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DEVELOPMENT OF AN ADVANCED, CONTINUOUS MILD GASIFICATION PROCESS FOR THE PRODUCTION OF CO-PRODUCTS

Quarterly Report
for the Period April 1, 1992 - June 30, 1992

By

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EXECUTIVE SUMMARY

Seventeen continuous coke tests were completed. Efforts to produce coke from lower rank non-coking coal resulted in a coke with 1/3 less crush strength. This lower quality coke made from cheaper coal may have value as a partial charge in a blast furnace.

A coke strength increase of 80% was obtained by curing the coke at 850°F for one hour prior to the normal cure of 1 1/2 hours at 1832°F.

Sixteen CMGU test runs were made using 13 different coals. A test run of 12 hours without problems was included. Design of the gas heaters for the screws was completed and the heaters will be shipped near the end of May 1992. Operations of the CMGU condensers were improved by preheating to above 212°F before starting coal feed. Installation of the screw heaters and improved condenser performance will permit operating the CMGU at the design capacity of 1000 lbs coal/hour.

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INTRODUCTION

Petroleum currently accounts for over 42% of the total energy consumption in the United States; over 40% of the petroleum consumed in the United States is imported from foreign countries. The remaining oil reserve available in the United States is less than 6% of proven recoverable fossil energy reserves while over 90% of the proven recoverable reserves are coal (1)*. Total coal resources in the United States are estimated to be more than 3.9 trillion tons (2). Just the demonstrated reserves, that is, the deposits that are proven and can be economically mined using today's technologies and mining techniques amount to 488 billion tons. At an annual production rate of 900 million tons per year, the demonstrated reserves alone will last more than 500 years. In view of the very abundant coal reserves and limited petroleum reserves, it would seem prudent to make good use of coal in our evermore difficult pursuit of energy independence.

Devising a continuous reactor system that can deliver a good quality co-products which require only minimal upgrading before being marketed is a major challenge. At present, mild gasification reactor configurations tend to fall into two broad categories: circulating or fluidized bed types characterized by high heating rates (up to 10,000 °C per second, or fixed or moving bed types characterized by slow (on the order of 0.2 to 0.5°C per second) heating rates. Circulating or fluidized-bed types produce high liquid yields at the expense of quality. Fixed or moving-bed types produce better quality liquids but in lesser quantities. An optimum reactor is envisioned as one which avoids the secondary reactions associated with slow heating rates and the quality problems associated with high heating rates. Importantly, an optimum reactor would be capable of processing highly caking coals. The reactor concept under investigation in this effort is an advanced derivative of a reactor once used in prior commercial practice which approaches the characteristics of an optimum reactor.

It is important that a mild gasification reactor interface easily with the subsequent product upgrading steps in which the market value of the products is enhanced. Upgrading and marketing of the char are critical to the overall economics of a mild gasification plant because char is the major product (65 to 75% of the coal feedstock). In the past, the char product was sold as a "smokeless" fuel, but in today's competitive markets the best price for char as a fuel for steam generation would be that of the parent coal. Substantially higher prices could be obtained for char upgraded into products such as metallurgical coke, graphite, carbon electrode feedstock or a slurry fuel

*Numbers in parentheses indicate the reference listed at the end of this report.

replacement for No. 6 fuel oil. In this effort, upgrading techniques are being developed to address these premium markets. Liquid products can similarly be upgraded to high market value products such as high-density fuel, chemicals, binders for form coke, and also gasoline and diesel blending stocks. About half of the non-condensible fuel gases produced by the gasification process will be required to operate the process; the unused portion could be upgraded into value-added products or used as fuel either internally or in "across the fence" sales.

The primary objective of this project is to develop an advanced continuous mild gasification process and product upgrading processes which will be capable of eventual commercialization. The program consists of four tasks. Task 1 is a literature survey of mild gasification processes and product upgrading methods and also a market assessment of markets for mild gasification products. Based on the literature survey, a mild gasification process and char upgrading method will be identified for further development. Task 2 is a bench-scale investigation of mild gasification to generate design data for a larger scale reactor. Task 3 is a bench-scale study of char upgrading to value added products. Task 4 is being implemented by building and operating a 1000-pound per hour demonstration facility. Task 4 also includes a technical and economic evaluation based on the performance of the mild gasification demonstration facility.

TASK 1. LITERATURE SURVEYS AND MARKET ASSESSMENT

Objective

The objectives of this Task are: (1) to identify the most suitable continuous mild gasification reactor system for conducting bench-scale mild gasification studies; (2) to identify the most feasible chemical or physical methods to upgrade the char, condensibles and gas produced from mild gasification into high profit end products; and (3) to assess the potential markets for the upgraded products from this process.

Summary

This task was completed and the Topical Report was submitted and approved by the DOE in January 1988 (3).

TASK 2. BENCH-SCALE MILD GASIFICATION STUDY

Objective

The objective of Task 2 is to study mild gasification in bench-scale reactor(s) to obtain the necessary data for proper design of the one ton/hour mild gasification screw reactor in Task 4.

Summary

After much consideration, it was concluded that it would not be necessary or desirable to build a bench-scale reactor. Instead, data and experience from Dr. David Camp's single screw reactor at Lawrence Livermore National Laboratory provided much useful information for the design of the reactor for this project. In addition, the information available from the literature on the eight years of operation of the Hayes process at Moundsville, West Virginia and the earlier Lauck's screw reactor supplied valuable process design data.

TASK 3. BENCH-SCALE CHAR UPGRADING STUDY

The rapid devolatilization of coal as it passes through its plastic zone was further examined this quarter. The proximate analyzer was programmed to do the ASTM moisture cycle normally. The volatile cycle was modified to ramp up to its final 950 degree C temperature at 10 degrees per minute. The weight loss vs. temperature was then plotted (Figure 1).

In the ten minutes ramping from 450 C to 550 C, the coal lost 9%

of its total weight due to volatile loss which is more than twice the loss in any other 10 minute period as shown in Figure 2.

This is very important to the economics of the process for two reasons:

(1) The equipment to provide a cure cycle at 475 C would be less expensive than comparable equipment designed to operate at 1000 C.

(2) By rapidly driving the volatiles off in a cure cycle at 475 C greatly reduces the residence time required in the coke oven. Less residence time in the coke oven results in a smaller and less costly oven to produce a comparable coke product with less than 2% volatiles.

A coke sample made using this cure at 450 C using continuous char made from Pocahontas Land Company coal was sent to USX Engineers & Consultants for CSR and CRI testing.

<u>Japanese Coke Reactivity Test</u>

Coke Reactivity Index (CRI)	30.4
Coke Strength After Reaction (CSR)	67.0

Normally, conventional coke is expected to have a CSR of greater than 55. This CSR of 67 is of course far superior to the standard. When the CSR test equipment is available here, we will carefully study the economics of changes to the product/process while maintaining a CSR above the required 55 to obtain the most economically appealing product.

Much of our coke work has been based on char made from the batch mild gasification unit (BMGU). Some of the coke word tended to indicate that BMGU char produced better coke briquettes than CMGU char. During May, this matter was investigated to determine the facts.

Two groups of continuous coke were made with the char being the only variable changed. Using the same parent coal, one batch of char was made in the batch mild gasification unit and one in the continuous mild gasification unit. The raw material recipe was 70% char, 20% coking coal, and 10% pitch. A relatively large portion of char was used to amplify the effect of the change in the char. The average crush strength of the briquettes was identical, 955 pounds for both the BMGU char and the CMGU char. The reactivity will be tested for each in the next quarter when the equipment is available. There was an unexplained difference of weight between the two groups of coke. A group of ten BMGU briquettes averaged 48.8 grams and the CMGU briquettes averaged 44.8 grams. A second set of ten BMGU coke briquettes averaged 48.7 grams each and the CMGU briquettes weighed 44.7 grams each.

This difference in weight may be insignificant but the cause can only be speculated at this point.

The char is a major factor in the quality of the coke made from that char. However, char made continuously is comparable to char made by the batch if other variables are equal. This statement is based on:

(1) This test, using the same control group changing only the method of char production, gave comparable results.

(2) Of the 147 coke tests done previously, the coke made from CMGU char is comparable to coke made from BMGU char. In fact, of all 147 coke tests the best coke CSR was made with CMGU char.

The CSR testing furnace was ordered on April 16, 1992, and shipped toward CTC on July 6. The reaction vessel was designed, ordered, built and received by CTC on June 12, 1992. We should have world standard CSR and CRI analysis capability by the middle of July. With this excellent coke evaluation equipment, we will be able to extend our coke making process into new areas of refinement.

TASK 4. 1000 LB/HR CONTINUOUS MILD GASIFICATION UNIT (CMGU)

A total of 13 CMGU test runs were made during the second quarter of 1992. All but one of these test runs were from a Sewell coal. Average char and coal liquids yields were 87.87% and 5.9%, respectively.

Improvements in the condenser system continued during this quarter. A 20 KW external heater was installed in the circulating line for condenser B, the middle of three condensers installed on the pyrolyzer . This heater with surface heaters on the condenser tank enables the condenser to be preheated prior to a test run. Prevention of water condensing in the condenser will solve the separation of water from the coal liquids problem.

Internal screws' heaters are on order and are expected to be received by July 15, 1992. Preparations for installing the heaters are underway. Insulation of the stub shafts has been completed. Hot gas flow control tubes have been installed in the screws. The major tasks for the heaters' installation will be: (1) mounts fabrication; (2) flues installation; (3) air supply fan installation; (4) control system wiring; and, (5) natural gas supply piping. The internal heaters should more than double the heat transfer rate during pyrolyzer operation and permit a coal feed rate of 1000 pounds per hour.

Forward rotation-reverse rotation ratios of the pyrolyzer screws have been varied over a wide range to control residence times of the coal in the pyrolyzer. Using standard screw conveyor rate calculations with a slip factor, calculated residence times of 2 to 10 minutes have been run. Using a probe to detect char flow indicates that the actual residence time is in the range of 45 to 60 minutes due to the non-conveying characteristics of the plastic coal. Since the plastic coal zone is the dominant factor in determining the residence time, full forward rotation of the screws was used for the last three test runs of the second quarter. Residence times as measured by a probe in the char stream were in the range of 40 to 50 minutes. Although two of these runs were terminated early due to mechanical problems, char quality and yield, coal liquids yield, and operation of the pyrolyzer were normal. Full forward screw rotation will permit simplification of the pyrolyzer drive system. Evaluation of full forward rotation of the screws will continue after the screws' heaters are installed.

The right screw of the pyrolyzer has developed cracks in two locations. The first one required removal of the screws and repair at an off-site shop. The other crack was repaired with the screws in the pyrolyzer. A failure of the first repair in the weld is thought to be due to a faulty weld. The screw was rewelded at a local shop. Purchasing a new pair of screws is being considered. Using schedule 80 stempipe instead of the original schedule 40 stempipe and 310 stainless steel instead of 304 stainless steel, should solve the screw cracking problem.

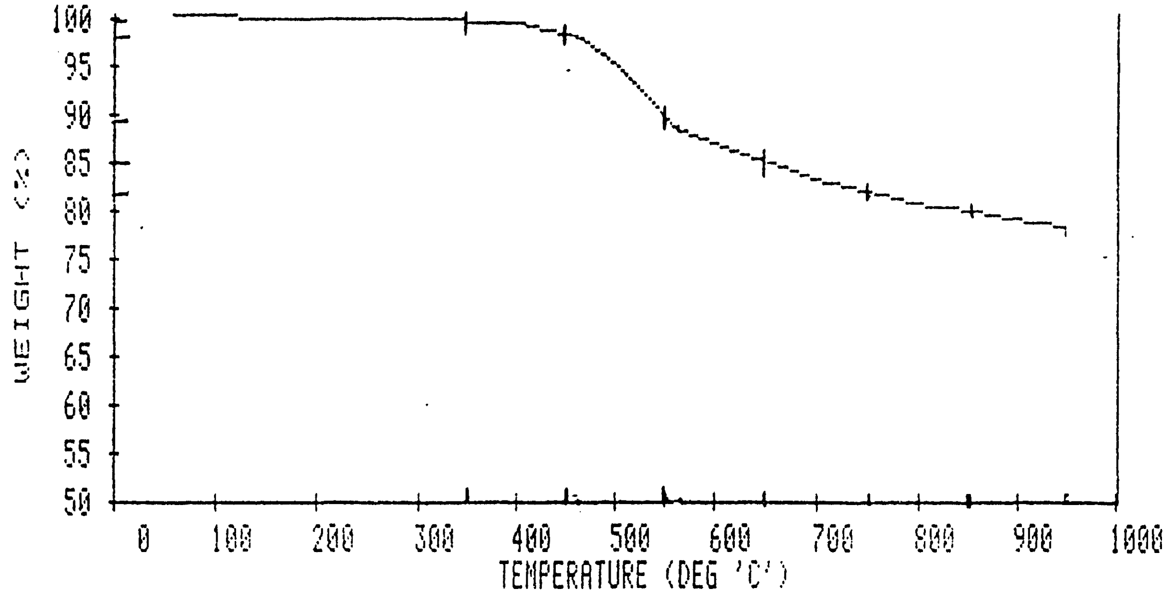
The current plans are to install the screws' heaters in the original repaired screws and evaluate the pyrolyzer with the original design which included internal heating of the screws.

Sincerely,

Glenn W. O'Neal
Project Manager

MOISTURE VOLATILE

Date : Apr. 21, 1992 Elapsed Time : 02:13:00



Frn.#1 Cr.# 6 Type:Classification. ID:KNOX CRK- Weight: 0.730 Gram(s)

Title : MOISTURE VOLATILE Zero Dev : 10 Max Dev : 5

Mac Mode	Cvr	Ramp Rate	Final Temp.	Mode/ ATM	Step End Mode.	Timeout or % Deviation
Mst	OFF	99 D/M	106 'C	B/N2	Cnst Wgt	0.05 %
Vol.	ON	10 D/M	950 'C	B/N2	Timeout	7 Min.

FIGURE 1

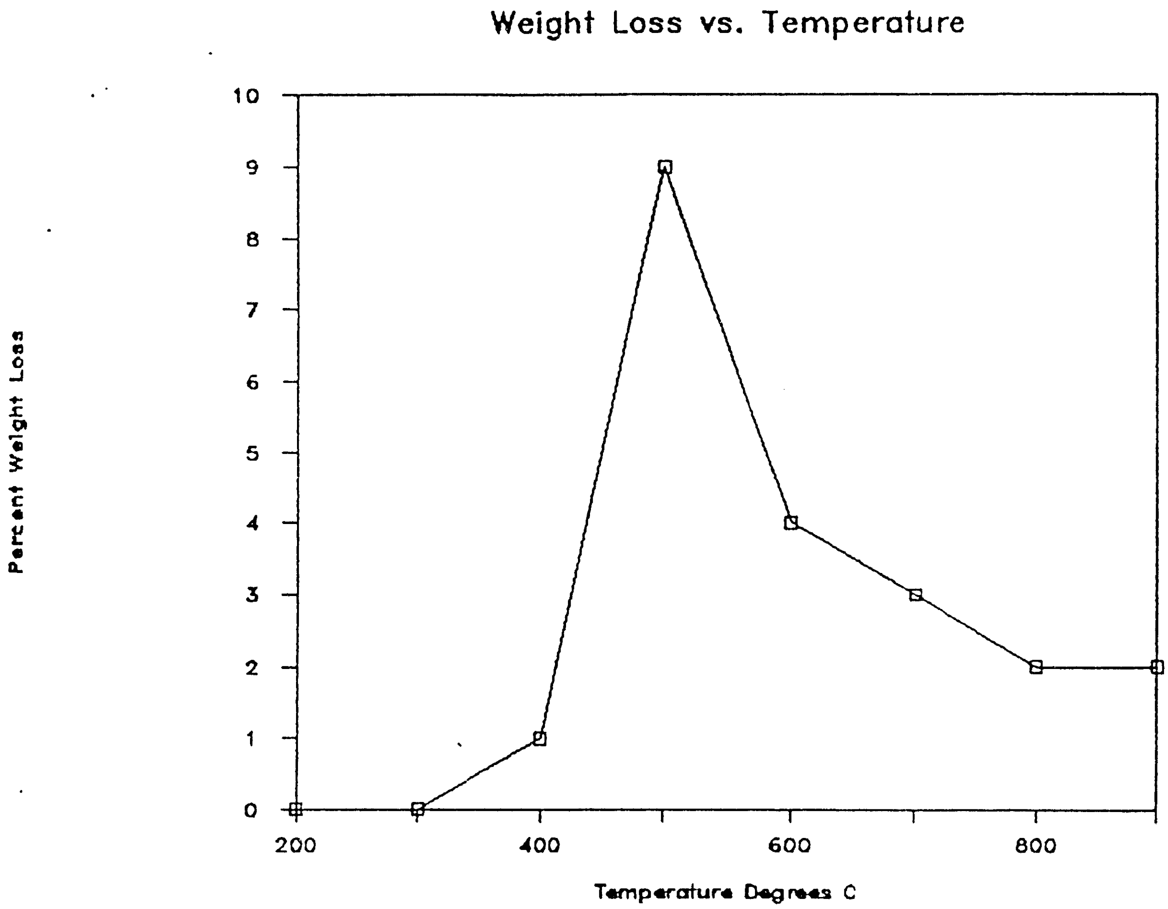

Weight Loss vs. Temperature
Percent Weight Loss
10
9
8
7
6
5
4
3
2
1
0
200
400
600
800
Temperature Degrees C

FIGURE 2