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

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Progress Report for the Period October 1-December 31, 1989

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SUMMARY

During the quarter, eleven mild gasification tests were conducted in the 8-inch-I.D. process research unit (PRU). Illinois No. 6 coal was used in nine of the tests and a West Virginia metallurgical grade of coal was used in the last two tests. Both coals were obtained from Peabody Coal Company preparation plants. The West Virginia coal had a much finer size consist, more than 90% smaller than 40 mesh, than the -12 mesh Illinois No. 6 coal. The West Virginia coal also exhibited a free swelling index value of 5-1/2 compared to a value of 1-1/2 for the Illinois coal. Because of these characteristics, the West Virginia coal was diluted with coke for the initial tests in a ratio of one pound coal to two pounds coke.

The tests conducted in the PRU this quarter were operated with feed rates about three times higher than those used in the last quarter. These tests added information to complete the investigation of the effect, initiated last quarter, of mild gasification temperature on Illinois No. 6 coal. The results presented show the effect of process temperature on the yields of char, oils/tars, and gases. Various compositional effects on the oils/tars were also discovered.

Char upgrading studies were completed for the char co-product options of smokeless fuel and adsorbent char, showing that mild gasification chars from the Illinois coal could be processed into these products. Work will continue on the formcoke product option for the West Virginia coal.

A total condensate collection system was designed for the PRU system. Components were ordered and will be installed in the next quarter. The system integration study has progressed in developing a process design for the 24 ton-per-day process development unit (PDU) with a material and energy balance. The PDU design is site-specific for a site at the Illinois Coal Development Park in Carterville, Illinois, operated by Southern Illinois University at Carbondale. The PDU process design incorporates two alternative methods of heat supply for the mild gasification reactor: heating a portion of the product gas for recycle to the gasifier, or heating a portion of the char for introduction to the gasifier.

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INTRODUCTION

The U.S. Department of Energy (DOE) is supporting the development of mild gasification technology to produce coal-derived fuels and chemical feedstocks. Mild gasification may be the most affordable route to increase coal utilization in the present economic climate. Mild gasification uses operating conditions of 1000° to 1500°F, near-atmospheric pressure, and inexpensive reactants to convert coal to a slate of co-products. In contrast, gasification and hydrogasification processes operate at temperatures of up to 1800°F and pressures up to 1000 psig.

Mild gasification could be considered as an advanced low-temperature coal carbonization process. Low-temperature carbonization of coal was popular in the U.S. until natural gas became abundantly available, and it is still used on a commercial scale in some foreign countries. The old technology, however, has been improved to produce value-added co-products through the application of technical and scientific knowledge about coal conversion that has been developed over the past twenty-five years. Improvements in reactor and process design are being applied to significantly enhance the yield and quality of co-products as well as the overall economics of the technology. Because of the mild operating conditions and process simplicity, mild gasification is anticipated to use available materials of construction and well-known engineering design and construction practices. As a result, the capital and operating costs are expected to be low. In this context, by successfully developing and marketing the co-products to derive the value-added benefits, it should be possible to commercialize the technology within the next ten years.

With the support of the U.S. DOE, a project team consisting of the Institute of Gas Technology, Peabody Holding Company, Inc., and Bechtel National, Inc., is developing a mild gasification process that uses a fluidized/entrained-bed reactor. This reactor is designed to process caking bituminous coals over a wide range of particle sizes without oxidative pretreatment, and also without the use of oxygen or air as reactants. Process heat, in the conceptual commercial reactor, would be provided by recycled hot char or high-temperature gases derived from burning a portion of the process-derived fuel gases. The addition of an in-bed sulfur-capture agent such as calcium oxide to capture the hydrogen sulfide released during coal conversion is an option that is being explored. The co-product streams, consisting of char, fuel gas, water, and condensables, would be separated by conventional means such as cyclones, staged condensers, and recycle-oil scrubbers.

An isothermal process research unit (PRU) has been built at IGT, consisting of an 8-inch-I.D., 8-foot-long fluidized-bed section and a 4-inch-I.D., 13-foot-long entrained flow section, externally heated by electrical heaters. The coal feed capacity is 100 lb/h, and the coal can be fed either to the fluidized bed or to the freeboard region above the fluidized bed and below the entrained section. The stainless steel reactor vessel is designed for a maximum temperature and pressure of 1500°F and 50 psig, respectively. Figures 1 and 2 show the block flow diagram and an isometric layout of the PRU.

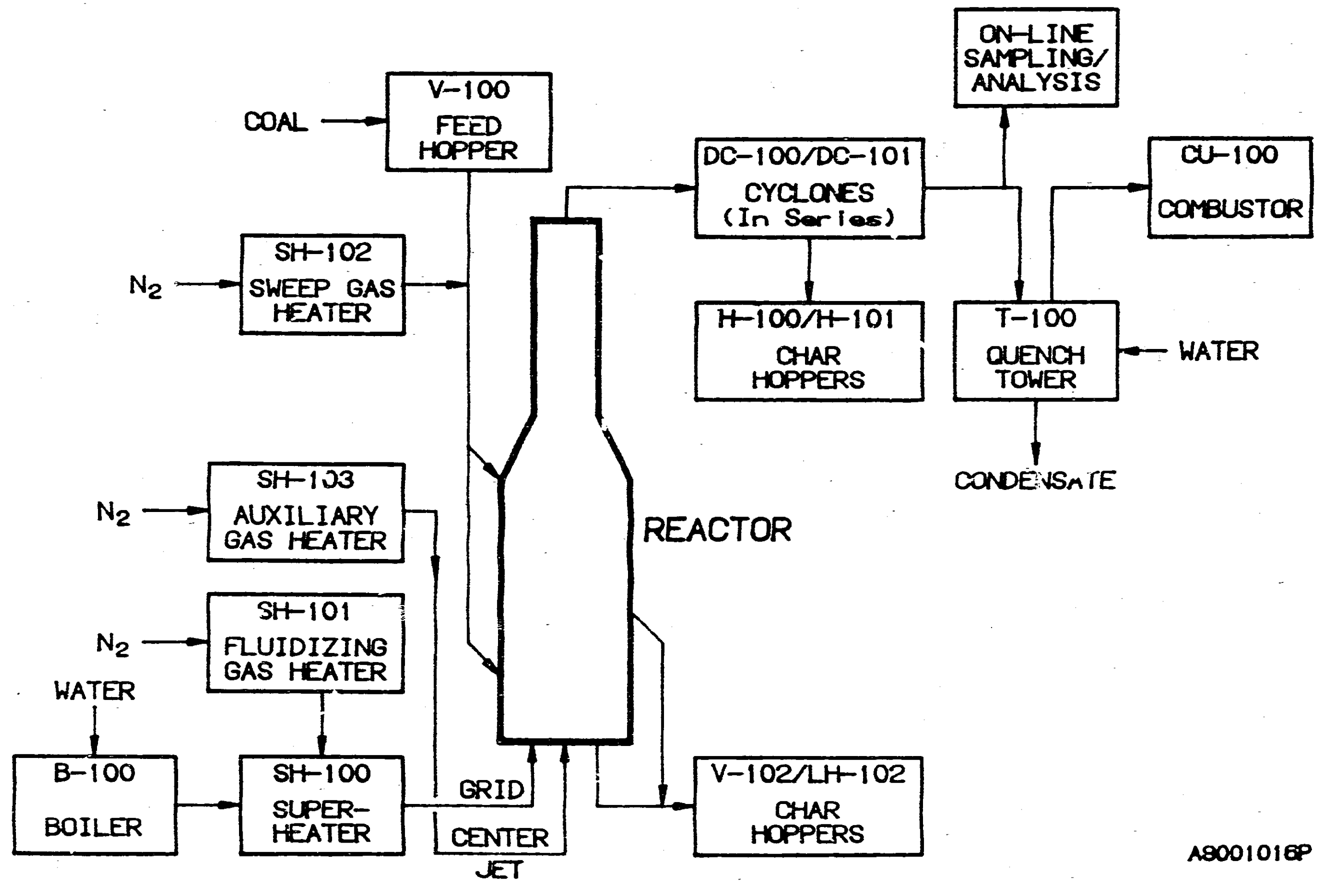


Figure 1. BLOCK FLOW DIAGRAM OF THE PRU SYSTEM

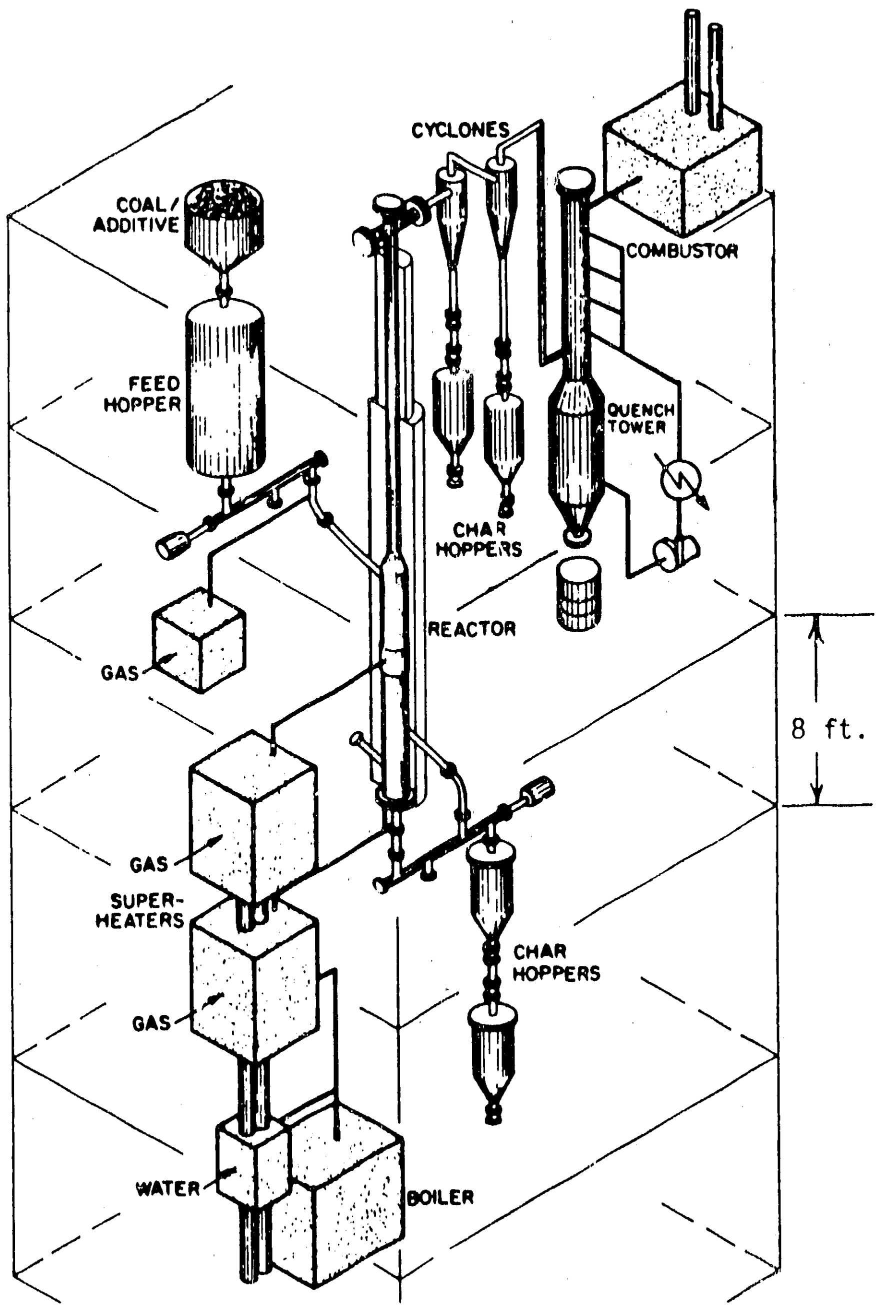


Figure 2. ISOMETRIC OF THE PRU SYSTEM

TECHNICAL DISCUSSION

Task 2. Bench-Scale Mild Gasification Study

During the quarterly reporting period, 11 mild gasification tests were conducted. The coal used in Tests MG-18 to MG-26 was a -12 mesh Illinois No. 6 coal obtained directly from a fines stream of Peabody's Randolph preparation plant in Baldwin, Illinois. The coal used in Tests MG-27 and MG-28 was a West Virginia metallurgical-grade coal obtained from a Peabody preparation plant in West Virginia. The West Virginia coal has a much finer size consist than the Illinois coal. The proximate, ultimate, and particle size distribution of these coals as received are given in Table 1. The process conditions used in these tests are summarized in Table 2, and the tests are described in the following text. Detailed analytical data from tests up to and including Test MG-28 are given in Appendix A. The results of tests conducted after this quarter and a discussion of the results will be reported in the topical report for Task 2 of this project, which will present the entire test results obtained from slip-stream sampling of the volatile products.

Summary of Mild Gasification Tests

Test MG-18 was operated with a higher steam rate and a higher fluidized-bed height to increase the char inventory in the bed. The char was removed via the char discharge nozzle located 15 inches above the gas distribution grid. The test ran smoothly for two hours, including a one-hour sampling period; however, shortly after the conclusion of the sampling period, the feed line became blocked. The feed line temperature at the feed hopper began to rise from its near-ambient level. This occurred because the hot feed sweep gas could not enter the reactor because of a small plug of material in the feed nozzle. The solid material recovered from the fluidized bed and the cyclones was free-flowing, so it appears that the agglomeration was localized at the feed point. The upset was correlated with a pressure pulse during a re-pressurization cycle of the first cyclone's lockhopper vessel.

Test MG-19 was conducted to repeat the higher feed rate conditions used in a previous test (Test MG-5), but with a deeper fluidized bed of a 36 inch height. This test also ran smoothly and parametric data were obtained in completing about two hours of operation until a pressure upset occurred during

Table 1. ANALYSES OF TEST COALS

	Illinois No. 6	West Virginia
Proximate	----- wt % are received	------
Moisture	7.7	7.3
Volatile Matter	34.5	32.0
Ash	13.2	5.5
Fixed Carbon	44.6	55.2
Total	100.0	100.0
Ultimate	----------- wt % dry	---------
Ash	14.3	5.9
Carbon	65.9	80.2
Hydrogen	4.4	5.2
Nitrogen	1.5	1.3
Sulfur	3.9	1.1
Oxygen (by difference)	10.0	6.3
Total	100.0	100.0
HHV, Btu/lb (dry)	11,599	14,535
Free Swelling Index	1-1/2	5-1/2
U.S. Screen Size	--- wt % retained on screen	--
12	3.88	0.00
20	17.49	0.32
40	40.48	9.82
60	25.29	14.39
80	8.87	12.09
100	2.11	7.09
140	1.00	13.59
200	0.33	7.72
230	0.11	1.29
270	0.11	3.55
325	0.11	3.06
Pan	0.22	27.08
Total	100.00	100.00

[a] Baldwin No. 1, Marissa and River King No. 6 Mines.

[b] No. 2 Gas and Campbell's Creek Seams.

Table 2, Part 1. SUMMARY OF MILD GASIFICATION TESTS DURING THE QUARTER

	Test No.			
	MG-18	MG-19	MG-20	MG-21
Purpose of Test	Operate with deeper bed, greater char inventory, higher steam rate	Greater bed height, higher feed rate, higher steam rate	200 lb/h feed rate	Repeat of Test MG-19 with reduced steam rate
Feed Material	1:1 mixture coal[a]/coke	1:1 mixture coal[a]/coke	1:1 mixture coal[a]/coke	1:1 mixture coal[a]/coke
Feed Rate, lb/h	48.2	90.8	93.8	94.0
Steam Rate, lb/h	23.4	23.7	18.2	8.5
Temperature, °F	1178	1102	1120	1109
Pressure, psig	10	10	10	10
Feed Location	Fluidized Bed	Fluidized Bed	Fluidized Bed	Fluidized Bed
Fluidized Bed Height, ft	2.5	3.0	1.8	2.0
Superficial Gas Velocity, ft/s	4.0	4.4	4.8	4.7
Solids Residence Time, min	28	14	--	10
Steady State Period, h	2.0	2.0	--	3.5
Remarks	Successful test operation; 35 minutes of sampling before feed interruption	Successful test operation	Start test at 100 lb/h, bed defluidized at 200 lb/h	Successful test operation

[a] Illinois No. 6 coal, -12 mesh obtained from Peabody's Baldwin, Illinois prep plant.

Table 2, Part 2. SUMMARY OF MILD GASIFICATION TESTS DURING THE QUARTER

	Test No.			
	MG-22	MG-23	MG-24	MG-25
Purpose of Test	Operate without steam	Use recycled MG-21 char as diluent	Entrained test, feed in bed nozzle, longer residence time	Repeat MG-23 conditions using MG-21 char as diluent
Feed Material	1:1 mixture coal[a]/coke	1:1 mixture coal[a]/MG char	coal[a] fines (-40 mesh)	1:1 mixture coal[a]/MG char
Feed Rate, lb/h	95.2	77.0	27.7	100.3
Steam Rate, lb/h	0.0	15.7	18.2	11.1
Temperature, °F	1147	1100	1180	1134
Pressure, psig	10	10	10	10
Feed Location	Fluidized Bed	Fluidized Bed	Nozzle in Fluidized Bed	Fluidized Bed
Fluidized Bed Height, ft	1.8	2.3	--	3.0
Superficial Gas Velocity, ft/s	4.6	4.2	8.1	4.8
Solids Residence Time, min	8	--	--	8
Steady State Period, h	2.5	--	--	2.0
Remarks	Successful test operation	Bed defluidized 15 min after start	Feed hopper discharge failure	Successful test operation

[a] Illinois No. 6 coal, -12 mesh obtained from Peabody's Baldwin, Illinois prep plant.

Table 2, Part 3. SUMMARY OF MILD GASIFICATION TESTS DURING THE QUARTER

	Test No.		
	MG-26	MG-27	MG-28
Purpose of Test	Feed coal mixed with calcium oxide	Test with West Virginia coal	Repeat MG-27 with feed sweep-gas at lower temp and higher flow
Feed Material	1:1 mixture coal[a]/lime	1:2 mixture coal[b]/coke	1:2 mixture coal[b]/coke
Feed Rate, lb/h	83.0	64.1	51.9
Steam Rate, lb/h	7.5	8.2	8.2
Temperature, °F	1140	1225	1150
Pressure, psig	10	10	10
Feed Location	Fluidized Bed	Fluidized Bed	Fluidized Bed
Fluidized Bed Height, ft	1.9	2.2	1.4
Superficial Gas Velocity, ft/s	3.0	3.6	3.7
Solids Residence Time, min	--	--	15
Steady State Period, h	--	1.0	3.5
Remarks	Bed defluidized 15 min after start	Plug at end of feed nozzle to bed	Successful test operation

[a] Illinois No. 6 coal, -12 mesh obtained from Peabody's Baldwin, Illinois prep plant.

[b] West Virginia coal, 90% below 40 mesh, obtained from Peabody's West Virginia prep plant.

the re-pressurization of the first cyclone lockhopper. The cause of the pressure upsets was found to be a plugged instrumentation line to a differential pressure switch that allows operation of the lockhopper solids dump valve after the lockhopper is sufficiently vented. During re-pressurization, the system over-pressurized the lockhopper and the pulse affected the fluidized-bed operation. All of the system tubing lines for venting, pressurization, and pressure equalization were inspected and cleaned prior to the following test.

The goal for Test MG-20 was to increase the feed rate to 200 lb/h. The test began normally with a smooth startup and steady operation with an initial feed rate of 93.8 lb/h for 45 minutes. At that time, the feed rate was increased to about 200 lb/h. After ten minutes at this rate, the fluidized bed became defluidized and char stopped discharging from the bed. After the test, a clump of material was found in the fluidized bed, indicating that too much feed coal was entering the fluidized-bed reactor compared to the volume of bed char.

Tests MG-21 and MG-22 were conducted at the same conditions as Test MG-19 but with different steam inputs to the fluidized bed. These three tests will be used to analyze the effect of steam upon mild gasification and the production and quality of the co-products. For these three comparative tests, the feed rate range was from 91 to 95 lb/h and the temperature range was from 1100° to 1150°F.

Test MG-23 was conducted with the purpose of reducing the amount of inert coke diluent used in the feed mixture for the tests. This was done by blending coal with the fluidized-bed char collected from a previous test, Test MG-21. An equal amount of Illinois No. 6 coal was blended with char from Test MG-21 to reduce the weight percentage of coke in the feed mixture from 50% to an estimated 32%. In this way, the Illinois No. 6 coal-derived char in the feed mixture more closely simulated mild gasification with a recycle char stream. The char collected from this test would have been used to blend with coal again to further reduce the amount of coke in the feed mixture; however, about one half-hour after the start of feeding the mixture with the reduced coke amount, a heater zone in the fluidized-bed zone failed and the fluidized-bed temperature declined, leading to test shutdown.

Test MG-24 was conducted to investigate entrained flow gasification while waiting for a replacement heater element for the fluidized bed. In Test MG-24, the -40 mesh fines fraction of the coal was fed to the fluidized-bed nozzle rather than to the freeboard nozzle, to gain additional solids residence time. The entraining gas velocity in the 8-inch section was set at 8 ft/s and, based on a gas-solids flow correlation, the solids residence time in the 8-inch, 8-foot section was calculated to be about 1.2 seconds. The 4-inch piping above the 8-inch zone added another 0.4 second for a total solids residence time of 1.6 seconds.

This arrangement of the fines feed location was designed to improve upon Test MG-17, in which the coal fines were fed to the 8-inch diameter freeboard section above the fluidized bed. The fluidization velocity in Test MG-17 was 3 ft/s in the 8-inch section. This was too low to entrain the fines and thus, they fell on the top of the fluidized bed and did not mix into it. In Test MG-24, the feed hopper stopped discharging the fine particles after 35 minutes of feeding. Inspection after the test showed that fine particles were plugging the pressure equalizing line between the feed hopper and the reactor as well as two instrumentation lines connected to the cyclone-lockhopper system.

Test MG-25 was conducted to repeat the aborted Test MG-23, using the coal and recycle char from Test MG-21 to reduce the amount of diluent coke in the feed mixture. The blended feed mixture was fed at 100 lb/h for two hours and the steady-state sampling period was completed before the feed was interrupted from the feed hopper. A plug in the feed line prevented the resumption of feeding and the test was stopped.

Test MG-26 investigated the addition of calcium oxide to the feed to react with hydrogen sulfide at the temperatures of mild gasification. The coal and calcium oxide were mixed in a 1:1 weight ratio without any diluent coke material to simplify analysis of the data. The feed rate was 85 lb/h and the fluidized-bed temperature was set at 1140°F. The mixture, however, behaved like moist sand, resisting flow. The test ran for 15 minutes when the bed began to de-fluidize. After 50 minutes were spent trying to fluidize the bed, the feed rate of the mixture from the hopper could not be maintained uniformly, and the test was terminated.

Calcium oxide is known to be reactive with moisture and to have a high heat of hydration. Thus, the mixture for Test MG-26 was prepared one hour before the test to avoid a temperature rise or change in physical characteristics of the mixture. In spite of this, the temperature in the drum did rise to about 250°F in the center and it was difficult to pour the feed.

Premixing of the 5%-moisture coal and the calcium oxide could be avoided in the PRU system with the addition of a second hopper and screw feeder for the calcium oxide or other additive. Prior to Test MG-26, a five-gallon bucket of the coal and calcium oxide was prepared, used in 6-inch cold flow fluidization test column work, and stored for 48 hours afterward. In this quantity, no temperature rise was noted and the mixture was very free-flowing and easy to pour. This suggests that mixing at the point of contact would be successful.

Test MG-27 was the first test conducted to evaluate the mild gasification performance of the metallurgical-grade coal obtained from Peabody's preparation plant in West Virginia. The coal as received from West Virginia had a finer size consist than the Illinois No. 6 coal, as shown in Table 1. The coal was mixed with diluent coke in a 1:2 weight ratio, because of its higher fines content and free swelling index compared to the Illinois No. 6 coal. This was done with the intent of increasing the coal:coke ratio for subsequent tests. The test proceeded well through two hours, after which the sampling period began. Five minutes into the sampling period, however, the feed line into the reactor became blocked. The blockage was temporarily relieved by isolating the feed hopper and increasing the feed sweep gas flow through the nozzle, but the blockage developed again and the test was stopped. Inspection of the reactor, cyclones, and piping showed that everything was clean and the blockage was restricted to a one-half inch plug in the feed nozzle at the point where it enters the reactor. To eliminate this occurrence in the next test, the feed sweep gas temperature was reduced from 690° to 500°F and the sweep gas velocity was increased.

Test MG-28 was conducted to repeat the conditions of Test MG-27. The temperature was 1170°F and the feed rate was 51.9 lb/h. The test operated well for over 3.5 hours with a very steady flow of fluidized-bed char discharge and steady fluidized-bed differential pressure values. Solids recovered from the reactor after the test were free-flowing.

Discussion of PRU Test Results

With the additional available analyzed data for Tests MG-11, 12, 14, 15, 16, 19, and the shakedown Test SD-6, an evaluation of the effect of temperature on the co-product yields, makeup, gas composition, and other selected properties of the oils and tars has been completed, and is presented in Figures 3 to 9 and in Tables 3 to 5. The material balances for each of the above tests are presented in the following section as Tables 6 through 11.

Figure 3 shows the effect of mild gasification temperatures from 1034° to 1390°F on the yields of gas and oils/tars observed from the seven tests listed above. As shown, the gas yield increases with temperature, whereas the maximum oils/tars yield appears to be at the lower end of the temperature range. The observed decrease in char yield is expected with an increasing temperature and the chemical water make appears fairly constant.

Figure 4 shows the influence of the process temperature on the boiling-range distribution of the oils and tars. It appears from these data that the principal change in the volatility of the condensables with increasing mild gasification temperature consists of an increase in light oils accompanied by a decrease in the fraction of material with a boiling point above 750°F, which is defined as pitch.

Figures 5 and 6 show the manner in which the heteroatom content of the condensables (not including light oils) changes with the process temperature. Nitrogen and sulfur levels increase slightly, whereas the oxygen content decreases sharply with an increasing mild gasification temperature. The decrease in oxygen content signals the loss of oxygen functionalities, such as phenolic -OH groups, and may partially explain the decrease in pitch content at higher temperatures, whereby the removal of polar oxygen groups reduces the boilingpoint and shifts some pitch components into lower-boiling fractions. The slight increase in N and S content with process temperature may indicate increasing incorporation of these heteroatoms into polycondensed aromatic rings.

The H/C ratio of the condensables, shown in Figure 7, also changes with process temperature. The decrease in the H/C ratio is consistent with an increase in aromaticity with process temperature.

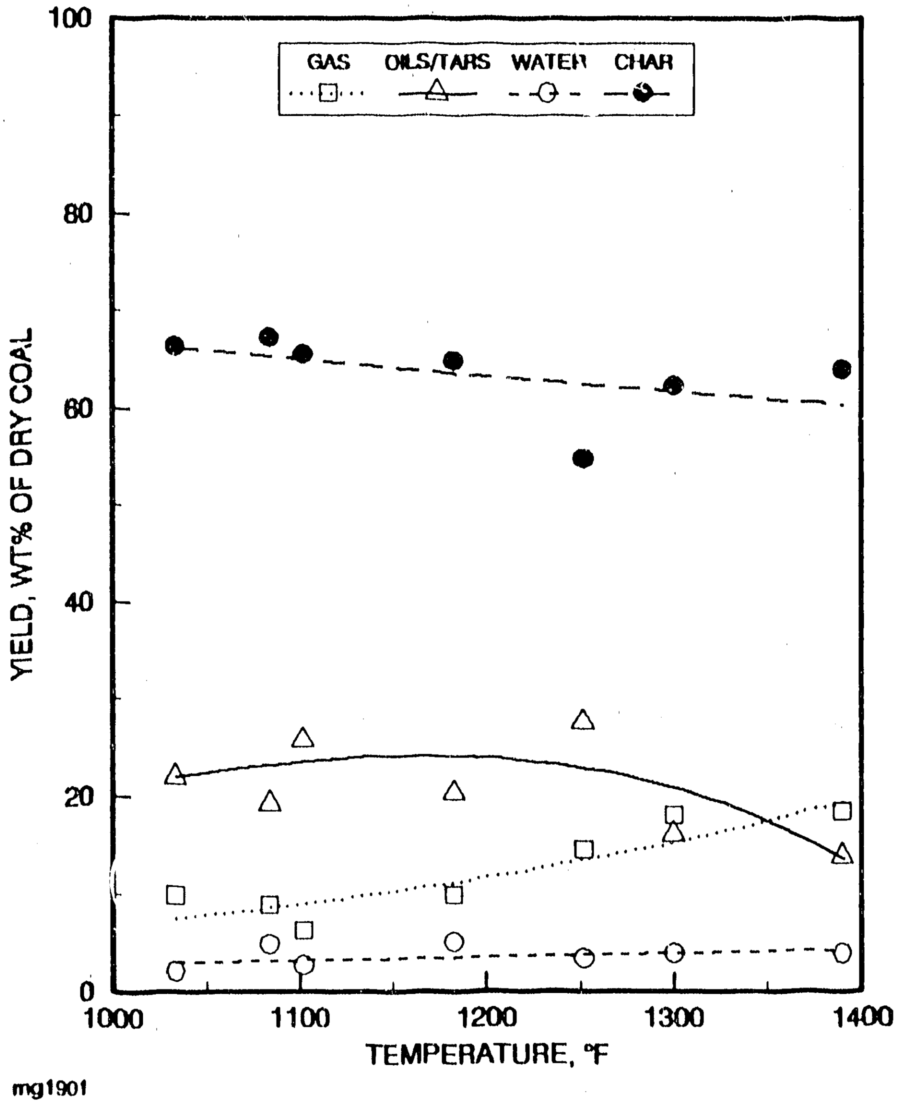


Figure 3. EFFECT OF MILD GASIFICATION TEMPERATURE ON CO-PRODUCT YIELDS

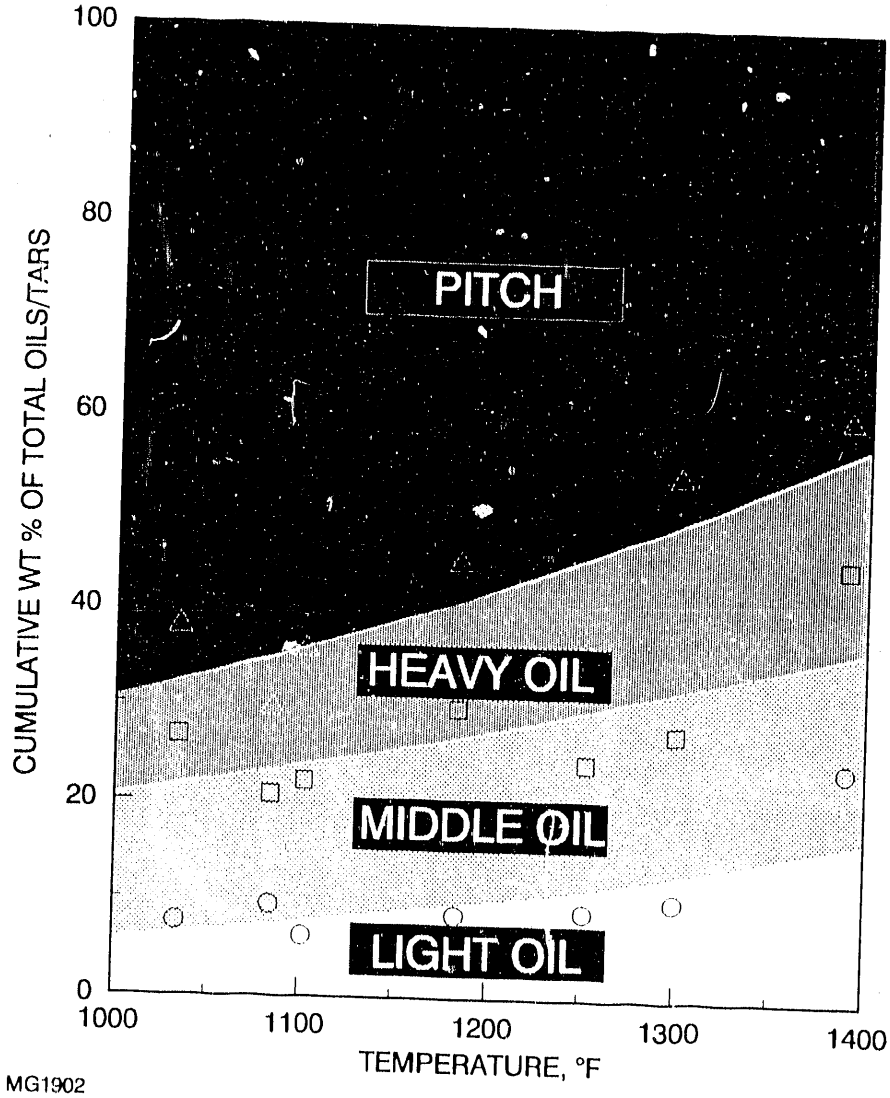


Figure 4. EFFECT OF MILD GASIFICATION TEMPERATURE ON THE BOILING FRACTIONS OF OILS/TARS

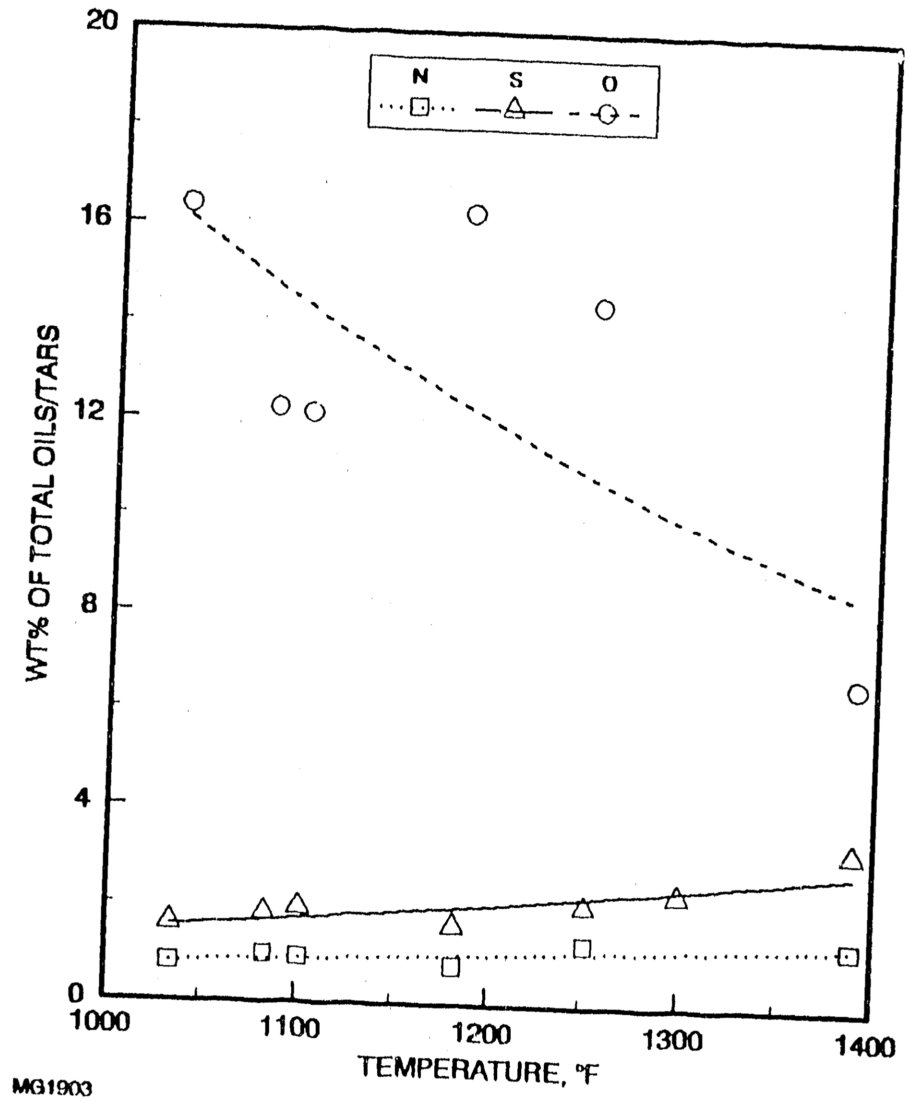


Figure 5. EFFECT OF MILD GASIFICATION TEMPERATURE ON HETEROATOMS IN OILS/TARS

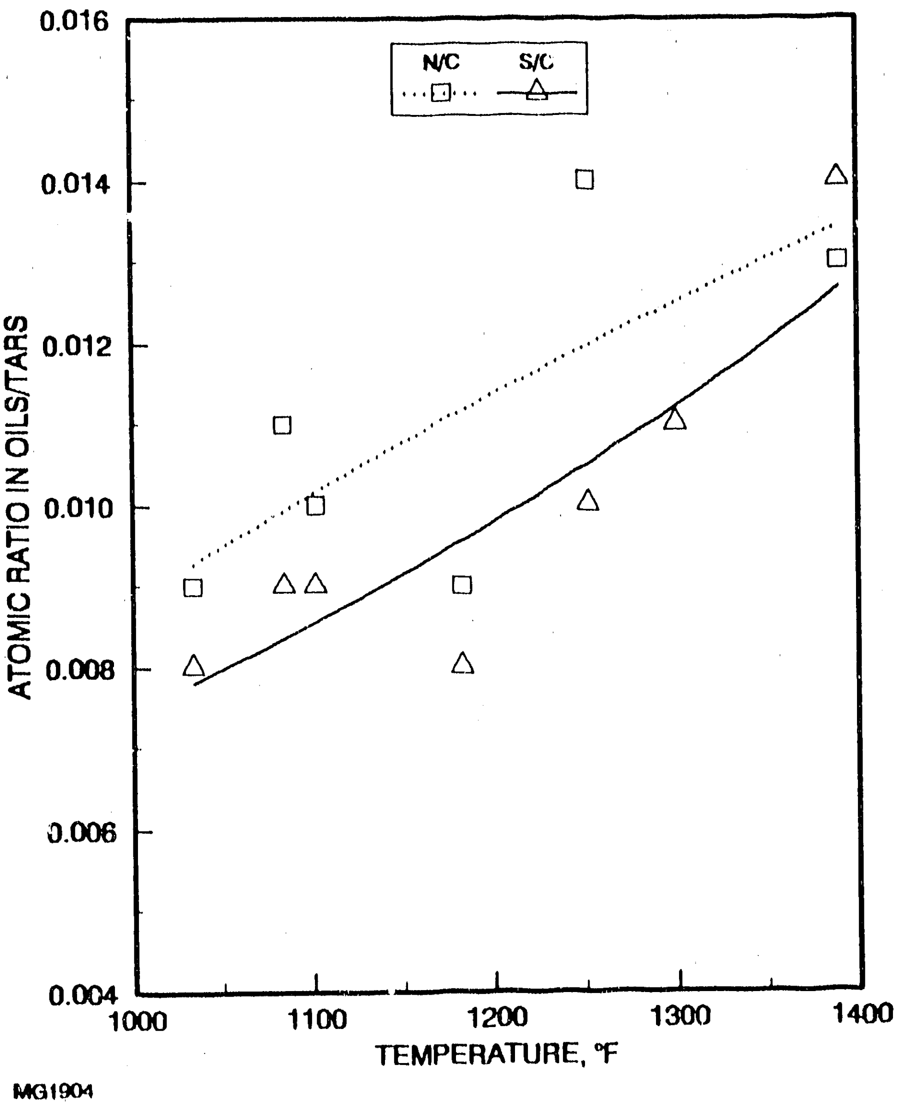


Figure 6. EFFECT OF MILD GASIFICATION TEMPERATURE ON N/C AND S/C RATIOS IN OILS/TARS

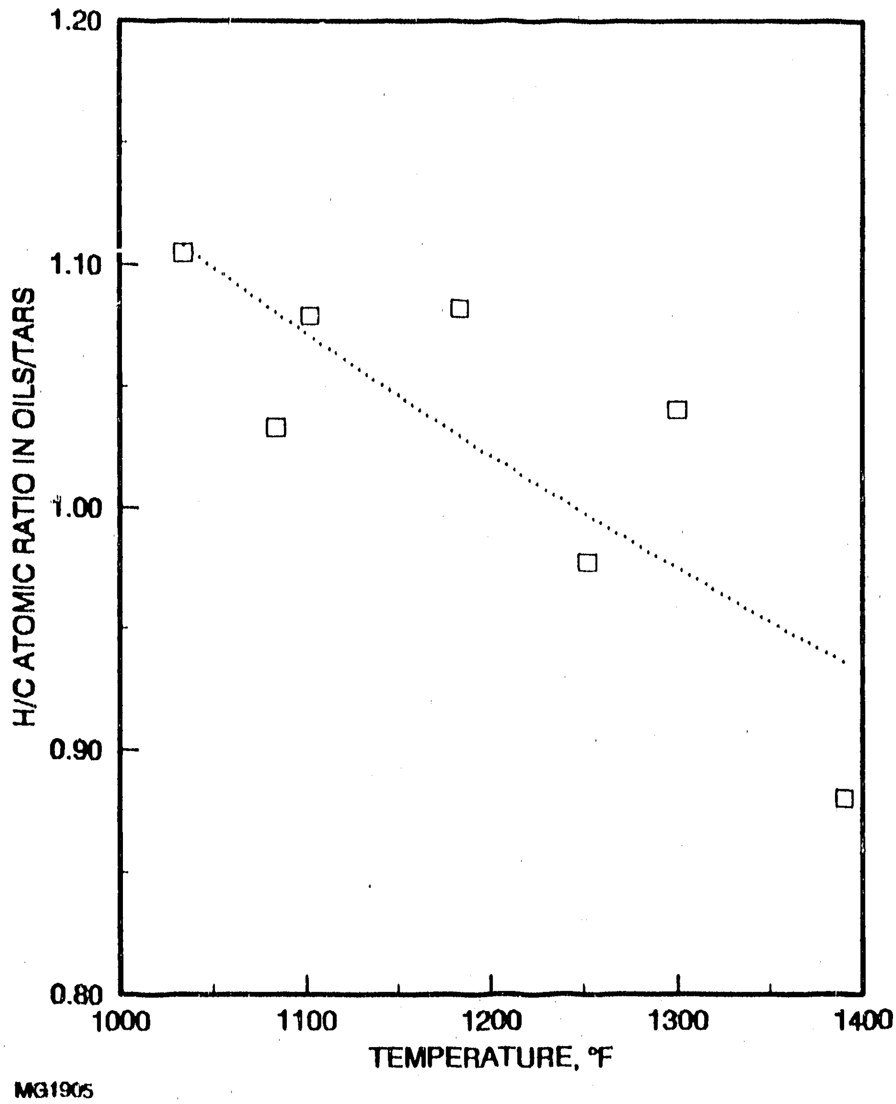


Figure 7. EFFECT OF MILD GASIFICATION TEMPERATURE ON H/C ATOMIC RATIO IN OILS/TARS

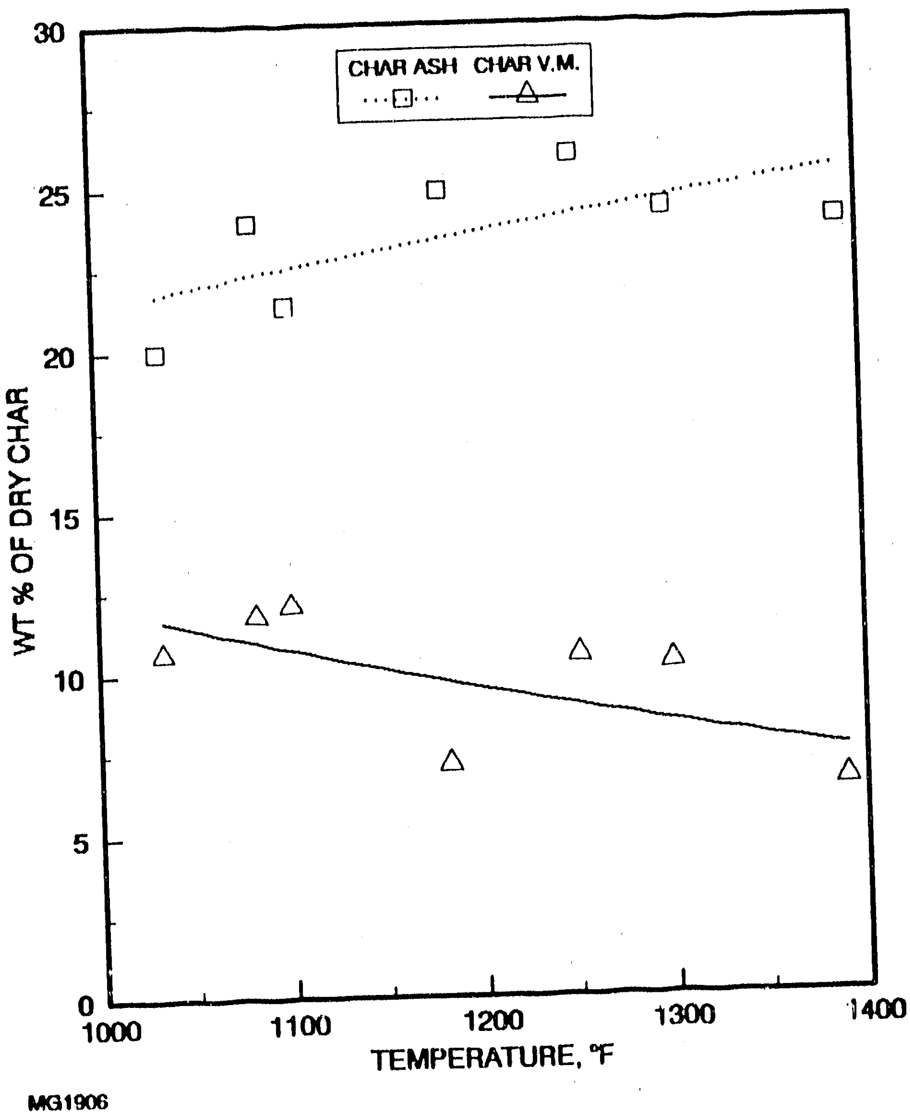


Figure 8. EFFECT OF MILD GASIFICATION TEMPERATURE ON ASH AND V.M. CONTENT OF CHAR

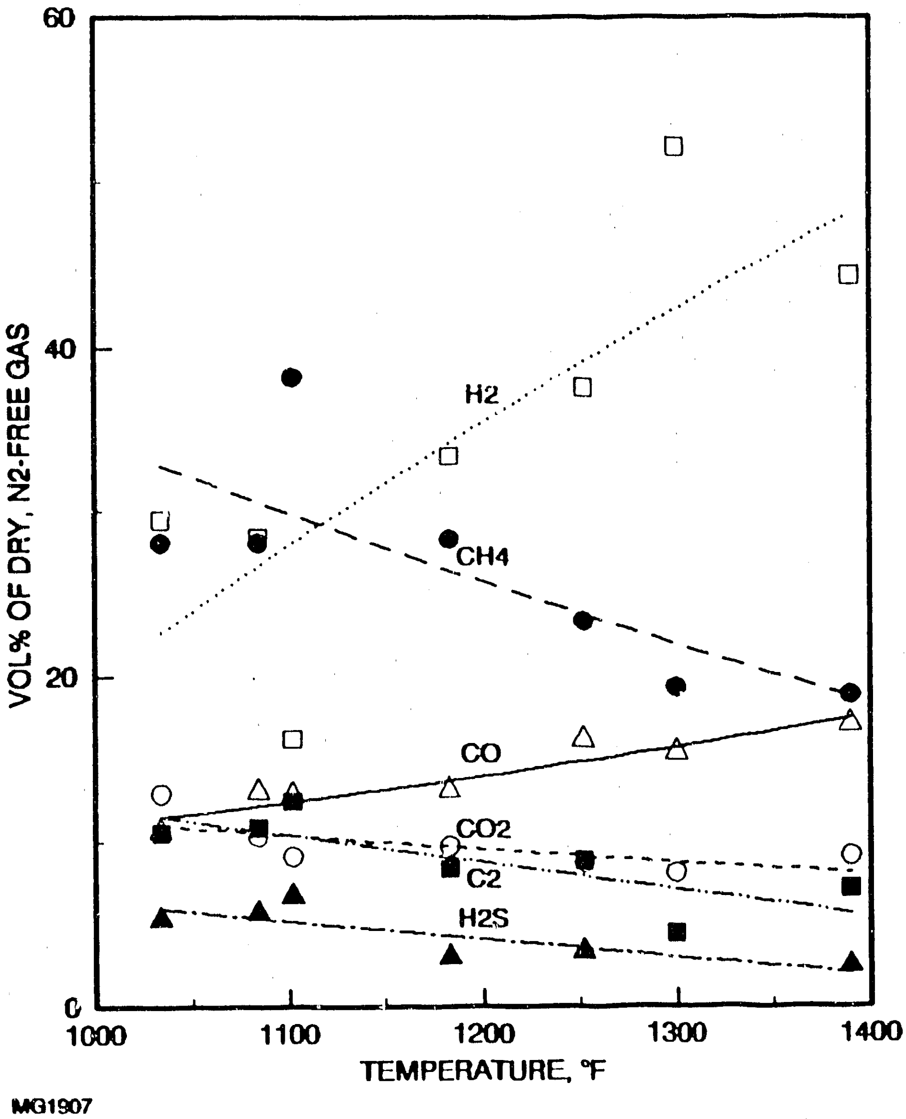


Figure 9. EFFECT OF MILD GASIFICATION TEMPERATURE ON GAS COMPOSITION

Table 3. COMPARISON OF PAH CONTENT OF MG-25 TAR WITH A TYPICAL COKE-OVEN TAR

Component	MG-25 Tar Weight %	Coke-Oven Tar Weight %
Biphenyl	0.010	0.420
Acenaphthene	0.011	1.280
Fluorene	0.027	2.560
Phenanthrene/Anthracene	0.066	2.870
2-Methylphenanthrene	0.083	0.700
1-Methylphenanthrene	0.064	0.750
Fluoranthene	0.003	0.531
Pyrene	0.015	0.520
Benz(a)anthracene	0.019	0.304
Chrysene/Triphenylene	not detected	0.221
Benzo(b,k)fluoranthene	not detected	0.354
Benzo(a)pyrene	0.017	0.293
Dibenzo(a,h)anthracene	0.009	0.039
Benzo(g,h,i)perylene	not detected	0.171

Table 4. COMPARISON OF CO-PRODUCT YIELDS WITH COKE OVEN BY-PRODUCT YIELDS

	Mild Gasification (Test MG-16)	Coke Oven
	wt % maf coal	
Product Gas	11.6	13.9
Oils/Tars	23.9	4.5
Water	5.9	14.1
Char or Coke	58.6	67.5

Table 5. COMPARISON OF PAH PRODUCTION LEVELS BETWEEN MILD GASIFICATION AND A TYPICAL COKE OVEN TAR

	Mild Gasification (Test MG-25)	Coke Oven
	-------- lb/ton dry coal	---------
Biphenyl	0.049	0.378
Acenaphthene	0.055	1.152
Fluorene	0.128	2.304
Phenanthrene/Anthracene	0.315	2.583
2-Methylphenanthrene	0.398	0.630
1-Methylphenanthrene	0.306	0.675
Fluoranthene	0.015	0.478
Pyrene	0.070	0.468
Benz(a)anthracene	0.091	0.274
Chrysene/Triphenylene	0.000	0.199
Benzo(b,k)fluoranthene	0.000	0.319
Benzo(a)pyrene	0.079	0.264
Dibenzo(a,h)anthracene	0.044	0.035
Benzo(g,h,i)perylene	0.000	0.154

Table 6. TEST MG-11 (1390°F) MATERIAL BALANCE

INPUT	C	H	O	N	S	Ash	Total
Feed Mixture	15.05	0.47	1.07	0.27	0.47	2.72	20.05
OUTPUT							
Char Mixture	13.12	0.08	0.09	0.22	0.24	2.72	16.47
Product Gas	0.81	0.23	0.61	0.00	0.19	--	1.84
Oils/Tars	1.12	0.08	0.08	0.02	0.04	0.00	1.34
Aqueous Condensate	0.00	0.04	0.33	0.03	0.00	--	0.40
Total	15.05	0.43	1.11	0.27	0.47	2.72	20.05

DILUENT-FREE CO-PRODUCT YIELDS, wt Coal

	dry	maf
Char	63.9	57.3
Gas	18.6	22.0
Oils/Tars	13.5	15.9
Water	4.0	4.8
Total	100.0	100.0

Table 7. TEST MG-12 (1252°F) MATERIAL BALANCE

INPUT	C	H	O	N	S	Ash	Total
Feed Mixture	8.91	0.28	0.68	0.15	0.27	1.55	11.84
OUTPUT							
Char Mixture	7.29	0.05	0.04	0.12	0.12	1.54	9.16
Product Gas	0.34	0.10	0.21	0.00	0.11	--	0.76
Oils/Tars	1.28	0.11	0.24	0.02	0.03	0.01	1.68
Aqueous Condensate	0.00	0.03	0.20	0.01	0.00	--	0.24
Total	8.91	0.28	0.69	0.15	0.26	1.55	11.84
Out/In	1.00	0.98	1.01	1.00	1.00	1.00	1.00

DILUENT-FREE CO-PRODUCT YIELDS, wt % Coal

	dry	maf
Char	54.3	46.7
Gas	12.9	15.2
Oils/Tars	28.7	33.4
Water	4.1	4.7
Total	100.0	100.0

Table 8. TEST MG-14 (1084°F) MATERIAL BALANCE

INPUT	C	H	O	N	S	Ash	Total
Feed Mixture	15.45	0.49	1.24	0.24	0.47	2.87	20.76
OUTPUT							
Char Mixture	13.45	0.13	0.41	0.21	0.26	2.87	17.33
Product Gas	0.41	0.12	0.21	0.00	0.17	--	0.91
Oils/Tars	1.59	0.14	0.24	0.02	0.04	0.00	2.03
Aqueous Condensate	0.00	0.05	0.43	0.01	0.00	--	0.49
Total	15.45	0.44	1.29	0.24	0.47	2.87	20.76
Out/In	1.00	0.90	1.04	1.00	1.00	1.00	1.00

DILUENT-FREE CO-PRODUCT YIELDS, wt % Coal

	dry	maf
Char	66.6	60.2
Gas	8.8	10.5
Oils/Tars	19.9	23.6
Water	4.7	5.7
Total	100.0	100.0

Table 9. TEST MG-15 (1034°F) MATERIAL BALANCE

INPUT	C	H	O	N	S	Ash	Total
Feed Mixture	14.63	0.45	1.00	0.26	0.37	2.39	19.11
OUTPUT							
Char Mixture	12.64	0.13	0.30	0.22	0.22	2.38	15.89
Product Gas	0.41	0.11	0.25	0.00	0.12	--	0.89
Oils/Tars	1.58	0.15	0.34	0.02	0.03	0.01	2.13
Aqueous Condensate	0.00	0.02	0.16	0.02	0.00	--	0.20
Total	14.63	0.41	1.05	0.26	0.37	2.39	19.11
Out/In	1.00	0.90	1.05	1.00	1.00	1.00	1.00

DILUENT-FREE CO-PRODUCT YIELDS, wt % Coal

	dry	maf
Char	66.0	60.9
Gas	9.4	10.9
Oils/Tars	22.4	25.8
Water	2.2	2.4
Total	100.0	100.0

Table 10. TEST MG-16 (1183°F) MATERIAL BALANCE

INPUT	C	H	O	N	S	Ash	Total
Feed Mixture	23.59	0.69	1.92	0.40	0.68	4.39	31.67
OUTPUT							
Char Mixture	20.52	0.12	0.43	0.31	0.33	4.38	26.09
Product Gas	0.67	0.19	0.37	0.00	0.30	--	1.53
Oils/Tars	2.40	0.22	0.52	0.02	0.05	0.01	3.22
Aqueous Condensate	0.00	0.09	0.67	0.07	0.00	--	0.83
Total	23.59	0.62	1.99	0.40	0.68	4.39	31.67
Out/In	1.00	0.90	1.05	1.00	1.00	1.00	1.00

DILUENT-FREE CO-PRODUCT YIELDS, wt % Coal

	dry	maf
Char	64.3	57.5
Gas	9.8	11.7
Oils/Tars	20.6	24.5
Water	5.3	6.3
Total	100.0	100.0

Table 11. TEST MG-19 (1102°F) MATERIAL BALANCE

INPUT	C	H	O	N	S	Ash	Total
Feed Mixture	67.26	2.12	3.73	1.21	1.78	11.05	87.15
OUTPUT							
Char Mixture	57.14	0.67	1.04	1.02	1.12	11.05	72.04
Product Gas	1.40	0.36	0.59	0.00	0.45	--	2.80
Oils/Tars	8.72	0.79	1.35	0.10	0.21	0.00	11.17
Aqueous Condensate	0.00	0.12	0.95	0.09	0.00	--	1.16
Total	67.26	1.94	3.93	1.21	1.78	11.05	87.17
Out/In	1.00	0.92	1.05	1.00	1.00	1.00	1.00

DILUENT-FREE CO-PRODUCT YIELDS, wt % Coal

	dry	maf
Char	64.2	58.5
Gas	6.6	7.7
Oils/Tars	26.4	30.7
Water	2.8	3.1
Total	100.0	100.0

Table 3 shows a comparison of selected polyaromatic hydrocarbons in the tar from Test MG-25 (process temperature of 1130°F) with a typical coke oven tar. As seen, the mild gasification tar contains at least an order of magnitude less of these compounds, many of which are environmentally sensitive, compared to conventional coke oven tar.

In Table 4, a comparison of the co-product yields from mild gasification at 1183°F with by-product yields from a typical coking process shows the major expected difference in the yields of oils/tars. Combining the values in Tables 3 and 4 reveal that the absolute quantities of environmentally sensitive PAH compounds, as well as their percentages in the total liquids, are lower in the mild gasification oils/tars. This is shown in Table 5, with PAH compounds expressed as pounds per ton of dry coal. Figure 8 shows the ash and volatile matter content of the mild gasification char with process temperature. These data verify the increasing devolatilization and carbon conversion of the feed coal as the mild gasification temperature increases.

Gas composition is also affected by the process temperature as is shown in Figure 9. The dry, nitrogen-free concentrations of hydrogen and carbon monoxide increase with temperature, whereas carbon dioxide and hydrocarbon gases decrease. These trends are consistent with well-known devolatilization and gas-phase equilibrium data. The hydrogen sulfide content of the gas also decreases with temperature, and it appears that, even when the increased gas yield at higher temperature is taken into account, the amount of sulfur released as hydrogen sulfide decreases with temperature.

Material Balances for the PRU Tests

The material balances are presented in Tables 6 through 11 for mild gasification Tests MG-11, 12, 14, 15, 16, and 19. These balances have been adjusted to provide the data values of each test on a consistent basis for comparison. The raw material balances are presented in Appendix A. The major measurable streams of carbon and ash were usually better than 90% in balance.

The data adjustment procedure that was applied is summarized as follows:

- The ash was balanced by adjusting the amount of fluidized bed char collected during the test.
- The carbon was balanced by adjusting the amount of oils and tars collected by solvent washing, assuming that the heavy components coating pipes are difficult to collect and also the sintered metal filter used to separate char from the gas stream provides an active surface that promotes the coking of a portion of the heavier tars.
- Sulfur was balanced by assuming that unaccounted sulfur is present as hydrogen sulfide in the gases, part of which may have been absorbed by stainless steel components in the system.
- Nitrogen from the coal that is not accounted for in the analyses was assumed to form ammonia in the aqueous condensate stream.
- Finally, diluent-free co-product yields were calculated, assuming that the diluent coke does not react significantly with nitrogen and steam, and the co-product yields were forced to 100% by adjusting the chemical water make.

This procedure leaves hydrogen and oxygen out of balance, generally by a few percent. No attempts were made to balance oxygen because this element is determined by the difference in solids and oil elemental analyses, and thus can be affected by accumulated uncertainties (error limits) in measurement of the other elements.

Task 3. Bench-Scale Char Upgrading Study

The char upgrading study with the chars from the test coals in the PRU tests were evaluated in terms of three major char products. Three solid co-products were identified as probable value-added products in the Task 1 topical report on the market survey of products from the mild gasification of coal. These solid co-products are: a smokeless fuel containing char mixed with limestone for sulfur retention, an activated adsorbent char, and a formcoke for blast furnaces in steelmaking.

The work in this quarter completed the upgrading and property evaluation tests for the smokeless fuel and the activated adsorbent co-products, and began evaluation of formcoke from the test coals. Further work in the test will focus only on the formcoke char product.

As reported in the last quarter, briquettes made from the chars of the test coals were made under a variety of forming conditions of temperature and pressure, using either pitch or a small amount of raw coal as a binder. These were subjected to a curing step after forming, either soaking at a temperature at 400°F in air for the smokeless fuel briquettes, or in a nitrogen atmosphere at 1800°F for the formcoke briquettes.

The smokeless fuel briquettes were prepared with the addition of limestone for sulfur retention upon combustion. A 2:1 calcium-to-sulfur mole ratio was blended in the briquette. The briquettes were combusted in a small pile and the residues from the top of the pile and from the center of the pile were analyzed for sulfur retention as calcium sulfate and for other sulfur forms present. Figure 10 shows the various sulfur forms and retention before and after combustion, with 84 and 88% of the sulfur retained in the ash from the center and top of the pile, respectively. Table 12 compares the heating value of the limestone-containing smokeless fuel briquette to the heating value of other solid fuels. The heating value of the smokeless fuel compares favorably with common domestic solid fuels.

The potential for adsorbent char carbon was explored by activating a number of Illinois No. 6 coal char samples with steam and measuring the adsorbent properties. Chars from the PRU tests and from a 2-inch batch fluidization test apparatus were used. The summary of the chars and their measured properties are presented in Table 13. Figure 11 shows the measured

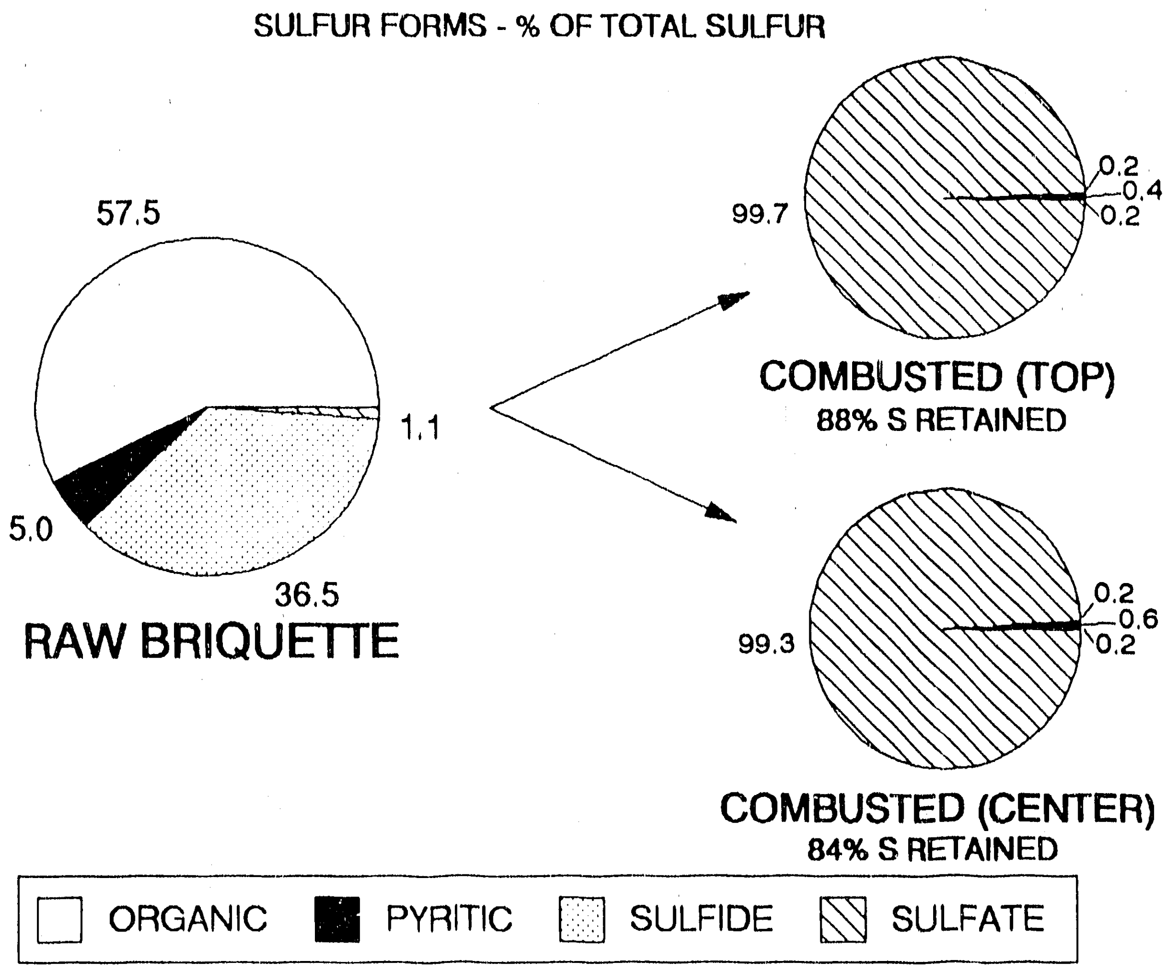
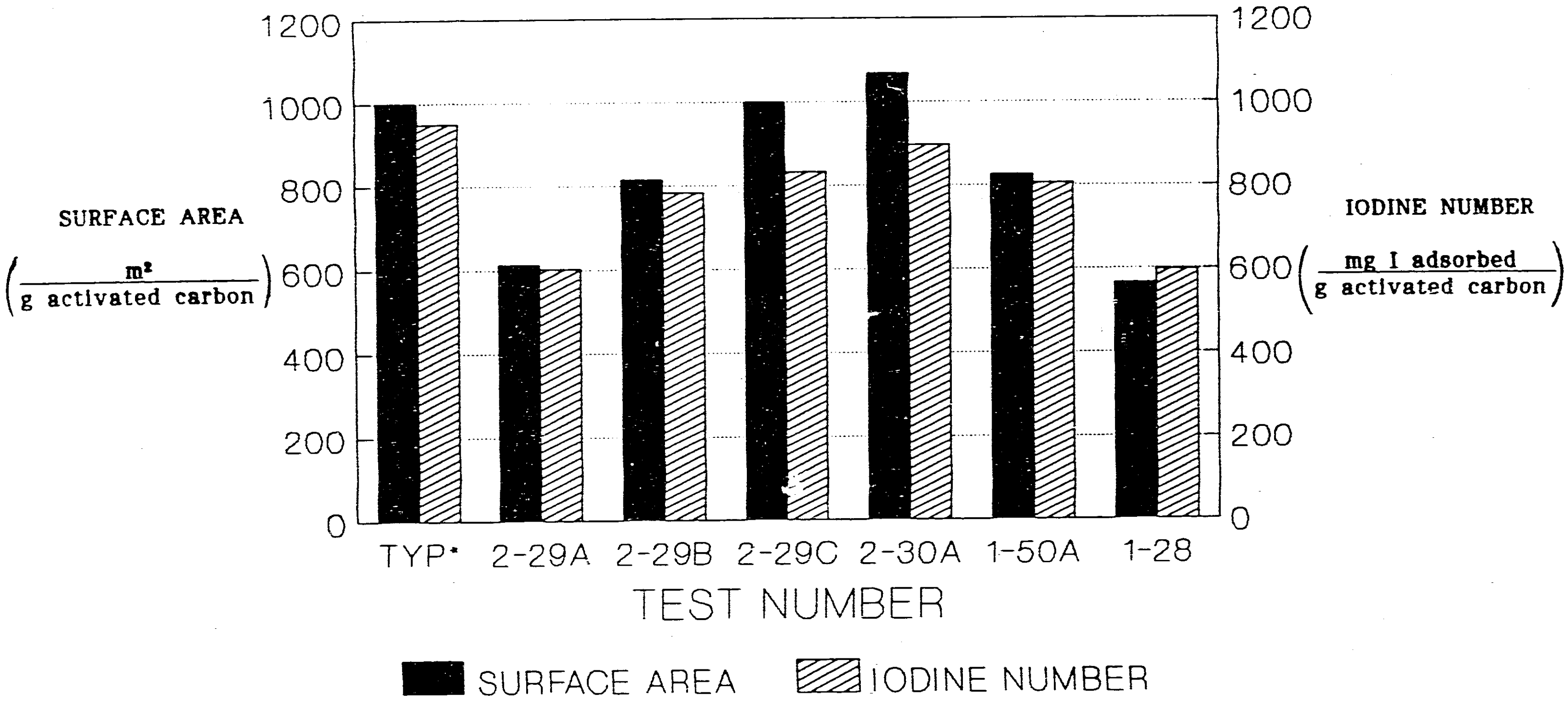


Figure 10. SULFUR FORMS IN COMBUSTED SMOKELESS FUEL



* TYPICAL COMMERCIAL BITUMINOUS BASED ACTIVATED CARBON.

Figure 11. ADSORPTION PROPERTIES OF ACTIVATED CHAR

Table 12. HEATING VALUE COMPARISON OF SMOKELESS FUEL WITH DOMESTIC FUELS

	Heating Value (million Btu/ton)
Wood (15% moisture)	14.6
Utility Bituminous Coal	21.1
Anthracite*	21.6
Charcoal Briquettes	30.0
Smokeless Fuel With Limestone	20.0

* Anthracite imported into Korea.

values for surface area and for an iodine adsorption test used to evaluate adsorbent carbon (ASTM Test D4607-86). These values compare favorably with values for a typical commercial bituminous-coal-based activated carbon.

The duration of steam activation at 1800°F was varied from 45 to 180 minutes, using char from the same sample, to evaluate the degree of activation. Figure 12 shows the increased values of surface area and iodine number as the duration of activation increases; however, at the same time, the amount of activated carbon available decreases as the duration of steam activation increases, as shown in Figure 13. Iodine numbers and surface area values adjusted for this "carbon burnoff" are shown in Figure 14, where an optimum carbon burnoff value of about 40% appears when these data are plotted against the amount of carbon burnoff. This shows that going beyond 40% carbon burnoff reduces the effective amount of adsorbent produced.

The formcoke co-product is considered to be a desirable product in view of declining U.S. coke production. In a meeting of the Industrial Project Advisory Group (IPAG) held at IGT, the consensus opinion was that this product should be developed. IPAG is a committee formed with representatives from the steel industry, the tar processing industry, and technical consultants to review the results of the mild gasification program and suggest market-oriented directions to the program. The committee is chaired by a representative from Peabody Development Company.

The balance of the work in Task 3 concentrated on the formcoke application. Briquettes were made under various conditions and tested for strength. A procedure for a carbon dioxide-carbon reactivity test for coke

Table 13. ADSORBENT CHAR TEST SUMMARY

ACTIVATION CONDITIONS								
Test Number	1-23A	1-28	1-10	1-45	1-15	1-50A	2-11	2-15A
Char Source	MG-6	MG-6	MG-9	MG-9	MG-5	1-49	1-50B	MG-17
Feed Char Composition (dry), wt%								
Carbon	68.30	68.30	62.93	62.93	75.87			
Sulfur	2.67	2.67	3.53	3.53	2.12			
Ash	21.64	21.64	28.46	28.46	15.07			
Activation Temperature, F	1607	1562	1562	1562	1607	1562	1562	1562
Duration of Activation, min	60	100	150	127	124	120		120
Activation Gas Composition, vol%								
N2	71.7	71.8	79.7	79.7	54.8	74.2	76.5	72.5
H2O	28.3	28.2	20.3	20.3	45.2	25.8	23.5	27.5
% Carbon Burnoff	43	40	47	30	75	58	41	
Iodine Number	524.5	596	464.3	348.0	296.0	804.0	537.1	361.1
Ball Pan Hardness Number	52.2	51..	16.1			88.1	45.6	
Apparent Density, (g/ml)	0.27	0.27	0.32	0.29		0.43	0.25	
Sieve Analysis								
+6 mesh	--	--	--			--	--	
6x12 mesh	13.3	--	22.84			2.06	--	
12x20 mesh	29.1	--	15.72			10.89	36.57	
20x40 mesh	32.8	--	14.28			38.94	36.87	
40x60 mesh	19.8	--	18.74			35.80	19.63	
60x80 mesh	3.2	--	18.61			8.19	4.66	
-80 mesh	1.5	--	9.81			4.12	2.27	
Surface Area, (m2/g)	--	563	--	--	--	825	--	--
Ultimate Analysis								
Ash		31.24				31.62		
Carbon		63.83				64.15		
Hydrogen		0.38				0.32		
Nitrogen		1.06				1.07		
Sulfur		1.69				1.59		
Oxygen		1.80				1.26		

ACTIVATION CONDITIONS				
Test Number	2-29A	2-29B	2-29C	2-30A
Char Source	2-28	2-28	2-28	2-28
Feed Char Composition (dry), wt%				
Carbon	73.52	73.52	73.52	73.52
Sulfur	2.38	2.38	2.38	2.38
Ash	17.89	17.89	17.89	17.89
Activation Temperature, F	1562	1562	1562	1562
Duration of Activation, min	45	90	135	180
Activation Gas Composition, vol%				
N2				
H2O				
% Carbon Burnoff	21	40	58	71
Iodine Number	601.8	781.7	832.2	896.3
Ball Pan Hardness Number	--	--	--	--
Apparent Density, (g/ml)				
Sieve Analysis				
+6 mesh				
6x12 mesh				
12x20 mesh				
20x40 mesh				
40x60 mesh				
60x80 mesh				
-80 mesh				
Surface Area, (m2/g)	611	815	1000	1070
Ultimate Analysis				
Ash	23.15	28.68	36.99	45.62
Carbon	72.17	66.91	59.67	52.16
Hydrogen	0.37	0.34	0.23	0.29
Nitrogen	1.43	1.18	0.87	0.87
Sulfur	2.23	1.95	1.71	1.22
Oxygen	0.65	0.94	0.53	-0.16

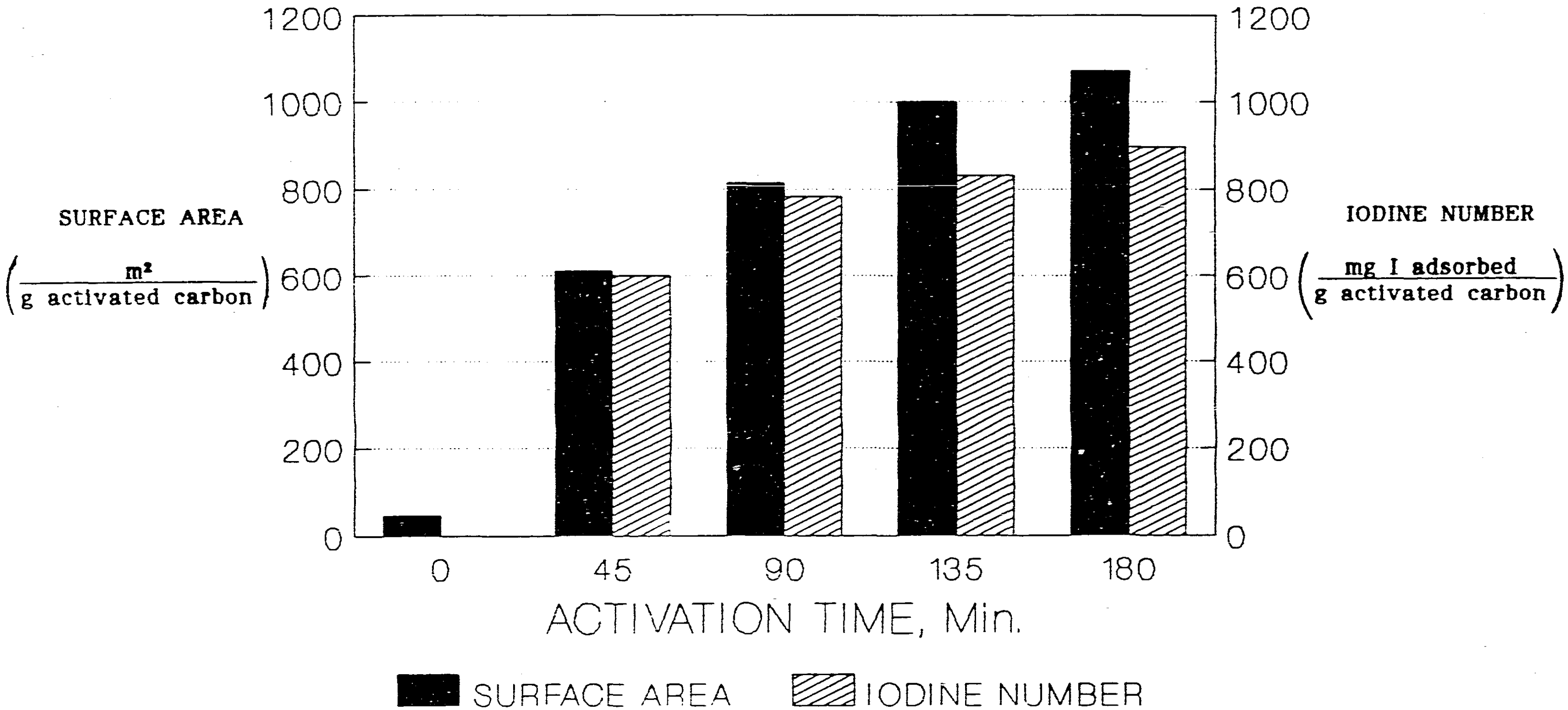


Figure 12. ADSORPTION PROPERTIES OF CHAR VERSUS ACTIVATION TIME

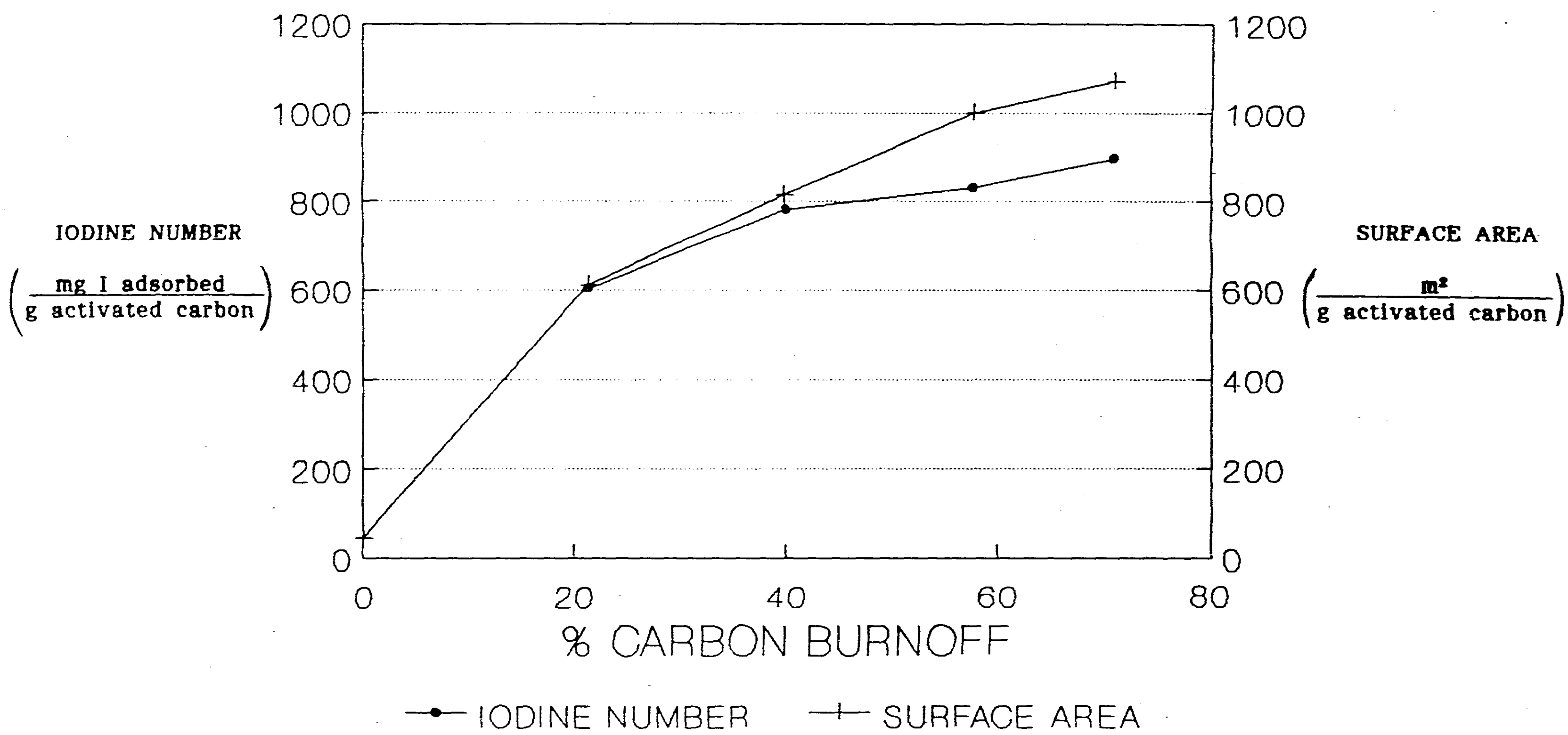


Figure 13. ADSORPTION PROPERTIES OF CHAR VERSUS CARBON BURNOFF

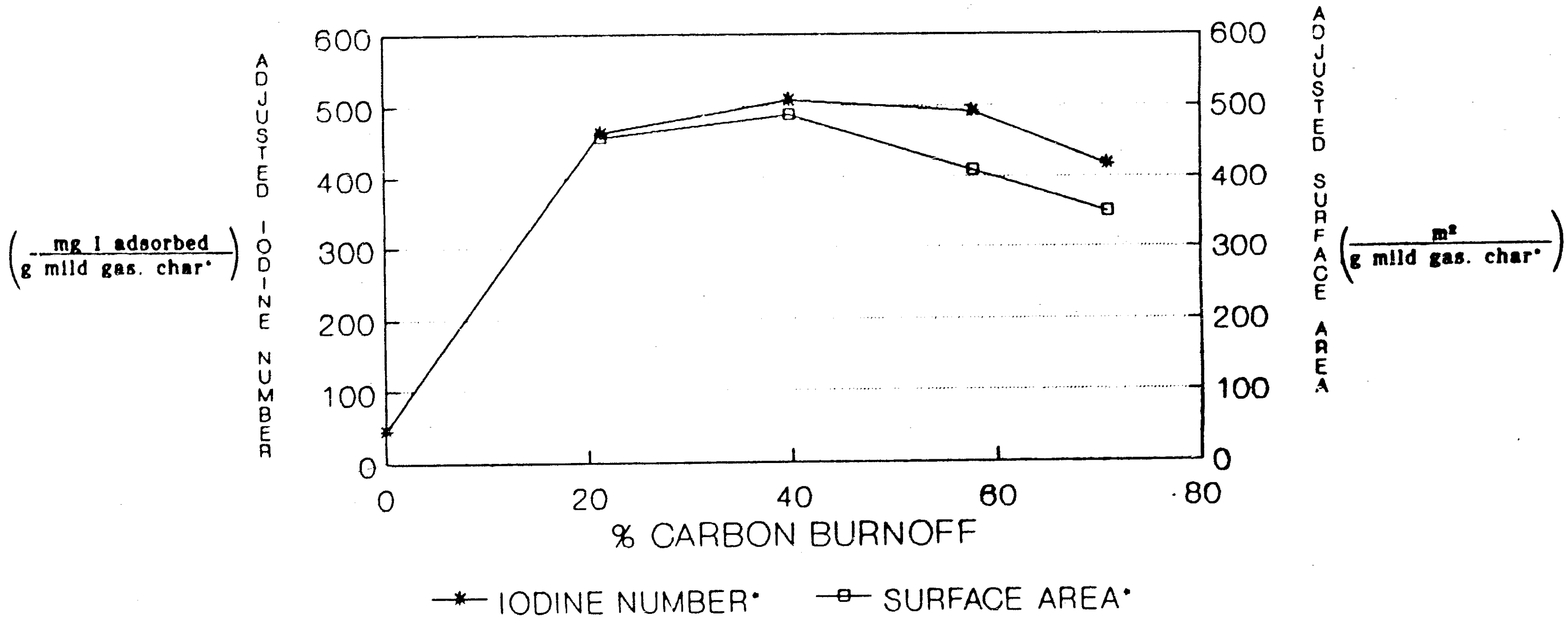


Figure 14. ADSORPTION PROPERTIES PER GRAM OF CHAR VERSUS CARBON BURNOFF

was obtained from Bethlehem Steel Company and applied to the formcoke briquettes.

The physical strength of the formcoke briquettes were measured by the diametral compression test (ASTM Test B485-76), which measures the tensile strength up to fracture. The range of tensile strengths obtained for the samples are shown in Figure 15. This figure shcws that the strength of briquettes from a mild gasification char could be made comparable to the available commercial coke. Work on briquette testing is continuing with chars from the West Virginia coal.

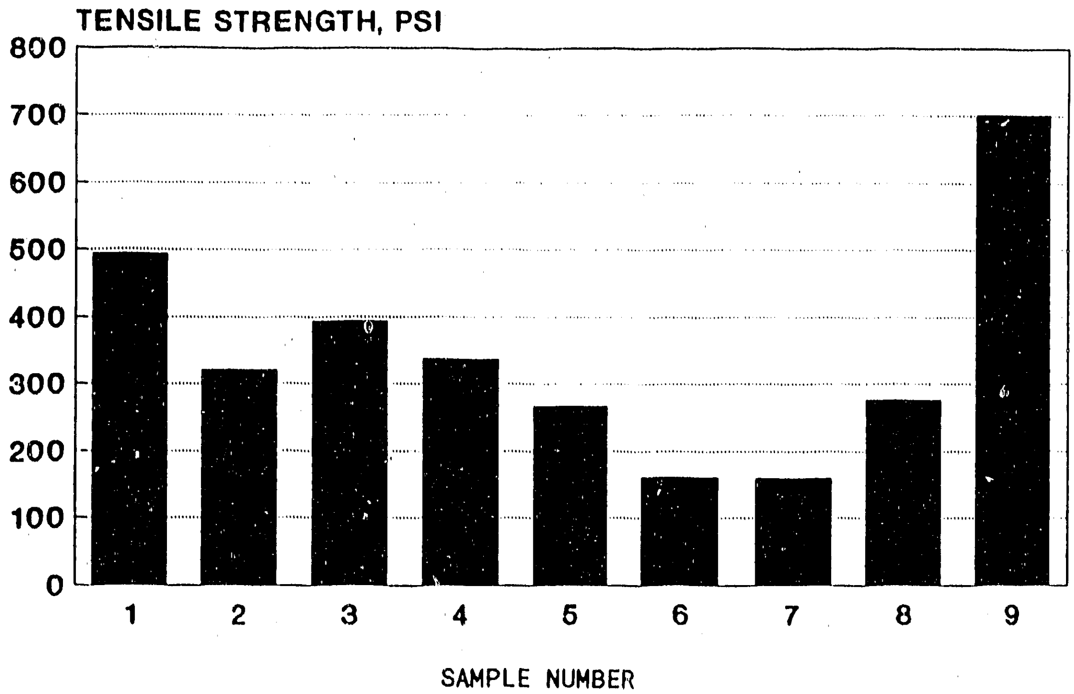
The coke reactivity test adapted from the Bethlehem procedure was calibrated with a sample of coke obtained from Inland Steel Company. The result is shown in Figure 16 along with data from a sample formcoke made from the West Virginia char. The Inland coke value is consistent with expectations from its description as a low reactivity coke. The West Virginia coke reactivity falls near the middle of a range of values for all types of coke. One of the uses of this test is to define the reactivity values of available cokes so that the blending of different coals can produce the desired coke properties.

Task 4. System Integration Studies

The work scope for Task 4 includes the installation and operation of a total condensate collection system for the PRU and a conceptual process design for a 24 ton per day (TPD) process development unit (PDU).

The total condensate collection system to be installed is shown schematically in Figure 17. It consists of a quench vessel with recirculated quench water that is cooled in a water-jacketed heat exchanger. The condensate system can be activated after steady-state conditions have been achieved by operation of three hot-service diversion valves installed in the pipeline upstream of the pressure letdown station. The fabricated quench vessel is scheduled to be delivered in January, and installation of the vessel and other equipment, pipe welding, and electrical work will begin immediately thereafter. Shakedown is expected to be completed by the end of February.

The process design for the 24 TPD PDU by Bechtel National, Inc. is nearing completion. The PDU design will be site-specific for installation at the Illinois Coal Development Park in Carterville, Illinois, operated by

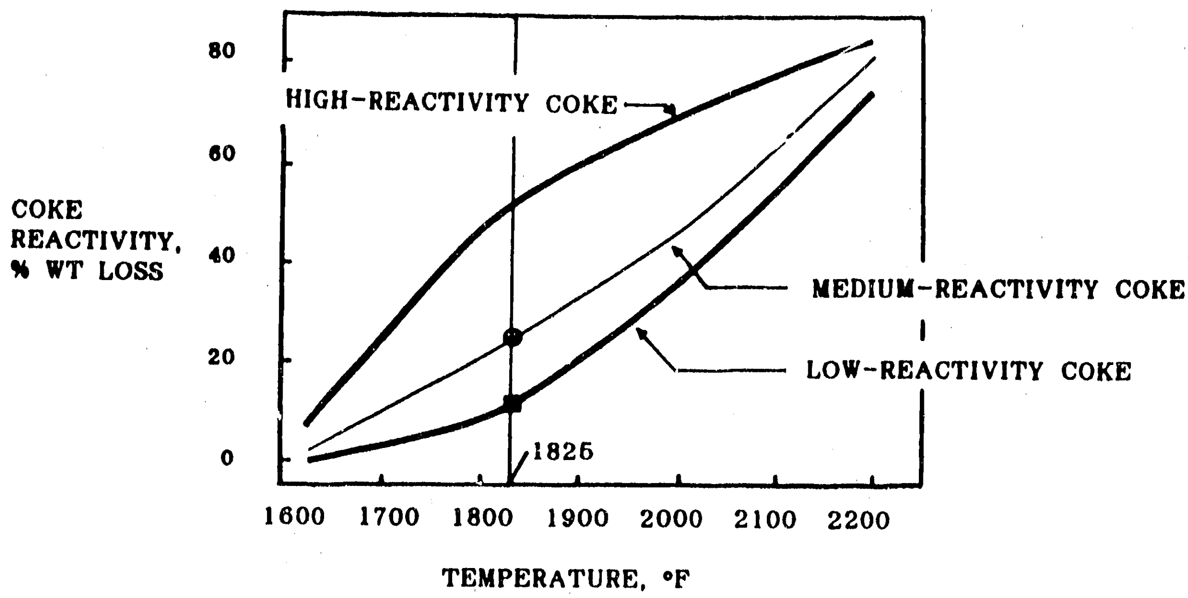


SAMPLE NO.	DESCRIPTION	BRIQUETTING PRESSURE (PSI)
1	COMMERCIAL COKE A*	---
2	COMMERCIAL COKE B*	---
3	FOUNDRY COKE*	---
4	HOT BRIQUETTE [-6 MESH MG-9 CHAR]**	4000
5	" " [-6 MESH MG-9 CHAR]	10000
6	HOT BRIQUETTE [20 X 60 MESH MG-17 CHAR]	4000
7	" " [20 X 60 MESH MG-17 CHAR]	10000
8	HOT BRIQUETTE [-20 MESH MG-9 CHAR]	4000
9	METALLURGICAL COKE SAMPLE INLAND STEEL	---

* VALUES FROM FUEL, JANUARY 1972, VOL.51

** BRIQUETTES MADE IN 1:1 WEIGHT RATIO OF CHAR AND ILL.NO.6 COAL

Figure 15. DIAMETRAL TESTS FOR TENSILE STRENGTH



● **BETHLEHEM CO_2 REACTIVITY TEST CONDUCTED ON FORM COKE MADE FROM WV CHAR AND CARBONIZED AT 1800 °F**

■ **COMPARATIVE TEST CONDUCTED WITH COKE SAMPLE OBTAINED FROM INLAND STEEL**

Figure 16. FORMCOKE REACTIVITY TESTS

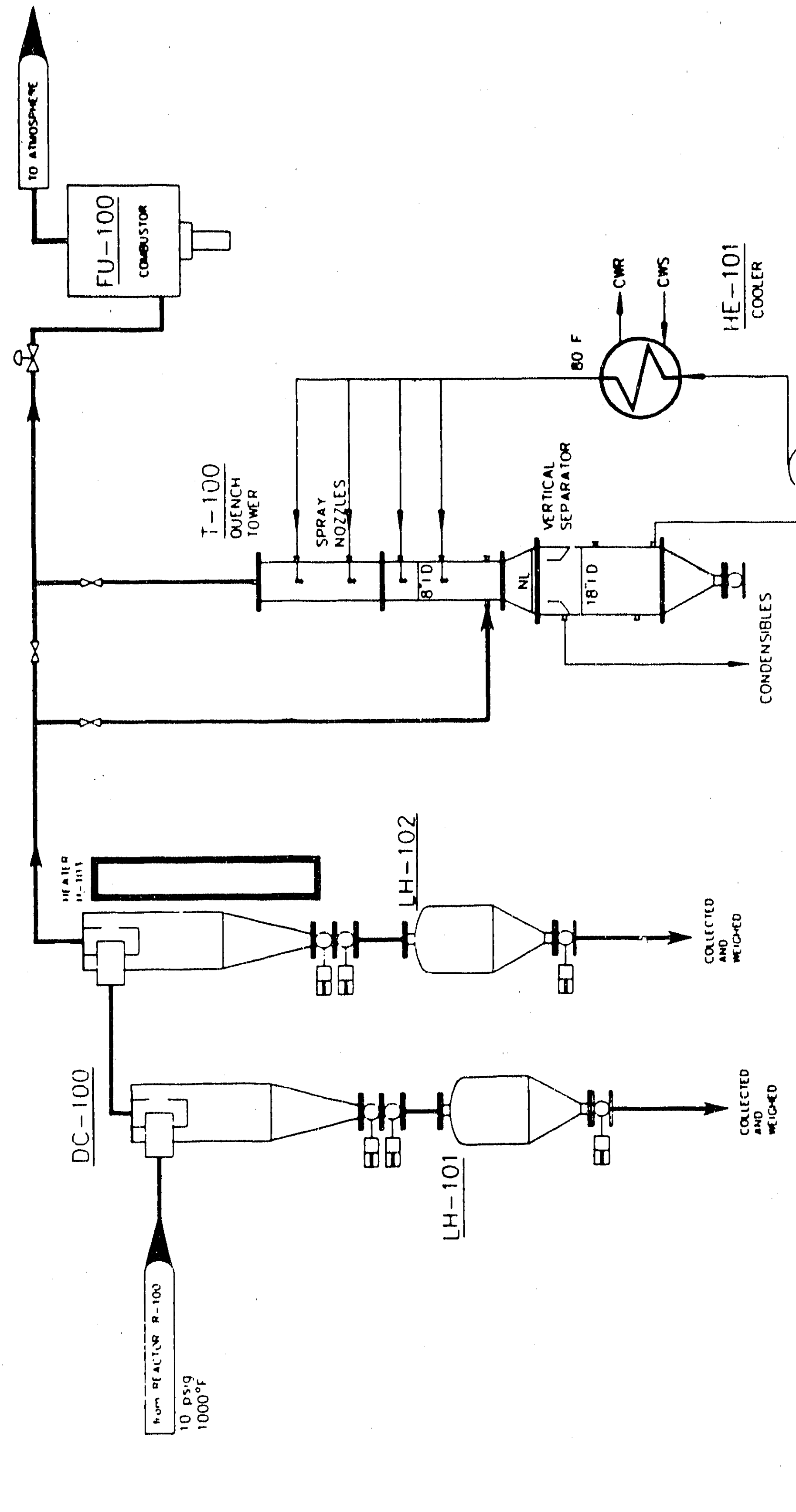


Figure 17. SCHEMATIC DIAGRAM OF TOTAL CONDENSATE SYSTEM

Southern Illinois University at Carbondale. The preliminary process flow diagrams are shown in Figures 18 through 22 and the corresponding material balances for each stream are given in Tables 14 through 18. Figure 19 shows two methods to be used in the PDU operation for supplying the heat required by the mild gasification process. One method for heat supply to the gasifier is to heat a portion of the product gas and recycle it to the gasifier; the other method under consideration is to heat a portion of the char and recycle it to the gasifier. The material and energy balances for this process design will be confirmed when the details of the process design are finalized. Following this, an equipment list and a preliminary capital cost estimate of the PDU will be prepared.

6WP/61089o-d/RPP

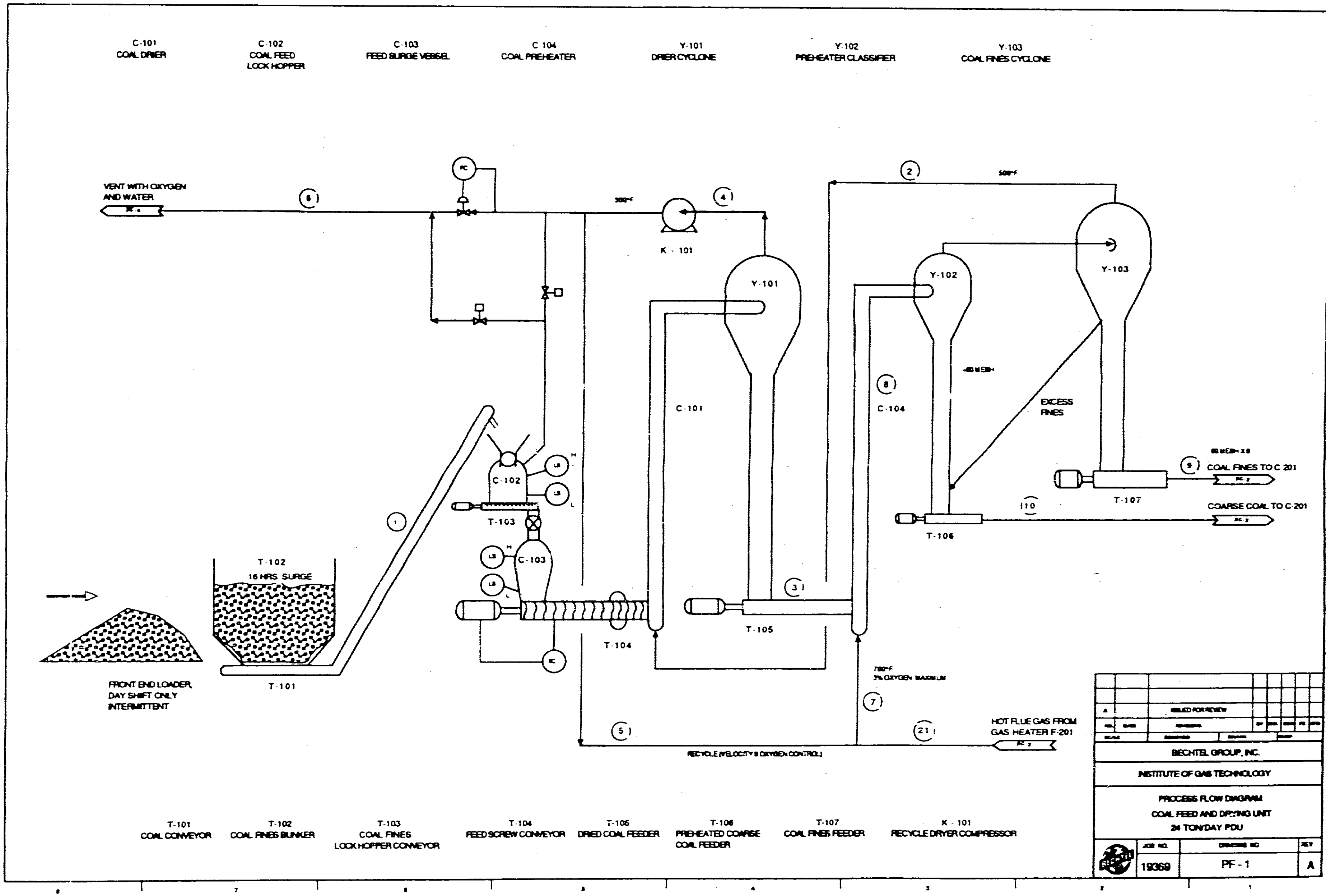


Figure 18. PROCESS FLOW DIAGRAM FOR 24 TPD PDU -- COAL FEED AND DRYING UNIT

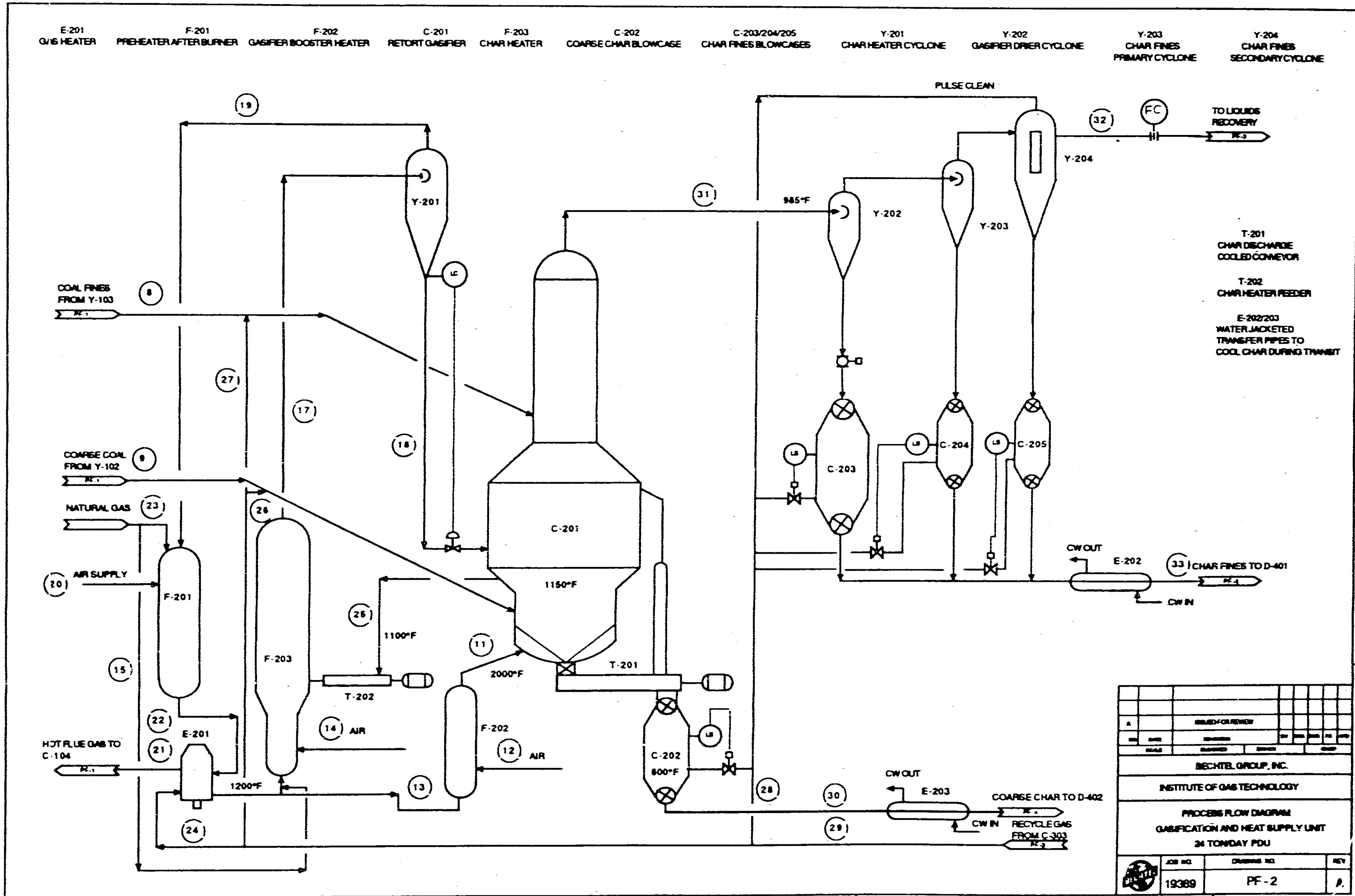


Figure 19. PROCESS FLOW DIAGRAM FOR 24 TPD PDU -- GASIFICATION AND HEAT SUPPLY UNIT

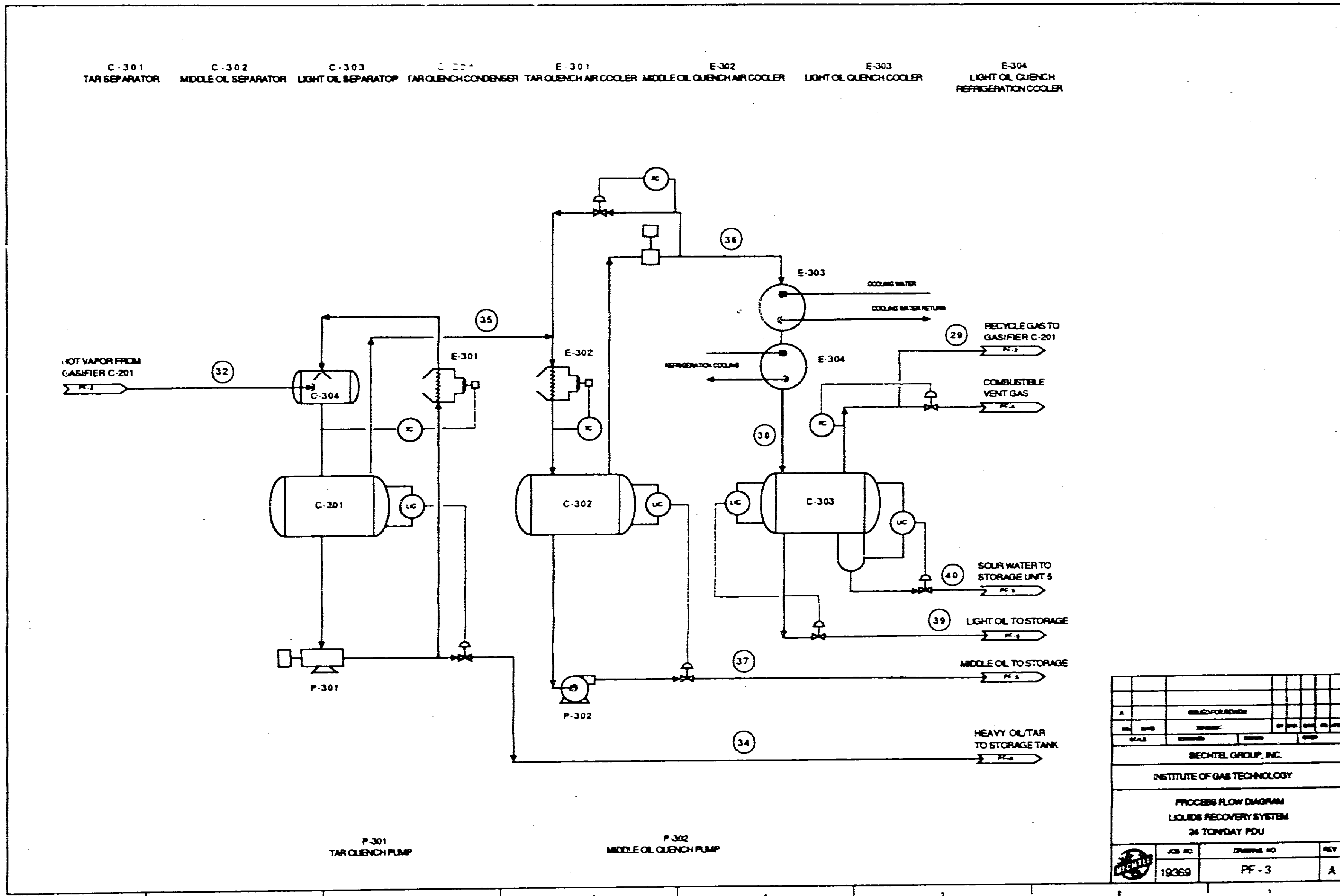


Figure 20. PROCESS FLOW DIAGRAM FOR 24 TPD PDU -- LIQUIDS RECOVERY SYSTEM

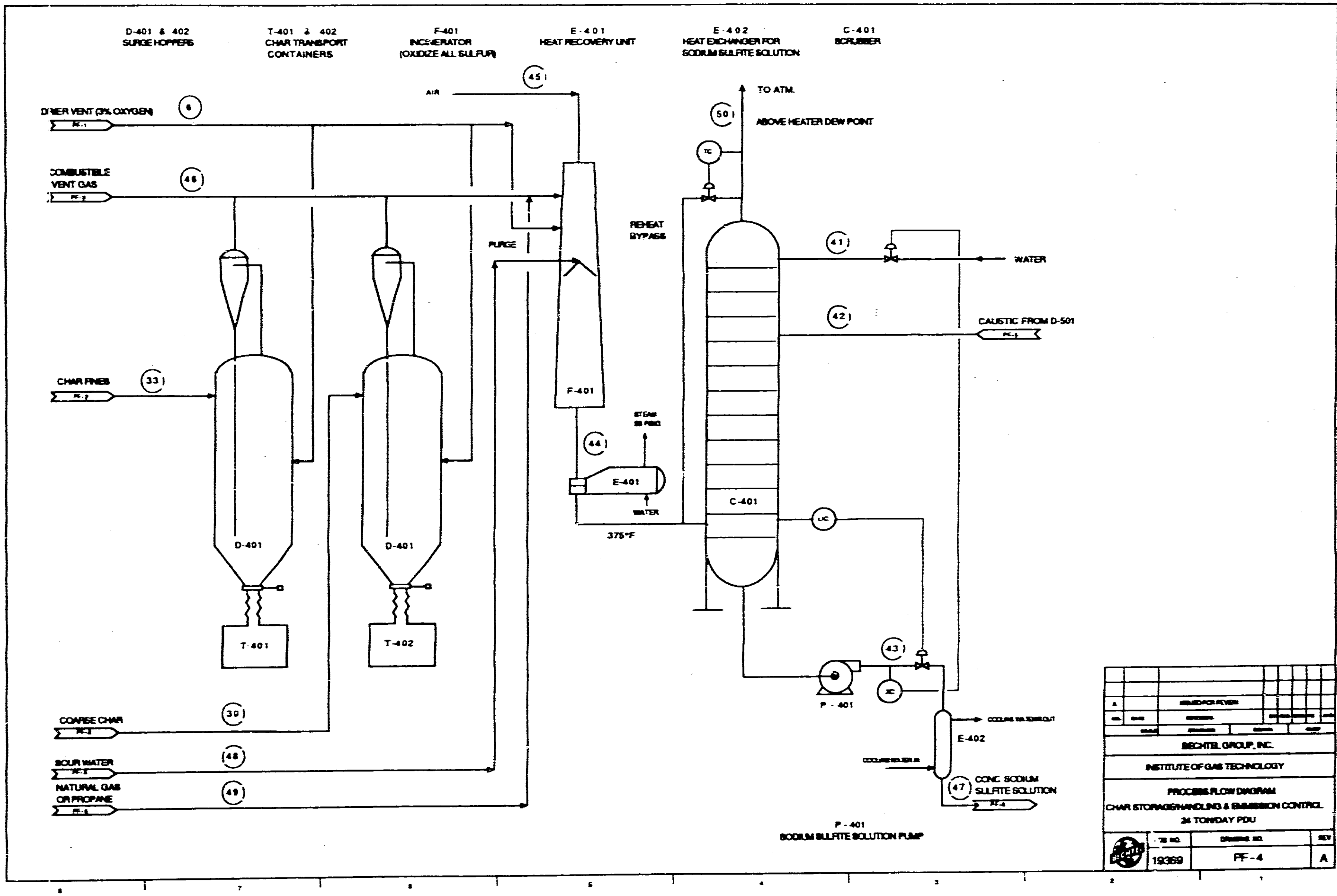


Figure 21. PROCESS FLOW DIAGRAM FOR 24 TPD PDU — CHAR STORAGE AND HANDLING AND EMISSION CONTROL

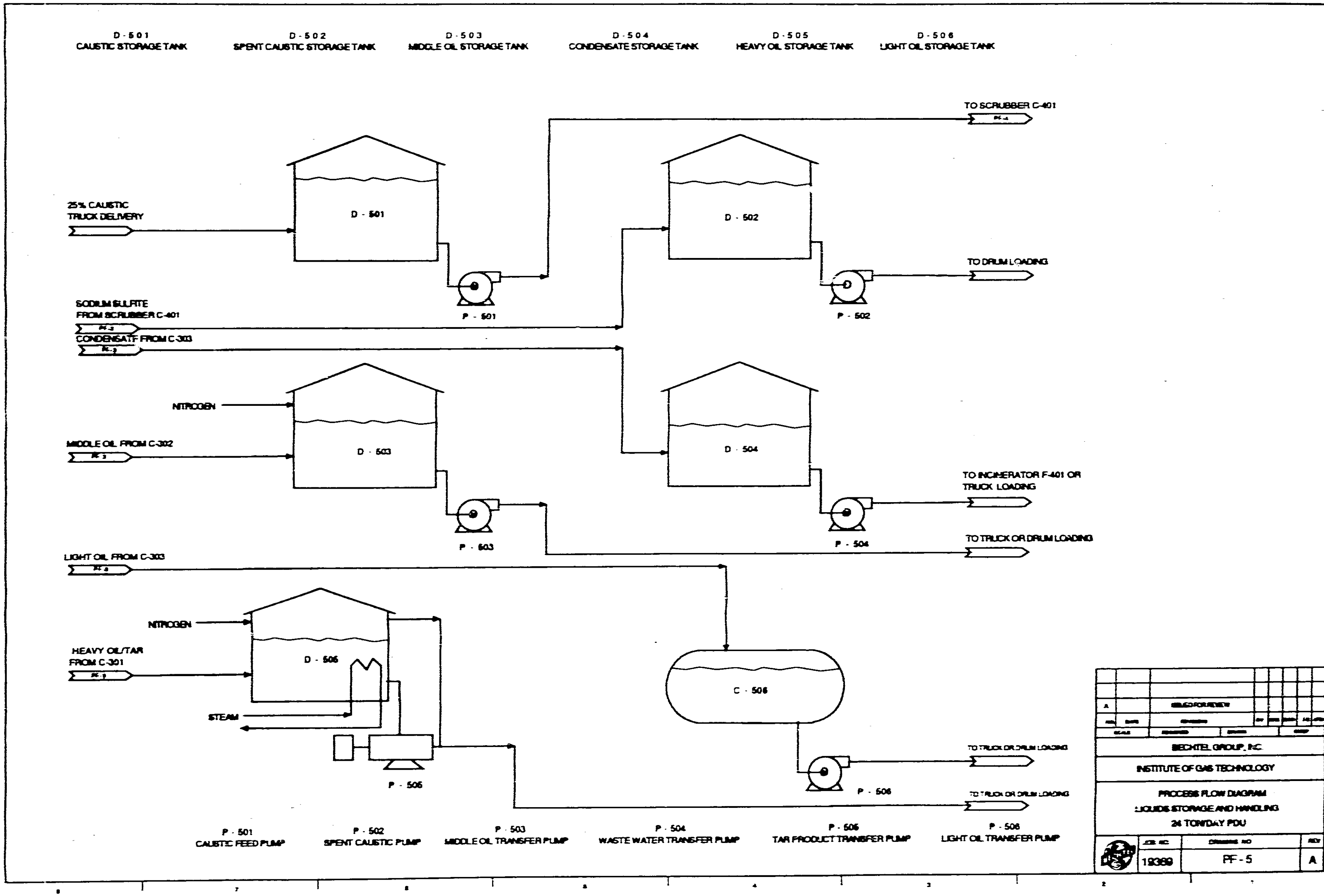


Figure 22. PROCESS FLOW DIAGRAM FOR 24 TPD PDU -- LIQUIDS STORAGE AND HANDLING

Table 14. MATERIAL BALANCE FOR 24 TPD PDU -- STREAMS 1 TO 11

STREAM NO.		1	2	3	4	5	6	7	8	9	10	11
	Unit	Wet Feed	Flue Gas	Dried	Flue Gas	Recycle	Vent Gas	Flue Gas	Feed To	Coal	Coarse	Hot Gas
		Coal	From	Feed	From	Gas To	From	To C-104	Preheater	Fines To	Coal to	To Pyrolyze
			Preheater	Coal	Coal Dryer	C-104	C-101			C-201	C-201	
Coal (MF)	lb/hr	2000.0	0.0	2000.0	0.0	0.0	0.0	0.0	2000.0	400.0	1600.0	
ASH	lb/hr											
CARBON	lb/hr											
SULFER	lb/hr											
HYDROGEN	lb/hr											7.00
CARBON MONO.	lb/hr											1.74
CARBON DIOXID	lb/hr		268.25	0.15	268.1	168.84	99.26	268.84	269.0	0.01	0.03	658.86
OXYGEN	lb/hr		1032.23	0.08	1032.2	650.00	382.15	1020.01	1020.1	0.01	0.06	0.00
NITROGEN	lb/hr		4337.08	0.14	4336.9	2731.22	1605.71	4301.22	4301.4	0.03	0.13	1492.40
METHANE	lb/hr											34.40
ETHYLENE	lb/hr											16.30
ETHANE	lb/hr											6.90
PROPYLENE	lb/hr											8.10
PROPANE	lb/hr											0.80
HYDROGEN SULF	lb/hr											10.30
LIGHT OIL	lb/hr											16.90
MIDDLE OIL	lb/hr											4.78
HEAVY/PITCH	lb/hr											
SO2	lb/hr											
WATER	lb/hr	500.00	1082.16	73.75	1508.0	949.94	558.48	1019.93	1093.7	0.10	0.42	46.03
CHAR	lb/hr											
NaOH (25%)	lb/hr											
Na2SO3 (25%)	lb/hr											
TOTAL FLOW	lb/hr	2500.00	6719.72	2074.12	7145.2	4500.0	2645.6	6610.0	8684.1	400.2	1600.6	2304.52
	lbmole/hr	38.97	253.23	15.35	276.86	174.36	102.51	248.13	263.45	2.26	9.03	78.03
	Scfh		96096		105068	66167	38900	94160	95702			29611
	Acfh		71106		52701	33189	19512	83317	70757			60605
LIQUID FLOW	lb/hr	2500.00		2074.12					2000.80	400.15	1600.64	
AV. MW		64.16	26.54	135.17	25.8	25.81	25.81	26.64	32.96	177.21	177.21	29.53
Av. DENSITY	lb/cu ft		0.09		0.14	0.14	0.14	0.08	0.09			0.04
Sp. Gravity		0.96	0.8526	0.96	0.8526	0.85	0.85	0.85	0.88	0.96	0.96	0.76
PRESSURE	Psia	37	37	37	37	37	37	37	37	37	37	35
TEMPERATURE	°F	60	509	199	199	199	199	698	508	508	450	2000

Table 15. MATERIAL BALANCE FOR 25 TPD PDU -- STREAMS 12 TO 22

STREAM NO.		12	13	14	15	16	17	18	19	20	21	22
	Unit	Air To	Hot Flue	Air To	Natural	Recycle	Flue Gas	Char From	Flue Gas	Air Supply	Hot Flue	Hot Flue
		Gasifier	Gas To	Char Htr	Gas To	Gas To	To Char	Y-201	From Y-201	To Preheater	Gas To	Gas To
		Booster Htr	Booster Htr	F-203	Char Htr	Char Htr	Htr Cyclone			Afterburner	C-104	E-201
Coal (MF)	lb/hr											
ASH	lb/hr						228.00	228.00				
CARBON	lb/hr											
SULFER	lb/hr											
HYDROGEN	lb/hr	0.00	7.00									
CARBON MONO.	lb/hr	0.00	280.10				4.55		4.55			
CARBON DIOXID	lb/hr	0.00	221.50				14.30		14.30		116.10	116.10
OXYGEN	lb/hr	150.00		13.00						466.00	325.77	325.77
NITROGEN	lb/hr	531.00	961.40	43.00			43.00		43.00	1547.96	1590.96	1590.96
METHANE	lb/hr		34.40		0.00							
ETHYLENE	lb/hr		16.30									
ETHANE	lb/hr		6.90									
PROPYLENE	lb/hr		8.10									
PROPANE	lb/hr		0.80									
HYDROGEN SULF	lb/hr		10.30									
LIGHT OIL	lb/hr		16.90									
MIDDLE OIL	lb/hr		4.78									
HEAVY/PITCH	lb/hr											
SO2	lb/hr											
WATER	lb/hr	21.40	24.63								77.51	77.51
CHAR	lb/hr						685.11	685.11				
NaOH (25%)	lb/hr											
Na2SO3 (25%)	lb/hr											
TOTAL FLOW	lb/hr	702.40	1593.11	56.00	0.00	2.30	974.96	913.11	61.86	2013.96	2110.34	2110.3
	lbmole/hr	24.79	57.89	1.94	0.00	0.08	11.57		2.02	69.82	73.91	73.91
	Scfh	9145	21967	12			37		768	26496	28049	28049
	Acfh	3837	29479	5			68		1465	11017	51801	68563
LIQUID FLOW	lb/hr	18.23					227.97					
AV. MW		28.33	27.52	28.85	16.04	27.52	84.29		30.58	28.84	28.55	28.55
Av. DENSITY	lb/cu ft	0.18	0.05	0.19	0.10	0.05	0.18		0.04	0.18	0.04	0.03
Sp. Gravity		0.86	0.73	0.86		0.73						
PRESSURE	Psia	37	37	37	37	37	35	35	35	35	37	37
TEMPERATURE	°F	60	1200	60	70	1200	1969	2000	1969	70	1825	2651

Table 16. MATERIAL BALANCE FOR 24 TPD PDU -- STREAMS 23 TO 33

STREAM NO.		23	24	25	26	27	28	29	30	31	32	33
	Unit	Natural Gas	Recycle	Hot Char	Recyc. Gas	Recyc. Gas	Recyc. Gas	Recycle	Coarse	Flue Gas	Gas To Liq.	Char Fines
		To Preheater	Gas To	To F-203	To Gasifier	To Gasifier	To Char Fines	Gas From	Char To	To Y-202	Recovery	To
		Afterburner	Gas Heater		(Coal Fines)	(Coarse Coal)	Second. Cycl.	C-303	D-402		C-304	D-401
Coal (MF)	lb/hr											
ASH	lb/hr			228.00								
CARBON	lb/hr											
SULFER	lb/hr											
HYDROGEN	lb/hr		7.00		0.07	0.07	0.22	7.33		7.11	7.33	
CARBON MONO.	lb/hr		280.10		2.95	2.95	8.84	294.80		285.97	294.81	
CARBON DIOXID	lb/hr		221.30		2.33	2.33	7.00	233.18		226.27	233.27	
OXYGEN	lb/hr				0.00	0.00	0.00	0.00		0.00	0.00	
NITROGEN	lb/hr		961.40		10.12	10.12	30.36	1011.95		981.64	1012.00	
METHANE	lb/hr	34.50	34.40		0.36	0.36	1.09	36.23		35.14	36.23	
ETHYLENE	lb/hr		16.30		0.17	0.17	0.51	17.12		16.62	17.13	
ETHANE	lb/hr		6.90		0.07	0.07	0.22	7.29		7.07	7.29	
PROPYLENE	lb/hr		8.10		0.09	0.09	0.26	8.55		8.30	8.56	
PROPANE	lb/hr		0.80		0.01	0.01	0.03	0.85		0.82	0.85	
HYDROGEN SULF	lb/hr		10.30		0.11	0.11	0.33	10.89		10.57	10.90	
LIGHT OIL	lb/hr		16.90		0.18	0.18	0.53	17.79		34.43	34.96	
MIDDLE OIL	lb/hr		4.78		0.05	0.05	0.16	5.33		92.43	92.59	
HEAVY/PITCH	lb/hr				0.00	0.00	0.00	0.00		264.21	264.21	
SO2	lb/hr											
WATER	lb/hr		24.63		0.26	0.26	0.77	25.82		232.22	232.99	
CHAR	lb/hr			772.00					1000.00	269.00	0.00	269.00
NaOH (25%)	lb/hr											
Na2SO3 (25%)	lb/hr											
TOTAL FLOW	lb/hr	34.5	1582.6	1000.0	16.77	16.77	50.31	1677.12	1000.00	2430.81	2253.12	269.00
	lbmole/h	2.15	57.51	10.03	0.61	0.61	1.83	60.90	10.03	88.99	73.54	2.70
	Scfh	816	21967		231.12	231.12	693.35	23112		27722		
	Acfh	338	9646		91.32	91.32	273.97	9132		20373	33933	
LIQUID FLOW	lb/hr			1000.00								
AV. MW		16.04	27.52	99.68	27.54	27.54	27.54	27.54	99.68	27.31	30.64	99.68
Av. DENSITY	lb/cu ft	0.10	0.17		0.18	0.18	0.18	0.18		0.10	0.07	
Sp. Gravity				1.08							1.24	
PRESSURE	Psia	37	37	37	37	37	37	37	35	35	35	35
TEMPERATURE	°F	70	100	1100	100	100	100	100	600	1100	985	985

Table 17. MATERIAL BALANCE FOR 24 TPD PDU -- STREAMS 34 TO 44

STREAM NO.	Unit	34 Heavy Tar To Storage Tank	35 Middle Oil To Separator	36 Light Oil To Cond. E-303	37 Middle Oil To Storage Tank	38 Light Oil To Separator C-303	39 Light Oil To Storage Tank	40 Sour Water To Storage	41 Water To Scrubber C-401	42 Caustic To C-401	43 Conc. Sod. Sulf. Sol. From C-401	44 Effluent From Scrubber
Coal (MF)	lb/hr											
ASH	lb/hr											
CARBON	lb/hr											
SULFER	lb/hr											
HYDROGEN	lb/hr	0.00	7.33	7.33	0.00	7.33	0.00					
CARBON MONO.	lb/hr	0.01	294.80	294.80	0.00	294.80	0.00					
CARBON DIOXID	lb/hr	0.01	233.26	233.23	0.03	233.23	0.05				0.32	218.96
OXYGEN	lb/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00				307.70
NITROGEN	lb/hr	0.02	1011.98	1011.97	0.01	1011.97	0.01	0.01				1842.72
METHANE	lb/hr	0.00	36.23	36.23	0.00	36.23	0.00					
ETHYLENE	lb/hr	0.00	17.13	17.13	0.00	17.13	0.00					
ETHANE	lb/hr	0.00	7.29	7.29	0.00	7.29	0.00					
PROPYLENE	lb/hr	0.00	8.56	8.56	0.00	8.56	0.01					
PROPANE	lb/hr	0.[illegible]0	0.85	0.85	0.00	0.85	0.00					
HYDROGEN SULF	lb/hr	0.0[illegible]	10.90	10.89	0.00	10.89	0.01					
LIGHT OIL	lb/hr	0.11	34.85	29.68	5.16	29.68	11.90					
MIDDLE OIL	lb/hr	6.97	85.62	21.34	64.27	21.34	16.01					
HEAVY/PITCH	lb/hr	250.67	13.54	0.00	13.54	0.00	0.00					
SO2	lb/hr											
WATER	lb/hr	0.03	232.96	232.88	0.08	232.88	0.01	207.05	400.00	125.00	243.50	953.18
CHAR	lb/hr											
NaOH (25%)	lb/hr									42.50	1.21	1.21
Na2SO3 (25%)	lb/hr										65.04	65.04
TOTAL FLOW	lb/hr	257.83	1995.29	1912.17	83.11	1912.17	27.99	207.05	400.00	125.00	2460.49	3388.81
	lbmole/hr	0.49	73.05	72.61	0.44	72.61	1.06	11.49	22.22	5.97	72.45	133.81
	Scfh		27722	27557		27557						50778
	Acfh		20373	14021		12838						65288
LIQUID FLOW	lb/hr	257.83			83.11		27.99	207.05	400.00	125.00	2460.49	3388.81
AV. MW		520.99	27.3141	26.33	190.75	26.33	26.33	18.02	18.00	20.94	33.96	25.32
Av. DENSITY	lb/cu ft		0.097943	0.14		0.15						0.05
Sp. Gravity		1.17			0.98		0.92	1.00	1.00	1.14		
PRESSURE	Psia	35	35	35	35	40	40	40	20	20	25	15
TEMPERATURE	°F	450	450	172	172	201	100	100	60	70	180	180

Table 18. MATERIAL BALANCE FOR 24 TPD PDU -- STREAMS 45 TO 50

STREAM NO.	Unit	45	46	47	48	49	50
		Air To Incinerator	Comb. Vent Gas To Incinerator	Conc. Sod. Sulf. Sol. To Disposal	Sour Water To Inciner.	Natural Gas Or propane	Flue Gas To Atm.
Coal (MF)	lb/hr						
ASH	lb/hr						
CARBON	lb/hr						
SULFER	lb/hr						
HYDROGEN	lb/hr		0.73				
CARBON MONO.	lb/hr		29.48				
CARBON DIOXID	lb/hr		23.32	0.32			218.64
OXYGEN	lb/hr	40.00	0.00		0.00		307.70
NITROGEN	lb/hr	135.00	101.19		0.01		1842.70
METHANE	lb/hr		3.62			10.00	
ETHYLENE	lb/hr		1.71				
ETHANE	lb/hr		0.73				
PROPYLENE	lb/hr		0.85				
PROPANE	lb/hr		0.08				
HYDROGEN SULF	lb/hr		1.09				
LIGHT OIL	lb/hr		1.78				
MIDDLE OIL	lb/hr		0.53				
HEAVY/PITCH	lb/hr		0.00				
SO2	lb/hr						
WATER	lb/hr		2.58	243.50	207.05		1109.67
CHAR	lb/hr						
NaOH (25%)	lb/hr			1.21			
Na2SO3 (25%)	lb/hr			65.04			
TOTAL FLOW	lb/hr	175.00	167.71	310.08	207.05	10.00	3478.71
	lbmole/hr	6.07	6.09	9.13	11.49	0.62	139.85
	Scfh	2303	2311			237	53068
	Acfh	1724	913			177	56190
LIQUID FLOW	lb/hr			310.08	207.05		
AV. MW		28.83	27.54	33.96	18.02	16.04	24.88
Av. DENSITY	lb/cu ft	0.10	0.18			0.06	0.06
Sp. Gravity					1.00		
PRESSURE	Psia	20	20	15	40	20	20
TEMPERATURE	°F	70	100	80	100	70	179

APPENDIX A. Laboratory Analyses of Solids, Liquids, and Gases for Tests Conducted During the Quarter

Table A-1. ANALYSES OF SOLIDS FROM TEST MG-18
Test Temperature = 1178°F

	Feed Mixture	Coal	Diluent	Fluid Bed Char	1st Cyclone Char	2nd Cyclone Char	Carry-Over Char
Proximate Analysis, wt %							
Moisture	3.59	6.53	0.65	0.21	0.77	1.29	0.00
Volatile Matter	17.36	31.05	3.67	5.50	7.25	11.34	43.03
Ash	11.83	11.44	12.22	15.71	15.64	16.22	17.58
Fixed Carbon	67.22	50.98	83.46	78.38	76.34	71.15	39.39
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ultimate Analysis, dry wt %							
Carbon	77.07	70.27	83.87	80.44	78.21	74.36	70.81
Hydrogen	2.26	4.08	0.44	0.49	1.09	1.85	1.20
Sulfur	1.98	3.21	0.75	1.15	1.92	2.19	1.53
Nitrogen	1.36	1.49	1.23	1.28	1.44	1.66	1.28
Oxygen (by diff.)	5.06	8.71	1.41	0.90	1.58	3.51	7.60
Ash	12.27	12.24	12.30	15.74	15.76	16.43	17.58
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Heating Value, Btu/lb	ND	ND	ND	ND	ND	ND	ND
Particle Density, g/cm^3	ND	ND	ND	ND	ND	ND	ND
Particle Size Distribution, wt % retained on screen (mesh)							
6	0.00	0.00	0.00	0.00	0.00	0.00	--
12	14.90	3.30	19.30	9.81	0.18	0.00	--
20	30.30	18.50	31.40	31.75	1.66	0.65	--
30	--	--	--	--	--	--	--
40	33.20	41.30	37.00	52.10	18.80	4.58	--
60	14.70	23.70	11.90	5.77	30.90	11.10	--
70	--	--	--	--	--	--	--
80	4.27	9.01	0.17	0.29	6.45	3.92	--
100	1.20	2.42	0.00	0.14	3.31	1.31	--
120	--	--	--	--	--	--	--
140	0.68	1.21	0.00	0.00	5.34	3.92	--
170	--	--	--	--	--	--	--
200	0.34	0.33	0.00	0.14	6.08	3.27	--
230	0.17	0.00	0.17	0.00	2.76	0.65	--
270	0.00	0.11	0.00	0.00	3.68	1.31	--
325	0.00	0.00	0.00	0.00	3.68	1.96	0.00
PAN	0.34	0.12	0.16	0.00	17.16	67.33	100.00
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table A-2. ANALYSES OF SOLIDS FROM TEST MG-19
Test Temperature = 1102°F

	Feed Mixture	Coal	Diluent	Fluid Bed Char	1st Cyclone Char	2nd Cyclone Char	Carry-Over Char
Proximate Analysis, wt %							
Moisture	4.02	6.92	1.12	0.57	0.92	ND	3.93
Volatile Matter	18.29	33.14	3.44	5.99	12.63	--	31.43
Ash	12.17	12.90	11.44	15.00	16.53	--	61.07
Fixed Carbon	65.52	47.04	84.00	78.44	69.92	--	3.57
	100.00	100.00	100.00	100.00	100.00	--	100.00
Ultimate Analysis, dry wt %							
Carbon	77.18	69.24	85.12	80.09	73.27	ND	36.43
Hydrogen	2.43	4.51	0.35	0.81	1.97	--	NA
Sulfur	2.04	3.38	0.70	1.43	2.68	--	NA
Nitrogen	1.39	1.57	1.21	1.41	1.51	--	NA
Oxygen (by diff.)	4.28	7.51	1.05	1.17	3.89	--	NA
Ash	12.68	13.79	11.57	15.09	16.68	--	63.57
	100.00	100.00	100.00	100.00	100.00	--	100.00
Heating Value, Btu/lb	ND	ND	ND	ND	ND	ND	ND
Particle Density, g/cm^3	ND	ND	ND	ND	ND	ND	ND
Particle Size Distribution, wt % retained on screen (mesh)							
6	0.00	0.00	0.00	0.00	0.00	ND	ND
12	11.30	1.69	21.30	20.80	0.00	--	--
20	26.90	6.58	26.90	59.10	0.25	--	--
30	--	--	--	--	--	--	--
40	36.70	31.00	20.80	17.60	8.17	--	--
60	17.60	35.70	11.90	1.73	17.10	--	--
70	--	--	--	--	--	--	--
80	4.64	16.90	6.26	0.16	7.18	--	--
100	1.19	4.51	2.68	0.16	3.71	--	--
120	--	--	--	--	--	--	--
140	0.83	2.26	3.58	0.16	7.92	--	--
170	--	--	--	--	--	--	--
200	0.24	0.38	2.46	0.16	8.17	--	--
230	0.12	0.19	0.67	0.00	4.46	--	--
270	0.12	0.19	0.89	0.00	5.69	--	--
325	0.12	0.19	0.67	0.00	4.70	--	--
PAN	0.24	0.41	1.89	0.13	32.65	--	--
	100.00	100.00	100.00	100.00	100.00	--	--

Table A-3. ANALYSES OF SOLIDS FROM TEST MG-21
Test Temperature = 1109°F

	Feed Mixture	Coal	Diluent	Fluid Bed Char	1st Cyclone Char	2nd Cyclone Char	Carry-Over Char
Moisture	3.46	5.79	1.12	0.38	0.74	1.23	7.46
Volatile Matter	17.34	31.24	3.44	6.03	13.15	13.59	25.42
Ash	11.39	11.34	11.44	14.40	13.98	15.28	51.31
Fixed Carbon	67.81	51.63	84.00	79.19	72.13	69.90	15.81
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ultimate Analysis, dry wt %							
Carbon	77.70	70.27	85.12	80.09	74.75	73.93	44.55
Hydrogen	2.27	4.19	0.35	0.74	2.21	2.14	NA
Sulfur	1.89	3.07	0.70	1.39	2.49	2.07	NA
Nitrogen	1.51	1.81	1.21	1.50	1.79	1.88	NA
Oxygen (by diff.)	4.83	8.64	1.05	1.82	4.68	4.51	NA
Ash	11.80	12.02	11.57	14.46	14.08	15.47	55.45
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Heating Value, Btu/lb	ND	ND	ND	ND	ND	ND	ND
Particle Density, g/cm^3	ND	ND	ND	ND	ND	ND	ND
Particle Size Distribution, wt % retained on screen (mesh)							
6	0.00	0.00	0.00	0.00	0.00	0.00	ND
12	16.30	3.30	19.30	18.20	0.00	0.00	--
20	29.80	18.50	31.40	54.20	0.00	0.00	--
30	--	--	--	--	--	--	--
40	34.00	41.30	37.00	23.60	5.36	0.57	--
60	14.00	23.70	11.90	2.40	11.10	2.27	--
70	--	--	--	--	--	--	--
80	3.51	9.01	0.17	0.40	5.16	1.70	--
100	0.84	2.42	0.00	0.20	3.37	1.14	--
120	--	--	--	--	--	--	--
140	0.70	1.21	0.00	0.20	7.94	2.27	--
170	--	--	--	--	--	--	--
200	0.28	0.33	0.00	0.20	11.30	3.41	--
230	0.14	0.00	0.17	0.20	5.16	2.27	--
270	0.14	0.11	0.00	0.20	7.74	4.55	--
325	0.14	0.00	0.00	0.00	6.75	2.27	--
PAN	0.15	0.12	0.16	0.20	36.12	79.55	--
	100.00	100.00	100.00	100.00	100.00	100.00	--

Table A-4. ANALYSES OF SOLIDS FROM TEST MG-22
Test Temperature = 1147°F

	Feed Mixture	Coal	Diluent	Fluid Bed Char	1st Cyclone Char	2nd Cyclone Char	Carry-Over Char
Proximate Analysis, wt %							
Moisture	3.49	5.86	1.12	0.25	0.54	0.69	1.76
Volatile Matter	17.88	32.31	3.44	5.88	12.17	12.52	30.88
Ash	11.89	12.33	11.44	15.56	15.56	14.61	64.92
Fixed Carbon	66.74	49.50	84.00	78.31	71.73	72.18	2.44
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ultimate Analysis, dry wt %							
Carbon	76.63	68.14	85.12	78.90	73.66	74.54	33.92
Hydrogen	2.26	4.16	0.35	0.73	1.89	2.12	NA
Sulfur	2.00	3.30	0.70	1.45	2.51	2.49	NA
Nitrogen	1.38	1.55	1.21	1.39	1.65	1.70	NA
Oxygen (by diff.)	5.42	9.79	1.05	1.85	4.64	4.44	NA
Ash	12.32	13.06	11.57	15.68	15.65	14.71	66.08
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Heating Value, Btu/lb	ND	ND	ND	ND	ND	ND	ND
Particle Density, g/cm^3	ND	ND	ND	ND	ND	ND	ND
Particle Size Distribution, wt % retained on screen (mesh)							
6	0.00	0.00	0.00	0.00	0.00	0.00	ND
12	15.20	3.30	19.30	12.50	0.00	0.00	--
20	29.30	18.50	31.40	62.26	0.19	0.00	--
30	--	--	--	--	--	--	--
40	33.48	41.30	37.00	22.20	7.62	1.87	--
60	15.20	23.70	11.90	1.78	15.10	7.46	--
70	--	--	--	--	--	--	--
80	4.20	9.01	0.17	0.36	6.88	4.10	--
100	1.18	2.42	0.00	0.18	4.09	3.36	--
120	--	--	--	--	--	--	--
140	0.79	1.21	0.00	0.18	9.48	4.85	--
170	--	--	--	--	--	--	--
200	0.39	0.33	0.00	0.18	11.00	11.90	--
230	0.00	0.00	0.17	0.18	5.20	1.49	--
270	0.13	0.11	0.00	0.00	6.88	7.84	--
325	0.00	0.00	0.00	0.00	6.32	2.99	--
PAN	0.13	0.12	0.16	0.18	27.24	54.14	--
	100.00	100.00	100.00	100.00	100.00	100.00	--

Table A-5. ANALYSES OF SOLIDS FROM TEST MG-25
Test Temperature = 1134°F

	Feed Mixture	Coal	Diluent	Fluid Bed Char	1st Cyclone Char	2nd Cyclone Char	Carry-Over Char
Proximate Analysis, wt %							
Moisture	2.86	5.34	0.38	0.27	0.38	0.34	0.67
Volatile Matter	16.27	26.51	6.03	7.44	15.33	14.80	22.72
Ash	12.92	11.44	14.40	16.63	17.34	16.36	22.29
Fixed Carbon	67.95	56.71	79.19	75.66	66.95	68.50	54.32
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ultimate Analysis, dry wt %							
Carbon	76.21	72.33	80.09	76.56	69.67	70.89	77.56
Hydrogen	2.16	3.58	0.74	1.05	2.38	2.35	NA
Sulfur	2.09	2.79	1.39	1.84	2.99	3.04	NA
Nitrogen	1.38	1.26	1.50	1.44	1.67	1.64	NA
Oxygen (by diff.)	4.86	7.90	1.82	2.43	5.88	5.66	NA
Ash	13.30	12.14	14.46	16.68	17.41	16.42	22.44
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Heating Value, Btu/lb	ND	ND	ND	ND	ND	ND	ND
Particle Density, g/cm^3	ND	ND	ND	ND	ND	ND	ND
Particle Size Distribution, wt % retained on screen (mesh)							
6	ND	0.00	0.00	ND	ND	ND	ND
12	--	3.30	19.30	--	--	--	--
20	--	18.50	31.40	--	--	--	--
30	--	--	--	--	--	--	--
40	--	41.30	37.00	--	--	--	--
60	--	23.70	11.90	--	--	--	--
70	--	--	--	--	--	--	--
80	--	9.01	0.17	--	--	--	--
100	--	2.42	0.00	--	--	--	--
120	--	--	--	--	--	--	--
140	--	1.21	0.00	--	--	--	--
170	--	--	--	--	--	--	--
200	--	0.33	0.00	--	--	--	--
230	--	0.00	0.17	--	--	--	--
270	--	0.11	0.00	--	--	--	--
325	--	0.00	0.00	--	--	--	--
PAN	--	0.12	0.16	--	--	--	--
	--	100.00	100.00	--	--	--	--

Table A-6. ANALYSES OF SOLIDS FROM TEST MG-28
Test Temperature = 1150°F

	Feed Mixture	Coal	Diluent	Fluid Bed Char	1st Cyclone Char	2nd Cyclone Char	Carry-Over Char
Proximate Analysis, wt %							
Moisture	0.80	0.16	1.12	0.17	0.19	0.02	1.58
Volatile Matter	9.23	20.81	3.44	3.94	7.92	17.37	13.46
Ash	11.55	11.77	11.44	12.77	16.10	31.56	8.31
Fixed Carbon	78.42	67.26	84.00	83.12	75.79	51.05	76.65
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ultimate Analysis, dry wt %							
Carbon	83.02	78.82	85.12	83.51	77.05	57.54	91.56
Hydrogen	1.49	3.77	0.35	0.64	1.83	2.24	NA
Sulfur	0.98	1.54	0.70	0.95	1.52	0.18	NA
Nitrogen	1.29	1.45	1.21	1.36	1.34	1.40	NA
Oxygen (by diff.)	1.58	2.64	1.05	0.75	2.13	7.07	NA
Ash	11.64	11.78	11.57	12.79	16.13	31.57	8.44
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Heating Value, Btu/lb	ND	ND	ND	ND	ND	ND	ND
Particle Density, g/cm^3	ND	ND	ND	ND	ND	ND	ND
Particle Size Distribution, wt % retained on screen (mesh)							
6	ND	0.00	0.00	ND	ND	ND	ND
12	--	3.30	19.30	--	--	--	--
20	--	18.50	31.40	--	--	--	--
30	--	--	--	--	--	--	--
40	--	41.30	37.00	--	--	--	--
60	--	23.70	11.90	--	--	--	--
70	--	--	--	--	--	--	--
80	--	9.01	0.17	--	--	--	--
100	--	2.42	0.00	--	--	--	--
120	--	--	--	--	--	--	--
140	--	1.21	0.00	--	--	--	--
170	--	--	--	--	--	--	--
200	--	0.33	0.00	--	--	--	--
230	--	0.00	0.17	--	--	--	--
270	--	0.11	0.00	--	--	--	--
325	--	0.00	0.00	--	--	--	--
PAN	--	0.12	0.16	--	--	--	--
	--	100.00	100.00	--	--	--	--

Table A-7. OILS AND TARS ANALYSES

Test Number Test Temperature, °F	MG-18 1178	MG-19 1102	MG-21 1109	MG-22 1147
Elemental Analysis of Oils and Tars[a]				
Ash	0.29	0.00	0.47	0.00
Carbon	76.54	77.98	77.57	77.56
Hydrogen	6.71	7.06	6.88	6.90
Nitrogen	1.00	0.92	1.00	0.85
Sulfur	1.74	1.93	1.93	1.84
Oxygen (by diff.)	13.72	12.11	12.15	12.85
Total	100.00	100.00	100.00	100.00
H/C Atomic Ratio	1.04	1.08	1.06	1.06
Simulate Distillation by Gas Chromatography[b]				
Cumulative wt % Recovered	Boiling Point, °F			
5	358	351	359	359
10	418	438	430	425
15	475	509	492	484
20	530	572	550	541
30	644	690	661	650
40	771	810	776	765
50	960	954	912	909
60	--	--	--	--
70	--	--	--	--
EP (end point)[c]	1068	1068	1068	1068
% Residue at EP	48.3	44.9	43.0	44.7

[a] Determined by evaporation at 100°F, 15-20 mm Hg; light oils boiling below approximately 300°F are not included.

[b] Correction applied for heteroatom content of coal liquids, which is not accounted for in standard simulated distillation method for petroleum-based liquids.

[c] Characteristic of chromatographic column and method, not necessarily true end point of distillation.

Table A-7, Cont. OILS AND TARS ANALYSES

Test Number	MG-25	MG-28
Test Temperature, °F	1134	1150
Elemental Analysis of Oils and Tars[a]		
Ash	0.17	1.14
Carbon	78.45	79.60
Hydrogen	7.09	7.09
Nitrogen	0.85	0.86
Sulfur	2.18	0.83
Oxygen (by diff.)	11.26	10.48
Total	100.00	100.00
H/C Atomic Ratio	1.08	1.06
Simulate Distillation by Gas Chromatography[b]		
Cumulative Wt % Recovered	Boiling Point, °F	
5	374	376
10	449	465
15	511	542
20	567	615
30	672	754
40	776	904
50	897	1068
60	--	--
70	--	--
EP (end point)[c]	1068	1068
% Residue at EP	41.6	51.8

[a] Determined by evaporation at 100°F, 15-20 mm Hg; light oils boiling below approximately 300°F are not included.

[b] Correction applied for heteroatom content of coal liquids, which is not accounted for in standard simulated distillation method for petroleum-based liquids.

[c] Characteristic of chromatographic column and method, not necessarily true end point of distillation.

Table A-8. COMPONENT ANALYSES OF FULL-RANGE OILS AND TARS

Test Number	MG-18	MG-19	MG-21	MG-22	MG-25	MG-28
Test Temperature, °F	1178	1102	1109	1147	1134	1150
Component, wt % of total oils and tars[a]						
Benzene	0.7	0.1	0.5	0.8	0.3	0.5
Toluene	0.8	0.3	0.4	0.7	0.5	0.7
Xylenes	0.5	0.2	0.3	0.4	0.4	0.5
Ethylbenzene	0.1	0.04	0.3	0.1	0.1	0.1
Indene	0.3	0.1	0.1	0.2	0.1	0.2
Styrene	0.2	0.1	0.1	0.1	0.1	0.05
Other Light Oils	4.8	5.4	22.0	4.7	4.2	7.3
Total Light Oil[b]	7.4	6.2	23.7	7.0	5.7	9.3
Phenol	0.8	0.6	0.6	0.8	0.8	0.4
Cresols	2.1	1.6	1.6	2.1	1.9	1.0
Xylenols	1.9	1.6	1.9	2.3	3.8	1.6
Naphthalene	0.5	0.3	0.1	0.4	0.1	0.6
Other Middle Oils	14.4	11.8	10.7	13.4	11.0	9.7
Total Middle Oil[c]	19.7	15.9	14.9	19.0	17.6	13.3
Heavy Oil[d]	12.9	13.5	11.4	13.4	15.2	10.8
Pitch[e]	60.0	64.4	50.0	60.6	61.5	66.6
Total Oils and Tars	100.0	100.0	100.0	100.0	100.0	100.0

[a] Includes light oils which are not included in the oils and tars of Table A-5.

[b] Atmospheric boiling point < 360°F; estimated from simulated distillation data.

[c] Atmospheric boiling point 360° to 590°F.

[d] Atmospheric boiling point 590° to 750°F.

[e] Atmospheric boiling point > 750°F.

Table A-9. GAS COMPOSITIONS

Test Number	MG-18	MG-19	MG-21	MG-22	MG-25	MG-28
Test Temperature, °F	1178	1102	1109	1147	1134	1150
Component	Mol % in gas, nitrogen-free					
H_2	40.4	17.1	18.6	23.1	17.4	27.1
CO	11.5	13.5	13.6	13.1	15.1	3.8
CO_2	9.5	9.6	10.0	7.5	11.3	8.2
CH_4	26.0	40.0	38.3	37.0	34.9	45.2
C_2H_4	4.8	5.7	5.9	5.7	4.7	5.3
C_2H_6	3.2	7.4	6.7	6.0	5.4	5.4
C_3H_6	2.2	3.0	3.0	3.8	3.0	2.6
C_3H_8	0.5	1.3	1.4	1.3	1.1	1.0
H_2S	1.9	2.4	2.5	2.5	7.1	1.4
Total	100.0	100.0	100.0	100.0	100.0	100.0
Molecular Weight	16.5	21.2	21.1	19.8	22.2	17.5
Higher Heating Value, Btu/lb	640	841	823	824	769	830

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