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(DE96004442)

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

Quarterly Report
October - December 1995

Glenn W. O'Neal

January 1996

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
Bristol, Virginia

DISCLAIMER

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103 Thomas Road
Bristol, Virginia 24201

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EXECUTIVE SUMMARY

Efforts continued to obtain financing for a commercial continuous formed coke plant. Discussions were held with two steel companies that are interested in producing coke for their use in steel production and foundry operations.

Planning for production of 40 tons of foundry formed coke is underway. This coke will be used in two 20–ton tests at General Motors' foundries. During this production, it is planned to determine if a tunnel kiln can be used as a coking furnace as an alternative for a rotary hearth. A rotary hearth is about three times more costly than a competitive–sized tunnel kiln.

Work continued on using Western non–caking coals to produce formed coke. Successful tests were made by using Eastern caking coals and other binders to permit using up to 50% of the cheaper Western non–caking coals in formed coke production.

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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

[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

Discussions with a large European steel and coke manufacturer and a U.S. steel manufacturer were held with the objective of using the CTC/DOE continuous coke technology in a commercial plant. The basic technology was slightly modified for this application and many technical questions were discussed and answered. A basic flow sheet was also made for this application. Some of the areas of discussion were: what are the technical limits of a scale–up and is a 20 X scale–up possible; what would be the reasonable life of the reactor; and how reliable would it be in a continuous commercial application. Reactor heat transfer calculations for pyrolysis were reviewed. Reactor process variables such as retention time, screw speed, temperature, and forward/backward motion were evaluated. The capital and economic calculations were reviewed. The funding and ownership were analyzed. A mass balance was studied. A heat balance was developed. Heat efficiency was evaluated including regeneration of heat and energy recovery. Process data were analyzed to clarify how variables within the process affect quality, economics, throughput and emissions. The type and size of the coking furnace and basic plant layout were discussed. Economic considerations were discussed including investment costs and the scope of those investments, hidden costs in infrastructure and utilities, operating costs and a general business plan. Lastly, the market for continuous coke was evaluated. This commercial plant is designed to produce 60,000 TPY. Equipment diagrams of the char and coke production operations are included in this report.

Commercial–sized coking furnaces continue to be studied. At present the tunnel kiln appears to have the most advantages. One of the major advantages is cost. A tunnel-kiln on a commercial scale was quoted at $2,000,000. A rotary hearth furnace on the same scale was quoted at $7,000,000. Another advantage is the briquettes are not handled or tumbled while they are taken through their heat cycle. At some point in the heat cycle while the bitumen is soft and while the binder coal is going through the plastic zone, the briquettes are fragile. Not handling them while they are fragile will greatly increase yield by reducing breakage and abrasion. A higher yield will impact on the economics which is always of prime importance in a commercial project.

TASK 5.3: FURNACE TEST

Two 20–ton tests were discussed with General Motors. One test would be in a production cupola and the other in the research lab cupola. These tests will be done on a cost–share basis. Success in these tests would eliminate any lingering doubts about the performance of the CTC continuous coke in the cupola. Investor confidence will increase and risk will be reduced after successful completion of these two tests done jointly with General Motors. This program will be an excellent way to benefit the development of a new manufactured coke product designed to give optimum furnace performance. To do this testing, CTC's contract was amended.

In summary, this tentative cooperative test program is structured as follows:

1. CTC will pay for the coal and other binding ingredients, make the coke, ship the coke to GM, and travel to be present during the testing program at CTC's expense.

2. CTC will make modifications to our existing pilot plant at a cost of about $40,000 to allow for continuous production of the coke.

3. CTC's total cost including labor, shipping, lab testing, equipment modification, etc. will be about $200,000.

4. GM will test the coke in both research and production cupolas at GM's cost. The exact test details and time frame will be worked out as the test gets closer. The production test will be using a blend of CTC/DOE continuous coke and conventional oven coke. At GM's request, the sample will be blended at CTC and sent to General Motors pre–blended. The second test will be conducted at the Pellestar, Ltd. cupola and will most likely occur in two heats, both to be funded by GM. The first will be a baseline heat using 100% conventional slot oven coke as the fuel/carburizer requirement for the cupola. The second heat will utilize 100% CTC/DOE continuous coke as the fuel/carburizer requirement. Data from the two heats can then be compared as the basis of a report. The Pellestar test will occur after successful completion of the production trial. The production trial will occur at either GM's Defiance, Ohio, foundry or at the Saginaw Metal Casting Operations Plant in Saginaw, Michigan.

5. A combined publication will be made from the data obtained in the tests.

6. Time schedule for the first shipment of coke to GM is tentatively set for mid–February, 1996, for the coke production testing soon after and a second shipment of coke in mid–March, 1996, for the research test.

Work has begun on producing the first test sample and it appears that a mid–February ship date is realistic.

TASK 5.4: NON-CAKING COKE TESTS

Five reactor runs were made using non–caking coal from the Rosebud seam. The first was to make char for the production of coke. The raw coal analysis was as follows:

	As Received	Dry
Moisture, %	27.39	——
Volatiles, %	31.25	43.05
Ash, %	5.52	7.60
Fixed Carbon, %	35.84	49.35

After the reactor run, the char analysis was as follows:

	As Received
Moisture, %	0.51
Volatiles, %	11.40
Ash, %	12.26
Fixed Carbon, %	75.83

Coke was made with this char using CTC/DOE technology with the following results:

CRI	56.4
CSR	19.2

Coke made from this non–caking coal will not meet the quality specifications of coke made from coking coal. However, these results have both major coal producers and coke users very excited because of the very low cost of the coal and subsequent coke. It is possible that this low cost coke could be blended with conventional coke and greatly reduce the total cost of coke in the blast furnace and cupola.

The next four reactor runs were made to test the reactor as a dryer for reducing only the moisture content while maintaining the stability of the coal and preventing spontaneous combustion. Conditions were modified in each run from data obtained in the prior run to bring the moisture down while maintaining the stability. The analysis of the dried coal following can be compared to the coal as received.

Moisture, %	0.61
Volatiles, %	34.57
Ash, %	7.00
Fixed Carbon, %	57.82

Size Analysis of Dried Coal

Size	Wt., %	Cum. Wt., %
+3/8"	29.8	29.8
3/8" x 4 mesh	23.1	52.9
4 mesh x 6 mesh	24.0	76.9
6 mesh x 16 mesh	19.0	95.9
16 mesh x 30 mesh	2.5	98.4
–30 mesh	1.6	100.0

The coal was completely dried with no loss of volatiles and stability was maintained.

In addition to the coking work done last month using non–coking coal from the Rosebud seam, work has begun on SynCoal mae from Rosebud coal. Rosebud SynCoal is made in conjunction with the U.S. Department of Energy under the Clean Coal Technology Program. This technology enhances Powder River Basin coal by reducing moisture and sulfur and substantially increased Btu content. The goal is to produce acceptable foundry coke with a majority of SynCoal as feedstock.

The analysis follows:

	Rosebud	SynCoal
Moisture, %	27.39	1.57
Volatiles, %	31.25	36.61
Ash, %	5.52	8.36
Fixed Carbon, %	35.84	53.46

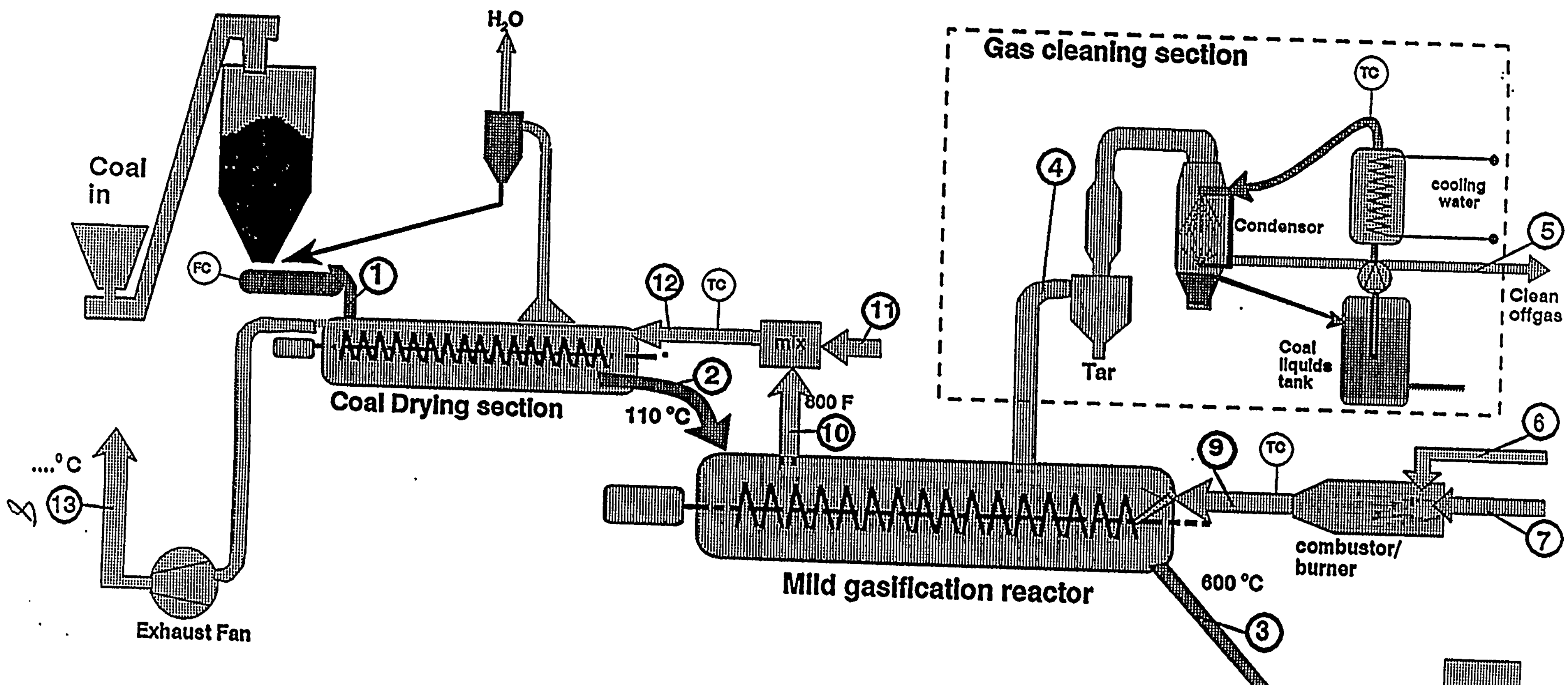
An initial test was done using 25% SynCoal, 25% char from SynCoal, 12% coke breeze and 38% binders. These 6 x 5 x 4 briquettes had a 69.4% shatter retention on a 3" screen. Next month a test matrix will be developed on CTC experience, knowledge and judgment.

Glenn W. O'Neal

Glenn W. O'Neal
Project Engineer

GWO:mds

CTC COKEMAKING FIRST PROCESS STEP

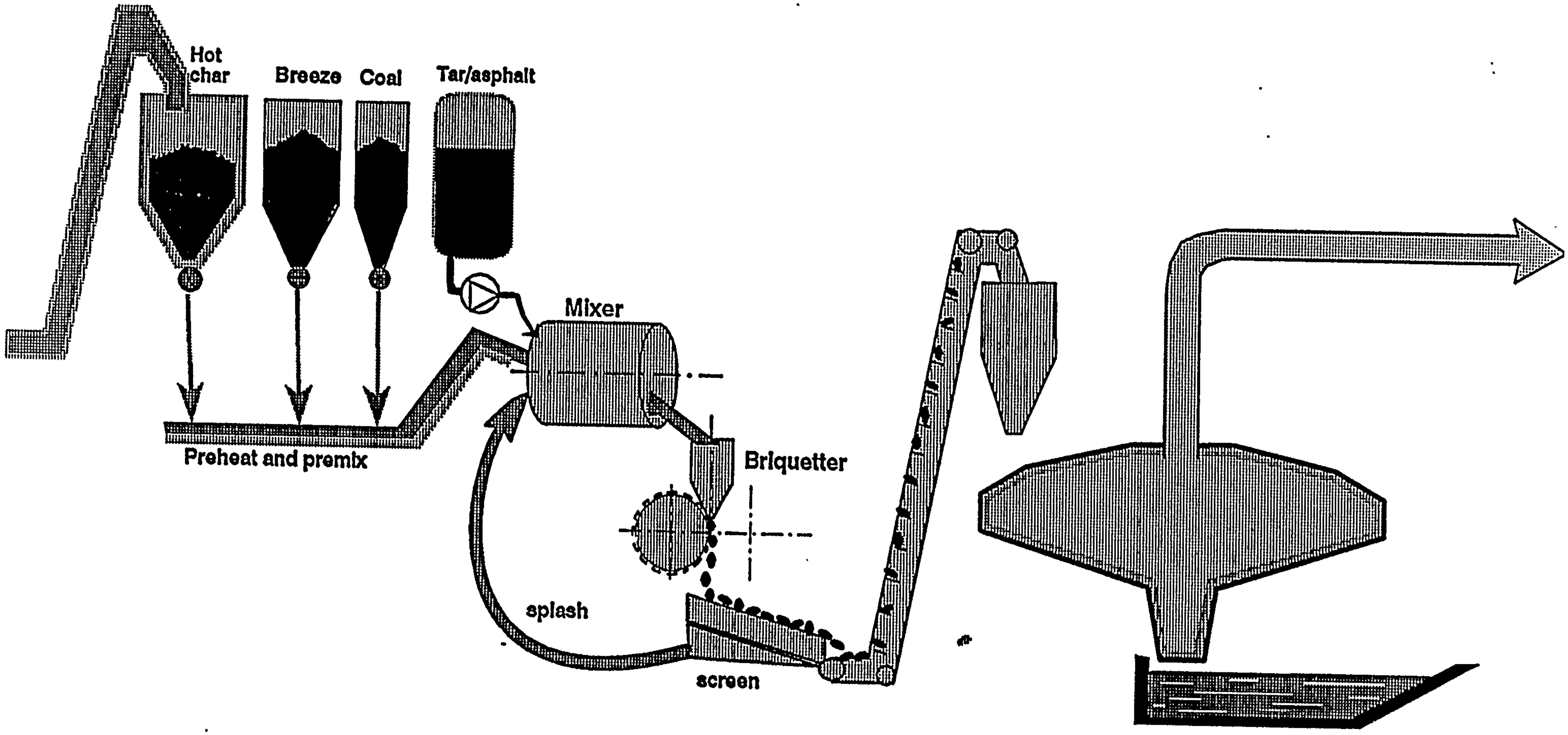


Main process parameters

	1	2	3	4	5	6	7	8	9	10	11	12	13
Material	Coal	Coal	Char	Reactor-Vapor	Non-Cond gasses	Air	Klingas	H2O	Hot Gas	Hot Gas	H2O	Hot Gas	Hot Gas
Temp F	Amb.	< 400	500	450-570	> 212	Amb.	2300	Amb.	1600 max	800	Amb.	**	500-600
Temp C	Amb.	< 200	260	230-300	> 100		1260		870 max	426			260-320
Mat Flow t	7.4	6,7	6,7	1,3	0,7	*	23 000	*			***		
							(ACFM)						

* Adjustable to obtain 1600 Fat pt 9
** Adjustable to obtain comlete .... , 2% O2 in pt9
*** Adjustable (water sprays) to temp at pt 12 will not exceed 400 F

CTC COKEMAKING SECOND PROCESS STEP



Main process parameters

	1	2	3	4	5	6	7	8	9	10	11	12	13
Material													
Temp F													
Temp C													
Mat Flow t													