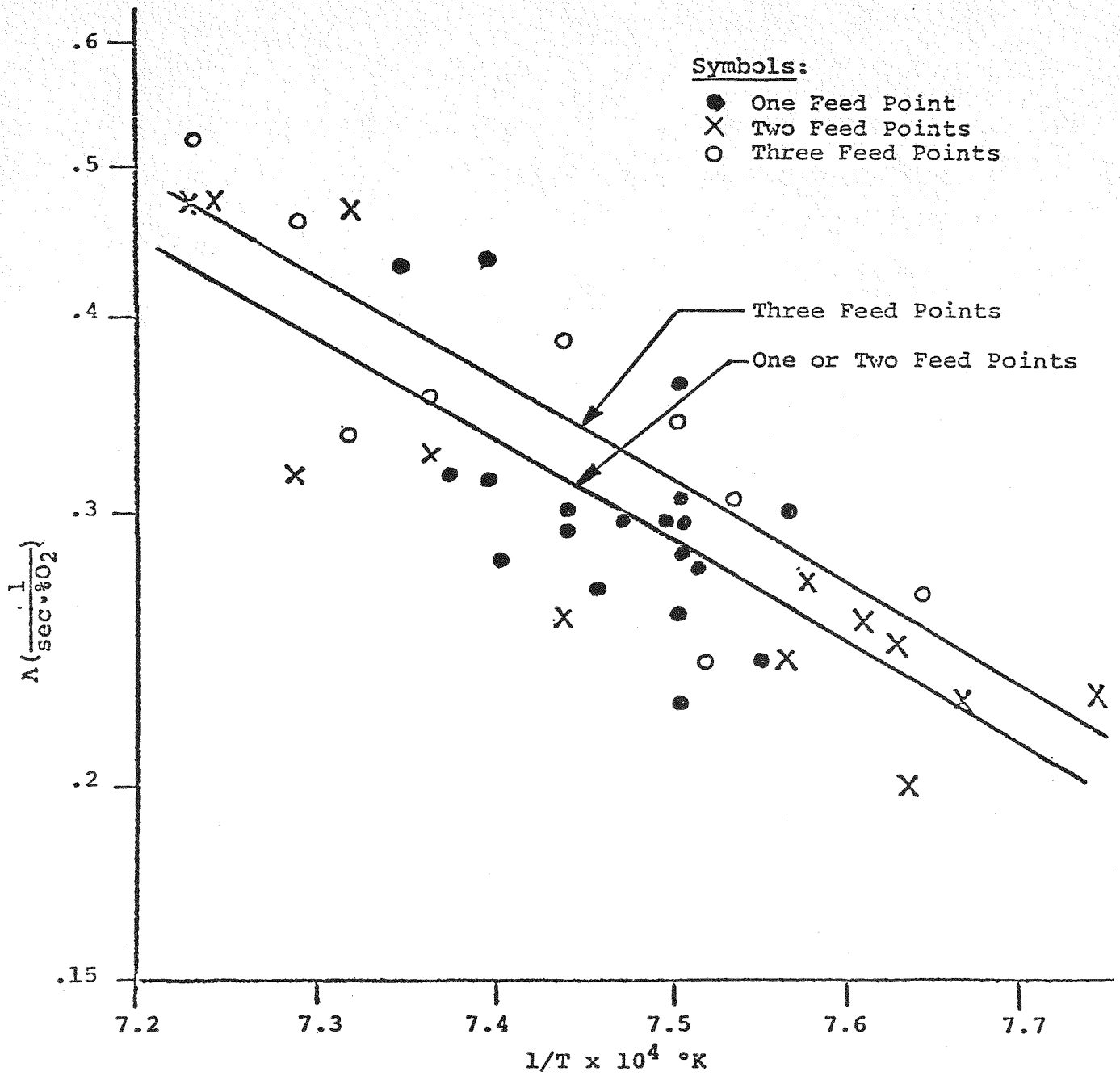
$$A = \frac{K^1}{d_o}$$

Rearranging Equation 4 to solve

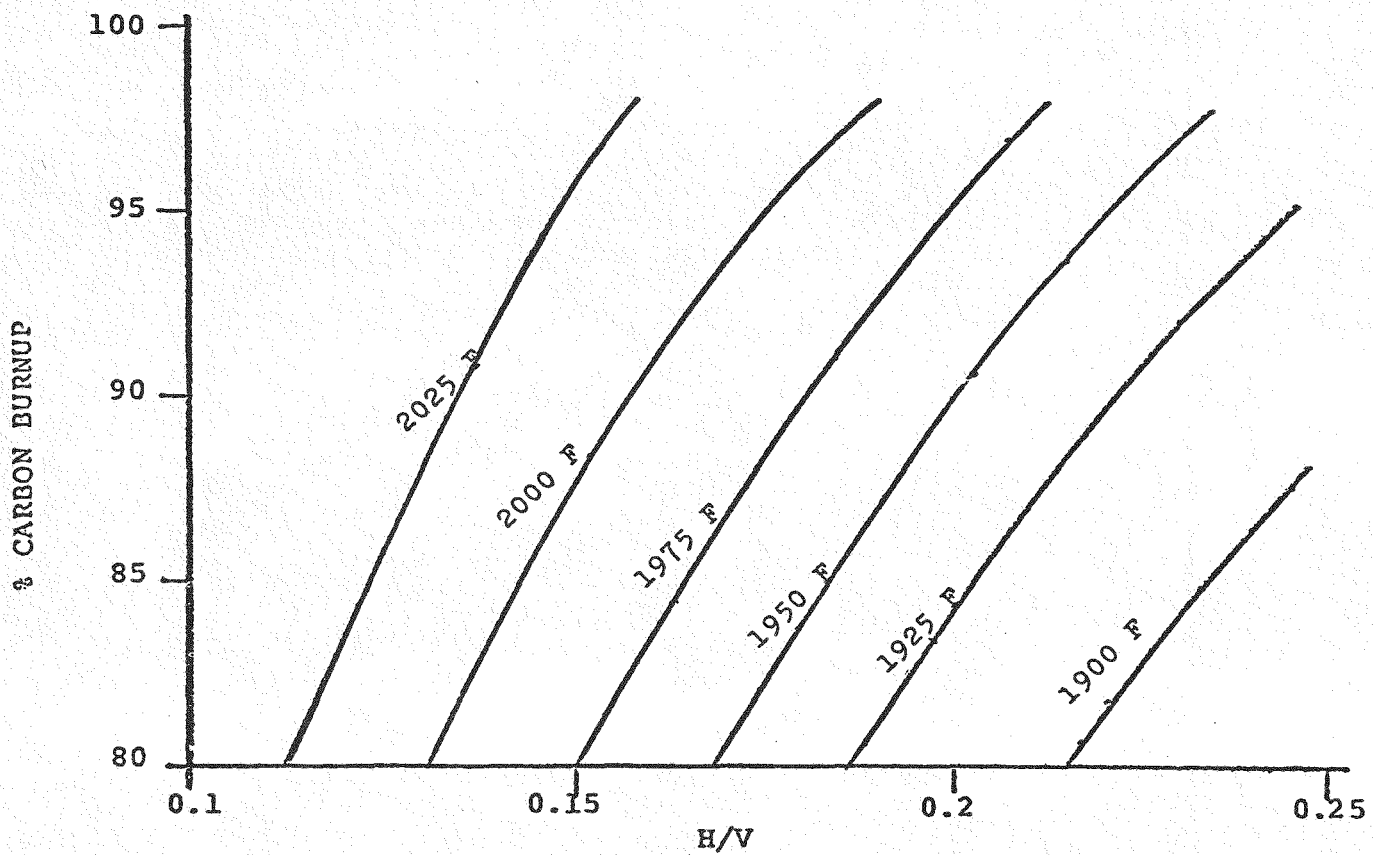
for A gives:

$$A = \frac{1 - (1-CB)^{\frac{2}{3}}}{\frac{HC_g}{V}} \quad (5)$$

Figure 3 is an Arrhenius plot of the values of A calculated from Table 1. The oxygen concentration used in this calculation is the average between the inlet (21 percent) and the outlet concentrations. The straight lines on the figure are the least square fit for the test data grouped by number of feeders. It is interesting to note that the 2 and 1 feed point arrangement give the same straight line while the 3 feed point data gives a slightly higher value of A. The apparent activation energy calculated from Figure 3 is 24.1 Kcal/mole. The apparent activation energy for combustion processes in this temperature range is about 25 Kcal/mole. The close agreement between activation energies supports the use of Equation 5. Figures 4 and 5 shown the predicted effects of bed temperature and percent excess oxygen based on Equation 5 for the percent carbon burnup. The application of Equation 5 should be limited to the range of test data shown in Table 1.

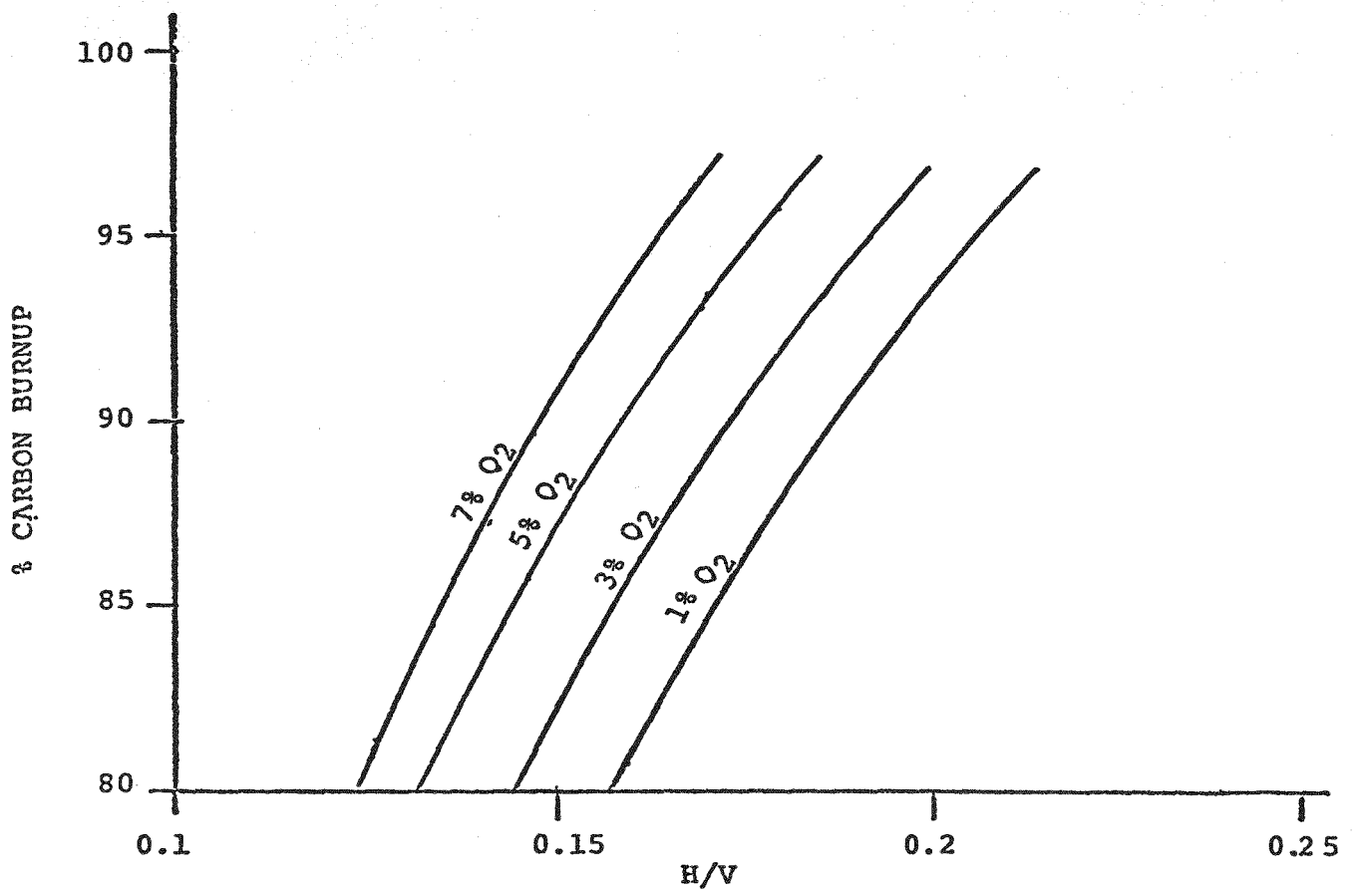


ARRHENIUS PLOT OF MULTIPLE FEEDER TEST DATA



CALCULATED EFFECT OF BED TEMPERATURE ON CARBON BURNUP  
 AT 5% EXCESS O<sub>2</sub> WITH TWO FEED POINTS

Figure 4



CALCULATED EFFECT OF EXCESS OXYGEN ON CARBON BURNUP  
 AT 2000°F WITH TWO FEED POINTS

Figure 5

There is considerable scatter of data in Figure 3. One reason could be uncertainties in the test data; another could be that the burnout model, based on the rate of a single particle burning in a gas, is an oversimplification of a very complex process. A more detailed model should include the effects of bed depth, combustion in the bed, as well as above the bed, actual concentration of burning fly ash in the bed at a given instant, and mixing effects within the fluidized bed.

A detailed combustion model to predict the operation of the CBC is currently being developed. Combustion of fly ash is assumed to take place both in the bed and above the bed in the freeboard space. The rate of combustion in the bed will be assumed to be oxygen diffusion limited.

Three distinct fractions of the fly ash are being examined on the basis of residence time in the bed. The first fraction consists of large particles (greater than 50 mesh) whose terminal velocity is greater than the superficial velocity. These particles are assumed to remain in the bed and be completely burned. The second fraction consists of the small particles whose terminal velocity is less than the minimum fluidization velocity. This fraction will be able to escape from the emulsion phase and, therefore, is assumed to pass through the bed at the speed of the fluidizing gases. The third fraction is the fraction of particles whose terminal velocity lies between the minimum fluidizing velocity and the superficial velocity. It is assumed that these particles leave the bed in the bubbles only and cannot escape from the emulsion phase until they diffuse into a bubble.

To calculate the extent of reaction in the bed, a modified form of Avedesian and Davidson's model for batch combustion in a fluidized bed will be used\*. The reaction times for each fraction will be the residence time based on the above assumptions. This will calculate the reaction rate to the top of the bed. A mass balance will estimate the percent oxygen at the top of the bed. Combustion in the freeboard will be estimated in the following manner. The freeboard space will be divided into four segments:

- Segment I:           FBM above bed to steam drum,  
                      Volume =  $60 \text{ ft}^3$  minus the bed volume,
  
- Segment II:          Gas cooler above steam drum,  
                      Volume =  $100 \text{ ft}^3$ ,

\*Trans. Instn. Chem. Engrs., Vol. 51, 1973, p. 121

Segment III: Air preheater,  
Volume = 70 ft<sup>3</sup>,

Segment IV: Cyclone dust collector  
Volume = 70 ft<sup>3</sup>

The average temperature in each segment will be determined from thermocouple readings taken during actual tests. Residence times in each section are assumed to be the gas residence time.

The combustion rate in Segment I will be calculated from

$$t = \frac{\rho_c d_i^2}{96 \text{ Sh } D_g D_o} \left(1 - \frac{d^2}{d_i^2}\right) \quad (6)$$

where

$\rho_c$  = carbon density  
Sh = Sherwood Number (assumed = 2.0)  
C = Oxygen concentration based upon mass balance  
 $D_o$  = Molecular diffusivity of oxygen  
 $d^g$  = diameter of carbon particle at the top of the bed  
 $d^i$  = diameter at time t

This equation has the same form as the previous simplified model. It will be assumed that the reaction rate in each segment can be determined from the reaction rate in Segment I adjusted for temperature by an activation energy of 25 Kcal/mole. The amount of combustion in Segments II through IV is expected to be small due to lower temperatures, lower oxygen concentrations and near complete reactions.

### 2.3 Evaluation of Instrumentation and Controls (Activity No. 709)

During the reporting period, the automatic control system for the Alexandria FBM was placed into operation. Substantial changes were made to the control system during the tuning process. Extra controls were added to the boiler water and steam system to simulate load changes. The major change to the control system involved using the low bed to freeboard pressure differential as a measure of bed depth. The current logic diagram for the control system is shown in Figure 6.

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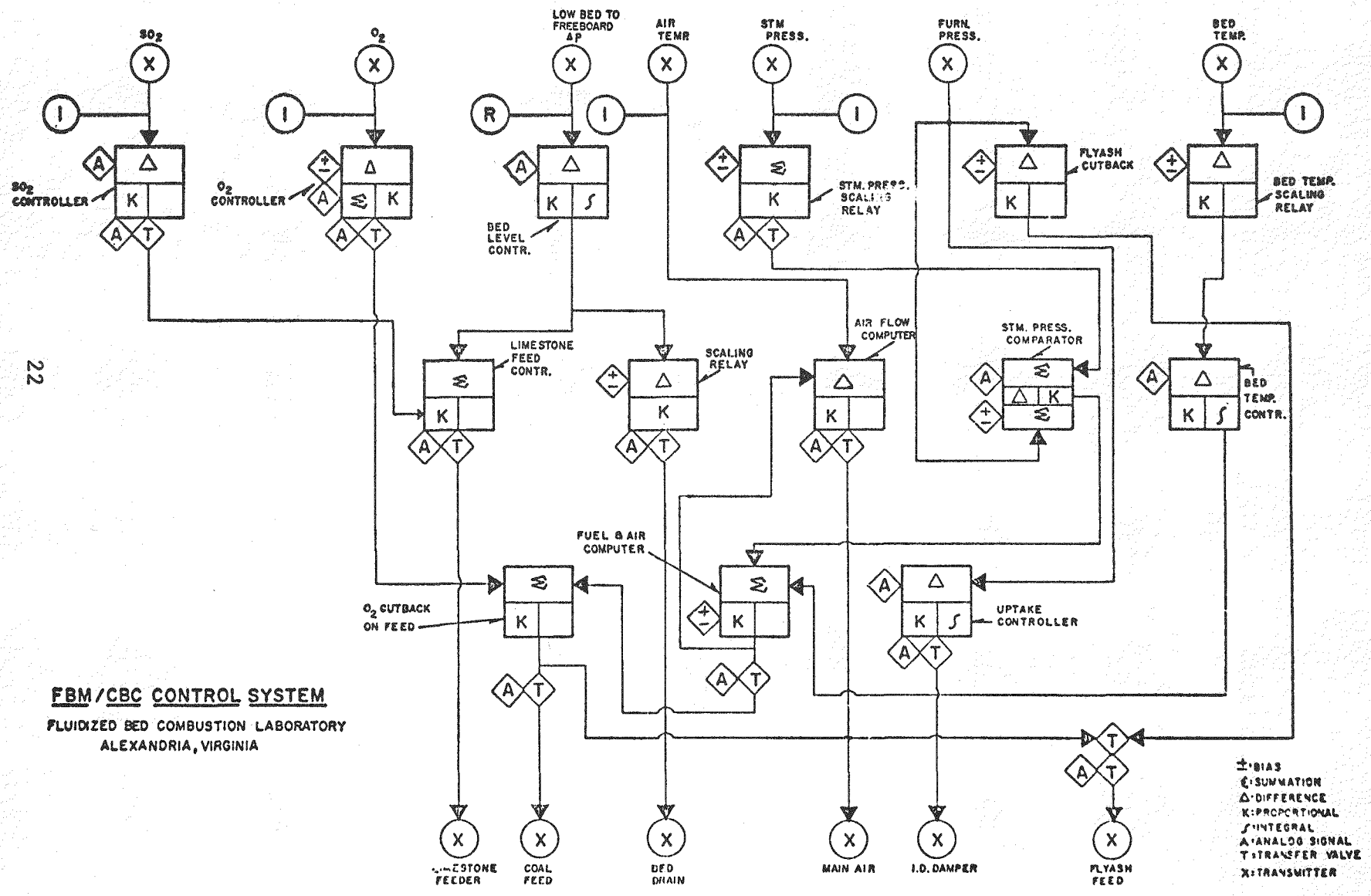


Figure 6

### 2.3.1 Hardware Modifications

Previously, the Alexandria FBM used a back pressure regulator to maintain a constant steam pressure while the rate of steam production varied. However, the automatic combustion control system was designed to adjust the firing rate to compensate for changes in load by responding to changes in the steam pressure. Since the rate of steam production is greatly affected by the air flow rate, steam pressure should act to trim changes in the firing rate. Thus a significant part of the control system was operating due to back pressure regulation.

To solve this problem, a boiler water level control loop and a steam flow control loop were installed. The boiler water level controller is a proportional integral controller which regulates the inlet water flow to maintain a constant water level with changes in steam flow. This system has been installed and tuned. The steam flow control loop consists of a differential pressure transmitter, and control valve. This unit has also been installed and is operational. With these new control loops, steam flow can be changed to simulate load changes on the boiler.

During the reporting period substantial changes were made to the bed level control loop. As originally designed, the static bed level was to be inferred by comparing plenum pressure and damper position. During testing it was observed that the static bed level could change by as much as three (3) inches with no noticeable change in plenum pressure. Thus, control of bed height using the plenum pressure was not satisfactory.

After several attempts to improve bed height control using combinations of main air rate, damper position, and plenum pressure, a constant purge system was installed on the freeboard pressure tap and the pressure tap one inch above the air distributor. Pressure signals from these locations were used with a differential pressure transmitter to generate a signal proportional to the pressure drop across the bed. With the pressure drop across the bed as a measure of bed level, the static bed height was automatically controlled to load operation. Using a constant air purge through the taps, plugging problems appear to have been eliminated since they have operated satisfactorily for more than 200 hours, including two 80 hour around the clock tests.

Control of bed level is essential to stable control of the boiler. An increase in bed level will increase the heat removal rate from the bed due to increased contact area between the bed and the water-walls. The result of this increased heat removal rate will be to either cool the bed or if temperature is maintained, lower the percent

excess O<sub>2</sub> in the stack. The fuel and air control loop (loop 2), controls temperature by changing the firing rate (fuel and air) and controls percent excess O<sub>2</sub> by changing the coal feed rate. In the event of an increase in bed depth, the controller will simultaneously increase the coal and the air feed rate to maintain the temperature and decrease the coal feed rate to lower the percent excess O<sub>2</sub>. The net result will be to cool the bed rather than heat it and the temperature will be uncontrollable. Thus it was found that during periods of changes in bed depth, the O<sub>2</sub> controller had to be deactivated so that the temperature of the bed could be maintained.

### 2.3.2 Automatic Control Tests

The first automatic control tests were conducted to establish the proper fuel to air ratio. In order to control temperature in the bed, a necessary condition is that an increased firing rate cause an increased bed temperature. As was observed in Test No. 645-1, an improper fuel to air ratio could result in the opposite effect. In order to determine the proper fuel to air ratio, step changes were made manually to the fuel and the air feed rates. The changes corresponded to various fuel to air ratios. The bed temperatures were then observed to see if the proper response was obtained. For a given fuel to air ratio, step changes were made to increase the firing rate and again to decrease the rate. In this manner a satisfactory fuel to air ratio was determined to be 2:1. It should be noted, that the fuel to air ratio corresponds to the pneumatic signals which control the coal feed rate and air damper position. Furthermore, boiler construction such as refractory on the waterwalls, will affect the fuel to air ratio. Therefore, this procedure should be followed to establish the proper ratio each time a significant change is made to the FBM.

The next series of tests were 80 hour duration tests. During these runs, the bed level controller (loop 3) was modified to accept a more direct measure of bed level. The low bed to freeboard pressure differential was used to control bed level to within one-half inch on either side of the set point. The SO<sub>2</sub> controller and limestone feed controller were also tuned at this time.

A third series of tests were conducted to begin tuning the fuel and air control loop (loop 2). The temperature and O<sub>2</sub> controllers are operational; however, additional tuning of the steam pressure comparison is necessary to maintain steam pressure at various loads. During the automatic control testing, it was found that the temperature controller could maintain bed temperature to within 10 degrees of either side of the set point when the O<sub>2</sub> controller was not in service. When the O<sub>2</sub> controller was turned on with the temperature controller, bed temperature was maintained to within 5 degrees on

either side of the set point. Further testing and tuning of the automatic control system is required to integrate the operation of the control loops and to determine the effect of disturbances to the system when the control loops are interactive.

## 2.4 Coal Feeder Tests (Activity No. 211)

### 2.4.1 Conversion of Petrocarb Injection System

A coal feeder evaluation program was started during the reporting period. The Petrocarb, Inc. fly ash injection system was modified for use as a coal injection system with various feeding arrangements. Due to the injector's fuel size limitation, the coal reprocessed to 1/8 inch or smaller. Figure 7 shows the coal flow diagram used in the evaluation program. This setup provided the greatest flexibility in switching between the Carman vibrating feeder table (needle feeders) and the Petrocarb, Inc. injector during test runs, which permitted ready comparison of the two systems.

New coal feeding arrangements consist of under bed tee and mushroom feeders and over bed feeders as seen in Figure 8. The over bed feeders utilize two separate feed lines from the Petrocarb, Inc. injector to insure even feed distribution and are located in the center of the FBM ash shown. They also have varying injection angles. The under bed feeder arrangement consists of a welding tee or mushroom cap located in the FBM as shown in Figure 9. Testing procedure consisted of light-off using the existing coal feeding equipment. The FBM was run at steady state for sufficient data gathering and then taken throughout the test for combustion efficiency comparisons. Limestone was fed throughout the test through the Carman feeder table only. Static bed depths of 15 inches and temperature of 1500°F to 1600°F were maintained with four percent excess O<sub>2</sub> prior to switching to the Petrocarb injector. After switching to the injector coal and air rates were held constant and changes in temperature and O<sub>2</sub> were observed.

### 2.4.2 Summary of Test Results

As of this date four coal feeding tests have been completed, Test Nos. 646-1 through 646-4.

Test No. 646-1. The first test in coal feeding was a systems shake-down test and consisted of switching between the injector feeding arrangement and the Carman feeder table. Results showed that there were no problems in changing to different coal feeding methods during test runs, and transition times of two to five minutes were observed. The feeding arrangements used were the under bed tee located in the center of the FBM, and the over the bed feeders at a

# COAL FLOW DIAGRAM - PETROCARB INJECTOR

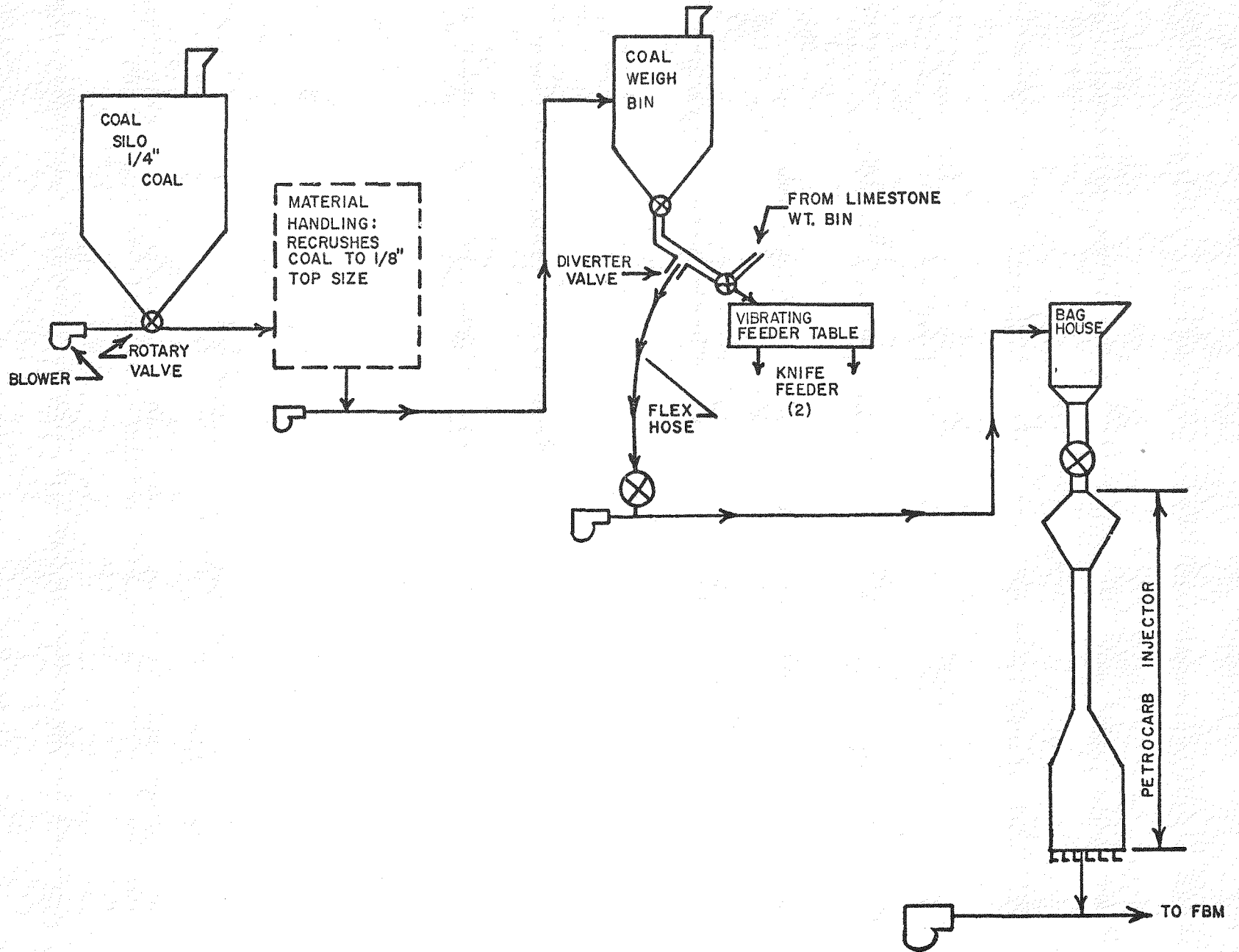
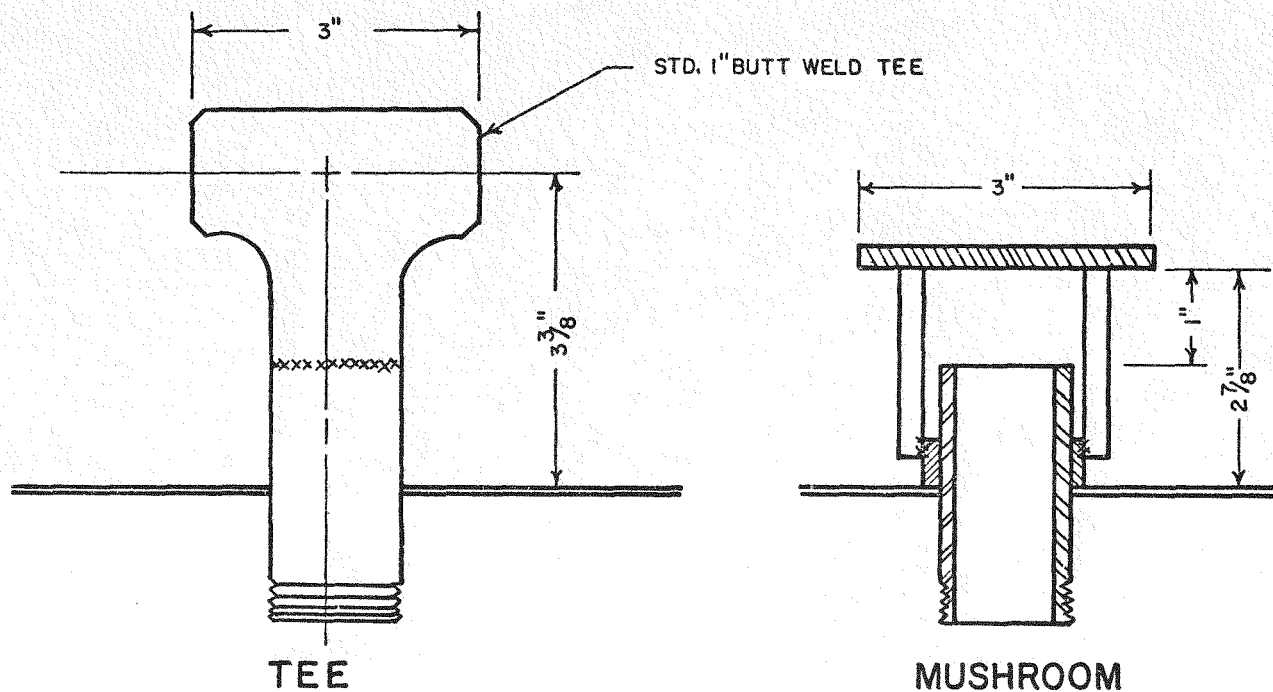
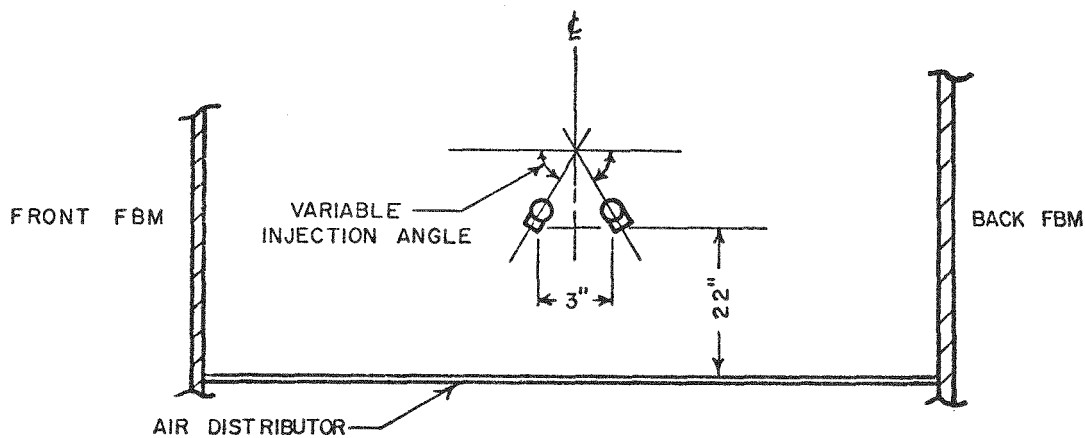


Figure 7



UNDER BED FEEDER ARRANGEMENTS



OVER BED FEEDER ARRANGEMENT

Figure 8



horizontal injection angle facing the front and back of the FBM. Although no data was recorded to perform combustion efficiency calculations some qualitative observations were made:

- . When testing the under bed tee the average bed temperature dropped 70°F, O<sub>2</sub> dropped from 5 percent to 2 percent, the fly ash collection rate decreased and uneven bed temperature distributions were observed. This would tend to indicate more combustion is happening above the bed.
- . When testing the over bed feeders a very high stack dust loading was observed and the feeders were turned off.

Test Nos. 646-2, 646-4. Short steady state conditions were achieved only in Test 646-2, using the over bed feeders and Test 646-4, using an under bed mushroom feeder because of plugging problems that occurred in the Petrocarb, Inc. injector. These plugging problems are similar to those experienced using the injector during initial CBC testing with fly ash as discussed in Progress Report No. 50, pg. 11. Work is now underway to correct the problem.

Table 2 summarizes the test results from the steady state conditions that were achieved. The results of Test No. 646-2 show essentially no difference between combustion efficiencies of the vibrating feeder table and the over bed feeders. The average bed temperature decreased about 100°F when the over bed feeders were in use. This indicates that combustion of more coal is taking place above the bed. The increase in SO<sub>2</sub> during the over bed feeder test also indicates over bed combustion. Results from Test No. 646-4 indicate about the same combustion efficiency using two needle feeders or one under bed mushroom feeder. Both tests had similar temperature distributions in the bed.

The results obtained to date are considered preliminary since only a limited number of runs have been completed and combustion efficiency evaluated for only one set of operating conditions.

## 2.5 Light-Off Procedures Study (Activity No. 1106)

During the reporting period tests were run to develop alternative light-off procedures. Two alternate light-off procedures were attempted; the first procedure used No. 4 heating oil to heat the bed to ignition temperatures; the second involved a normal light-off procedure on a partially slumped bed.

Light-off of a fluidized bed requires heating the bed to the ignition temperature of coal char and then introducing a steady coal feed rate. Normally the heat is supplied to the bed by gas or oil burners.

TABLE 2

Summary Test Results  
Steady State Operating Conditions

Test	646-2		646-4	
	10:00	12:30	10:00	11:30
Feeder Arrangement	Carman Feeder (Knf. Fdr.)	Over Bed Feeder ~60° from Horz.	Carman Feeder (Knf. Fdr.)	Under Bed Feeder (Mshrm. Fdr.)
Bed Temp., °F	1570	1470	1640	1590
O <sub>2</sub> in flue gas, %	4.5	3.0	4.5	4.8
SO <sub>2</sub>	500	750	600	470
Coal feed rate, lb/hr	535	567	537	516
Fly ash collection rate, lb/hr	101	108	158	178
Stack dust rate, lb/hr	35.1	32.6	21.3	17.3
Total air flow rate, lb/hr	6425	6505	5949	5918
Superficial velocity, ft/sec	10.1	9.7	9.7	9.4
Static bed depth, inches	16.9	16.8	15.7	15.9
EOBH (effective operating bed ht.), inches	--	--	18.3	18.8
Combustion efficiency, %	86.1	86.5	83.3	82.0

Some heat can be supplied to the bed by the volatiles in the coal if an inventory of coal (usually 5 to 10 percent of the bed by weight) is present in the bed prior to light-off. In this case the burning volatiles help raise the bed temperature to the ignition temperature of the char (usually between 800 and 1000°F). Normally, light-off is accomplished at or near minimum fluidization. This insures some mixing in the bed while minimizing the sensible heat loss from the bed. Thus, light-off time of a fluidized bed can be reduced by two approaches. The first involves addition of fuel to the bed prior to light-off. The second approach involves blocking portions of the grid plate, thereby reducing the total air flow through the cell and reducing the sensible heat loss.

### 2.5.1 Oil Assisted Light-Off

The first alternative light-off procedure involved the addition of number 4 heating oil to the bed prior to light-off. Six gallons of heating oil and 50 pounds of coal were added to a 1000 pound charge of spent bed material (about 12" static bed depth). The bed was then fluidized for 15 minutes to thoroughly mix the oil in the bed and allow the oil to be absorbed into the bed material. The air flow was then reduced to minimum fluidization and the light-off burner turned on. The light-off burner remained on until the bed temperature rose to 800°F. It was necessary to keep the oil ignited. The burner was turned off when the temperature reached 800°F after which the oil continued to burn by itself. By the time the bed temperature reached 1000°F the oil was completely consumed and the coal had begun to burn. The total time for light-off to a 1500°F bed temperature was under 8 minutes using this method.

Three problems were encountered using this light-off procedure. The first was the fast temperature rise in the bed. The bed temperature rose to 1000°F in just under three minutes. This could be a problem in a large bed if too much fuel is present. The second problem involved the formation of clinkers in the bed when the bed was slumped before all of the oil was consumed. The third problem was caused by burning oil being carried over to the dust collector and igniting fly ash in the collector.

### 2.5.2 Reduced Air Flow Procedure

The second light-off procedure tested attempted to reduce the sensible heat loss from the bed during light-off. This was done by covering the back two-thirds of the grid plate with cardboard prior to adding bed material. This resulted in a small (1½ ft. x 2 ft) fluidized region near the burner while the rest of the bed remained slumped. Thus only the front third of the bed had to be heated to ignition temperature with the over bed light-off burner.

The burning bed then supplied the heat to light-off the remaining bed as the cardboard burned back. The anticipated benefit of such a light-off scheme is that a large fluidized bed could be started up with less over bed burner capacity than required for the entire fluidized bed.

The procedure used for this light-off was as follows. The back two-thirds of the grid plate was covered with cardboard held in place by wood strips and wire. Bed material (11.5 inches, static) was then placed on top of the grid and mixed with 65 pounds of coal. The air flow was turned on and as the cardboard burned back, the air flow was increased to maintain minimum fluidization.

Figure 10 shows the temperatures normally encountered during light-off two inches above the air distributor and 9, 45, and 63 inches back from the light-off burner. In a normal light-off procedure the front portion of the bed is heated to about 1000°F. The air velocity is then increased to mix the bed to a uniform temperature and the temperatures all rise at the same time. Figure 11 shows the same temperatures for the light-off with no fluidization of the back two-thirds of the grid plate. Here the front third is ignited, and as the cardboard burned back (at a rate of about 3.5 inches per minute) the rest of the bed ignited.

Figures 10 and 11 indicate that the total time to light-off the bed is about the same for both techniques. This is because the total fuel input from the burner and the coal is the same in both cases. However, it is believed that with only one-third of the bed fluidized, light-off could have been accomplished with a smaller burner.

## 2.6 Process Development Unit (Activity No. 1116)

Design work on a replacement boiler for the Alexandria laboratory continued during the reporting period. Preliminary heat and mass balances were performed and compared to calculations by Cleaver Brooks, the boiler manufacturer. Detailed drawings from Cleaver Brooks were reviewed and modifications recommended.

A preliminary water flow schematic was developed as shown in Figure 12. Most of the steam produced will be condensed and returned to the boiler. This will reduce water pretreatment requirements of the present once through system. Air preheat will be obtained from condensing saturated steam which will permit about 250° F of preheat. Superheated steam will be cooled down to saturation with a feed water spray prior to entering a fan cooled condenser. Flue gas cooling will be accomplished either by a low pressure water recirculation system or by a direct contact spray cooling system. Provision for using superheated steam to obtain higher air preheats is being considered.

# GRAPH of TEMP vs TIME

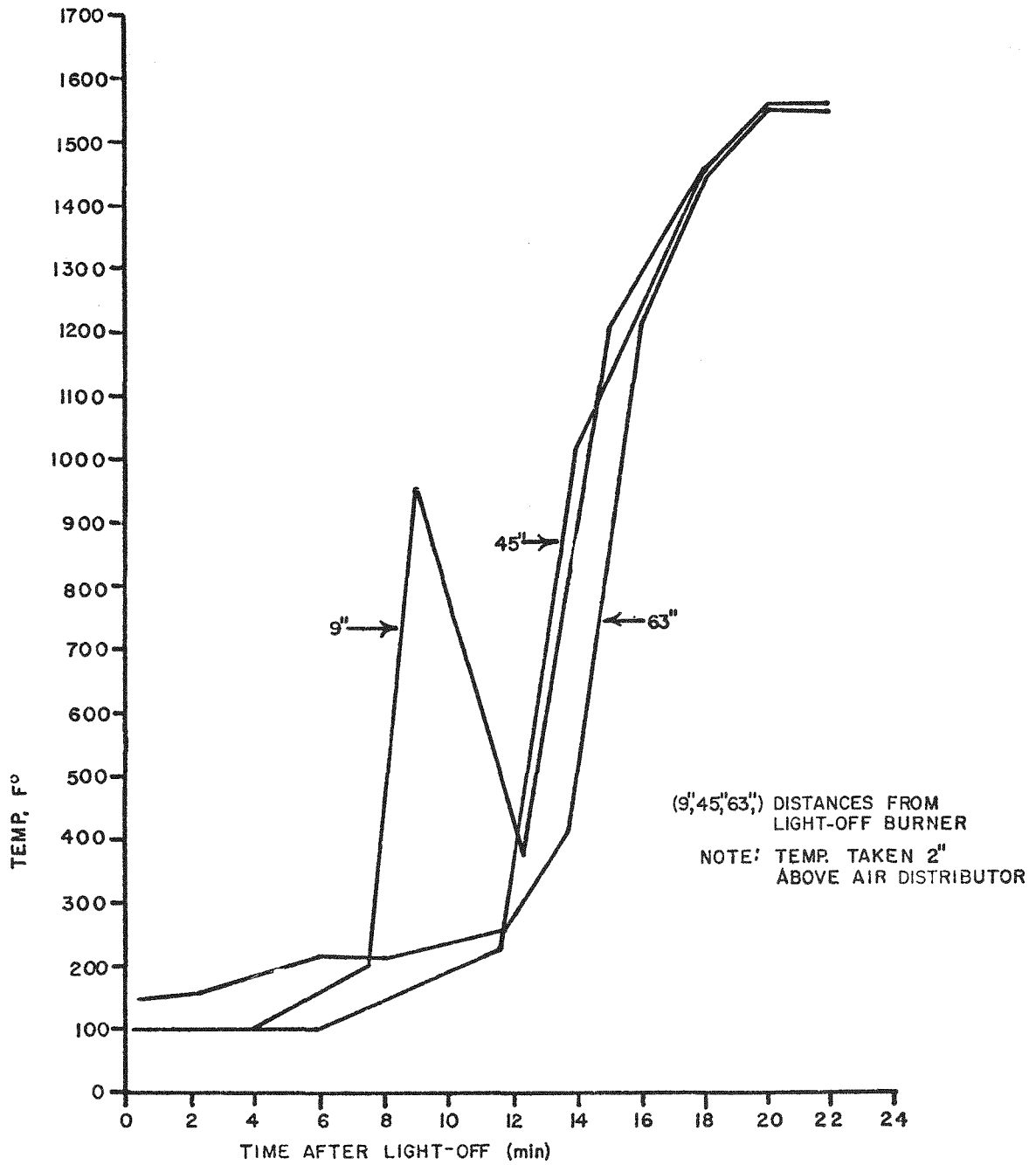


Figure 10

# GRAPH of TEMP. vs. TIME

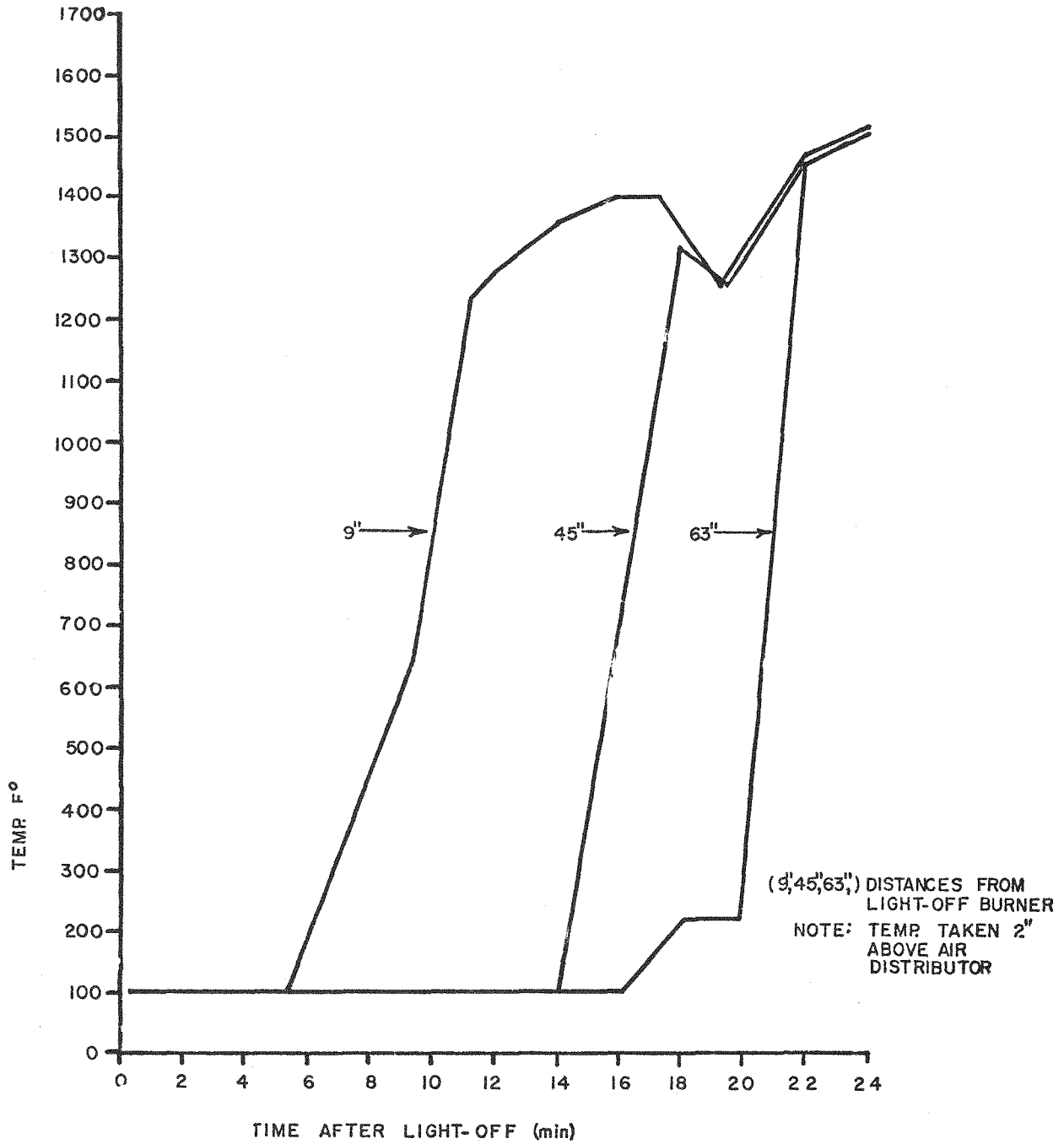
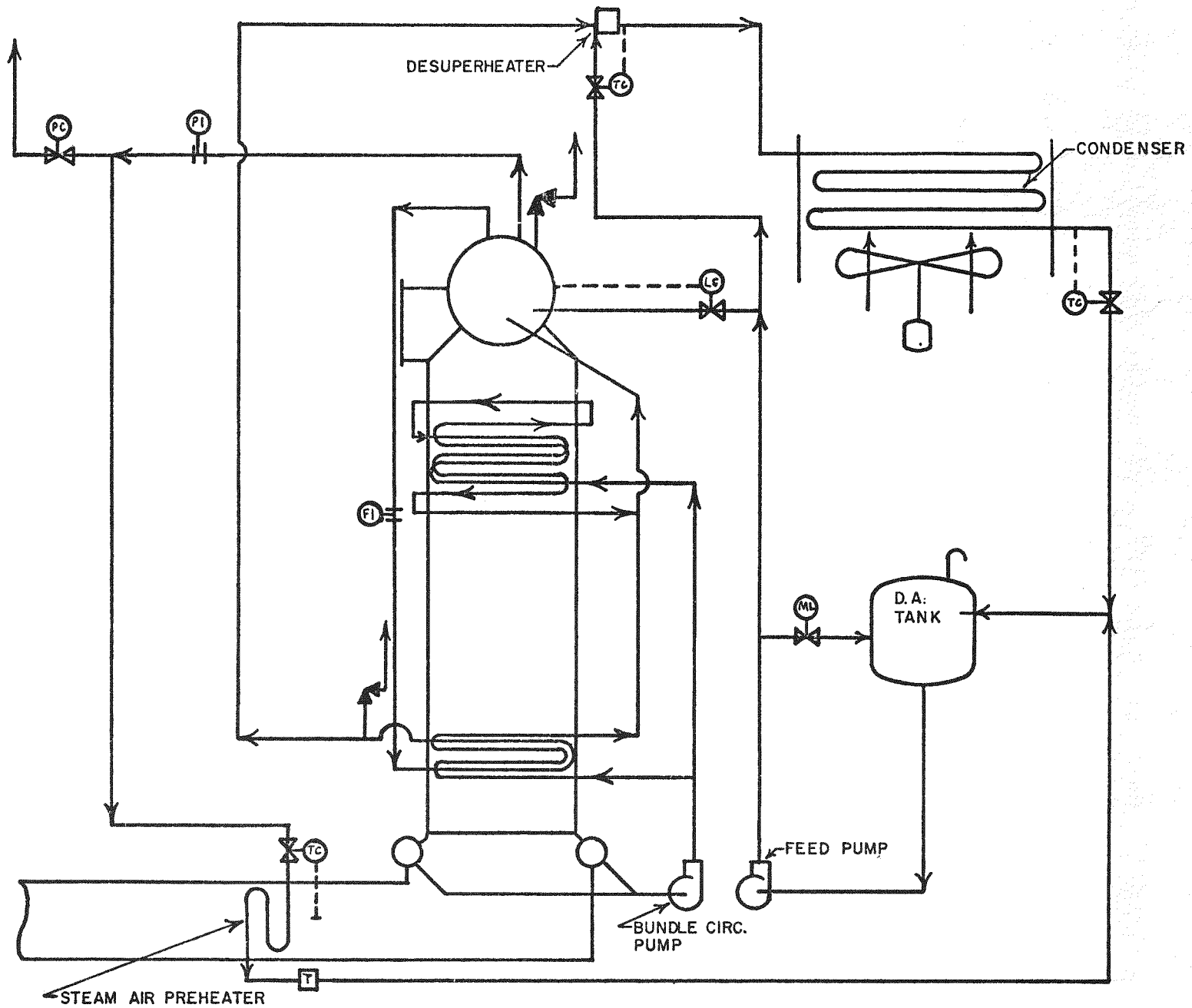


Figure 11

Figure 12



3'X3' CROSS SECTION, PROCESS DEVELOPMENT UNIT WATER FLOW DIAGRAM

Present engineering work is directed toward sizing and purchasing the auxiliary equipment to complete installation of the replacement boiler.

## 2.7 By-Product Study (Activity No. 1005)

During the reporting period the FBM was operated continuously for two 80 hour periods. One purpose for these tests was to generate sufficient spent bed material, approximately 20 tons, to satisfy requests of other ERDA contractors. The spent bed is to be used in a variety of experiments. Facilities to which spent bed material was shipped during the reporting period are as follows:

U.S.D.A. 11.7 tons sulfated bed material  
Beltsville, Md.

U.S.D.A. 1.8 tons sulfated bed material  
Poultry Research Lab.  
Georgetown, Delaware

U.S.D.A. 3 tons sulfated bed material  
Valley Forge Lab.  
Valley Forge, Pa.

U.S.D.A. 2.7 tons sulfated bed material  
Agriculture Research  
West Virginia University  
Morgantown, W. Va.

## 2.8 Corrosion/Erosion Studies (Activity No. 1207)

During the reporting period two corrosion/erosion test racks supplied by the International Nickel Company were installed in the Alexandria FBM. Metal coupons of the following composition were contained in each rack:

1010 carbon steel	Incoloy 800
Alloy T-22	Incoloy 804
Type 304 stainless steel	Inconel 600
Type 309 stainless steel	Inconel 601
Type 310 stainless steel	Inconel 671
Type 314 stainless steel	Inconel 690
Hastelloy X	In - 809
	In - 811

One rack was located in the bed  $6\frac{1}{2}$  inches above the grid plate while the other was located six inches below the steam drum. The test racks were removed after about 210 hours of operation and returned to

the International Nickel Company for analysis. Four more racks are being furnished by International Nickel. Two are to be mounted in the bed and two are to be mounted in the freeboard area. One set will be removed after about 300 hours and the other will be removed after 1000 hours. Materials in the racks are the same as those in the previous racks.

### 3.0 MFB PLANT OPERATION

#### 3.1 General Activities

During the period January through March 1977, major activities at the Rivesville MFB Plant consisted of identifying and resolving problems arising from sustained operation of Cells D and C and installing supplemental instrumentation.

The following additional major items of work were also performed:

- . Completed outfitting of Chemistry Laboratory with equipment and supplies,
- . Purchased supplies, equipment and tools to support preventive maintenance program,
- . Trained maintenance and operation personnel, and equipment operators,
- . Completed construction punch lists and final testing of equipment for acceptance,
- . Operated MFB Cells C and D for sustained periods and debugged auxiliary equipment,
- . Finalized MFB light-off procedures.

#### 3.2 Specific Activities

##### 3.2.1 Results Engineering

Results Engineering activities during this period included:

- 1) Completed heat balance calculations to establish coal flow rate required to sustain combustion in Cell C when transferring bed.
- 2) Conducted tests to establish mass flow rate of coal, limestone and coal/limestone mixture vs. percent sized to rotary feeder from control station on boiler combustion control panel.
- 3) Evaluated feedwater consumption during MFB light-off.
- 4) Analyzed heat energy dissipation for light-off conditions.
- 5) Conducted cold mode airflow tests.

##### 3.2.2 Instrumentation

The following activities were engaged in during this period:

- 1) Completed calibration checks of transmitters,
- 2) Reviewed instrumentation systems for improvements to increase reliability,
- 3) Determined and acquired materials, supplies and tools required to support preventive maintenance program,
- 4) Calibrated O<sub>2</sub> transmitters for Cells C and D,
- 5) Installed thermocouples in Cell B and for monitoring temperature of gas and air in and out of the air preheater,
- 6) Performed general maintenance of instrumentation.

### 3.2.3 Chemical Laboratory

The following activities were engaged in during this period:

- 1) Monitored, analyzed and treated boiler water,
- 2) Analyzed solid samples,
- 3) Sampled and analyzed delivered coal for moisture content and size distribution,
- 4) Calibrated and operated SO<sub>2</sub> and NO<sub>x</sub> analyzers.

### 3.2.4 Equipment Maintenance

- 1) Performed general electric maintenance and repairs.
- 2) Repaired ash cooler.
- 3) Assisted manufacturer's representative in repairing electrostatic precipitator.
- 4) Completed check-out of electrical interlocks, alarm and indicating lights systems.
- 5) Set-up and operated fly ash system for sustained periods.
- 6) Calibrated Autoweigh Mark IV scales.
- 7) Calibrated air preheater oil pump auto-start temperature sensor.
- 8) Completed testing of auxiliary equipment and systems for acceptance.

### 3.2.5 Testing - Inspection of Equipment for Acceptance

During this reporting period, testing/inspection of equipment supplied by the construction subcontractor, Champion Construction & Engineering Co., Inc. was completed. All major outstanding items of equipment were accepted for maintenance and operation based on the subcontractor having demonstrated the equipment's satisfactory performance.

### 3.2.6 Construction Punch Lists

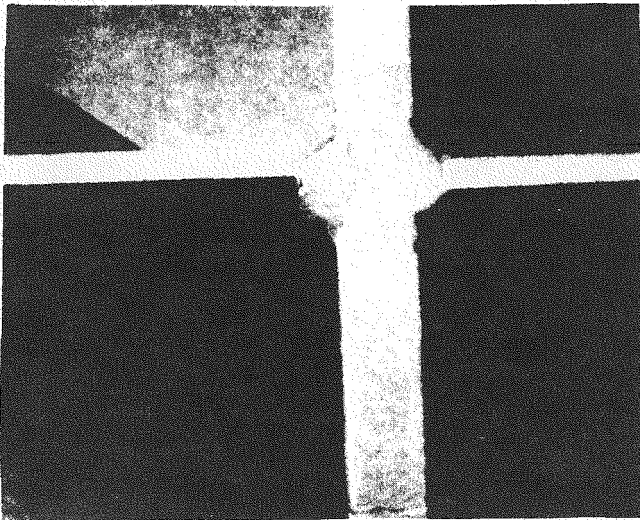
Construction completion punch lists were prepared and updated as the construction subcontractor initiated appropriate corrective action. At the close of this reporting period, all work has been completed.

### 3.2.7 Training of Personnel

Training of operating and maintenance personnel continued during this period by developing familiarization with installed systems and equipment as the result of inspection and operation and reference to manufacturer's drawings and instruction manuals.

### 3.3 Operational Problems

#### 3.3.1 Induced Draft Fan Failure



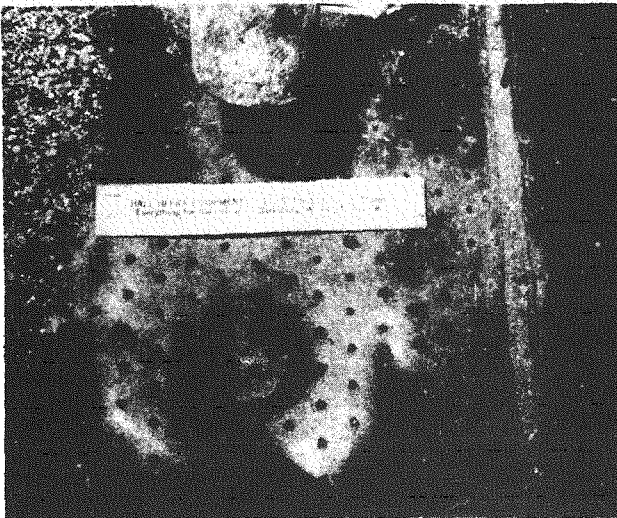
I.D. Fan Rotor Blade Cracking

- (a) Equipment -Induced Draft Fan.
- (b) Manufacturer -Zurn Industries.
- (c) Warranty -Guaranteed against defects in workmanship or material for a period of one full year from initial operation or 18 months after shipment, whichever occurs first.
- (d) Nature of Failure
  - Thirty-three bolts which attach inlet cones to I.D. Fan housing sheared.
  - One blade on I.D. Fan rotor had large crack.
  - Housing of I.D. Fan cracked where directional van on outlet of I.D. Fan is attached to housing.
  - Welded housing on either side of directional vane.
  - Rectangular section of cracked blade cut out and new piece welded in.

-Sheared bolts drilled out, replaced with through bolts, double nutted, and tack welded.

All remaining inlet cone bolts were double nutted and tack welded.

### 3.3.2 Grid Plate Distortion/Failure



a) Nature of Failure - During routine inspection, the grid plate was noted to have failed in the following manner under three feed nozzles:

- Distortion
- Local Overheating
- Failure (cracked)

b) Repairs: The three failure spots were cut out and new sections of grid plate welded in.

The ends of four (4) feeder tubes were shortened from 1" - 4" to prevent grid plate failure under these tubes.

CBC Grid Plate Distortion

### 3.3.3 Light-Off of Cell D

Initial light-off Cell C in December 1976 and subsequent light-off in January 1977, indicated that the time required to bring the system up to temperature for coal ignition was excessive. Approximately 12 -14 hours of oil burner firing was required to raise the temperature of 90,000 lbs. of water in the system to  $400 \pm ^\circ\text{F}$ , raise the boiler mass of approximately 500,000 lb to  $400 \pm ^\circ\text{F}$ , and raise the temperature of the bed material to coal ignition temperature of  $800 \pm ^\circ\text{F}$ . During this period, make-up feedwater for blowdown at the rate of 5000 lb/hr was also required. To reduce the time required to a more realistic period and effect savings in both fuel oil and feedwater make-up alternate light-off methods were studied at the Alexandria Laboratory.

### 3.3.4 Cell C Light-Off (Attempt No. 4) February 10, 1977.

#### Summary of Events

<u>Time (Hour)</u>	<u>Event</u>
1740	RF1-CN to 50 percent (5,000 lb/hr coal).
1742	Slide gate open.
1744	RF1-CN & CS to 75 percent (7,600 lb/hr).
1745	Bed temperature (C-Cell) 1600°F Main Furnace uptake temperature 600°F. C-Cell 8 percent excess O <sub>2</sub> . Drum pressure rose from 750 psi to 1100 psi. Bed heights stablized at 14".
1755	RF1-CN and CS to 0 percent, slumped cell C bed. Bed temperature rose to between 500°F and 1000°F.
1800	Fluidized Cell C, RF1-CN and CS to 50 per- cent (5,000 lb/hr coal flow).
1810	RF1-CN and CS to 0 percent.
1812	RF1-CN and CS to 0 percent, slumped Cell C, bed temperature rose to between 500°F and 1580°F.
1818	Fluidized cell C RF1-CN and CS to 100 per- cent (10,400 lb/hr).
1822	RF1-CN and CS to 0 percent.
1835	Closed slide gate.

Prior to light-off attempt, Cell D bed height was raised to 33" WG static, Cell D bed temperature was 1800°F, Cell C bed height was 7"-8" static, had 90,000 lb/hr airflow through Cell C, and combustion air temperature was 440°F.

Coal was introduced to Cell C two minutes prior to the opening of D-C slide gate in order to provide a coal charge in Cell C. Approximately fifty (50) seconds after opening the slide gate, the bed material had equalized between the two cells and one (1) minute after the cells had equalized Cell C bed temperature started to rise sharply, leveling off at 1500° to 1600°F. C Cell bed temperature then started dropping to 750° - 800°F. Recording charts (enclosed on the following pages) indicate that bed temperature remained above 1000°F for nine (9) minutes.

In an attempt to raise the bed temperature again, the coal feed was stopped and Cell C bed slumped for four (4) minutes. At this time, the bed temperature ranged from 450°F to 1400°F. The bed was then fluidized and coal feed started at which time the average bed temperature rose to 800°F. This same approach was attempted once again but proved unsuccessful.

### MFB Unit Inspection

After the Cell C light-off attempt was completed, the unit was shut-down and a routine inspection was conducted. The plant appeared normal with the exception of the Forced Draft and Induced Draft Fans.

Forced Draft Fan: Several nuts had vibrated off the inlet cones.

Induced Draft Fan: Thirty-three bolts had sheared off the inlet cones.

Fan Blade was cracked.

Fan housing was cracked on either side of turning vane on discharge of fan.

Zurn Industries, forced draft and induced draft fan manufacturer, was contacted and a representative dispatched in order to remedy the situation.

### Solids Analysis

Solids analysis was performed on the following sample in order to give a greater insight into actual conditions during Cell C light-off attempt.

<u>Sample</u>	<u>Carbon*</u>	<u>Hydrogen</u>
Cell C Bed Material Sample	2.08%	.2%
Cell D Bed Material Sample	2.23%	.14%
Fly Ash from Dust Collector No. 1		
(West Hopper)	26.8 %	1.02%
(East Hopper)	14.3 %	.64%
Fly Ash from Dust Collector No. 2	28.25%	.65%

\*Carbon may be contained in  $\text{CaCO}_3$

Although light-off Attempt No. 4 was not completely successful, results of the attempt indicate that the light-off technique should be successful when Cell C operating condition is improved to reduce bed heat losses. It is important to note that during the light-off

attempt the air flow rate through Cell C was approximately 90,000 lb/hr which was raised to a maximum of 7,500 lb/hr. These air to fuel ratios represent a percent excess air of approximately 100 percent and 33 percent respectively. Normal main cell operation is at 15 percent excess air. It can be seen that a large amount of excess air was being introduced to Cell C during light-off. This large amount of air did not contribute to combustion but rather resulted in a large heat removal source in two ways, (1) it increased the amount of heat removed as sensible heat in the flue gas and (2) it increased the rate of heat removal via the lower horizontal bundle by increasing the bundle heat transfer coefficient.

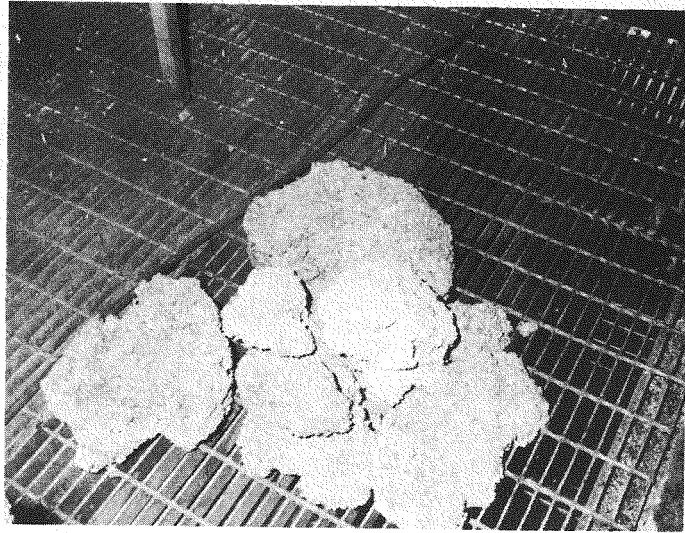
By decreasing the air flow rate to Cell C both of these heat losses will be reduced 50 percent without defluidizing the bed. Such a reduction would greatly reduce the heat removal rate from the bed.

Short term coal combustion in Cell C was achieved during light-off attempt No. 4 as was evidenced by the momentary drop in the O<sub>2</sub> content of the flue gas coming off Cell C. This indicates that the light-off technique of transferring hot bed material can be used to ignite coal in Cell C.

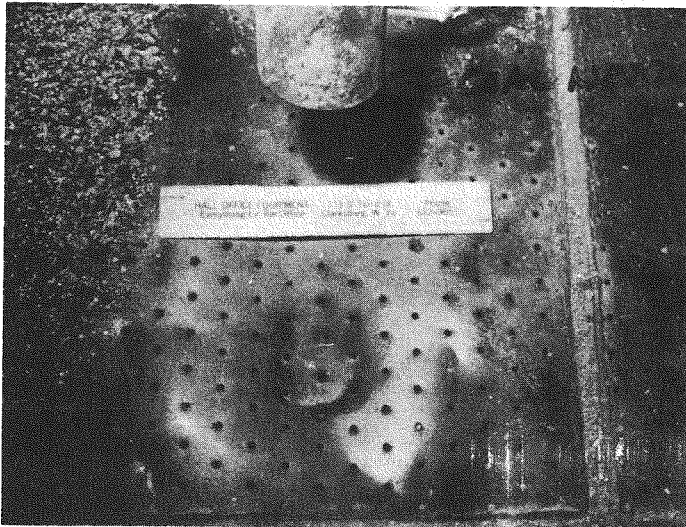
Clinkers formed and removed from Cell D (CBC) after the mid December 1976 coal burning operation, also clinker formation in Cell D bed during the early January 1977 coal firing are shown on the enclosed photographs. Slagging of the oil burner throat in Cell D is also shown on one of the photographs.

MFB PLANT  
RIVESVILLE, W. VA.

CELL D (CBC)



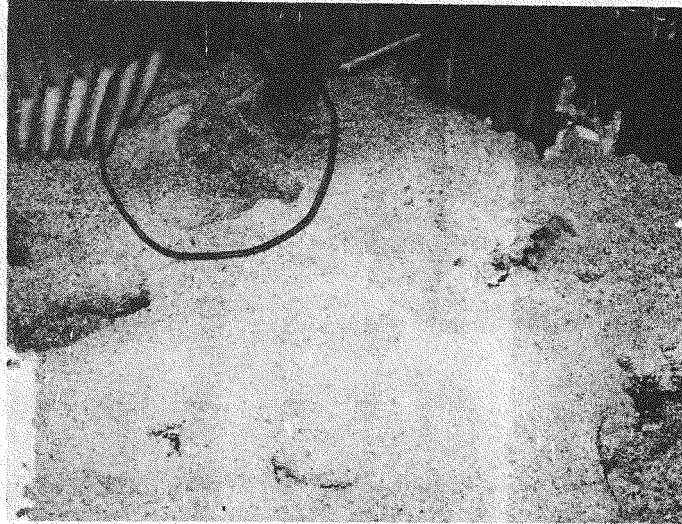
Clinkers removed from Cell on December 20, 1976



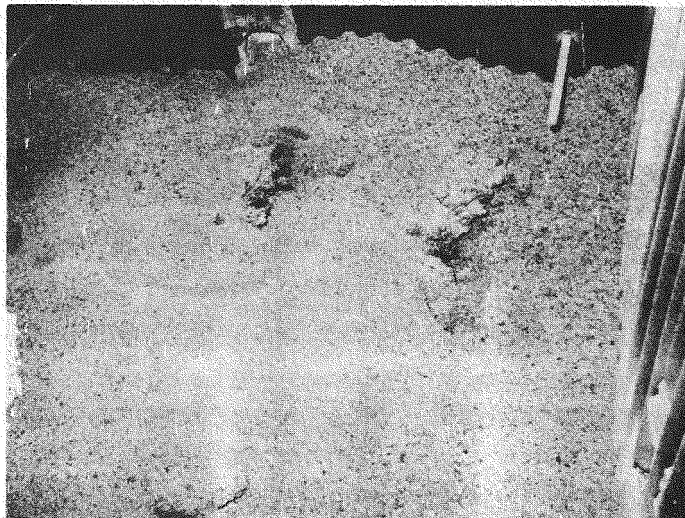
Air supply grid plate deformation, February 17, 1977

MFB PLANT  
RIVESVILLE, W. VA.

CELL D (CBC) - January 6, 1977



Clinker Formation at D/C Cells Material Transfer Slide Gates



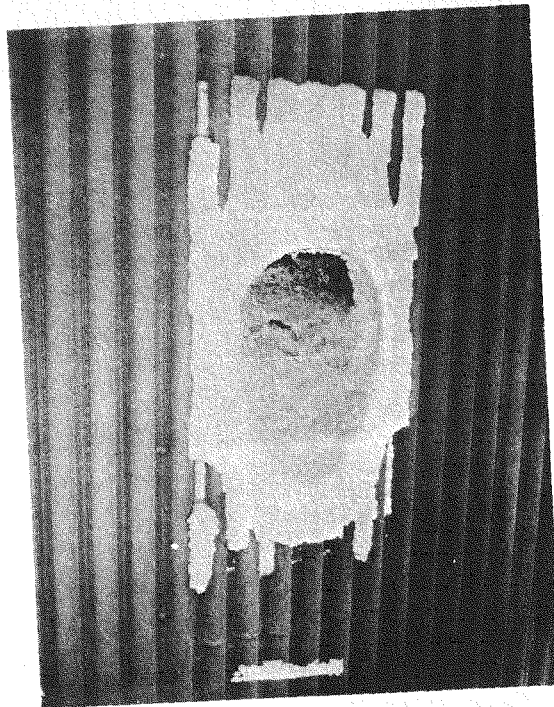
Clinker Formation at NE Cell Area

MFB PLANT  
RIVESVILLE, W. VA.

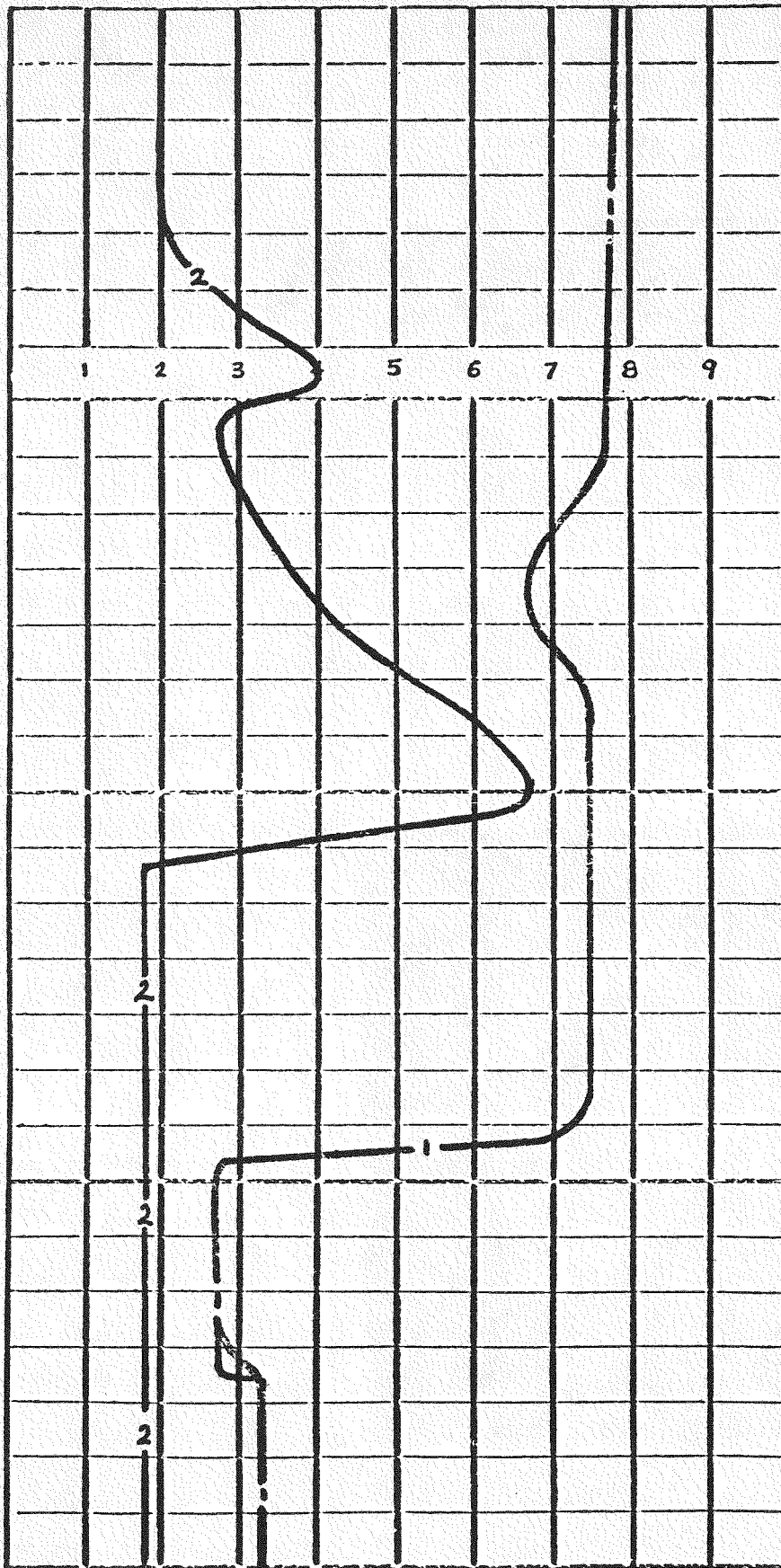
CELL D (CBC) - January 6, 1977



Clinkers in the bed at Center of Cell



Slagging of burner throat in South Wall



1815 HOUR

Scale

Bed Temperature  
Multiply by 240°F

— 1 — Cell D

— 2 — Cell C

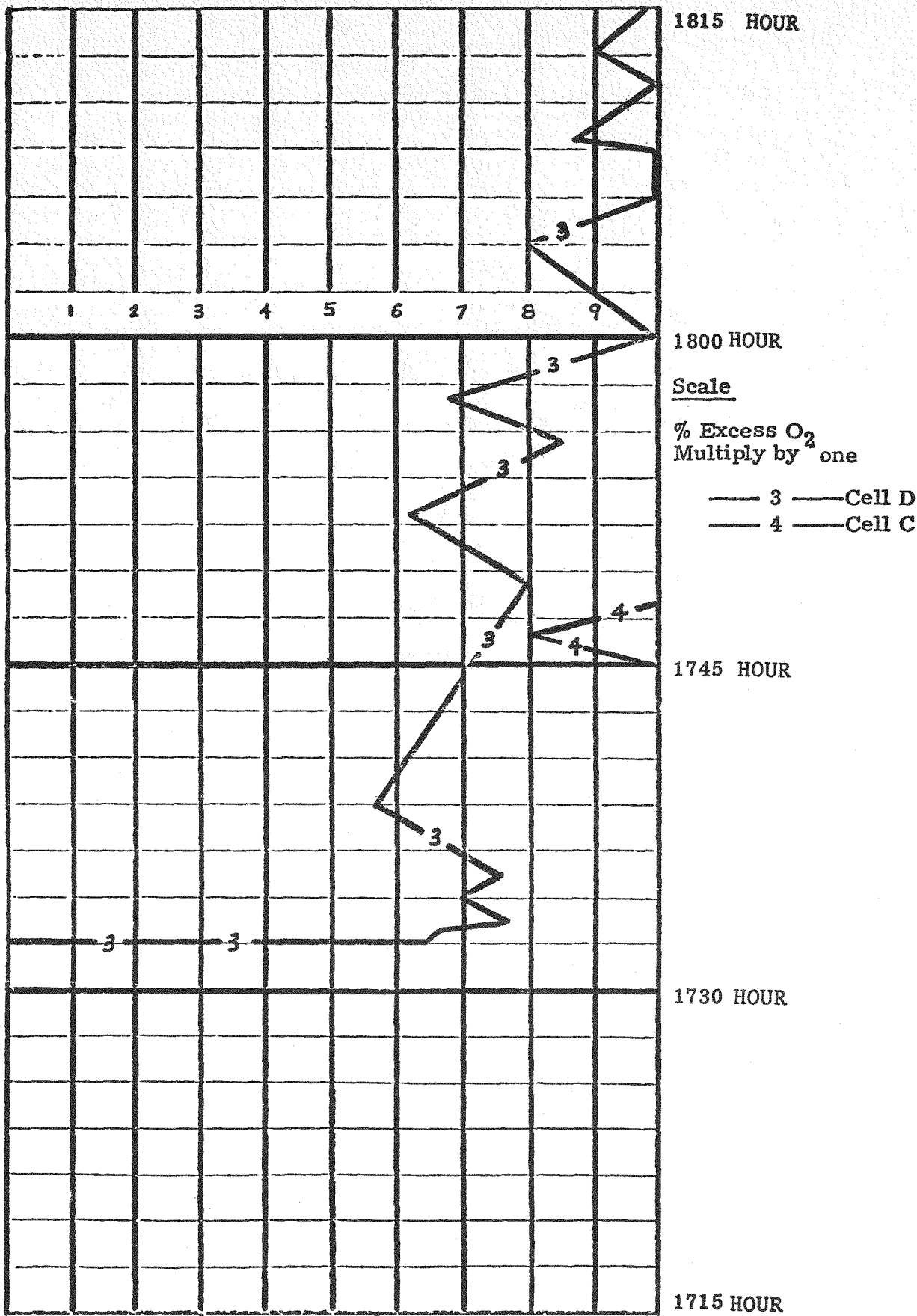
1800 HOUR

1745 HOUR

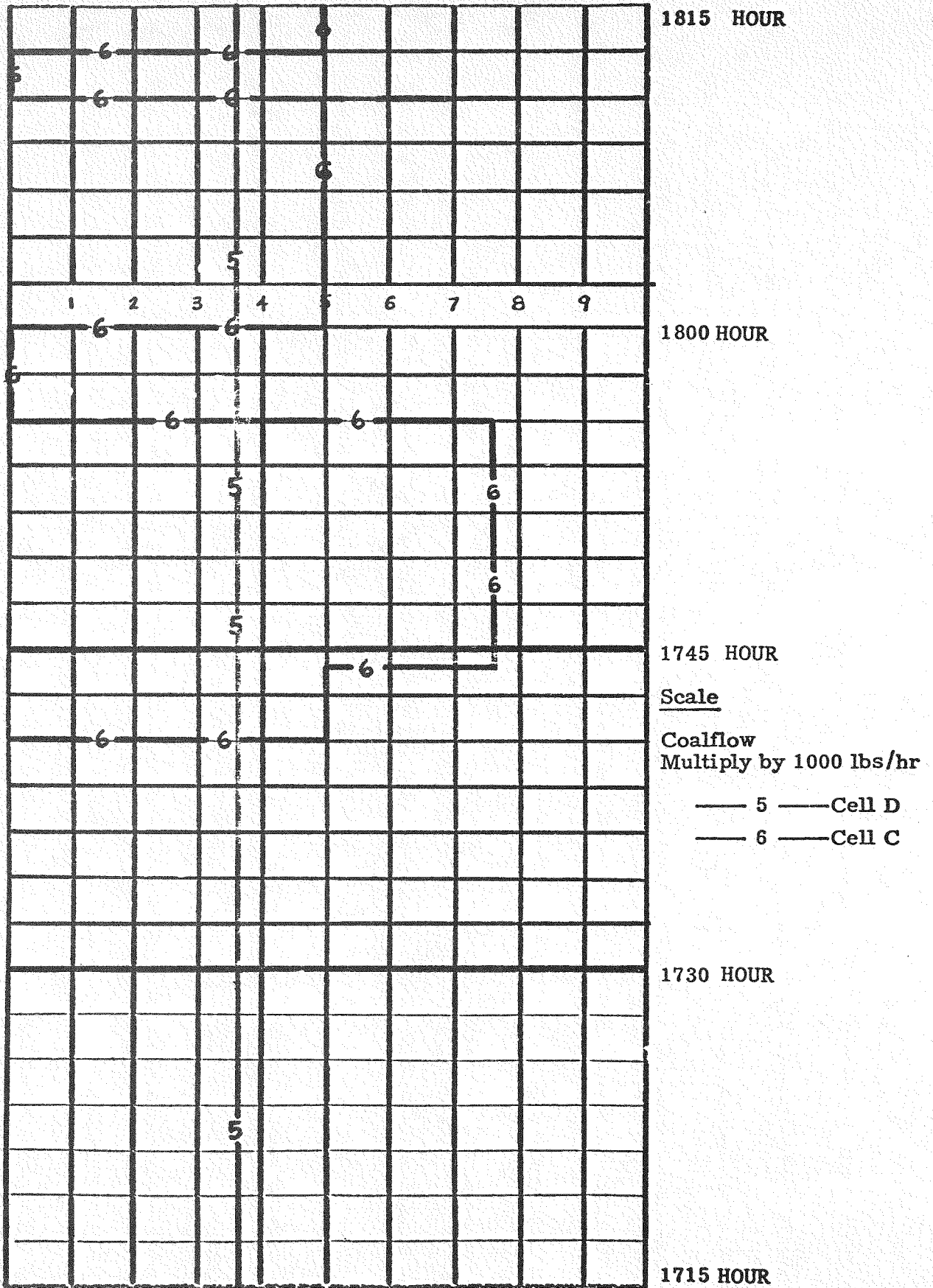
1730 HOUR

1715 HOUR

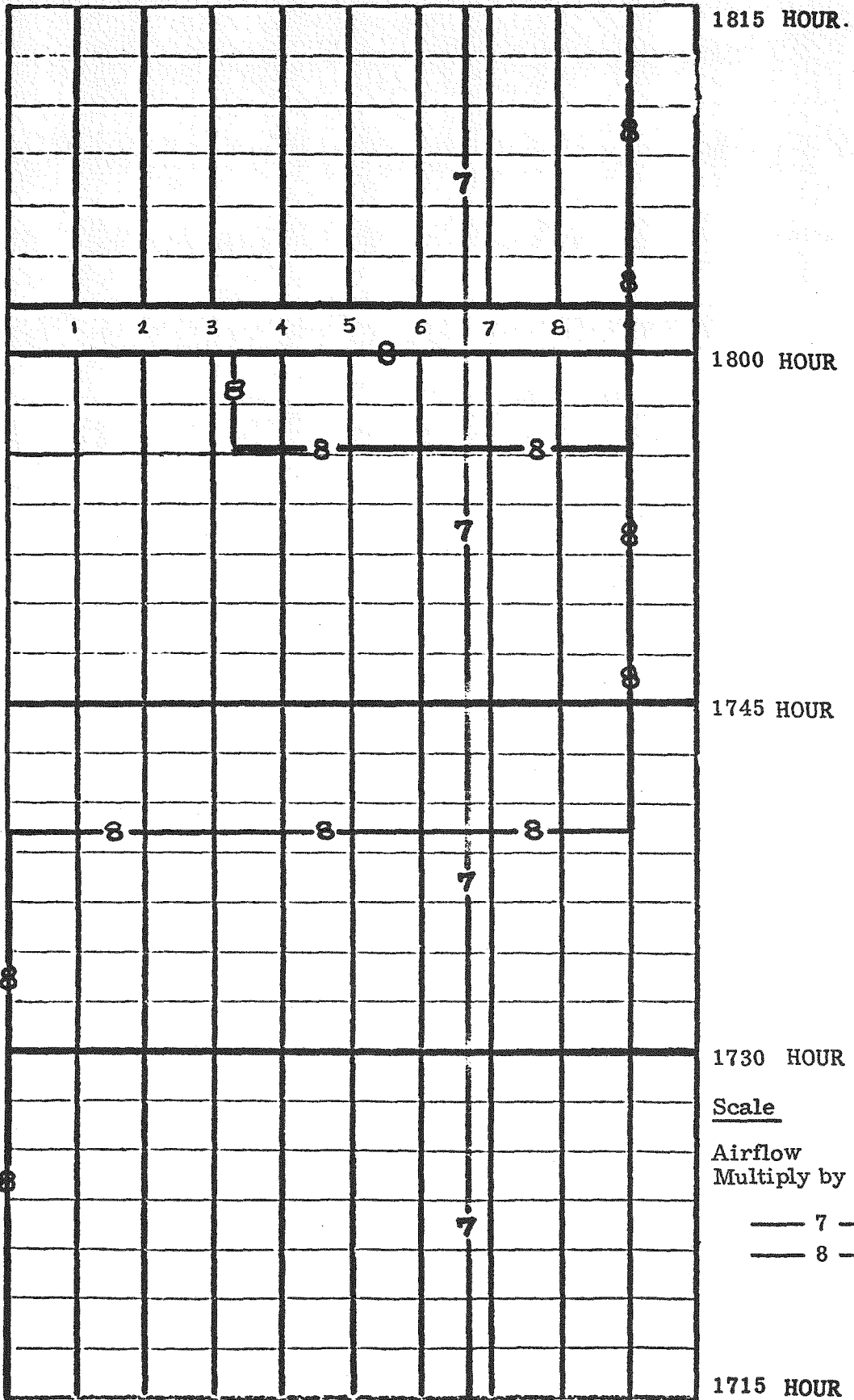
Cell C Light-Off - February 10, 1977



Cell C Light-Off, February 10, 1977



Cell C Light-Off, February 10, 1977



Cell C Light-Off, February 10, 1977

CELL C LIGHT-OFF ATTEMPTS

TABLE 1

Revision 1

Test Run	Cell D Conditions	Cell D Air, Coal, Lmstn. Flow	Cell C Air, Coal, Lmstn. Flow	Cell C Conditions	Results (Comments)
#1 1/30/77	30" static bed ht. 34" expanded bed ht. Sulfated lmstn. 75 lbs/ft <sup>3</sup> bed density 1700°F bed temp. (Hagan)	55,000 lbs/hr airflow 3600 lbs/hr coal flow No lmstn. flow Burners off CBC uptake approx 750°F Excess O <sub>2</sub> approx 7%	100,000 to 90,000 lbs/hr airflow 4200 lbs/hr coal flow No lmstn. flow.	5-6" static bed ht. Approx. 8" expanded bed ht. Raw lmstn. 95 lbs/ft <sup>3</sup> bed density.	C-cell coal feed was started 30 sec. prior to opening of slide gate. Material did not transfer from Cell C to cell D. Inspection of cell D showed a clinker sitting in front of slide, preventing material transfer. Cell C bed temperature rose to approx. 400°F and held constant.
#2 2/2/77	30" static bed ht. 34" expanded bed ht. Sulfated lmstn. 75 lbs/ft <sup>3</sup> bed density 1700°F bed temp. (Hagan) 1600°F bed temp. (L & N recorder)	55,000 lbs/hr airflow 3600 lbs/hr coal flow No limestone Burners off CBC uptake approx 750°F Excess O <sub>2</sub> approx 8%	100,000 to 90,000 lbs/hr airflow 4200 lbs/hr coal flow No limestone Excess O <sub>2</sub> did not register	0-2" static bed ht Raw limestone 95 lbs/ft <sup>3</sup> bed density	Any material in cell C was just the amount which could not be removed via the bed drainage system. Coal feed was started at the same time that the slide gate was opened. Bed material transferred to Cell C within 60 seconds and Cell C bed temperature rose to 850°F and dropped to 500°F

CELL C LIGHT-OFF ATTEMPTS

TABLE 1 (con't)

Test Run	Cell D Conditions	Cell D Air, Coal, Lmstn. Flow	Cell C Air, Coal, Lmstn. Flow	Cell C Conditions	Results (Comments)
#3 2/8/77	31" static bed ht. 35" expanded bed ht. Sulfated lmstn. 75 lbs/ft <sup>3</sup> bed density 1800°F bed temp. (Hagan) 1650°F bed temp. (L & N Recorder)	55,000 lbs/hr airflow 3600 lbs/hr coal flow No limestone Burners off CBC uptake approx 780°F Excess O <sub>2</sub> approx 6%	95,000 to 85,000 lbs/hr airflow 4200 lbs/hr coal flow No limestone Excess O <sub>2</sub> did not register	5-6" static bed ht. 350°F bed temp. Sulfated lmstn. 75 lbs/ft <sup>3</sup> bed density	Coal flow to Cell C was started at the same time the slide gate was open. Cell C had approximately 6% combustible carbon in bed material. Cell C bed temperature rose to 1100°F and decreased to 750°F-800°F and was maintained at this temperature for approximately 1 1/2 hours. Analysis of bed after test run showed 2% carbon content in Cell C.
#4 2/10/77	33" static bed ht. 36" expanded bed ht. Sulfated lmstn. 75 lbs/ft <sup>3</sup> bed density 1800°F bed temp. (Hagan) 1650°F bed temp. (L & N Recorder)	55,000 lbs/hr airflow 3600 lbs/hr coal flow 1000 lbs/hr lmstn. flow	90,000 lbs/hr airflow 5,000 lbs/hr coal flow No limestone Excess O <sub>2</sub> registered 8% momentarily	7-8" static bed ht. 400° bed temp. Sulfated limestone 75 lbs/ft <sup>3</sup> bed density	Coal flow was started 1 1/2 minutes prior to opening slide gate (approx. 120 lb coal charge) Cell C bed temperature rose to 1500°F and dropped to 700°F-750°F. Temperature was above 1000°F for nine (9) minutes.

### 3.4 MFB Operation

During the reporting period, the MFB unit was shutdown for the first three weeks in January due to need to replace the failed refractory in the combustion chamber of the light-off fuel oil burners. The unit was also shut down from February 10 through March 31 due to:

- . repairs to induced draft fan as the result of rotor and housing failure,
- . repairs to electrostatic precipitator resulting from failure of structural supports,
- . lack of feedwater supply from Monongahela resulting from outage of their units (during initial operation, the MFB unit does not return steam to the plant system).

The MFB was operated in the following modes for the durations indicated:

<u>Month</u>	<u>Cell D (Oil Fuel)</u>	<u>Cell D (Coal Fuel)</u>
January	203.0 hr.	42.0 hr
February	135.0 hr	79.5 hr

### 3.5 Tests

During the reporting period, various tests were conducted on the MFB unit and auxiliaries to determine flows and control settings. These are described in the following systems.

#### 3.5.1 Coal Feed Distribution and Flow Rates Tests - Activity No. 211

Feed distribution and flow rate tests were continued during this reporting period. From January through March, a series of eleven (11) tests were conducted.

Test Nos. 1-77-1, 1-77-3, 1-77-4, 2-77-1 and 2-77-2 were run for vibrating feeders which feed Cells D, C and B in order to determine whether each table equally distributes material into its eight (8) tracks and out of the discharge ports, as specified.

Test Nos. 1-77-5, 1-77-6, 1-77-7 and 1-77-8 were run for the coal and limestone rotary feeders which feed Cell C to determine coal or limestone feed rates during operation.

#### Test Results

The results from the distribution tests were used to adjust the vibrating feeders to obtain material distribution equivalent to that obtained by Carman Industries, under laboratory conditions.

Figures 13 and 14 show coal and limestone feed rates vs. percent signal to the rotary feeder for Cells D, C, B and A.

### 3.5.2 Transfer of Material from Cell D to Cell C

Test No. 1-77-2 was performed to determine the time necessary to transfer material from Cell D to Cell C. The test was run with a static bed height of 33" in Cell D and no material in Cell C. Cell D was fluidized, Cell C had approximately 90,000 lbs/hr airflow and the slide gate was opened. The following data was recorded just prior to opening the slide gate and every ten seconds thereafter.

Low Bed Pressure - Cell D  
Low Bed Pressure - Cell C  
Pressure Differential - Annubar Cell D  
Pressure Differential - Annubar Main Cells  
Pressure Differential - Cell D  
Pressure Differential - Cell C

### Test Results

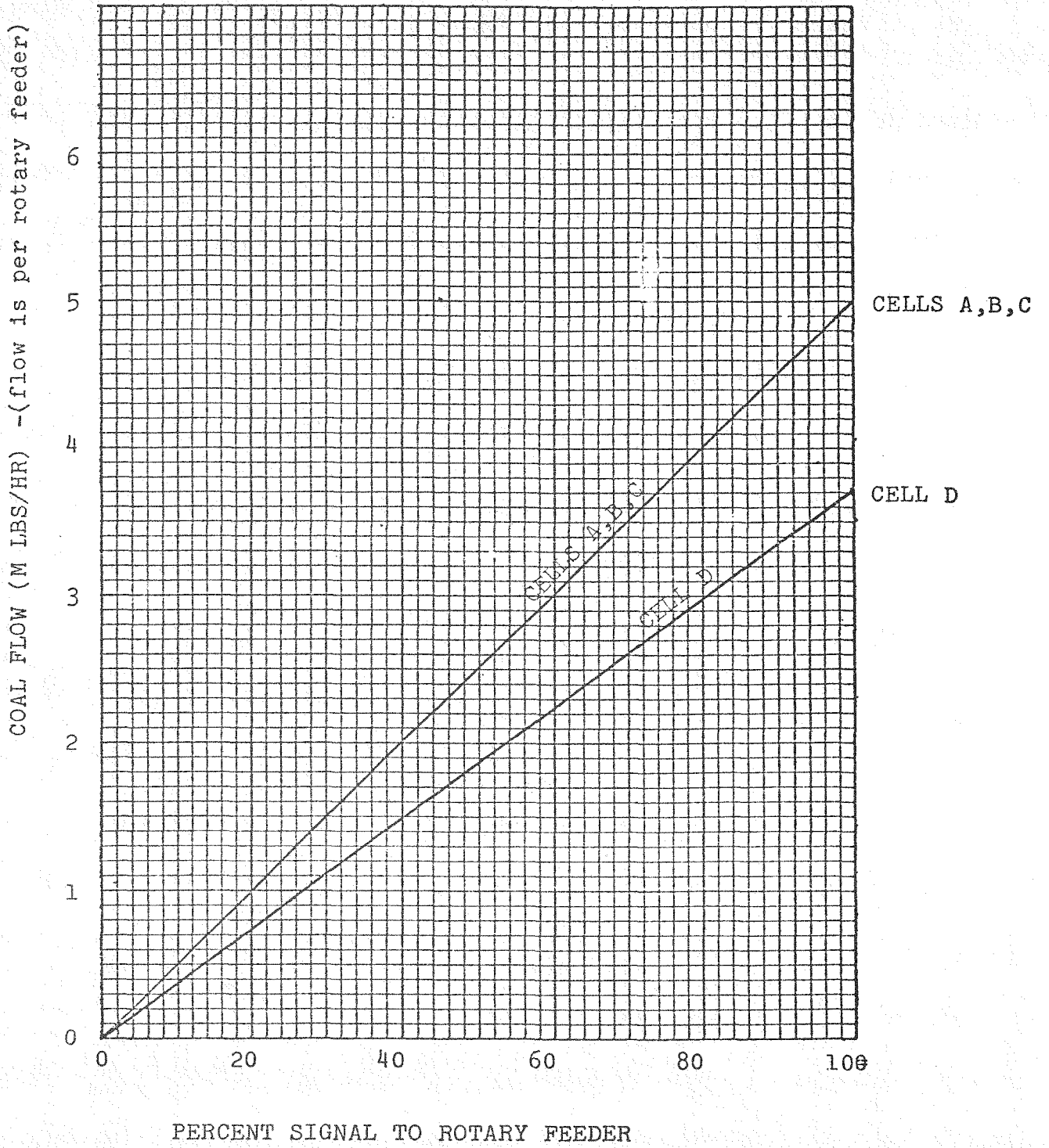
As Figure 15 indicates, under a cold condition, the bed height in Cell D and Cell C equalized approximately fifty (50) seconds after the slide gate was opened.

### 3.5.3 MFB Light-Off Procedure - Activity No. 1106

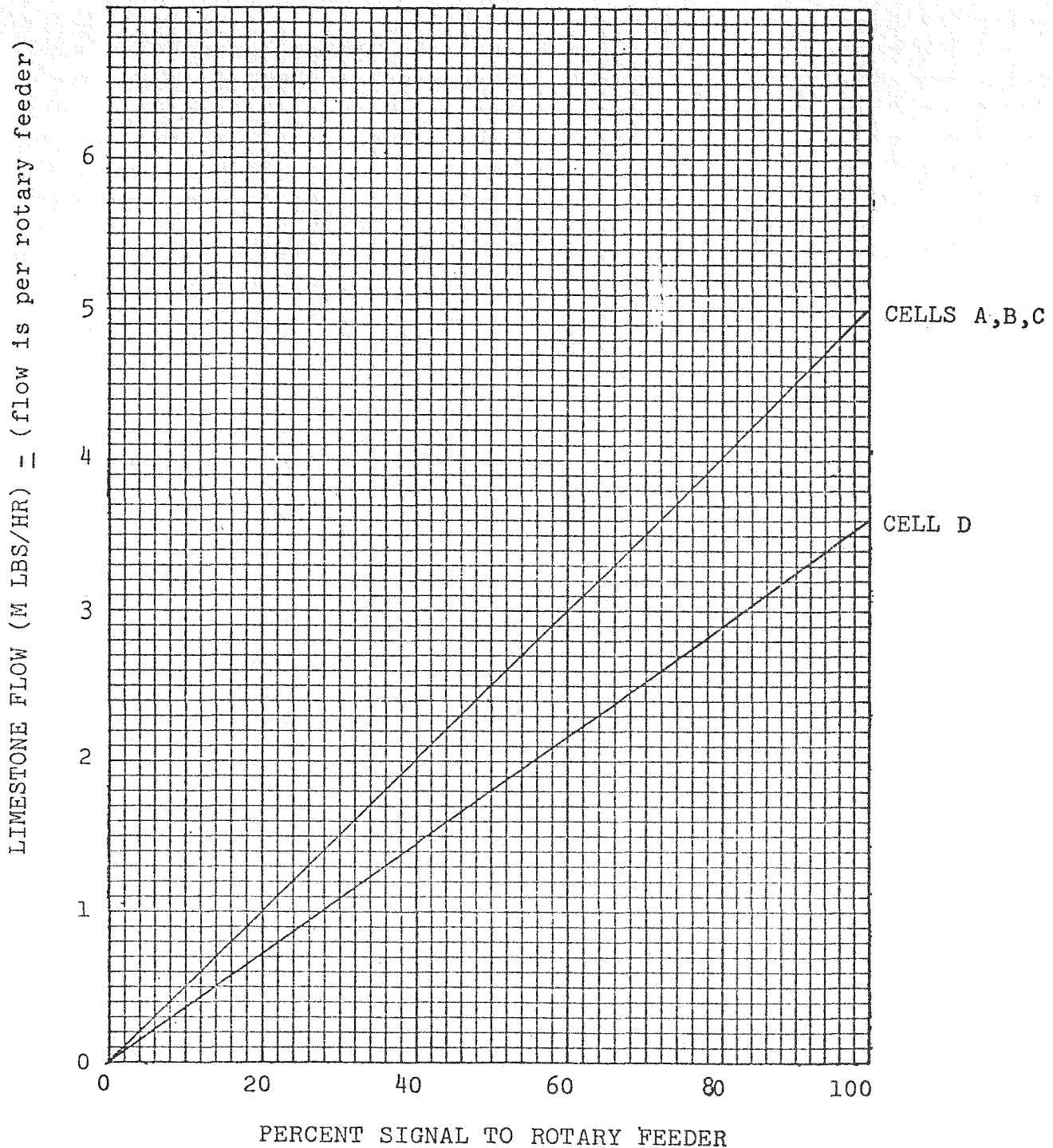
In order to standardize the light-off technique being used for Cell D and to provide a guideline for the light-off of Cell C and subsequent light-off of Cell B and Cell A, a procedure was prepared for the complete light-off of the MFB unit.

This procedure includes a step-by-step light-off technique commencing with the light-off of the CBC cell fuel oil burners. The following graphs and check-off lists are included in the procedure for operator convenience:

- . Cell A, Airflow (M lbs/hr) vs. Grid Plate  $\Delta$  P,
- . Cell B, Airflow (M lbs/hr) vs. Grid Plate  $\Delta$  P,
- . Cell C, Airflow (M lbs/hr) vs. Grid Plate  $\Delta$  P,
- . Cell D, Airflow (M lbs/hr) vs. Grid Plate  $\Delta$  P,
- . Cell D Annubar, Airflow (M lbs/hr) vs. Grid Plate  $\Delta$  P,
- . Drum Blowdown Flow
- . Static Bed Height vs. Bed  $\Delta$  P (fluidized condition),
- . Cell D, Coal Flow vs. Hand/Automatic Signal from Control Room,
- . Cell A, B, C, Coal Flow vs. Hand/Automatic Signal from Control Room,
- . Cell D, Limestone Flow vs. Hand/Automatic Signal from Control Room,



PERCENT SIGNAL TO ROTARY FEEDER VS. COAL FLOW (M LBS/HR)



PERCENT SIGNAL TO ROTARY FEEDER VS. LIMESTONE FLOW(M LBS/HR)

EQUALIZATION OF CELLS D&C BED HEIGHT VS. TIME (SEC.)

55

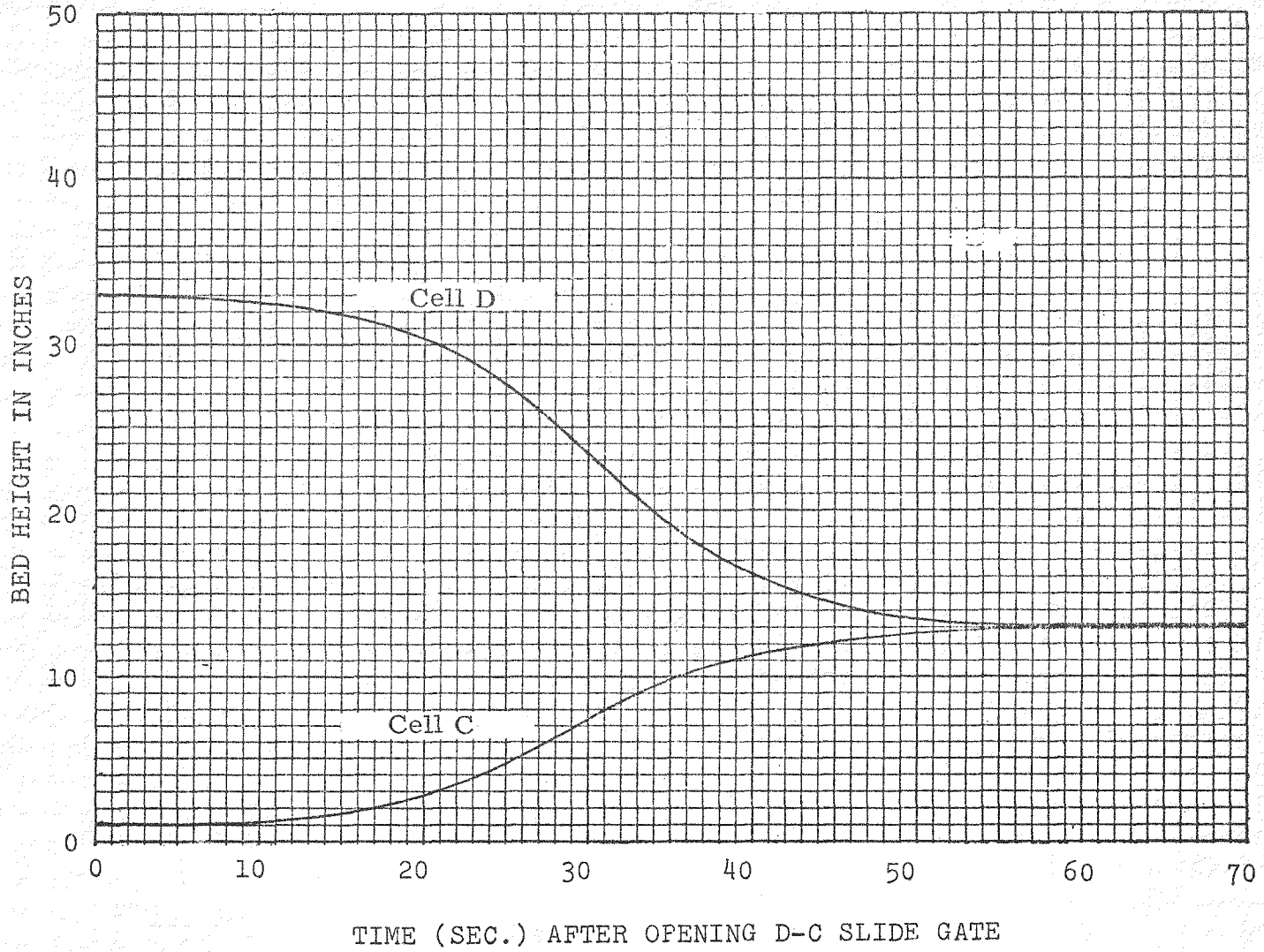


Figure 15

- . Cells A, B, C, Coal Flow vs. Hand/Automatic Signal from Control Room,
- . Boiler Pre-Firing Check List,
- . Boiler Initial Firing Check List,
- . Cell D Light-off Check List,
- . Cell C Light-off Check List,
- . Cell B Light-off Check List
- . Cell D, Coal Injection Nozzle Air Flow,
- . Cell C, Coal Injection Nozzle Air Flow,
- . Cell A & B, Coal Injection Nozzle Air Flow,
- . Airfoil, pressure drop vs. Airflow (M lbs/hr),
- . Downcomer Pitot Pressure Differential vs. Water Flow,
- . CV4 and CV7, Percent open vs. Flow,
- . Economizer Recirculation Valve Operation, CV-6,
- . Equalization bed heights for Cell C and D

### 3.5.4 Cold Mode Airflow Tests - Activity No. 1107

Test Nos. 3-77-1, 3-77-2 and 3-77-3 were run due to the necessity of having an accurate air flow measurement to the individual cells of the MFB, tests were run to determine the following:

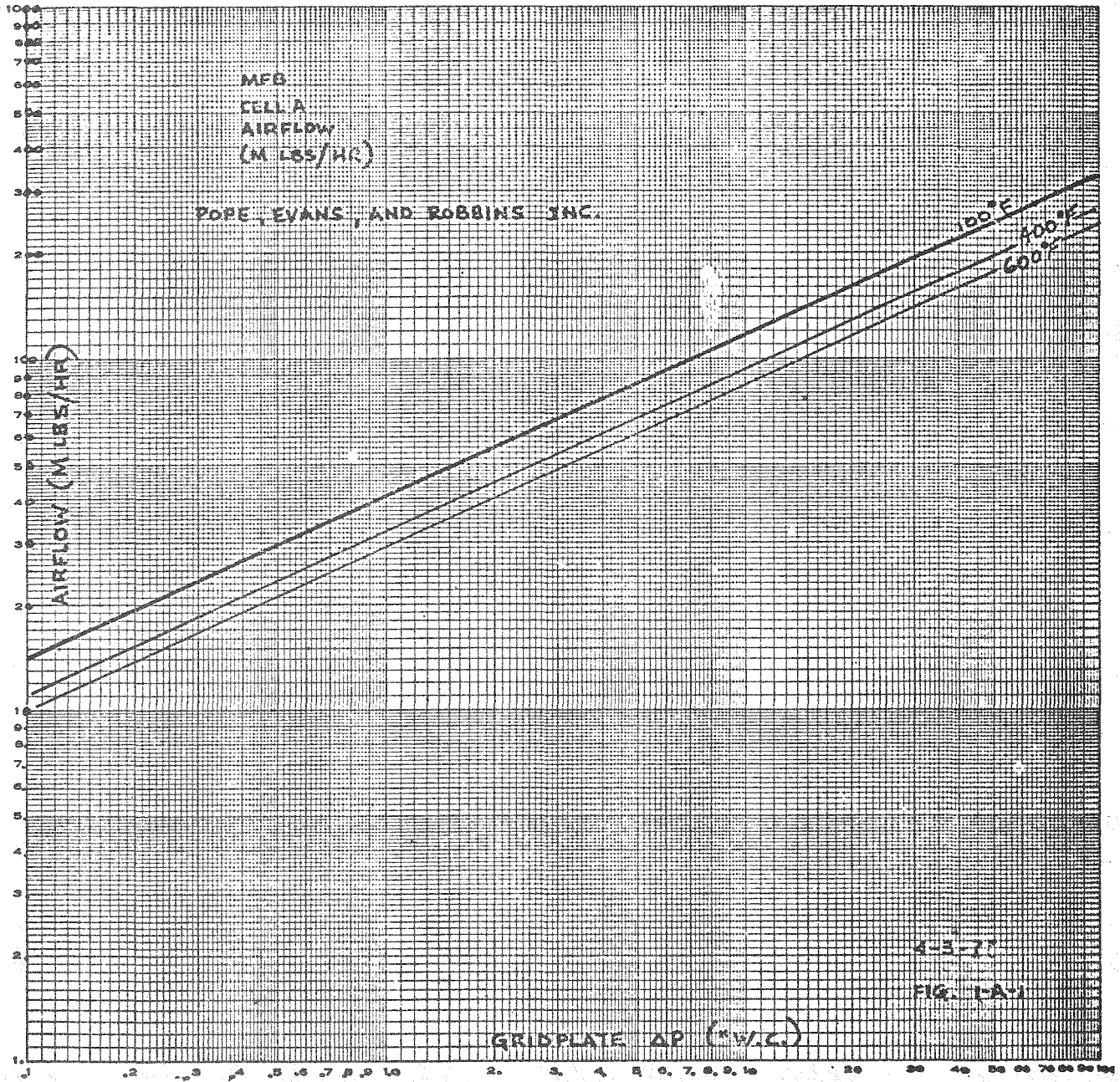
- . Cell D - Airflow (M lbs/hr) vs. Grid Plate  $\Delta$  P,
- . Cell C - Airflow (M lbs/hr) vs. Grid Plate  $\Delta$  P,
- . Cell B - Airflow (M lbs/hr) vs. Grid Plate  $\Delta$  P,
- . Cell A - Airflow (M lbs/hr) vs. Grid Plate  $\Delta$  P,
- . Cell D Annubar - Airflow (M lbs/hr) vs. Annubar  $\Delta$  P,
- . Main Cells Annubar - Airflow (M lbs/hr) vs. Annubar  $\Delta$  P,
- . Airfoil - Airflow (M lbs/hr) vs. Airfoil  $\Delta$  P.

In order to effectively accomplish the above, all branches from the main air duct not being tested were sealed, all gauges were tested before being hooked up, and all seals were checked prior to any data collection.

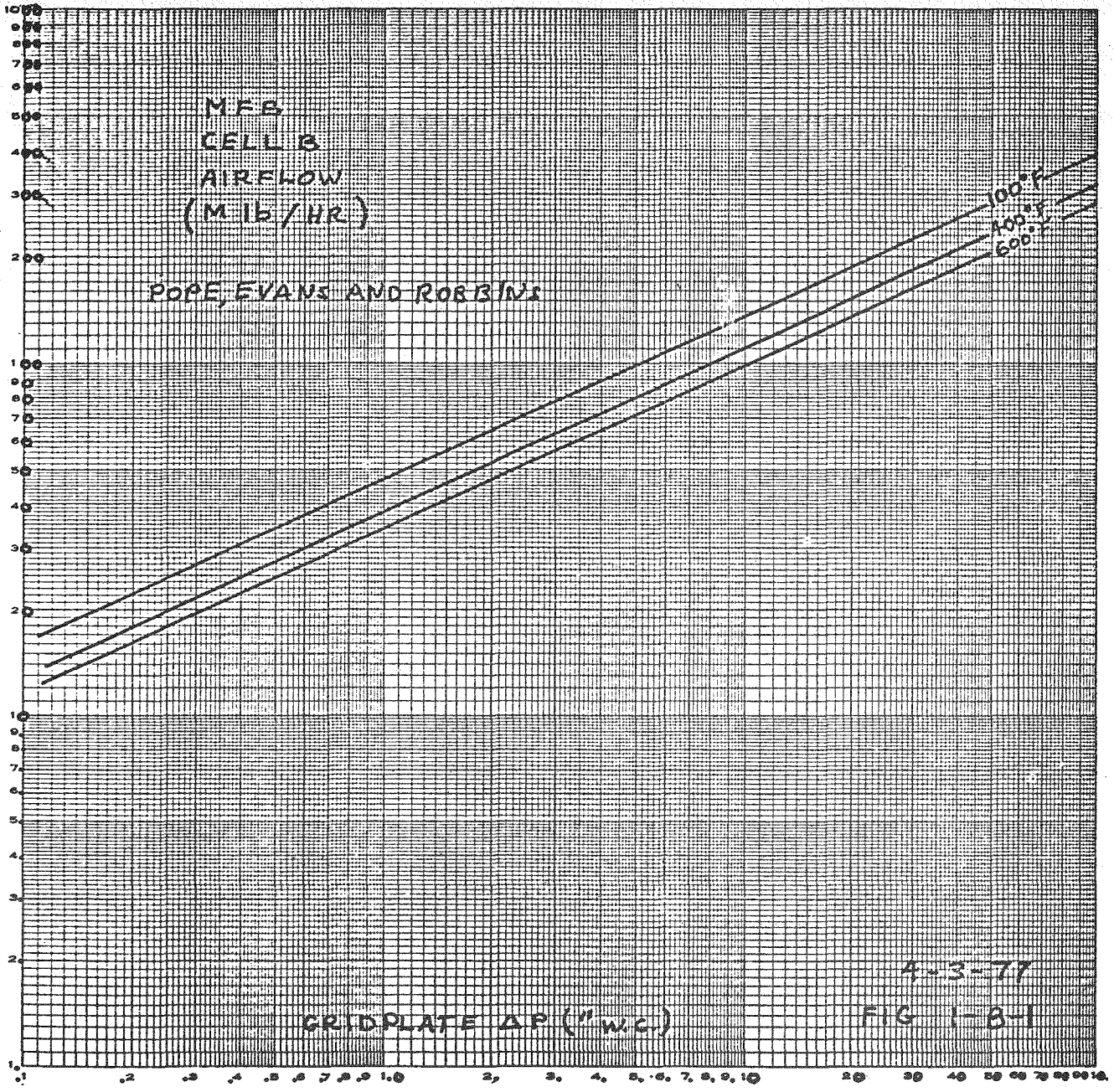
#### Test Results

The results of the grid plate pressure drop vs. airflow rate tests are shown in Figures 16, 17, 18 and 19 for cells A, B, C and D, respectively. The temperature lines represent plenum temperature. The cold test data was used to develop the 100°F line and this data was scaled up to develop lines for 400 and 600°F plenum air temperature.

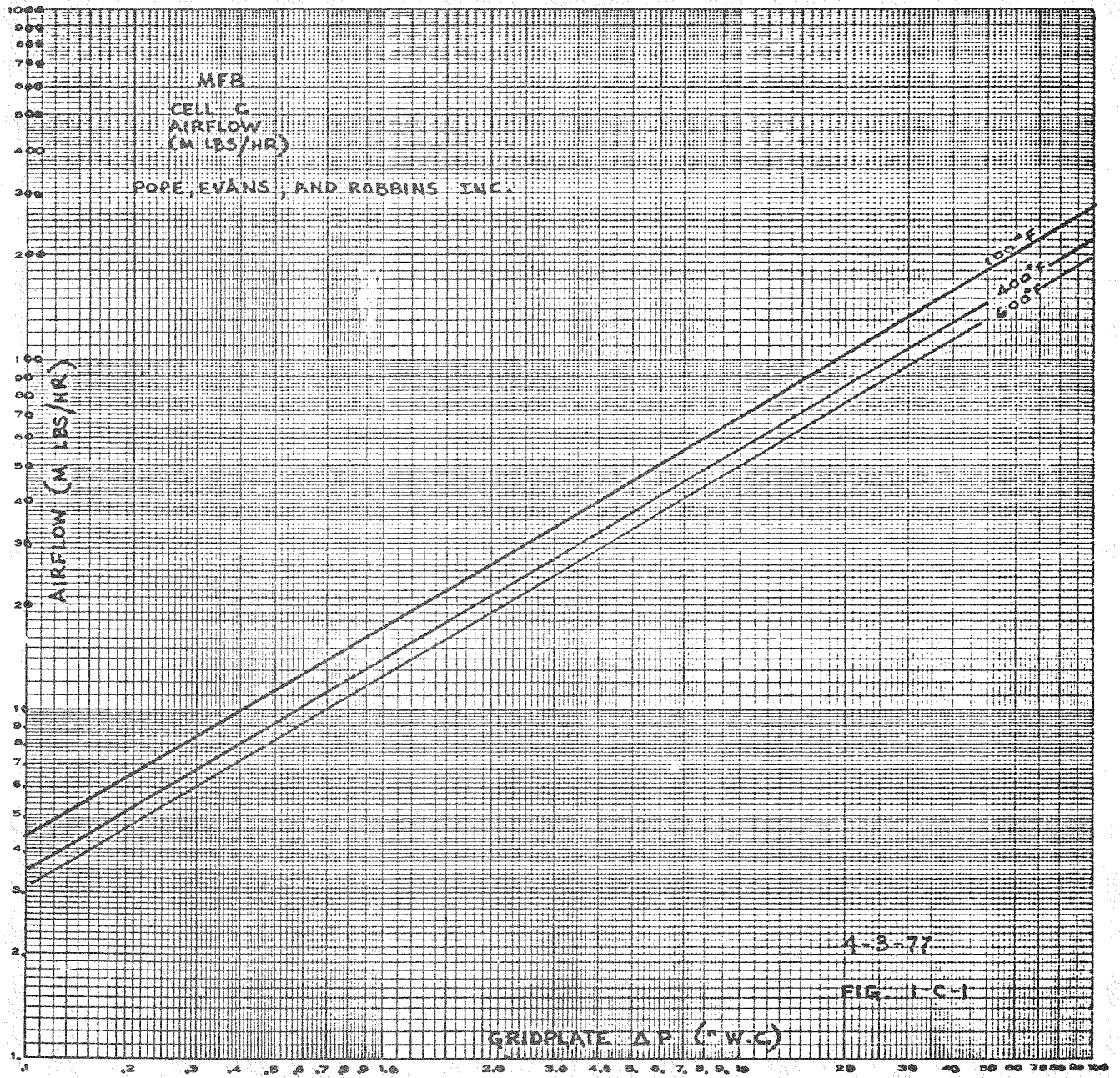
Based on the results of the air foil calibration test, a new main duct total air flow curve was developed and is shown in Figure 20.



CELL A AIRFLOW vs. GRID PLATE DELTA P



CELL B AIRFLOW vs. GRID PLATE DELTA P



CELL C AIRFLOW vs. GRID PLATE DELTA P

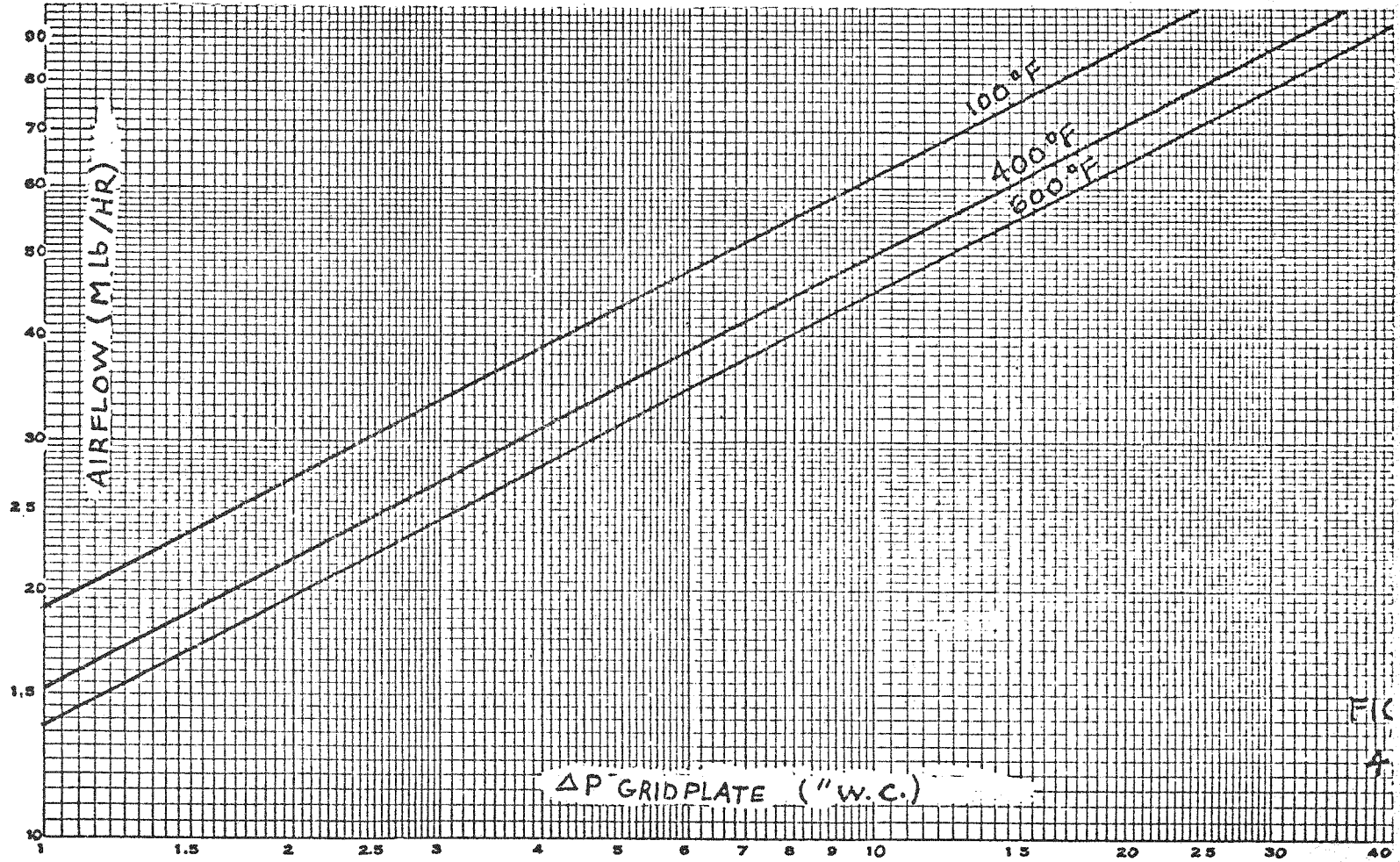
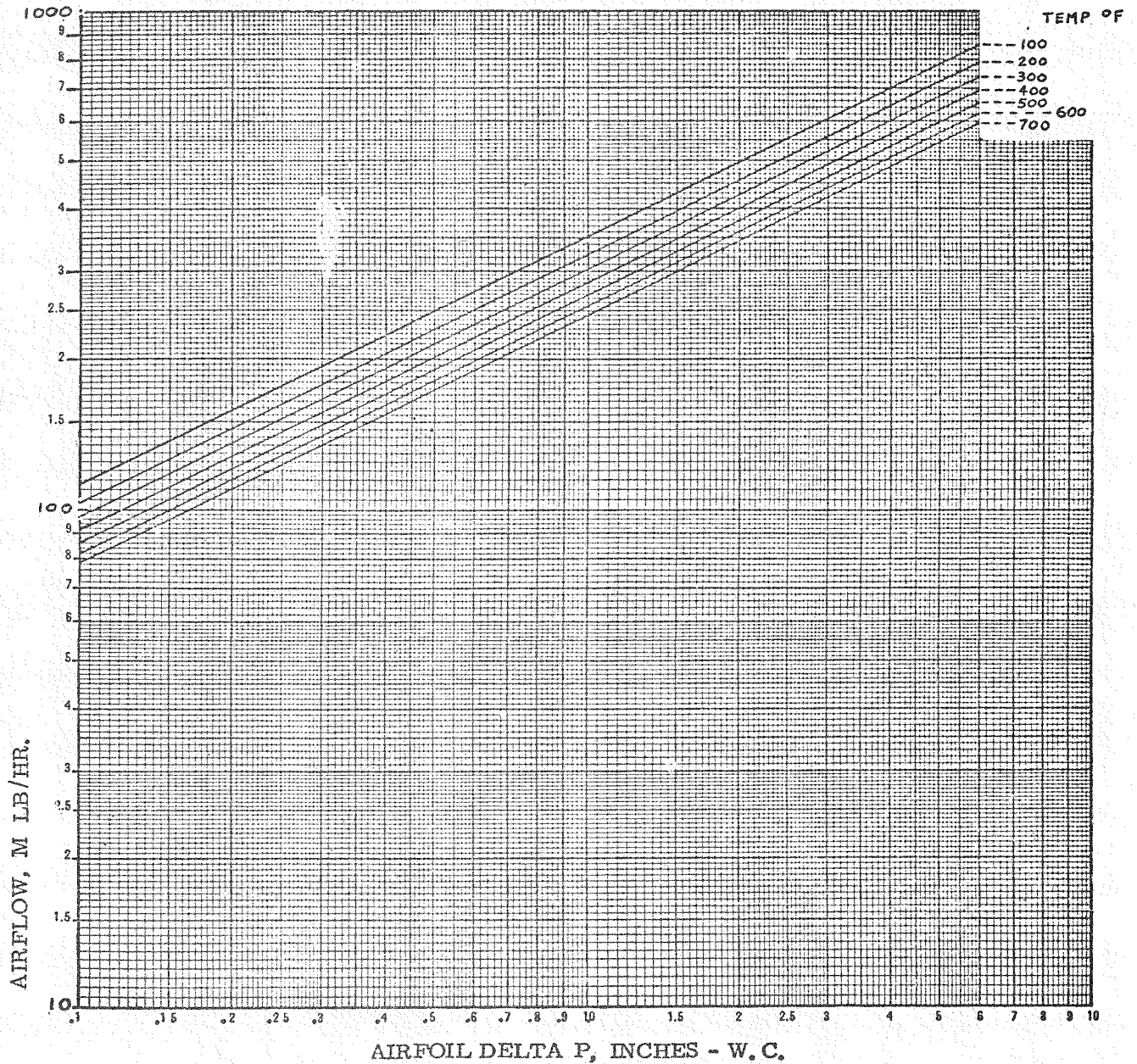


Figure 19

CELL D GRID PLATE DELTA P vs. AIRFLOW



AIRFOIL DELTA P, INCHES - W. C.

AIRFOIL AIRFLOW MEASUREMENT

The main cells annubar air flow curve is shown in Figure 21. This curve was developed from the main duct pitot traverse air flow indication minus the D Cell annubar air flow indication. The D cell annubar pressure differential vs. air flow rate curve is shown in Figure 22. This curve was developed from an earlier pitot traverse of the D cell air duct.

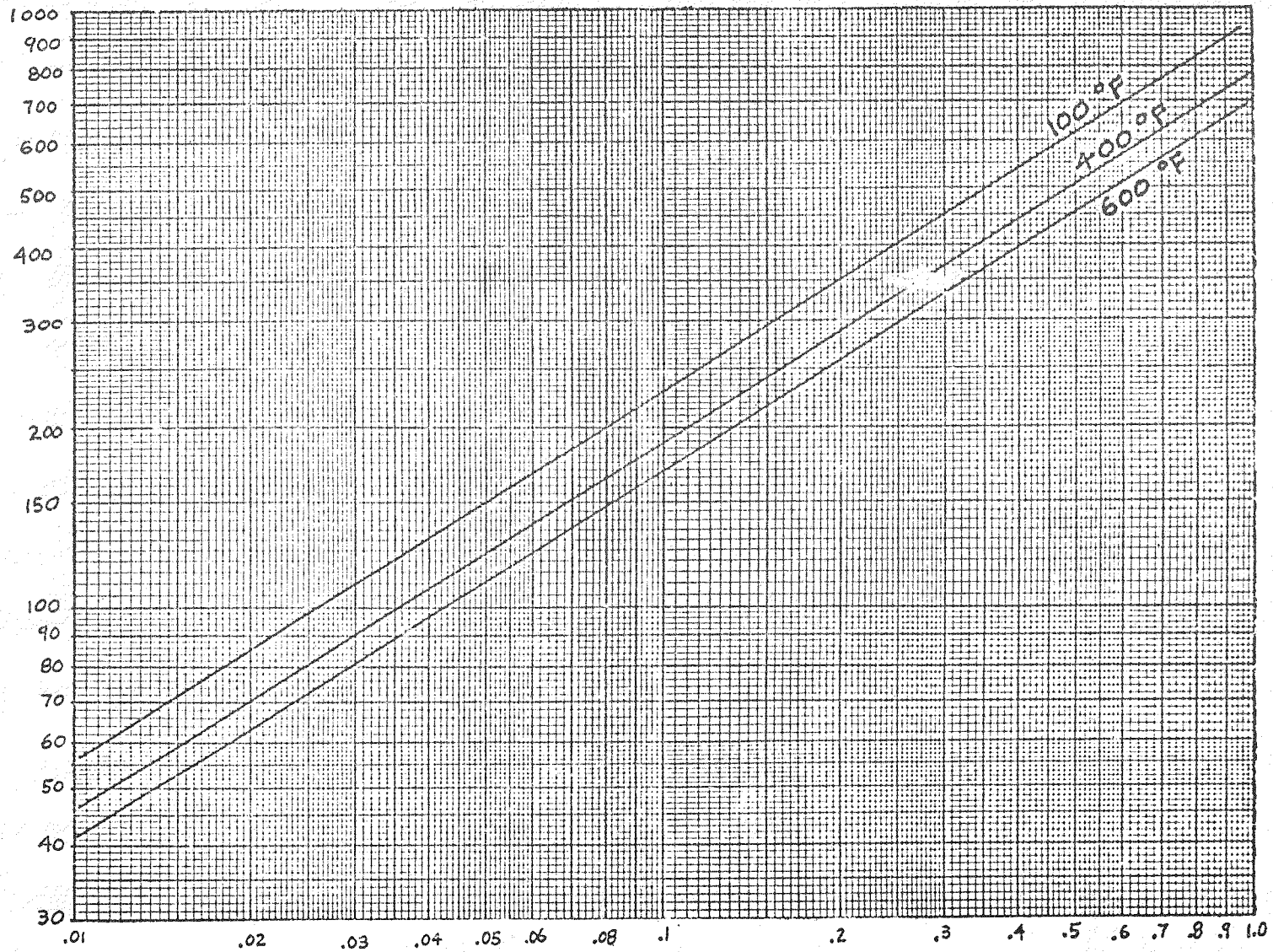
Curves were developed to show the relationship between the cell inlet damper position and the air flow rate through each cell. These graphs are contained in Figures 23, 24, 25 and 26 for cells A, B, C and D, respectively. It can be seen from Figure 23 for Cell A, that 90 percent of the maximum air flow is reached when the damper is 50 percent open. By examining Figures 24 through 26, it can be seen that the same relationship holds for cells B, C and D. This indicates that in the low flow ranges for each cell, small changes in the damper position results in large changes in the air flow rate through the cell thus giving poor control of the air flow rate in the lower portion of the operating range.

#### 3.5.5 Acceptance of Processed Coal

In order to eliminate coal handling and feed system operational problems, the MFB unit will continue to burn processed coal. See Figure 27 for a typical "as received size analysis". Moisture analyses have ranged between two and four percent total moisture.

At present, coal is sampled at the mine site in order to eliminate need to handle high moisture and high fines content coal with attendant problems.

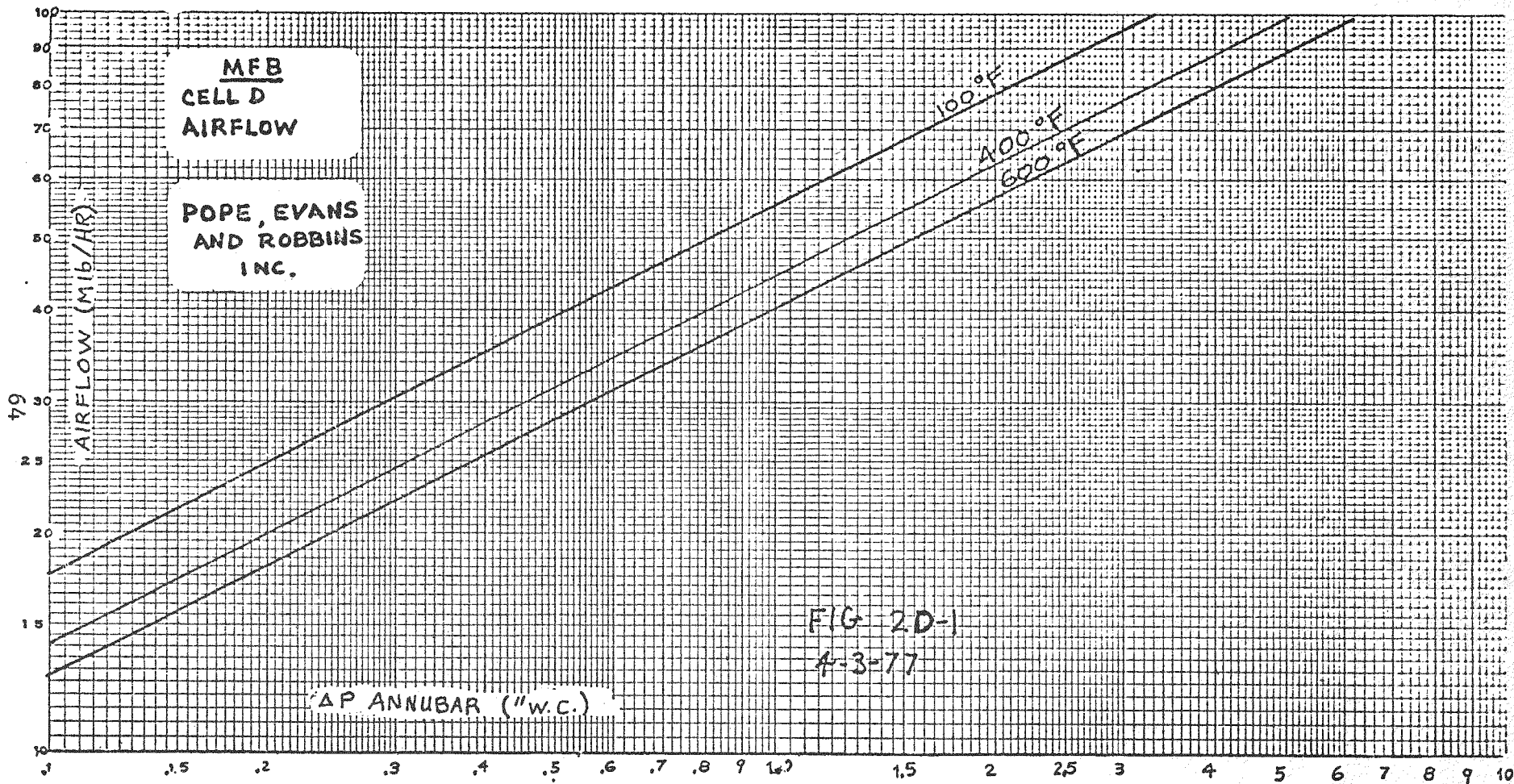
MAIN CELLS AIRFLOW M LBS/HR



Main Annubar Delta P

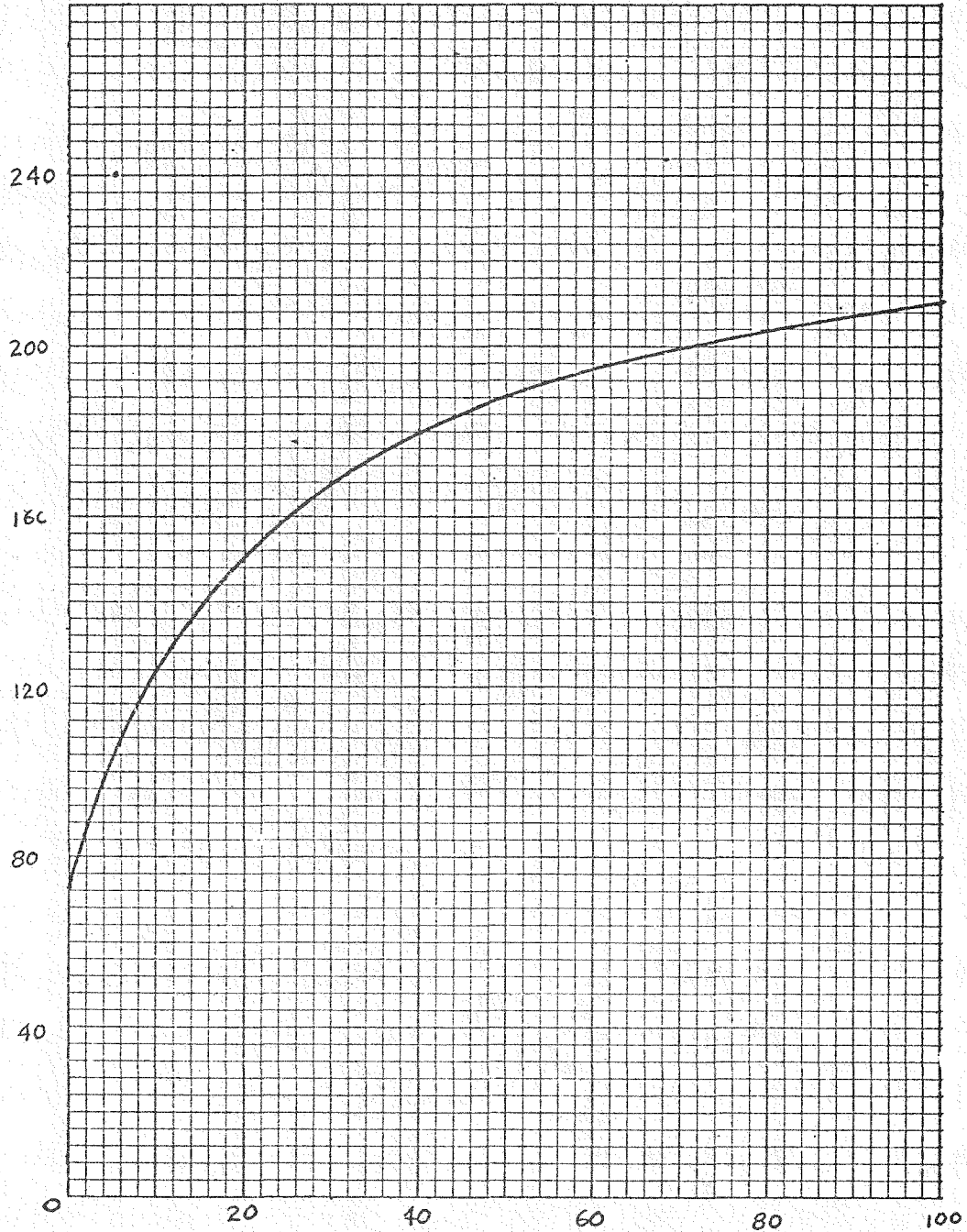
MAIN CELLS ANNUBAR DELTA P vs. AIR FLOW

Figure 21



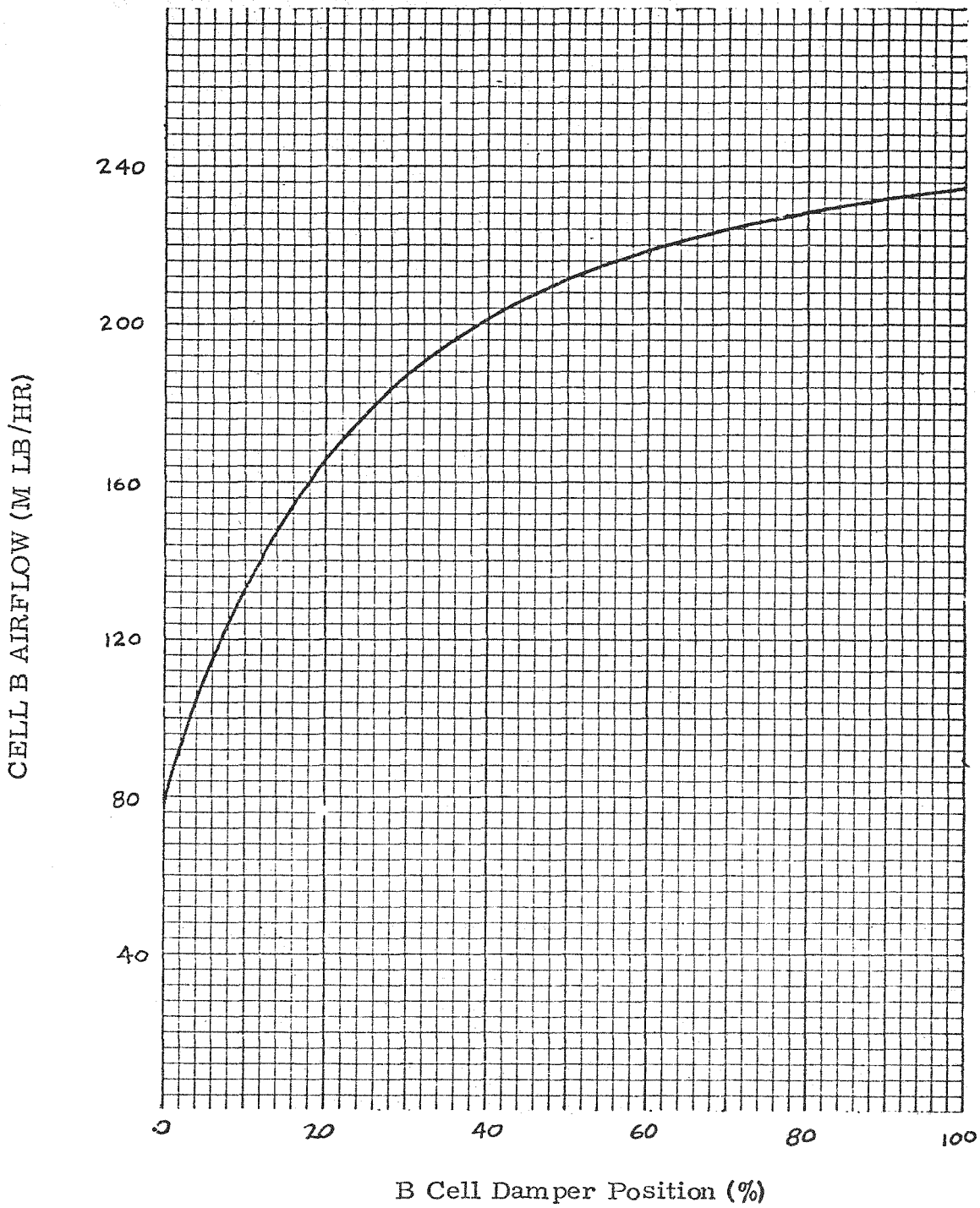
CELL D ANNUBAR DELTA P vs. AIR FLOW

CELL A AIRFLOW (M LB/HR)

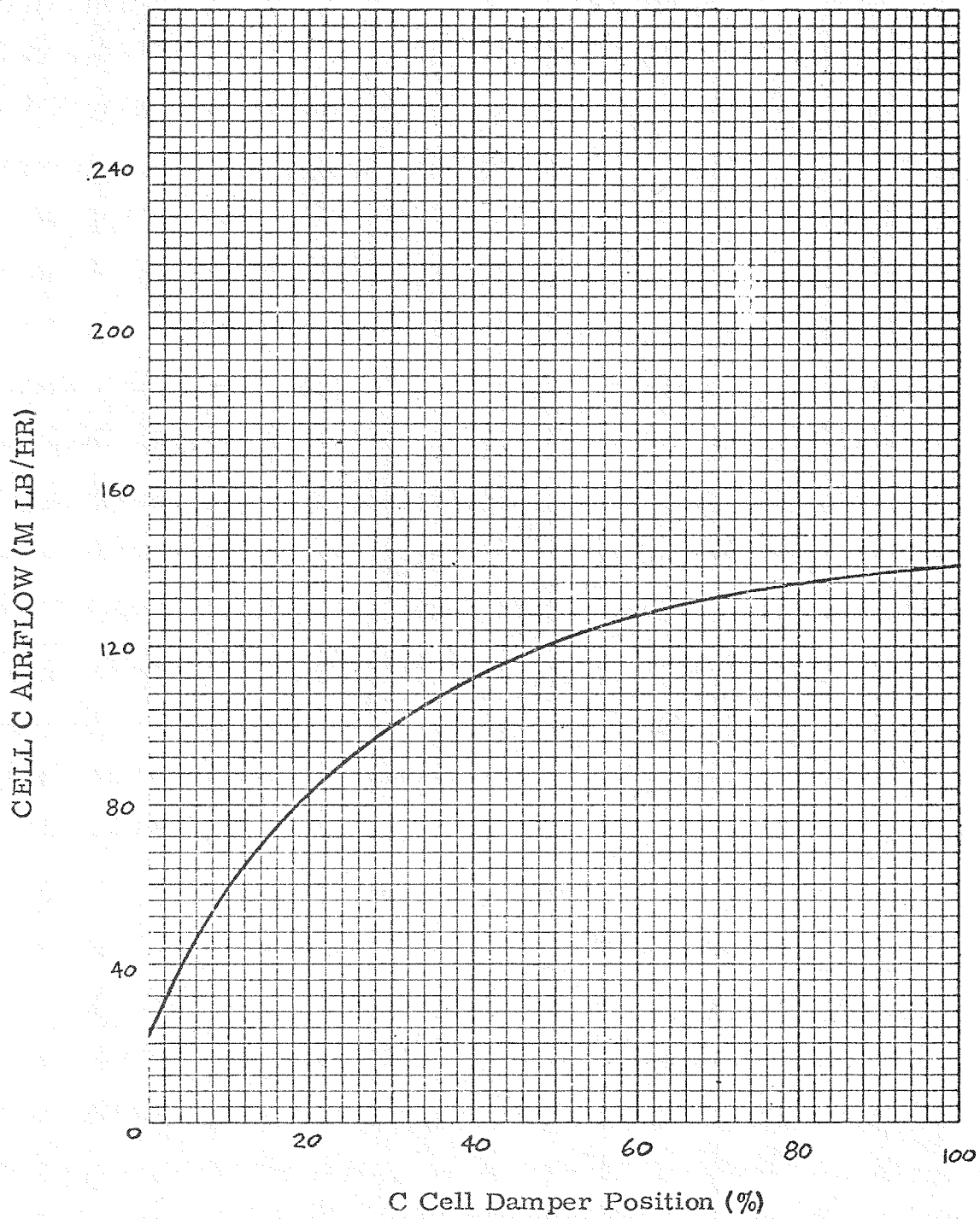


A Cell Damper Position (%)

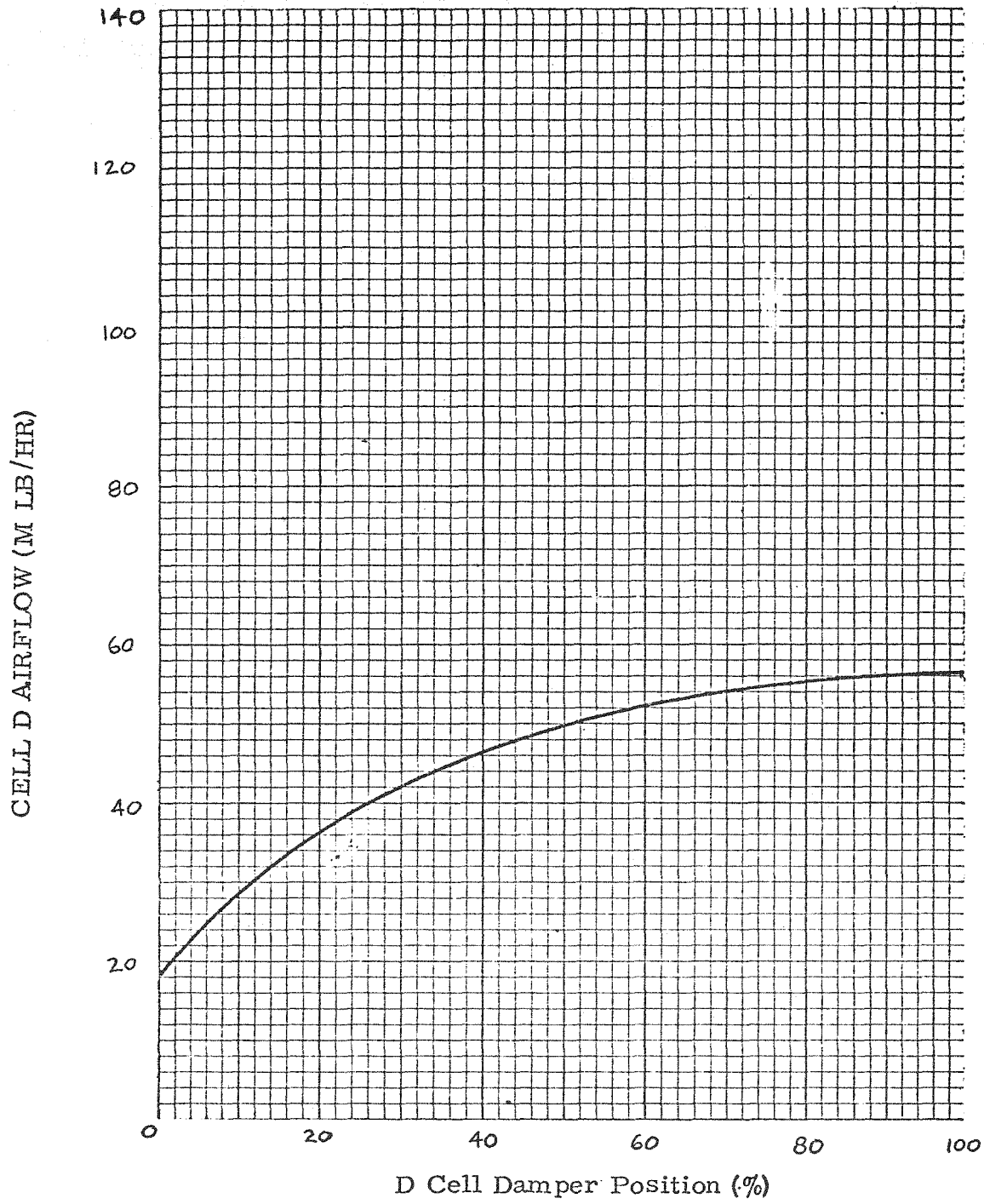
CELL A DAMPER SETTING vs. AIR FLOW



CELL B DAMPER SETTING vs. AIR FLOW



CELL C DAMPER SETTING vs. AIR FLOW



CELL D DAMPER SETTING vs. AIR FLOW

SIZE DISTRIBUTION ANALYSIS

Test No. PLANT

Date Completed 3/16/77

Test Date 3/16/77

Sample No. LOAD #1

Analysis by H. Guyton

Sample Type COAL

U. S. S. SIEVE	WEIGHT (grms.)	(X <sub>i</sub> ) FRACTION	FRACTION SMALLER THAN	(d <sub>p</sub> ) MEAN PARTICLE DIAMETER (u)	X <sub>i</sub> /d <sub>p</sub>
+ 1/2					
- 1/2 + 1/4	716.5	.6742			
- 1/4 + 5	261.6	.2462			
- 5 + 10	55.4	.0521			
- 10 + 14	4.9	.0046			
- 14 + 20	7.1	.0067			
- 20	17.2	.0162			
TOTALS	1062.7	1.0000			

Sample Wt. (before Screening) 1066.1 grms

% Diff. .3

Sample Mean Particle Size \_\_\_\_\_ u

Moisture - 3.33%

#### 4.0 FABRICATION AND CONSTRUCTION WORK PROGRESS

##### 4.1 Boiler Design, Fabrication and Erection

###### 4.1.1 Steam Generator Design and Cold Component Testing (Foster Wheeler Energy Corporation, Subcontract No. 2-58-2126)

Foster Wheeler Energy Corporation's work scope includes: (Phase I) functional design study of the steam generator; (Phase II) steam generator design, technical specifications, arrangement drawings, bill of materials, fabrication and erection instrumentations; (Phase III) preparation of specifications for pumps, valves and burners directly attached to the steam generator and design and preparation of arrangement drawings for a calcium sulfate regenerator; (Phase IV) preparation of an auxiliary system test program; (Phase V) design, construction and testing of cold model system; (Phase VI) preparation of an Operating Instruction Manual and a test and instrumentation program for the MFB unit; (Phase VII) field construction and supervision for additional boiler work at the MFB Plant; (Phase VIII) preparation of an Operating Instruction Manual for the MFB Plant auxiliary systems; (Phase IX) evaluation of alternate light-off techniques for the MFB unit; (Phase X) design, procure and construct test instrumentation at the Rivesville Plant.

Work included under Phases I through VIII has been completed and published in reports submitted to ERDA during the September 1973 through January 1976 time period for Phases I through VI, and during September 1976 for Phase VII. Phase VIII Operating Instruction Manuals were distributed during January 1977. Phase IX task was completed during July 1976.

During this reporting period, all FWEC efforts were directed toward progressing Phase X of the subcontract. Bid specifications for the thermocouple system, rotary feed speed indicators and the particulate samplers were completed. Quotations were solicited from qualified vendors, evaluated and purchase orders placed.

The following items of equipment have been ordered and expected shipping dates noted.

<u>EQUIPMENT</u>	<u>EXPECTED SHIPPING DATE</u>
Gas Analyzer System	July 22, 1977
Data Logger	July 1, 1977
Wattmeter Panel	July 17, 1977
Thermocouples	July 1, 1977
Particulate Samplers (flue gas)	June 17, 1977
Speed Indicators	May 20, 1977

EQUIPMENTEXPECTED SHIPPING DATE

Particulate Sampler (B.M. Separator Vent)	June 22, 1977
Orifice Meter	May 27, 1977
D/P Gages	July 21, 1977
Pressure Gages	May 27, 1977
Vinyl Tubing	June 3, 1977
Fly Ash Sampling Valves	June 17, 1977
Barometer	June 3, 1977
Turning Vanes, T/C Supports	June 30, 1977

Additional miscellaneous hardware items will be field purchased.

4.2 MFB Plant Construction (Champion Construction & Engineering Co., Inc., Subcontract No. 7412)

4.2.1 General Activity

During this reporting period, Champion concentrated their efforts on completing construction of all major contract items, including amendments and outstanding punch list items. All work was completed by mid-March and at the end of the reporting period, Champion and their subcontractors started demobilization of their field offices and personnel in preparation for moving off the site.

During this period, the following spare parts were confirmed for delivery by the vendors:

Spare Parts

<u>P.O. No.</u>	<u>Company (Vendor)</u>	<u>Date</u>	<u>Description</u>
1650	Yound Ind.	3/16/76	Limestone Handling
1655	Air Preheater	3/17/76	Air Preheater
1646	Tri-State ind.	3/15/76	F.D. & I.D. Fan Motors
1644	Reliance	3/15/76	Instrumentation
1648	Stephens-Adamson	3/16/76	7" Redlers
1659	Carman Industries	3/23/76	Vibrating Feeder
1661	Trane Thermal	3/24/76	Burner, Pump
1676	Koppers	3/29/76	Dryer
1683	F.M.C.	3/31/76	Ash Cooler
1677	Koppers	3/29/76	Crusher
1674	Autoweigh	3/29/76	Weigh Belt Feeder
1673	Aerodyne	3/26/76	Knife Gates
1675	Buell	3/29/76	Electrostatic Precipitator
1711	Allen-Sherman-Hoff	4/19/76	Air Locks
1703	Joy Mfg. Co.	4/14/76	Dust Collectors
1705	Tanuton Eng.	4/14/76	Bucket Elevators
1710	Allen-Sherman-Hoff	4/19/76	G.D. Air Blowers
1687	Zurn Industries	4/2/76	F.D. Fan
1688	Zurn Industries	4/2/76	I.D. Fan
2093	VICO	12/22/76	Flexible Joints