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

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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

Seventeen continuous coke tests, 131 through 147 were made in the first quarter of 1992. The first ten of these tests were done using a Consolidation Coal Company poorly coking (less costly) coal. This coal has an FSI of 2-3 and therefore is not desirable for use as a coking coal in conventional coke ovens. The better coke made from these ten tests has a crush strength of about two thirds of the best coke made from coking coal.

If there is interest shown for coke made from non-coking coal at a somewhat reduced price, this testing could be expanded to improve the product from this preliminary testing. Coke made from non-coking parent coal would be used in relatively low percentages in the blast furnace.

With an extended test program using "strength after reaction" as the quality measure, the coke product could be optimized. However, coke made from lower rank parent coal will not equal coke made from higher rank parent coal.

A temperature control was installed on the coke oven which allows much better control on the heat history of the coke than manual control.

A cure at 850°F was tested with very promising results. Results of coke with and without this cure are charted below:

	Crush Strength	Volatile Matter
1 1/2 Hr Coke at 1832°F	1500 lbs	4.76
1 Hr Cure at 850°F and 1 1/2 Hr Coke at 1832°F	2772 lbs	.72

This data is phenomenal! To drop the volatile matter to one fifth and increase the strength by 80% is a major conclusion. The first impression would be that adding a soak at 850°F would lengthen the total heat history of the coke. However, because the volatile matter comes off so much faster while the coal is in the plastic zone, the total heat history will be shortened. The rapidly heated green briquette apparently makes a shell which restrains the volatiles.

From testing at Salem Furnace, ABB Raymond and Hankin, Inc., it's been known that briquettes containing swelling coal of 15% or more cannot be introduced into a coke oven at temperature. The briquette makes a hard surface or shell and the following coal contraction and swelling cause the briquette to self-destruct. This curing will eliminate that problem.

The last test in this quarter, 147, was to focus on strength after reaction. UEC tested a sample which resulted in a CSR of 67.0; our prior best CSR was 62.1. The standard for conventional coke typically is 55 or greater. This is interesting because our literature search hast not shown any other formed coke work that produced coke of this strength tested by an independent third party.

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

During the first Quarter 1992, 16 test runs were completed using 13 different coals. Test runs are no longer terminated due to pyrolyzer hydraulic drive overloading. The coal feed rate is controlled as required for each coal to avoid overloading. The maximum feed rates are in the 300 to 500 lbs/hr range depending upon the characteristics of the coal being pyrolyzed. A summary of these test runs is attached.

Test run 8-92 was a planned 12 hour run that was completed without any problems. A 24 hour run is planned for May 1992 prior to installation of internal screw shaft heaters.

The heaters are scheduled to be shipped in late May 1992. Design of flow control tubes that will be installed in the screw shafts and insulation of the stub shafts to prevent bearings overheating are underway. Also, plans to provide a flue for the heaters' combustion gases are being made.

The effort to improve the condenser system continued. Heating of the condensers to above 212°F prior to starting coal feed and maintaining the condensers above 212°F during the test run should prevent water condensing with the coal liquids. Separation of water from coal liquids by decantation is not possible. Problems with heat tape failure have plagued this project and a better method of heating the condensers is being considered.

When the heaters have been installed and the condensers' improvement work has been completed, it is expected that the CMGU design capacity of 1000 pounds coal/hour can be reached.

TABLE 1
SUMMARY OF CMGU TESTS

Run No.	Date & Hrs./Min. Duration	Coal Used	Coal Feed Rate lb/Hr	Forward Reverse Ratio	Zone #2 °F	Liquid Lb/Hr	Char % Volatile Avg.	Char % Ash Avg.	Char % Fixed Carbon Avg.	Char Lb/Hr	Coal Liq. %	Char %	Notes	Residence Time Min.
2-92	1/7/92 2:10	Char from 1-92	650	19F/7R/20P	1393		10.78	9.95	79.27	646		98.71 (99.3)	(1)(3) (2)	7.80
3-92	1/17/92 4:00	Sewell Coal	417	19F/7R/20P	1398	30	5.11	39.43	55.46	368	5.3	91.50 (88.3)	(1)(3) (2)	7.80
4-92	1/21/92 2:00	Beckley Coal	552	19F/7R/20P	1411	19	8.24	13.08	78.68	482	3.4	90.55 (87.3)	(1)(3) (2)	7.80
5-92	2/7/92 1:37	Beckley	518	19F/7R/20P	1343		11.45	8.52	80.02	463		74.28 (88.23)	(1)(3) (2)	7.80
6-92	2/14/92 6:10	Eastern KY Met.	411	19F/7R/20P	1347	59.0	9.78	11.23	78.99	314	18.76	77.95 (68.62)	(1)(3) (2)	7.80
7-92	2/17/92 1:30	Eastern KY Met.	356	19F/7R/20P	1370	54.7	7.81	10.70	81.17	320	15.33	72.48 (89.70)	(1)(3) (2)	7.80
8-92	2/25/92 12:00	Eastern KY Met.	369	19F/7R/20P	1401	54.0	8.96	8.62	82.42	237	14.6	75.56 (64.10)	(1)(3) (2)	7.80
9-92	3/3/92 8:00	Eastern KY Met.	495	17F/7R/10P	Not Working	73	12.23	7.51	80.26	300	14.75	75.53 (69.99)	(1)(3) (2)	7.00
10-92	3/11/92 4:00	Eastern KY Met.	448	17F/7R/10P	1384	72	10.59	7.69	81.76	316	16.20	75.16 (70.67)	(1)(3) (2)	7.00
11-92	3/16/92 3:00	PLC #3	313	17F/10R	1407	8.0	4.65	5.20	90.14	287	3.0	82.92 (91.49)	(1)(3) (2)	8.30
12-92	3/17/92 4:00	PLC #6	398	17F/10R	1424	17.5	4.83	4.04	91.13	345	4.4	82.94 (86.79)	(1)(3) (2)	8.30
13-92	3/19/92 5:00	PLC #1	283	17F/10R	1422	7.6	4.34	6.08	88.96	262	2.8	87.93 (92.58)	(1)(3) (2)	8.30
14-92	3/24/92 3:30	PLC #2	451	17F/10R	1422	25.1	5.15	3.21	91.63	304	5.6	80.38 (67.41)	(1)(3) (2)	8.30
15-92	3/25/92 4:30	PLC #4	316	17F/10R	1418	20.9	4.18	3.59	92.24	270	6.5	85.71 (85.26)	(1)(3) (2)	8.30
16-92	3/26/92 4:30	PLC #5	337	17F/10R	1424	6.6	4.80	6.36	89.00	306	1.9	88.73 (83.13)	(1)(3) (2)	8.30
17-92	3/31/92 3:30	PLC #16	464	17F/10R	1428	40.6	6.64	7.76	85.60	308	8.9	74.84 (66.46)	(1)(3) (2)	8.30

Notes:

(1) Calculated Yield Char Yield % = $(100 - \text{Coal Vol }\%) + \dfrac{\text{Char Vol }\%\ (100 - \text{Coal Vol }\%)}{100 - \text{Char Vol }\%}$

(2) Actual Yield

(3) Char Rate includes char cleared from pyrolyzer and cooler after coal feed stopped