Multicell Fluidized Bed Boiler Design Construction and Test Program

*Quarterly Progress Status Report
for Period January - March 1979*

Published - July 1979

MASTER

Prepared For:

U.S. Department of Energy
Assistant Secretary for Energy Technology
Division of Fossil Fuel Utilization

Under Contract No: EX-76-C-01-1237

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Prepared By:
Pope Evans and Robbins, Incorporated
New York, New York 10036

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Assistant Secretary for Energy Technology
Division of Fossil Fuel Utilization
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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 January, February and March 1979.

1.0 SUMMARY OF PERFORMED TASKS

1.1 Alexandria, Va. Laboratory Operation

Work in the Alexandria laboratory focused primarily on the following:

<u>Activity No.</u>	<u>Description</u>
114	Air Distributor Testing
1619	Large Size Coal Feed - Minimum Fluidization
1618	Oil Firing
1110	Sulfur Capture
1620	Flue Gas Baghouse Program

The following tests were completed during the reporting period.

<u>Test No.</u>	<u>Date</u>	<u>Description</u>	<u>Duration (Hrs)</u>
700-32	1/ 9/79	Drilled bolt grid plate and bed material samples	7.0
702-10	1/18/79	Shakedown	4.0
702-11	1/19/79	Preliminary #4 Oil firing	7.0
PDU-5	2/15/79	Shakedown coal feed system changes	6.0
700-33	2/28/79	Drilled bolt grid plate	6.0
700-34	3/ 2/79	Drilled bolt grid plate	7.0
PDU-6	3/ 3/79	Shakedown	2.0
700-35	3/ 8/79	Drilled bolt grid plate	5.0
700-36	3/15/79	Lowellville limestone	27.0
700-37	3/21/79	Lowellville limestone	6.0
700 38	3/22/79	Lowellville limestone	31.0

1.2 Rivesville MFR Plant Operations

Repair, reconstruction and plant improvement activities were completed and were followed by equipment and systems check-out. Modifications made to the bed material/flyash system and Beckman gas analysis system were significant improvements. The replacement nuts and bolts distributor installed in Cell D operated successfully. During January and February, calibration

tests were performed on all airflow measuring devices to ensure accuracy for future performance testing. Calibration tests were also run on all belt feeders. The MFB unit resumed hot firing operation in mid-March. The unit was operated intermittently to the end of the reporting period to identify and correct minor equipment operating problems. The unit was operated in the flyash reinjection mode which resulted in modifications to the reinjection system for improved control and operational reliability.

Summary of Operating Hours

CBC (Light-off oil fired burners)	37.33 hrs
CBC (coal fired)	118.51 hrs
Cell C	67.18 hrs
Cell B	.67 hrs

1.3 New York Office Engineering

The New York Office design and engineering staff continued to perform various tasks in support of resumed operation of the Rivesville MFB Boiler Plant and improvements for increased reliability. Tasks performed included:

- Confirmed stability of the existing stack with new silencer under critical wind velocity conditions,.
- Prepared design calculations and drawings for structural framing to accommodate replacement belt conveyor for Redler,
- Completed study to provide for redundant FD and ID fans and selective use of electrostatic precipitator or baghouse filter,
- Prepared design calculations and drawings for installation of flue gas sample ducts to support EPA test program,
- Prepared design calculations and drawings for supports and guides for atmospheric vent silencer extensions,
- Investigated structural framing additions and modifications to accommodate proposed Instrument Shop.

1.4 Subcontract Activities

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

S&W continued to furnish operations assistance at the Rivesville MFB Plant and provide engineering and design support for the plant modernization program.

Home office engineering tasks performed included coordination and procurement of FD and ID fan vibration instrumentation and readings at the site to establish baseline data; establishing maximum acceptable noise levels for the air cooled condenser and noise control options for the turbine by-pass system; completion of studies for alternate coal and limestone distribution and feed systems; completed conceptual design of turbine by-pass system; continued work on Control Room relocation and modernization; prepared drawings for installation of DC-1 by-pass damper; completed Particulate Emission Control and Draft Equipment Modernization Study.

Field Activities included checkout of nuclear source heads for precipitator hopper level detectors; modifications to flyash reinjection system; designed and specified material for precipitator hopper heating system; performed verification analysis of MFB performance calculation equations and recommended revisions to computer programs; participated in testing program dry runs; updated test plan.

Conducted daily safety tours and investigation of minor accidents.

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 operation and improvement;

- Completed fabrication of replacement air distributor for Cell D and shipped to site,
- Continued engineering evaluation of full load and part load performance of the Rivesville MFB unit,
- Completed and issued the Materials Surveillance Report on samples taken from the Rivesville MFB.

1.5 Review of Significant Events

During the October 1978 through March 1979 FY-79 contract period, the following significant events occurred:

<u>Event</u>	<u>Date</u>
Conducted No. 6 oil burning tests in the Alexandria PDU	October 1978
Conducted Coal Firing tests with drilled bolt air distributor in Alexandria PDU	November 1978
Conducted oil - coal firing tests with drilled bolt air distributor in Alexandria PDU	January 1979
Completed fire damage repairs and plant improvements of Rivesville MFB Plant	February 1979
Resumed hot firing operation of the Rivesville MFB unit.	March 1979

1.6 Future Planning

The following activities are scheduled for the April, May, June 1979 period:

- 1) Complete hot firing testing operations and instrument calibration of Rivesville MFB plant.
- 2) Resume performance and emission testing of Rivesville MFB plant.
- 3) Start EPA emission control test program at Rivesville MFB plant.
- 4) Conduct flyash reinjection performance tests in the Alexandria PDU.
- 5) Conduct baghouse filter performance tests at the Alexandria PDU.
- 6) Conduct performance tests on new source Rivesville limestone in the Alexandria PDU.
- 7) Continue New York Office engineering support to improve Rivesville MFB operation and reliability.
- 8) Complete evaluation of the Rivesville MFB performance at full load and part load conditions by FWEC.
- 9) Complete report on studies of coal and limestone distribution and injection systems and feed to bunkers by S&W.
- 10) Complete Control Room modernization study by S&W.
- 11) Evaluate vendor cost proposals for baghouse filter and heat exchangers by S&W.

2.0 ALEXANDRIA, VA. LABORATORY RESULTS

2.1 Air Distributor Testing (Activity No. 114)

Testing of the drilled bolt air distributor continued in accordance with the test program described in the previous quarterly report, No. 14. The 9 sq ft test grid is a prototype of the grid design now operating in D Cell of the Rivesville MFB. It consists of 2784, 5/16" x 18 stainless steel bolts on 0.724" centers on a 1/4" thick carbon steel base. Each bolt projects 1-3/4" above the plate and is drilled out to 7/64" (.1094") at the end projecting into the bed, yielding approximately 2% open area. During operation, the bed material around the bolts is not fluidized and forms a 1-3/4" stagnant layer which insulates the grid plate from the hot fluidized portion of the bed. An updated summary of air distributor tests through Test No. 700-38 is given in Table 1. To date, a total of 184 hours of hot testing including approximately 24 start-up and shutdown cycles have been completed.

Since each drilled bolt represents an orifice through the base plate, the pressure drop across the drilled bolt air distributor varies directly as the square of the air velocity. The initial ambient test without bed material on the grid plate verified the orifice equation as ΔP varying with the air flow rate to the 1.988 power. Using this relationship as the baseline grid performance, any deviation using the same test conditions would, depending on the direction of the deviation, indicate either leakage or pluggage. Results of pressure drop versus air flow rates for three, no bed, ambient temperature tests following 0, 44, and 184 hours of hot testing are shown in Figure 1. As shown by the data, the drilled bolt air distributor has experienced no significant pluggage or leakage to date. Furthermore, routine inspection of the plenum indicates sifting to be minimal.

In Table 2, the average temperature of the grid plate, the temperature in the middle of the insulating layer, and the average bed temperature are summarized. From this data it can be seen that the stagnant layer of bed material serves the purpose of insulating the grid from normal operating bed temperatures.

2.2 Large Size Coal Feed - Minimum Fluidization (Activity No. 1619)

Recent trends in FBC technology and cold light-off difficulties have led to a reevaluation of the predictive methods for calculating minimum fluidization velocity. Specifically, the use of large top size coal with overbed stoker feeding and the trend toward lower design superficial velocities to improve sulfur capture will result in operation near the minimum fluidization velocity of the bed. Also, cold light-off conditions set the

Table 1

Summary of Drilled Bolt Air Distributor Tests

Date	Description
11/13/78	Test 700-26; 5 hr. run at 1550°F followed by overnight slump.
11/14/78	Test 600-27; 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.
1/9/79	Test 700-32; 7 hrs. at 1442°F.
1/19/79	Test 702-11; 7 hr. oil fire test at 1452°F.
2/15/79	6 hr. shakedown test at 1419°F.
2/28/79	Test 700-33; 6 hr. test of carbon limestone at 1644°F with 3 unscheduled slumps.
3/15/79	Test 700-36; 27 hr. Carbon Limestone Company test.
3/21/79	Test 700-37; 6 hr. aborted carbon limestone test; lost limestone feed.
3/23/79	Test 700-38; 31 hr. carbon limestone test at Ca/S of 3.0.

Total hot test hours: 184

Approximate # of cycles: 24

GRID PRESSURE VERSUS AIR FLOW

Figure 1

Table 2

Drilled Bolt Air Distributor Temperatures at
Normal Operating Conditions***

Test No.	Avg. Bed Temp., °F	Avg. Air * Dist. Temp., °F	Avg. Mid** Dead Zone Temp., °F
700-28A	1528	351	466
	1513	346	463
	1558	352	489
700-30	1476	326	417
	1472	332	404
	1489	327	391
	1513	331	410
700-33	1531	363	500
	1575	362	500
	1585	357	495
	1436	304	410
700-36	1560	378	502
	1543	361	475
	1481	351	448

* Avg. of TC #1, #2, #5 attached from the underside of the grid 1/8" into the base.

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

*** Fluidizing Air Temperature 300°F.

design volume requirements for the fluidizing air since mixing by fluidization of the bed is required. Occasionally, due to design limitations, change in limestone supply, or mixing of large coal particles in the bed, the bed mean particle size may become too large to be fluidized under start-up conditions. This situation has occurred in the Rivesville MFB and illustrates the need for accurate prediction of the minimum fluidization velocity of the bed.

The equation generally used to predict the minimum fluidization velocity is a modified form of the Ergun equation. In simplified form, the Ergun equation can be written as;

$$U_{mf} = \frac{\mu}{\rho_g D_p} \left\{ A^2 + B(G_A) \right\}^{\frac{1}{2}} - A \quad (1)$$

where:

U_{mf} = minimum fluidization velocity

μ = gas viscosity

ρ_g = gas density

D_p = particle diameter

G_A = Galileo number = $\frac{D_p \rho_g (\rho_s - \rho_g) g}{\mu^2}$

g = gravitational constant

ρ_s = solid density

$A = \frac{42.86 (1 - \epsilon_{mf})}{\phi_s}$

$B = \frac{\phi_s \epsilon_{mf}^3}{1.75}$

ϵ_{mf} = voidage at minimum fluidization

ϕ_s = shape factor

Wen and Yu¹ have suggested using an approximation for ϕ_s and ϵ_{mf} such that:

$$\frac{1}{\phi_s \epsilon_{mf}^3} \sim 14 \text{ and } \frac{1 - \epsilon_{mf}}{\phi_s^2 \epsilon_{mf}^3} \sim 11 \quad (2)$$

This gives values of A and B in equation (1) of 33.7 and .0408 respectively. The Institute of Gas Technology² in developing a minimum fluidization velocity correlation for material normally found in an FBC, recently correlated available data to develop the following empirical values:

$$\frac{1}{\phi_s \epsilon_{mf}^3} = 8.81 \text{ and } \frac{1 - \epsilon_{mf}}{\phi_s^2 \epsilon_{mf}^3} = 5.19 \quad (3)$$

This gives values for the quantities A and B of 25.25 and 0.0649 respectively.

Figure 2 shows a plot of the calculated minimum fluidization velocities of limestone as a function of particle size at 80°F and at 1550°F for both above correlations. The curves show a rather large difference in the predicted minimum fluidization velocities. In previous cold minimum fluidization tests, the PDU and the FBM have yielded results in agreement with those predicted by the correlation of Wen and Yu. However, due to operational difficulties, the minimum fluidization velocity could not be measured under hot conditions. To test the correlations under hot conditions a four inch diameter, propane fueled, hot cell was used to obtain the minimum fluidization velocity at 1550°F from pressure drop across the bed data. The tests were also run at 80°F in the same cell.

Two series of tests were run in the four inch hot cell using Carbon limestone in the first series and Greer limestone in the second. In each series, the minimum fluidization velocity was measured first at 80°F and then after one hour of operation at 1550°F. After a minimum fluidization velocity measurement, a sample was withdrawn for density and mean particle size determinations. Three trials were conducted in each series using fresh limestone for each trial. Minimum fluidization was determined in a conventional manner by plotting bed pressure drop versus superficial velocity. The results of the tests are shown in Table 3.

Table 4 shows a comparison of measured minimum fluidization velocities to the values predicted by the two correlations. In calculating the predicted values, the measured mean particle sizes and particle densities were used. In this way, effects due to calcination of the limestone were considered. The results in the table show that the prediction of Wen and Yu (Equation (2)) gave

¹ C.Y. Wen and Y.H. Yu, AIChE Journal, 12, 610 (1966).

² Institute of Gas Technology Coal Conversion System Technical Data Book 1978.

PREDICTED MINIMUM FLUIDIZATION VELOCITIES OF LIMESTONE* AT 80 AND 1550°F

Table 3

Summary of Minimum Fluidization Tests
(Four Inch Diameter Bed)

Test	Material	Bed Temperature (°F)		Particle Size (microns)	Minimum Fluidization Velocities	
		Cold	Hot		80°F (fps)	1550°F* (fps)
Series I						
Trial 1	Carbon LS	80	1565	1724	2.6	3.69
" 2	"	77	1540	1724	2.85	3.13
" 3	"	88	1570	1724	2.5	2.85**
Average		81	1558	1724	2.65	3.22
Series II						
Trial 1	Greer LS	82	1590	1785	2.65	3.0
" 2	"	78	1535	1785	2.50	2.6**
" 3	"	88	1560	1785	2.55	3.2
Average		82	1561	1785	2.57	2.95

* Superficial velocity under hot conditions were calculated using flue gas flow rates and densities.

** Scatter of data due to difficulty in measuring fluidization velocities.

Table 4

Summary of Predicted and Experimental
Minimum Fluidization Velocities*

Test	Bed Temperature	Equation 2 Prediction	Equation 3 Prediction	Experimental
Series I	80°F	3.25	4.52	2.65
Series II	80°F	3.34	4.62	2.57
Series I	1550°F	1.83	3.43	3.22
Series II	1550°F	1.95	3.61	2.95

*Ft/Second.

better results under the cold conditions. This is consistent with earlier measurements made in the PDU and the FBM under cold conditions; however, at 1550°F the IGT correlation [Equation (3)] gave better results.

Solution of Equation (2) for ϕ_s and ϵ_{mf} gives values of $\phi_s = .57$ and $\epsilon_{mf} = .50$. The IGT correlation gives values of $\phi_s = .82$ and $\epsilon_{mf} = .52$. Thus the major difference in the two correlations lies in the choice of shape factors. The results of these tests seem to indicate that the shape factor changes between cold and hot tests.

The shape factor is a measure of the roundness of the particle. Perfect spheres have a shape factor equal to one. The lower the value of ϕ , the more irregular the shape. Since the calcined limestone is softer than raw limestone, abrasion of the calcined limestone particles could result in smoother particles thereby changing their shape factor.

The results of these tests show that the correlation of Wen and Yu is acceptable for use at low temperatures. However, the IGT correlation appears to be more accurate at 1550°F. It is not known which correlation works best at intermediate temperatures. Further testing will be needed to verify the correlations in the intermediate temperature regions.

2.3 Oil Firing (Activity No. 1618)

Analyses of samples from oil firing Test 702-9 conducted in the previous quarter were completed. This test was run using No. 6 oil after minor modifications to the oil firing system were made based on preliminary tests on No. 6 and No. 2 fuel oil. This test run was the longest (11 hours) and most efficient oil firing test. Sufficient data was collected to measure combustion efficiency and sulfur capture.

Operating conditions for Test 702-9 are given in Table 5. Based on chemical analyses of the samples, the combustion efficiencies and calcium to sulfur molar feed ratios reported in Table 5 were calculated. Using 98% combustion efficiency, a heat balance around the bed indicates that about 95% of the fuel input was burned in the bed. This high rate of inbed burning was confirmed by visual observation during the test since very little above bed burning could be seen.

The sulfur capture for Test 702-9 was found to be 99%. This high rate of sulfur capture was apparent from the extremely low SO_2 emissions level during the test. Although an analyzer malfunction was suspected, every effort to find a problem confirmed the gas analysis. As a final confirmation of the flue gas analysis, coal firing was resumed at the end of the oil firing test to validate the flue gas analysis system readings.

Table 5
Operating Conditions for Test 702-9, 11/1/78

Time, Hrs.	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, lb/hr	4486	4463	4341	4156	4620	4556
NO _x , ppm	204	206	217	218	189	560
Hydrocarbons, ppm	188	136	82	129	325	772
Combustion efficiency, %	--	98.44	--	98.36	98.11	--
Ca/S, molar feed ratio	--	5.01**	--	4.99**	5.5**	2.63

* Data not taken.

** Additional limestone fed to maintain bed level.

Due to the low SO_2 emissions level, the fuel oil was sent to two independent laboratories for analysis. The results of these analyses are shown in Table 6. As can be seen, the average fuel oil sulfur content was 2.35% and the vanadium content was significant. For this reason, the bed material was also analyzed for vanadium and the result is shown in Table 6. Since the fuel oil and bed material contained a significant amount of vanadium, it is possible that the high sulfur capture rate was due to the influence of vanadium on the sulfur capture reaction.

Another interesting observation from the test was that when coal firing was resumed at the end of the test, the SO_2 concentration in the stack increased from 10 ppm to only about 330 ppm after about an hour of coal feed with a reduced Ca/S feed ratio. Since the SO_2 emission did not immediately increase on the switch to coal firing, and since the level of emission was lower than expected, activation of the limestone by the oil was suspected.

To further examine the unusually high sulfur capture, scanning electromicrographs (SEM) of samples of sulfated bed material were made, to look for physical changes in the material. Due to the time delay between sampling and the SEM work, some decomposition of the bed material will occur and obscure these changes. Figures 3 and 4 show some of the electromicrographs which were made. Microcrystals of calcium carbonate show up as characteristic plates on the surface of the material and are well defined in all of these illustrations. These pictures do not indicate any smooth round surfaces of bed material that would be indicative of a "salt effect". Furthermore they do not appear different from micrographs of bed material formed by burning coal. Thus the only explanation for the enhanced sulfur capture is due to some method of activating the limestone particles by an element in the fuel.

2.4 Sulfur Capture (Activity No. 1110)

During the reporting period chemical analysis of samples from Tests 700-28B and 700-30 were completed. These tests were run during the previous quarter to provide additional sulfur capture results using Greer limestone. Calcium to sulfur molar feed ratio in these tests were selected at the high and low end of the range of interest to supplement earlier test data. Sulfur capture tests were also started on Lowellville limestone from the Carbon Limestone Company of Lowellville, Ohio. This limestone is currently the sorbent material supplied to the Rivesville MFB.

Table 6
#6 Oil Analysis and Bed Material Analysis
Test 702-9, 11/1/78

	Lab I	Lab II
Carbon, %	85.22	85.76
Hydrogen, %	11.03	10.80
Oxygen, %	.53	1.04
Nitrogen, %	.19	.41
Sulfur, %	2.38	2.31
Ash, %	.09	.10
High Heating Value Btu/#	18,286	18,310
Trace Elements		
V, ppm	455	690 (as V_2O_5)
Ni, ppm	54	64 (as NiO)
Fe, ppm	6	61 (as Fe_2O_3)
Cl, ppm	238	590
Bed Material at 1400 hrs.		
Sulfur, %	3.58	
Iron, %	2.03	
Vanadium, %	.07	
Calcium, %	38.16

Sample 2: Bed Material
(Magnified 10,000 times)

Sample 2: Bed Material
(Magnified 10,000 times)

ELECTROMICROGRAPHS OF SULFATED BED MATERIAL

Sample 1: Bed Material
(Magnified 10,000 times)

Sample 1: Bed Material (Magnified 10,000
times)
ELECTROMICROGRAPHS OF SULFATED BED MATERIAL

2.4.1 Greer Limestone Tests

Test 700-28B was started with bed material from Test 700-28A and was run for 16 hours at an average Ca/S molar feed ratio of 6.7. The average sulfur capture for the 16 hours was approximately 85% and the combustion efficiency was about 84%. Based on previous test results, 85% sulfur capture would be achieved at a Ca/S molar feed ratio of about 3 when firing 4.5 percent sulfur coal. The sulfur content of the coal in Test 700-28B showed a decrease from 3.4 to 2.2% during the course of the test. This tends to lend doubt as to the actual sulfur content of the coal during the test and could affect the usefulness of the results. Based on averages for the test period, 85% sulfur capture at the high Ca/S molar feed ratios may indicate the effect of low concentration of SO₂ on the capture reaction.

The chemical analyses for Test 700-30 are shown in Table 7. This test was run to obtain transient data on bed material composition and SO₂ emissions during initial operation with a fresh limestone bed. The SO₂ concentration in the stack gas as a function of hours of operation is plotted in Figure 5. From these test results it can be seen that a steady level of emissions had not been reached after six hours of operation on coal at a Ca/S molar feed ratio of 6. To reach steady state emissions, even at a very high Ca/S feed ratio, a longer test effort is required and should be planned for in any limestone evaluation tests. Bed material samples showed no significant change in sulfur content for the test period.

2.4.2 Lowellville Limestone Tests

Test 700-36 was the preliminary test run using Lowellville limestone. Operating conditions for the test are given in Table 8. Limestone feed was erratic throughout the test, however, and was finally lost after approximately five to seven hours of steady state operation. Thus, sulfur capture results were not determined. The test was continued for another twelve hours with no limestone feed to allow the bed to reach a saturation point in terms of sulfur capture. During this period, fly ash samples were taken and later analyzed for calcium. Since more than 99% of all calcium input is in the limestone, the calcium in the fly ash is a means of comparing limestone attrition characteristics. Fly ash calcium values for Test 700-36 ranged from 12.5 to 16.3 percent, comparable to those when testing Greer limestone. A more detailed comparison will be made when results of future tests are available.

Test 700-38 was a Lowellville limestone test run at a Ca/S molar ratio of 3.0. During this 31 hour run, several samples were taken to provide sulfur capture and fly ash calcium data. A list of operating conditions is given in Table 9. Samples are currently being analyzed.

Table 7

Chemical Analysis of Bed Material
Test 700-30, 12/28/78*

Time	Calcium	Sulfur
1000	40.38	5.29
1100	44.91	4.83
1200	40.50	4.80
1300	41.62	5.08
1400	40.81	5.41
1500	41.40	5.31

* All analysis are listed as percentages.

SO₂ EMISSIONS VERSUS TIME FOR TEST 700-30
(Fresh Limestone Bed Light-Off)

Figure 5

Table 8
Operating Conditions for Test 700-36, 3/15/79

Time, Hrs.	1130	1400	1630	1930	2100	2330	0230	0430	0745
Fuel									
Bed Temp., °F	1560	1544	1556	1563	1531	1589	1508	1543	1481
O ₂ in flue gas, %	4.0	6.0	6.0	6.0	6.0	6.0	6.6	6.0	7.0
Fuel feed rate, lb/hr (Coal)	954	998	929	970	946	986	955	948	707
Fly ash collection rate, lb/hr	222	264	226	247	247	212	206	208	206
Limestone feed rate, lb/hr	158	344	267	364	310	0	0	0	0
Bed drain rate, lb/hr	0	0	88	92	17	56	12	0	0
Stack dust rate, lb/hr	*	58.1	*	*	58.1	*	*	*	51.1
Main air flow rate, lb/hr	7784	7593	7735	7836	7780	8167	7795	7645	7572
Total air flow rate, lb/hr	8372	8159	8007	8104	8048	8446	8064	7924	7847
Superficial velocity, ft/sec	12.6	12.0	11.9	12.1	11.8	12.8	11.7	11.6	11.2
Static bed depth, inches	23.0	27.0	25.5	26.0	26.5	24.0	25.0	28.0	28.0
EOBH (effective operating bed ht.), inches	33.5	45.0	41.0	42.5	41.5	41.0	40.5	43.0	41.5
SO ₂ , ppm	589	390	562	563	549	102**	1340**	1323**	907**

* Data not taken.

** No limestone feed, feeder inoperative.

Table 9
Operating Conditions for Test 700-38, 3/22/79

Time, Hrs.	1430	1900	0200	0500	0830	1000	1115	1300
Bed Temp., °F	1507	1543	1571	1548	1509	1571	1553	1479
O ₂ in flue gas, %	3.5	3.7	3.1	3.5	3.2	3.0	3.1	3.5
Coal feed rate, lb/hr	735	708	752	728	734	774	772	708
Fly ash collection rate, lb/hr	*	246	238	252	339	240	220	*
Limestone feed rate, lb/hr	0	316	341	328	310	316	248	351
26 Bed drain rate, lb/hr	2	143	88	91	152	148	296	0
Stack dust rate, lb/hr	*	*	*	*	*	31.3	31.4	29.8
Main air flow rate, lb/hr	7401	7602	7485	7662	7250	7541	7507	7280
Total air flow rate, lb/hr	7662	7868	7782	7959	7545	7836	7801	7574
Superficial velocity, ft/sec	11.1	11.6	11.7	11.8	10.9	11.7	11.6	10.9
Static bed depth, inches	25.0	26.0	26.0	26.5	30.0	27.0	26.0	28.0
ECBH (effective operating bed ht.), inches	42.0	42.5	43.5	42.0	47.5	45.0	43.0	45.0
SO ₂ , ppm	122	281	307	330	368	519	700	522

* Data not taken

2.5 Flue Gas Baghouse Program (Activity No. 1620)

The installation of a flue gas baghouse was completed during the reporting period. This baghouse was designed and furnished by Buell Emission Control, Division of Envirotech, to test the application of fabric filters to the coal fired fluidized bed process. Using a bag material of teflon coated fiberglass, different cleaning methods and air to cloth ratios can be tested at 400-500°F stack temperature. Initial operation of the system will use reverse air and/or shake bag cleaning mode. A description of the baghouse test system is given in previous Quarterly Report, No. 14.

Work completed during the reporting period included thermal insulation and installation of electrical and pneumatic controls. This work was delayed approximately four weeks due to abnormally severe winter and snow conditions. Tie-in of the existing induced draft fan to the completed baghouse test system is in progress. The installed equipment is shown in Figure 6. The process and instrument flow diagram for the system is shown in Figure 7.

To obtain useful information from operation of the baghouse while conducting planned test activities on improved sorbent utilization and large size coal feed, a trend toward increased duration test runs is planned. To meet the goal of longer duration test runs on a routine basis, modification of the fly ash handling system is necessary to simplify disposal. Depending on the demand for sulfated limestone to support utilization studies, improvements in spent bed disposal may also be necessary.

Planned modifications to the fly ash system include recycle of fly ash from the main cyclone to the PDU, relocation of fly ash weighing hopper to the new flue gas baghouse solids outlet, and transport of fly ash to a sufficient elevation for gravity drop to disposal bins. These changes are depicted in the flow diagram in Figure 8. With these modifications, the need to weigh the main cyclone catch will be eliminated (for most testing) and the sensitivity of efficiency results to flue gas isokinetic sampling will be greatly reduced. The overall result should be simplified fly ash disposal and reduced effort during the collection of test data.

FLUE GAS BAGHOUSE AS INSTALLED AT ALEXANDRIA, VIRGINIA

STACK GAS BAGHOUSE FLOW DIAGRAM

Figure 7

FLY ASH SYSTEM FLOW DIAGRAM

3.0 RIVESVILLE MFB PLANT OPERATIONS

3.1 General

The first quarter of 1979 was an outage-to-operations transition period for the Rivesville MFB. The demolition and reconstruction effort was replaced by an operational check-out period containing no unusual problems associated with equipment, design, and control changes. Modifications to the bed material/flyash system and the Beckman gas analysis system during the outage proved to be significant improvements. Preliminary observations indicated that the "nuts and bolts" air distributor in the CBC was a successful design change. As equipment and instrumentation improvements were completed, each system was operated and/or tested to insure proper installation. The equipment/systems check-out was followed in mid-March by a successful light off.

3.2 Plant Outage

Buell completed reconstruction and airflow tests of the electrostatic precipitator on 7 February. The airflow tests involved having a safety-equipped man inside the boiler during cold air operation of the fans.

One of the last remaining tasks to be accomplished during the outage was pouring of a new insulating roof on the precipitator. Sub-freezing temperatures prevented pouring but on 15 February, the mercury rose above 32°F and the job was completed.

Completion and balancing of the new and larger ID fan as well as the FD fan was accomplished in January. They were bumped, coupled, and accepted on 18 January.

Vibration monitoring heads were installed on the fan foundations during January and vibration readings recorded on 27 January. They are listed below:

<u>I.D. FAN</u>		
	<u>Motor</u>	<u>Fan</u>
Horizontal	0.07 mils	0.12 mils
Vertical	0.42 mils	0.12 mils
Axial	1.4 mils	0.90 mils
<u>F.D. FAN</u>		
Horizontal	0.11 mils	0.08 mils
Vertical	0.06 mils	0.04 mils
Axial	0.02 mils	0.03 mils

The ductwork was completed including lead sheathing which will reduce ambient noise originating in the ductwork.

The steam silencers have been extended and redirected to reduce ambient noise levels and provide safe access to the stack platform sampling station. A stack silencer was also installed to further reduce ambient noise levels.

During the outage, the makeup feedwater capacity was increased 60% due to relocation and expansion of the Ecolochem demineralization headers. The previous setup (i.e. the Ecolochem trucks outside, fire hose hookup, etc.) allowed a maximum flow of 200 gallons per minute. There are now two pipe headers inside the plant, each with the capacity of 160 gallons per minute.

The air preheater (APH) installation, including rotor, drive motor, oil motor, solenoid, and filter was completed in January. The main drive was bumped 22 January and confirmed to be operating properly. In addition, the deluge system is in place and operational.

The coal handling system was completed and operational including relocation of the Rotex screen, installation of the 75 foot belt conveyor replacing the 102 foot Redler, and relocation of the coal crusher.

An extension of the data logging (Doric) equipment has been added in the Control Room to provide a convenient secondary read-out.

After being successfully tested at the Alexandria Laboratory, a decision was made to install a hollow bolt air distributor in the CBC of the MFB. The grid plate consists of twelve sections compared to nine sections for the thin plate. Exhibit 1 illustrates the hollow bolt and the hollow bolt spacing.

The dust problem associated with limestone deliveries has been alleviated by installation of a baghouse filter for the limestone bunker transport air discharge. Only small amounts of dust can now be detected outside the enclosed bunker area.

A new Betalarm panel has been installed to improve the safety and operational response of the plant. The previous annunciator had 60 alarm points available. Although all of the windows in the new panel are not yet connected, 115 have been labeled and 15 new alarm points have been installed and tested.

D" CELL AIR DISTRIBUTOR

Hollow Bolt

2" Long
S.S. Hollow
Bolt

Hollow Bolt Spacing, D Cell

Exhibit 1

Although the outage was extended due to certain "unpredictables", it was declared officially ended at 1600 hours, 16 February 1979. The "unpredictables" causing the 20 day extension included;

- a. Buell constructed an updated flow model and as a result of analysis, modified their original flow guide design.
- b. A new, larger ID Fan and associated duct work was designed, specified, purchased and installed.
- c. Disassembly of the air preheater was more complex than originally anticipated. Rotating parts were an almost total "melt down" and took three weeks longer than original estimate to remove from roof.
- d. The original 24 week schedule had been predicted on a 28 August DOE release. While work was initiated the first week in September, the DOE release was received 18 October.
- e. From 6 January through the end of the month, the outside temperature was never above 32°F, making it impossible to pour the roof of the electrostatic precipitator (ESP).

3.3 New DC-1 Damper

At the time the reconstruction and modernization outage was completed and the MFB unit was available for operation, Monongahela Power Company's #7 boiler was out of service for an indefinite period of time due to fuel shortages. Because the unavailability of feedwater prevents MFB operation, the unit was declared unavailable and work proceeded on installation of the DC-1 damper.

The purpose of the damper is to improve the dust collector efficiency at low loads (when only cells D and C are in service). This is accomplished by increasing the velocity through the dust collector. Vendor delivery problems had delayed the installation (See Exhibit 3).

3.4 Bed Material Transport Modifications

During the outage, major modifications were made to the bed material transport system. Exhibit 4 illustrates schematically, the modified system.

The classifier with the screens removed, now serves only as a transport duct. The rotary feeders at each end of the classifier

LOW LOAD DC-1 ISOLATION DAMPER

NEW _____
 EXISTING _____

Exhibit 4

BED MATERIAL TRANSPORT MODIFICATIONS

have been removed. The bed material is now transported by an upstream vacuum of 2" - 14" Hg created by the new steam ejectors utilizing 160 PSIG steam. The C Blower which used to supply this transport air is now used for auxiliary purposes.

3.5 Results

3.5.1 Airflow Test Accomplished

During the months of January and February, calibration tests were performed on all airflow measuring devices in the combustion air and auxiliary air systems. These calibrations were made because some previous airflow measurements were in doubt. Test conditions for the Auxiliary FD Fan tests are shown in Exhibit 5 and for the FD - ID Fan tests in Exhibit 6.

Test Procedures

In both sets of airflow tests, a pitot traverse of the appropriate fan discharge was performed. Sketches of pitot traverse locations and points are shown in Exhibits 7 through 10.

Prior to testing, all sensing lines were leak checked and blown out. All instruments were zeroed and checked. In all cases, where applicable, instruments were placed as close as possible to the measuring device.

In all tests, conditions were allowed to stabilize before data collection began. Data was taken at five minute intervals and two complete pitot traverses were performed for each condition.

In order to maintain similar conditions for various test runs, duct pressure was closely monitored and restored to same pressure for all conditions.

Duct temperatures were monitored by a Doric Datalogger every five minutes.

Test Results

Equations used:

$$1. \quad \rho = .09658[PD + (PB) (13.595)]/(TD + 460)$$

where:

ρ - air density (lb/ft³)
.09658 - density constant @ 60% RH (lb/ft³)
PD - duct pressure ("WC)
PB - Barometric pressure ("Hg)
TD - Duct temperature (°F)

FD -- ID Fan Tests

1. Airfoil airflow

$$M_{AF} = 1,333,256 \sqrt{\Delta P_{AF} \rho_{AF}}$$

$$M_{AF} = \text{airfoil airflow (lb/hr)}$$

$$\Delta P_{AF} = \text{air foil differential ("WC)}$$

$$\rho_{AF} = \text{air density at air foil}$$

2. Cell Annubars

A cell

$$M_{AANN} = 237,983 \left[\sqrt{\rho_{AF} \Delta P_{AN}} + \sqrt{\rho_{AF} \Delta P_{AS}} \right]$$

B cell

$$M_{BANN} = 213,142 \left[\sqrt{\rho_{AF} \Delta P_{AN}} + \sqrt{\rho_{AF} \Delta P_{AS}} \right]$$

C cell

$$M_{CANN} = 225,266 \left[\sqrt{\rho_{AF} \Delta P_{BN}} + \sqrt{\rho_{AF} \Delta P_{BS}} \right]$$

D cell

$$M_{DANN} = 222,479 \sqrt{\rho_{AF} \Delta P_{DA}}$$

where:

$$M_{XANN}^* = \text{Cell airflow from annubar (lb/hr)}$$

$$\Delta P_{xN} = \text{Cell north annubar differential ("WC)}$$

$$\Delta P_{xS} = \text{Cell south annubar differential ("WC)}$$

$$\Delta P_{DA} = \text{D cell annubar differential ("WC)}$$

3. Gridplate ΔP vs airflow

A cell

$$M_{AGRID} = 119,417 \sqrt{(\Delta P_{AG}) \rho_A}$$

B cell

$$M_{BGRID} = 119,417 \sqrt{(\Delta P_{BG}) \rho_B}$$

* x = cell designation.

$$2. \quad V_p = 1096.2 \sqrt{\frac{\Delta P_p}{\rho}}$$

where:

V_p - pitot velocity (fpm) (from mfg's equation)

ΔP_p - pitot differential pressure ("WC)

Auxiliary FD Fan Test

1. Aux. FD Fan pitot - Venturi

$$M_{AFD} = (49044.7) \sqrt{\rho_{AFD} \Delta P_{AFD}}$$

where:

M_{AFD} = auxiliary F.D. air flow (lb/hr)

ρ_{AFD} = Aux F.D. air density (lb/ft³)

ΔP_{AFD} = Aux F.D. fan pitot - venturi differential ("WC)

2. Vibrating Feeder Annubars

$$M_{VF} = 9470.96 \sqrt{\Delta P_{VF} \rho_{VF}}$$

where:

M_{VF} = air flow to vibrating feeder (lb/hr)

ΔP_{VF} = vibrating feeder annubar differential ("WC)

ρ_{VF} = vibrating feeder air density

3. Burner Airflow

$$M_{BRN} = 28,258 \sqrt{\Delta P_{BN} \rho_{AFD}}$$

where:

M_{BRN} = burner airflow

ΔP_{BN} = burner annubar differential ("WC)

Seal air and belt feeder leakage air could not be determined. For testing, seal air will be valved out.

C cell

$$M_{\text{CGRID}} = 104,922 \sqrt{(\Delta P_{\text{CG}}) \rho_{\text{C}}}$$

D cell

$$M_{\text{DGRID}} = 42,998 \sqrt{(\Delta P_{\text{DG}}) \rho_{\text{D}}}$$

where:

M_{GRID} = cell airflow from grid plate differential (lb/hr)

ρ_{x} = air density based on undergrid press ("WC)

ΔP_{XG} = cell grid plate differential ("WC)

4. Main Cells Annubar

$$M_{\text{MN}} = 2,603,933 \sqrt{\Delta P_{\text{MN}} \rho_{\text{AF}}}$$

where:

M_{MN} = main cells annubar airflow (lb/hr)

ΔP_{MN} = Main Cells Annubar Differential ("WC)

5. D Cell Pitot - Venturies

$$M_{\text{DP}} = 67,716.73 \left[\sqrt{\rho_{\text{AF}} \Delta P_{\text{DE}}} + \sqrt{\rho_{\text{AF}} \Delta P_{\text{DW}}} \right]$$

where:

M_{DP} = D cell airflow from pitot - venturies

ΔP_{DE} = D cell east pitot - venturi differential ("WC)

ΔP_{DW} = D cell west pitot - venturi differential ("WC)

Results are depicted graphically as Flow Rate vs. ΔP in the following set of graphs, Exhibits 11 through 22.

Conclusions and Recommendations

Based on observations made during performance tests, airflow tests and Alexandria experience, the following recommendations are made:

AUXILIARY F.D. FAN TEST CONDITIONS

RUN	DATE	CONDITIONS	COMMENTS
1-D	01/16/79	69" WC, D Vib Fdr On	D Seal Air On, 2.75" Δ P
1-CN	01/16/79	69" WC, C-N Vib Fdr On	C-N Seal Air On, 2.4" Δ P
1-BN	01/16/79	70" WC, B-N Vib Fdr On	B-N Seal Air On, 2.6" Δ P
1-AN	01/16/79	69" WC, A-N Vib Fdr On	A-N Seal Air On, 1.1" Δ P
1-AS	01/16/79	70.5" WC, A-S Vib Fdr On	A-S Seal Air On, 2.5" Δ P
1-BS	01/16/79	70" WC, B-S Vib Fdr On	B-S Seal Air On, 1.6" Δ P
1-CS	01/16/79	70" WC, C-S Vib Fdr On	C-S Seal Air On, 1.9" Δ P
2	01/16/79	70" WC, D, C-S Vib Fdrs	No Seal Air
3	01/16/79	69" WC, D, C-N+S, B-N	No Seal Air
4	01/17/79	69.5 WC, A-N+S Vib Fdrs	No Seal Air
5	01/17/79	70" WC, A+B-N+S	No Seal Air
6	01/17/79	69" WC, A, B + C N+S	No Seal Air
7	01/17/79	69" WC, All Vib Fdrs	No Seal Air
8	01/17/79	69" WC, All Vib Fdrs	Seal Air On
9	01/17/79	69" WC, D, C-N+S Vib Fdrs	No Seal Air, Burners Unblanked

Exhibit 5

RUN	DATE	CONDITIONS	COMMENTS
1	2/8/79	A,B,C & D OPEN 80%	30" WC COMBUSTION AIR PRESS
2	2/8/79	A,B,C OPEN 80%, D 0%	30" WC COMBUSTION AIR PRESS
3	2/8/79	A,C OPEN 80%, B,D 0%	30" WC COMBUSTION AIR PRESS
4	2/8/79	C OPEN 80%, A,B,D 0%	30" WC COMBUSTION AIR PRESS
5	2/11/79	A OPEN 100%, B,C,D CAPPED	30" WC COMBUSTION AIR PRESS
6	2/11/79	A OPEN 50%, B,C,D CAPPED	30" WC COMBUSTION AIR PRESS
7	2/13/79	A,B, OPEN 80%, C,D CAPPED	30" WC COMBUSTION AIR PRESS
8	2/13/79	A 80%, B 40%, C,D CAPPED	30" WC COMBUSTION AIR PRESS
9	2/13/79	A 80%, B 20%, C,D CAPPED	30" WC COMBUSTION AIR PRESS
10	2/13/79	A,B,C OPEN 80%, D CAPPED	30" WC COMBUSTION AIR PRESS
11	2/13/79	A,B, 80%, C 40%, D CAPPED	30" WC COMBUSTION AIR PRESS
12	2/13/79	A,B, 80%, C 20%, D CAPPED	30" WC COMBUSTION AIR PRESS
13	2/15/79	A,B,D OPEN 80%, C 0%	30" WC COMBUSTION AIR PRESS
14	2/15/79	A,B, 80%, C 0%, D 100%	30" WC COMBUSTION AIR PRESS
15	2/15/79	A,B, 80%, C 0%, D 100%	40" WC COMBUSTION AIR PRESS
16	2/15/79	A 80%, B,C,D 0%	60" WC COMBUSTION AIR PRESS

FD-ID FAN TESTS CONDITIONS & COMMENTS

Exhibit 6

Main Air Sampling Location

Duct Dimensions - 7' X 7'6" (84" X 90")

Diameters (Equivalent) - 86.9"

Number of Sampling Points - 30

Main Air Duct Sampling Configuration

Aux Air Sampling Location

Circular Duct - ID = 19.25"
 Number of Sampling Points = 20

Aux Air Duct Sampling Location

Traverse Point Number on Diameter	Traverse Point Location on Diameter (Inches)
1	1.0
2	1.6
3	2.8
4	4.4
5	6.6
6	12.7
7	14.9
8	16.4
9	17.7
10	18.2

Aux FD Fan Pitot-Venturi

EXHIBIT 11

VIB FEEDER PAIR F. FLOWS

0.25 in.

1.00 in.

EXHIBIT 12

Airfoil Flowrates

A CELL ANNUAL FLOW RATES

B Cell Annular Airflow

EXHIBIT 15

D Cell Analyzer Airflow

A CELL GRIDPLATE AIRFLOW

B Cell Gridplate Airflow

C CELL GRIDPLATE AIRFLOW

D Cell Gridplate

MAIN CELL ANNUAL AIRFLOW

D Cell Pilot-Venturi

EXHIBIT 22

1. Until further testing can be performed on gridplate ΔP vs. airflow, this measurement should not be used with a "hot" cell. Based on data accumulated at Alexandria, this function changes greatly between hot and cold conditions. Further tests will be performed on gridplate ΔP as the unit is placed in service.
2. Due to leakage rates through A cell, A cell dampers should be blanked prior to testing.
3. Aux FD fan seal air should remain valved out during testing. This will not inhibit unit operation and will result in less error in total airflow.

Based on a review of all data, the expected error is $\pm 5\%$.

Damper leakages for each cell are as follows:

CELL	LEAKAGE (lb/hr)
A	30,000
B	29,500
C	23,000
D	12,400

3.5.2 Belt Feeder Tests Complete

All belt feeder calibration tests have been completed. The feeders were calibrated so that the following three readings would agree as closely as possible:

- a. Control Room Hand/Auto % Setting
- b. SCR Motor Voltage
- c. Strip Chart in Control Room

Each of these was compared to an empirical value, i.e., the actual weight of coal in order to generate a curve of "Lbs/hr Coal Feed" vs. "Hand/Auto % Setting".

3.5.3 Fuel and Sorbent

During the first quarter of 1979, 1314 tons of coal and 719 tons of limestone were delivered to the MFB. The following table summarizes the as-received qualities of the coal:

COAL	
Total Moisture	2.05%
Carbon	71.16%
Hydrogen	5.16%
Sulfur	2.91%
Ash	15.05%
Heating Value (Btu/lb)	12,717

3.5.4 Test Plan

Final preparations for the upcoming emissions and performance test plan were finalized. Items such as staffing, gas analysis, organization, computer programs, etc., were completed. A summary list follows:

- a. Approximately 25 part-time temporary employees were hired to do isokinetic work and data gathering.
- b. Solids sampling systems were installed and tested.
- c. Rotation counters were installed on limestone and drain rotary feeders.
- d. The Beckman gas analysis system problems have been solved and, in the case of many of the analyzers, redundancy has been added.
- e. Data sheets for the Data Acquisition Periods are complete.
- f. Isokinetic stations have been made ready for use by GCA Corporation and the data technicians.
- g. Computer programs are in final form.

3.5.5 Planning EPA Test Program

Since June, 1978, G.C.A., the central environmental contractor with EPA, has been involved with PER in forming an overall EPA test plan, an extensive set of environmental tests planned for the Rivesville MFB. The purpose of these tests is to analyze the chemical, physical, and biological properties of air and solid waste emissions from the fluidized bed boiler and to study the performance of air pollution control systems as related to fluidized bed combustion. Most of these pollution control tests are being sponsored by the U.S. Environmental Protection Agency, with some corollary tests being done by the U.S. Department of Energy's Lawrence Livermore Laboratory. Also participating will be, Pope, Evans and Robbins, Inc., G.C.A. Corporation, Southern Research Institute, and Acurex Corporation.

During the interim period, PER discussed and acted upon unresolved items, particularly the responsibilities of the participants. A meeting was held on 28 February 1979 at Morgantown Energy Research Center, to review and comment on the submitted EPA Test Program. This meeting was attended by Dr. Bruce Henschel of EPA, Dr. John Wilson of DOE, Dr. Paul Fennelly of GCA and others. It led to the distribution of the draft copy of the Test Plan for Environmental Measurements at the U.S. Department of Energy's Fluidized Bed Combustion Facility, Rivesville, West Virginia (Spring/Summer 1979) which was presented by G.C.A. Corporation and dated 28 March 1979. Comments will be considered and a final version of the test plan submitted in April.

3.5.6 Modernization Engineering

Four major areas of engineering study are underway to upgrade the Rivesville plant. The objective is to provide a more reliable, versatile and environmentally acceptable test facility for long term use. The engineering studies will result in reports that review all options, clearly depict concepts, provide estimates and schedules, provide recommendations and draft purchase specifications.

The four areas of study are:

a. Flue Gas Fabric Filter

Department of Energy in mid-1978 made a commitment to the West Virginia Air Pollution Control Commission that Rivesville would be back-fitted with a baghouse at the earliest opportunity. This is desirable both to ensure compliance during transient conditions (both purposeful and inadvertent) as well as to permit evaluation of this collection technique on a fluidized bed boiler. This study considers alternative numbers of fans and evaluates various equipment arrangements. A report was submitted to DOE January, February and March 1979.

b. Air Cooled Condenser

Independence from MPC's steam and feedwater cycles is a necessity if predictable performance programs are to be accomplished. Independence can best be provided by an air cooled condenser or dry cooling tower. Results of this study were submitted to DOE in January, February and March 1979.

c. Control Room Revision and Expansion

The original instrumentation and control system and physical control room was based on an experimental concept. A further instrumentation package has since been added, but there is little data logging, and the present control room is considerably undersized. A study will review alternate control room arrangements and locations as well as analyze various instrumentation, controls, and data gathering schemes. The study will be complete by May 1979.

d. Coal Delivery, Unloading, Handling Systems

It is generally recognized that sharing of uncertain coal handling facilities with MPC has been a serious bottleneck. Possibilities for independent facilities are limited by the site layout. A report on various options will be completed during April 1979.

3.5.7 Operations

At 0520 hrs 12 March check-off began for CBC start-up. At 1031 hrs both burners were established and the gradual increase of bed temperature began. After two 500 lb. coal charges, at 1146 and 1305 hrs, bed temperatures were increasing very rapidly. Coal feed was established at 1425 hrs. Good stack conditions were observed. The burners were backed off and the precipitator energized. At 1550 hrs coal feed was discontinued due to a suspected clinker formation in the northwest corner of the cell. The unit was cooled and the clinkers removed from the CBC.

At 2105 hrs 14 March the fuel oil burners were at high fire and preparations made to light off D cell. After 32 hours of firing oil, D cell was finally ignited with coal. The lag time was due to many problems with the Trane burners and difficulty fluidizing with cold air.

On 15 March at 1812 hrs CBC coal fire was established. Bed height was increased to 30" (static) and held until 0455 hrs 16 March when C cell was ignited. At 0622 hrs Monongahela Power Company called and ordered the MFB out of service due to low water levels in their deaeration tank and surge tank. Later, with permission to relight CBC, coal fire was once again established at 0834 hrs. Preparations were made to relight C cell, but found that DC-1 flyash transport system had malfunctioned and needed repairing before relighting C cell. At 2249 hrs, 16 March, coal fires were established in C cell and maintained until 0840 hrs the following day, when both cells were shut down to repair a broken spring and replace the rheostat on CBC vibrating feeder.

At 1945 hrs 17 March these repairs were completed and coal fires were again established in CBC. At 2310 hrs 17 March, C cell was re-ignited on coal and fires maintained until 0404 hrs 18 March. Coal fire was interrupted to C cell due to low auxiliary air flow on feed tubes. At 1108 hrs 18 March coal fire in C cell was re-established and maintained until 1250 hrs that day when coal flow was again lost to Cell C. Problem appears to have been coal jamming at the inlet of the vibrating feeders. At 1330 hrs coal fire was banked in the CBC and the unit cooled for scheduled inspections.

After a short outage and unit inspection, the MFB was placed back into service at 0645 hrs on 20 March with coal ignition in the CBC. During the inspection, the general condition of the unit was found to be good with the exception of minor mechanical problems with auxiliary equipment. Additional sealing was done at the south-east corner of the CBC air distributor.

At 1220 hrs, the D-C slide gate was opened and a coal fire was established in cell C. During the afternoon and evening, operation was hampered by flyash conveying problems. By 2200 hrs, these appeared solved. At 2000 hrs, an attempt was made to reinject flyash and from initial indications (oxygen, bed temperature) there was some reinjection. A high hopper level in DC-1 prevented further testing and at 2030 hrs, the reinjection system was secured. The unit maintained steady state operation until 0405 hrs 21 March, when the CBC vibrating feeder motor and rheostat burned out. The problem was in the B phase of the circuit. C cell remained on line with the CBC slumped.

During the time of C cell operation, the D cell vibrating feeder motor and rheostat were repaired and tested for proper operation and the flyash reinjection system was cleaned out.

Also during operation of C cell alone it was found that operating static bed heights greater than 25" contributed to coal feed problems by causing bridging above belt feeders. Once the bed height was lowered to 24", steady state operation was maintained with no problems. At 1427 hrs on 21 March the fuel oil burners were lit in order to re-light D cell. At 1452 hrs the unit received a master fuel trip (MFT) which trips all running equipment. The alarm indication was FD and ID fan power loss.

As fan power had not been lost, all equipment was restarted and coal fires in D and D cells were re-established by 1506 Hrs. The Control Room was notified that the cause of the trip was due to a loose connection on the FD and ID fan power loss relays.

A second MFT was experienced at 1520 hrs while repairing wiring problems. Coal fires were re-established at 1526 hrs and the unit was brought back to stable conditions.

The unit maintained steady state conditions and flyash reinjection was attempted at 1840 hrs. At 2225 hrs the reinjection system was shut down since it was evident that the system was deficient in transporting material.

At 0720 hrs on 22 March, coal feed was cut to C cell and the cell taken out of operation due to a low Mon Power condensate tank level. The MFB usage rate coupled with Mon Power's restriction on the raw water supply to the portable demineralizers does not permit 24 hour 2 cell operation.

The CBC maintained steady operation until 0120 hrs 23 March when the vibrating feeder (VF-DE) suddenly quit operating. The cell was slumped and the problem was found to be exposed wires in the motor. At 0528 hrs a coal fire was re-established in D cell. Two hours later a coal fire was established in C cell.

Flyash reinjection was attempted at 0840 hrs and looked promising. Coal feed was cut back and temperatures appeared good. Reinjection continued until 1006 hrs when DC #1 showed a high level alarm.

At 1315 hrs a coal fire was established in B cell to be ended forty minutes later by a main fuel trip and a gihh steam trip. All cells were shut down. The fans were racked out at 0555 hrs 24 March and a weekend inspection of the unit began.

During the weekend a number of items were repaired including the precipitator. C and D cell limestone rotary feeders were tested and calibrated. On 26 March the unit was released for service but start up was deferred until 28 March due to a Mon Power tube leak in Boiler #7.

On 28 March PER was notified not to start up, this time due to problems with the Mon Power flyash system which threatened to shut down both their boilers.

At 1600 hrs 28 March release was granted to the MFB for start-up. Once again Boiler #7 developed a tube leak, this time a very serious superheater leak. The unit was out of service for the remainder of the month.

3.5.8 FD Fan Failure

On March 13, 1979, at 2200 hrs, a failure of the auxiliary FD motor starter was reported and the following recorded in the daily log book:

"Attempted to start Aux. F.D. Fan, starter blew out, blowing door open. M.C.C.A., Section A main breaker tripped."

Maintenance report, dated March 13, 1979, regarding incident states in part:

"During our investigation of the Aux. F.D. Fan starter, we found the main line contacts severely burned and the main coil fuses blown."

It turns out that the curves of acceleration and thermal overload relay cross each other. While the motor acceleration time is 46 seconds, the thermal overload relay will trip in 15 to 20 seconds. Present operational procedure is to start the Aux. FD fan and when the thermal overload trips, to reset it while the fan is still rotating, and restart the motor. While this procedure permits the fan to be started, it has a damaging effect on the starting equipment and motor. Briefly, this is what happens when an attempt is made to restart the motor while it is still rotating. The instant the motor is disconnected (tripped), it acts as a self excited generator that delivers substantial amounts of current because the magnetic flux within the air gap does not collapse immediately. The resulting residual voltage decreases in amplitude exponentially. The length of time it takes for the residual voltage to drop to zero, depends on the motor's open circuit time constant. In addition to the residual voltage decreasing, the phase angle between the motor voltage and supply voltage changes. Reconnecting a motor to a power source while the motor residual voltage is high (the motor rotating at substantial speed at the instant of reconnection), results in extremely high inrush currents which can lead to breaker tripping, starter contact burning, motor damage and coupling damage.

3.5.9 Foster Wheeler Development Corporation's Metallurgical Examination (Phase II)

In February 1978 Phase I of a Materials Surveillance Program was conducted by Foster Wheeler Development Corporation (FWDC) for tube and tube support materials in the Rivesville Multi-cell Fluidized Bed Boiler (MFBB). A complete metallurgical analysis of sixty-eight (68) samples was performed. In addition, tube diameter and wall thickness measurements were taken to establish a bases of comparison for future measurements, and a comparison of subsequent wall thickness measurements against the base values would give some indication of fireside corrosion if it occurred.

In September 1978 a Phase II program was proposed by FWDC. The primary objectives of the Phase II analysis were twofold:

- a. To determine if any deleterious effects occurred during the operating period following the Phase I study and,
- b. To ascertain if the boiler components suffered metallurgical damage because of the air preheater fire which occurred on August 9, 1978.

During the week of November 6-10, 1978, a total of thirty-nine samples were removed from selected areas in Cells A, B, and C. The samples included twenty-eight (28) boat-types from waterwall, boiler, and superheater tubes, eight (8) corners from ladder supports, and three (3) wedges from slide gates. These samples were submitted for complete analysis and the results compared with those of the Phase I program. Tube diameter and ultrasonic thickness measurements were made at the sites of the Phase I tests to determine the amount of general fireside tube corrosion which may have occurred.

Most of the current readings revealed a small difference when compared to the initial measurements; this difference being less than 0.5%. These differences were probably the result of deposits on the surfaces which could not be seen and/or removed.

In general, no significant deterioration of any of the sampling locations was observed since the Phase I study. The unit had operated the following hours since the Phase I study:

A Cell	3 hours
B Cell	240 hours
C Cell	465 hours
D Cell	1050 hours

POPE, EVANS AND ROBBINS, INC.
RIVESVILLE, WEST VIRGINIA

MFB Quarterly Operating Summary

Period January-March

OPERATING HOURS

	<u>Quarter</u>	<u>To Date</u>
(Light-off Burner - Oil Fired)- CBC	<u>37.33</u> hrs.	<u>1,566.33</u> hrs.
Coal Fired - CBC	<u>118.51</u> hrs.	<u>2,364.06</u> hrs.
- C Cell	<u>67.18</u> hrs.	<u>798.75</u> hrs.
- B Cell	<u>.67</u> hrs.	<u>346.57</u> hrs.
- A Cell	<u>0</u> hrs.	<u>5.75</u> hrs.
Commercial Operation	<u>0</u> hrs.	<u>192.10</u> hrs.

Total Coal Consumption	<u>980,153</u> lbs.	<u>490.08</u> Tons
Total Sorbent Consumption	<u>330,000</u> lbs.	<u>165.00</u> Tons
Approximate Feedwater Consumption	<u>11,457,669</u> lbs.	<u>1,364,316</u> gals.
Approximate Steam Vented	<u>9,262,330</u> lbs.	<u>1,110,991</u> gals. of BFW
Approximate Blow Down	<u>2,030,950</u> lbs.	<u>243,607</u> gals. of BFW
Commercial Steam Generation	<u>0</u> lbs.	<u>0</u> gals. of BFW
Total Fuel Oil Consumption		<u>10,856</u> gals.
Demineralized Water Credit		<u>1,247,890</u> gals.

Number of Starts

CBC	<u>7</u>
C Cell	<u>7</u>
B Cell	<u>1</u>
A Cell	<u>0</u>

Multicell Operation

D	<u>61.97</u> hrs.
DC	<u>55.87</u> hrs.
DCB	<u>.67</u> hrs.
DCEA	<u>0</u> hrs.

10.64 hrs in C only.

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 Stack Silencer Installation

Based on a review of calculations prepared by S&W on the stability of the existing stack with the new silencer, it was determined that the critical wind velocity (for instability) was greater than the 50 year maximum recorded in the Rivesville area. Maximum wind velocities recorded for the period 1974 through 1978 in the Rivesville area were obtained from NOAA and indicated recorded velocities were below the calculated critical velocity. Rivesville operations was advised that structural reinforcing of the stack due to the addition of the silencer was not required.

4.2 Redundancy Study

A study was conducted to evaluate the feasibility and costs for FD and ID fan redundancy and selective use of the ESP or baghouse. General arrangement drawings and cost estimates were prepared for four alternate configurations. The alternates were evaluated and the study recommending the lowest cost scheme was released for review.

4.3 Rotex Screen Relocation

To minimize degradation of delivered coal by the plant handling and transport systems, the 102 ft. horizontal Redler conveyor was replaced by a 24 in. by 75 ft. belt conveyor; the Rotex screen was relocated to the head of the belt conveyor and the crusher relocated adjacent to the screen. This necessitated changes in the existing structural support system which was checked for adequacy and new members added. Design calculations were up-dated and drawings revised to reflect the changes.

4.4 EPA Particulate Control Test

Stress analysis for the 6 in. and 10 in. duct runs with and without expansion joints was completed. Results indicated that expansion joints were required to avoid overstress. Drawings were prepared of piping arrangements which included expansion joints, guides and anchors to reduce stresses to allowable limits and released for construction.

4.5 Steam Vent Silencer Extensions

Extensions to the existing steam vent silencers were recommended by S&W to reduce ambient noise levels. Based on a sketch prepared by S&W, and thrust loads from the silencer vendor, silencer supports and guides were designed and a construction drawing prepared.

4.6 Control Room Modification

Structural information regarding the modifications required for extension of the present control room was provided S&W for two alternate arrangements under consideration.

4.7 Central Vacuum Cleaning System

Preliminary designs for a central vacuum system for the MFB Plant were prepared along with a budgetary cost estimate. The prepared material was released for review and evaluation.

4.8 Instrument Shop

The proposed location of the Instrument Shop at El. 911' - 11¹/₄", east of the existing MPC elevator was reviewed. Design sketches of additional structural framing required were released to Rivesville operations for implementation.

5.0 SUBCONTRACT ACTIVITIES

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

Stone & Webster provided support in areas directly related to startup activities. Particular attention was directed to FD and ID fan startup. Final bid specifications for the Fabric Filter (Baghouse) and for major equipment purchases for the Turbine Bypass System were completed. A report entitled "Particulate Emission Control and Draft Equipment Modernization" i.e., Baghouse study was issued. During this period the bulk of S&W work was concentrated on modernization studies to be implemented during the summer outage.

BOSTON OFFICE ACTIVITIES

Noise Review (EDR-02)

Coordinated procurement and installation of FD & ID fan vibration instrumentation. Readings were taken at site to establish baseline data. Data was analyzed and baseline parameters set. Noise requirements were established for the Air Cooled Condenser Specification and noise control options for the Turbine Bypass System were defined.

Coal Delivery and Injection System (EDR-08)

Studies were completed related to coal and limestone distribution and injection systems and coal and limestone feed to bunkers. Final draft in preparation for submittal.

Turbine Bypass System (EDR-10)

Conceptual design of the bypass system was completed. Final bid specifications for purchase of major equipment were submitted to PER. Engineers visited site to review the proposed installation location and to develop structural input for geotechnical design criteria. Preparation of the Boiler Feed Pump Specification was started as backup should the effort to locate a used pump and motor be unsuccessful.

Control Room Modernization (EDR-14)

MFB operating personnel were interviewed to develop location of controls for new main control panel and additional control requirements. Listings were developed of instrumentation by system to optimize plant operating efficiency. Alternate board layouts were discussed with PER. Preliminary layouts were developed together with control board design to provide improved functional arrangement and to determine optimum control room size. Arrangements were made for an April 5 meeting to discuss the philosophical and practical aspects of the Control Room Modernization effort.

DC-1 Bypass (EDR-16)

Prepared and issued engineering sketches detailing the modifications and duct fabrication work required to install the new bypass damper in the existing DC-1 ductwork. Control circuits and hardware for damper control were provided and a design drawing developed from engineering sketches.

General Arrangements and Site Plan (EDR-17)

General Arrangement and Site Plan drawings were issued on January 31.

Review Baghouse Installation (EDR-23)

Final copies of "Particulate Emission Control and Draft Equipment Modernization" study issued on February 20. Fabric Filter Bid Specification (Baghouse) were issued to PER.

FIELD ACTIVITIES

Precipitator Review (EDR-05)

Assisted vendor in installation and checkout of nuclear source heads for precipitator hopper level detectors. Supervised modifications to assure correct operation of equipment.

CBC Flyash Reinjection System (EDR-09)

Assisted in modification work on Flyash Reinjection System. Tested system and modified to meet design requirements.

Water Requirements for Ecolochem Demineralizers (FR-15)

Routed supply and discharge lines for the Ecolochem demineralizer headers.

Water Supply for the APH Deluge System (FR-20)

Supported design, procurement, installation and check-out of the deluge system.

APH & Plenum Drains (FR-24)

Assisted in procurement and installation of the APH & Plenum Drains Systems.

Bed Material Letdown System (EDR-13)

Assisted in conversion of Bed Material Letdown System to vacuum operation.

Medium Pressure Steam System Review (FR-32)

Designed and specified material for precipitator hopper steam heaters.

Results

Results activities centered on set up and performance tests of coal feeders, auxiliary air and main air. Verification analysis of performance calculation equations was undertaken. Discussed and implemented with PER personnel, recommended revisions to performance calculations in computer program. Completed partial verification of computer changes vs. hand calculation. Participated in testing program dry runs at site. Updated Test Plan.

Safety

Conducted daily safety tours of the plant and investigations of minor accidents. Discussed unsatisfactory safety areas at 2 February Staff Meeting. Conducted a fire drill on 14 March. Attended DOE meeting in Morgantown relative to unsafe conditions and responsible supervisors were notified verbally or in writing of violations.

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 fabrication of replacement air distributors for Cell D was completed and units delivered to Rivesville for installation; engineering evaluation of full load and part load performance of the Rivesville MFB steam generator were conducted; a Materials Surveillance Report based on metallurgical samples taken from the Rivesville MFB unit was completed and issued.

Systems Modification

The replacement air distributor for the Rivesville MFB Cell D was delivered to the jobsite on 5 January and subsequently installed by field personnel. Minor fit up problems were corrected and fabrication drawings for Cells C and B replacement grids corrected to avoid recurrence.

Laboratory evaluation of metallurgical samples taken from the Rivesville steam generator was completed. A report of the results was completed and issued to PER and DOE.

Conceptual designs and a cost estimate were prepared for fabrication of economizer baffles for the Rivesville MFB unit and submitted to PER for evaluation.

Systems Evaluation

Work continued on evaluation of the Rivesville MFB performance at full load and part load conditions. Evaluation at full load operating condition, three cell operation and service conditions has been completed and is being reviewed for accuracy.

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