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TEST AND EVALUATE THE TRI-GAS LOW-BTU
COAL GASIFICATION PROCESS

Quarterly Report for the Period
April-June 1980
(BCR Report L-1115)

Bituminous Coal Research, Inc.
Monroeville Pennsylvania

Date Published
July 1980

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PREPARED FOR
THE UNITED STATES DEPARTMENT OF ENERGY

Under Contract No. DE-AC21-78ET10254

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James R. Garvey, President and Director of Research

Organization

Bituminous Coal Research, Inc., 350 Hochberg Road, Monroeville, PA 15146

Signature

Date

July 24, 1980

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BITUMINOUS COAL RESEARCH, INC.
DOE-SPONSORED RESEARCH PROGRAM

TEST AND EVALUATE THE TRI-GAS LOW-BTU
COAL GASIFICATION PROCESS

Report No. FE-10254-82
(BCR Report L-1115)

I. INTRODUCTION AND PROJECT OBJECTIVE

This report summarizes progress during the quarter April to June 1980 on fluidized-bed gasification research being conducted by Bituminous Coal Research, Inc., under the general program, "Test and Evaluate the TRI-GAS Low-Btu Coal Gasification Process." This research was initiated under Contract No. 14-32-001-1207, was subsequently transferred to Contract No. E(49-18)-1527, then to Contract No. DE-AC21-78MC02798, and is now being conducted under Contract No. DE-AC21-78ET10254 as sponsored by the U.S. Department of Energy.

The overall objective of the program continues to be to develop processes for gasifying coal, with emphasis on the production of a fuel gas. Laboratory-scale coal gasification experimentation is to be continued, together with process and equipment development.

Success of laboratory studies has led to the design and construction of a 100 lb/hr process and equipment development unit. This unit is being operated to demonstrate the process and economic feasibility of fluidized-bed gasification for the commercial production of low-Btu fuel gas. No liquids, tar, or char are produced as waste or by-product.

II. SCOPE OF WORK

Laboratory-scale gasification experimentation is to be continued, together with process and equipment development. The laboratory work will be conducted to improve the fluidized-bed coal gasification process and to provide data for design of continuous flow systems.

The primary purpose of the process and equipment development work is to generate data and provide information needed to design a pilot-scale system.

III. SUMMARY OF PROGRESS TO DATE

During the quarter, four tests were conducted in the TRI-GAS PEDU. Test No. 3S-55 was prematurely shut down because of failure of the steam boiler. Steady-state operation was not achieved.

Following repairs to the steam boiler, Test No. 3S-56 was conducted. This test was also terminated prematurely, due to failure of the power controller for the steam boiler. Repairs were again made.

In Test No. 3S-57, bed temperatures in Stages 2 and 3 were lower than required for gasification, although some reaction occurred at the top of the reactors where the temperatures exceeded 1600 F. The test was concluded somewhat prematurely due to plugging of the coal-feed line.

PEDU Test No. 3S-58, an integrated three-stage test, was conducted in June. The heating value of the product gas was about 100 Btu per cu ft even though failure of the reactor heaters prevented the Stage 2 temperature from exceeding 1550 F.

IV. DETAILED DESCRIPTION OF TECHNICAL PROGRESS

A. Fluidized-bed Gasification Studies

1. Fluidized-bed Gasification PEDU Testing

a. Experimental Program: During the quarter, four integrated tests were completed in the TRI-GAS PEDU.

(1) Test No. 3S-55: PEDU Test No. 3S-55 was conducted the week of March 31. This was an integrated three-stage test with smooth flow of gas and char between vessels, but failure of the steam boiler caused an early shutdown. The reactor heaters performed satisfactorily during the test, but the Stage 2 heater failed shortly after shutdown had commenced.

Initially, there was a problem in transferring char from Stage 1 to Stage 2, but this was apparently because Stage 2 was overfilled. After some char was transferred from Stage 2 to Stage 3, it was possible to transfer char from Stage 1 to Stage 2. The level indicators are based on differential pressure readings and were erroneous throughout the test. Some of the pressure lines were repiped; following Test No. 3S-55, to make all the purges and taps similar. A level system not based on differential pressures would be most desirable.

After several hours of operation, the distributor ring feeding the Stage 1 off-gas into Stage 2 became plugged. In order to continue the test, the vessels were operated independently. Following an inspection of the ring after the test, it was decided to move the holes from the side of the ring to the bottom to make it harder for char to accumulate inside the ring.

When the temperature in Stage 2 reached the 1500-1600 F range, steam was added to the feed. However, it soon became apparent that the steam boiler was malfunctioning, as steam pressure could not be maintained. A check of the boiler power controller revealed that a fuse had blown. Further checking revealed a short to ground in one set of heaters. Therefore, it was decided to shut down the test and make the necessary repairs.

Inspection of the vessels following the test revealed no clinkers or cinders except right on the gas nozzles in Stages 2 and 3. Most of the nozzles in Stage 2 were plugged with slag as were several of the Stage 3 nozzles. Since there was no buildup in the beds, it was concluded that there was simply too much heat in the distributor area. In future tests, therefore, steam will be introduced with air even when the reactor temperature is below the temperature at which steam reacts.

One side of the Stage 2 reactor heater chamber had filled with several inches of char. Apparently, the char had fallen in from the top as the refractory in the upper seal area is chipped, and the upper seal ring was probably not tight in this area. Several of the Globar connectors were destroyed, but the Globar elements were not harmed. The connectors were rebuilt and the heater assembly was reinstalled. Since the refractory cannot

be patched, the top was sealed by stuffing rope gasket material into the crack after the heater assembly had been installed.

In the steam boiler, two of the twelve electric heating elements were found to be shorted and water was leaking out the ends of these elements. The elements were welded into flanges; and, even if new elements were readily available, replacing them would be complicated and would also risk damaging good elements. It was felt that the boiler could be operated satisfactorily without the broken elements; therefore, the boiler was rewired and the ends of the broken elements were plugged.

(2) Test No. 3S-56: Shortly after initiating air and steam flows in Test No. 3S-56, it was apparent the steam boiler was again malfunctioning. The boiler pressure could not be maintained with the desired steam flows. A check of the unit revealed that the boiler power controller was not supplying full power to the boiler. After several hours of trying to adjust the controller, the test was shut down. The controller was removed and returned to the manufacturer for repairs.

Less than an hour after shutdown had commenced, the Stage 2 reactor heater again failed "open." After the heater had been lowered, the problem was traced to the upper connectors to the Globars. The graphite packing had disappeared and allowed the connector to loosen and fail "open." The upper part of the vessel had been much hotter than the lower portion and, apparently, the graphite oxidized at the top due to the higher temperature. The connectors had been made from 1-1/2-inch schedule 40 nickel pipe, which is about 1/4-inch larger diameter than the Globars. In an effort to solve this problem, the connectors were changed to 1-1/2-inch schedule 80 pipe of type 304 stainless steel (Alloy 330 stainless steel would have been preferred but was not readily available). The inside diameter of the schedule 80 pipe is close to the outside diameter of the Global, which should help to keep the connection tight. Since the graphite packing did not last at the higher temperatures, a piece of 16-gauge stainless sheet was wedged between the pipe and the Global to keep the connection tight and to keep the set screws from gouging the Globars. The Stage 3 heater was removed and similarly modified.

(3) Test No. 3S-57: Following reinstallation of the steam boiler power controller, system warmup for Test No. 3S-57 was commenced. Coal feed commenced and it was intended to run until the lock hopper had been exhausted. However, after about 10 hours of operation, the feed nozzle became plugged and the test was terminated. About 1300 pounds of coal were fed to Stage 1.

Gas and char flow between the vessels was smooth during this test. Good solids level measurements were obtained throughout most of the test, apparently as a result of a combination of repiping the pressure tap purges and extra care in setting the purge flows. The coal feed nozzle may have become plugged due to a high level in Stage 1.

Bed temperatures during Test No. 3S-57 were lower than the temperature above the beds in Stages 2 and 3, which indicates that most of the

reaction was occurring above the beds. The most reasonable explanation for this is that a high percentage of the gas was circumventing the bed. Air and steam enter the vessels below the grid and enter the beds through nozzles in the grid plate. The grid plate is sealed to the heater chamber by compression of the lower vessel flanges. It may be that thermal expansion of the vessel shell allows the grid seal to leak gas into the heater chamber and the gas then leaks past the upper seal to the top of the bed.

In order to prevent the gas from circumventing the bed, the preheater flows will be brought in through sparger rings, such as are presently used for the PG-33 and RL-40 gas flows. In Stage 1, the same ring will carry both the RL-40 and preheater flows. Once into the bed, the gas could still leak out under the silicon carbide tube; however, it is more likely to flow up through the bed.

(4) Test No. 3S-58: PEDU Test No. 3S-58 was conducted the week of June 2, with coal feed being initiated on June 5. Coal was fed for a total of 9 hours when the test was terminated because the Stage 3 bed had been consumed. With the Stage 3 bed consumed, oxygen began to carry over to Stage 1, which caused a rapid increase in the temperature of Stage 1. An effort was made to rebuild the bed in Stage 3, but this was unsuccessful. After shutdown, a clinker the width of the bed was discovered in Stage 3. There was also considerable clinkering in Stage 2.

The clinkering is apparently caused by excessive heat released in the grid area. In an effort to distribute the heat of reaction more evenly throughout the bed, the Stage 2 air and steam flow will be split between two spargers. The present sparger will be retained, but a second one, located about a foot above the present sparger, will be added. If this arrangement proves satisfactory, Stage 3 will be modified similarly. A schematic of the revised inlet gas system is shown in Figure 1. FE210A and B and FCV210 have been added to allow control of gas to the spargers. The percentage of gas supplied to the spargers is determined by FIC210, a pneumatic ratio-metric controller.

Several sparger configurations were tested in the cold model. First, there were holes both in the top and bottom of the upper sparger ring; however, this seemed to stagnate the bed between the spargers. With holes only in the top of the upper sparger, mixing was very good. With the holes in the top of the lower sparger, fluidization was not as good as with the holes in the bottom. Therefore, the upper sparger in the PEDU will have holes only in the top, while the lower sparger will have holes only in the bottom.

With all the gases entering the beds through spargers during the PEDU test, there was apparently no gas circumventing the beds. This observation is based on the bed temperatures being uniform, and the area above the bed being cooler than the bed. With the gases fluidizing the beds as designed, significant gasification reactions were occurring, even though the Stage 2 bed temperatures were only on the order of 1500 to 1550 F. The Stage 2 product gas had a heating value of 99 Btu per cu ft, while the Stage 3 offgas had a 117 Btu per cu ft heating value. The Stage 3 bed temperatures

Figure 1. Stage 2 Inlet Gas Piping

were quite a bit higher than those in Stage 2, at 1800 to 1900 F. This would indicate that if Stage 2 temperatures can be raised above 1650 F, a product gas with a higher heating value would, in fact, be produced. A summary of test conditions and results is shown in Table 1.

Higher temperatures in Stage 2 would have been achieved had the reactor heaters for Stages 2 and 3 not shorted to ground early in the test. Post-shutdown examination of the heaters at first revealed no apparent cause for the failure. The Globars were all intact and there was electrical continuity through the heaters. However, when the spargers were removed from the silicon carbide liner, the source of the problem was revealed. The heater short was caused by conduction through the silicon carbide liner to the grounded gas sparger. Apparently, silicon carbide becomes a very good electrical conductor at temperatures in the range of 1500 F. This problem will be corrected by insulating the Globars from the silicon carbide liner, as well as insulating the gas spargers and all other metal probes from the liner.

Reworking of the heaters to insulate all metal connections has been completed. Repiping of the Stage 2 inlet gases is in progress and should be completed by mid-July.

b. Data Processing

(1) Automated Data Acquisition: During the report period, a minor change was made to the utility program, TRIMON. Prior to this modification, critical data were printed on a time-initiated basis. Henceforth, critical data will be obtained via a change in the switch register.

In addition, a calculation for the heating value of the product gas, in Btu per cu ft, was added to the on-line system. The Btu's for each stage will now print out along with the current Honeywell gas chromatograph analysis. Also, constants used in calculating the flow for Stage 2 and Stage 3 steam orifices were changed due to recalibration.

The data acquisition system was used in conjunction with all TRI-GAS tests. Data were collected and reports were generated. No problems concerning data acquisition were observed.

(2) Scientific Computing: There was no activity during the current report period.

TABLE 1. SUMMARY OF TEST NO. 3S-58 CONDITIONS

Gas Flow, lb/hr	<u>Stage 1*</u>	<u>Stage 2**</u>	<u>Stage 3</u>
Air	0	230	96
N ₂	0	0	0
H ₂ O	0	55	32
Coal Feed, lb/hr	108		
Dry Product, volume percent	***		
H ₂		13.7	16.6
CO ₂		10.9	10.9
CH ₄		1.8	0.7
CO		11.5	17.8
N ₂		61.7	53.5
O ₂		0.4	0.5
Heating Value, Btu per cu ft		99	117
Bed Temperature, F		1520	1770

*Excludes Stage 3 product gas

**Excludes Stage 1 product gas

***Stage 1 gas analyses were erroneous

B. Visitors During April, May, and June 1980

June 18, 1980

Dr. Clarence Karr, Jr.
Morgantown Energy Technology Center
P. O. Box 880
Morgantown, West Virginia 26505

C. Trips and Meetings During April, May, and June 1980

None

D. Papers Presented During April, May, and June 1980

None

V. WORK PLAN AND SCHEDULE

A. Work Schedule

Work on the fluidized-bed gasification PEDU will continue according to the revised Milestone Plan attached. A revised Milestone Plan was requested by Dr. Karr on his visit of June 18, 1980.

B. Work Planned for July, August, and September 1980

Repiping of the Stage 2 inlet gases will be completed. Three-stage PEDU tests will be conducted during the quarter with the first one scheduled during the week of July 14.

Bench-scale reactivity tests will continue as needed.

U S ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
MILESTONE PLAN AND MANAGEMENT REPORT

PAGE OF

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1	Reactor Modification																								100
2	Additions to Coal Preparation Area																								100
3	Stage 3 Testing																								100
4	Integrated 3-Stage Operations																								60
5	Devolatilization in Stage 1																								
	Oxidizing Atmosphere																								100
	Reducing Atmosphere																								40
6	Laboratory Studies																								85
7	Final Report																								0
11. Remarks																									
12. Signature of Contractor's Project Manager and Date <i>E. K. Baker</i> 6/30/80													13. Signature of Government Technical Representative and Date												

INTERMEDIATE EVENT LOG

Contract No.
DE-AC21-78ET10254

Event No.	Description	Comments
1 A	Modification of Stage 3 Reactor Completed	
1 B	Modification of Stage 1 Reactor Completed	
1 C	Modification of Stage 2 Reactor Completed	
2 A	Pavement of Driveway and Storage Pad Completed	
2 B	Installation on Conveyors and Coal Dryer Completed	
3 A	Testing in Stage 3 at Moderate Temperatures (1500-1600 F)	
3 B	Testing in Stage 3 at High Temperatures (1700-1900 F)	
4 A	Complete Testing with Noncaking Coals (Montana Rosebud)	
4 B	Complete Testing with "Mild Caking" Coals (Illinois No. 6)	
4 C	Complete Testing with "Highly Caking" Coals (Pittsburgh Seam)	
5 A	Devolatilization of Noncaking Coal in an Oxidizing Atmosphere; No Treatment of Products. Task 5.1	
5 B	Devolatilization of Noncaking Coal in an Oxidizing Atmosphere; Products Treated in Gasification Stage 2. Task 5.2	
5 C	Devolatilization of Caking Coal in an Oxidizing Atmosphere; No Treatment of Products. Task 5.5	
5 D	Devolatilization of Caking Coal in an Oxidizing Atmosphere; Products Treated in Stage 2. Task 5.6	

INTERMEDIATE EVENT LOG (continued)

Contract No.
DE-AC21-78ET10254

<u>Event No.</u>	<u>Description</u>	<u>Comments</u>
5 E	Devolatilization in Reducing Atmosphere, Noncaking Coals, No Treatment of Products. Task 5.3	
5 F	Devolatilization in Reducing Atmosphere, Noncaking Coals, Treatment of Products in Stage 2. Task 5.4	
5 G	Devolatilization in Reducing Atmosphere, Caking Coals, No Treatment of Products. Task 5.7	
5 H	Devolatilization in Reducing Atmosphere, Caking Coals, Treatment of Products in Stage 2. Task 5.8	
6	Laboratory Studies in Support of PEDU Operation	
7	Final Report Preparation	

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