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RESEARCH AND DEVELOPMENT OF RAPID HYDROGENATION FOR COAL CONVERSION TO SYNTHETIC MOTOR FUELS

(RISER CRACKING OF COAL)

MASTER

Third Quarter Report
For the Period October 1 to December 31, 1978

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ABSTRACT

During the reporting period, work on processing of caking coals was continued, and methods of pretreating caking coals have been developed which have been demonstrated by successful runs in the bench-scale unit. Exploratory work was also done to evaluate the effects of bentonite clay, iron oxide, and heating rate on the reaction system. Both bentonite clay and iron oxide were found to have beneficial catalytic effects. Depth of carbon conversion was found to be more a function of severity of thermal treatment than heating rate over the range studied.

Construction of the process development unit (PDU) was continued, and much of the major equipment has been received. Contracts have been made for supplying high-pressure gases to the PDU. Fabrication of the preheater coil has been completed, and construction of the preheater furnace is underway.

Tests were continued in a low-pressure simulator of a PDU combustor section, and for a coaxial construction, ceramic shields in the vicinity of the oxygen injection point do not appear to be necessary.

I. OBJECTIVE AND SCOPE OF WORK

The objective of the research and development program described in this report is to develop the technology of short residence time hydropyrolysis of lignites and coals for optimized yields of high-octane gasoline blending stock constituents. The scope of the investigation will include the design, construction, and operation of a bench-scale unit (5 to 10 lb/hr) and a process development unit (50 to 100 lb/hr). The process under development is called "Riser Cracking of Coal." In the final phase of the project, the technical and economic aspects of large-scale operation will be evaluated.

II. ACHIEVEMENT OF PROJECT OBJECTIVES

During the last quarter, work on processing caking coals was continued, and a method of pretreatment was developed in which the coal is impregnated with calcium oxide at ambient pressure and mild conditions so that the volatile matter content of the coal is essentially unchanged. Several variations of this pretreatment were used to prepare quantities of feed coal which were subsequently processed successfully in the bench-scale unit. In addition, two successful runs using Illinois No. 6 coal (FSI=4-1/2) were treated with bentonite clay/calcium oxide and iron oxide/calcium oxide to determine if bentonite clay or iron oxide would exhibit beneficial catalytic effects.

The effect of heating rate on carbon conversion was then explored by operating the bench-scale unit so that above $1000^{o}F$ the feed was subjected to linear heating rates to a coil outlet temperature of $1500^{o}F$, with no appreciable residence time at coil outlet temperature. The heating rates were varied from $150^{o}F/s$ to $412^{o}F/s$. The study was then enlarged to provide residence times of from 1 to 3 seconds at coil outlet temperature, with heating rates from room temperature to coil outlet temperature as high as $1275^{o}F/s$. From the current analytical data available, depth of carbon conversion appears to be more a function of severity of thermal treatment than heating rate.

Construction of the PDU was continued, and fabrication of the preheater coil has been completed. The frame holding the preheater furnace has been built, and the base and annular sections of refractory for containing the preheater coil have been cast. The pressure shell for the riser reactor has been received along with several other pieces of major equipment. Erection of the equipment and shakedown tests will be done during the forthcoming quarter.

III. SUMMARY OF PROGRESS TO DATE

During the reporting period, 18 runs were made in the bench-scale unit (Figure 1); the overall objectives and results of these runs are summarized in Table 1. The first runs in the quarter (CT-4 through CT-13) were a continuation of work on processing caking coals. In prior work, it was found that it is technically possible to process caking coal by mixing it with large quantities of devolatilized char or sand. In further development work, it was found that treatment of caking coal with calcium oxide at ambient pressure and mild conditions would render Illinois No. 6 coal noncaking, allowing the coal to be processed directly in the bench-scale unit.

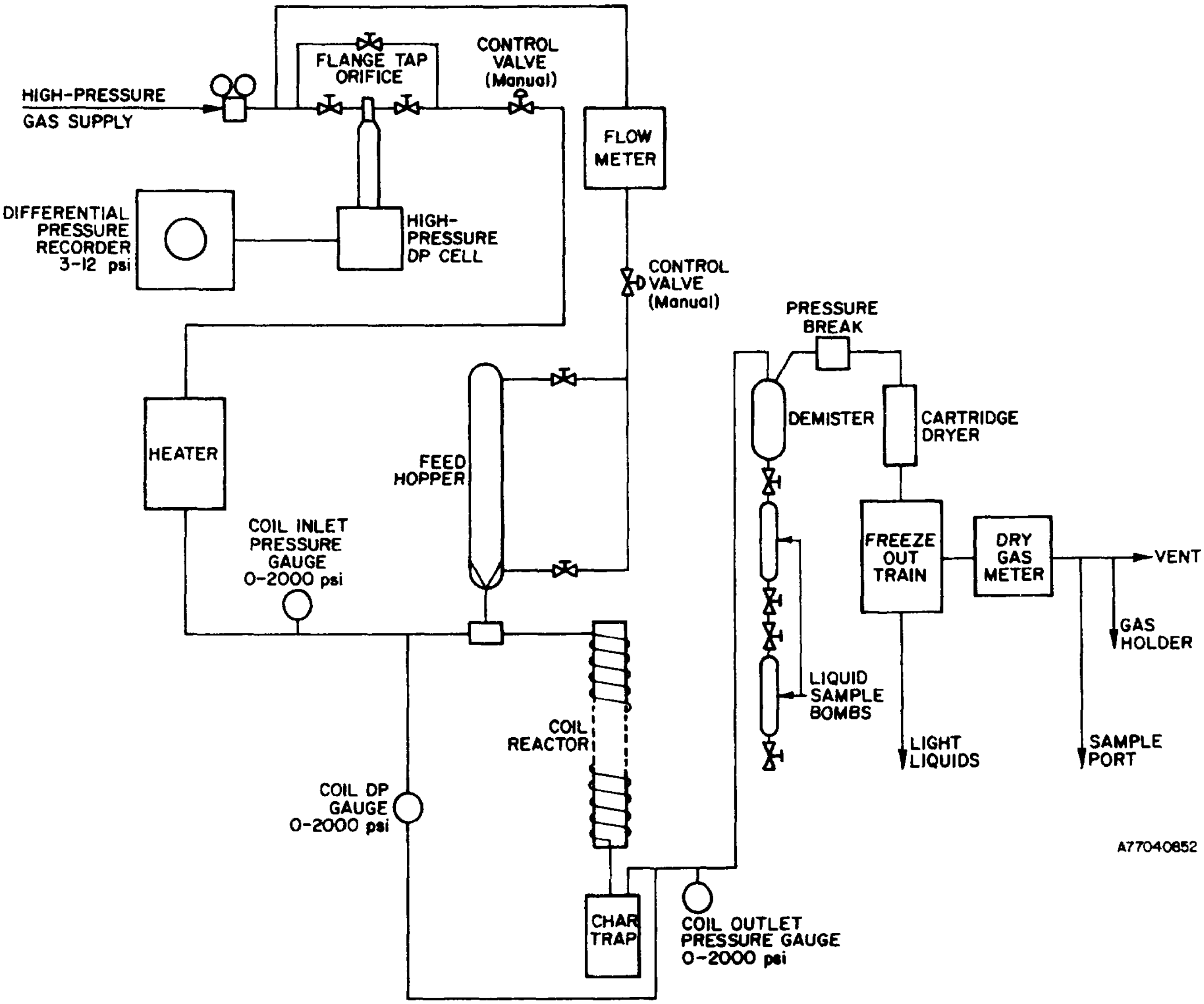

Figure 1. REVISED EQUIPMENT LAYOUT

Table 1. SUMMARY OF RUNS MADE FROM OCTOBER 1 THROUGH DECEMBER 31, 1978

Run/Date	Objective	Results
CT-4/10-3-78	Operate with bituminous coal pretreated with 10% by weight calcium hydroxide at 2000 psig and soaking temperature profile of 1475°F.	Successful; operated for 56 minutes with voluntary shutdown.
CT-5/10-10-78	Replication of CT-4.	Partially successful; plug formed in heat exhanger after 22 minutes of operation.
CT-6/10-12-78	Replication of CT-4.	Successful; operated for 90 minutes with voluntary shutdown.
CT-7/10-18-78	Operate with bituminous coal pretreated with 10% by weight bentonite clay at 2000 psig and soaking temperature profile of 1475°F.	Unsuccessful; plug formed in coil after 1.5 minutes of operation.
CT-8/10-24-78	Operate with bituminous coal pretreated with 10% by weight calcium hydroxide at 2000 psig and soaking temperature profile of 1425°F.	Successful; operated for 90 minutes with voluntary shutdown.
CT-9/10-31-78	Replication of CT-8.	Successful; operated for 3 hours with voluntary shutdown.
CT-10/11-2-78	Operate with bituminous coal pretreated with 10% by weight calcium hydroxide at 2000 psig and soaking temperature profile of 1475°F.	Successful; operated for 180 minutes with voluntary shutdown.
CT-11/11-7-78	Replication of CT-10.	Successful; operated for 180 minutes with voluntary shutdown.
CT-12/11-9-78	Operate with bituminous coal pretreated with 8% by weight ferric oxide and 1-1/2% CaO at 2000 psig and soaking temperature profile of 1475°F.	Successful; operated for 60 minutes with voluntary shutdown.

Table 1. SUMMARY OF RUNS MADE, Cont'd.

Run/Date	Objective	Results
CT-13/11-14-78	Operate with bituminous coal pretreated with 2% by weight calcium hydroxide and 8% by weight bentonite clay at 2000 psig and soaking temperature profile of 1475°F.	Successful; operated for 120 minutes with voluntary shutdown.
CT-14/11-17-78	Operate with bituminous coal pretreated at moderate temperature in air with coil outlet temperature of 1500°F at 2000 psig.	Unsuccessful; plug formed in coil after 0.5 minute of operation.
HR-1/11-21-78	Operate with lignite coal and linear heating rate from 1000°F to outlet temperature of 1500°F at 2000 psig.	Successful; operated for 130 minutes with voluntary shutdown.
HR-2/11-28-78	Replication of HR-1.	Successful; operated for 175 minutes with voluntary shutdown.
HR-3/11-30-78	Operate with lignite coal and high linear heating rate from 600°F to outlet temperature of 1500°F at 2000 psig.	Successful; operated for 120 minutes with voluntary shutdown.
HR-4/12-2-78	Investigate the effects of high heating rate (458°F per second) on product yield at 2000 psig and 1500°F.	Successful; operated for 120 minutes with voluntary shutdown.
HR-5/12-12-78	Investigate the effects of low heating rate on product yield at 2000 psig and 1500°F.	Successful; operated for 180 minutes with voluntary shutdown.
HR-6/12-14-78	Investigate the effects of high heating rate (1000°F per second) on product yield at 2000 psig and 1500°F.	Successful; operated for 120 minutes with voluntary shutdown.
HR-7/12-20-78	Investigate the effects of high heating rate (1200°F per second) followed with descending profile to determine presence of exothermic hydrogenation.	Successful; operated for 120 minutes with voluntary shutdown.

An array of experiments to explore and compare product distributions with those obtained from North Dakota lignite used in previous work (1) was then devised. In the experimental plan, two levels of temperature (1425° and 1475°F) were used with two levels of hydrogen-to-MAF coal weight ratio (0.33 and 1.0). The flow rates in these runs were adjusted so that the severity of thermal treatment was held constant, as measured by kinetic severity function. The experimental plan was then executed in runs CT-4 through CT-11.

By altering the pretreatment process, it was found that potentially catalytic materials could be incorporated into the coal without loss of the imparted noncaking property. Iron oxide has been reported to increase benzene yields at the expense of naphthalene (3), and bentonite clay has been used as a cracking catalyst. Because large naphthalene yields are generally undesirable, a run (CT-12) was made with Illinois No. 6 coal treated with 8 weight percent iron oxide and 1.5 weight percent calcium oxide to determine if a reduction in naphthalene yield could be obtained. A run (CT-13) was also made in which Illinois No. 6 coal was treated with 8 weight percent bentonite clay and 1.5 weight percent calcium oxide to determine if beneficial catalytic effects could be obtained from the bentonite clay addition.

Some additional exploratory runs were made using hydrogen and North Dakota lignite to evaluate the effects of heating rate on carbon conversion and product distribution. An additional objective was to separate effects under conditions of rapid heating to maximum temperature (1500°F), with no appreciable residence time at maximum temperature, and effects due to residence time at maximum temperature. In these runs (HR-1 through HR-7) the coil outlet was fixed at 1500°F and the hydrogen-to-MAF coal weight ratio was fixed at 0.5. From analytical data available at this time, the depth of carbon conversion appears to be more a function of severity of thermal treatment than heating rate.

Construction of the PDU was continued, and at this time the pressure shell for the riser has been received, along with several other items of major equipment. The preheater coil has been fabricated, and construction of the preheater furnace is underway. The bench-scale unit is being modified to allow the feed gas to be preheated to as high as 1500°F prior to contact with the feed coal and passage through the reactor.

Our approximate position in the technical program is shown on the progress chart (Figure 2).

IV. DETAILED DESCRIPTION OF TECHNICAL PROGRESS

A. Task 2. Build and Operate a Bench-Scale Unit

1. Work Accomplished

a. Bench-Scale Unit Operations

During the reporting period, 18 runs were made in the bench-scale unit using Illinois No. 6 coal (FSI=4-1/2, CT-4 through CT-13) as feedstock and also North Dakota lignite (HR-1 through HR-7). The Illinois No. 6 coal was pretreated to destroy its caking properties prior to its use in the bench-scale

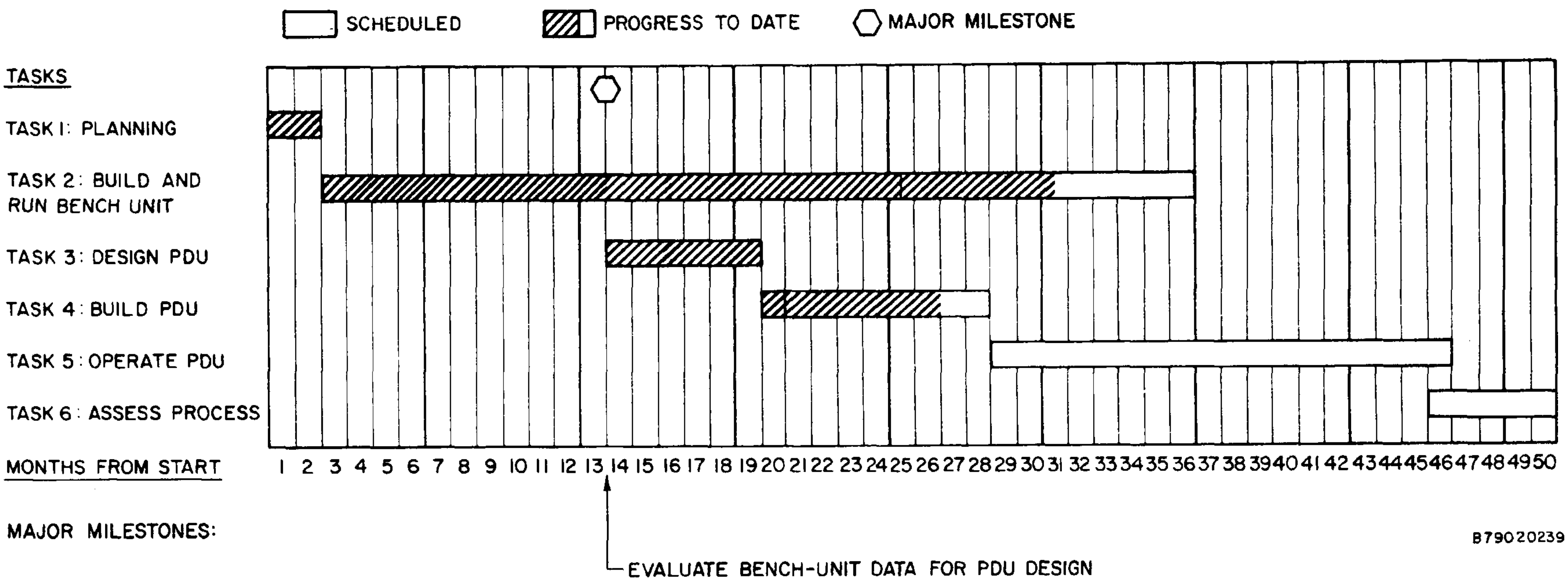

Figure 2. PROGRESS CHART

unit. The screen analyses of the untreated Illinois No. 6 coal and North Dakota lignite are shown in Table 2; the various treatments of the bituminous coal did not change the particle size distribution appreciably.

Eight runs were made to explore the distribution of products obtained from Illinois No. 6 coal pretreated with 7.5 weight percent calcium oxide using two levels of coil outlet temperature (1425° and 1475°F), a coil outlet pressure of 2000 psig, and two levels of hydrogen-to-MAF coal weight ratio (0.33 and 1.0). Two additional runs (CT-12 and CT-13) were made using Illinois No. 6 coal pretreated with iron oxide/calcium oxide and bentonite clay/calcium oxide at 2000 psig, a coil outlet temperature of 1475°F, and hydrogen-to-MAF coal weight ratios of 0.295 and 0.622. The operating conditions and main results of these runs are summarized in Table 3.

A series of runs using North Dakota Lignite (HR-1 through HR-7) were then made to separate the effects of heating rate and residence time at maximum temperature on carbon conversion and product distribution. The time/temperature histories of feed materials passing through the reactor in these runs are shown in Figures 3, 4, and 5. In all of these runs, the operating pressure was fixed at 2000 psig, the coil outlet temperature at 1500°F, and the hydrogen-to-MAF coal weight ratio at 0.5. In the first runs, the upper sections of the coil were held at temperatures at which prior work had shown that no appreciable conversion occurs. The heaters in the lower section were set so that the heating rate to coil outlet temperature was 152°F/s and linear in time. In the last 6 inches of coil, the effluent cooled to 1200°F, and then to 450°F in the char trap entrance, so that the effluent was "quenched" within a few tenths of a second to temperatures at which pyrolysis reactions stopped.

A similar technique was used in Run HR-3, but the heating rate to coil outlet temperature was increased to 385°F/s, again with no appreciable residence time at maximum temperature. Due to "chimney" effects, it is impossible to keep the upper sections of the coil at room temperature.

In Run HR-4 the heating rate to coil outlet temperature was increased to 412°F/s, and a residence time of 1.25 seconds at maximum temperature was provided. In comparison, in Run HR-5 the heating rate was decreased to 155°F/s, with a 1.25 second residence time at 1500°F provided. In Run HR-6 the heating rate was increased to 780°F/s, and a residence time of 3.5 seconds at coil outlet temperature was provided.

Finally, in Run HR-7 the heaters were programmed to provide a heating rate of 1275°F/s, a residence time at maximum temperature of 2 seconds, and a linear descending profile in the lower section of the coil. The descending profile was used to test for the presence of exothermic effects. If large exothermic effects were present, the temperatures in the descending profile section would rise above their set points. However, in Run HR-7 the temperatures in the descending profile section remained close to set point, showing that exothermic effects, if present, were not large enough to compensate for heat losses, nor large enough to cause a rise in bulk-stream temperature.

Table 2. SCREEN ANALYSES OF MATERIALS USED FROM OCTOBER 1 THROUGH DECEMBER 31, 1978

Size, U.S.S. mesh	North Dakota Lignite	Illinois No. 6 Coal
>60	0	0.5
60 x 80	1.2	24.1
80 x 100	1.9	12.0
100 x 200	13.6	40.5
200 x 325	34.4	21.4
pan	48.9	1.5
	100.0	100.0

Table 3, Part 1. OPERATING CONDITIONS AND RESULTS OF RUNS MADE FROM OCTOBER 1 THROUGH DECEMBER 31, 1978

Run No.	CT-4	CT-6	CT-8	CT-9	CT-10
System Outlet Pressure, psig	2000	2000	2000	2000	2000
Coil Outlet Temperature, ^{o}F	1475	1475	1425	1425	1475
Residence Time, s	3.6	3.6	3.7	3.7	3.7
Solids Feed Rate, lb/hr	2.74	3.30	2.40	0.873	0.328
Run Length, min	56	90	90	180	180
Solids in Feed Gas, wt %	63.4	68.0	59.6	35.7	17.8
H_2/MAF Coal Weight Ratio	0.3259	0.2830	0.3863	1.0422	2.688
Balances, wt %					
Ash	95.30	100.97	98.89	98.66	100.00
Carbon	96.76	98.70	92.07	98.95	97.95
Hydrogen	100.85	90.51	103.66	101.45	97.50
Overall	100.11	104.63	101.64	104.33	99.84
Carbon Distribution, wt %					
Liquids	10.89	13.72	14.68	16.28	8.97
Carbon Oxides	5.50	5.78	5.15	9.79	20.04
Methane	17.14	17.06	14.29	16.20	21.87
Light Gases	9.89	9.50	8.80	10.21	8.94
Char	53.34	52.64	50.43	46.47	38.12

Table 3, Part 2. OPERATING CONDITIONS AND RESULTS OF RUNS MADE FROM OCTOBER 1 THROUGH DECEMBER 31, 1978

Run No.	CT-11	CT-12	CT-13	HR-1	HR-2
System Outlet Pressure, psig	2000	2000	2000	2000	2000
Coil Outlet Temperature, ^{o}F	1475	1475	1475	1500	1500
Residence Time, s	3.6	3.2	3.5	4.0	4.6
Solids Feed Rate, lb/hr	0.957	3.452	1.519	3.203	1.560
Run Length, min	180	60	120	130	175
Solids in Feed Gas, wt %	37.6	67.4	50.0	69.5	55.9
H_2/MAF Coal Weight Ratio	1.0090	0.2949	0.6224	0.2578	0.4375
Balances, wt %					
Ash	86.54	94.42	96.32	86.58	101.14
Carbon	95.78	106.43	102.64	*	*
Hydrogen	94.13	93.05	91.42	*	*
Overall	100.00	104.48	101.34	102.24	100.46
Carbon Distribution, wt %					
Liquids	15.24	17.46	13.51	*	*
Carbon Oxides	9.77	6.00	7.86	9.05	9.47
Methane	17.66	19.90	17.29	10.90	12.40
Light Gases	9.07	11.08	8.45	11.36	7.37
Char	44.04	51.99	52.89	51.23	52.20

* Required analyses not completed.

Table 3, Part 3. OPERATING CONDITIONS AND RESULTS OF RUNS MADE FROM OCTOBER 1 THROUGH DECEMBER 31, 1978

Run No.	HR-3	HR-4	HR-5	HR-6	HR-7
System Outlet Pressure, psig	2000	2000	2000	2000	2000
Coil Outlet Temperature, ^{o}F	1500	1500	1500	1500	1500
Residence Time, s	2.6	3.0	4.9	*	*
Solids Feed Rate, lb/hr	2.506	2.544	2.172	2.063	1.738
Run Length, min	120	120	180	120	120
Solids in Feed Gas, wt %	54.3	57.5	65.3	*	*
H_2/MAF Coal Weight Ratio	0.4823	0.4282	*	*	*
Balances, wt %					
Ash	95.70	76.99	*	*	*
Carbon	*	*	*	*	*
Hydrogen	*	*	*	*	*
Overall	100.67	102.04	*	*	*
Carbon Distribution, wt%					
Liquids	*	*	*	*	*
Carbon Oxides	8.18	11.27	*	*	*
Methane	10.59	16.34	*	*	*
Light Gases	6.26	8.43	*	*	*
Char	58.87	52.51	*	*	*

* Required analyses not completed.

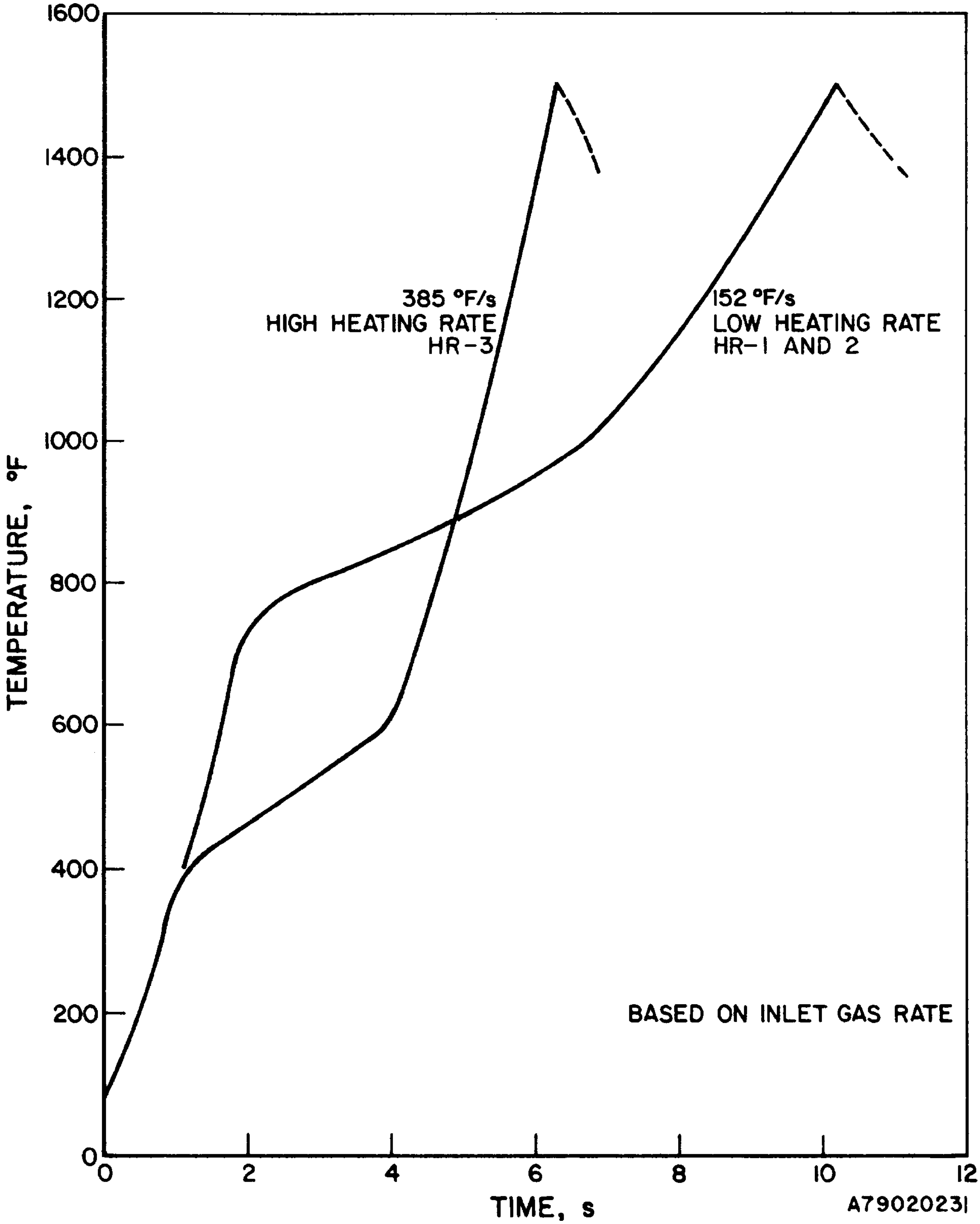

Figure 3. TIME/TEMPERATURE HISTORY IN HEATING RATE RUNS

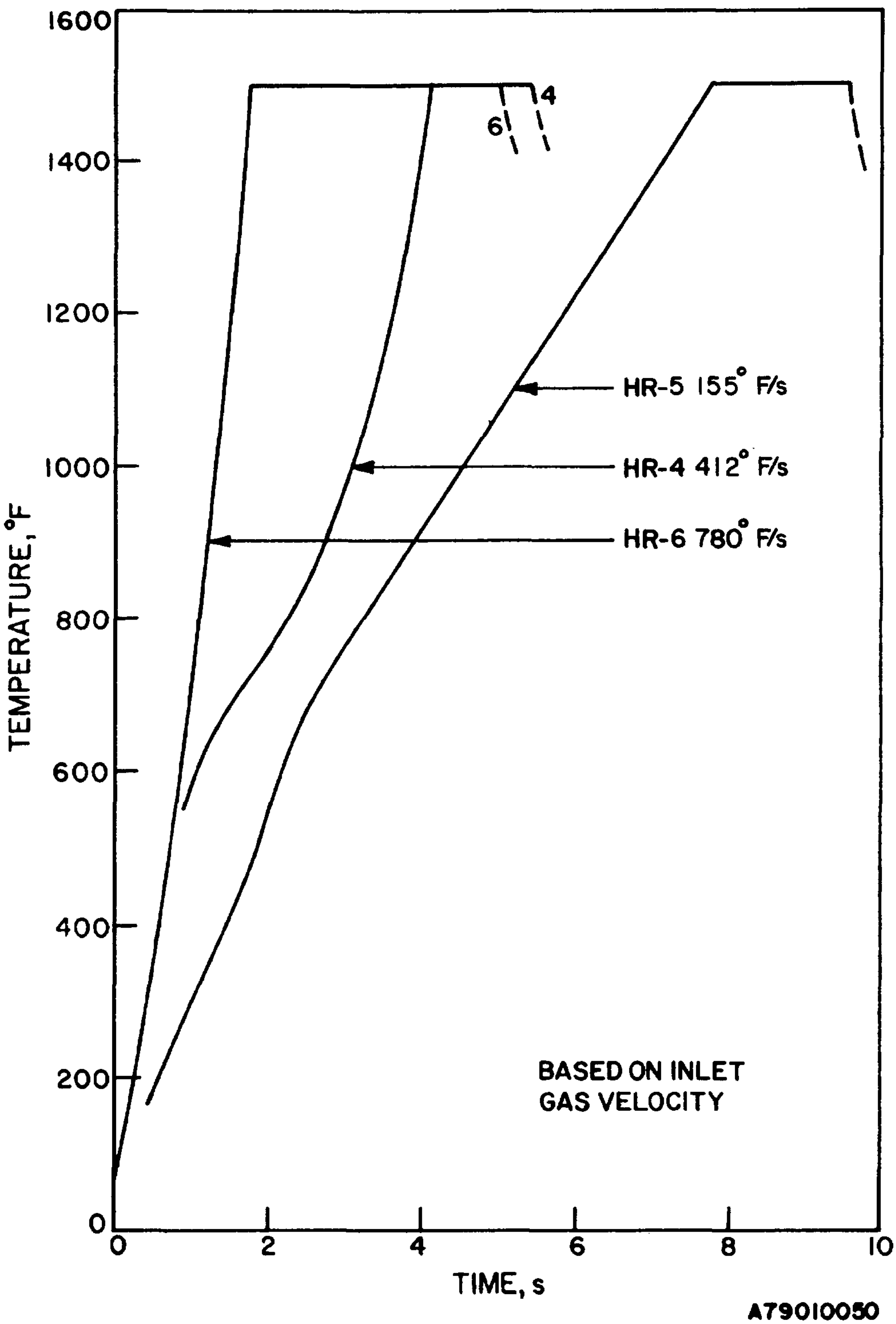

Figure 4. HEATING RATES AND TIME/TEMPERATURE HISTORIES FOR RUNS HR-4, 5, and 6

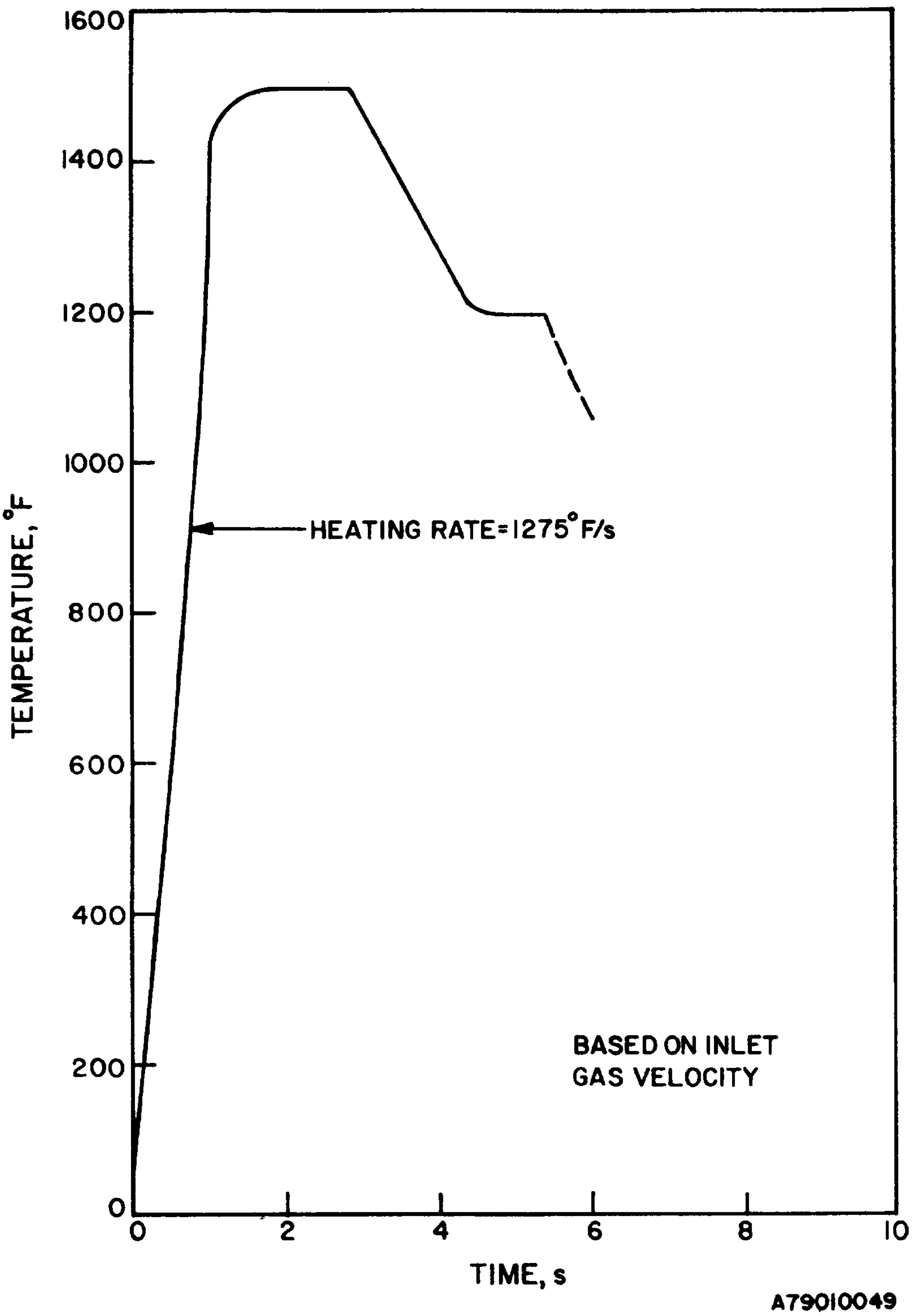

Figure 5. HEATING RATE AND TIME/TEMPERATURE HISTORY FOR RUN HR-7

The proximate and ultimate analyses for the feed solids and spent char from the runs made during the past quarter are shown in Tables 4 and 5, the mass balance data are shown in Table 6, and the average make-gas analyses are shown in Table 7.

The analyses of the main liquid products available at this time are shown in Table 8, and the analyses of the gasoline boiling range liquids are shown in Table 9. From the data, it can be seen that the gasoline boiling range liquids obtained from bituminous coal differ from those obtained from lignite by the presence of appreciable quantities of thiophenes and pyridines.

The analyses of the light liquids recovered from the cold trap are shown in Table 10, and the analyses of the fuel oil fraction of the main liquid product are shown in Table 11.

A comparison between the liquid hydrocarbons obtained from Illinois No. 6 coal and North Dakota lignite is shown in Table 12. The products obtained by processing untreated Illinois No. 6 coal mixed with silica sand (BC-11, BC-12, and BC-13) and devolatilized char (BC-16) are essentially controls and represent what would be obtained if it were possible to process untreated caking coals directly. The data for CT-11, CT-12, and CT-13 are for coals pretreated with calcium oxide, iron oxide/calcium oxide, and bentonite clay/calcium oxide respectively, and the data for P-28 are for products obtained from lignite.

Overall, the sulfur content of the main liquid product obtained from untreated bituminous coal (BC-11, BC-12, and BC-13) is greater than the sulfur content of the liquids obtained from treated coals (CT-11, CT-12, and CT-13) and lignite (P-28); this is also true for the gasoline boiling range liquids. The sulfur contents of the liquids obtained from the treated coals are comparable to that of the liquids obtained from lignite, showing the pretreatments are effective in reducing the sulfur content of the products. There was, however, little change in the phenols or naphthalenes content.

In general, the prior work with lignite (1) has shown that conversion of coal to gas and liquid products is a function of temperature, hydrogen partial pressure, and residence time (2). The processing treatment of the coal can also be characterized by hydrogen-to-MAF feed coal weight ratio, kinetic severity function (a measure of the intensity of the thermal treatment imparted in the process), and coil outlet temperature.

Comparing Run CT-12 with P-28 and BC-11, BC-12, and BC-13, it can be seen that approximately 50% of the feed carbon was converted at hydrogen-to-MAF feed coal ratios of 0.295, 1.85, and 1.29 respectively. Two processing benefits can be obtained by using treated coal; the reactor throughput can be increased through the lower hydrogen-to-MAF feed coal ratio needed, and the subsequent separation of carbon monoxide and hydrocarbon gases from recycle hydrogen would be made easier and more efficient by the higher concentrations of hydrocarbon gases and carbon monoxide in the make gas.

By using higher hydrogen-to-MAF coal ratios, it would also be possible to operate the system at lower pressure, using the higher hydrogen-to-coal ratio to maintain the hydrogen partial pressure at a value consistent with the carbon conversion needed. Clearly, the pretreatments have enhanced both

Table 4, Part 1. ANALYSIS OF FEED SOLIDS

Run No.	CT-4	CT-6	CT-8	CT-9	CT-10	CT-11
Proximate Analysis, wt %						
Moisture	4.5	8.4	5.6	4.1	6.9	5.2
Volatile Matter	37.5	36.5	36.6	35.9	36.1	37.3
Ash	15.1	13.3	16.2	17.8	18.2	19.5
Fixed Carbon	42.9	41.8	41.6	42.2	38.8	38.0
Total	100.0	100.0	100.0	100.0	100.0	100.0
Ultimate Analysis (Dry Basis), wt %						
Ash	15.85	14.49	17.16	18.54	19.59	20.61
Carbon	60.20	62.30	60.80	59.10	58.00	59.10
Hydrogen	4.28	4.38	4.42	4.29	4.15	4.22
Sulfur	3.87	3.96	4.35	4.35	4.50	4.58
Nitrogen	1.12	0.99	1.22	1.23	0.91	1.06
Oxygen (By Diff)	14.68	13.88	12.05	12.49	12.85	10.43
Total	100.00	100.00	100.00	100.00	100.00	100.00

Table 4, Part 2. ANALYSIS OF FEED SOLIDS

Run No.	CT-12	CT-13	HR-1	HR-2	HR-3	HR-4
Proximate Analysis, wt %						
Moisture	0.9	1.0	12.7	9.6	9.6	9.9
Volatile Matter	34.2	32.2	--	38.5	38.3	38.3
Ash	21.4	20.2	9.7	8.8	9.3	10.4
Fixed Carbon	43.5	46.6	--	43.1	42.8	41.4
Total	100.0	100.0		100.0	100.0	100.0
Ultimate Analysis (Dry Basis), wt %						
Ash	21.61	20.38	11.08	9.73	10.31	11.50
Carbon	59.50	59.50	61.00	61.00	60.90	61.00
Hydrogen	4.22	3.97	3.97	4.11	3.97	4.04
Sulfur	4.44	4.26	0.87	0.80	0.81	0.77
Nitrogen	1.08	1.04	1.01	1.01	0.98	0.85
Oxygen (By Diff)	9.15	10.85	22.07	23.35	23.03	21.84
Total	100.00	100.00	100.00	100.00	100.00	100.00

Table 5, Part 1. ANALYSIS OF SPENT SOLIDS

Run No.	CT-4	CT-6	CT-8	CT-9	CT-10	CT-11
Proximate Analysis, wt %						
Moisture	0.2	0.3	0.4	0.3	0.3	0.2
Volatile Matter	14.6	15.0	14.4	13.4	10.8	12.6
Ash	28.5	27.1	31.4	34.0	38.0	34.3
Fixed Carbon	56.7	57.6	53.8	52.3	50.9	52.9
Total	100.0	100.0	100.0	100.0	100.0	100.0
Ultimate Analysis (Dry Basis), wt %						
Ash	28.59	27.15	31.55	34.10	38.16	34.35
Carbon	61.40	62.30	59.20	56.80	54.00	56.20
Hydrogen	2.21	2.22	2.15	2.18	1.93	2.05
Sulfur	4.95	4.14	4.64	5.61	6.19	5.36
Nitrogen	0.87	0.79	1.08	1.01	0.75	0.78
Oxygen (By Diff)	1.98	3.40	1.38	0.30	0.00	1.26
Total	100.00	100.00	100.00	100.00	101.03	100.00

Table 5, Part 2. ANALYSIS OF SPENT SOLIDS

Run No.	CT-12	CT-13	HR-1	HR-2	HR-3	HR-4
Proximate Analysis, wt %						
Moisture	0.2	0.2	0.3	0.3	0.2	0.2
Volatile Matter	8.3	8.2	13.5	14.0	13.9	12.2
Ash	37.0	34.5	21.1	21.1	19.2	18.9
Fixed Carbon	54.5	57.1	65.1	64.6	66.7	68.7
Total	100.0	100.0	100.0	100.0	100.0	100.0
Ultimate Analysis (Dry Basis), wt %						
Ash	37.07	34.58	21.19	21.12	19.22	18.98
Carbon	58.00	59.30	71.00	71.40	72.60	71.20
Hydrogen	2.07	2.13	2.52	2.62	2.61	2.32
Sulfur	6.57	2.55	0.74	0.65	0.67	0.62
Nitrogen	0.78	0.83	0.81	0.77	0.71	0.56
Oxygen (By Diff)	0.00	0.61	3.74	3.44	4.19	6.32
Total	104.49	100.00	100.00	100.00	100.00	100.00

Table 6, Part 1. MASS BALANCE AND PRODUCT DISTRIBUTION IN RECENT RUNS

Run No.	CT-4	CT-6	CT-8	CT-9	CT-10	CT-11
Component, g						
Feed Solids	1161	2246	1632	1188	446	1302
Feed Hydrogen	304	498	493	965	965	988
Feed Methane	9	36	37	82	65	118
Feed CO	0	7	7	29	29	0
Feed Nitrogen	4	22	51	43	43	44
Feed Argon	352	493	512	1022	956	1006
Total Mass In	1830	3302	2732	3329	2504	3458
Spent Char/Solids	587	1112	811	613	214	642
Liquids	274	673	477	300	93	369
Light Liquids	20	23	20	22	14	34
Gases	951	1647	1474	2535	2179	2396
Total Mass Out	1832	3455	2782	3470	2500	3441
Distribution of Products, g						
Hydrogen	299	461	496	967	938	918
Nitrogen	9	28	16	44	28	52
Argon	314	519	544	1072	938	946
Methane	154	299	186	162	88	193
Ethane	89	153	102	88	29	86
Propane	2	3	6	7	0	0
Light Gases (C_2-C_4)	1	0	0	0	0	0
Carbon Oxides	88	181	121	182	142	186
Hydrocarbon Liquids						
Main Liquid Product (MLP)	74	177	147	109	5	104
Freeze-Out	11	23	20	22	14	34
Make Gas	2	3	4	11	11	4
Gases (MLP Work-Up)	9	20	13	5	3	12
Char	587	1112	811	613	214	642
Water (By Difference)	193	476	316	188	90	264
Total Mass Out	1832	3455	2782	3470	2500	3441

Table 6, Part 2. MASS BALANCE AND PRODUCT DISTRIBUTION IN RECENT RUNS

Run No.	CT-12	CT-13	HR-1	HR-2	HR-3	HR-4	HR-5
Component, g							
Feed Solids	1566	1378	3148	2064	2273	2308	2956
Feed Hydrogen	359	676	630	737	889	788	706
Feed Methane	30	80	59	52	51	36	37
Feed CO	16	0	9	22	26	47	42
Feed Nitrogen	27	40	28	22	26	23	21
Feed Argon	326	584	654	793	918	814	763
Total Mass In	2324	2758	4528	3690	4183	4016	4525
Spent Char/Solids	856	776	1248	873	1057	972	1207
Liquids	383	283	1212	703	750	765	1001
Light Liquids	16	22	27	18	18	34	36
Gases	1173	1714	2143	2113	2387	2327	2335
Total Mass Out	2428	2795	4630	3707	4212	4098	4579
Distribution of Products, g							
Hydrogen	290	580	546	699	833	705	612
Nitrogen	22	43	38	27	84	22	33
Argon	335	672	643	787	906	799	735
Methane	253	201	251	197	184	287	376
Ethane	129	92	120	97	83	114	168
Propane	3	0	123	12	18	4	2
Light Gases (C_2-C_4)	0	0	0	1	0	0	0
Carbon Oxides	137	172	190	279	268	366	405
Hydrocarbon Liquids							
Main Liquid Product (MLP)	153	112	188	137	146	142	180
Freeze-Out	16	22	25	17	17	33	36
Make Gas	4	4	3	8	9	8	5
Gases (MLP Work-Up)	13	15	35	16	13	8	14
Char	856	776	1248	873	1057	972	1207
Water (By Difference)	217	106	900	557	594	638	806
Total Mass Out	2428	2795	4630	3707	4212	4098	4579

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Table 7, Part 1. AVERAGE MAKE-GAS COMPOSITIONS

Run No.	CT-4	CT-6	CT-8	CT-9
Component	mol % (Wet Basis)			
CO	1.37	1.98	1.19	0.95
CO_2	0.01	0.10	0.10	0.13
Hydrogen	86.73	81.81	87.24	90.68
Methane	4.16	5.76	3.45	1.78
Ethane	1.18	1.56	1.04	0.52
Propane	0.02	0.02	0.04	0.03
Butane	0.00	0.00	0.00	0.00
Ethylene	0.00	0.00	0.00	0.00
Propylene	0.00	0.00	0.00	0.00
Acetylene	0.01	0.00	0.00	0.00
Benzene	0.01	0.01	0.01	0.02
Argon	4.61	4.64	4.84	5.07
Nitrogen	0.20	0.36	0.20	0.30
Steam	1.70	3.76	1.91	0.52
Total	100.00	100.00	100.00	100.00

Table 7, Part 2. AVERAGE MAKE-GAS COMPOSITIONS

Run No.	CT-10	CT-11	CT-12	CT-13
Component	mol % (Wet Basis)			
CO	0.76	1.19	2.05	1.37
CO_2	0.00	0.00	0.10	0.20
Hydrogen	92.42	90.27	82.96	88.59
Methane	0.91	2.15	7.17	3.47
Ethane	0.19	0.57	1.94	0.85
Propane	0.00	0.00	0.03	0.00
Butane	0.00	0.00	0.00	0.00
Ethylene	0.00	0.00	0.00	0.00
Propylene	0.00	0.00	0.00	0.00
Acetylene	0.00	0.00	0.00	0.00
Benzene	0.02	0.01	0.02	0.01
Argon	4.66	4.69	4.83	4.80
Nitrogen	0.20	0.37	0.45	0.47
Steam	0.84	0.75	0.45	0.24
Total	100.00	100.00	100.00	100.00

Table 7, Part 3. AVERAGE MAKE-GAS COMPOSITIONS

Run No.	HR-1	HR-2	HR-3	HR-4
Component	mol % (Wet Basis)			
CO	2.63	1.91	1.44	2.18
CO_2	0.67	0.22	0.24	0.24
Hydrogen	79.22	86.36	87.49	84.77
Methane	4.02	2.77	2.19	3.73
Ethane	1.01	0.72	0.54	0.92
Propane	0.80	0.06	0.08	0.02
Butane	0.00	0.00	0.00	0.00
Ethylene	0.00	0.00	0.00	0.00
Propylene	0.00	0.00	0.00	0.00
Acetylene	0.00	0.01	0.00	0.00
Benzene	0.01	0.03	0.02	0.02
Argon	4.70	4.94	4.80	4.85
Nitrogen	0.40	0.24	0.63	0.19
Steam	6.54	2.74	2.57	3.08
Total	100.00	100.00	100.00	100.00

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Table 8. ANALYSES OF MAIN LIQUID PRODUCTS

Run No.	SF-2	SF-3	CT-4	CT-6	CT-8	CT-9	CT-10	CT-11	CT-12	CT-13
Specific Gravity	0.871	0.969	1.029	1.014	1.054	--	--	1.051	1.025	1.034
IBP, ^{o}F	220	< 220	150	156	148	--	--	148	148	150
Ultimate Analysis, wt %										
Carbon	91.17	82.54	83.02	88.16	82.10	83.64	81.19	86.15	82.24	83.33
Hydrogen	8.68	7.66	6.35	6.49	5.86	5.97	5.63	5.97	5.86	5.84
Sulfur	0.11	0.10	1.34	1.06	1.29	1.22	3.36	1.10	0.75	0.77
Nitrogen	0.00	0.06	0.79	0.79	0.97	1.11	1.33	0.84	1.15	0.85
Oxygen (Diff)	0.00	9.44	8.50	3.50	8.98	8.06	8.29	5.84	10.00	9.01
Ash	0.00	0.20	0.00	0.00	0.80	0.00	0.20	0.10	0.00	0.20
C/H Weight Ratio	10.50	10.78	13.07	13.58	14.01	14.01	14.42	14.43	14.03	14.27
Fraction, wt %										
C_5-400^{o}F+	100.00	91.50	46.70	47.40	41.90	39.50	--	35.90	43.70	46.10
400^{o}F+	0.00	8.50	53.30	52.60	58.10	60.50	--	64.10	56.30	53.90

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Table 9. ANALYSES OF GASOLINE FRACTION OF MAIN LIQUID PRODUCT

Run No.	SF-2	SF-3	CT-4	CT-6	CT-8	CT-9	CT-11	CT-12	CT-13
Component	wt %								
Benzene	7.55	2.35	48.20	54.80	32.40	30.60	50.10	55.50	52.00
Toluene	92.00	56.40	17.20	15.40	21.00	21.70	16.00	15.00	10.70
Ethylbenzene	0.11	0.03	0.76	0.68	1.01	1.54	0.79	0.64	0.54
Xylenes	0.15	0.05	0.87	0.76	2.00	1.19	0.73	0.64	0.46
C_9 Aromatics	0.06	--	0.19	0.14	0.33	0.56	0.19	0.12	0.16
Indans	--	--	1.05	0.91	1.63	1.94	1.16	0.98	1.01
Indene	--	--	0.34	0.15	0.08	0.32	0.08	0.21	0.15
Naphthalenes	--	12.40	15.35	13.81	23.27	18.14	20.14	14.40	25.03
Phenols	--	28.70	10.72	9.40	14.67	18.59	9.45	10.09	8.22
Cresols	--	--	0.38	0.38	0.23	0.36	0.02	0.03	0.04
Pyridines	--	--	1.23	1.37	Tr	Tr	Tr	0.99	Tr
Thiophenes	--	--	1.27	0.82	2.44	2.55	1.00	0.67	0.79
Unidentified	0.13	0.07	2.44	1.38	0.94	2.51	0.34	0.73	0.90
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 10, Part 1. ANALYSES OF LIGHT LIQUIDS FROM COLD TRAP

Run No.	CT-4	CT-6	CT-8	CT-9	CT-10	CT-11
Component	wt %					
Benzene	93.60	92.90	88.00	81.20	96.90	94.40
Toluene	5.29	6.04	10.10	15.80	1.46	4.24
Xylenes	0.05	0.06	0.18	0.58	0.04	0.03
Indan + Indene	0.00	0.00	0.02	0.06	0.11	0.05
Ethylbenzene	0.04	0.07	0.13	0.39	0.11	0.11
Thiophenes	0.95	0.91	1.15	1.69	0.55	0.81
Unidentified	0.07	0.02	0.42	0.28	0.83	0.36
Total	100.00	100.00	100.00	100.00	100.00	100.00

Table 10, Part 2. ANALYSES OF LIGHT LIQUIDS FROM COLD TRAP

Run No.	CT-12	CT-13	HR-1	HR-2	HR-3	HR-4
Component	wt %					
Benzene	96.20	93.50	76.00	76.90	58.80	95.30
Toluene	3.14	3.31	22.10	20.50	33.60	3.86
Xylenes	0.02	0.06	0.84	0.90	4.11	0.12
Indan + Indene	0.02	0.05	0.09	0.20	0.39	0.15
Ethylbenzene	0.06	0.07	0.22	0.20	1.15	0.03
Thiophenes	0.37	2.71	0.14	0.18	0.41	0.05
Unidentified	0.19	0.30	0.61	1.12	1.54	0.49
Total	100.00	100.00	100.00	100.00	100.00	100.00

Table 11. ANALYSES OF FUEL OIL FRACTION OF MAIN LIQUID PRODUCT

Run No.	SF-3	CT-4	CT-6	CT-8	CT-9	CT-11	CT-12	CT-13
Ultimate Analysis, wt %								
Carbon	91.79	90.24	92.15	90.44	89.75	91.30	91.77	91.40
Hydrogen	6.32	5.98	5.93	5.68	5.72	5.77	5.83	5.68
Sulfur	0.01	0.82	0.75	1.02	0.93	0.77	0.56	0.66
Nitrogen	0.71	1.11	0.97	1.58	1.66	1.25	1.62	1.46
Oxygen (Diff)	0.07	1.85	0.00	0.58	1.94	0.71	0.22	0.40
Ash	1.10	0.40	0.20	0.70	0.00	0.20	0.00	0.40
C/H Weight Ratio	14.52	15.09	15.54	15.92	15.69	15.82	15.74	16.09
CC Residue, wt %	5.20	7.70	5.20	9.30	9.80	4.20	3.00	4.80

Table 12. ANALYSES OF HYDROCARBON LIQUIDS FROM BITUMINOUS COAL* AND NORTH DAKOTA LIGNITE

Run	BC-11, 12,13	BC-16	CT-11	CT-13	CT-12	P-28
Treatment	Silica Sand	Char	Lime Treated	Clay and Lime	Fe_2O_3 and Lime	North Dakota Lignite
H_2/MAF Coal Weight Ratio	1.85	1.10	1.01	0.622	0.295	1.294
Outlet Hydrogen Pressure, psi**	1773	1880	1804	1757	1624	1821
Coil Outlet Temperature	1500	1450	1475	1475	1475	1500
Kinetic Severity Function	0.311	0.191	1.229	1.203	1.110	0.657
Percent Carbon Conversion	43.4	43.5	54.0	48.5	51.2	51.9
Hydrocarbon Liquids, g/100 g feed carbon	18.1	9.6	19.5	17.0	18.7	19.0
C_5 – 400°F Liquids, wt % of total hydrocarbon liquids	44.8	†	53.1	56.2	50.2	43.9
Weight % S in gasoline fraction	1.43	†	0.92	0.42	0.42	0.12
Weight % N in gasoline fraction	0.20	†	0.11	0.14	0.55	0.30
Analysis of C_5 – 400°F Liquids						
Benzene	42.0	†	72.5	65.8	64.9	82.3
Toluene	16.4	†	10.0	8.2	12.3	6.7
Xylene	2.2	†	0.4	0.4	0.4	0.3
Phenols	18.5	†	4.6	5.5	7.6	6.1
Naphthalenes	10.8	†	10.0	16.7	11.1	3.7
Unidentified	10.1	†	2.5	3.4	3.7	0.9
	100.0	†	100.0	100.0	100.0	100.0
Ultimate Analysis of Main Liquid Product						
Carbon	81.56	80.71	86.15	83.33	82.24	89.47
Hydrogen	6.05	6.37	5.97	5.84	5.86	5.92
Sulfur	2.71	3.24	1.10	0.77	0.75	1.02
Nitrogen	0.84	0.70	0.84	0.85	1.15	0.71
Oxygen	8.64	8.98	5.84	9.01	10.00	2.88
Ash	0.20	0.00	0.10	0.20	0.00	0.00
	100.00	100.00	100.00	100.00	100.00	100.00

* Illinois No. 6; FSI=4-1/2.

** Coil Outlet Pressure = 2000 psig.

† Insufficient sample.

the effectiveness of the process and quality of the products and opened avenues of potential processing cost reductions.

The data from runs using calcium oxide-treated coals comparing the effects of hydrogen-to-MAF feed coal weight ratio and coil outlet temperature at constant kinetic severity function are shown in Table 13. From the data, it can be seen that increasing the coil outlet temperature from 1425^o to 1475^oF resulted in a reduction in the sulfur content of the gasoline boiling range liquids. Carbon conversion, however, was not affected greatly by the increase in coil outlet temperature, but was increased by the increase in hydrogen-to-MAF feed coal weight ratio. The fraction of phenol in the gasoline boiling range liquids was reduced slightly by the increase in coil outlet temperature; methane and light gas yields were also increased slightly.

The data available at this time for the heating rate study are summarized in Table 14. The depth of carbon conversion is more a function of the severity of the thermal treatment than heating rate. From prior work, (1) some differences in product liquids composition are expected, but the needed analyses which would confirm this have not been completed at this time and will be reported at a future time.

b. Simulation of PDU Combustor

A low-pressure simulator of a riser reactor combustor section (Figure 6) was built and is being operated to uncover any potential problems in the operation of the PDU combustors. Several tests have been made, and thus far there have been no problems with burning or melting of the oxygen injection needle. To achieve a better degree of control, a thermocouple has been installed directly in the combustor exit, allowing the temperature of the bulk gas/solids stream to be measured directly. In several tests the temperature of the bulk gas stream has been controlled at 1500^oF without damage to the metal walls of the combustor, so that the need for ceramic shields appears to be minimal at this time. Tests at 1600^o and 1700^oF will be made to explore this further.

c. Noncaking Additives and Diluents

The most promising methods of pretreating Illinois No. 6 coal to render it noncaking were used to prepare quantities of feed for trials in the bench-scale unit. As time permits, further work will be done to improve present methods and identify new treatment methods.

2. Work Forecast

The bench-scale unit is being modified to allow the feed gases to be preheated as high as 1500^oF prior to contact with feed solids. A new coil is being installed, and initial runs with preheated feed gas will be made during the forthcoming quarter.

Table 13. ANALYSES AND CARBON DISTRIBUTIONS OBTAINED FROM ILLINOIS NO. 6 COAL PRETREATED WITH 7.5% CaO

Run	CT-8	CT-9	CT-6	CT-4	CT-11	CT-10
Coil Outlet Temperature, ^{o}F	1425	1425	1475	1475	1475	1475
H_2/MAF Coal Weight Ratio	0.3863	1.0422	0.2830	0.3259	1.009	2.688
Outlet Hydrogen Pressure, psi*	1690	1810	1652	1690	1804	1846
Kinetic Severity Function	0.9520	1.0081	1.1438	1.1931	1.2294	1.2646
Fraction Carbon Conversion	0.452	0.530	0.448	0.447	0.540	0.611
Hydrocarbon Liquids, g/100 g feed carbon	18.3	21.3	15.8	13.0	19.5	12.5
C_5 – 400^{o}F Liquids, wt % total hydrocarbon liquids	50.1	53.6	54.1	54.7	53.1	**
Weight % S in gasoline fraction	1.05	1.00	0.53	0.59	0.92	**
Weight % N in gasoline fraction	0.13	0.27	0.48	0.42	0.11	**
Analysis of C_5 – 400^{o}F Liquids, wt %						
Benzene	48.0	52.4	63.9	60.6	72.5	**
Toluene	17.9	19.1	13.2	13.8	10.0	**
Xylenes	1.5	3.6	0.6	0.7	0.4	**
Phenols	10.7	10.7	7.5	8.1	4.6	**
Naphthalenes	16.7	10.3	10.6	11.1	10.1	**
Unidentified	5.2	3.9	4.2	5.7	2.5	**
	100.0	100.0	100.0	100.0	100.0	**
Carbon Distribution, %						
Liquids	14.68	16.28	13.72	10.89	15.24	8.97
Carbon Oxides	5.15	9.79	5.78	5.50	9.77	20.04
Methane	14.29	16.20	17.06	17.14	17.66	21.87
Light Gases	8.80	10.21	9.50	9.89	9.07	8.94
Char	50.43	46.47	52.64	53.34	44.04	38.12

* Coil Outlet Pressure = 2000 psig.

** Insufficient sample.

Table 14. LIQUIDS YIELDS AND CARBON DISTRIBUTION OBTAINED AT VARIOUS HEATING RATES

Run	HR-1	HR-2	HR-3	HR-4
Heating Rate, °F/s	152	152	385	412
Coil Outlet Temperature	1500	1500	1500	1500
Coil Outlet Pressure	2000	2000	2000	2000
H_2/MAF Lignite Weight Ratio	0.2578	0.4375	0.4823	0.4282
Kinetic Severity, Function	0.3154	0.3902	0.1385	0.7649
Fraction Carbon Converted	0.488	0.478	0.411	0.475
Hydrocarbon Liquids, g/100 g feed carbon	12.88	14.2	13.7	14.4
Carbon Distribution, %				
Liquids	*	*	*	*
Carbon Oxides	9.05	9.47	8.18	11.27
Methane	10.90	12.40	10.59	16.34
Light Gases	11.36	7.37	6.26	8.43
Char	51.23	52.20	58.57	52.51

* Analyses not complete.

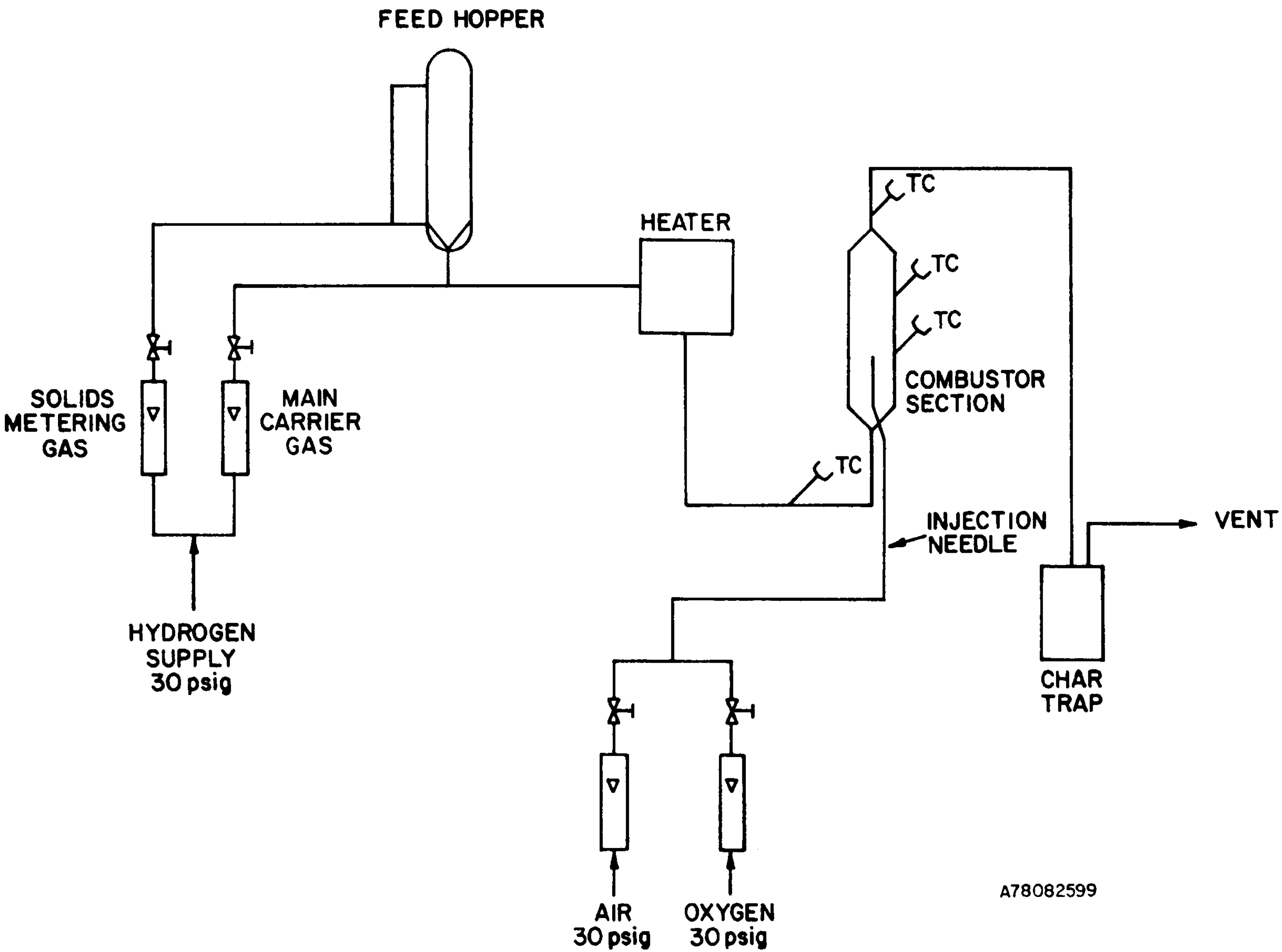

Figure 6. FLOW DIAGRAM OF PDU COMBUSTOR SIMULATOR

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B. Task 4. Construction of a PDU

1. Work Accomplished

Site preparation has been virtually completed, and many major items of equipment have been received. Fabrication of the preheater coil has been completed, and construction of the preheater furnace is underway. No major problems have been encountered in the execution of the construction project. Suppliers for high-pressure hydrogen, oxygen, and nitrogen have been identified, and contract arrangements have been made for the operating phase of the PDU program. The status of equipment procurement is summarized in Table 15.

2. Work Forecast

Erection of the equipment will be done during the forthcoming quarter, and shakedown testing started. The preparations for the compressor house to compress hydrogen to storage pressure will be made, and the completed facility has been promised for March 1.

V. CONCLUSIONS

The main findings from the work performed during the reporting period can be summarized as follows:

1. Successful methods for pretreating Illinois No. 6 coal have been developed which allow the coal to be processed directly in the bench-scale unit without any special precautions or techniques. The pretreatment method involves the incorporation of calcium oxide into the coal at ambient pressure and moderate temperature.

2. Bentonite clay and iron oxide have been successfully used to render caking coals noncaking and also have beneficial catalytic effects on the reaction system. When these materials are used, a given carbon conversion can be obtained at lower hydrogen-to-MAF feed coal weight ratio than would otherwise be required.

3. Depth of carbon conversion is more a function of the severity of thermal treatment and hydrogen partial pressure than heating rate.

4. Exothermic reaction effects are too small to cause an upset in the control system of the bench-scale unit.

Table 15, Part 1. STATUS OF EQUIPMENT PROCUREMENT

Item No.	No. Req'd	Description (Supplier)	Req'd Delivery Date	IGT P.O.	Date Order Placed	Date Rec'd	Remarks
1	1	Refrigerator (Brinkman Instruments)	1/5/79	S-14901	8/25/78	12/20/78	
2	1	Chromatograph (Perkin-Elmer)	Rec'd			11/1/78	
3	3	Emergency blowdown valves (Hoke)	10/30/78	S-14906	8/29/78		
4		Main pressure vessels (Gray Tool Co.)	1/15/79	P-25383	10/18/78	12/27/78	Partially received.
5	2	Rockwell dry-gas meters (Walnor Co.)	11/13/78 1/15/79	P-26170	10/13/78		
6	5	Control valves (Instrument Associates)	11/17/78	P-27803	9/28/78	12/15/78	
7	1	Hydraulic motor and control assembly (Davie Machine)	Rec'd	P-27805	9/22/78	10/18/78	
8	1	Tube stock for oxygen injection (Tube Sales Corp.)	Rec'd	P-27809	10/4/78	10/16/78	
9	--	Tubing fittings for oxygen injection (Lakeview)	Rec'd	P-27818	10/9/78	10/13/78	
10	1	Temperature recorder (Honeywell Controls)	12/18/78	P-27813	10/16/78		
11	2	Dialatrol controller switches	Rec'd	P-27813	10/16/78	Rec'd	
12		Castable refractory (Harbison Walker), 9000 lb	Rec'd	P-27824	10/17/78	11/7/78	
13		Stock for preheater coil supports, 36-ft 3/4-in. SS 316 stainless hexagon bar stock; and 16-ft 1-in. diameter hot rolled round (Central Steel & Wire Co.)	Rec'd	P-27826	10/17/78	10/20/78	
14		Materials for fabricating preheater coil mandrel, 7-ft 24-in. diameter schedule 10 black pipe and 21-ft 2-1/2-in. diameter schedule 40 black pipe	Rec'd	P-27827	10/17/78		

Table 15, Part 2. STATUS OF EQUIPMENT PROCUREMENT

Item No.	No. Req'd	Description (Supplier)	Req'd Delivery Date	IGT P.O.	Date Order Placed	Date Rec'd	Remarks
15	2	Emergency oxygen shutoff valves, aktomatic solenoid (Miller Engineering)	Rec'd	P-27834	10/24/78	10/31/78	Rec'd
16	2	Hoke check valves for oxygen service (Enpro)	Rec'd	P-27835	10/29/78		
17		Incoloy 802 bar stock for preheater coil couplings, 5-ft 1-in. diameter round (Midco Pipe & Tube)	Rec'd	P-27836	10/25/78	11/3/78	
18		Preheater gas and air combustion equipment, 30 items (North American Manufacturing Co.)	11/23/78	P-27837	10/25/78		Partially received.
19	1	Low-pressure gas regulator (Fisher)	Rec'd	P-27842	11/2/78	11/6/78	
20		Differential pressure cells, flow recorder and control, and air filter regulator (Moore Industrial Controls)		P-29557	9/25/78		16 weeks delivery.
21	3	High-pressure gas regulators (Coastal Control Engineering)	Rec'd	P-27831	10/19/78	11/2/78	
22		Air cooler fan, control valve, and air motor (North American Mfg. Co.)			11/6/78		Fan rec'd 12/27/78.
23		High-pressure hydrogen supply (Chemetron)			11/8/78		
24		High-pressure nitrogen supply					
25		Insulation (Babcock & Wilcox)	Rec'd	P-27832	10/23/78		

Table 15, Part 3. STATUS OF EQUIPMENT PROCUREMENT

Item No.	No. Req'd	Description (Supplier)	Req'd Delivery Date	IGT P.O.	Date Order Placed	Date Rec'd	Remarks
26	1	A 5-ft, 1-7/8-in. diameter stainless steel 303 for orifice plates and flanges machining (Central Steel Co.)	Rec'd	P-27845	11/10/78	11/14/78	
27	4	Sono tubes for forming furnace inner-cylindrical walls (National Construction Specialties Co.)	Rec'd	P-27846	11/27/78	11/30/78	
28		Structural steel (angle iron, steel plate, etc.) for furnace construction (Central Steel Co.)	Rec'd	P-30367	11/20/78	11/27/78	
29		Plywood for furnace refractory forming	Rec'd	P-30368	11/20/78	11/22/78	
30		Machining of —	1/5/79		11/28/78	Coupling rec'd.	
	6 pairs	Orifice flanges					
	5 pieces	Orifice plates					
	25 pieces	Preheater-coil tube coupling					
		(Oribit Machining Co.)					
31	4	Stainless steel and carbon steel rods (Central Steel Co.)	12/18/78	P-27860	12/14/78	12/18/78	
32	3	Stainless steel and carbon steel rods (Central Steel Co.)	12/22/78	P-27863	12/19/78	12/22/78	
33		Conax fittings and thermocouples (Conax Corporation c/o Automation Equipment Co.)	1/18/78	P-27865	12/21/78		

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