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COAL FEEDER DEVELOPMENT,

Phase III

Progress Report for the Period July 1—December 31, 1978

By
John C. Harding

MASTER

June 1979

Work Performed Under Contract No. EX-76-C-01-1793

Foster-Miller Associates, Inc.
Waltham, Massachusetts

U. S. DEPARTMENT OF ENERGY

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PHASE III, 2#5
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FOR THE PERIOD
1 JULY 1978 TO 31 DECEMBER 1978

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ABSTRACT

This report covers Phase III effort on the Foster-Miller Associates, Inc. (FMA) Coal Feeder Development Program from 1 July 1978 to 31 December 1978. At the end of this period, the FMA Linear Pocket Feeder (LPF) had been operated for 234 hours. Problems with the unit have been limited to excessive wear of the conveyor joints. This problem is expected to be relatively easy to solve. Design, fabrication, and assembly of the 500 psig Centrifugal Feeder prototype was completed during the reporting period, and testing of the feeder was initiated. The enlarged feeder test facility (5-ton capacity) was completed during the reporting period.

1. OBJECTIVE AND SCOPE OF WORK

A number of research and development programs are currently underway to investigate and/or demonstrate coal conversion processes. A critical problem with all conversion processes which operate above atmospheric pressure is the delivery of coal to the process. Present commercial and pilot plant installations utilize either lock hopper or slurry feed systems to feed processes which operate at significant pressures (>50 psig). Both of these systems have shortcomings which bring into question their viability as feed systems for future commercial scale gasification processes. Lock hoppers are substantially more expensive than slurry feed systems in terms of both capital and operating costs. Unreliable valve performance has been cited as a serious operational problem with lock hoppers. With one reservation, slurry feed systems offer substantial economic and performance advantages over lock hopper systems. This reservation concerns the impact of the liquid used to slurry the coal on the process that is being fed. In some cases, the heat required to evaporate the slurrying liquid can have a substantial negative impact on process economics. The objective of this program is the successful development of alternative (second generation) dry coal feeder systems for pressurized coal conversion processes. The program to accomplish this objective has been defined through three phases as described below.

Phase I - Coal Feeder Conceptual Development

This phase was of six months duration and was essentially completed by the end of December 1975. The Phase I effort established coal feeder requirements and generated and evaluated concepts for coal feeders. Conclusions were made as to the desirability of each of the concepts generated and four feeder concepts were recommended for further development in Phase II of the program. This effort has been documented in the Phase I report dated March 1976 (1).

Phase II - Pilot Scale Coal Feeder Development

During the initial stages of Phase II, the development of four feeder concepts was pursued. By the time Phase II was completed, two of the four original concepts had been eliminated from consideration. Initially, the phase was conducted as five sub-programs which included the development of the four feeder concepts and the feeder test loop. Development of each of the feeder concepts proceeded through one or more stages, starting with the design and testing of bench scale or process development units (PDU), and culminating in the design and test of pilot scale feeder prototypes. A coal feeder test loop was developed for the conduct of the prototype testing. Phase II effort was completed in April 1978. Results of the Phase II effort are documented in the Phase II report dated August 1978 (2).

Phase III - Pilot Plant Feeder Performance Testing

The feeder concepts selected for further development, based on the results of the Phase II efforts, are being designed and built to pilot plant scale specifications. The feeders will be subjected to a performance test program on an expanded coal feeder test loop constructed for this task. Conceptual designs of the feeder systems will be prepared for pilot and/or demonstration scale applications. The selected feeder concepts for the Phase III effort are the Foster-Miller Linear Pocket and Centrifugal Feeders. The Phase III effort began on 1 October 1977. This report reviews the results of the Phase III effort for July through December 1978.

2. SUMMARY OF PROGRESS TO DATE

Program effort during the period from July through December 1978 has been directed toward the following major task areas:

- Durability testing of the Linear Pocket Feeder (LPF)
- Design, fabrication, and assembly of the 500 psig Centrifugal Feeder prototype
- Fabrication and assembly of an enlarged, batch operation, feeder test facility.

Results to date in each of these areas are summarized below.

2.1 LPF Development

The LPF has been operated for a total of 234 hours. The critical sealing tube and sealing rings have been in operation 204 and 151 hours respectively and have exhibited *no measurable wear*. The only durability problem with the feeder to date has been excessive wear of the conveyor joints. This problem is being addressed and should be resolved by the end of the present contract Phase.

2.2 Centrifugal Feeder Development

Support testing of the 200 psig centrifugal feeder prototype has been suspended so that more effort can be directed to the 500 psig prototype development. Design, fabrication, and assembly of the 500 psig unit were completed and testing was initiated. Coal feed testing will begin in January 1979.

2.3 Test Loop Development

The 5-ton capacity batch test loop was completed during the reporting period. The facility is presently being used for the testing of the 500 psig centrifugal feeder prototype.

3. DETAILED DESCRIPTION OF TECHNICAL PROGRESS

Program effort from July through December 1978 has been directed at continued development of the FMA LPF and Centrifugal coal feeders and the development of an enlarged batch facility to test the feeders. The details of this work are described below.

3.1 LPF Development

The schedule for the LPF development program is presented in Figure 1. Basically, the Phase III effort consists of a continuing cycle of test, evaluation, redesign, and retest. The objective of this program is to develop, debug, and demonstrate the LPF concept under conditions which simulate field operation. The results achieved to date and future efforts under subtasks 1.3 through 1.7 are detailed in the following subsections.

3.1.1 Critical Component Redesign (Task 1.3)

Tasks 1.3 through 1.7 are essentially being performed in parallel with design and material changes being made to the feeder as problems become evident. The objective of this series of tasks is to develop a prototype LPF design which has had the "bugs" worked out and has accumulated a significant amount of operating time on all components.

Phase III redesign of the feeder includes the following areas (see Figure 2 for nomenclature):

- The hopper station has been redesigned to improve feed characteristics. The station length was doubled to allow the coal more time to settle before it enters the sealing tube.

Figure 1. Projected Schedule for Linear Pocket Feeder Development

LINEAR POCKET FEEDER FLOW SCHEMATIC

**HIGH PRESSURE GAS
DRYING & RECIRCULATION**

Figure 2. Linear Pocket Feeder Schematic

- All feeder tubes have been redesigned to have the same inside diameter with the same tolerance. The material for all tubes was changed to the Xaloy[®] type which has been used in the sealing tube.
- The gas/water transfer station has been redesigned.
- The rod and clevis ends of the conveyor connecting links have been redesigned for higher wear resistance. The rod and clevis holes were enlarged so that tungsten carbide bushings could be installed. The pins which join the conveyor links were changed to hardened stainless steel.
- In addition to redesigning some feeder subsystems, alternative sealing ring materials are being evaluated. Tungsten carbide and titanium carbide sealing rings were specified to be run with the alumina sealing rings in long term testing.
- Detail changes to the machine which are necessary to accommodate the redesigned subassemblies and components noted above have been completed (mounting brackets, etc.).
- Conceptual designs for several alternative conveyor chain configurations have been developed. At present, it is not expected that these designs will be carried through detail design and fabrication due to time and funding constraints.

The critical component redesign task will continue in response to problem areas which become evident as testing of the feeder continues. Alternative materials evaluation will also continue. New parts will be installed on the feeder as they become available.

3.1.2 Test Revised/New Feeder (Task 1.6)

Initial redesign of the feeder was based on the results of Phase II testing (83 hours of total operating time). Subsequent testing has shifted the emphasis of the development effort, and procurement of the redesigned components has been adjusted accordingly. The specific procurement action taken to date is detailed in subsection 3.1.3. A chronology of the test results to date is presented below.

- a. Phase II Testing, 0 to 30 hours. Basic performance data was developed as presented in the Phase II report (1). Excessive wear was noted in the "borofuse" sealing tube and the hardened aluminum water station tube. The sealing tube was replaced with Xaloy tube and the water station tube with an electroless nickel coated stainless steel tube. Wear of the sealing tube was attributed to corrosion effects and misalignment of the machine. A laser alignment system was obtained at this point and has since been employed to assure that the machine is aligned accurately.
- b. Phase II Testing, 30 to 83 hours. During this period initial performance data was rechecked and additional performance data was obtained. The Xaloy® sealing tube and the alumina sealing tubes showed no signs of wear. Occasional breakage was noted with the alumina sealing rings which prompted the ordering of rings constructed of alternative materials (subsection 3.1.1). Ten titanium carbide sealing rings were installed at this point.

The clevis and rod end holes and linking pins were essentially worn out by this time. The holes were

bored out and enlarged pins were installed as a "fix." The carbide bushing design change (subsection 3.1.1) was initiated to correct the hole wear problem.

- c. Phase III Testing, 83 to 100 hours. At 83 hours the Phase III development testing was initiated. Under continuous testing (8 hr/day) the alumina sealing rings were breaking at the rate of about 1/hr. No problems were noted with the tungsten carbide sealing rings. At 100 hours, all remaining alumina sealing rings were replaced with tungsten carbide wear rings.
- d. Phase III Testing, 100 to 216 hours. After 216 hours of total machine operating time, no sealing tube or sealing ring wear was detectable, based on measurement (to 0.0001 in.) or leakage testing. No breakage problems were noted with either the titanium carbide or tungsten carbide sealing rings.

The rod and clevis end hole and link pin "fix" was worn out at this point.

The tungsten carbide clevis and rod end bushings and 440⁰C stainless steel pins were available at this time. Many of the carbide bushings did not meet dimensional requirements for outside diameter and roundness. The pins were Rc 53-55 instead of the Rc 61 specified. The new pins and bushings were installed despite these problems.

- e. Phase III Testing, 216 to 234 hours. After 18 hours of testing with the carbide bushings, the conveyor chain was disassembled and examined. Nine fractured bushings were found. In addition, some evidence of the carbide bushings wearing the pins was noted.

Analysis of the bushing fractures showed that a combination of out-of-round rod and clevis holes coupled with the out-of-round bushings and/or alignment problems in inserting the bushings could have caused the fractures. Pin wear was attributed to the relatively soft pins running against the edges of the carbide bushings.

All the carbide bushings were removed and bearing steel drill jig bushings were ordered to effect a short term fix. Long term corrective action is discussed under conclusions and recommendations.

3.1.3 Fabricate, Procure, Assemble, and Checkout Critical Components (Tasks 1.4 and 1.5)

On the basis of the LPF test results to date, not all of the design changes discussed in subsection 3.1.1 are being implemented. The present procurement status of each of the changes outlined in subsection 3.1.1 is discussed below:

- The redesigned hopper station has not been ordered as this change is not essential to the successful operation of the feeder.
- The order for new Xaloy tubes has been cancelled. No problems have been encountered with the tubes in the test program and the funds can be used more effectively in other areas of the program.
- As noted in subsection 3.1.2, the carbide bushings for the rod and clevis end holes have been received and tested. Further development will be required in this area. The details of this effort are discussed in subsection 3.1.4.

- The tungsten carbide and titanium carbide sealing rings have been received, installed and successfully tested (see previous subsection).
- Brackets and other hardware items necessary to install the new hopper station, Xaloy[®] tubes, and gas/water transfer station have been designed but will not be ordered in this phase of the program. This decision has been made because the test program to date indicates that none of these items are critical with regard to successful operation of the feeder.

3.1.4 Conclusions on LPF Development

On the basis of feeder testing completed to date (234 total operating hours), only one unresolved technical problem has been identified. This problem is demonstrating the durability of the conveyor chain joints. The approach to solving this problem is discussed in the next subsection.

Test results to date show no evidence of wear at the critical sealing tube/sealing ring interface. Solving the potential three body wear problem (coal/sealing ring/sealing tube) at this interface has long been accepted as the most critical aspect in the successful development of the LPF concept, so this is encouraging.

3.1.5 Future LPF Development

- The carbide bushings have been removed from the conveyor chain and bearing steel drill jig bushings have been ordered to effect a short term fix.
- The LPF should be operational again in early January. Testing will be resumed. In addition to the usual

durability testing, the feeder will be tested with minus 1/16 in. coal and 70 percent through 200 mesh coal. Feeder operation to date has been performed with 3/4 in. by 0 coal.

- Solution of the conveyor chain joint problem is viewed as straightforward effort involving available technology. Two approaches which can be taken in solving the problem include the "conventional" approach of sealing the coal out of the joint, and the "advanced" approach of using materials which are harder than the hardest element in the coal. In the later approach, no effort is made to prevent the coal from entering the joint and the coal in effect acts as a lubricant. The carbide bushing approach is viewed as one of several long term solutions to the joint problem which involve the advanced approach. Noting this, a test program utilizing five piston and rod assemblies will be run using carbide bushings and different pin materials. The goals of this test program are to establish material wear compatibility and eliminate bushing breakage. The "ultimate" pin is likely to be stainless steel with a tungsten carbide plasma spray coating. Several of these pins will be purchased and tested. It is anticipated that several acceptable solutions to the joint problem will be generated and demonstrated before the conclusion of the Phase III program effort.
- Present plans are to install the LPF on the enlarged feeder test facility in early 1979.

3.2 Centrifugal Feeder Development

The schedule for Phase III of the Centrifugal Feeder development effort is presented in Figure 3. The development program can be broken down into two major tasks:

Figure 3. Projected Schedule for Centrifugal Feeder Development

- The development of additional theoretical and operating data on the centrifugal feeder concept, using a modified version of the existing 200 lb/in.² centrifugal feeder prototype.
- The design, fabrication, and testing of a new centrifugal feeder prototype for 500 lb/in.² operation at feed rates of 3 to 5 tons/hr.

3.2.1 Development of Modified 200 lb/in.² Feeder Prototype
 (Tasks 2.1 through 2.6)

The objective of continued work with the 200 lb/in.² feeder prototype has been to gather additional information on the centrifugal feeder concept with regard to the following areas:

- Determine the power requirements of the prototype feeder and how the requirements are broken down by subassembly.
- Study techniques to reduce the drag on the feeder rotor. Shrouding of the rotor and streamlining of the rotor are the drag reduction techniques which are to be investigated.
- Evaluate the possibility of operating the feeder in a pump configuration (operate the rotor within a casing) rather than the rotor-within-a-vessel configuration which has been employed in previous testing.
- Evaluate feeder metering techniques. In previous testing, feed rate has been a function of rotor speed for a given rotor geometry. In this task, mechanical techniques for controlling feed rate at a fixed number of rpm will be examined.

- Obtain data on the pressure profile along the feeder sprues during operation. This information will be used to verify the analytical model of feeder performance and thus increase our confidence in using the model as a design tool.

All test work on the first two items has been completed and was reported on (3).

Additional support work with the 200 psig centrifugal feeder prototype was suspended in August in order to maximize effort on the 500 psig prototype development. No further work with the 200 psig prototype is contemplated at this time. *The 200 psig prototype has exceeded its original performance goals by feeding in excess of 1-1/2 tons/hr of pulverized coal against a 200 psig back pressure with no gas loss from the receiving vessel. Back pressure limits were established by the ASME code limits of the receiving pressure vessel and not by feeder capability.*

3.2.2 Design of the 500 psig Feeder (Task 2.7)

The design of the 500 psig centrifugal feeder prototype was completed in August. The device is designed for feed rates of 3 to 5 tons/hr at pressures to 500 psig and above. The feeder and support equipment is designed to ASME requirements for operation up to 1000 psig.

3.2.3 Fabrication and Assembly of the 500 psig Feeder (Task 2.8 and 2.9)

Fabrication and assembly of the 500 psig feeder prototype was completed in mid-December. The assembled feeder is shown in Figure 4. The rotor is mounted within a housing which is in turn mounted to a 36 in. flange. In Figure 5, the flange and feeder assembly are attached to a lifting fixture prior to installation in the receiver pressure vessel. Figure 6 shows the rotor

Figure 4. Centrifugal Feeder Assembly

Figure 5. Centrifugal Feeder Assembly and Mounting Fixture

Figure 6. Feeder Rotor and Drive Shaft

and bearing assembly removed from the feeder housing. The splined drive shaft is installed in this photo. In Figure 7, the rotor is viewed from above. The main coal inlet can be seen in the center of the rotor and the inlet to one of the four feeder sprues is visible. Figure 8 gives a closer view of one of the four sprue outlets.

Assembly of the feeder was completed approximately 1-1/2 months behind schedule due to late deliveries of several key components. Among the items which were late in delivery were the main seals (1 month), the mounting flange (1 month), and the seal coolant system (3 months).

3.2.4 Testing of the 500 psig Feeder (Task 2.10)

Testing of the prototype feeder began in mid-December. Testing to date has been limited to debugging. The feeder has

Figure 7. Centrifugal Feeder Rotor

Figure 8. Feeder Sprue Outlet

been mounted and driven to a maximum speed of 4500 rpm. Some oil leakage from the lower main seal has been noted. This problem was corrected by having the seal faces reground.

3.2.5 Future Centrifugal Feeder Development

Operation of the centrifugal feeder with coal will begin in early January. Once successful coal feed has been achieved, pressure differential testing will begin.

3.3 Development of Enlarged Batch Test Loop

The enlarged feeder test facility at FMA has been developed to allow batch run testing of feeders to 5 tons at back pressures to 1000 psig. For the FMA feeders, this allows a test run of 1 hr at their maximum feed rates of 5 tons/hr. The facility was designed by FMA. Taunton Engineering of Taunton, MA was subcontracted to perform the major share of the test loop fabrication and assembly. The schedule for the development of the facility is given in Figure 9.

3.3.1 Test Loop Description

The coal feeder test loop is illustrated schematically in Figure 10. A pictorial representation of the actual loop is presented in Figure 11. The loop consists of a supply vessel, a structure to support the test feeders and materials handling equipment used to move the coal from the feed vessel outlet to the feeder inlet, a 5-ton solids capacity receiver vessel, a belt and bucket elevator system to recycle the coal from the receiver vessel to the supply vessel, and a vent and baghouse system to contain coal blow back.

In operation, the feed vessel is loaded from ground level through the bucket elevator. When the supply vessel is full, the bucket elevator is stopped. Using procedures appropriate for

Figure 9. Projected Schedule for Enlarged Batch Test Loop Development

78 ft 4 in.

0 ft 0 in.

Figure 10. Loop II Schematic Layout

Figure 11. Coal Feeder Test Loop

the test feeder, a test run is conducted with up to 5 tons of coal being fed from the supply vessel to the receiver vessel. The receiver vessel may be pressurized up to 1000 psig during the test run. Upon completion of the test run, the receiver vessel is vented to atmospheric pressure and unloaded. The coal charge may be recycled to the supply vessel or discarded and a new coal charge loaded. In the event of a feeder failure which allows the receiver vessel to blow back, the blow back is routed through the baghouse to contain the coal.

3.3.2 Loop Development

The test loop was completed about 1 December. This represents about a 2 month slippage from the original development schedule. The major cause of this was a 2-1/2 month delay in the delivery of the high pressure receiver vessel.

4. REFERENCES

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