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Development of an Advanced Continuous Mild Gasification Process for the Production of Co-Products

Quarterly Report
January - March 1996

Glenn W. O'Neal

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Work Performed Under Contract No.: DE-AC21-87MC24116

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
Coal Technology Research Corporation
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EXECUTIVE SUMMARY

Determination of the best furnace for a commercial coke plant is underway. A shuttle or tunnel kiln has economic advantage over a rotary hearth design. Production of 20 tons of coke in a small shuttle kiln is near completion which will provide experience for this design.

Twenty tons of CTC continuous coke are being produced for testing at a General Motors' foundry. The production is approximately 75 percent complete. During this production, variables of the process are being studied to aid in design of a commercial coke plant. Raw material composition, blending, briquetting variables, and calcining heat profile are the major areas of interest.

Western SynCoal Company produces a dried coal product from sub–bituminous coal. This upgraded product was evaluated for producing coke products by blending char from this coal product with the coal product along with suitable binders. The green briquettes were then calcined to produce coke. The resulting coke was judged to be usable as part of a cupola coke charge or as a fuel in cement kilns and sugar beet furnaces.

TABLE OF CONTENTS

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

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[1]T. R. Scollon, "An Assessment of Coal Resources," CHEMICAL ENGINEERING PROGRESS, June 1977, pp. 25-30.

[2]J. M. Eggleston, "Bituminous Coal Marketing," presented at the Third U.S.A.-Korea Joint Workshop on Coal Utilization Technology, Pittsburgh, October 5-7, 1986.

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 5: CONTINUOUS BRIQUETTING AND COKING

Objective

The objectives of Task 5.1 are to design and construct a 1000 lbs/hour continuous briquetting and coking facility interfaced to the existing twin screw reactors.

In Task 5.2, the facility will be operated at steady state to produce coke for actual testing by industry.

Summary

The design of the facility will be done by CTC personnel with outside help used only as needed. The basic plan is to use equipment available at CTC and purchase used equipment wherever possible. The equipment installation will be done by CTC personnel with a minimum of outside contractor help.

TASK 5.1: DESIGN

Furnaces continue to be evaluated for application in a commercial plant. A 500–pound sample of green briquettes was taken to Swindell Dressler for testing in a shuttle kiln. This test was conducted on January 23 and monitored by CTC personnel. The test succeeded in producing quality coke and providing the concept of a shuttle or tunnel kiln. Engineering now is to burn the volatiles from the coke that will be economically attractive. In parallel an available shuttle kiln was evaluated for coking the 40–ton sample to ship to General Motors. This kiln was originally designed for curing pottery. The capacity will be one ton per cycle.

TASK 5.3: FURNACE TEST

In the First Quarter of 1996 most of the manhours were spent producing the 20 tons of coke for the General Motors cupola test. The task is going well but is still very labor intensive. All the raw materials have to be dried, crushed, weighed, and blended before they are briquetted. In demonstration quantities, as designed, the PDU process is well suited. In large quantities the PDU process is too labor intensive to be efficient. In making this test sample many quality factors are being closely monitored. Some of the factors are:

Raw material recipe
Moisture
Particle size
Blending time
Briquetting temperature
Briquetting roll speed
Calcining heat profile

In addition, there have been many delays caused by nuisance breakdowns and bad weather. At present the coke is scheduled to ship April 15 for testing on April 17.

An eight ton test was conducted at a working cupola with very favorable results. This test was run using 50 percent CTC continuous coke and 50 percent conventional coke. In this run, temperature was maintained at desirable levels and carbon pickup was as

it should be. No negative characteristics were detected. To date, this is the longest test run of CTC continuous coke. Each of these tests further proves the acceptability of CTC continuous coke in the cupola and helps to reduce any perceived risk.

In parallel with the General Motors' test, work was done on making char for Elkem Metals from a Pittston coal. It is tentatively planned to make a 20 ton char sample for testing. Initially a two ton sample was made for evaluation. This initial test sample went well and is currently being studied to determine how best to proceed.

TASK 5.4: NON-CAKING COKE TESTS

Coal Technology Corporation conducted a test program with Western SynCoal Company to upgrade a sub–bituminous dried coal product from the Western Energy Company's Rosebud Mine at Colstrip, Montana. Western SynCoal supplied approximately one ton of their dried coal product to accomplish this test program.

The as–received samples were analyzed for proximate (moisture, ash, volatiles, fixed carbon) by CTC through a Mac 500 Determination Analyzer.

Char was first produced from the dried coal product and proximate analysis done with the volatiles at 13.4 percent. This char was then used to make coke. The coke made from the Western SynCoal product was analyzed with the following results:

Test 1

Western SynCoal Char, %	25
Western SynCoal Coal, %	25
Coke Breeze, %	25
Pitch, %	10
Binder Coal, %	10
Coal Tar, %	5

Product Analysis

Moisture, %	0.65
Ash, %	12.12
Volatile, %	1.32
Fixed Carbon, %	85.91
CSR	0.0
CRI	70.43
Drop Shatter, %	72.13

Test 2

Western SynCoal Char, %	50
Western SynCoal Coal, %	23
Coke Breeze, %	12
Pitch, %	15
Binder Coal, %	10

Product Analysis

Moisture, %	0.82
Ash, %	11.77
Volatile, %	1.42
Fixed Carbon, %	85.99
CSR	1.19
CRI	66.12
Drop Shatter, %	94.62

Test 3

Western SynCoal Char, %	50
Western SynCoal Coal, %	30
Coke Breeze, %	10
Pitch, %	10

Product Analysis

Moisture, %	0.71
Ash, %	12.02
Volatile, %	1.10
Fixed Carbon, %	87.27
CSR	1.10
CRI	71.19
Drop Shatter, %	96.40

The goal of this project was to enhance Western SynCoal's coal into a usable coke product. The coke produced could be used in a cupola operation as a carbon enhancer or for a fuel into the cement or sugar beet furnace to replace conventional coke. The CSR and CRI although not to industry standards for the blast furnace industry have an excellent drop shatter index. The large size retention is of the utmost importance for the cupola, cement or sugar beet industry.

Glenn W. O'Neal
Project Engineer

GWO:mds