FOSSIL ENERGY

MULTICELL FLUIDIZED BED BOILER DESIGN, CONSTRUCTION AND TEST PROGRAM

Quarterly Progress Status Report for October—December 1978

February 1979
Date Published

Work Performed Under Contract No. EX-76-C-01-1237

Pope, Evans and Robbins Incorporated
New York, New York

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

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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 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 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-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 DOE Contract No. EX-76-C-01-1237 is to test a multicell fluidized-bed boiler as a pollution-free method of burning high-sulfur 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 MFB Boiler Performance.
Phase II	Fabrication, Installation and Shakedown Status Operation.
Phase III	Demonstration Operation under SO_2 Acceptor Mode.
Phase IV	Preparation of Design and Operation Manuals and design of a factory-assembled industrial MFB unit.

This Quarterly Report covers work performed under Phase I, III and IV of the contract in the period October, November and December 1978.

1.0 SUMMARY OF PERFORMED TASKS

1.1 Alexandria, Va. Laboratory Operation

Work at the Alexandria laboratory concentrated on oil firing as a back-up fuel supply for AFB units and testing of a drilled bolt air distributor.

Work in the following areas is described in this report.

Activity No.	Description
114	Air Distributor Testing
1621	Bed Level Measurement
1619	Large Coal Feed
1618	Oil Firing
1616	PDU Performance Characterization
1110	Sulfur Capture
1620	Flue Gas Baghouse Program

The following tests were completed during the reporting period.

Test No.	Date	Description	Duration (Hrs)
703-2	10/ 5/78	Large size coal	7.0
703-3	10/10/78	Large size coal	8.0
703-4	10/12/78	Large size coal, 3/4" x 1/2"	5.0
703-5	10/17/78	Large size coal, 3/4" x 1/2"	5.0
702-7	10/20/78	Coal light-off preliminary #6 oil	6.0
700-25	10/25/78	Illinois #6 coal	5.0
702-8	10/27/78	#6 oil firing	7.0
702-9	11/ 1/78	Heat transfer and sulfur capture of #6 oil	16.0
700-26	11/13/78	1500°F slump	5.0
700-27	11/14/78	2000°F slump	6.0
700-28A	11/20/78	Drilled bolt grid plate, heat transfer and combustion efficiency, material balance for Ca/S ratio of 1	44.0

700-28B	12/ 5/78	Drilled bolt grid plate, heat transfer and combustion efficiency, material balance for Ca/S ratio of 5	16.0
700-29	12/12/78	Drilled bolt grid plate, combustion efficiency, low bed high temperature	7.0
700-30	12/28/78	Drilled bolt grid plate, sulfur capture fresh bed light-off, Greer limestone	7.0

1.2 Rivesville MFB Plant Operations

Repair, reconstruction and plant improvement activities continued on schedule during the reporting period. In addition to reconstruction of the fire damage, improvements were made in the coal feed system, monitoring and control of boiler conditions during operation, and spent bed material handling and disposal. Experience gained in past MFB performance and emission testing has resulted in modifications to test instrumentation and test procedures for the upcoming test program. MFB operators participated in a comprehensive training program including prescribed responses to emergency operating conditions. The repairs and improvements on completion will permit long duration runs of the MFB at steady state conditions and allow collection of accurate data for meaningful results.

1.3 New York Office Engineering

The New York Office design and engineering staff continued to perform various tasks in support of reconstruction of the Rivesville MFB Boiler Plant fire damage and plant improvement for increased reliability. Tasks performed included:

- Design and preparation of drawings for additional access platforms and stairs,
- Preparation of feasibility study and cost estimate for removal and relocation of coal dryer,
- Evaluation of existing flue gas duct expansion joints for use with replacement I.D. fan,
- Preparation of feasibility study and cost estimate for providing redundant F.D. and I.D. fans,
- Evaluation of existing flue gas ducts for exposure to elevated temperature flue gas,

- Design and preparation of drawings for baghouse filter at storage silo for direct venting to atmosphere,

- Preparation of feasibility study to improve transport of spent bed material from the classifier discharge to the bed material storage tank and/or the ash cooler,

- Design and preparation of drawings for extensions to fire protection system.

1.4 Subcontract Activities

1.4.1 MFB Plant Advisory Operations Assistance (Stone & Webster Engineering Corporation)

S&W continued to furnish advisory operations assistance at the Rivesville MFB Plant and provide engineering and design support in areas critical to plant start-up.

Home office engineering tasks performed included preparation of designs and drawings and procurement of steam vent silencers and a stack silencer for noise reduction; evaluation and analysis to improve performance efficiency of electrostatic precipitator; design, engineering and preparation of equipment specifications for turbine by-pass system; engineering, preparation of specification and procurement of by-pass damper for Dust Collector No. 1 to improve efficiency during one and two cell operation; feasibility study to replace electrostatic precipitator with baghouse filter and provide redundant F.D. and I.D. fans.

Field activities included development of air preheater deluge system; recommendations for reduced voltage starting for auxiliary F.D. fan; compilation of instrument list; evaluation of operational results efforts and preparation of error analysis report.

Daily safety tours were conducted and discussions held with OSHA Compliance Office relative to reconstruction activities. Formal MFB Operator training program was conducted.

1.4.2 MFB Steam Generator Development (Foster Wheeler Energy Corporation)

Foster Wheeler Energy Corporation engaged in the following activities in support of the Rivesville MFB reconstruction and improvement;

- Evaluation of Cell A, B, C and D air control dampers to reduce leakage,

- Designed and fabricated new drilled bolt air distributor for Alexandria PDU,

- Designed replacement drilled bolt air distributors for Rivesville Cells B, C and D and fabricated Cell D distributor,

- Removed and analyzed metallurgical samples from Rivesville MFB,

- Modified Beckman gas analyzer to improve reliability of samples,

- Completed remaining sections of Boiler Design Manual.

1.5 Review of Significant Events

During the January 1978 through December 1978 contract period, the following significant events occurred:

Event	Date
(Unit not operational in January, February and March due to strike by United Mine Workers)	
Conducted FBM/PDU verification tests at the Alexandria Laboratory	April 1978
Initiated shakedown operation of the Rivesville MFB on completion of modifications and improvements	April 1978
Operated Rivesville MFB D Cell continuously for 200 hours	May 1978
Started comprehensive performance test plant of the Rivesville MFB	May 1978
Completed Rivesville MFB D Cell performance Tests	June 1978
Fire occurred at Rivesville MFB on August 9 which damaged electrostatic precipitator, air preheater, ID Fan and interconnecting ductwork	August 1978
Started repair (reconstruction) work of the fire damaged Rivesville MFB equipment	September 1978
Conducted No. 6 oil burning tests in the Alexandria PDU	October 1978
Conducted tests on drilled bolt air distributor in the Alexandria PDU.	November 1978

1.6 Future Planning

The following activities are scheduled for the January, February and March 1979 period:

1) Complete repair-reconstruction and plant improvement activities for the Rivesville MFB unit, including installation of drilled bolt air distributor,

2) Conduct cold mode testing of Rivesville MFB plant and equipment and prepare for start-up,

3) Initiate hot firing testing in Rivesville MFB plant and complete performance and emission testing,

4) Complete testing of drilled bolt air distributor in Alexandria PDU,

5) Complete data analysis on the large size coal and oil firing tests in the Alexandria PDU.

6) Complete installation and initiate testing of baghouse filter in Alexandria PDU.

7) Continue engineering studies to improve MFB performance and operational reliability.

2.0 ALEXANDRIA, VA. LABORATORY RESULTS

2.1 Air Distributor Testing (Activity No. 114)

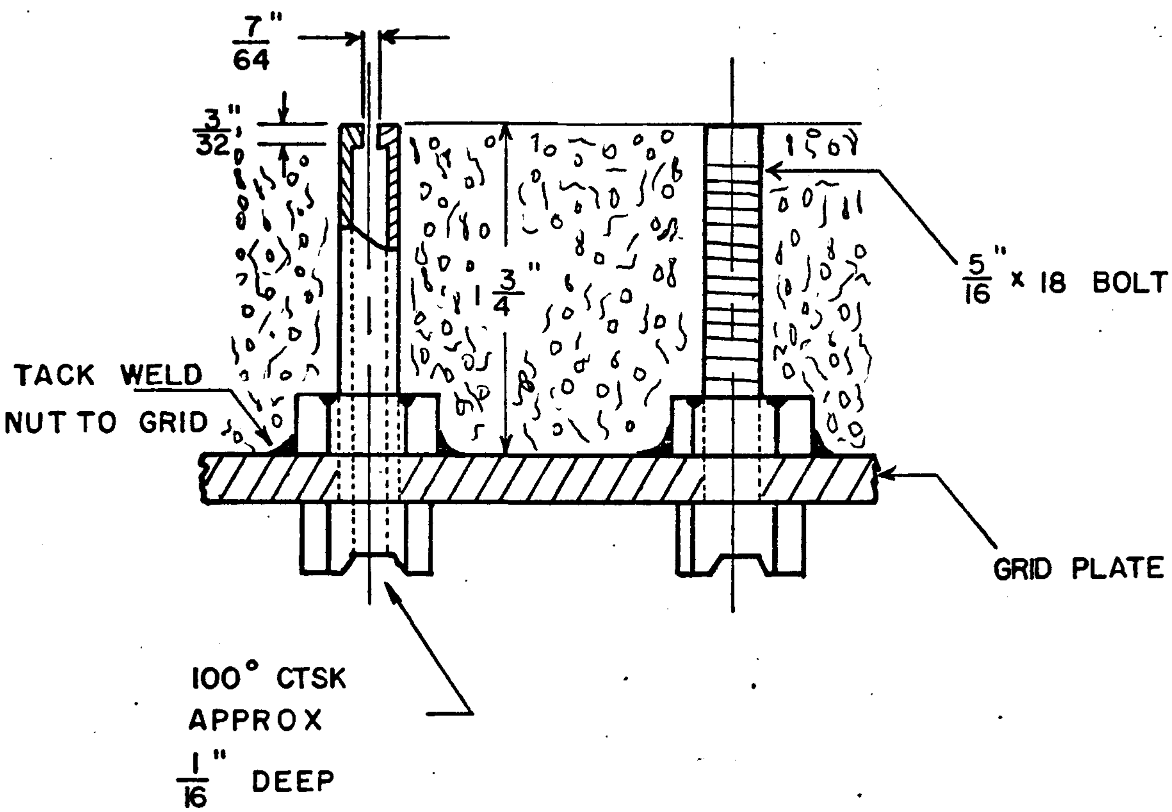
A fundamental component in the FBC unit is the air distributor. Over the past few years various air distributor designs have been tested at the Alexandria facility. Based on economic considerations and performance evaluations derived from these tests, a perforated plate was selected as the air distributor for the Rivesville MFB. The perforated plate distributor has not performed satisfactorily and analysis concluded that buckling of the plate resulted in high temperature stress-oxidation cracking. This was believed to be the result of grid plate restriction during thermal expansion and exposure to excessive operating temperatures. Various methods of insulating the grid plate from the operating bed have been tested at Alexandria. These methods included layering rocks and refractory materials over the perforated grid plate.

In this report, tests results are presented on a drilled bolt air distributor design proposed for the Rivesville MFB, see Figure 1. The test grid is 9 sq. ft. of 1/4" thick carbon steel containing 2784 5/16" x 18 stainless steel bolts on 0.724" centers. Each bolt projects 1-3/4" above the plate and is drilled out to 7/64" (.1094 in.) at the end projecting into the bed. This results in approximately 2 percent open area. In theory, during operation the 1-3/4" space fills with bed material. Since this material is not fluidized, it will form a stagnant zone insulating the grid plate from the fluidized portion of the bed. To date, a total of 94 hours of hot testing have been completed with approximately 15 temperature cycles. A summary of tests is given in Table 1.

2.1.1 Test Procedures

Following installation of the air distributor, five Type K thermocouples with 1/8" diameter sheaths were mounted to monitor temperatures at various locations as shown in Figure 2. Thermocouples #1, #2, and #4 were mounted from underneath the distributor, 1/8" into the carbon steel base to measure metal temperatures. Thermocouple #3 was also mounted from below the plate but passed through the 1/4" thick base and extended 7/8" into the dead zone of bed material. Thermocouple #5 was located on the plate divider approximately one inch below the base. All thermocouples were peened into position. Preliminary tests were run to determine the quality of the air seal between the distributor and boiler frame. Sulfated bed material was placed in half of the dead zone and air flow initiated through the grid. Any leaks would show as spouts through the bed material. Finding no leaks, an initial pressure drop across the grid plate at ambient conditions without bed material was recorded. Following this test, similar data was gathered at ambient conditions with 24 inches of static bed depth.

Test No. 700-26 was the first hot test run with the drilled bolt grid plate. To simulate Rivesville conditions, the bed was run at 24" static depth and a temperature of 1550°F. The steam air preheater



NOZZLE DETAILS

DETAILS OF DRILLED BOLT AIR DISTRIBUTOR

Figure 1

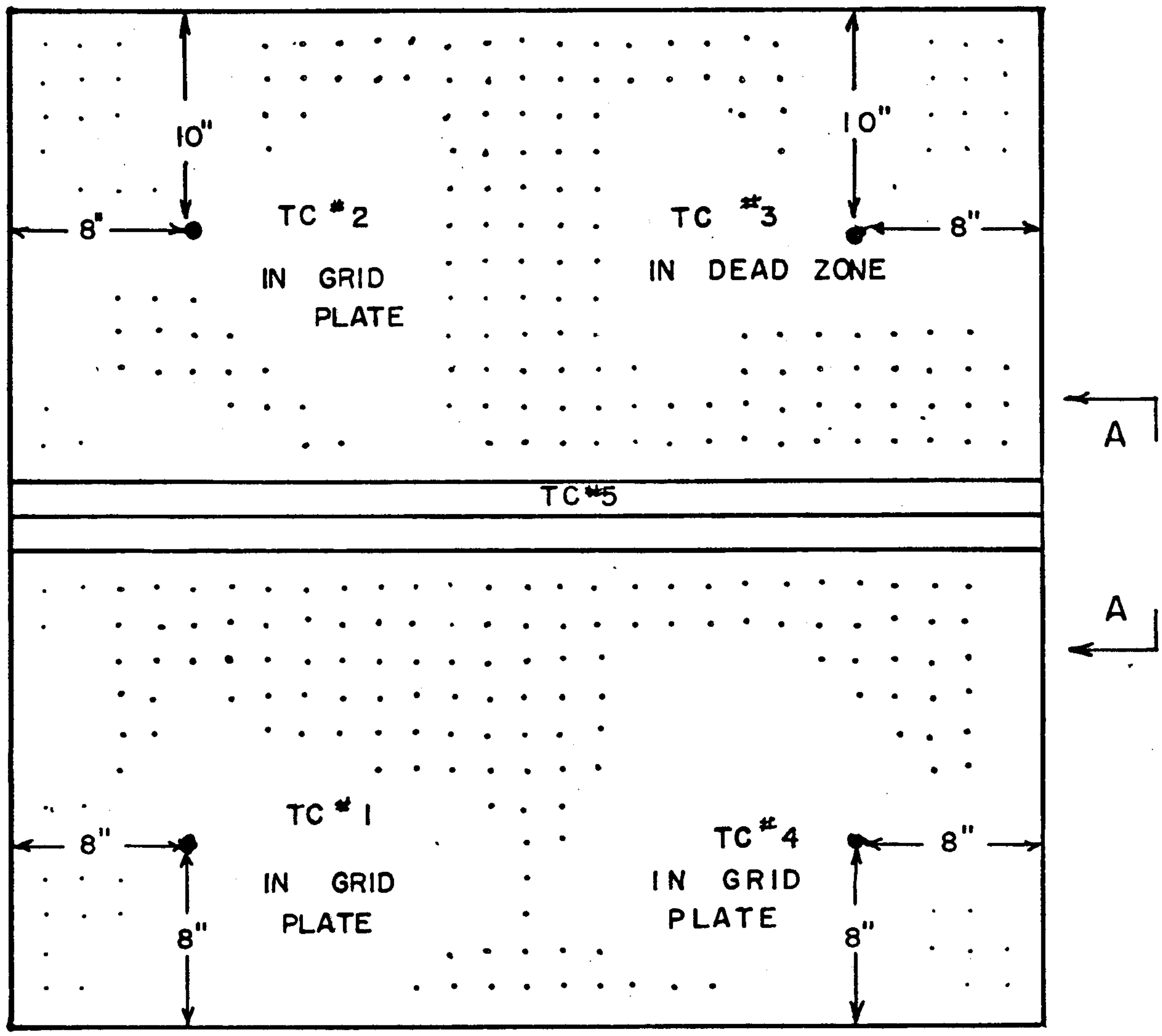
Table 1

Summary of Drilled Bolt Air Distributor Tests

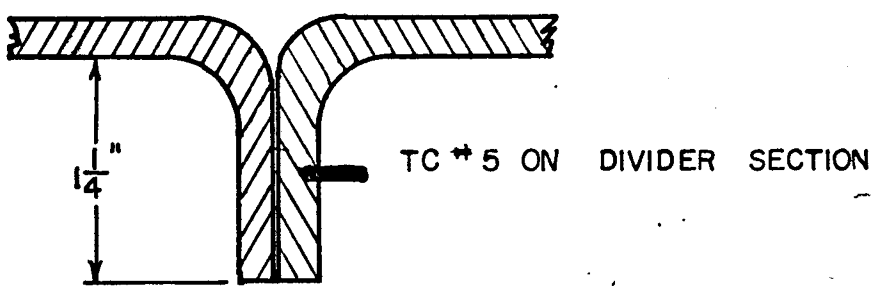
Date	Description
10/30/78	Air Distributor delivered.
11/8/78	Installation in PDU completed.
11/9/78	Seals checked; initial ambient, no bed pressure drop tests.
11/10/78	Ambient, 24" pressure drop tests.
11/13/78	Test 700-26; 5 hr. run at 1550°F followed by overnight slump.
11/14/78	Test 700-27; 6 hr. run at 2000°F followed by overnight slump.
11/20-22/78	Test 700-28A;44 hr. run at 1550°F including two non-scheduled slumps.
12/5/78	Test 700-28B, 16 hr. at 1550°F.
12/8/78	Slumping training for operators; 4 slumps at 1550°F.
12/12/78	Test 700-29; 10 hrs. at 1700°F.
12/14/78	Isokinetic hot tests, 6 hrs. at 1550°F.
12/28/78	Test 700-30; 7 hrs. at 1550°F.

Total Hot Test Hours: 94.0

Approximate # of Cycles: 15



TOP VIEW



ENLARGED VIEW 'A"A'

THERMOCOUPLE LOCATIONS ON DRILLED BOLT AIR DISTRIBUTOR coil (designed for 300°F preheat) and the below-bed propane burner were used during the entire test to achieve an air preheat near the Rivesville design value of 600°F. During this test, data was collected for plotting ΔP grid plate versus main air flow. During Test No. 700-26, an emergency shutdown was simulated by slumping the bed on the air distributor and monitoring the temperature as a function of time.

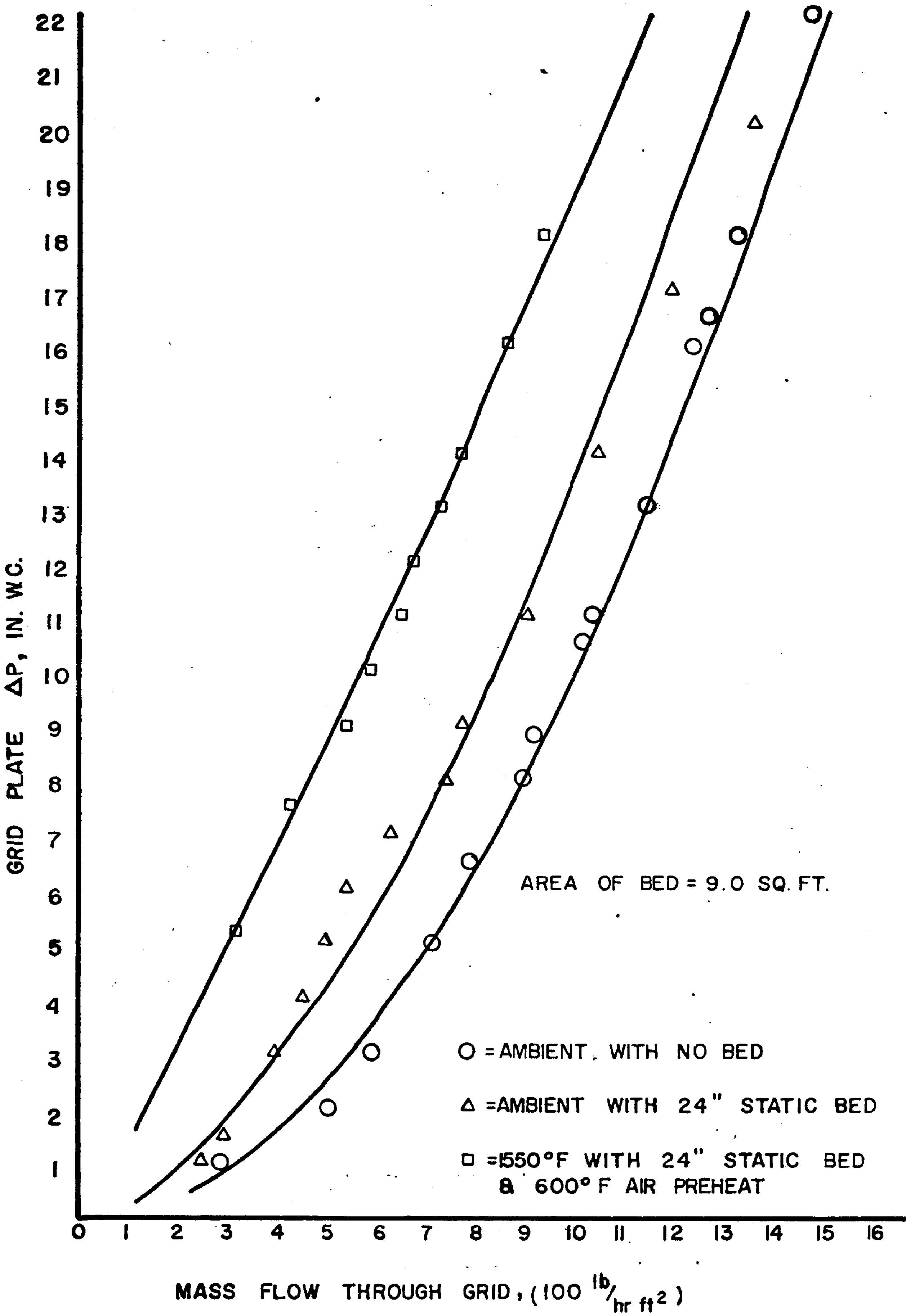
A second hot test, Test No. 700-27, was run at a bed temperature of 2000°F. This condition would exist in the Rivesville CBC and would be the most extreme temperature to which the grid would be exposed. In order to attain this temperature during the test run, it was necessary to operate with a reduced bed depth of 8" static. As in Test No. 700-26, the bed was slumped after maintaining an operating condition of 2000°F for a period of time.

Following these tests conducted specifically for air distributor characterization, Test No. 700-28A, a 44 hour sulfur capture test was run. For this and all following tests, thermocouple #5 was removed from the plate divider and peened into the frame which supports the grid plate. After each hot test, the bed was drained and vacuumed clean and the grid examined for signs of buckling and bolt damage. To determine whether the bolts were plugging, a grid pressure drop test at ambient conditions without bed was performed after each hot test. If plugging occurred, the pressure drop at the same air flow rate would increase. When not in use, the grid plate was covered with 4" to 6" of bed material. The bed material was also occasionally rolled with steel bars when on the grid plate. These steps were to induce plugging of bolt holes arising from down time or maintenance on the boiler requiring walking on the grid as would be the case at Rivesville. The plenum was also examined for sifting of fine bed material through the grid.

2.1.2 Test Results

2.1.2.1 Air Distributor Pressure Drop

The change in air distributor pressure drop in inches of water with air flow is shown in Figure 3. Values are shown for 1550°F and ambient conditions with a 24" static bed as well as ambient with no bed. Because of the severity of the 2000°F condition in Test No. 700-27, the air flow was not variable over a large enough range to both gather data and maintain temperature. The MFB design superficial velocity in the main cells at 1550°F bed temperature is 12 ft/sec with 600°F air preheat. The curve in Figure 3 shows that in order to attain 12 ft/sec at 1550°F, the pressure drop across the grid plate must be 16 in. W.C. (7776 lb/hr through a PDU cross section of 9 sq. ft.). This result is lower than the design pressure drop of 20.0 in. W.C. for the perforated plate type distributor.



PRESSURE DROP ACROSS DRILLED BOLT AIR DISTRIBUTOR
AT VARIOUS CONDITIONS

Figure 3

2.1.2.2 Fluidization

During the ambient 24" static bed test, data was collected to determine the pressure drop across the grid plate needed to attain minimum fluidization. Following the onset of fluidization, the pressure drop across the bed is constant over a wide range of fluidizing velocities since the excess air at higher velocities goes into bubble formation. This fact was used along with the pressure drop across the grid versus main air flow plot for the ambient 24" static bed case to determine the grid plate pressure drop at minimum fluidization. This value was 4.2 in. W.C. and is nearly identical to that of the performated grid plate value of 4.0, see Figure 4.

2.1.2.3 Grid Plate Temperatures at Normal Operating Conditions

The 44 hour test 700-28A was run at normal operating conditions, i.e., 12 ft/sec, 1550°F, 24" static bed and 300°F air preheat. Three periods of four hour duration were examined during the test, one near the beginning, one in the middle and one near the end. For each period, the bed temperature was averaged as were the grid plate thermocouples #1, #2, and #4. Thermocouple #3 located midway in the dead zone was averaged separately. Thermocouple #5 located on the frame read the same value as the grid plate thermocouples in all cases. The results are summarized in Table 2. Similarly, Test 700-30 was run at normal operating conditions and the grid plate temperatures are shown in Table 3. Test 700-29, run at 1700°F bed temperature is summarized in Table 4.

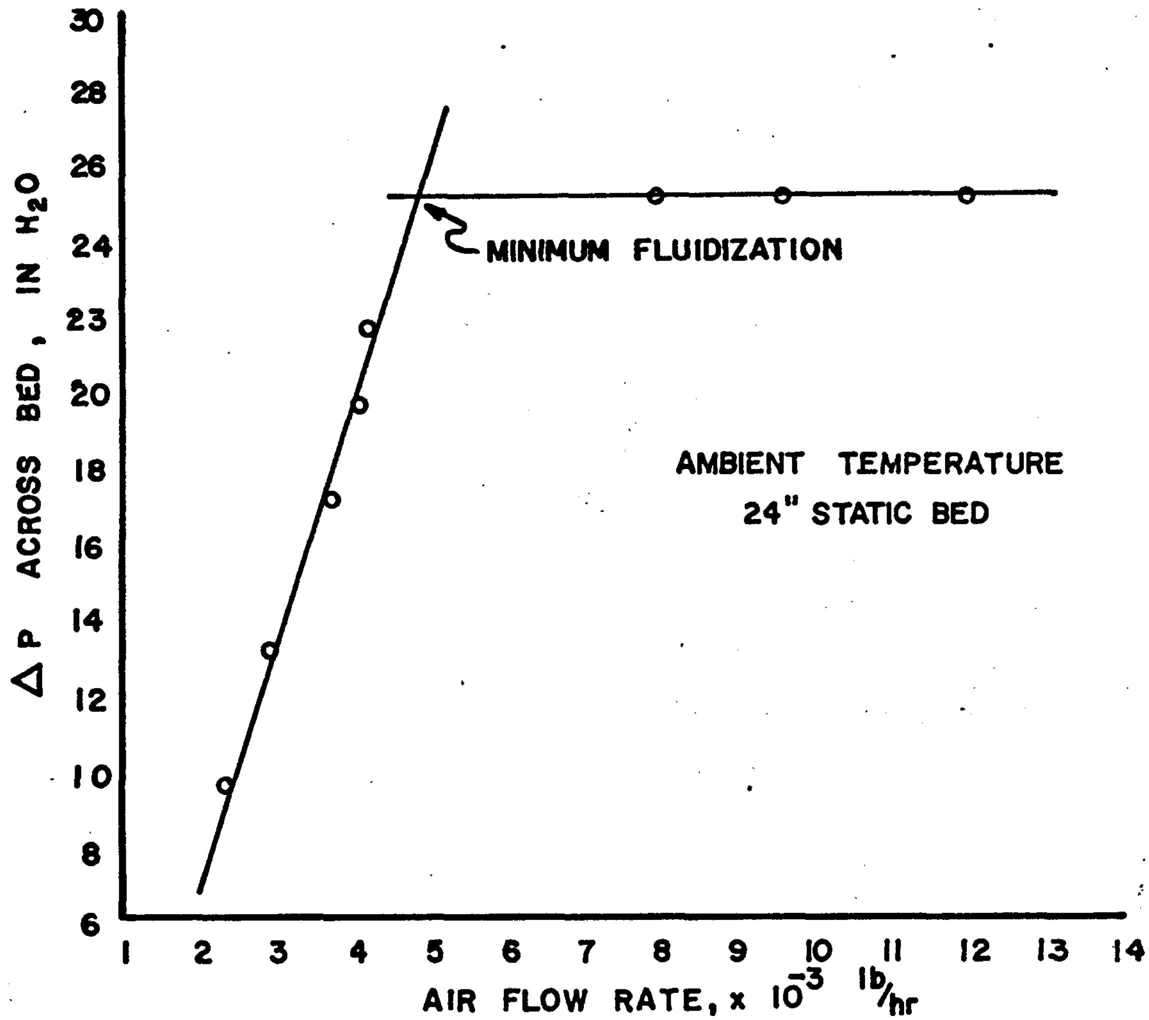
2.1.2.4 Air Distributor Temperature at Emergency Shutdown

Tests Nos. 700-26 and 700-27 simulated emergency slumping at 1550°F and 2000°F respectively. The results are shown in Table 5. Following slumping of the 1550°F bed in Test No. 700-26, the plate thermocouples were monitored to follow grid plate temperatures as a function of time. However, some thermocouples were influenced by use of the below bed burner. As a result, after slumping, these temperatures showed cooling trends since the burner was extinguished. Therefore, thermocouple #4, away from the burner yet still in the 600°F plenum air, was used as the grid plate temperature.

During Test No. 700-27, the plenum burner was not used resulting in the normal 300°F air preheat. This produced even temperatures across the grid plate. On slumping the 2000°F bed, temperatures were monitored every 30 seconds for 65 minutes. These temperatures versus time are shown in Figure 5. The maximum average grid temperature was 603°F for the three grid plate thermocouples.

2.1.2.5 Plugging and Sifting

Following each hot test the grid was examined for damage and signs of wear. As many as 50 to 100 nozzles were found to contain small amounts of bed material. However, ΔP grid versus main air flow results at ambient no bed conditions after each hot test, were well within the



DETERMINATION OF MINIMUM FLUIDIZATION WITH DRILLED BOLT AIR DISTRIBUTOR

Figure 4

Table 2

Drilled Bolt Grid Plate Air Distributor

Temperatures for Normal Operating Conditions for Test 700-28A

(11/20/78)

Period	Avg. Bed Temp., °F	Avg. Air Dist. Temp., °F	Avg. Mid* Dead Zone Temp., °F
I	1528	351	466
II	1513	346	463
III	1558	352	489

Table 3

Drilled Bolt Air Distributor Temperature for Test 700-30
(12/28/78)

Bed Temperature, °F	Avg. Grid Temp.	Mid Dead * Zone Temp.
1476	326	417
1472	332	404
1489	327	391
1513	331	410

Table 4

Drilled Bolt Air Distributor Temperature for Test 700-29,
(12/12/78)

Bed Temperature, °F	Avg. Grid Temp.	Mid Dead * Zone Temp.
1734	345	470
1681	349	465
1688	354	465
1656	336	375

* Thermocouple mounted from underside of grid plate, passing thru plate and extending about 7/8" into dead zone of bed material.

Table 5

Summary of Drilled Bolt Grid Plate Slump Test Results

Test No.	Condition	Bed Temp.	Air Preheat	Max. Avg. Grid Temp.	Max. Dead Zone Temp.	Max. Divider Temp.
700-26 (11-13-78)	Run	1550	600*	653	620	903*
	Slump	1550	None	697	642	655
700-27 (11-14-78)	Run	2000	300	390	570	386
	Slump	2000	None	603	667	566

* Attained with below bed propane burner.

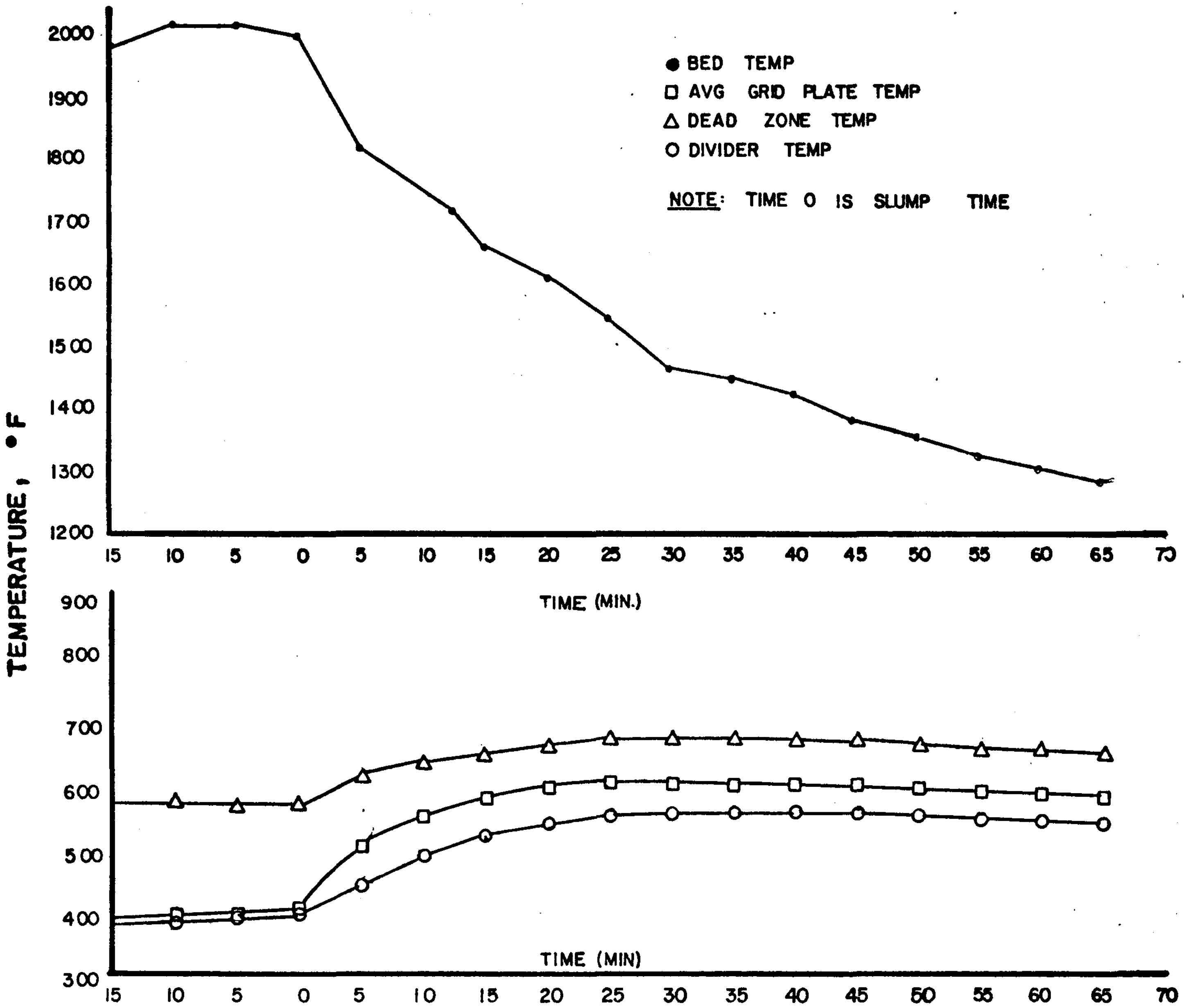


Figure 5

GRID PLATE TEMPERATURES VERSUS TIME FOR 2000°F SLUMP limits of error when compared to the initial run at similar conditions prior to testing. This fact is shown in Figure 6 where the initial and final 700-28A no bed ambient test results are shown. Similar results following Tests 700-29 and 700-30 yielded identical curves. Examination of the plenum after each test showed sifting to be minimal in all cases.

2.1.3 Conclusions

From testing conducted to date it appears that the prototype FWEC nut and bolt air distributor design is satisfactory for the Rivesville MFB unit. Since only 94 hours of hot testing and 15 temperature cycles have been completed, longterm performance has not been determined. Additional factors which will affect performance in the MFB are:

- multiple coal feed points,
- light-off conditions of D cell,
- dust loading of air passing through the grid.

2.2 Bed Level Measurement (Activity No. 1621)

2.2.1 Introduction

Ongoing work continued on an alternative to the differential pressure tap means of determining bed height. Because the inbed heat transfer coefficient is 3 to 5 times the above bed coefficient, the steam flow rate can be changed by small changes in bed height in the region of the submerged tube bundle. Since the reliability and accuracy of the differential pressure tap level measurement method is limited by pluggage and pressure fluctuations, the development of a useful alternative is desirable.

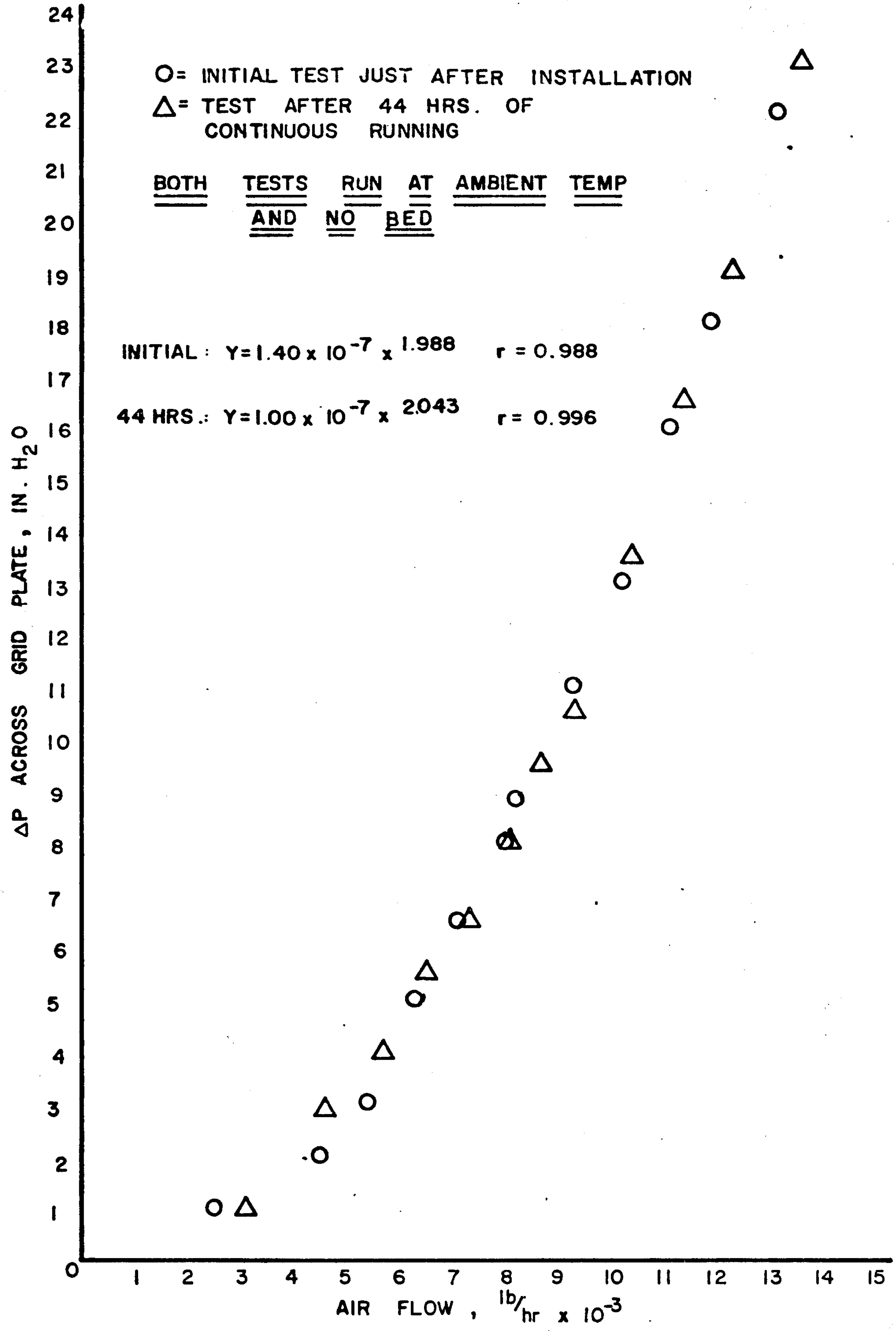
2.2.2 Theory

The measuring technique currently employed is based on the large difference between heat transfer coefficients in the bed and in the gas above the bed. A fluid passed from the freeboard into the bed through a vertical tube should experience a more rapid heating rate in the bed region than in the freeboard. Thus, if the heating rate in the bed is greater, the temperature rise over a given distance in the bed will be greater than that over the same distance in the freeboard. Thermocouples located intermittently along the inside of the tube would give the temperature as a function of distance through the pipe. This temperature profile may be related to bed height by heat transfer principles in the following manner. Consider first, heat transfer to the inbed portion of the vertical tube as shown in Figure 7. Performing a steady state heat balance around the differential element dx;

heat into element = heat out of element

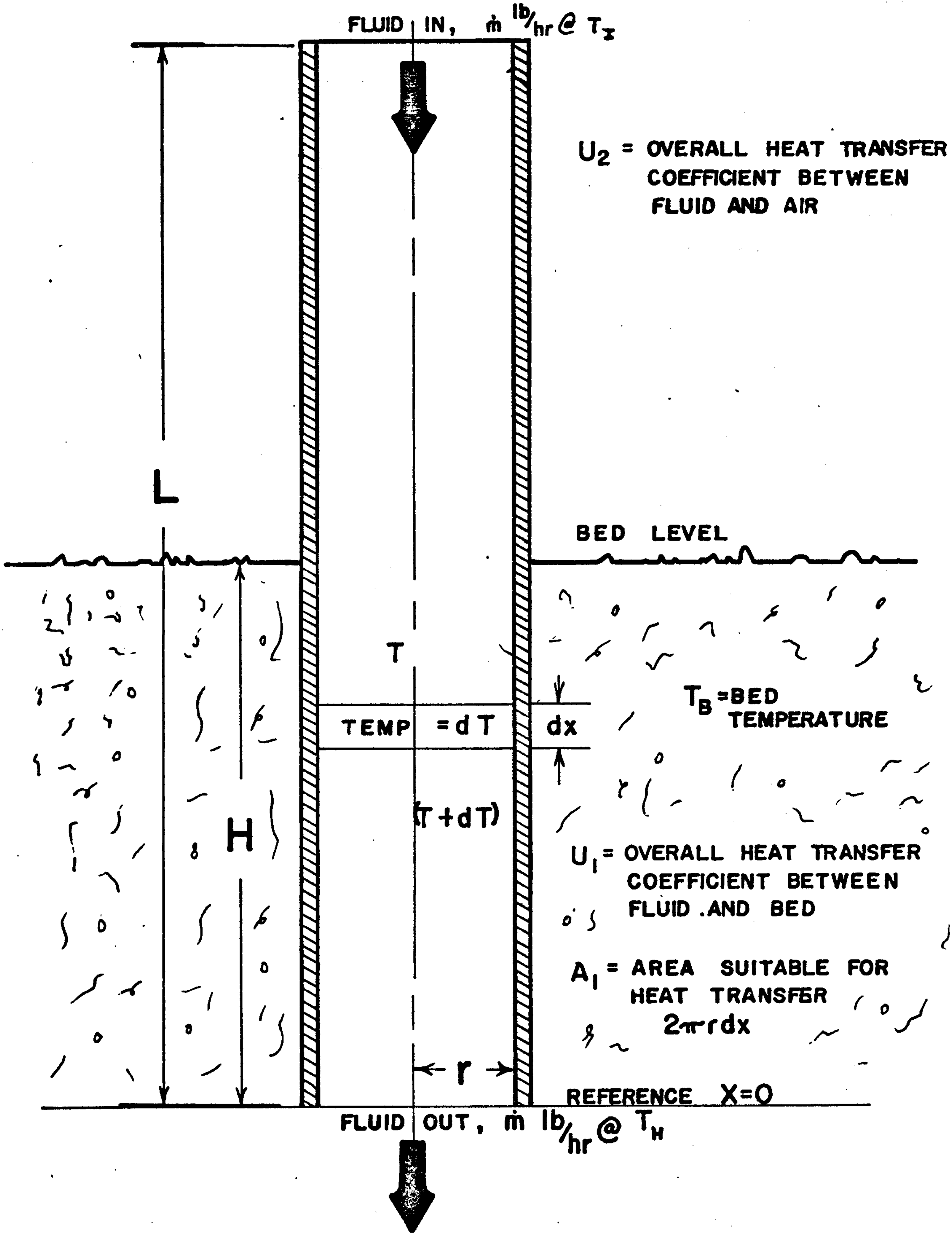
$$\dot{m}CpT + U_1 \ (T_B - T) = \dot{m}Cp \ (T + dT)$$

$$U_1A_1 \ (T_B - T) = \dot{m}CpdT$$



PLOT OF P ACROSS GRID VERSUS AIR FLOW RATE FOR DRILLED BOLT GRID PLATE AIR DISTRIBUTOR

Figure 6



DIFFERENTIAL HEAT BALANCE ON THE INBED PORTION OF BED LEVEL SENSOR

Figure 7

where the symbols are as follows:

Cp	=	Specific heat of fluid, Btu/lb/°F.
dT	=	Change in fluid temperature through differential element, °F.
dx	=	Differential element of height along tube, ft.
H	=	Height of tube from reference plane to top of bed, ft.
L	=	Overall height of tube above reference plane, ft.
$\dot{m}$	=	Mass flow rate of fluid, lb/hr.
r	=	Radius of tube, ft.
T	=	Temperature of fluid entering the differential element, °F.
T_B	=	Temperature of bed, °F.
T + dT	=	Temperature of fluid leaving the differential element, °F.
U_1	=	Overall heat transfer coefficient between fluid and freeboard Btu/hr/ft^2/°F.
U_2	=	Overall heat transfer coefficient between fluid and bed Btu/hr/ft^2/°F.
x	=	Height of tube above reference plane.
A_1	=	Area available for heat transfer, sq ft.

The area available for heat transfer A_1 is $2\pi r dx$. Substituting this quantity and rearranging gives the following expression:

$$\int \frac{dT}{T_B - T} = R_1 \int dx$$

where $$R_1 = \frac{2\pi r U_1}{\dot{m} Cp}$$

Integrating and substituting the following boundary conditions:

$$T = T_H \text{ @ } X = 0$$

$$T = T_C \text{ @ } X = H$$

one obtains

$$\ln (T_B - T) = R_1 (X - H) + \ln (T_B - T_C) \qquad (1)$$

Thus, a plot of $\ln (T_B - T)$ vs X should yield a straight line of slope R_1 for all temperatures and distances in the bed.

A similar analysis of the freeboard region, assuming the temperature in the freeboard to be the same as that in bed, results in an equation similar to (1), i.e.

$$\ln (T_B - T) = R_2 (X - L) + \ln (T_B - T_1) \quad (2)$$

where $$R_2 = \frac{2\pi r U_2}{\dot{m} Cp}$$

A plot of $\ln (T_B - T)$ vs X for temperatures and distances above the bed should again yield a straight line of slope R_2.

Thus, equations 1 and 2 together give the temperatures-distance profiles in and out of the bed respectively. The intersection of the two lines is the heat transfer bed height (HTBH). Assuming Equations 1 and 2 to be of the form

$$\ln (T_B - T) = a_n X + b_n$$

The HTBH may be solved for by Equation 3:

$$HTBH = \frac{\ln \frac{a_1}{a_2}}{b_2 - b_1} \quad (3)$$

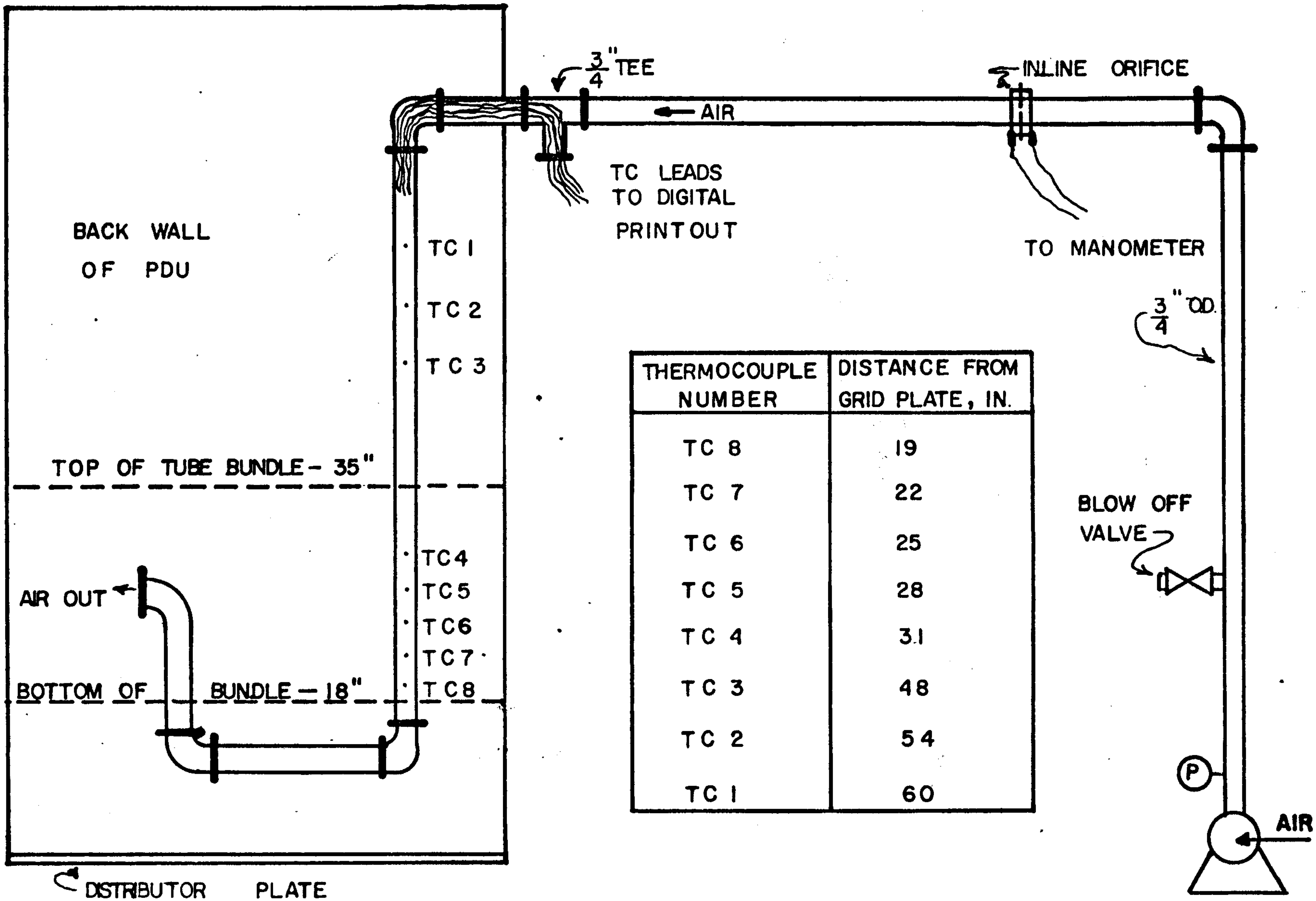
2.2.3 Materials

To put this theory into practice, a test level probe was constructed and mounted in the PDU. The vertical tube was 3/4", 304 stainless steel piping 48 in. long. The fluid used was air for two reasons. First being a gas, it is very sensitive to temperature change relative to a liquid. Second was the fact that the Cρ of air is about constant over the temperature range being considered (500°F - 1200°F). The air was supplied by a 20 CFM blower to keep the thermocouples below 1200°F. The thermocouples used were 1/16" chromelalumel (type K) with inconel sheaths. The orientation of both the sensor and thermocouples in the bed are shown in Figure 8. The apparatus was mounted on the back wall of the PDU, taking air in at the top and expelling it to the bed.

2.2.4 Results and Discussion

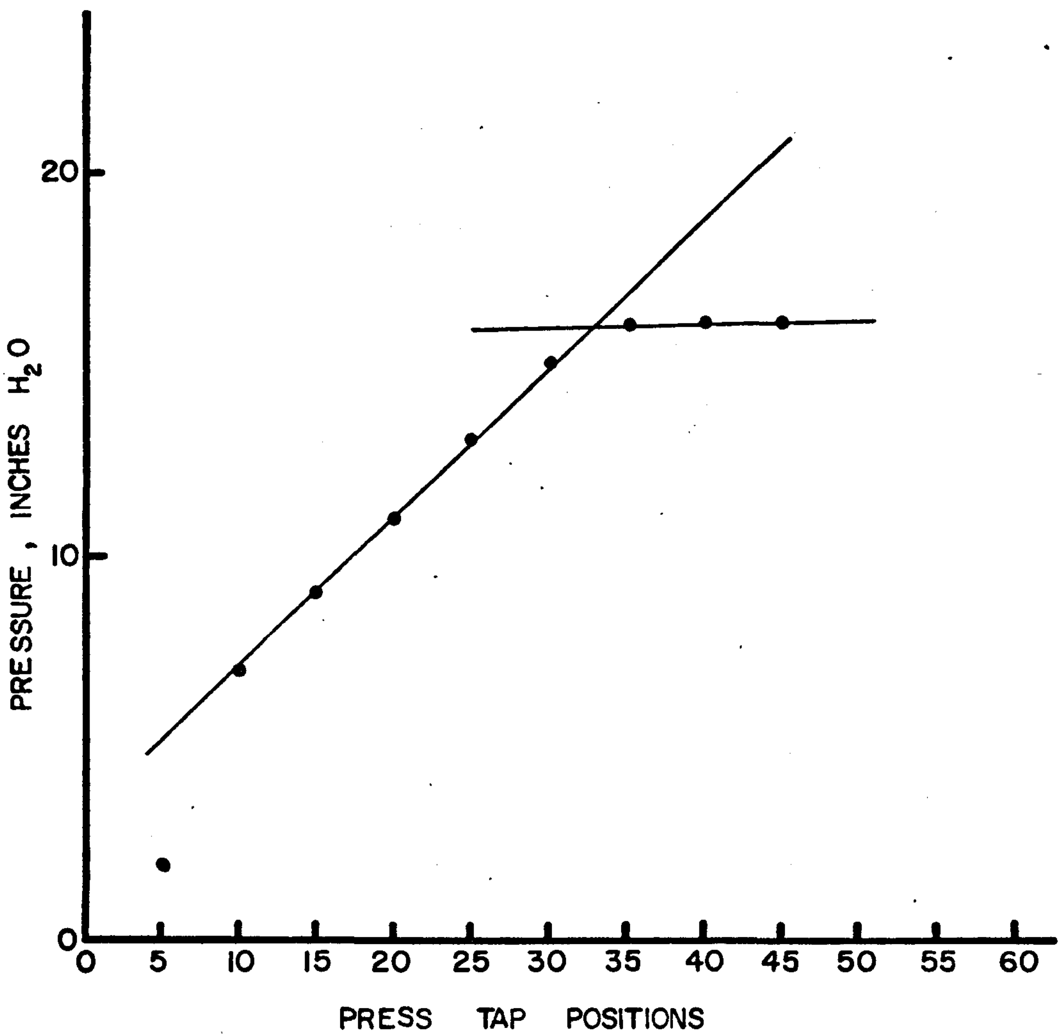
In order to test the theory, the bed level sensor was operated during four tests, Tests 702-7, 700-25, 700-28A and 700-28B. Normal pressure tap logs were kept during building of the bed to the 24" static level and the effective operating bed height (EOBH) from the pressure tap readings calculated as for every test. Figures 9 and 10 show typical plots of EOBH and HTBH respectively. As Figure 10 shows, the HTBH data falls on two straight lines as predicted by theory. To determine the intersection of the two lines, both sets of data points, those in and those above the bed were fitted to curves of the form $\ln (T_b - T) = aX + b$ and solved simultaneously to obtain the HTBH by Equation 3.

[redacted]



THERMOCOUPLE NUMBER	DISTANCE FROM GRID PLATE, IN.
TC 8	19
TC 7	22
TC 6	25
TC 5	28
TC 4	31
TC 3	48
TC 2	54
TC 1	60

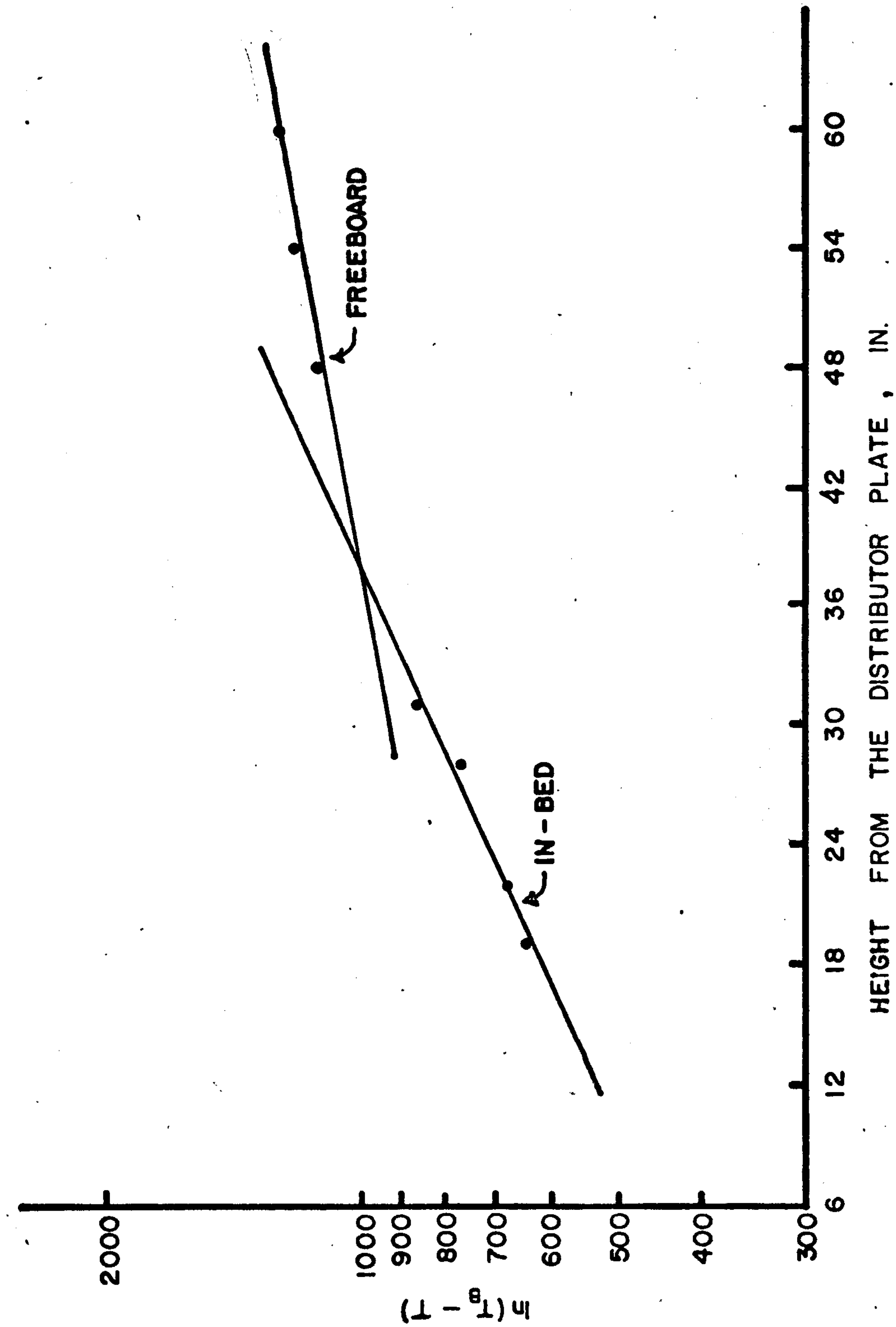
Figure 8 EXPERIMENTAL SETUP OF BED LEVEL SENSOR



IN INCHES ABOVE GRID

TYPICAL DIFFERENTIAL PRESSURE PLOT OF EOBH

Figure 9



TYPICAL PLOT OF ln $(T_B - T)$ VS. DISTANCE
FOR INBED AND FREEBOARD SECTIONS OF LEVEL SENSOR

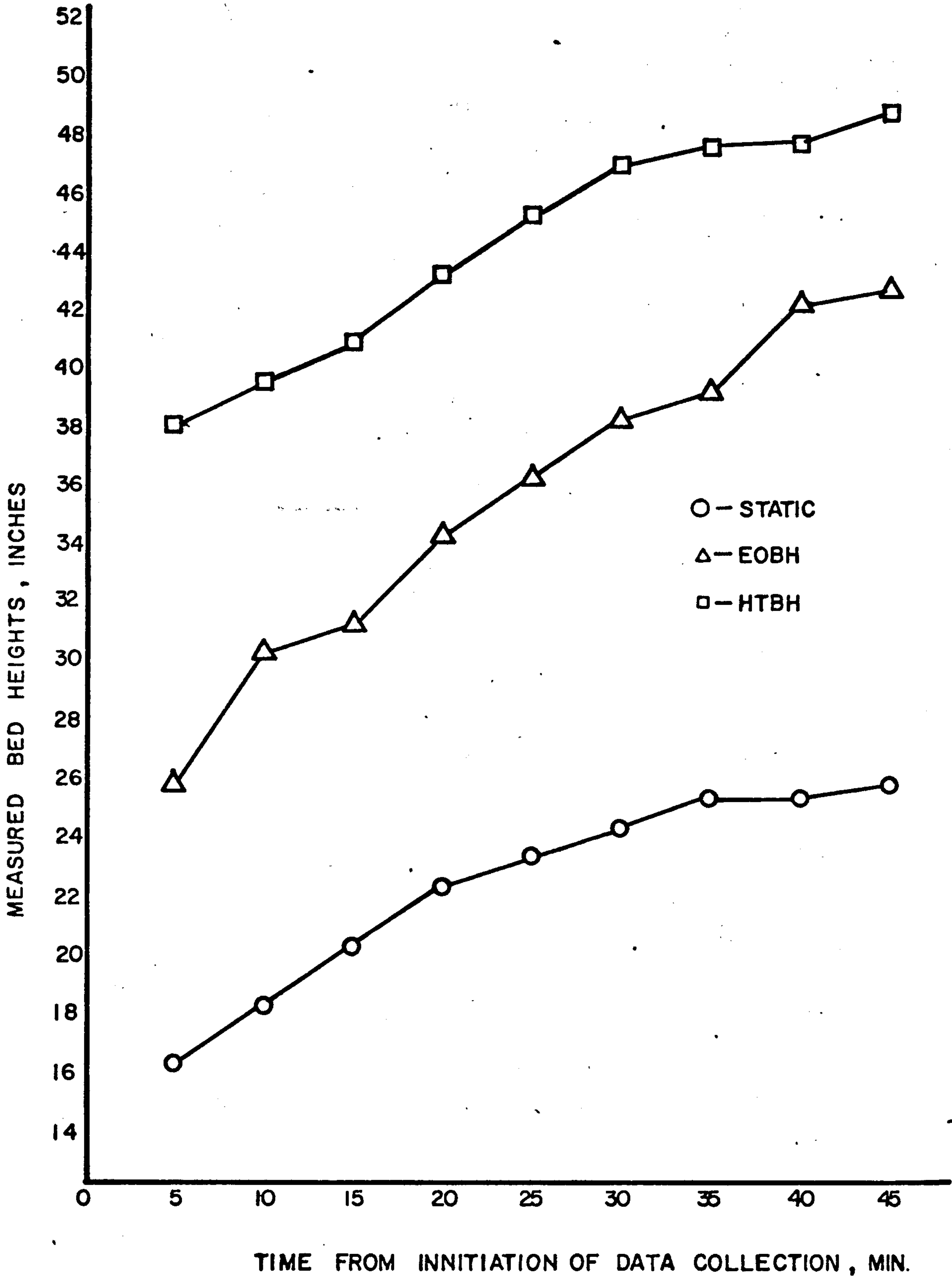
Figure 10

The results of the HTBH method for Tests 700-25, 702-7, 700-28A and 700-28B are shown in Figures 11 through 14 respectively. Since the first thermocouple was 19" off the distributor and a minimum of two points are needed to use Equations 1 or 2, data comparison was not attempted until the static bed height was at least 16", corresponding to an EOBH of about 25 inches.

Comparison of EOBH and HTBH data indicates that for the same static bed heights, the two methods give different expanded bed depths. The reason for this lies in what each method actually measures. The EOBH from the differential pressure tap technique measures the mass of bed material above a point in the bed relative to a tap 1" above the grid. A pressure tap will only give a constant reading when covered by the bed. Therefore, by plotting the differential pressure versus tap location, the plot shown in Figure 9 is obtained to give the EOBH. The HTBH method, on the other hand, measures the total height due to splashing. When the bed splashes due to bubbles breaking the surface, a portion of the bed is suspended and contributes nothing to the mass of the bed seen by the pressure taps. This splashing, however, is perceived by the bed level sensor since the heat contained by the hot bed is transferred to it by contact with the splashing material. Herein lies the difference in the EOBH and HTBH recordings.

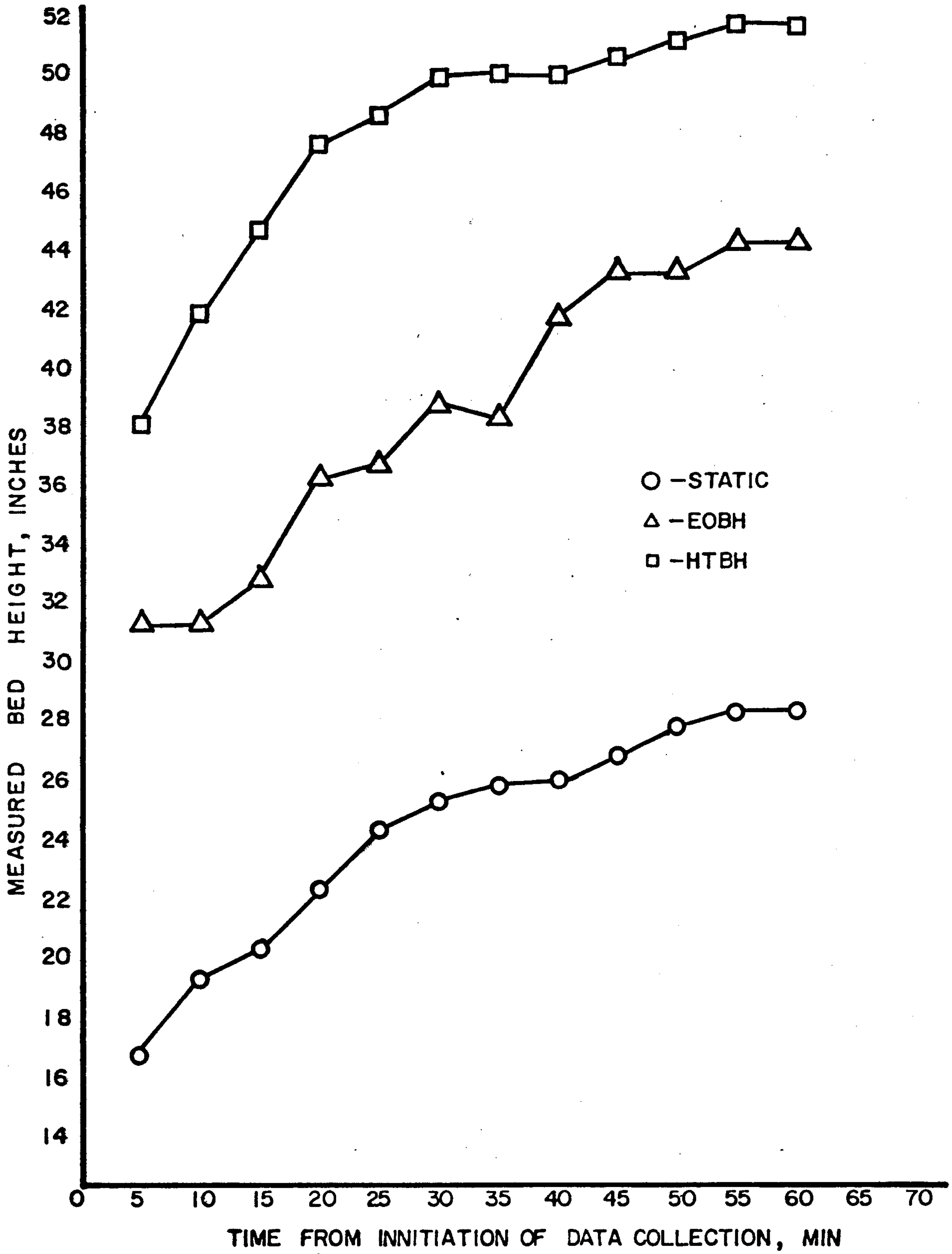
The basic qualities to be examined with this new procedure were consistency, repeatability, sensitivity and endurance. Since the HTBH measures the splash height of the hot bed, at constant bed mass it is affected primarily by changes in superficial velocity. Because superficial velocity during bed height building is difficult to keep uniform from test to test, comparison between tests is difficult. However, trends repeatably show the HTBH to more closely parallel the static bed height than the EOBH (see Figures 11 through 14). This fact is clearly evident in Figure 12 where the bed building was very slow and extended to 28" static. The EOBH appears very erratic whereas the HTBH consistently parallels the static measurement.

The sensitivity of the HTBH technique is demonstrated in Tables 6 through 8. For Test 702-7 (Table 6), a change in the static bed from 16.5" to 19" produced no change in the EOBH readings but was registered by a change in the HTBH. On the other hand when the static bed remained constant at 25.5" the EOBH showed a change of almost 3" whereas the HTBH remained essentially constant. Similar results may be seen in the 18", 21" and 24" static readings of Test 700-28A (Table 7) and the 25" reading of Test 700-28B (Table 8). Consistency is further demonstrated in Table 9. During Test 700-28B data was taken during steady state running at 1550°F as bed depth was kept as close as possible to 24". It can be seen that this mean value of 48.90" agrees with the value of 48.50" for the same static reading during Test 700-28B. The probe held up well for the four runs for which it was used, plus two preliminary test runs, a total of approximately 80 hours of hot testing.



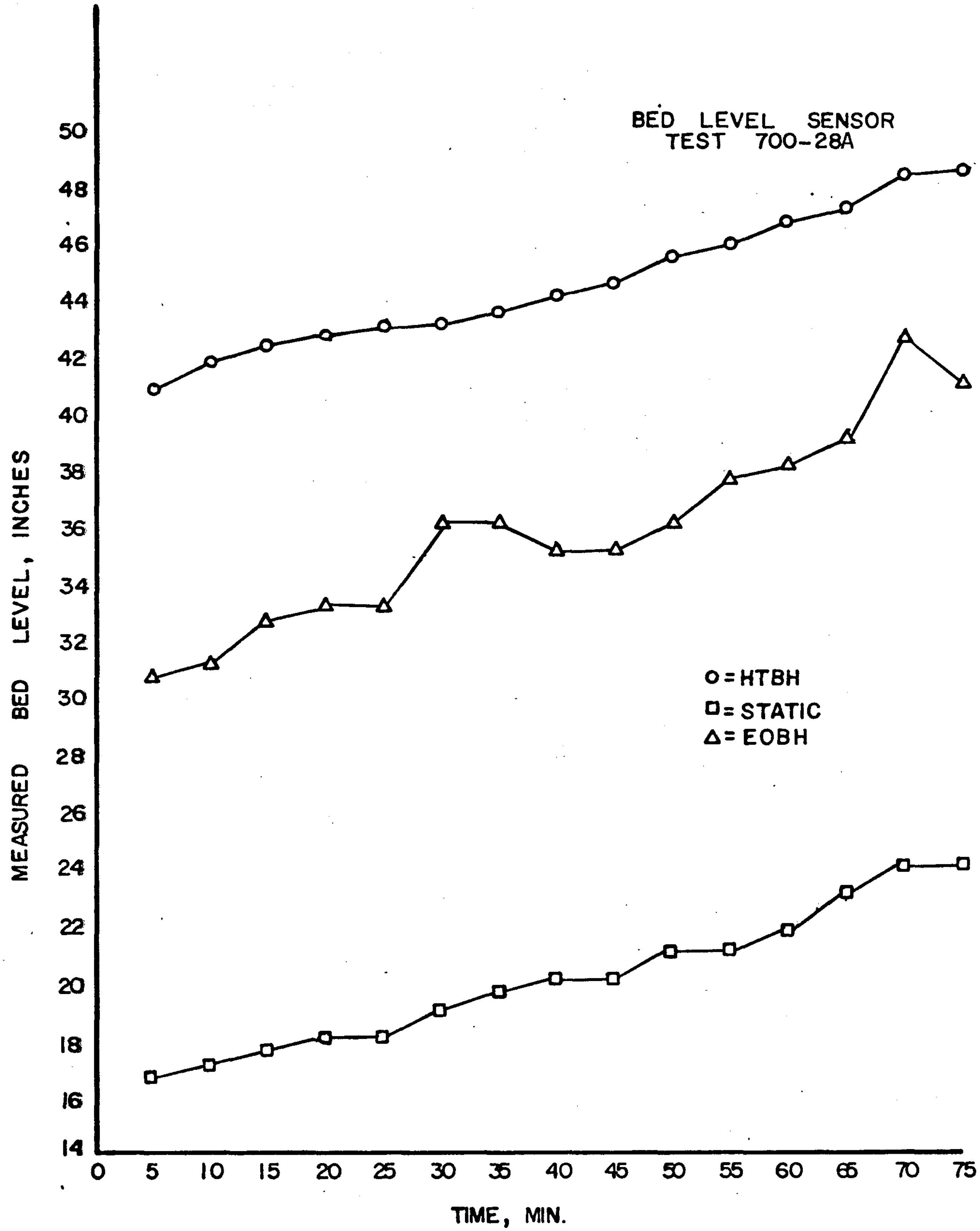
COMPARISON OF EOBH AND HTBH METHODS FOR BED BUILDING IN TEST 700-25

Figure 11



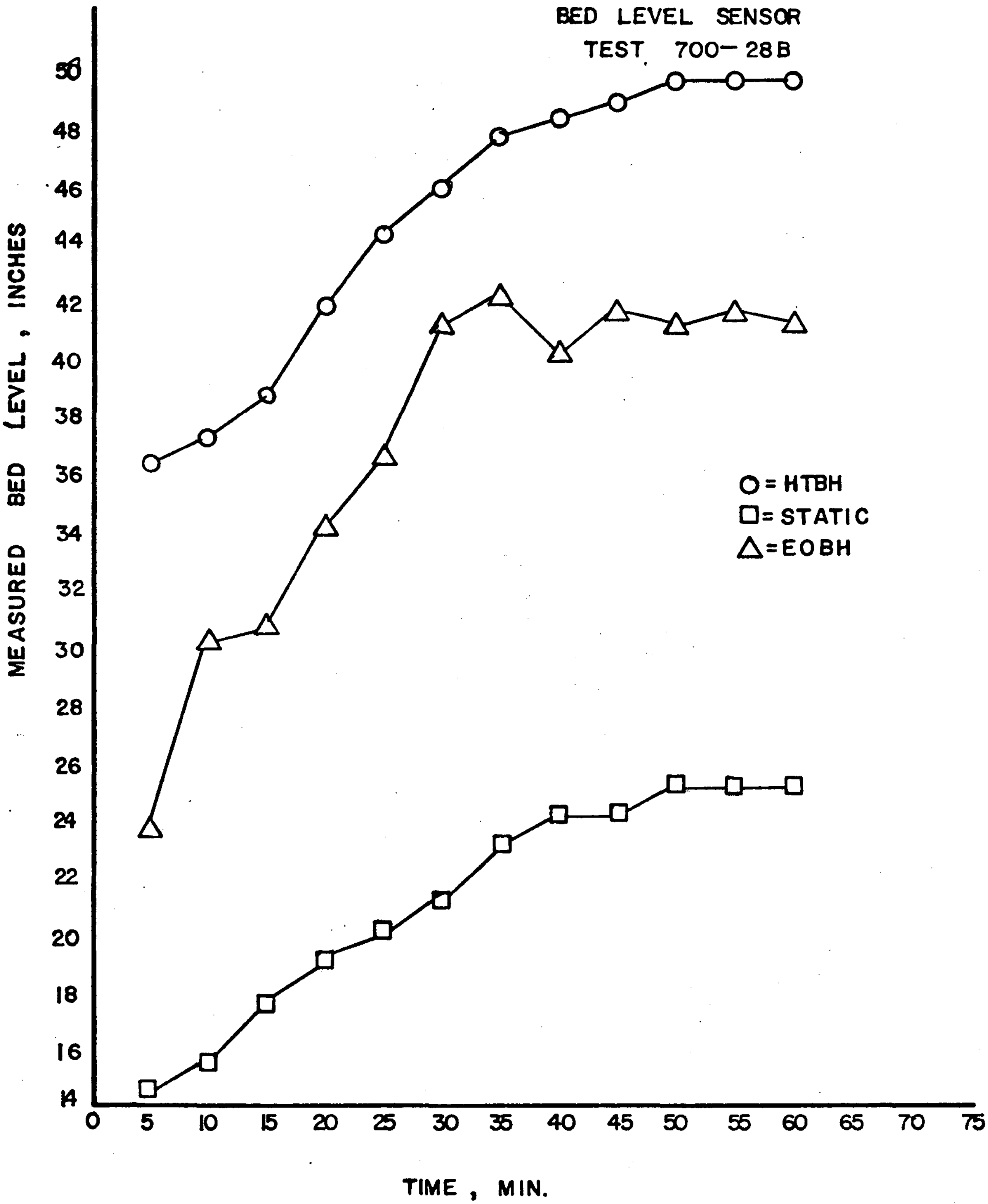
COMPARISON OF EOBH AND HTBH METHODS
DURING BED BUILDING OF TEST 702-7

Figure 12



BED LEVEL MEASUREMENTS DURING BED BUILDING OF TEST NO. 700-28 A

Figure 13



BED LEVEL MEASUREMENTS DURING BED BUILDING OF TEST NO. 700-28B

Figure 14

Table 6

Comparison of HTBH and EOBH Methods to Static Bed Depth for Test 702-7*
10/20/78

Static Bed	EOBH	HTBH
16.5	31.0	37.85
19.0	31.0	41.59
20.0	32.5	44.39
22.0	36.0	47.42
24.0	36.5	48.35
25.0	38.5	49.62
25.5	38.0	49.41
25.5	41.5	49.10
26.5	43.0	50.30
27.5	43.0	50.88
28.0	44.0	51.38
28.0	44.0	51.11

* All measurements in inches.

HTBH = Heat Transfer Bed Height

EOBH = Effective Operating Bed Height

Table 7

Comparison of Static, HTBH and EOBH

Bed Level Measurements* for Test No. 700-28
(11-20-78)

Static Bed Depth	HTBH	EOBH
16.5	40.69	30.5
17	41.56	31.0
17.5	42.22	32.5
18	42.42	33.0
18	42.85	33.0
19	42.87	36.0
19.5	43.44	36.0
20	43.96	35.0
20	44.45	35.0
21	45.45	36.0
21	45.81	37.5
21.5	46.58	38.0
23	47.11	39.0
24	48.25	42.5
24	48.96	41.0

*All measurements in inches

HTBH = Heat Transfer Bed Height

EOBH - Effective Operating Bed Height

Table 8

Comparison of Static, HTBH and EOBH
Bed Level Measurements* for Test No. 700-28B
(12-5-78)

Static Bed Depth	HTBH	EOBH
15.5	37.14	30.0
17.5	38.54	30.5
19	41.68	34.0
20	44.18	36.5
21	45.80	41.0
23	47.56	42.0
24	48.18	40.0
24	48.82	41.5
25	49.48	41.0
25	49.48	42.0
25	49.53	41.0

*All measurements in inches

HTBH = Heat Transfer Bed Height

EOBH = Effective Operating Bed Height

Table 9

Consistency Test Results of HTBH Probe for

Test No. 700-28B
(11-20-78)

Time (hr)	HTBH
0300	48.93
0400	49.47
0500	49.37
0600	49.16
0700	48.19
0800	49.57
1200	49.03
1300	49.02
1400	48.33
1600	47.89

HTBH = Heat Transfer Bed Height

HTBH = 48.90"

s = 0.57"

2.2.5 Conclusions

Tests performed in this reporting period show the **HTBH** method to be a viable alternative to the differential pressure tap approach. Four tests showed that the HTBH paralleled the static bed depth much more closely than the erratic EOBH. Not only did the sensor monitor the static bed depth more closely, but the HTBH was much more sensitive to small changes in the bed depth compared to the EOBH. Results also show the HTBH method to be repeatable. In addition to these advantages the HTBH may be a more useful control signal for bed level since it relates directly to heat output. No additional testing of this bed level sensing technique is planned.

2.3 Large Coal Feed (Activity No. 1619)

The objective of the 703 test series is combustion of large size coal in the PDU and the comparison of its behavior and performance to that or typical 1/4" x 0 coal size under equivalent conditions. Firing larger size coal can affect the carbon content of the bed, NO_x production, SO_2 capture, combustion efficiency and heat transfer. These factors are of prime importance in the design and operation of an FBC.

A total of five large size coal feed tests were run. Tests 703-1 through 703-3 used 1/2" x 16 mesh coal feed. A combination of equipment and sampling problems encountered during Tests 703-1 and 703-2 caused early termination of these tests. The samples that were taken were carefully documented and are now in the process of chemical analysis. From these results, size and composition of the various PDU solid streams will be analyzed. As the result of the first two tests, minor modifications for large size coal feed data and sampling collection were made. Thereafter, Test 703-3 was a successful 8 hour run on 1/2" x 16 mesh coal (see Table 10 for operating conditions). Samples taken included those required to determine combustion efficiency at three different stack O_2 levels, 1%, 3% and 5%. This information should on completion of chemical analysis, lead to a better understanding of coal burnout as a function of stack oxygen.

Anticipation of the next larger size coal feed; 3/4" x 1/2", led to a modification of the feed system. Whereas the 1/2" x 16 mesh coal was fed through the normal 1-1/2" feed needles into the bed, it was felt that 3/4" x 1/2" feed could plug this line. Therefore, a 2" overbed feed line was arranged through the middle front door of the boiler such that the pneumatic transport could still be utilized. With this modification, Tests 703-4 and 703-5 with 3/4" x 1/2" coal were run. As in the case of Tests 703-1, 2 and 3, no problems were encountered in establishing and maintaining steady state conditions while combusting large coal. However, difficulty was encountered in both bed sampling and draining.

Examination of the bed after testing revealed that numerous large ash particles had caused clogging of the bed drain system. Modification of the bed sampling and drain systems will be required so that larger coals may be tested. Chemical analysis of the five large size coal tests is in progress.

Table 10

Operating Conditions, Test 703-3
10/10/78

Time-hr	12:00	13:00	14:45	16:20
Bed temp., °F	1610	1640	1590	1406
O_2 in flue gas, %	1.3	1.0	3.0	5.0
Coal feed rate, lb/hr	808	714	638	629
Fly ash collection rate, lb/hr	276	258	228	224
Limestone feed rate, lb/hr	346	336	318	245
Bed drain rate, lb/hr	173	173	224	226
Stack dust rate, lb/hr	*	116.1	38.7	54.2
Main air flow rate, lb/hr	7383	7500	7682	7541
Total air flow rate, lb/hr	7678	7796	7977	7837
Superficial velocity, ft/sec	11.7	12.1	12.1	10.9
Static bed depth, inches	25.0	25.0	25.0	23.0
EOBH (effective operating bed ht.), inches	42.5	41.5	41.5	36.0

* Data not taken.

2.4 Oil Firing, (Activity No. 1618)

2.4.1 Preliminary #6 Fuel Oil Tests

Two preliminary tests, Nos. 702-7 and 702-8 were run using #6 fuel oil in combination with coal. These two tests were run to determine if any changes were required to the oil nozzle design and to characterize the boiler operation on heavier fuel oil. Both tests had normal light-off using the propane burners and coal. The fuel oil was fed to the PDU when the boiler was at operating conditions on coal. Oil feed was controlled using the method developed for the #2 fuel oil (see Quarterly Report No. 13, Oil Firing, Activity No. 1618). Stack oxygen level was monitored and used as an indication to vary the oil feed. Operating conditions for Test No. 702-8 are shown in Table 11 where oil feed was initiated at 11:30 hours.

Test No. 702-8 was a four hour test on #6 oil. During the test, samples were taken to calculate combustion efficiencies. From analyses of fly ash and dust collected, the combustion efficiency for the test was 98 percent. Using this efficiency in a heat balance program, it was calculated that only 64 percent of the fuel was burning in the bed. This is comparable to values calculated for #2 fuel oil with the same static bed heights and is probably due to insufficient mixing of the oil in the bed. Because of the amount of freeboard burning, an excess of fuel oil had to be fed to the boiler to maintain bed temperatures at 1550°F. Therefore, the stack oxygen levels were very low, see Table 11.

Heat transfer results from Test No. 702-8 were calculated, see Table 12. They are compared to Test No. 702-5, a #2 fuel oil test, Test No. 700-17, a coal test to determine the effects of superficial velocity on heat transfer, and Test No. 700-19, a sixteen hour coal run for sulfur capture. From the results, it was found that the overall heat transfer coefficients are larger when the boiler is firing oil. This may be due to the amount of oil burning in the tube bundle region, (see Quarterly Report No. 13, Oil Firing, Activity No. 1618). The calculated values are lower for #6 fuel oil than for #2 fuel; the difference is within the accuracy of the measurements.

One of the most significant demonstrations during these preliminary tests was a rapid change to oil firing during a coal feed interruption. During Test No. 702-8 a coal feed problem was simulated; immediately oil feed was initiated and the bed temperature was maintained.

2.4.2 Test With The Modified Oil Air Feed System

During the preliminary tests, the major problem encountered was the amount of above bed burning of the fuel. Prior to the next test, the oil feed air piping was replaced to increase the air flow to the oil nozzles. Test 702-9, an eleven hour run for combustion efficiencies and sulfur capture, was made with this improvement. Samples were taken and are being analyzed.

An immediate result of the improved oil feed system was that 1550°F bed temperature could be easily maintained with 4 percent oxygen in the stack, and a visual inspection of the surface of the bed through the

Table 11

Operating Conditions for Test No. 702-8

October 27, 1978

Time-hr	11:00	11:30	12:30	13:00	15:30
Bed Temp., °F	1520	1508	1462	1427	1441
O_2 in flue gas, %	3.0	3.1	.1	.2	.3
Coal feed rate, lb/hr	696	573	0	0	0
Fly ash collection rate, lb/hr	326	264	80	62	42
Limestone feed rate, lb/hr	300	300	28	28	0
Bed drain rate, lb/hr	102	102	51	0	50
Stack dust rate, lb/hr	*	*	8.9	*	1.9
Main air flow rate, lb/hr	7539	7534	7445	6402	7369
Total air flow rate, lb/hr	8066	8065	7982	6939	7906
Superficial velocity, ft/sec	11.7	11.6	11.2	9.5	10.9
Static bed depth, inches	29.0	30.0	31.0	31.0	31.0
EOBH (effective operating bed ht.), inches	45.0	46.5	46.5	45.0	48.0
SO_2, ppm	423	383	68	91	85
Oil flow, gpm	0	0	1.02	.92	1.12

* Data not taken.

Table 12

Calculated Heat Transfer Coefficients

Test	700-17	700-19	702-5		702-8	
Date	5/23/78	6/8/78	9/14/78		10/27/78	
Fuel	Coal	Coal	#2 Fuel Oil	#2 Fuel Oil	#6 Fuel Oil	#6 Fuel Oil
Bed temp, °F	1535	1519	1479	1466	1427	1441
Static bed depth, inches	26.8	25.5	30.0	31.5	31.0	31.0
EOBH (effective operating bed ht.),inches	40.0	39.0	43.0	45.0	45.0	50.0
Superficial velocity	11.9	11.6	13.2	12.6	9.5	10.9
Economizer						
Overall coefficient*	31.3	32.21	36.6	37.3	36.4	36.6
Inside coefficient*	271.1	312.2	298.6	303.7	298.8	296.9
Outside coefficient*	38.2	38.8	45.6	46.6	45.4	45.7
Calculated average wall temp., °F	404	387	406	407	381.6	388.6
Superheater						
Overall coefficient*	33.8	33.4	38.0	37.0	35.1	37.3
Inside coefficient*	222.6	223.6	243.6	235.3	221.8	234.6
Outside coefficient*	43.9	43.3	50.1	48.8	46.3	49.4
Calculated average wall temp., °F	609	602	600	601	592.9	595.4

* All heat transfer coefficients have units of Btu/hr/ft^2/°F.
All coefficients are uncorrected for bed temperature.

viewport showed no above bed burning. For operating conditions, see Table 13. With increased combustion in the bed, the heat transfer coefficients shown in Table 14, are typical of the results expected when firing coal. At the end of the run, the PDU was switched from oil to coal and the heat transfer coefficient remained essentially the same.

The overall heat transfer coefficient in Test No. 702-9 was slightly lower than in Tests 702-5 and 702-8. During these earlier oil tests, the amount of oil burning at the upper portion of the expanded bed was high as evidenced by the flue gas analysis which showed higher levels of hydrocarbons and lower values of stack oxygen. It is suspected that the magnitude of the outside coefficient increased somewhat because of the oil burning higher in the bed during the earlier tests.

2.5 PDU Performance Characterization (Activity No. 1616)

During the reporting period Test No. 700-29 provided data to further characterize PDU performance. In two previous characterization tests, Nos. 700-19 and 700-24, the carbon content as a function of size for fly ash was determined and is shown in Figure 15. It can be seen that the overall shape of the two curves is nearly identical since both curves have two peaks, one at 90 microns and another at 300 microns. It is also interesting to note that the position of the curves remained the same despite a change in magnitude. The major reason for the differences in peak magnitudes is attributed to the different coal burned in these tests, see Table 15.

Test 700-24 used a coal of higher ash and lower carbon content than Test 700-19. It is believed that the higher ash content was responsible for the increase in fly ash production and an increase in the carbon content of the fly ash in Test 700-24. Accordingly, combustion efficiencies were 89 percent for Test 700-19 and 77 percent for Test 700-24 as shown in Table 16. However, despite differences in coal feed compositions, the position of the peaks remained the same.

If one or both of the peaks of Figure 15 could be reduced, the loss due to the fly ash carbon would decrease causing the combustion efficiency to increase. In order to decrease the amount of carbon in a size cut, conditions must be such that the time for burnout of the particles in that size fraction must be brought closer to its residence time. Theoretically, this may be done for all size fractions by increasing both temperature and percent O_2 in the freeboard.

Data was gathered during Test 700-29 in an attempt to support this theory, see Table 16. In this test the bed temperature was 100 - 200°F hotter and the stack O_2 was 0.5 percent higher than for Tests 700-19 or 700-24. Samples were taken at 1330 and 1430 hours and chemical analyses similar to those of Tests 700-19 and 700-24 are in progress.

Table 13

Operating Conditions for Test No. 702-9, 11/1/78

Time -hr	10:30	11:00	12:00	13:00	14:00	15:00
Fuel	#6 oil	#6 oil	#6 oil	#6 oil	#6 oil	coal
Bed temp., °F	1523	1523	1515	1490	1540	1530
O_2 in flue gas, %	4.1	4.0	4.5	4.5	3.2	4.0
Fuel feed rate, lb/hr	428.3	437.1	383.2	414.4	445.9	636
Fly ash collection rate, lb/hr	90	90	90	82	90	257
Limestone feed rate, lb/hr	206	197	200	186	221	174
Bed drain rate, lb/hr	1	1	42	2	2	‡
Stack dust rate, lb/hr	15.79	16.10	‡	22.91	27.87	‡
Main air flow rate, lb/hr	7293	7293	7288	7126	7120	7120
Total air flow rate, lb/hr	7976	7976	7971	7807	7799	7811
Superficial velocity, ft/sec	11.6	11.6	11.5	11.1	11.4	11.4
Static bed depth, inches	30	30	29	31	31	29
EOBH (effective operating bed ht.), inches	46.5	44.5	45.0	48.5	45.0	43.5
SO_2, ppm	6	5	10	10	7.5	295
Steam flow	4486	4463	4341	4156	4620	4556
NO_x, ppm	204	206	217	218	189	560
Hydrocarbons, ppm	188	136	82	129	325	772

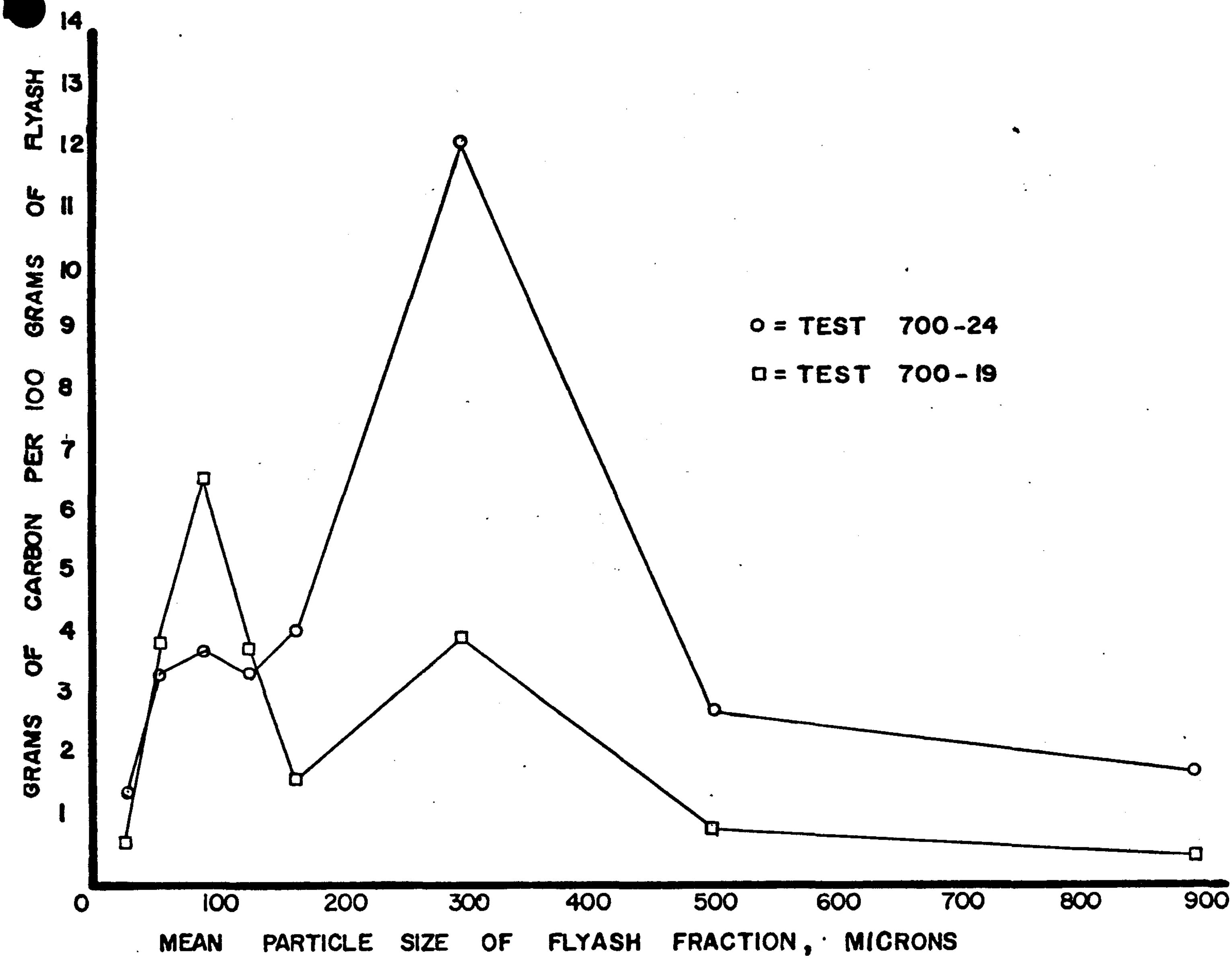
Table 14

Calculated Heat Transfer Coefficients for Test No. 702-9, 11/1/78

Time - hr	10:30	11:00	12:00	13:00	14:00	15:00
Bed temp, °F	1523	1523	1515	1490	1540	1530
Static Bed depth, inches	30	30	29	31	31	29
E.O.B.H., inches	46.5	44.5	45.0	48.5	45.0	43.5
Superficial velocity	11.6	11.6	11.5	11.1	11.4	11.4
Fuel	#6 oil	#6 oil	#6 oil	#6 oil	#6 oil	coal
Economizer						
Overall coefficient	34.81	34.54	35.25	33.82	34.40	34.71
Inside coefficient	301.55	299.7	305.8	302.88	324.8	328.5
Outside coefficient	42.84	42.47	43.39	41.32	41.69	42.08
Calculated Avg. wall temp, °F	387.1	387.3	387.2	387.0	390.4	387.5
Superheater						
Overall coefficient	34.79	33.86	34.68	31.06	33.32	33.75
Inside coefficient	234.9	233.6	228.2	219.2	240.8	237.2
Outside coefficient	45.05	43.57	45.19	39.57	42.38	43.22
Calculated Avg. wall temp, °F	607.1	604.6	608.5	597.9	602.7	600.6

Table 15
Comparison of Coal Analyses for
Tests 700-19 and 700-24

Percent of:	Test 700-19	Test 700-24
Carbon	68.43	56.19
Hydrogen	4.71	3.91
Sulfur	5.19	5.07
Calcium	3.06 (.45 if corrected)	0.62
Ash	14.56	27.35
LOI	85.44	72.65
Heating value, Btu/lb	12721	10504



GRAMS OF CARBON PER 100 GRAMS FLY ASH VERSUS
MEAN PARTICLE SIZE OF FLY ASH FRACTION FOR
TESTS 700-19 AND 700-24

Figure 15

Table 16

Operating Conditions for Tests
700-19 (6/8/78), 700-24 (8/24/78), 700-29 (12/12/78)

Test No.	700-19	700-24	700-29	
Time/hr	1530	1400	1330	1430
Bed Temp., °F	1502	1515	1688	1656
O_2 in flue gas, %	3.4	2.5	3.8	3.9
Coal feed rate, lb/hr	720	750	604	636
Fly ash collection rate, lb/hr	216	252	204	197
Limestone feed rate, lb/hr	348	350	226	228
Bed drain rate, lb/hr	140	150	48	48
Stack dust rate, lb/hr	21.5	23.42	55.3	92.9
Main air flow rate, lb/hr	7638	6906	6968	7036
Total air flow rate, lb/hr	7934	7201	7276	7344
Superficial velocity, ft/sec	11.5	10.4	11.8	11.8
Static bed depth, inches	25.5	28	15.0	15.0
EOBH (effective operating bed ht.),inches	39.0	39.0	29.0	29.0
SO_2, ppm	987	263	664	655
Ca/S	2.43	1.79	*	*
Combustion efficiency, %	89.05	76.84	*	*

* In progress.

2.6 Sulfur Capture (Activity No. 1110)

Data was collected during Test Nos. 700-28A and 700-28B and 700-30 to provide additional sulfur capture results using Greer limestone. Calcium to sulfur molar feed ratios were selected at the low and high end of the range of interest to supplement earlier test data. Test 700-28A was a 44 hour test starting with a fresh bed of limestone and was run for 34 hours at an average Ca/S molar feed ratio of 1.9. During this 34 hour period, six samples were collected and analyzed. Test No. 700-28B was a sixteen hour test at an average Ca/S molar feed ratio of 5.0. Samples for this test were collected during the last 8 hours of operation and are being analyzed. Test No. 700-30 was a short test starting with a fresh bed of limestone. Bed samples were taken every hour for 6 hours and are being analyzed.

The chemical analyses of Test 700-28A have been completed. Using this information, combustion efficiencies have been calculated and are reported in Table 17. Fluctuations in the results are attributed to changes in the size distribution of the coal feed. Because of problems with the coal feed at 2200 hours, the results of data collected at that time have not been reported.

During Test 700-28A, one of the important variables to consider was the time required to achieve steady state. Therefore, the stack emissions of SO_2 were plotted versus hours of operation, see Figure 16. From these results it was found that the SO_2 in the stack reached a steady level after 21 hours at an average Ca/S molar feed ratio of 1.9. This was used as the reference point for the next 13 hours of operation. The average sulfur capture for those 13 hours was calculated to be 51 percent at an average Ca/S molar feed ratio of 2.0.

The scatter of some of the data points in Figure 16 is thought to be due to a wide fluctuation in the size of the coal feed. Based on lab experience and general consideration of size segregation problems, it appears that the amount of coal fines in the feed increases as the level in the coal feed weigh hopper decreases. This may be due to a build up of fine size coal along the hopper walls during operation. This problem worsens with operating time since more empty and fill cycles result in a greater amount of fines holdup. As the percentage of fines in the feed stream increases, more coal must be fed to maintain bed temperature. This results in fluctuations in stack emissions.

Test No. 700-28B was a sulfur capture test at an average Ca/S ratio of 5.0. The test started with the spent bed from Test 700-28A and was run for 16 hours during which time 5 samples were taken. The first two sets were taken four hours apart after eight hours of operation on coal. The last three samples were taken at one hour intervals before the end of the test. All samples are being screened and analyzed by screen cut for calcium, carbon, hydrogen, sulfur, ash and loss-on-ignition. Operating conditions for the test are shown in Table 18.

Table 17

Operating Conditions for Test 700-28A (11/20/78)

Time/hr	1600	0400	1600	1700	1750
Bed temp., °F	1516	1500	1544	1550	1521
O_2 in flue gas, %	4.0	3.0	4.0	4.0	4.5
Coal feed rate, lb/hr	660	608	694	684	700
Fly ash collection rate, lb/hr	192	209	170	168	175
Limestone feed rate, lb/hr	168	151	122	120	152
Bed drain rate, lb/hr	70	43	125	94	167
Stack dust rate, lb/hr	52.25	16.6	32.9	30.97	25.16
Main air flow rate, lb/hr	7528	7392	7590	7666	7597
Total air flow rate, lb/hr	7828	7694	7892	7967	7899
Superficial velocity, ft/sec	11.4	11.1	11.7	11.8	11.5
Static bed depth, inches	25	27	26	26	26
EOBH (effective operating bed ht.),inches	40.5	41.5	41	40.5	39
SO_2, ppm	1300	1400	1413	1306	1101
Ca/S	2.41	2.58	1.46	1.53	1.94
Combustion efficiency, %	82.8	81.2	85.4	82.6	86.5

SO_2 EMISSIONS VERSUS TIME FOR TEST 700-28A

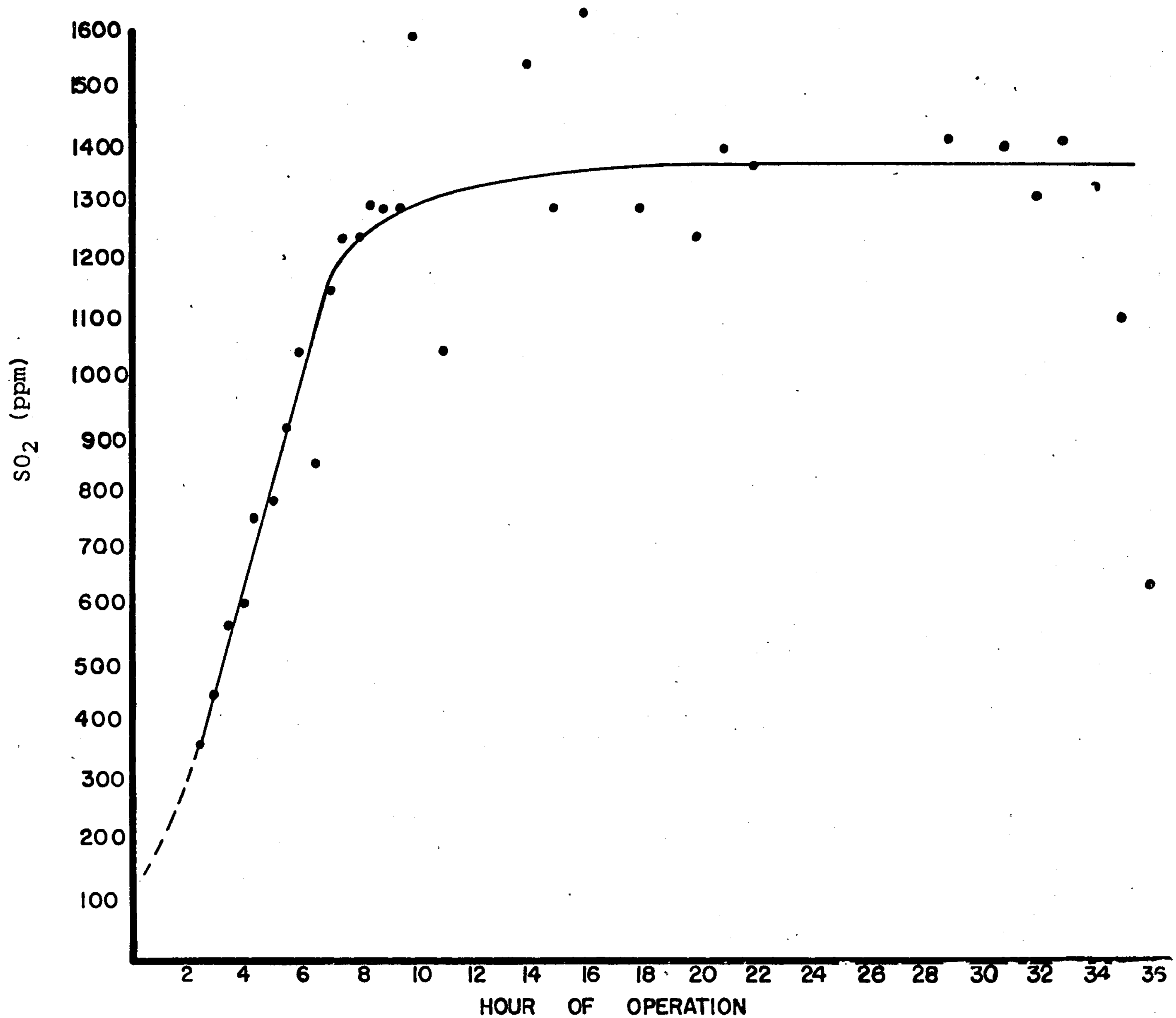


Figure 16

Table 18

Operating Conditions for Test 700-28B, 12/5/78

Time /hr	0800	1020	1330	1500	1600
Bed temp., °F	1511	1568	1422	1513	1505
O_2 in flue gas, %	4.0	2.5	4.0	3.3	4.0
Coal feed rate, lb/hr	768	716	666	679	681
Fly ash collection rate, lb/hr	262	293	248	244	243
Limestone feed rate, lb/hr	519	307	444	548	458
Bed drain rate, lb/hr	311	188	200	215	195
Stack dust rate, lb/hr	59.88	91.61	42.58	32.9	27.48
Main air flow rate, lb/hr	7639	7639	7611	7604	7597
Total air flow rate, lb/hr	7929	7929	7902	7895	7888
Superficial velocity, ft/sec	11.5	11.9	11.0	11.5	11.5
Static bed depth, inches	26	26	26	26	24
EOBH (effective operating bed ht.),inches	45	47	42.5	46.5	39.5
SO_2, ppm	460	350	310	300	300

Test 700-30 was a sulfur capture test during a fresh bed light-off. The purpose of this test was to obtain transient data on bed chemistry during the first six hours of operation. Samples of bed material were taken and are being analyzed for sulfur and calcium. The operating conditions for Test 700-30 are shown in Table 19.

2.7 Flue Gas Baghouse Program (Activity No. 1620)

Erection of a flue gas baghouse, designed and furnished by Buell Emission Control Division of Envirotech, has been 90 percent completed. The baghouse is located downstream of the existing primary induced draft fan and has its own fan (secondary induced draft fan) and stack, see Figure 17.

The unit is designed to test the application of high temperature baghouse technology to fluidized bed coal combustion. The baghouse was designed to handle 3000 ACFM of flue gas at 400° - 500°F. Two air casing caps have been supplied to permit testing of the pulse jet cleaning mode and the reverse air plus shaker cleaning mode.

In the pulse jet cleaning mode, dirty flue gas is drawn into the baghouse where the dust is separated from the gas via high temperature filter bags. The filter bags and air casing cap are periodically pulsed by high pressure air at automatically controlled time intervals, knocking off the accumulated dust. Figure 18 is a flow diagram of the pulse jet system.

The reverse air/shaker cleaning mode can be operated with reverse air only, shaker only or combinations of both via control and timing circuits. Figure 19A depicts normal operation and shaker cleaning mode. Filter bag cleaning is accomplished by periodically shaking the dust off the bags. The reverse air mode, see Figure 19B, employs the use of three pneumatically operated flow diverting valves. During this bag cleaning mode, the flue gas bypasses the baghouse. The gas in the baghouse is momentarily reversed as shown, causing the filter bags to puff out and knock off accumulated cakes of dust.

Data acquisition will consist of pressure and temperature monitoring and dust loading in the stack using an isokinetic probe. In addition, an opacity probe will be installed to obtain relative performance of the different cleaning modes.

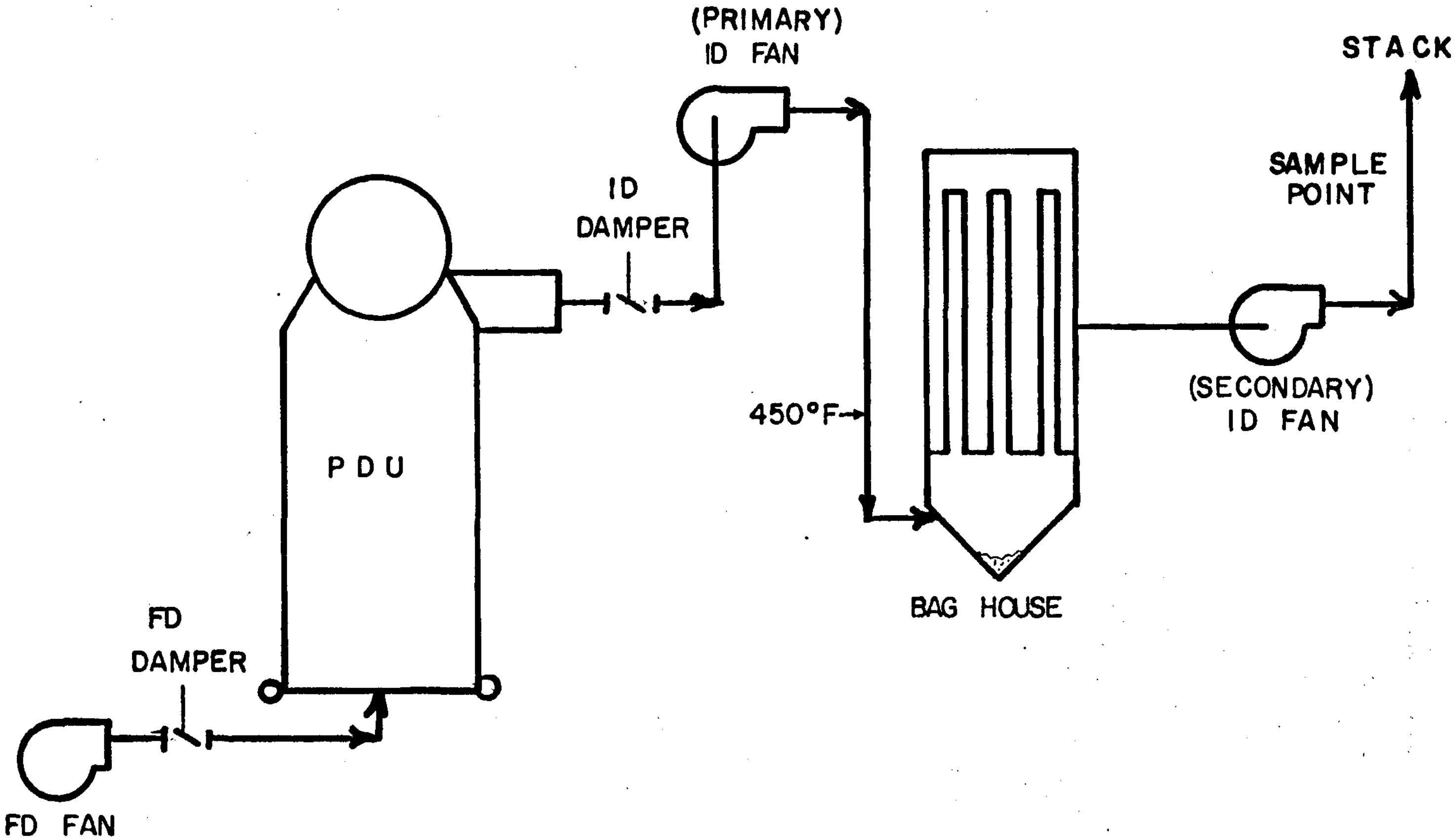
Table 19

Operating Conditions for Test 700-30 (12/28/78)

Time/hr	1200	1300	1400	1500
Bed temp., °F	1476	1472	1489	1513
O_2 in flue gas, %	5.0	3.5	3.5	3.0
Coal feed rate, lb/hr	660	602	677	654
Fly ash collection rate, lb/hr	200	199	198	‡
Limestone feed rate, lb/hr	207	216	232	206
Bed drain rate, lb/hr	0	0	0	0
Stack dust rate, lb/hr	*	*	*	*
Main air flow rate, lb/hr	7751	6578	6734	6734
Total air flow rate, lb/hr	8052	6879	7035	7034
Superficial velocity, ft/sec	11.7	9.9	10.2	10.3
Static bed depth, inches	18.0	20.0	22.0	24.0
EOBH (effective operating bed ht.), inches	35.0	36.0	37.0	38.5
SO_2, ppm	300	338	317	320

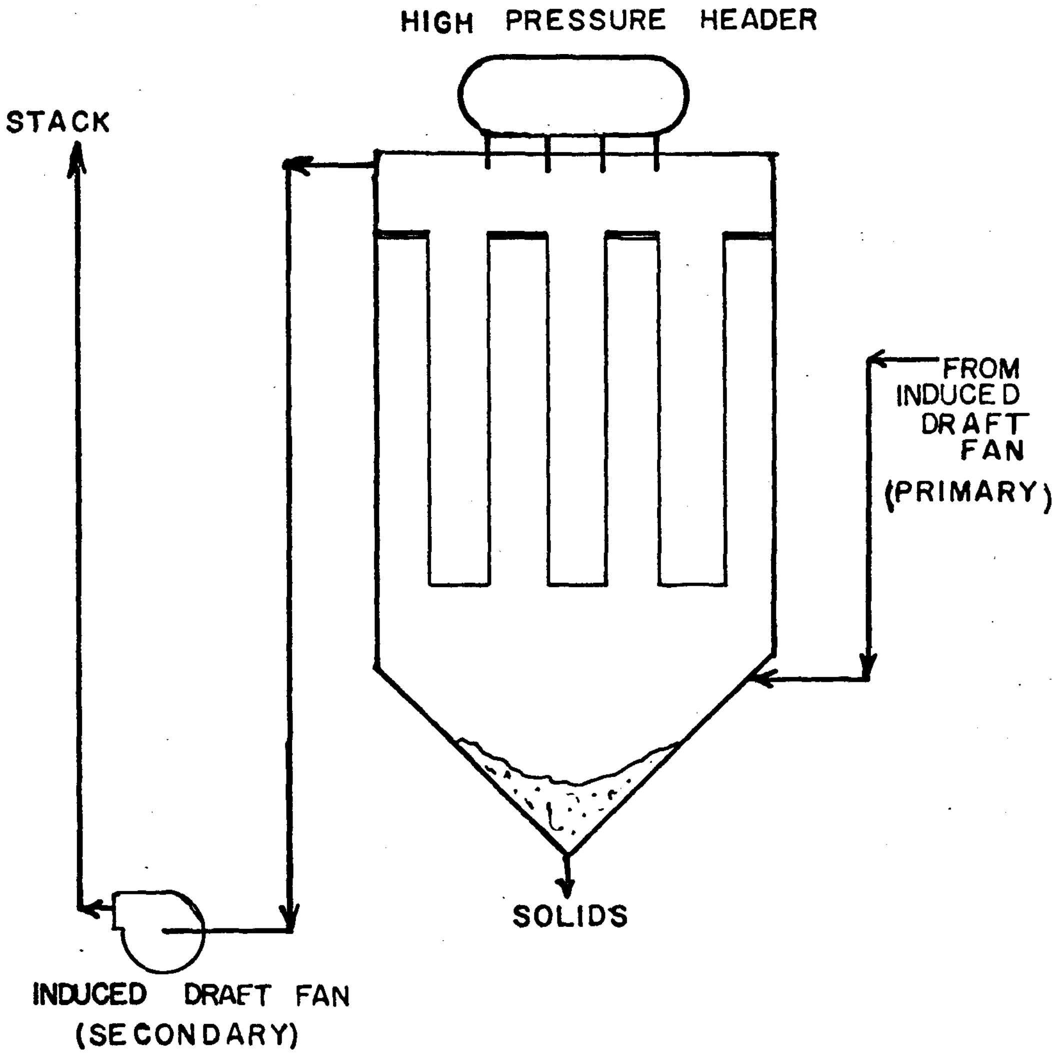
* Data not taken.

‡ Shutdown



GAS FLOW DIAGRAM

Figure 17



PULSE JET CLEANING GAS FLOW DIAGRAM

Figure 18

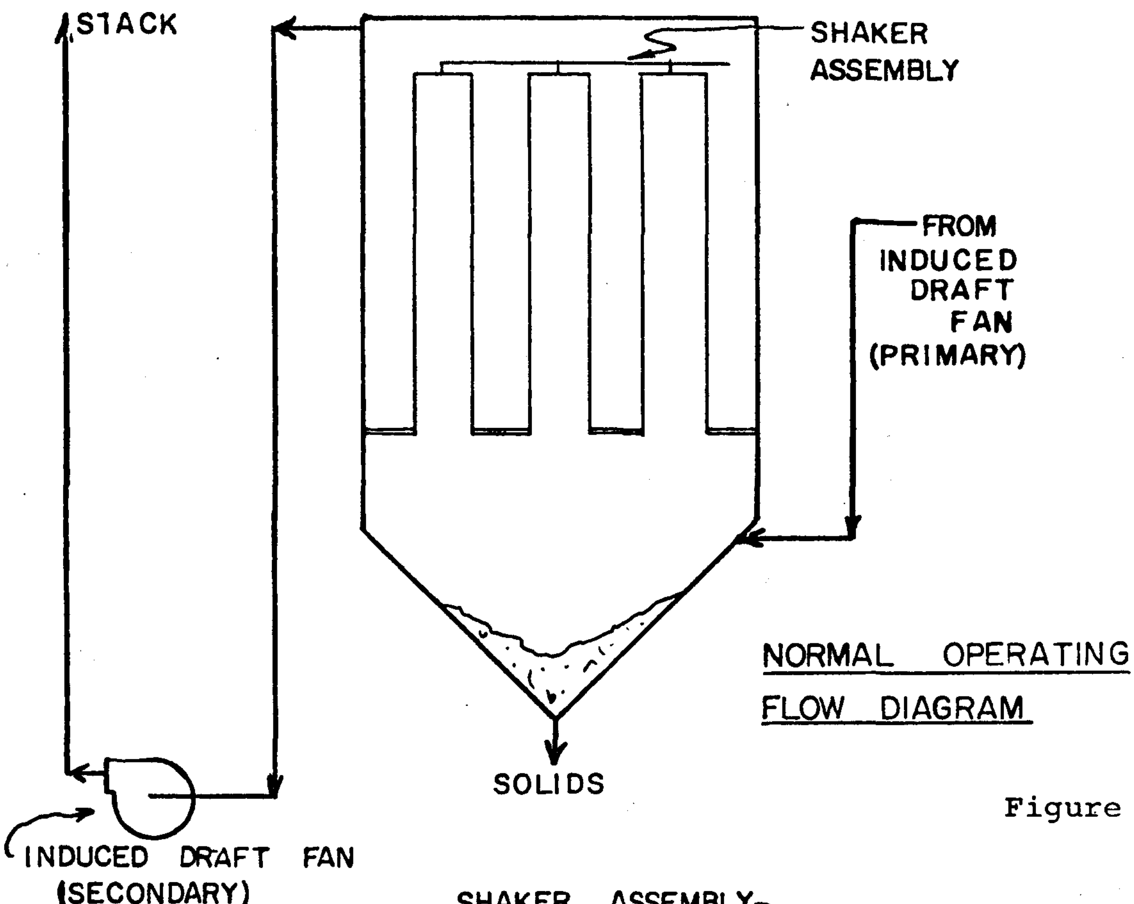


Figure 19A

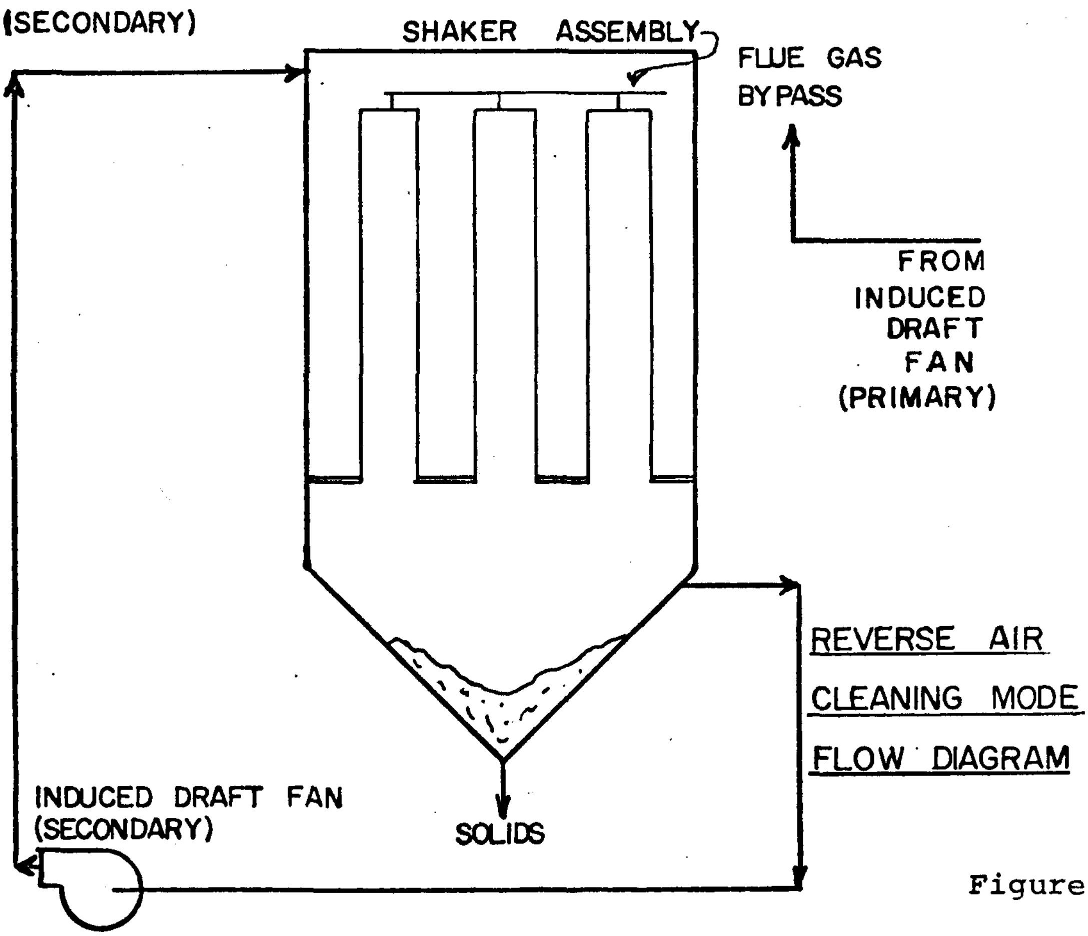


Figure 19B

3.0 RIVESVILLE MFB PLANT OPERATIONS

3.1 General

Repair, reconstruction and plant improvement activities continued on schedule throughout the reporting period. At the close of the period, many items were completed and the remaining items in the final stages of completion. Improvements have been made in the areas of coal feed, boiler condition monitoring and control, and solid waste handling and disposal. Experience gained from past testing has resulted in extensive revamping of test instrumentation and test procedures for the upcoming emissions and performance testing. Operator awareness has significantly improved as the result of the Training Program. The modifications and improvements will permit long duration runs of the MFB at steady state conditions to collect accurate data and obtain meaningful results.

3.2 Fire Damage Reconstruction

3.2.1 Electrostatic Precipitator

- Replacement of fire-damaged particle collecting plates completed.
- A new support frame has been installed.
- New flow patterning devices have been added as per Buell's recommendation. These devices should minimize the problems of crossflow and maldistribution of gases.
- Nuclear level detectors have been installed in the precipitator hoppers. Elimination of air inleakage should reduce the possibility of a precipitator hopper fire. Buell is also studying the feasibility of installing a fire sensor at the hopper level with a signal to the Control Room.
- In addition to rappers located at the roof, side rappers have been installed to supplement rapping the collector plates. To prevent buildup on the emitting wires, impactors have been installed on the emitting system.
- System conditions are to be reviewed for the purpose of rewriting startup procedures and/or operating procedures as necessary.
- All plates and walkways in and around the ESP are completed. The outlet duct is welded in place.

3.2.2 Air Preheater

Reconstruction of the regenerative rotary air preheater is essentially completed with a few tasks remaining. Work completed includes:

- Demolition of the fire damaged APH.
- Installation of basket housing, new baskets, radial seals and angles.
- Installation and alignment of trunnion bearings.
- Repiping the APH and repair of the Beckman heat traced gas analysis sample lines.
- Insulation work continues.
- The APH Deluge System, an emergency fire system, is nearly complete. An infrared fire sensor will be installed which will automatically start the Deluge System.

3.2.3 Fans

- F.D. Fan is 100% complete and ready for insulation. Plans are to bump and couple the fan after 6 January 1979.
- A new, larger I.D. Fan and associated ductwork was purchased and installed. I.D. Fan rotor installation is underway.
- Ductwork from the air preheater to the I.D. Fan is 45% complete.
- Ductwork from I.D. Fan to stack is completed awaiting spring hangers.

3.2.4 Additional Items

- Rotex screen relocation and installation is complete. The Rotex is now located in the coal handling area.
- Crusher has been moved to new location and made ready for installation.
- Installation of a trial eductor assisted coal injection for north and south side of Cell C was initiated.
- The coal belt conveyor (replacing the 102' Redler) and its distribution hopper are complete and ready for use.
- "Y" feed needles for flyash reinjection into the CBC are complete.
- Demolition of obsolete Mon Power equipment in order to make room for Ecolochem's indoor water treatment system is complete. Construction of a drain and retainer curb has begun. Delivery of headers is scheduled for 22 January 1979.

3.3 Operations

3.3.1 Training Program

During November 1978, the Operations Department completed a Training Program developed and presented by Stone and Webster Engineering Company.

The purpose of the Operations Training Program was to provide detailed instruction to Shift Supervisors, Control Room Operators and Equipment Operators on the MFB Systems. This supplements previous instruction given in the Power Plant Course. In addition, Shift Supervisors and Control Room Operators were given specific training in supervisory skills. Shift Supervisors, Control Room Operators and Equipment Operators were also given training on prescribed responses to general and specific emergency operating conditions.

Shift work is scheduled to resume on 8 January 1979.

3.3.2 Plant Improvements

- Flyash reinjection distribution piping was redesigned to provide more effective flow splitting.
- All preventative maintenance and repair items planned for the scheduled outage have been accomplished.
- Installation of the Taylor Oxygen Analyzer in the Beckman System console is completed.
- Installation of Beckman Models 402 and 865 (Hydrocarbons and carbon monoxide) analyzers has begun as an addition to the TECO console. The Teledyne Oxygen Analyzer will also be installed at the same location. When the TECO is completely modified, a complete duplication of gas analysis will be available.
- Two coal samplers have been ordered from Gustafson, Inc. to be placed just upstream of the north and south bucket elevators. Shipment is scheduled for 1/20/79.
- Fabrication has begun on a bed material sampler.
- Design is complete for a manual coal sampler to be installed at the 18" standpipe below the east coal bin. Fabrication will begin on arrival of materials.
- Computer program modifications are nearly complete.
- Extension of Fire Protection System is complete.
- The limestone distribution separator located in the limestone bunker is installed.
- Repair of BFWV-4, BFWV-6 and CV-7 is complete.

- Installation of the drilled bolt air distributor continues in CBC. Minor cracks in Cell C distributor are being repaired.
- Installed a third Hagan recorder bed temperature probe in each cell.
- Test thermocouples in cell beds are being re-routed through compression type fittings.
- Recalibration of all MFB instrumentation is complete.
- The newly installed limestone baghouse is being prepared for operation.
- Installed an emergency air supply system to the actuators on HPSV-3 and BFWV-10.
- The main uptake bypass control damper actuator was removed, aligned and reassembled.
- Ran conduit and wiring for five additional Gai-Tronics public address stations.
- Assembled control enclosures for the coal bin level probes.
- Reinstalled 3" conduit above circulating pumps.
- Precipitator hopper platform conduit and lighting change complete.
- Temporary lighting in bunker area complete.
- All cell air damper seals have been replaced.
- Boiler safety circuit relays relocated outside above the Control Room.
- Installation of vibration monitoring system for I.D., F.D. fans nears completion. The ambient noise problems have been reduced by lead sheathing of duct work, extension and redirection of the steam silencers and installation of a stack silencer.
- Power to boiler water test area is complete. The water lab is now ready to support normal boiler operation as well as all solids sample preparations.
- A complete and detailed test plan has been prepared, including personnel requirements, contingency plans, schedule goals, calibration and reporting.

3.4 Performance Testing

3.4.1 General

During the period May through August 1978, the MFB underwent a series of tests to measure performance of the unit. Prior to May 1978, an instrumentation package had been installed to enable performance measurements to be made. Throughout the test period, problems with various instrument components hindered testing efforts. Specifically, major descrepancies were experienced in the Beckman Gas Analyzer and the Autoweigh coal feeder belt scales.

During the testing period, the MFB was operated for 397 hours on D cell operation, 177 hours on 2 cell operation, 226 hours on 3 cell operation and 3 hours on 4 cell operation. A total of eleven performance tests were conducted during this time. Due to the previously noted equipment problems, only tests 10, 14 and 15 are sufficiently complete to be representative of unit performance.

3.4.2 Test Results

Due to malfunctioning Autoweigh belt feeders, reliable coal feed rates could not be measured. Therefore, the coal feed rates were calculated using the boiler duty and the loss analysis. This calculation procedure is essentially a heat balance around the entire unit. This heat balance yields the total coal feed rate. In order to determine the coal feed rate to individual cells, a heat balance around the bed in each cell was conducted.

The sulfur capture results in test 10 appear to be inconsistent with the results obtained in tests 14 and 15. These inconsistent results could be due to a malfunction in the Beckman System, or the result of a faulty coal sample. The coal for this test was analyzed to contain 1.63% sulfur while tests 14 and 15 contained over 3.2% sulfur. Other reasons that could explain the low sulfur capture could be the low operating temperatures in Cell B or an overly sulfated bed prior to testing.

3.4.3 Conclusion

Although the test results have shown reasonable combustion efficiencies, operating bed temperatures have been lower than desired. Due to equipment problems in the bed material drain system, static bed levels were difficult to control at the desired height. This resulted in additional heat removal from the beds. Limestone feed had to be continued in order to accomplish sulfur capture, leading to the increased bed heights.

In future tests, it may prove beneficial to operate the MFB at one set of conditions for combustion efficiency data and at another set for sulfur capture data. This would reduce the constraints on operational parameters and permit a full range of correlating data.

SO_2 monitoring and Ca/S feed ratios will also be improved to provide more reliable and accurate results.

3.4.4 Projection

Testing of the MFB thus far has been complicated by schedule considerations, which allowed little time for on-line instrument calibration and encouraged testing during periods of commercial operation.

Modifications to test instrumentation and procedures are being implemented to improve future test results. Following is a list of major improvements to be completed prior to testing.

1. Bed material drain rotary feeders will be fitted with higher torque motors and low speed sprockets to prevent jamming of rotary feeders at low speeds.

2. Limestone rotary feeders will be fitted with low speed sprockets to prevent feeder stoppage at low speeds.

3. Bed material drain and limestone feed rotary feeders now incorporate mechanical counters in order to provide an accurate account of feed and drain rates.

4. Monitors from test plan instrumentation have been provided in the Control Room for operator use.

5. A thorough recalibration program including all test instrumentation is almost complete.

The MFB is scheduled to return to service early in 1979 for a program of equipment startup, debugging and on-line instrument calibration. About 1 March, testing will re-commence and the EPA sponsored program will be scheduled to begin 1 May. Together these testing cycles will occupy a 16 week period and should provide a detailed performance profile of the unit.

4.0 NEW YORK OFFICE - ENGINEERING

The New York Office design and engineering staff has been engaged in various tasks in support of the overall program and 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 since initial start-up and follow-on operation.

During this quarterly reporting period the New York Office engaged in the following tasks:

4.1 Access/Egress

Studies were conducted on plant and equipment Access/Egress requirements which resulted in development of construction drawings for additional platforms and improved access to existing platforms. Drawings were prepared for the following;

- Access to platform above coal distribution hopper,
- Extension to existing platform at top of limestone bunker,
- Additional access to air preheater platform.

4.2 Coal Dryer Removal and Reinstallation

As a result of a field trip to the site to determine the feasibility of removing the existing coal dryer, drawings were prepared detailing the removal procedure to be followed. The study included an investigation into the possibility of relocating the dryer to the Smithfield Mine Tipple to insure a ready supply of dry coal. A final report was prepared and submitted to DOE which included a budget cost estimate to provide for relocating the dryer and the addition of a combustor heat source, dryer building, a coal storage shed, and covered conveyors.

4.3 I.D. Fan Replacement

The fire damaged I.D. Fan was replaced with a fan having a greater static head in order to overcome additional pressure drops in the system resulting from modifications to the electrostatic precipitator and possible future replacement with a baghouse filter. The I.D. fan replacement necessitated redesign of the flue gas duct run from the air preheater to the stack. General arrangement drawings prepared by S&W indicating the expansion joints required for thermal growth were reviewed and comments noted. Design drawings for the ducts and support systems also prepared by S&W were reviewed and comments noted prior to their release for construction. The existing structural support system was checked to determine its adequacy to support the additional loads imposed by the new duct system.

4.4 F.D. Fan Relocation

A study was initiated to investigate the feasibility of relocating the F.D. fan to a more rigid support medium in order to eliminate vibration problems. Various alternative locations were studied during a visit to the site. In addition, the possibility of providing a second F.D. fan for redundancy was considered. It has been determined that there are several areas within the plant that could accomodate these fans and a preliminary report and cost analysis is being prepared on this basis.

4.5 Duct Temperature Study

To improve the efficiency of the electrostatic precipitator, it was proposed that the flue gas temperature be increased to 800°F from 730°F. An investigation was conducted to determine if the existing duct system and expansion joints could withstand this temperature increase in addition to the pressure increase of 20 in to 25 in W.C. resulting from the new I.D. fan. The study concluded that it was permissable to operate at the increased temperature and pressure with periodic checks of the ducts and joints for any signs of distortion.

4.6 Dust Collector No. 1 Bypass

The efficiency of Dust Collector No. 1 is extremely low when the MFB is in one or two cell operation due to the reduced quantity of flue gas. To improve this condition, the use of a small by-pass collector was investigated. A study was completed on the use of Dust Collector No. 4, originally designated for use with the coal dryer, including the method of supporting the collector and its associated ductwork.

4.7 Alexandria PDU Baghouse Filter

During the course of excavation for the baghouse foundation, water was encountered. On inspection, proper drainage and backfilling procedures were recommended.

4.8 Eductor System

As a result of a visit to Alexandria to review the type of blower proposed for the MFB eductor feed system, a Sundstrand centrifugal blower capable of providing 800 CFM at a pressure of 10 psi was selected. Based on Alexandria Laboratory tests, it was determined that the feed needles should terminate about 4" above the grid plate. To prove the effectiveness and reliability of the eductor system, the decision was made to equip only Cell "C" north and south sides initially. Installation and fabrication drawings were prepared for a complete system for Cell C.

4.9 Silo Vent Baghouse Filter

A study was conducted to determine the feasibility of providing a baghouse filter mounted on top of the 80 ton silo to provide a direct vent to atmosphere. This would avoid discharging the transport air to the flue gas duct which significantly lowers the flue gas temperature and downgrades the efficiency of the precipitator. Based on the results of the study, detailed installation drawings were prepared and arrangements made to ship an existing baghouse filter at the Alexandria Laboratory to Rivesville. A replacement baghouse was ordered for Alexandria and installation at Rivesville was implemented.

4.10 Replacement of Redler Conveyor With Belt Conveyor

In the course of removing the coal dryer, the existing horizontal Redler conveyor was replaced with a belt conveyor to minimize degradation of coal. The substitution required several changes in the structural framing. A trip to the site was made to obtain information needed to check the structural adequacy of existing members and design new members. Information for additional access grating areas was also obtained.

4.11 Rotex Screen Relocation

Along with replacement of the Redler conveyor by a belt conveyor, the Rotex screen has been relocated to the head of the belt conveyor. In addition, the crusher has been relocated adjacent to the Rotex screen to facilitate handling oversize material. A check on the structural adequacy of existing members was completed and Rivesville Operations advised that the support structure for the Rotex screen at the new location can safely support the load.

4.12 Bed Material Letdown System Modernization

The existing pressurized material transport system for classified bed material was converted to a vacuum system and additional required equipment ordered from Allen-Sherman-Hoff. The classifier screen will be removed and the outlets modified by removal of the rotary feeder valves from outlets 1 and 3. Installation drawings for system modification were prepared and forwarded to Rivesville Operations for implementation.

4.13 Install Fire Protection System Extensions

The existing fire protection system in the vicinity of the Northwest roof area was extended by the addition of three more stations with provision for a fourth. Drawing and bill of materials were forwarded to Rivesville Operations for implementation.

4.14 Baghouse, Preheater Roof Installation

A study was initiated on replacing the electrostatic precipitator with a baghouse and placing a heat exchanger upstream of the baghouse to cool the flue gas.

4.15 Investigate Limestone Storage At Quarry

A feasibility study and cost estimate was prepared for on-site storage of limestone at the quarry which included budget costs for several sizes of storage silos.

4.16 Atmospheric Vent

Guide framing and structural supports were designed for the vent silencer extensions and a detailed installation drawing prepared.

4.17 Stack Silencer Installation

Reviewed the data from Aeroacoustic Corporation for the stack silencer and investigated in conjunction with S&W, effect on stack stability and stress.

5.0 SUBCONTRACT ACTIVITIES

5.1 MFB Plant Advisory Operations Assistance (Stone & Webster Engineering Corp. Subcontract)

Stone & Webster continued to provide headquarters and on-site engineering and design support in areas critical to the scheduled January, 1979 MFB startup. Particular attention was devoted to procurement of the new I.D. fan, field fabrication of associated ductwork, stack and steam vent silencers, combustion air damper modifications, preparation of general arrangement drawings and site plans and preparation of instrument lists.

HEADQUARTERS ACTIVITIES

Noise Review (EDR-02)

Stack silencer and steam vent silencers engineering completed. The vibration monitoring report scheduled for January, 1979 completion.

Electrostatic Precipitator Review (EDR-05)

Met with Buell personnel to review ESP performance and evaluate data.

Coal Delivery & Injection System (EDR-08)

Alternative coal injection system arrangement drawings were developed. Drawings together with a preliminary draft of the task report are scheduled for issue during the first two weeks of January, 1979.

Turbine Bypass System (EDR-10)

Engineering and preparation of purchase specifications continued.

Control Room Modernization (EDR-14)

Studies relative to Control Room modernization alternatives was initiated. Preliminary control board layout was prepared. Relocation or expansion studies of existing Control Room scheduled for January.

DC-1 Bypass (EDR-16)

Bypass damper was released for fabrication and general arrangement drawing transmitted to PER.

General Arrangements & Plot Plan (EDR-17)

Completed preliminary General Arrangement drawings. Drawings will be formally issued in January. Site Plan drawings are being developed from McCoy Surveying Company Drawings.

Review Baghouse Installation (EDR-23)

Work continued on development, review and evaluation of various alternatives for baghouse installation and fan relocations. Preliminary report and recommendation scheduled for end of January, 1979.

FIELD ACTIVITIES

Air Preheater Deluge System (FR-20)

Design layouts, equipment specifications and recommended vendor lists submitted to PER.

Reduced Voltage Motor Starter (FR-25)

Recommendation transmitted to PER.

Instrument List Compilation (FR-26)

Compilation of instrument list was 90% completed during this period.

Replacement I.D. Fan (FR-27)

Assisted PER personnel and S&W Boston engineers in installation of ducts and expansion joints for new I.D. Fan.

Results

Re-evaluated entire results effort including instrumentation, test procedures, computer programs, results reporting and formating, data collection and requirements. Initiated an error analysis procedure. Completed preliminary report entitled "Analysis of Errors in Rivesville Test Data". Continued to evaluate direction of future results effort.

Safety

Conducted daily safety tours of MFB plant. Conferred with OSHA Compliance Officer relative to complaint on asbestos removal procedures.

> Procedures satisfactory, no citations issued nor further action required.

Weekly "Tool Box" meetings were held with maintenance, operations and construction personnel.

Training

Formal operator training program was conducted and completed for two groups of PER operators. Presentation was conducted for Georgetown University visitors.

5.2 MFB Steam Generator Development (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. During this quarterly reporting period, engineering evaluations on operation of the MFB were performed; a new air distributor for the Alexandria Laboratory PDU was designed and fabricated, replacement air distributors for the Rivesville MFB Cells B, C and D were designed and Cell D distributor fabricated; metallurgical samples were removed from the Rivesville MFB and analyzed; modifications were made to the Rivesville MFB, Beckman gas analysis system to prevent dilution of samples; remaining sections of the Boiler Design Manual were completed and submitted to PER.

Systems Evaluation

Remaining sections of the Boiler Design Manual were completed and submitted to PER. All work by FWEC on the Boiler Design Manual has now been completed.

An evaluation of the Rivesville Cell A, B, C and D air control damper was performed and techniques to reduce damper leakage were recommended. The recommendations included elimination of one of the damper blades in each cell and modification of the curved plates that determine the damper flow characteristics plus an improved seal design.

An evaluation of techniques to increase the flue gas exit temperature from Cells A, B and C was performed and the following recommendations submitted;

1) Operate at a higher drum pressure than has been maintained during previous unit operations (recommended 1350 psig).

2) Open the economizer recirculation valve (CV-6) to the wide open position.

3) Modify the air control damper seals to reduce leakage.

4) Maintain operating bed temperature at the design point.

5) Modify the economizer in Cells B and C to provide baffles to block off one third of the heat transfer surface.

At the end of the reporting period, PER requested FWEC to proceed with design and fabrication of the economizer baffles for Cells B and C. An evaluation of light off of Cell D with a single ignition burner was performed. The evaluation indicated that Cell D could be lit off with one ignitor. However, a considerable number of assumptions were required to arrive at that conclusion. Since the calculated single ignitor light off was based on a large number of assumptions, and DOE representatives indicated that there should be no modifications during this outage that would jeopardize operation subsequent to start up. FWEC agreed that the spreader feeder for Cell D should not be installed at the present time.

FWEC was requested to evaluate the possibility of modifying the heat transfer surface within the fluidized bed in Cell C. This evaluation was performed based on available test data. It was determined that the test data was not sufficient to conclude that any change in the heat transfer surface in the fluidized bed of Cell C was justified at this time. FWEC recommended further review of the heat transfer surface requirements based on data to be taken during 1979. Recommendations were made to modify boiler operation to improve overall performance.

Evaluation of data for Tests 7 through 17 was performed and it was concluded that an in-depth review of this data was not warranted at this time due to inconsistent readings. Recommendations for improving data taking and data preparation during the 1979 tests were submitted to PER.

Review of the boiler design at full load and part load operation continued. Work was delayed due to late receipt of information concerning air preheater performance. The part load and full load performance evaluation will be completed during the first quarter of 1979.

Test Instrumentation

During the 1978 testing, difficulty was experienced in obtaining proper gas analysis data due to dilution of the gas samples in the Beckman gas analysis system as a result of air in-leakage. The Beckman gas analysis system was modified to replace the nylon tubing with stainless steel tubing. The system was leak tested and is presently satisfactory. Modifications within the Beckman gas analysis cabinet were also made to change the gas sequencing valves which were also leaking and replace them with an improved design.

Systems Modifications

A hollow bolt type air distributor was designed and fabricated and installed in the Alexandria facility. Testing of this air distributor during this time period has been successful.

Design drawings were prepared for hollow bolt type air distributors for Cells B, C and D of the Rivesville unit. Release was given to fabricate the Cell D air distributor and shipment to the Rivesville site is expected during the first week of January 1979. Fabrication of the air distributors for Cells B and C have been put on hold.

Material samples were taken from the fluidized bed steam generator and metallurgical evaluations of these samples were performed during this time period. A report on these evaluations will be submitted during the first quarter of 1979.