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RIVESVILLE MULTICELL FLUIDIZED-BED BOILER

Topical Report: Fuller Feed System Test Program

March 1981

Work Performed Under Contract No. AC21-81MC16230

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

TECHNICAL INFORMATION CENTER
UNITED STATES DEPARTMENT OF ENERGY

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Prepared by

Pope, Evans and Robbins, Incorporated

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For the period March 1981

Prepared for

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

Under Contract No. DE-AC21-81MC16230

Table of Contents

	<u>Section</u>	<u>Page No.</u>
	List of Exhibits	i
1.0	Introduction	iv
2.0	Fuller Feed System Operation and Control	1
2.1	General Operation	1
2.2	System Control	2
3.0	Installation of the Fuller Feed Systems	3
3.1	System Installation	3
3.2	Equipment Costs and Labor Requirements	3
4.0	Testing	5
4.1	General	5
4.2	System Reliability and Performance	5
4.2.1	Startup and General Operation	5
4.2.2	System Derived Problems	6
4.2.3	Air Leakage To Feed Control Points	7
4.2.4	System Derived Down Time Versus System Operating Time	8
4.2.5	Performance of the Flow Splitters	8
4.3	System Durability	9
4.4	System Effects on Fluid Bed Operation	10
5.0	Conclusions and Recommendations	12

List of Exhibits

Exhibit No.	Description
1	Schematic of Fuller Feed System
2	Fuller Feed System Installation; Plan View
3	Fuller Feed System Installation; Side View
4	Installation of Fuller-Kinyon screw pumps; looking north
5	Close up of south Fuller-Kinyon screw pump
6	Breaker installation for screw pumps and rotary feeders
7	Typical installation of constant speed rotary feeder
8	South side splitter arrangement
9	Vent barrel installation
10	Compressor installation and inlet baghouse
11	Compressor installation and cooling water radiator
12	Installation of compressor and cooling water system starters
13	Fuller compressor blowoff valve arrangement
14	Fuller feed system test arrangement
15	Fuller feed system distribution test results; north side 12/79
16	Fuller feed system distribution test results; south side 12/79
17	Size analysis of coal discharging Fuller system 12/79

List of Exhibits (con't.)

Exhibit No.	Description
18	Fuller feed system distribution test results; north side 8/80
19	Fuller feed system distribution test results; south side 8/80
20	Comparison of Fuller feed system distribution tests
21	Size analysis of coal discharging Fuller system 8/80
22	Fuller-Kinyon screw pump shaft measurements
23	Fuller-Kinyon screw pump casing measurements
24	Fuller feed system splitter internal measurements
25	Fuller feed system splitter orifice nozzle measurements
26	Close up of south Fuller feed system splitter
27	Close up of splitter cone; south side
28	Base of south splitter cone
29	Divider plate from south splitter
30	Close up of south splitter divider plate
31	North screw pump shaft
32	Close up of north screw pump shaft
33	Close up of north screw pump shaft
34	North screw pump casing
35	Close up of north screw pump casing
36	South screw pump shaft

List of Exhibits (con t.)

Exhibit No.	Description
37	Close up of south screw pump shaft
38	Close up of south screw pump shaft
39	Close up of south screw pump casing
40	C cell gas traverse ports and feed needles
41	%O ₂ gas traverse of C cell at 80 fps
42	%CO ₂ gas traverse of C cell at 80 fps
43	Ppm CO gas traverse of C cell at 80 fps
44	Ppm hydrocarbons gas traverse of C cell at 80 fps
45	Temperature (°F) traverse of C cell at 80 fps
46	%O ₂ gas traverse of C cell at 50 fps
47	%CO ₂ gas traverse of C cell at 50 fps
48	Ppm CO gas traverse of C cell at 50 fps
49	Ppm hydrocarbons gas traverse of C cell at 50 fps
50	Temperature (°F) traverse of C cell at 50 fps

1.0 Introduction

One objective of the experimental MFB at Rivesville, WV, was the evaluation of alternate feed systems for injecting coal and limestone into a fluidized bed. A continuous, uniform feed flow to the fluid bed is essential in order to maintain stable operations. The feed system originally installed on the MFB was a gravity feed system with an air assist to help overcome the back pressure created by the fluid bed. The system contained belt, vibrating, and rotary feeders which have been proven adequate in other material handling applications. This system, while usable, had several operational and feeding problems during the MFB testing. A major portion of these problems occurred because the coal and limestone feed control points; a belt feeder and rotary feeder, respectively; were pressurized in the air assist system. These control points were not designed for pressurized service. An alternate feed system which could accept feed from the two control points, split the feed into six equal parts and eliminate the problems of the pressurized system was sought.

An alternate feed system designed and built by the Fuller Company was installed and tested at the Rivesville facility. Fuller feed systems were installed on the north and south side of 'C' cell at the Rivesville facility. The systems were designed to handle 10,000 lb/hr of coal and limestone apiece. The systems were installed in late 1979 and evaluated from December 1979 to December 1980. During this time period, nearly 1,000 hours of operating time was accumulated on each system.

2.0 Fuller Feed System Operation and Control

2.1 General Operation

Two identical Fuller feed systems were installed on 'C' cell, one to feed the north side and one to feed the south side. Each system received coal and limestone in an identical manner. However, because of space limitations, the feed for the south side came through the 'A' north control points. Exhibit 1 shows a schematic of the feed systems.

Each Fuller system received coal and limestone in a combined stream. Coal coming out of a storage bin was controlled by a variable speed weigh belt. Limestone was controlled by a variable speed rotary feeder. The limestone then passed through a constant speed rotary feeder which served as an airlock. The coal and limestone flows mixed prior to entering a constant speed rotary feeder, which provided an even feed flow to the screw pump hopper. Approximately 1/2" Hg vacuum is maintained within the pump hopper to accomodate the air displaced by the feed material falling from the rotary feeder.

The screw inside the Fuller-Kinyon pump compresses the feed mixture against a weighted flapper valve. The combination of the compressed coal/limestone and the flapper valve form a dynamic air seal. The feed material moves into a mixing chamber where compressed air flow sufficient to fluidize the mixture is introduced through a series of nozzles. The fluidization permits pumping of the material through a transport line connected to the end of the mixing chamber.

The coal/limestone mixture, now in the transport air stream is lifted vertically into a six-way conical splitter. A cone in the center of the uniform air flow forces the material outward toward the walls of the splitter where six orifices are evenly spaced around the perimeter. The size of these orifices is variable and to insure an even distribution, they can be adjusted during a pre-operation calibration period. Once the mixture leaves the splitter, it enters the furnace via the original feed tubes at a velocity consistent with necessary operating procedures.

Each of the two pumps is supplied compressed air by separate air compressors; the intakes of which are manifolded into a single intake filter which insures clean air to both compressors. The filter is cleaned by manual operation during periods of no operation.

A single closed-loop cooling water system consisting of a water pump, storage tank, and a forced air radiator is employed to maintain specified operating temperatures at both compressors' bearings.

2.2 System Control

The overall control of the rate of coal flow to each pump is determined by the speed of the weigh belt, a variable controllable from the boiler control panel. As for the limestone flow rate to the pump, the adjustable RPM's of the limestone rotary feeders allow control of sorbent flow. Both the screw pumps and their associated rotary feeders are operated at constant speeds, thereby not affecting the control of the system.

Because the 'A' cell north belt feeder supplied coal to the south side of 'C' cell, the appropriate label changes were made in the control room. The same is true of the limestone rotary feeders. Both the 'A' cell belt feeder and the limestone rotary feeder required calibration before start-up.

The wiring of the system incorporated an electrical interlock system dictating an exact component startup sequence. The compressor cooling loop must be started first. Lack of proper water or oil flow prohibits the compressors being started. The compressors are then started to supply the Fuller pumps with necessary purge air. After the compressors are running; the pumps, vent hopper fans, pump rotary feeders, and finally, the coal belt feeders and limestone rotary feeders are started, in that order. Failure of any piece of equipment will trip the entire system, in reverse order, to protect the equipment.

3.0 Installation of the Fuller Feed Systems

3.1 System Installation

Exhibits 2 and 3 show plan and elevation drawings of the Fuller feed systems, with respect to the MFB.

Illustrations of actual equipment installation are:

- Exhibit 4 - Both Fuller-Kinyon screw pumps located underneath the MFB, looking north. The north side screw pump is located on the right.
- Exhibit 5 - View of the south side Fuller-Kinyon screw pump.
- Exhibit 6 - Breaker installation for north and south side screw pumps and rotary feeders.
- Exhibit 7 - Typical installation of constant speed rotary feeder.
- Exhibit 8 - South side splitter arrangement.
- Exhibit 9 - Vent barrel installation.
- Exhibit 10 - Compressor installation with inlet baghouse in background (left).
- Exhibit 11 - Compressor installation. South side compressor in foreground cooling water radiator also in foreground.
- Exhibit 12 - Installation of compressor and cooling water system starters.

3.2 Equipment Costs and Labor Requirements

The Fuller Company supplied the following equipment:

- 2 - 150 M Type Fuller Pumps, complete with V-belt drive assemblies and guards.
- 2 - C150 Fuller Compressors complete with standard accessories.

- 2 - 75 Hp 1800 rpm Motors (for compressors) with slide bases.
- 2 - Fuller Rotary Feeders with 1½ Hp motors.
- 2 - Fuller In-Line (six-way) splitters.
- 2 - Vented Pump Hopper Extensions
- 2 - 50 Hp 1200rpm Motors (for pumps) with slide bases.
- 1 - BC Intake Filter.
- 1 - Fan with 2 Hp motor.
- 1 - Self Contained Compressor Water Cooling Unit.

The cost of this equipment was \$73,432. This cost did not include one (1) pump and one (1) splitter, which were supplied by the Fuller Company at no charge because of the experimental nature of the project.

Miscellaneous electrical equipment, piping and hardware cost an extra \$16,752.

The labor force required to install the two feed systems, including all conveying lines and electrical work was:

Ironworkers	105 man-hours
Pipefitters	2,200 man-hours
Electricians	945 man-hours
<hr/>	
TOTAL	3,250 man-hours

Total labor cost was approximately \$60,000.

4.0 Testing

4.1 General

In order to fully evaluate the performance of the two Fuller feed systems with respect to fluid bed operation, a detailed test plan was developed by the members of the Fuller Company and Pope, Evans and Robbins. This test plan, shown in Appendix I, dealt with three main areas of performance; reliability, durability, and effects on a fluid bed. Each area of performance was then broken down into specific studies. Test procedures and results for each area are presented in this section.

4.2 System Reliability and Performance

This section deals with actual operation of the two Fuller feed systems. Areas of study in this section include:

1. Start-up and general operation of the Fuller feed systems. This area will encompass systems operational difficulties, as encountered by the operations group.
2. System derived problems. A study of all problems and their solutions of the Fuller feed systems encountered during the testing period.
3. Monitoring of air leakage to coal and limestone feed control points.
4. System down-time versus system operating time. A study of unit down time caused by failure of the Fuller feed systems.
5. Performance of the flow splitters. The ability of the flow splitters to evenly distribute material.

4.2.1 Startup and General Operation

Startup and operational procedures for the Fuller feed systems were detailed by the vendor. These procedures, shown in Appendix II, were followed by PER operations personnel. The use of these procedures provided quick and easy startup of the system and nearly trouble-free operation.

During the initial startup period several minor problems were encountered. These problems were mostly the result of improper installation. Some typical problems encountered during the initial periods of operation of the Fuller feed systems were:

- Improper alignment of motors and motor-driver equipment.
- Installation of improperly set zero speed switches on rotary feeders.

4.2.2 System Derived Problems

During the test period, three distinct system derived problems emerged; 1) plugging of the hopper vent lines, 2) excessive noise generated in the area of the two air compressors, and 3) excessive wear of all elbows on the transport side.

The problems with the hopper vent line pluggage was caused by low air velocities in the horizontal leg of the vent piping to the receiver drums. The extremely low velocity in this area allowed material to drop out and, eventually, plug the line. Studies of this problem revealed the material within the vent line was extremely fine. Also, velocities were so low that they could not be measured with a standard pitot arrangement. The cause of the low velocity was determined as the actual piping configuration.

As a result of the extremely fine particles involved, it was necessary to put a filtering device on the barrel atmospheric discharge. A filter bag was used for filtering. This was, however, inadequate. The final solution was two filtering bags on the discharge of each barrel.

The excessive noise in the compressor area seems to be inherent to the compressors being used. This noise, while not actually measured, was extremely troublesome to personnel working in the immediate area. No solution was effected for this problem.

The wear through problem developed in March 1980, after approximately 300 hours of system operation. During a 200 hour continuous run, elbows in both the transport lines and feed needles started to wear through and leak to the atmosphere. On-line repairs were made, preventing boiler shutdown. After completion of the run, a study was made to determine the cause of elbow deterioration. Results of the study indicated that the degradation of elbows was brought on by excessive transport air velocity.

The original specifications to the Fuller Company stated that feed needle transport velocity should be 80 fps. This would be comparable to feed needle velocities of the pressurized, vibrating feeder system. Test results indicated needle transport velocities of approximately 140 fps, far in excess of design specifications.

In order to correct the high velocity situation, manual blow-off valves were installed on the discharge of each compressor, Exhibit 13. With these valves, air from the compressors could be manually bled off to the atmosphere, thereby reducing needle air velocities. By use of a calibrated annubar in each compressor discharge line, the air flow was adjusted to produce 80 fps needle velocities. At this time, the system operated satisfactorily.

At the request of the Department of Energy (DOE) and the Tennessee Valley Authority (TVA), the system was to be tested at 50 fps, which corresponded to needle velocities proposed for the TVA test facility. Needle velocities were reduced to 50 fps and after a few hours of operation, the south side feed system began demonstrating symptoms of "slug-flow" operation. Soon afterward, a high torque condition existed on the south screw feeder causing a failure of the drive belts. Following unit shutdown, inspection of the south feed system revealed coal to be solidly packed in the screw flights and in the 5" horizontal piping run. Also all six feed needles on the south side were coked, indicating a loss of transport air. A study of the situation revealed that at 50 fps needle velocity, transport velocity in the 6" vertical riser prior to the splitter was insufficient to transport the larger particles of feedstock. A "slug-flow" condition would be present, which would eventually lead to a system pluggage. In order to permit operation at 50 fps needle velocity, the transport velocity in the vertical riser would have to be increased. This was accomplished by replacing the 5" horizontal and 6" vertical riser with 4" sch. 80 pipe. The two feed systems were then operated at 50 fps needle velocity with no problems.

After initial repair of the elbows, ultrasonic measurements of all feed tubes and transport lines were made and periodic checks made to determine the amount of wear. This is reported in another section.

4.2.3 Air Leakage to Feed Control Points

During the test periods, pressure measurements made on the belt feeders feeding the two Fuller feed systems (BF-AN and BF-CN) indicated a pressure of approximately +3" WC. This is

considerably less than the +30" WC pressure experienced with a pressurized vibrating feeder system. It is the opinion of several engineers that the +3" WC pressure is an acceptable condition.

4.2.4 System Derived Down Time Versus System Operating Time

During the test period the only major attributable down time caused by the Fuller feed systems was replacing the 6" vertical risers with 4" risers as described in the previous section. This outage was brought about utilizing the feed systems in a situation for which they were not designed, namely 50 fps needle velocity. There was also some down time as a result of rotary feeders jamming, drive chains binding, etc. These were minor incidents.

4.2.5 Performance of the Flow Splitters

In December 1979, prior to any boiler operation with the Fuller feed system, the mechanical splitters were tested for feed distribution. In order to do this, splitter discharge was directed into six vented barrels, as shown in Exhibit 14. Pressure taps on each splitter discharge point and the splitter inlet were installed in order to obtain pressure drop for each discharge point. This would then be correlated with fuel distribution attained. The barrels were weighed prior to and at the conclusion of each run. Test runs were made at 4000, 6000 and 8000 pounds per hour as indicated by control settings. Samples were taken from the feed bin and each barrel for size analysis.

Distribution results from the splitter tests are shown in Exhibits 15 and 16. From these results it can be said that both north and south side splitters performed within acceptable limits. The distribution could be improved; however, since the distribution was well within limits of vibrating feeder table distribution, the splitter distribution was left as is.

Results of the size analysis of the splitter discharge are shown in Exhibit 17. From these results it can be seen that the feedstock undergoes a considerable size degradation, reducing the mean particle size by about 50%. Also, considerable amounts of fines (-20 mesh) were generated, as much as 40%.

The mechanical feed splitters were again tested for feed distribution in August 1980. At the time the second distribution test was conducted, each Fuller feed system had accumulated better than 800 hours of operation.

Tests were conducted in a similar manner as the first series of tests. Coal feed rates used were the same as the initial tests. During the August 1980 distribution tests, airflow rates were set at three conditions: full flow, 80 fps needle velocity, and 50 fps needle velocity. The full flow tests were to be used for comparison with the initial distribution tests and the 80 fps and 50 fps tests were conducted to observe any discrepancies which might occur at lower air flow rates.

The distribution results from the August 1980 tests are shown in Exhibits 18 and 19. Exhibit 20 shows a comparison of the December 1979 and August 1980 tests. As can be seen from these exhibits, a deterioration of feed distribution had developed. There are three probable explanations for the deterioration of the feed distribution.

1. Splitter wear with normal operation.
2. Slight misalignment of the 4" vertical risers entering the splitter.
3. A combination of splitter wear and riser misalignment.

Test results from the size analyses are shown in Exhibit 21. These results show virtually no change from initial size analyses.

4.3 System Durability

This section of the evaluation of the Fuller feed systems deals with the amount of wear sustained by the screw pumps, feed tubes, and splitters during the course of the test period.

Prior to any operation of the Fuller feed systems, one splitter and one pump had their internals measured at various locations by Fuller personnel. In January 1981, both pumps and splitters were remeasured by Fuller and Pope, Evans and Robbins personnel. Exhibits 22 through 25 show the results of these measurements. In addition to these measurements, the splitter cones were each worn approximately 0.25 inches.

The wear on the splitter cones seems fairly extensive, but would be expected since the cones were made of carbon steel and not treated for heavy wear. With this amount of wear, it appears that the lifetime of a splitter cone would be approximately one year. The nozzle units of both splitter cones also showed signs of wear, especially at the discharge end. Exhibits 26 through 30 show photographs of areas of wear on the internals of the south splitter.

The final measurements of the two screw pumps showed severe wear on the pump shafts. Most of the wear on each shaft was at the discharge end. Vane edges were rounded and in some cases, undercut. The casing of the pump, on the inlet side, indicated a bell mouthed erosion with large ripples continuing down the entire casing. This amount of wear to the pump casing and shaft is very extensive, especially since the pump shafts were treated for heavy, abrasive wear. Exhibits 31 through 39 show photographs of pump casing and shaft wear.

As mentioned earlier in this report, during a 200 hour commercial run in March 1980, the transport pipes and feed needles began to wear through. This occurred after 400 - 500 hours of operation. At that time wear plates were installed on all bends and elbows and were ultrasonically tested for thickness in order to establish baseline data.

After approximately 100 hours of operation, the transport lines and feed tubes were again ultrasonically tested for wear. The results showed severe wear in all 90° elbows of the transport lines. The amount of wear in these areas were approximately 85 mil/100 hrs. Excessive wear in 45° elbows was also observed, approximately 30 mil/100 hrs. Results from the splitter tubes showed some wear but not as extensive. In all cases, transport piping and splitter piping were of carbon steel construction.

4.4 System Effects on Fluid Bed Operation

This section of the Fuller feed system test plan was designed to observe and study the effects, if any, of a Fuller feed system on fluid bed operation. Close attention would be placed on combustion efficiency, sulfur capture, fines generation, etc. Methods for determining these values are discussed in the MFB test plan, located in another text. Comparisons of this data will be made with data prior to Fuller feed installation.

Test results from the feed system test period show one significant effect on fluid bed operation. The effect appears to be a generation of large amounts of CO and hydrocarbons, plus excessive

freeboard burning. The primary cause appears to be the tremendous amount of fines generated by the Fuller system. The smaller particles are not retained sufficiently in the bed for complete burn-up. Their residence time within the bed is such that the volatiles (hydrocarbons) are burned off and CO generated but the particle is not allowed to burn completely before it is quenched in the tube bundle regions. Because of the extremely low residence time in the bed, any burning which occurs would probably occur in the freeboard regions.

The technique used to determine this phenomena was a series of gas traverses, approximately 14 feet above the air distributor, between the above bed and economizer tube bundles, as shown in Exhibit 40. A total of three ports in 'C' cell, each above a feed needle discharge, provides an insight to the combustion process within the cell.

Gas traverses at various needle velocities indicate better combustion at the lower needle velocities, as shown by plots of gas traverses in Exhibits 41 through 50. The lower needle velocities would provide longer residence time within the bed. In order to further increase particle residence time, the feed needles were extended from 9" above the air distributor to 4" above the air distributor.

Although it is felt that the Fuller feed system contributes significantly to combustion problems in 'C' cell, it is not the only source of these problems.

5.0 Conclusions and Recommendations

Based on data obtained, visual observation and experience during the period from December 1979 to December 1980, it appears that the Fuller feed systems are a viable means of injecting coal and limestone into a fluid bed. The systems operated well, with little or no mechanical difficulties. The systems were also able to allow the control points for coal and limestone to operate at near atmospheric design.

The Fuller feed systems proved to be a very reliable method of feeding coal and limestone. Its reliability helped produce a 132 hour continuous commercial operation in February 1980 and a 200 hour continuous commercial operation in March 1980, neither of which had been accomplished earlier. This is not saying that the Fuller feed systems caused the record setting runs, but contributed to the overall performance of the unit.

With a Fuller feed system, however, several matters must be dealt with in order to fully optimize the system's performance in conjunction with a fluidized bed boiler. The first of these matters is degradation of feedstock. With the tremendous amounts of fines generated by the screw pump and the design and configuration of Rivesville 'C' cell, inefficient combustion and freeboard burning were clearly evident. This could be solved in future units by the following:

1. Increased freeboard area.
2. Designs for lower superficial velocities within the beds.
3. Operate with deeper beds.
4. Operate with needle velocities sufficient to overcome the back-pressure caused by the fluid bed, yet allow the majority of particles to remain within the bed.

Another matter to consider is the amount of wear on transport lines, the screw pump and splitter internals. All materials should be able to withstand the highly erosive action of the coal and limestone in transport. Wear plates should probably be installed on all bends and elbows in the transport lines. Operation at reduced velocities will also help reduce wear. From the wear observed at Rivesville, it appears that the length of service of this system is marginal. This could cause problems for larger units and be very costly in terms of time and spare parts required.

A third matter to consider is the cost, both in money and power. Since each system consists of a screw pump, an air compressor, a splitter and a rotary feeder, for a large unit this would be quite costly and very bulky. The power required by the compressors and screw pumps (75 hp and 50 hp, respectively) on a large unit would be prohibitive.

Schematic of Fuller Feed System

Fuller Feed System Installation
Plan View

Fuller Feed System Installation
Side View

Installation of Fuller-Kinyon Screw Pumps; Looking North

Close Up of South Fuller-Kinyon Screw Pump

Breaker Installation For Screw Pumps and Rotary Feeders

Typical Installation of Constant Speed Rotary Feeder

South Side Splitter Arrangement

Exhibit 9

Vent Barrel Installation

Compressor Installation and Inlet Baghouse

Compressor Insatllation and Cooling Water Radiator

Exhibit 12

Installation of Compressor and Cooling Water System Starters

Fuller Compressor Blowoff Valve Arrangement

Fuller Feed System Test Arrangement

Fuller Feed System Distribution Test Results
North Side
12/79

Feed Needle No.	40% Control Setting		80% Control setting	
	Weight Collected lbs.	% of Total Flow	Weight Collected lbs.	% of Total Flow
1	107.0	17	225.5	17
2	97.5	15	239.0	16
3	120.2	19	278.0	19
4	110.5	17	244.0	17
5	101.5	16	231.5	16
6	98.0	15	228.0	15
Total Wt., lbs.	635.0		1476.0	
Average Wt, lbs	105.8		246.0	

Fuller Feed System Distribution Test Results
South Side
12/79

Feed Needle No.	40% Control Setting		60% Control Setting		80% Control setting	
	Weight Collected lbs.	% of Total Flow	Weight Collected lbs.	% of Total Flow	Weight Collected lbs.	% of Total Flow
1	89.5	16	152.5	16	194.0	16
2	86.0	15	157.0	17	189.5	16
3	97.5	17	158.5	17	208.0	17
4	94.0	17	160.0	17	210.0	17
5	97.5	17	160.5	17	211.0	17
6	103.0	18	160.0	17	210.0	17
Total Wt., lbs.	567.5		948.5		1222.5	
Average Wt., lbs	94.6		158.1		203.8	

Screen Size (inches or mesh)	Coal Entering System	Coal Discharging Fuller System				
	N Bin	S 40%	S 60%	S 80%	N 40%	N 80%
+1/2"	0.5%	0.0%	0.5%	0.6%	0.3%	0.2%
-1/2" +1/4"	43.7%	14.8%	17.9%	16.2%	26.9%	20.7%
-1/4" +5	31.6%	22.1%	25.7%	18.5%	27.7%	26.3%
-5 +10	12.6%	21.4%	21.1%	14.8%	18.5%	19.0%
-10 +12	1.2%	2.7%	2.0%	1.7%	2.1%	2.0%
-12 +20	0.4%	8.2%	5.3%	5.4%	6.0%	6.6%
-20	6.8%	30.9%	27.6%	42.8%	18.6%	25.2%
Mn. Size (microns)	2886	1060	1178	852	1552	1252

Size Analysis of Coal Discharging Fuller Systems 12/79

Fuller Feed System Distribution Test Results
North Side
8/80

31

Feed Needle No.	40% Control Setting		60% Control Setting		80% Control Setting		80 fps	50 fps
	Weight Collected lbs.	% of Total Flow	Weight Collected lbs.	% of Total Flow	Weight Collected lbs.	% of Total Flow	% of Total Flow	% of Total Flow
1	142.5	20	152.5	20	138.5	19	20	20
2	149.5	21	161.5	21	146.5	21	20	18
3	135.5	19	150.5	19	136.5	19	19	19
4	101.5	14	105.0	13	97.5	14	14	15
5	89.0	12	93.5	12	88.0	12	12	12
6	108.0	15	119.0	15	107.5	15	15	16
Total Wt.,lbs.	726.0		782.0		714.5		---	---
Average Wt,lbs	121.0		130.3		119.1		---	---

All values presented are for full airflow conditions

Exhibit 18

Fuller Feed System Distribution Test Results
South Side
8/80

Feed Needle No.	40%Control Setting		50%Control Setting		80%Control Setting		80 fps	50 fps
	Weight Collected lbs.	% of Total Flow	Weight Collected lbs.	% of Total Flow	Weight Collected lbs.	% of Total Flow	% of Total Flow	% of Total Flow
1	77.0	14	52.0	14	69.5	14	14	14
2	83.5	15	57.0	16	77.0	15	15	15
3	89.0	16	58.0	16	82.0	16	16	17
4	99.5	18	66.0	18	100.0	20	19	19
5	94.5	17	64.5	18	78.5	16	17	17
6	102.0	19	67.0	18	96.0	19	19	19
Total Wt.,lbs.	545.0		364.5		503.0		----	----
Average Wt,lbs	90.2		60.8		83.8		----	----

All values presented are for full airflow conditions

Comparison of Fuller Feed System Distributuin Tests

Feed Needle No.	North Side		South Side	
	12/79	8/80	12/79	8/80
	% of Total Flow	% of Total Flow	% of Total Flow	% of Total Flow
1	17	20	16	14
2	16	21	16	15
3	19	19	17	16
4	17	14	17	19
5	16	12	17	17
6	15	15	17	19

Screen Size (inches or mesh)	Coal Entering System	Coal Discharging Fuller System					
	N Bin	S 40%	S 60%	S 80%	N 40%	N 60%	N 80%
+1/2"	0.2%	0.1%	0.1%	0.2%	0.2%	1.2%	0.2%
-1/2" +1/4"	32.3%	8.4%	9.6%	8.4%	9.3%	9.0%	10.5%
-1/4" +5	33.2%	11.2%	15.5%	14.3%	14.0%	13.0%	16.0%
-5 +10	17.4%	17.8%	22.2%	22.5%	23.6%	19.5%	23.1%
-10 +12	2.08%	3.8%	3.8%	4.4%	4.8%	10.8%	4.3%
-12 +20	3.5%	13.5%	11.7%	14.0%	14.6%	13.9%	13.2%
-20	11.3%	45.3%	37.3%	35.2%	33.6%	40.2%	32.7%
Mn. Size (microns)	2417	763	887	908	932	803	961

All values shown taken under full airflow conditions

Size Analysis of Coal Discharging Fuller Systems 8/80

Locat	Orig. Meas. in.	North Feeder 1/81	South Feeder 1/81
A	0.637	0.635	0.652
B	0.637	0.445*	0.410*
C	0.637	0.635	0.602
D	0.664	0.445*	0.455
E	4.188	4.182	4.175
F	4.168	4.164	4.020
G	4.223	3.938	4.087*
H	-----	-----	-----
J	-----	-----	-----
K	-----	-----	-----
L	5.859	5.855	5.840
M	0.528	0.565	0.533

*These configurations were not uniformly shaped.

Fuller-Kinyon Screw Pump Shaft Measurements

Locat.	Original Measure. in.	North Feeder 1/81	South Feeder 1/81
N	6.0125	6.250*	6.125*
P	6.0215	6.187	6.125
Q	6.0215	6.125*	6.188
R	5.894	6.008	5.975
S	5.895	5.938	6.905
T	5.894	6.010	5.939

*These configurations were not uniformly shaped.

Fuller-Kinyon Screw Pump Casing Measurements

Location	Initial (South)	1/81 Measurements	
		North	South
1A	2.173	2.200	2.184
1B	2.193	2.195	2.195
2A	2.228	2.195	2.185
2B	2.190	2.195	2.205
3A	2.192	2.162	2.185
3B	2.199	2.165	2.185
4A	2.206	2.215	2.178
4B	2.191	2.198	2.196
5A	2.212	2.250	2.178
5B	2.194	2.240	2.201
6A	2.181	2.218	2.180
6B	2.191	2.185	2.185

Fuller Feed System Splitter Internal Measurements

Location	Initial		1/81 Measurements			
	(South)		North		South	
	Taper	Flat	Taper	Flat	Taper	Flat
1A	2.007	2.004	2.050	2.025	2.020	2.020
1B	2.000	2.007	2.009	2.030	2.001	2.020
2A	2.011	2.010	2.030	2.029	2.020	2.020
2B	2.005	2.010	2.001	2.021	2.000	2.020
3A	2.000	2.004	2.030	2.019	2.020	2.030
3B	2.003	2.004	2.004	2.016	2.002	2.004
4A	2.010	2.001	2.032	2.035	2.019	2.017
4B	2.004	2.011	2.009	2.035	2.012	2.004
5A	2.002	1.993	2.030	2.025	2.025	2.020
5B	2.000	1.997	2.011	2.021	2.024	2.005
6A	2.015	1.996	2.029	2.020	2.025	2.023
6B	1.999	2.000	2.011	2.019	2.022	2.024

Close Up of South Fuller Feed System Splitter

Close Up of Splitter Cone; South Side

Base of South Splitter Cone

Divider Plate From South Splitter

Close Up of South Divider Plate

North Screw Pump Shaft

Close Up of North Screw Pump Shaft

Close Up of North Screw Pump Shaft

Exhibit 34

North Screw Pump Casing

Close Up of North Screw Pump Casing

South Screw Pump Shaft

Close Up of South Screw Pump Shaft

Close Up of South Screw Pump Shaft

Close Up of South Screw Pump Casing

C Cell Gas Traverse Points & Feed Needles

C Cell
 $\% O_2$
 80 fps /w/ header on
 12/9/80

C Cell
CO
80 fps /w/ header on
12/9/80

C Cell
O₂
50 fps /w/ header on
12/9/80

C Cell
% CO₂
50 fps /w/ header on
12/9/80

Exhibit 49

C Cell
HC
50 fps /w/ header on
12/9/80

APPENDIX I
FULLER FEED SYSTEM TEST PLAN

FULLER-KINYON TEST PLAN

1.0 Introduction

The purpose of this test plan is to evaluate the performance of a Fuller-Kinyon feed system in relation to a fluidized bed boiler. This system is currently being installed in the C cell of the Rivesville Multicell Fluidized Bed Boiler.

The Fuller-Kinyon feed system to be tested represents an alternative method for feed distribution in a cell. In essence, this system will replace the vibrating feeders and auxiliary air assist. Figure I shows a schematic of the new system. Coal and limestone will be fed into a constant speed rotary feeder. This rotary feeder does not serve as an air lock, but as a means of supplying a controlled feedrate entering the screw pump. Flow control of coal and limestone will remain with the current belt feeders and limestone feeders, respectively. A vacuum of approximately .5 "Hg will be maintained on the screw pump in order to account for the air displaced by the entering coal and limestone mixture.

The screw inside the pump compresses the coal/ limestone mixture against a weighted flapper valve. This combina-

tion provides a dynamic air seal. The mixture moves into a mixing chamber, where compressed air is introduced through a series of nozzles. The air fluidizes the mixture, which permits this mixture to be "pumped" to the feed needles.

Prior to entering the needles, the feed mixture is fed into a cone splitter, which provides equal distribution of the mixture to the needles. Distribution is insured by six variable orifices installed at the perimeter of the cone splitter.

The implentation of this test program will last for six to eight weeks, beginning approximately the first week in December 1979.

2.0 Evaluation Consideration

The Fuller-Kinyon feed system will be evaluated using the following sections:

1. System reliability and performance
2. System durability
3. Effects on fluid bed operation

2.1.0 System Reliability and Performance

This section deals with the actual operation of the system. Items to be studied under this section include:

1. Start-up and general operation of the system
2. System derived problems such as needle and/or tube pluggages; bridging of material above rotary feeder; loss of air seal; etc.
3. Air leakage to control points
4. System derived down time vs. system operating time.
5. Performance of the flow splitters

Each of these items are detailed in the following sections.

2.1.1 Start-up and General System Operation

This item shall encompass system operation difficulties encountered by the operations group. A written log of

all difficulties will be kept and reviewed. All start-up and operational procedures will be followed. These procedures were developed by the vendor.

2.1.2 System Derived Problems

This item pertains to all problems and/or solutions derived from the Fuller-Kinyon system. Specific problems such as frequency of needle and/or tube pluggage, material bridging in the stand pipe above the rotary feeder, loss of air seal will be closely examined. Again, a written log of all such problems will be kept and reviewed.

2.1.3 Air Leakage to Control Points

This item is of major importance. One of the main purposes of these tests is to determine the amount of air leakage to the belt feeders and rotary feeders. If air leakage is extensive, then the belt feeders will not operate properly unless they are pressurized. It is this situation that is trying to be corrected. Air leakage can be measured by recording the pressure at the belt feeder. This will be accomplished by a magnahelic, currently installed.

2.1.4 System Down-Time vs. System Operating Time

This item is an expression of unit down-time caused by the Fuller-Kinyon system with respect to two and three cell operation. Only down-time caused by the new feed system will be considered.

2.1.5 Performance of the Splitter

This item is also of major importance, since feed distribution is dependant upon splitter performance. Splitter performance will be studied in terms of flow distribution verses time.

In order to determine splitter performance, several tests will be performed. These tests will consist of air and material distribution. First, a test with just airflow will be performed. Pressure differentials across an anubar, located upstream of the pump, and across the variable orifices will be recorded. If the pressure differentials of the orifice are not equal, then orifice sizes will be adjusted until air distribution is equalized. This establishes an air-only reference point.

The second step is to conduct a material/air distribution.

In order to accomplish this, six (6) containers will be fabricated (see Figure II). These containers will attach to the splitter outlets and collect material. A filter arrangement will allow the air to exit the container. The containers will be weighed before and after each test for material loading. From these weights, feed distribution can be obtained. Air readings will also be taken. Orifices will be adjusted as necessary to obtain uniform distribution. If orifice adjustment is needed, then a final air flow test will be run in order to redefine the reference point.

Purge air indicators will be placed on all orifice sensing lines to minimize the chance of line pluggage.

With this method, splitter performance should be able to be observed while in operation. If this is not possible then additional feed distribution tests will be required.

2.2.0 System Durability

This section deals with degradation of the pump, feed tubes and splitter due to erosion and/or corrosion. In order to examine this, the pump, pump casing, splitter, and feed tubes should be measured with a micrometer before and after testing begins.

2.3.0 Effects on the Fluid Bed

In this section , the effects of a Fuller-Kinyon system upon a fluid bed will be observed. Items such as combustion efficiency, fines generation, etc. will be studied. These tests should be performed with cells D and C in operation only. The procedures put forth in the formal MFB test plan will be followed during execution of these tests.

2.3.1 Combustion Efficiency

Combustion efficiency, as defined in the formal test plan of the MFB, will be measured using gas analysis, feed material analysis and waste material analysis.

A gas analysis traverse of C cell will also be made during each test for observation of in bed distribution.

3.0 Test Instrumentation

With the exception of additional airflow measuring devices, all test instrumentation will remain as described in the test plan for the MFB.

4.0 Test Personnel

Test personnel will be as described in the formal test plan. A Fuller-Kinyon representative will be included, if desired.

5.0 Test Reporting

Reports of all tests will be through D.O.E., with a copy to Fuller-Kinyon. Figure III illustrates a schedule of performance to be initiated after system installation is complete.

FIGURE II
DISTRIBUTION TESTING CONTAINER

FULLER-KINYON SCHEDULE OF PERFORMANCE

FIGURE III

APPENDIX II
FULLER FEED SYSTEM OPERATING PROCEDURES

GENERAL OPERATION

Carefully observe the following twelve points prior to initial startup and during subsequent operation of the Fuller-Kinyon system.

1. Assuming an individual compressor* is part of the Fuller-Kinyon system, check the intake duct for loose dirt or other foreign material; then check alignment, orientation and lubrication of compressor.
2. If the air supply is from an individual compressor to an individual pump, no valve should be in the air line between the compressor and the Fuller-Kinyon pump.
3. The Fuller-Kinyon pump is a precision piece of machinery which requires a rigid foundation. For maximum maintenance-free operation, the pump base must be flat, true, and anchored solidly in the foundation. If the above is not adhered to, distortion of the Fuller-Kinyon pump will occur, thereby putting undue strain on the pump components.
4. There are two drive options for the Fuller-Kinyon pump, either V-belt or direct coupling drive. If a coupling drive is used, disconnect the coupling and verify the proper alignment between the motor and the pump coupling halves. Coupling misalignment may cause premature bearing failures and pump vibration. In those instances where a V-belt drive is used, verify alignment between the pump and motor sheaves.
5. Inspect the Fuller-Kinyon pump hopper, mixing chamber, and air manifold for foreign material.
6. On both ends of the Fuller-Kinyon pump, housed in the bearing housing supports, there are material seal arrangements which require a steady flow of air or air purge for proper operation.

Before starting the pump, verify the presence of the air flow through both material seal arrangements by the use of petcock. Upon verification of air flow, close the petcock. If there is no air flow, check all piping back to the air purge source and correct the problem. The Fuller-Kinyon pump must never be run without purge air to the material seal arrangement.

* "Individual compressor" refers to a compressor whose sole purpose is to supply air to the Fuller Kinyon pump. Normally it is a rotary machine with no aftercooler or receiver in the system.

7. Start the Fuller-Kinyon pump motor only after air is entering the pump. Check the Fuller-Kinyon pump screw rotation; it should be counter-clockwise when viewed from the motor end.
8. Start the Fuller-Kinyon pump without feed. Note the pressure on the manifold gauge and line gauge. The manifold pressure gauge should indicate 5 to 6 psi, higher than the line pressure gauge.
9. Open feed valve or start feed conveying equipment. As the load through the Fuller-Kinyon pump increases, the pressure on both the manifold gauge and line gauge will rise.

If, with normal fuel feed, the pressure on the line gauge fluctuates continuously from high to low readings, the amperage of the pump motor varies through the same cycle, and the flapper valve lever continually moves up and down, blowback through the Fuller-Kinyon pump material seal is indicated. Adjust the counterweight to a position farther out on the flapper valve lever. If the blowback condition persists for a long period of time, consult Fuller Company.

10. When shutting down the Fuller-Kinyon pump, first stop the material flow and after the pump is completely empty, stop the driving motor.
11. When the Fuller-Kinyon pump screw has come to a complete stop, the air should be allowed to blow through the transport line until gauge stabilizes at nearly zero.
12. When the material feed rate to the Fuller-Kinyon pump becomes excessive, and the pump motor overloads, the trip relay then operates the solenoid air valve and air is admitted into the Fuller-Kinyon pump hopper. This reduces the Fuller-Kinyon pump motor overload condition and when motor load becomes normal again, the solenoid valve closes.

This instantaneous trip relay is set at 95% of the motor full load current and the reset point is 82% of the trip relay setting.

The bypass valve should be closed at all times to insure that the air line is open, this will allow air flow and keep the line clean. This bypass valve is furnished with an orifice that allows air flow when in the closed position.