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

Quarterly Report
for the Period October 30, 1991 - January 2, 1992

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EXECUTIVE SUMMARY

During this quarter the work on Task 3, char upgrading, was in two areas; upgrading Penelec char made from Penelec filter cake to blast furnace formed coke, and evaluating various bituminous pitch binders.

The formed coke from Penelec filter cake was of good quality with a high crush strength of 3000 pounds. The reactivity was not equal to that of conventional coke but it is felt that it could be made to equal conventional coke with further study, specifically by adding binder coal to the raw material recipe.

The work evaluating bituminous pitch binders confirmed earlier thinking that will be valuable to a commercial scale-up. Asphalt binders are compatible with coal tar binders and produce a coke of equal quality. Hence asphalt binders can be used to supply deficiencies of tar production in units employing coals with insufficient volatile matter to supply enough tar for the coking process. Asphalt binders have about a 50% savings from coal tar pitch.

During the 4th Quarter of 1991, a total of 15 CMGU test runs were made. Efforts continued to determine the optimum forward/reverse ratio to maximize coal feed rate. The success of these efforts has been limited with a maximum coal feed rate of 400 lbs/hr obtainable with a caking coal. The handicap of not having screw shaft heaters cannot be overcome by adjustment of the forward/reverse ratio.

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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

Nine briquetting tests were made in this quarter 122 through 130. In addition 300 pounds of formed coke were produced from Penelec filter cake for evaluation.

The Penelec filter cake had the following proximate analysis as received:

	As Received	Dry Basis
% Moisture	44.22	-
% Ash	6.00	10.76
%Volatile	14.78	26.50
% Fixed Carbon	35.00	62.74
	100.00	100.00
BTU/lbs	7,744	13,883
% Sulfur	.56	1.01

This filter cake was dried in the heater/mixer to less than 4% moisture, loaded into the mild gasification unit and made into char with the following proximate analysis:

	As Received	Dry Basis
% Moisture	.80	-
% Ash	12.56	12.66
%Volatile	5.68	5.73
% Fixed Carbon	80.96	81.61
	100.00	100.00
BTU/lbs	12,990	13,095
% Sulfur	1.00	1.01

The char was then made into formed coke using the ratio of 90% char and 10% CMGU tar. The formed coke had the following proximate analysis:

	As Received	Dry Basis
% Moisture	.38	-
% Ash	12.06	12.11
%Volatile	.97	.97
% Fixed Carbon	86.59	86.92
	100.00	100.00
BTU/lbs	12,380	12,427
% Sulfur	.93	.93

This formed coke has a crush strength of 3,000 pounds which is good. The reactivity of this coke was fair having a CRI of 43.5 It is felt the reactivity could be greatly improved by analyzing various different recipes and ratios of the raw materials, specifically, by adding a portion of binder coal.

A second focus of our work this quarter was to compare various bituminous binder. This work is critical to justify the economics of a scale up. Presently, hard coal tar pitch such as Allied 110°C pitch is $300/ton, asphalt such as Shell AC 20 is $140/ton. These prices constantly vary, but the price of asphalt is about half the price of coal tar pitch. Tests 126, 127, 128, 129 and 130 were made to evaluate different binders and how varying the binder varied the final coke product. The control material was held as constant as possible and was maintained at 90% by weight. The following bituminous binders were used in a 10% ratio:

Test	Binder	Crush Strength
126	150°C Allied Coal Tar Pitch	2350
127	110°C Allied Coal Tar Pitch	2050
128	Lion 6/9 Pen Asphalt Pitch	2290
129	Shell AC 20 Road Asphalt	2100
130	Roofing Tar, Asphalt Base	2120

The crush strength is typical of our better briquette runs. These tests indicate that many different binders can be used to produce quality coke including asphalt pitch.

It is important to note that the control material included 5% CMGU coal tar. Tests 128, 129, and 130 were various asphalt products. They all were compatible with coal tar pitch. Hence, they can be used to supply the deficiencies of pitch production in any installation employing coals having insufficient volatile matter to furnish enough pitch binders for coking all of the char produced.

Next quarter part of our work will be with a poorly coking Consolidation Coal Company coal. This coal has an FSI of 2-3, therefore, it is not desirable for use in conventional coke process. We plan to make 150- 00 lbs of briquettes to be sent to Consol for their testing.

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

During the 4th Quarter 1991, 15 test runs were made of varying durations. The foremost objective of these test runs was to determine the maximum capacity of the CMGU. Secondary objectives were:

(1) to produce char from various coals for formed coke work;
(2) improve the existing condenser performance;
(3) evaluate different coals; and
(4) obtain other operational data for scale-up to a commercial size CMGU.

Achieving the designed 1000 lbs per hour coal feed rate has been greatly handicapped by the early failure of the electric heaters originally installed in the CMGU screw shafts. The heaters failed during the start-up period and the effects on coal feed rate of internal screw shaft heaters was never determined.

Non-confidence in the heaters design corrections by Accutherm, Inc. prevented use of electric heaters. Efforts are underway to design a gas heater system for the screw shafts. Any commercial CMGU will use gas fired screw shaft heaters with the non-condensible gas from the process as the fuel. A successful gas heater design for the pilot plant CMGU will be of value in the scale-up.

To determine the maximum coal feed rate without shaft heaters, the screws forward/reverse ratio was varied to provide residence times from 3 to 15 minutes. Up to a 20 second pause was included in a screw time cycle based on historical information from a hand cranked screw pyrolyzer operated in 1927. No significant increases in coal feed rates were obtained. When pyrolyzing a caking coal, sustainable coal feed rate is limited to about 400 pounds per hour. Installation of shaft heaters will allow experimenting with higher feed rates.

The major problem with the condenser system is plugging of vapor lines. Insulating the vapor lines to prevent condensation and accumulation of tar did not solve the problem. Electric heating tapes were used to preheat and maintain one of the three vapor lines at 1000°F which seemed to be about 50% effective in prevention of plugging. Heating of vapor lines and use of high pressure nitrogen "blasts" to clear lines are the next efforts to solve the plugging problem.

An improved condenser design is needed. A proposed design is being evaluated to verify that the problems associated with the current design have been eliminated. The new design will have a 12 inch vapor outlet line to a tar trap and a vertical bayonet condenser to minimize plugging.

Installation of gas heaters in the two screw shafts of the pyrolyzer and a non-plugging condenser system will solve the two basic problems in the pyrolyzer operation. Making test runs of 24 hours duration will then be possible.

Sincerely,

Glenn W. O'Neal

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Project Engineer

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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.
27	10/30/91 1:45	Splash Dam	1342	60F/9R	1410	23	27.29	4.47	67.89	991	1.7	73.8	(1)	
28	10/30/91 4:00	Splash Dam	548	60F/9R	1386	39	7.14	5.79	86.48	354	7.0	64.4		
29	11/04/91 3:30	Splash Dam	268	20F/9R	1426	47	6.80	2.97	89.59	147	17.5	54.7	(2)	4.57
30	11/06/91 3:00	Splash Dam	605	20F/9R	1376	72	8.00	5.90	85.65	445	11.9	73.5		4.57
31	11/11/91 3:00	Splash Dam	296	49F/9R	1405	8.3	7.05	5.77	86.42	231	2.8	78.0	(3)	3
32	11/11/91 3:00	Splash Dam	300*	39F/19R	1402	8.3	5.87	6.03	87.67	153	2.7	51.0	(3)	3.83
33	11/11/91 3:00	Splash Dam	288	35.7F/ 22.3R	1424	6.3	4.49	6.12	89.92	143	2.0	49.7	(3)	8.17
34	11/14/91 3:00	Splash Dam	320	34F/24R	1387	46.3	3.99	6.32	89.32	198*	15.1	61.9	(3)	10.38
35	11/20/91 3:00	Splash Dam	293	17.4F/10.6R	1415	15	4.3	6.0	88.5	115	5.1	39.2	(4)	7.63
36	11/20/91 3:00	Splash Dam	315	23.4F/14.6	1400	18	4.2	6.3	88.4	158	5.8	50.2	(5)	7.88
37	11/26/91 2:00	Splash Dam	510	48F/7R/20P	1413	30	8.52	6.2	83.8	250 328	-	55.2 72.0	(6) (7) (8)	3.66
38	11/27/91 1:30	Splash Dam	800	48F/7R/20P	1377	-	13.66	5.8	79.8	156	-	41.9 67.2	(7) (8)	3.66

* This figure has been corrected from an earlier issue of this summary.

(1) Purpose of this run was to determine maximum coal feed rate.
(2) A special test to make char for use in ferro-silicon production.
(3) *This run was a part of a series of 4 runs designed to determine effect of residence time.*
(4) 30 seconds cycle.
(5) 45 seconds cycle.
(6) 75 seconds cycle.
(7) Based on char weight when coal feed stopped.
(8) Based on char weight after clearing pyrolyzer and cooler of char.

TABLE 2

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.
39	12/09/91 4:30	Splash Dam	503	48F/7R/20P	1408	5.5	6.94	5.92	87.14	410	10.08	79.38 (81.5)	(1) (2)	3.66
40	12/30/91 4:50	Splash Dam	461	48F/7R/20P	1403	2.7	6.90	5.94	87.16	347	6.1	79.34 (77.4)	(1) (2)	3.66
1-92	01/02/92 3:12	Consol EKC	581	19F/7R/20P	1389	8.5	11.84	12.09	76.06	425	14.6	72.12 (73.1)	(1) (2)	7.80

Notes:

(1) Char yields previously reported have been actual yields based on coal used and char weights obtained for each test run. Above char yields and future char yields will be calculated by the following formula:

$$\text{Char Yield \%} = (100 - \text{Coal Vol \%}) + \frac{\text{Char Vol \%}\,(100 - \text{Coal Vol \%})}{100 - \text{Char Vol \%}}$$

Actual yields for the above test runs are in parenthesis in the char % Column

(2) Char rate includes char cleaned from pyrolyzer and cooler after coal feed stopped.

END

DATE FILMED

9/15/92