BITUMINOUS COAL RESEARCH, INC.
SPONSORED RESEARCH PROGRAM

GAS GENERATOR RESEARCH AND DEVELOPMENT

Progress Report No. 9

(BCR Report L-467)

I. INTRODUCTION

This report summarizes progress achieved during the month on the general program, "Gas Generator Research and Development," being conducted by Bituminous Coal Research, Inc., for the Office of Coal Research. The program which was initiated under Contract No. 14-01-0001-324, December 20, 1963, was transferred to Contract No. 14-32-0001-1207 on August 19, 1971. Thus, this report represents the ninth report of progress under the new prime contract.

The overall objective of the program continues to be to develop processes for gasifying coal to produce fuel gas and high-Btu pipeline gas.

Laboratory-scale coal gasification experimentation is to be continued together with process and equipment development. With the aid of engineering subcontractor(s), a multipurpose research pilot plant facility is to be designed, constructed, and test operated.

A. Work Schedule

Work on the project is being conducted according to a schedule reflecting the program outlined under the new prime contract. This schedule was shown in Figure 1, page 2, Progress Report No. 1.

B. Monthly Progress Charts

Monthly progress charts reflecting proposed rate of effort and expenditures are shown in Appendixes A-1 and A-2.

II. PHASE II PROGRESS ACHIEVED DURING MONTH ENDING MAY 25, 1972

A. Laboratory-scale Process Studies

1. Gas Processing (M. S. Graboski): Work continued in the area of gas processing methanation studies in accordance with the time schedule shown in Figure 123, Progress Report No. 8. This report summarizes progress achieved in the bench-scale and PEDU gas processing programs during the month of May.

a. Bench-scale Studies: The purpose of the bench-scale program is to investigate methanation catalysts under conditions imposed by the BI-GAS process. These include high carbon monoxide concentrations, high pressure, and a nominal 3/1 hydrogen to carbon monoxide ratio.

Three processing schemes are currently under investigation. These were summarized in Figure 107, Progress Report No. 7. Scheme A reflects current planning where methanation follows shift conversion and acid gas removal, Scheme B considers hydrogen sulfide removal before and carbon dioxide removal after methanation, and Scheme C shows both hydrogen sulfide and carbon dioxide removal after methanation. Bench-scale tests are being conducted to determine which scheme is optimal for the BI-GAS process.

(1) BSM Tests: During the month, four exploratory BSM tests, Numbers 65 through 68, were conducted. Test 65 was conducted on chromic oxide, Lot 2904, and Tests 66, 67, and 68 on molybdenum oxide, Lot 2903. The system configuration used was that described in detail in Progress Report No. 6, page 318. The reactor vessel used was a 1.25 inch ID fluidized bed.

(a) BSM Test 65: BSM Test 65 was based on the same charge of catalyst used in Test 64. In Progress Report No. 8, it was indicated that activity had suffered in that test. Test 65 results indicated that the remaining catalytic activity was negligible.

(b) BSM Test 66: BSM Test 66 was conducted with 150 grams of fresh molybdenum oxide, Lot 2903, catalyst. Test conditions were 840 to 900 F mean temperature and 1000 psig pressure. The feed gas used had the following composition:

	Volume, Percent	
Component	Period 1	Periods 2 and 3
Carbon Monoxide	20.61	24.93
Carbon Dioxide	0.08	17.39
Hydrogen	61.53	48.45
Nitrogen	2.37	0.20
Methane	15.33	0.03
Ethane	0.08	0.00
	100.00	100.00

Period 1 simulated conversion under Scheme A conditions. Periods 2 and 3 were conducted under Scheme B conditions with a partially shifted gas having a hydrogen/carbon monoxide ratio of 1.95.

Results for Test 66: A major reason for returning to Lot 2903 catalyst was to determine what effect, if any, the stainless steel tube heater had on the methanation conversion. The rebuilt unit contains a copper liner; the liner is inert to carbon monoxide and thus any difference in conversion can be attributed to the heater surface.

Table 107, Period 1, shows the material balance data for the standard 3/1 hydrogen/carbon monoxide ratio synthesis gas using the new preheater system. The reaction zone temperature varied from 925 F at the bottom of the reactor to 860 F at the top.

In Test 66, Period 1, a bypass valve was left open resulting in a much larger flow of gas through the reactor than measured. A 5-minute flow determination was made at the conclusion of the test period after the error was discovered. For this reason, the product rate and hence velocity data are only approximate. The conversion in the test (as summarized in Table 108) was lower than that realized for Test 53 conducted at the same temperature and pressure. In Test 66, however, the throughput was much higher while the volume of bed was approximately the same. For these conditions, one would expect less conversion. From Period 1, therefore, the effect of the new heater cannot be determined.

Periods 2 and 3 were conducted at a reduced hydrogen/carbon monoxide ratio. The material balances for this case were not in balance, as Table 107 indicates. Analytical analysis of the catalyst showed that substantial carbon deposition had occurred. Concurrently, methane and ethane had been produced. If the catalyst could be promoted properly to suppress carbon formation, it is felt that high methane yields could have been obtained with this lower hydrogen/carbon monoxide ratio.

(c) BSM Test 67: BSM Test 67 was conducted with a 325 gram batch of molybdenum oxide, Lot 2903, catalyst. Test conditions were 770 to 975 F mean temperature and 1000 psig. The feed gas used had the following composition:

Component	Volume, Percent
Carbon Monoxide	19.99
Carbon Dioxide	0.06
Hydrogen	62.54
Nitrogen	2.24
Methane	15.10
Ethane	0.07
TOTAL	100.00

All periods simulated conversion under Case A conditions.

Results for Test 67: Material balance data for Test 67 are given in Table 109. Overall results are summarized in Table 110. Conversion for Test 67 was much lower throughout all periods than for Test 66, Period 1. Examination of test data indicated that the temperatures of the periods were

TABLE 107. DATA AND RESULTS FOR BSM TEST 56, PERIOD 1, CONDUCTED AT 892 F AND 990 PSIG MOLYBDENUM OXIDE CATALYST NO. 2903

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	20.61	9.63	4.03	1.20
Carbon Dioxide	0.08	0.04	7.70	2.29
Hydrogen	61.53	28.75	39.95	11.89
Nitrogen	2.37	1.11	3.49	1.04
Methane	15.33	7.16	44.60	13.28
Ethane	0.08	0.04	0.23	0.07
Propane	0.00	0.00	0.00	0.00
Water	0.00	0.00	-	3.92
Total	100.00	46.73	100.00	33.69
Total Moles Carbon		16.91		16.91
Total Moles Hydrogen		86.38		85.15
Total Moles Oxygen		9.71		9.71

B. Conversion Data

	Raw Data g moles/hr
CO → Products	8.43
H_2 → Products	16.86
Reactants → H_2O	3.92
CO → CH_4	6.11
CO → C_2H_6	0.06
CO → C_3H_8	0.00
CO → CO_2	2.25
[illegible], Percent	64.3
[illegible], Percent	1.0
K_{shift} (experimental)	5.80
K_{shift} (theoretical at outlet)	5.82

TABLE 107. DATA AND RESULTS FOR BSM TEST 56, PERIOD 2, CONDUCTED AT 846 F AND 1000 PSIG MOLYBDENUM OXIDE CATALYST NO. 2903 (Continued)

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	24.93	5.15	11.65	1.79
Carbon Dioxide	17.39	3.59	20.87	3.21
Hydrogen	48.45	10.00	31.80	4.89
Nitrogen	0.20	0.04	0.32	0.05
Methane	9.03	1.86	34.34	5.28
Ethane	0.00	0.00	1.02	0.16
Propane	0.00	0.00	0.00	0.00
Water	0.00	0.00	-	1.46
Total	100.00	20.64	100.00	16.84
Total Moles Carbon		10.60		10.60
Total Moles Hydrogen		27.47		40.09
Total Moles Oxygen		12.33		12.33

B. Conversion Data

	Raw Data g moles/hr
CO → Products	3.35
H_2 → Products	5.11
Reactants → H_2O	1.46
CO → CH_4	3.42
CO → C_2H_6	0.31
CO → C_3H_8	0.00
CO → CO_2	-0.38
α, Percent	97.5
β, Percent	8.4
K_{shift} (experimental)	2.13
K_{shift} (theoretical at outlet)	7.18

TABLE 107. DATA AND RESULTS FOR BSM TEST 66, PERIOD 3, CONDUCTED AT 845 F AND 1000 PSIG MOLYBDENUM OXIDE CATALYST NO. 2903 (Continued)

A. Material Balance

	Feed		Product	
Component	mole percent	g moles/hr	mole percent	g moles/hr
Carbon Monoxide	24.93	5.32	12.19	1.93
Carbon Dioxide	17.39	3.71	20.60	3.26
Hydrogen	48.45	10.35	31.46	4.98
Nitrogen	0.20	0.04	0.38	0.06
Methane	9.03	1.93	34.29	5.43
Ethane	0.00	0.00	1.08	0.17
Propane	0.00	0.00	0.00	0.00
Water	0.00	0.00	-	1.46
Total	100.00	21.35	100.00	17.29
Total Moles Carbon		10.97		10.97
Total Moles Hydrogen		28.41		41.31
Total Moles Oxygen		12.75		12.75

B. Conversion Data

	Raw Data g moles/hr
CO → Products	3.39
H_2 → Products	5.37
Reactants → H_2O	1.46
CO → CH_4	3.50
CO → C_2H_6	0.34
CO → C_3H_8	0.00
CO → CO_2	-0.45
[illegible], Percent	97.0
[illegible], Percent	8.9
K_{shift} (experimental)	1.96
K_{shift} (theoretical at outlet)	7.21

TABLE 108. SUMMARY OF RESULTS FOR BSM TEST 66. CATALYST NO. 2903

Period	Temp, F	Pressure, psig	Space Velocity[1]	U/U_{mf} Inlet	U/U_{mf} Outlet	α^2	^{3}	$K_s{}^4$	τ, sec[5]
1	892	990	4486	12.0	8.5	64.2	1.0	5.8	31.0
2	846	1000	1982	5.0	4.2	97.5	8.4	2.1	37.1
3	845	1000	2051	5.3	4.2	97.0	8.9	2.0	36.0

[1] Standard volumes/volume catalyst/hr at inlet conditions

[2] α, useful conversion, 100 x (moles ($CO + H_2$) converted to hydrocarbons)/(total moles ($CO + H_2$) fed)

[3] , moles CO to hydrocarbon above methane produced/total moles CO to hydrocarbons produced

[4] K_s, shift constant, $(P_{CO_2})(P_{H_2})/(P_{CO})(P_{H_2O})$ at outlet

[5] τ, residence time assuming 30% bed expansion and $U = (U_{in} + U_{out})/2$

TABLE 109. DATA AND RESULTS FOR BSM TEST 67, PERIOD 1, CONDUCTED AT 771 F AND 1000 PSIG MOLYBDENUM OXIDE CATALYST NO. 2903

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	19.99	3.62	8.92	1.35
Carbon Dioxide	0.06	0.01	6.59	1.00
Hydrogen	62.54	11.33	55.44	8.39
Nitrogen	2.24	0.41	2.63	0.40
Methane	15.10	2.73	26.12	3.95
Ethane	0.07	0.01	0.31	0.05
Propane	0.00	0.00	0.00	0.00
Water	0.00	0.00	-	0.30
Total	100.00	18.11	100.00	15.44
Total Moles Carbon		6.39		6.39
Total Moles Hydrogen		33.67		33.45
Total Moles Oxygen		3.64		3.64

B. Conversion Data

	Raw Data g moles/hr
$CO \rightarrow$ Products	2.27
$H_2 \rightarrow$ Products	2.94
Reactants $\rightarrow H_2O$	0.[illegible]
$CO \rightarrow CH_4$	1.22
$CO \rightarrow C_2H_6$	0.07
$CO \rightarrow C_3H_8$	0.00
$CO \rightarrow CO_2$	0.99
α, Percent	34.2
[illegible], Percent	5.3
K_{shift} (experimental)	20.73
K_{shift} (theoretical at outlet)	10.6

TABLE 109. DATA AND RESULTS FOR BSM TEST 67, PERIOD 2, CONDUCTED AT 865 F AND 1000 PSIG MOLYBDENUM OXIDE CATALYST NO. 2903 (Continued)

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	19.99	4.06	6.70	1.05
Carbon Dioxide	0.06	0.01	7.71	1.21
Hydrogen	62.54	12.71	51.73	8.11
Nitrogen	2.24	0.46	2.83	0.44
Methane	15.10	3.07	30.73	4.82
Ethane	0.07	0.01	0.30	0.05
Propane	0.00	0.00	0.00	0.00
Water	0.00	0.00	-	0.62
Total	100.00	20.32	100.00	16.30
Total Moles Carbon		7.17		7.17
Total Moles Hydrogen		37.77		37.00
Total Moles Oxygen		4.09		4.09

B. Conversion Data

	Raw Data g moles/hr
$CO \rightarrow$ Products	3.01
$H_2 \rightarrow$ Products	4.60
Reactants $\rightarrow H_2O$	0.62
$CO \rightarrow CH_4$	1.75
$CO \rightarrow C_2H_6$	0.07
$CO \rightarrow C_3H_8$	0.00
$CO \rightarrow CO_2$	1.20
α, Percent	43.1
γ, Percent	3.6
K_{shift} (experimental)	15.09
K_{shift} (theoretical at outlet)	6.56

TABLE 109. DATA AND RESULTS FOR BSM TEST 67, PERIOD 3, CONDUCTED AT 975 F AND 1000 PSIG MOLYBDENUM OXIDE CATALYST NO. 2903 (Continued)

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	19.99	4.33	5.54	0.87
Carbon Dioxide	0.06	0.01	7.72	1.21
Hydrogen	62.54	13.56	49.07	7.69
Nitrogen	2.24	0.49	2.56	0.40
Methane	15.10	3.27	34.67	5.43
Ethane	0.07	0.02	0.44	0.07
Propane	0.00	0.00	0.00	0.00
Water	0.00	0.00	-	1.07
Total	100.00	21.68	100.00	16.74
Total Moles Carbon		6.39		6.39
Total Moles Hydrogen		40.30		39.68
Total Moles Oxygen		4.36		4.36

B. Conversion Data

	Raw Data g moles/hr
CO → Products	3.47
H_2 → Products	5.87
Reactants → H_2O	1.07
CO → CH_4	2.16
CO → C_2H_6	0.11
CO → C_3H_8	0.00
CO → CO_2	1.20
α, Percent	50.4
[illegible], Percent	4.7
K_{shift} (experimental)	10.00
K_{shift} (theoretical at outlet)	4.10

TABLE 110. SUMMARY OF RESULTS FOR RSM TEST 67. CATALYST NO. 2903

Period	Temp, F	Pressure, psig	Space Velocity[1]	U/U_{mf}		α^2	γ^3	$K_s{}^4$	τ, sec[5]
				Inlet	Outlet				
1	771	1000	803	4.2	4.0	34.2	5.3	20.7	129.0
2	865	1000	900	5.0	4.5	43.1	3.6	15.1	111.0
3	975	1000	961	6.0	5.2	50.4	4.7	10.0	98.9

[1] Standard volumes/volume catalyst/hr at inlet conditions

[2] α, useful conversion, 100 x (moles ($CO + H_2$) converted to hydrocarbons)/(total moles ($CO + H_2$) fed)

[3] γ, moles CO to hydrocarbon above methane produced/total moles CO to hydrocarbons produced

[4] K_s, shift constant, $(P_{CO_2})(P_{H_2})/(P_{CO})(P_{H_2O})$ at outlet

[5] τ, residence time assuming 30% bed expansion and $U = (U_{in} + U_{out})/2$

also lower. Data in Table 110 show a trend of increased conversion with temperature. The most striking item in the table is the very high shift ratios, which indicate lower process temperatures.

In Period 1, the temperature indicated by the shift ratio was 100 F low, while in Period 3 it was 200 F low. This could be due to the large bed inventory which places the unexpanded height 9 inches above the top thermocouple. It is possible that in the expanded state, the top of the bed was cooled to the point where the actual exit temperature was more closely related to the shift ratio temperature.

(d) BSM Test 68: BSM Test 68 used the same catalyst mass and feed gas as Test 67. Runs were made at 960 and 1040 F.

Results for Test 68: Material balance data for Test 68 are given in Table 111. Overall results are given in Table 112.

Data for Tests 67 and 68 are plotted in Figure 130 to show the effect of temperature on conversion. It is apparent that at constant pressure, space velocity, and feed composition conversion is strictly a function of temperature. The rate function must also be of zero order. The corresponding shift ratio is also plotted as a function of temperature on the same figure. A good correlation was achieved.

It was also apparent from these test results that some correlation exists between the extent of reaction and shift ratio for a particular feed gas. Data for Tests 66, 67, and 68 are plotted in Figure 131 to show the relationship of exit shift ratio and useful conversion. Conversion data from Test 53, which had been run with the steel heating tube, do not agree with this plot and thus are suspect. The figure suggests that the shift reaction temperature is an excellent indicator of the degree of conversion achieved over a catalyst.

(2) Life Tests: The multi-tube life test unit described in the March progress report, has been in operation for a second full month. During this period, the feed gas has been altered several times. These alterations are:

Phase	Feed Gas $CO_2/H_2/CO$
1	0/3.1/1
2	0.7/3.4/1
3	0.9/3.0/1
4	0.8/2.7/1
5	0.6/2.3/1

An important side reaction which is dependent upon feed gas composition is the carbon deposition reaction:

$$2CO \rightarrow C + CO_2$$

TABLE 111. DATA AND RESULTS FOR BSM TEST 66, PERIOD 1,
CONDUCTED AT 965 F AND 1012 PSIG
MOLYBDENUM OXIDE CATALYST NO. 2903

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	19.84	4.37	4.33	0.67
Carbon Dioxide	0.00	0.00	8.17	1.26
Hydrogen	62.54	13.78	47.04	7.25
Nitrogen	2.18	0.48	3.18	0.49
Methane	15.37	3.39	36.54	5.63
Ethane	0.07	0.02	0.74	0.11
Propane	0.00	0.00	0.00	0.00
Water	0.00	0.00	-	1.19
Total	100.00	22.04	100.00	16.60
Total Moles Carbon		7.79		7.79
Total Moles Hydrogen		41.20		40.09
Total Moles Oxygen		4.37		4.37

B. Conversion Data

	Raw Data g moles/hr
CO → Products	3.70
H_2 → Products	6.53
Reactants → H_2O	1.19
CO → CH_4	2.25
CO → C_2H_6	0.20
CO → C_3H_5	0.00
CO → CO_2	1.25
α, Percent	53.3
[illegible], Percent	8.1
K_{shift} (experimental)	11.55
K_{shift} (theoretical at outlet)	4.28

TABLE 111. DATA AND RESULTS FOR BSM TEST 68, PERIOD 2,
CONDUCTED AT 968 F AND 1042 PSIG
MOLYBDENUM OXIDE CATALYST NO. 2903
(Continued)

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	19.84	4.57	4.23	0.67
Carbon Dioxide	0.00	0.00	8.90	1.41
Hydrogen	62.84	14.40	46.45	7.38
Nitrogen	2.18	0.50	3.17	0.50
Methane	15.37	3.54	36.36	5.77
Ethane	0.07	0.02	0.89	0.14
Propane	0.00	0.00	0.00	0.00
Water	0.00	0.00	-	1.07
Total	100.00	23.03	100.00	16.94
Total Moles Carbon		8.14		8.14
Total Moles Hydrogen		43.07		40.84
Total Moles Oxygen		4.57		4.57

B. Conversion Data

	Raw Data g moles/hr
CO → Products	3.90
H_2 → Products	7.03
Reactants → H_2O	1.07
CO → CH_4	2.23
CO → C_2H_6	0.25
CO → C_3H_8	0.00
CO → CO_2	1.41
[illegible], Percent	51.7
[illegible], Percent	10.1
K_{shift} (experimental)	14.49
K_{shift} (theoretical at outlet)	4.22

TABLE 111. DATA AND RESULTS FOR BSM TEST 68, PERIOD 3,
CONDUCTED AT 1042 F AND 1010 PSIG
MOLYBDENUM OXIDE CATALYST NO. 2903
(Continued)

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	19.84	4.52	3.57	0.54
Carbon Dioxide	0.00	0.00	8.33	1.26
Hydrogen	62.54	14.26	44.18	6.68
Nitrogen	2.18	0.50	3.33	0.50
Methane	15.37	3.50	39.75	6.01
Ethane	0.07	0.02	0.84	0.13
Propane	0.00	0.00	0.00	0.00
Water	0.00	0.00	-	1.47
Total	100.00	22.80	100.00	16.59
Total Moles Carbon		8.06		8.06
Total Moles Hydrogen		42.64		41.08
Total Moles Oxygen		4.52		4.52

B. Conversion Data

	Raw Date g moles/hr
CO → Products	3.98
H_2 → Products	7.58
Reactants → H_2O	1.47
CO → CH_4	2.50
CO → C_2H_5	0.22
CO → C_3H_8	0.00
CO → CO_2	1.26
α, Percent	57.4
[illegible], Percent	8.1
K_{shift} (experimental)	10.63
K_{shift} (theoretical at outlet)	3.21

TABLE 111. DATA AND RESULTS FOR BSM TEST 63, PERIOD 4, CONDUCTED AT 1042 F AND 1009 PSIG MOLYBDENUM OXIDE CATALYST NO. 2903 (Continued)

A. Meterial Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	19.84	4.38	3.38	0.50
Carbon Dioxide	0.00	0.00	8.24	1.21
Hydrogen	62.54	13.82	44.22	6.48
Nitrogen	2.18	0.48	3.34	0.49
Methane	15.37	3.40	39.96	5.86
Ethane	0.07	0.02	0.86	0.13
Propane	0.00	0.00	0.00	0.00
Water	0.00	0.00	-	1.47
Total	100.00	22.10	100.00	16.14
Total Moles Carbon		7.81		7.81
Total Moles Hydrogen		41.31		40.08
Total Moles Oxygen		4.38		4.38

B. Conversion Data

	Raw Data g moles/hr
CO → Products	3.89
H_2 → Products	7.34
Reactants → H_2O	1.47
CO → CH_4	2.46
CO → C_2H_6	0.22
CO → C_3H_8	0.00
CO → CO_2	1.21
α, Percent	58.3
[illegible], Percent	8.2
K_{shift} (experimental)	10.72
K_{shift} (theoretical at outlet)	3.21

TABLE 112. SUMMARY OF RESULTS FOR BSM TEST 68. CATALYST NO. 2903

Period	Temp, F	Pressure, psig	Space Velocity[1]	U/U_{mf} Inlet	U/U_{mf} Outlet	α[2]	β[3]	K_s[4]	τ, sec[5]
1	965	1012	976	6.0	4.5	53.3	8.1	11.6	98.7
2	968	1010	1021	6.2	4.5	51.7	10.1	14.5	91.9
3	1042	1010	1010	6.4	4.7	57.4	8.1	10.6	97.1
4	1042	1009	979	6.2	4.5	58.3	8.2	10.7	94.6

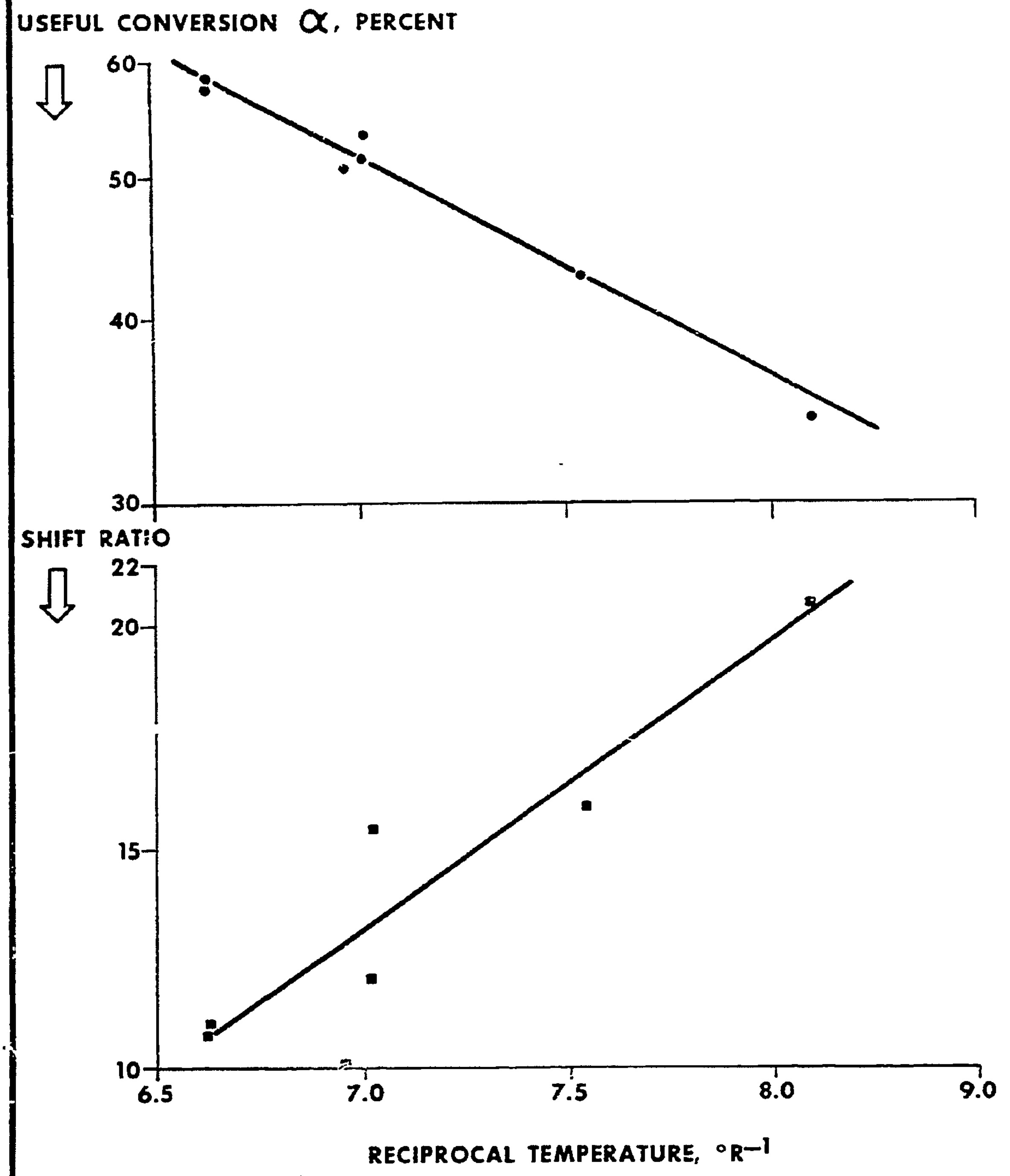
[1] Standard volumes/volume catalyst/hr at inlet conditions

[2] α, useful conversion, 100 x (moles ($CO + H_2$) converted to hydrocarbons)/(total moles ($CO + H_2$) fed)

[3] β, moles CO to hydrocarbon above methane produced/total moles CO to hydrocarbons produced

[4] K_s, shift constant, $(P_{CO_2})(P_{H_2})/(P_{CO})(P_{H_2O})$ at outlet

[5] τ, residence time assuming 30% bed expansion and $U = (U_{in} + U_{out})/2$



Bituminous Coal Research, Inc. 8040G55

Figure 130. Effect of Temperature on Conversion and Shift Ratio Using Lot 2903 MoO_3 Catalyst and a 3/1 H_2/CO Ratio at Constant Space Velocity and Pressure

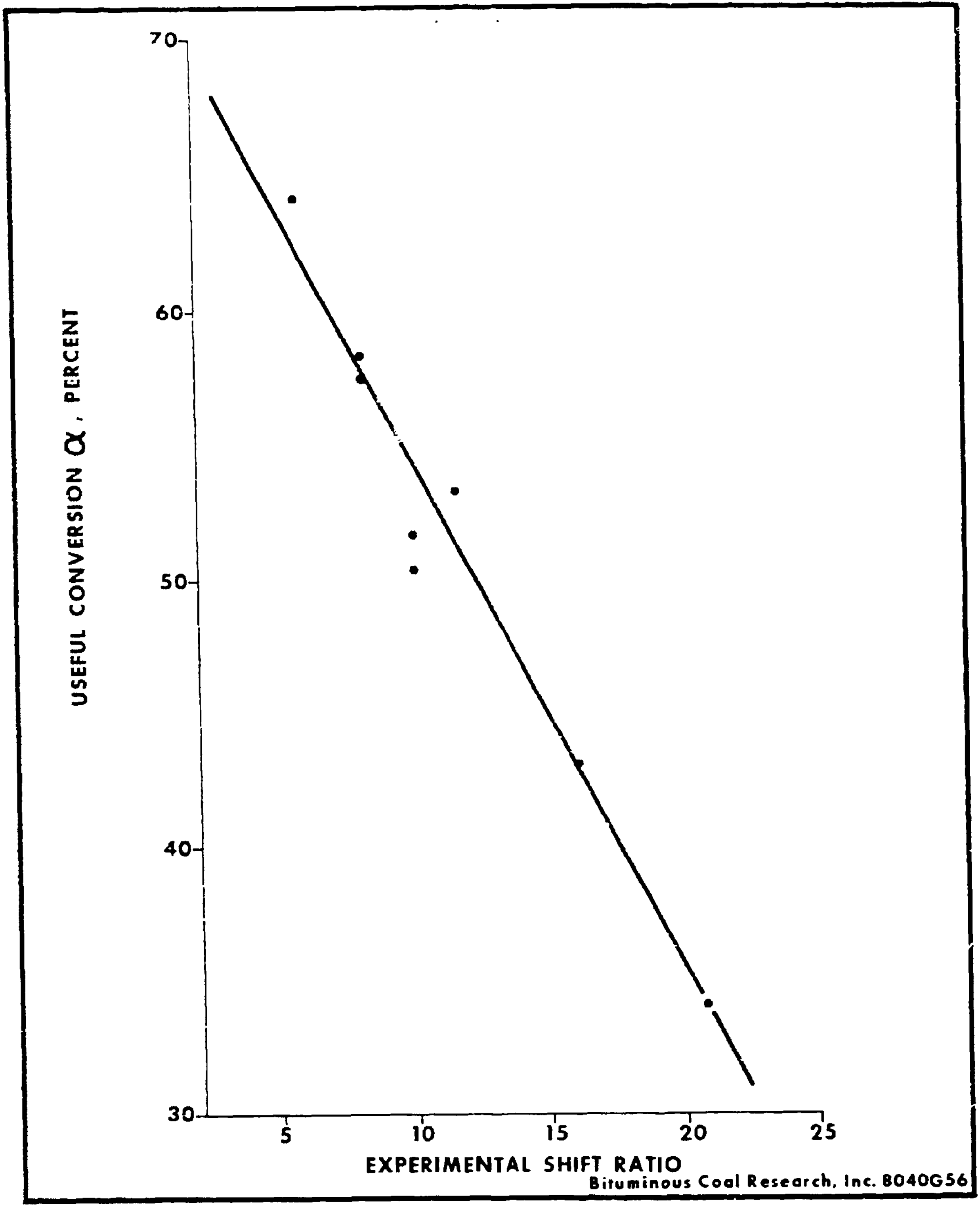


Figure 131. Comparison of Conversion to Hydrocarbons with Shift Ratio for Lot 2903 Catalyst

Thermodynamic calculations were made on the hydrogen, oxygen, and carbon system to develop a carbon deposition plot. This is given in Figure 132. Path of reaction is critical in carbon formation and thus some catalysts can operate at much lower hydrogen/carbon and oxygen/carbon ratios than indicated by equilibrium because of high reaction selectivity. In analyzing the feed gases used in the life test unit, all are in the carbon deposition region. Assuming that methane is stable, and thus will not decompose to carbon in the reactor, only the Phase I feed will not deposit carbon.

Figure 133 shows the results of the life test to date. Due to a failure of the analytical equipment, quantitative results are not available for Phases IV and V. Test duration reported has been extended to 1250 hours. At 650 hours of test duration, Phase II of the life test began. Shortly thereafter, the catalyst 2903 tube plugged solidly with carbon. At that point the reactor was shut down and the 2903 tube was refilled with Lot 2905 nickel tungsten catalyst. The unit was placed back on stream. The 1250 hours represents the system operated through Phase III. No further evidence of catalyst deterioration has occurred. Activity has been fairly stable with variations of gas composition. Lot 2905 nickel tungsten has the highest activity of the catalysts investigated. It also produces no hydrocarbons higher than methane. This could be due to the silica in the support which tends to greatly enhance the cracking ability of catalysts.

b. PEDU Studies: Progress continued to be made on the methanation PEDU during May. Engineering was conducted by Koppers in all phases of the PEDU program. Requisite permits for construction were applied for and excavation of the site began. Negotiations with Duquesne Light, with respect to the transformer, continued. Difficulty has been encountered in acquiring certified drawings from vendors for purchased equipment.

(1) Engineering: During the month, a large volume of PEDU material was received from Koppers. Table 113 summarizes the drawings and specifications completed in May.

(a) Vessels: Detail drawings for eight PEDU vessels were received. These are of sufficient detail for fabrication purposes. Specifications, where required, were also received.

(b) Buildings: Specifications and drawings for the reformer enclosure were received. Based on these, quotations have been solicited.

(c) Piping and General Arrangement: Piping and general arrangement drawings of the high pressure stall are currently being reviewed. These are of sufficient detail to permit fabrication of the structural steel, placement of the stall vessels, and piping and instrumentation about the vessels. General piping specs have been reviewed.

(2) Electrical: Lighting and grounding plans have been reviewed and approved. A single line diagram showing the loads on a new electrical control panel and those on the reused PEDU motor control center has also been approved. The new control panel will be fabricated by the electrical subcontractor.

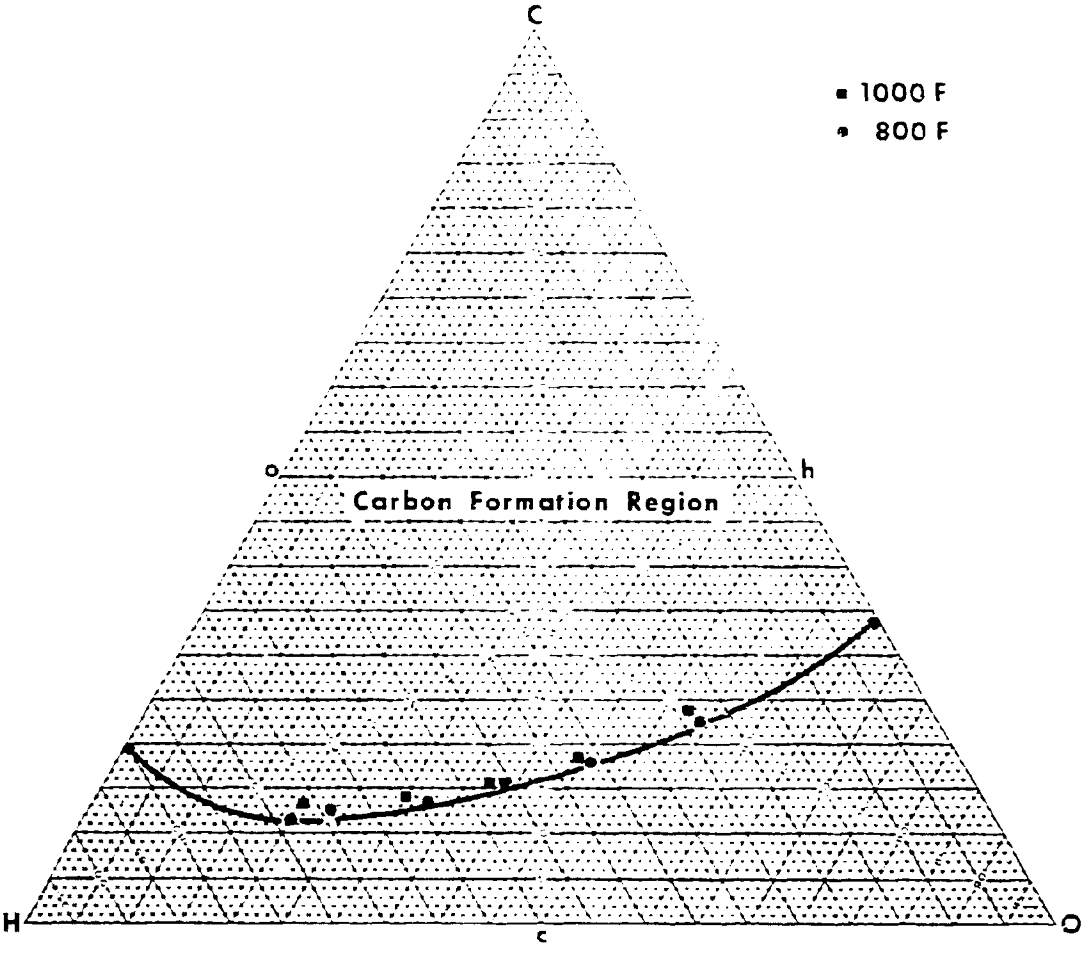


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Figure 132. Carbon Deposition Data for C-H-O System at 68 atm

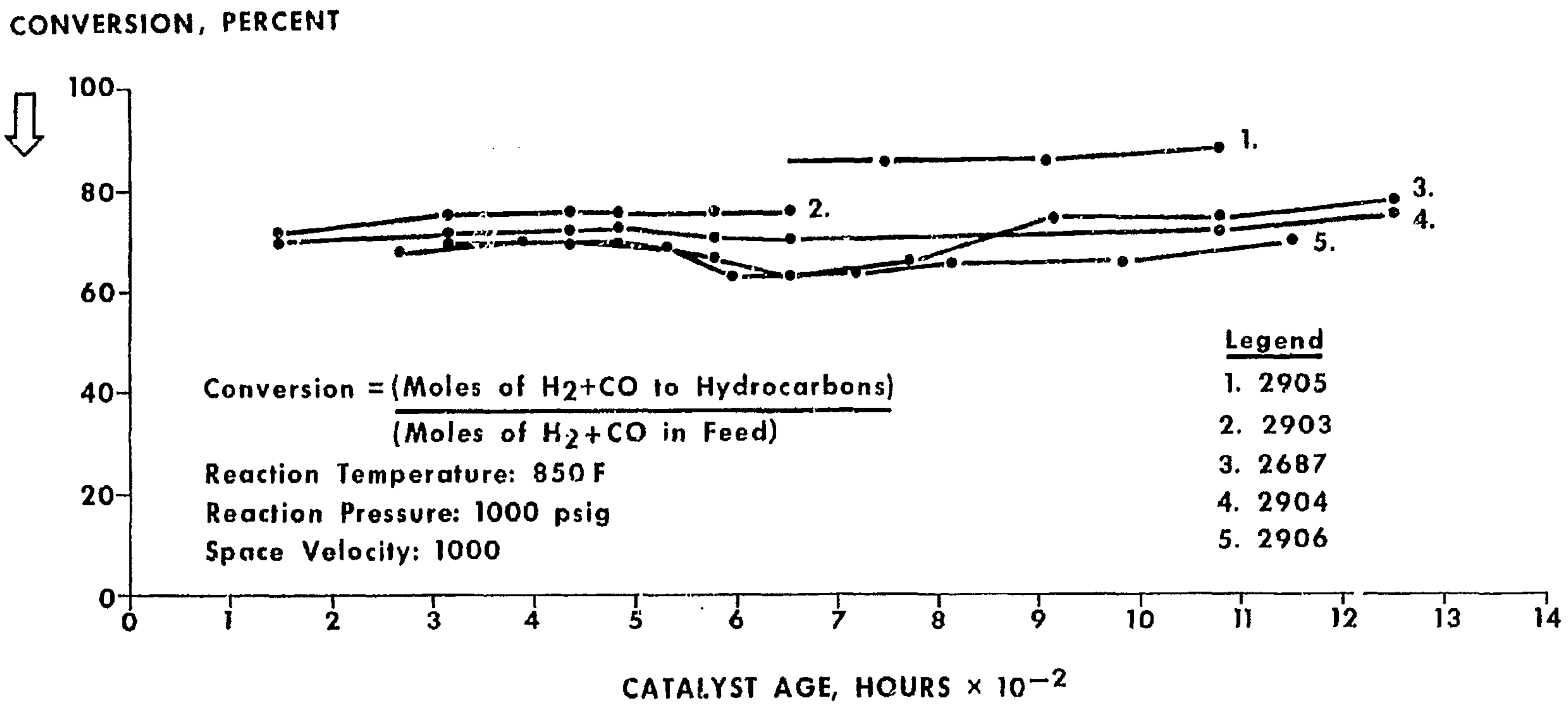

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Figure 133. Life Test Data for Several Methanation Catalysts

TABLE 113. DETAIL ENGINEERING DRAWINGS AND SPECIFICATIONS RECEIVED DURING MAY, 1972

Drawing or Specification Number	Description
I. Vessel Drawings	
2415-2A700 (R5)	Fluid Bed Methanator
2415-2A714 (R3)	Fluid Bed Methanator
2415-2A722 (R1)	Demister
2415-2A723 (R1)	Filter Blowback Heater
2415-2A725 (RO)	Reformer Feed Receiver
2415-2A729 (RO)	H_2S Flash Tank
2415-2A735 (RO)	H_2S Removal Tanks
2415-2A736 (RO)	Water Letdown Tank
2415-2A739 (RO)	Water Head Tank
II. Vessel & Equipment Specs	
MK-770	Air Compressor
MV-615	Water Letdown Tank
MV-763 A & B	H_2S Removal System
MV-764	Drip Pot
MV-766	Water Head Tank
III. Building Drawings & Specs	
2415-2A718 (R1)	Reformer Enclosure Arrangement
2415-4F701 (RO)	Notes for Steel Design
2415-4F702 (RO)	Reformer Enclosure Specifications
IV. Piping and General Arrangement Drawings	
2415-2A712 (R1)	General Piping Specs
2415-2A713 (R1)	General Piping Specs
2415-2A730 (RO)	High Pressure Stall Piping
2415-2A731 (RO)	High Pressure Stall Piping
2415-2A732 (RO)	High Pressure Stall Piping
2415-2A733 (R3)	Site Plan

TABLE 113. DETAIL ENGINEERING DRAWINGS AND SPECIFICATIONS RECEIVED DURING MAY, 1972 (Continued)

Drawing or Specification Number	Description
V. Electrical Drawings	
2415-6A700 (R0)	Lighting Plan
2415-6A701 (R0)	Grounding Plan
2415-6A702 (R0)	Single Line Wiring Plan
VI. Instrument Specifications	
2415-9F303 (R1)	Annunciator
2415-9F304 (R0)	Flow Elements
2415-9F305 (R0)	Pneumatic Flow Transmitters
2415-9F306 (R0)	Flow Integrator
2415-9F307 (R0)	Flow Totalizers
2415-9F313 (R0)	Local Temperature Indicators
2415-9F314 (R0)	Thermocouples
2415-9F315 (R0)	Multiple Probe Thermocouples
2415-9F317 (R0)	Electrical Temperature Transmitters
2415-9F323 (R0)	Flow Computing Devices
2415-9F600 (R0)	Flow Transmitter Alterations
2415-9F601 (R0)	Flow Totalizer Alterations
2415-9F603 (R0)	Temperature Recorder Alterations
2415-9F606 (R0)	Indicating Controller Alterations

(3) Instrumentation: Instrument specifications for new and reused instruments have been reviewed and in some cases new items have been procured. The instrumentation work by item count is 35 percent complete.

(4) Procurement: Table 114 shows the procurement status of major PEDU items. The critical items, as far as delivery is concerned, are the fluid bed methanator, methanator feed gas compressor, and reformer, in that order. Difficulty is currently being encountered in obtaining certified data from vendors for most major equipment items. This has a twofold effect on the program. First, without certified data, Koppers cannot perform certain detail engineering functions such as foundation and structural design. Second, delivery could be longer than estimated since most delivery dates are based on receipt of BCR-approved drawings.

(5) Permits: Based on Koppers' specifications for the reformer enclosure, the hydrogen sulfide removal system and the thermal oxidizer, the necessary building and air pollution permits were applied for.

(6) Transformer: Duquesne Light is currently submitting to BCR certified drawings for the new 750 KVA transformer. These will enable Koppers to engineer the pad and grounding system for the unit. In addition, Duquesne Light has indicated to BCR the route of the new power line into the transformer so that BCR can clear the path for the new wire poles.

(7) Excavation: Groundbreaking for the PEDU has begun. Excavation of the site is currently underway.

(8) PEDU Problem Areas: Four major problem areas exist in the PEDU work.

(a) Feed Gas Heater: Koppers is currently contacting tube manufacturers to determine if 60 feet of duplex copper-stainless tubing can be obtained for the feed gas heater. There has been no progress in this area.

(b) Compressor Area: No detail engineering can proceed in the compressor area until certified prints for MK-102 and MK-305 are received. The scheduled date for receipt of these is June 12.

(c) Boiler Room: No detail engineering can proceed in the boiler area until certified prints are received. There is no indication from the vendor as to when this will be.

(d) Reformer Pad: No work on detailing the reformer pad can proceed until certified layout prints are received. These are scheduled to be sent to BCR on May 30, 1972.

c. Cold Model Studies: No progress was made in this area during May.

TABLE 114. SUMMARY OF STATUS OF PEDU EQUIPMENT ITEMS

Index	Equipment Item	Status[1]	Estimated Delivery Date
ME-405	Feed Gas Preheater	D	--
ME-410	Filter Blowback Heater	Q	--
ME-605	Cooler Condenser	P	9/05/72
ME-700	Water Cooler	P/A	6/30/72
MF-420	Catalyst Filters	Q	--
MK-102	Natural Gas Compressor	P	7/31/72
MK-305	Methanator Feed Gas Compressor	P	11/13/72
MK-770	Air Compressor	D	--
MP-710	Cooling Water Pump	P/A	7/07/72
MR-420	Fluid Bed Methanator	P/A	11/30/72
MV-104	Reformer Feed Gas Receiver	P/A	6/11/72
MV-260	H_2S Flash Tank	P/A	7/17/72
MV-307	Oil Separator	P	7/12/72
MV-310	Methanator Feed Gas Receiver	P/A	7/28/72
MV-610	Water Metering Tank	P/A	6/01/72
MV-615	Water Letdown Tank	Q	--
MV-620	Demister	P	--
MV-710	Cooling Water Tank	P/A	6/02/72
MV-763 A & B	H_2S Removal Towers	Q	--
MV-764	Drip Pot	D	--
MV-766	Water Break Tank	Q	--
MX-100	Reformer	P	11/08/72
MX-500	Therminol System	P	8/23/72
MX-720	Steam Boiler	P	9/20/72
MX-750	Demineralizer	P	--
MX-770	Thermal Oxidizer	Q	--
MY-700	Reformer Enclosure	Q	--

[1] D Design Stage
Q Quote Stage
P Procurement Stage
P/A Procured and Vendors Drawings Approved

d. Future Work: Work planned for June is as follows:

At the bench-scale level, fluidized reactor tests will be conducted on 2905 nickel tungsten catalyst. Life testing of four catalysts will continue.

PEDU work planned involves further detail engineering and procurement.

Some equipment items will be received in June.

Cold model work will be continued.

2. Analytical Services (J. E. Noll): During the past month, 49 samples were analyzed by gas chromatography. The types of analyses requested were as follows:

Types of Analyses Requested	No. of Samples Analyzed
Gas Chromatography	
Methanation Unit Gas Samples	49
TOTAL	49

3. Gas Chromatographic Procedures (J. E. Noll): A second gas chromatograph, a Hewlett Packard 810, is being standardized for the above type of analysis. This unit will then be used as a backup unit.

Future Work: The use of argon as a carrier gas in gas chromatography will be examined. Although its cost is considerably higher than that of helium (90 cents per hour against less than 1 cent per hour), its thermal characteristics should permit very good hydrogen analysis without materially affecting the analyses of the other gases. With helium, the analysis of hydrogen is the poorest of all the analyses made.

B. Cold Flow Model Experiments - 5 ton/hr Two-stage Gasifier (R. J. Grace, J. E. Noll, R. D. Harris, R. L. Zahradnik, and E. E. Donath)

Tests on the cold flow model during the month consisted of experiments with water and glycerine sprayed into Stage 1 of the model to simulate slag droplets. The tests indicate that a cloud of fine slag droplets would probably be entrained into Stage 2, but that a top for Stage 1 could be designed to eliminate any upward creep of slag droplets towards the gas exit. The remaining concern was to develop means of preventing the small amount of slag that might be deposited directly in the throat from migrating into Stage 2. Work on Stage 1 is currently being concluded.

No work was done on characterization of the reactivity or the grindability of PEDU chars, or possible startup materials.

1. Stage 1 Model Tests

a. Review of Previous Tests: The cold model test program was outlined in Progress Report No. 90 (pp 3758-9) and a detailed program was given in Progress Report No. 92 (pp 3911-12). The Stage 1 tests were to be conducted in three phases: Phase I single-burner tests, Phase II multiple-burner tests, and Phase III multiple-burner tests with simulated slag injection. The Phase I tests were completed and summarized in Progress Report No. 3 (pp 184-98).

The equipment for Phases II and III was assembled and ready for test at the time Phase I was completed. However, after a few initial tests, this work was delayed while the properties of certain PEDU chars were evaluated. During this interval, reevaluation of the modeling criteria indicated that slag behavior would be more realistically evaluated at higher air rates. As a consequence, a blower with a significantly higher capacity was obtained and installed.

b. Phase II Tests: The results of the Phase I tests indicated that rapid mixing of the char, oxygen, and ambient gas stream was obtained. With this rapid mixing by the action of the burner alone, there was no need to investigate additional downstream mixing as a means to assure that there would be no unmixed oxygen near the sidewalls. The mixing in Phase I was obtained without adjusting the flow of the inner air stream to produce the additional momentum of the char feed. However, with this additional momentum more rapid mixing would be expected.

c. Phase III Tests: Some initial Phase III tests were conducted prior to the remodeling of the test installation. To date, 17 tests have been conducted on the remodeled installation.

Air was supplied to the three burners at a total rate of 600 cfm, and liquid was sprayed from the center of one or more of the burners to simulate the molten char-ash droplets expected during slagging operation. Water was used during the first six tests and glycerine during the later ones.

The type of atomization obtained with water is shown in Figures 134 and 135 where a dense mist of fine water droplets was made by an air-operated atomizer located in the center of the prototype burner. It was necessary to modify the nozzles to enable glycerine to be atomized at comparable rates. In the model, the glycerine sprays appeared comparable to the water sprays, but no glycerine tests were made on the test stand.

The results of the three-burner tests conducted at high air rates with water and glycerine sprays are summarized in Table 115.

(1) Details of Tests Conducted: For Tests 1 and 2, the arrangement shown schematically in Figure 125, page 467, Progress Report No. 8, was used. The burners were located 1 ft from the bottom of the cylindrical portion of the model at the location specified in the original Koppers Company design. The water losses in Tests 1 and 2 were attributed to evaporation, and a number of small leaks that were systematically eliminated during the tests. No water

8016P272

Figure 134. Water Spray from Stage 1 Burner at 12 GPH

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Figure 135. Water Spray from Stage 1 Burner at 15 GPH

TABLE 115. SUMMARY OF THE THREE-BURNER TESTS CONDUCTED AT HIGH AIR RATES WITH WATER(W) AND GLYCERINE(G) SPRAYS

			Burner Settings				
Test	Liquid	Rate GPH	Height, In.	Deflection	Depression	Top Cone Angle	Liquid Loss Wt., %
1	W	15.5	1	max	nil	45	24.5
2	W	15.5	1	min	nil	45	17.3
3	W	15.5	3	min	nil	45	13.9
4	W	15.9	3	max	nil	45	15.9
5	W	38.0	3	min	nil	45	12.4
6	W	37.0	3	max	nil	45	11.0
7	G	13.9	3	max	nil	flat	5.3
8	G	16.2	1	max	nil	45	7.0
9	G	18.4	1	max	nil	45 v[1]	4.1
10	G	16.9	1	min	nil	45 v	1.3
11	G	16.2	1	min	5"	45 v	1.2
12	G	18.8	1	max	5"	45 v	0.9
13	G	21.5	1	max	nil	45 v	3.6
14	G	22.4	1	max	nil	60 v	3.2
15	G	23.8	1	max	nil	60 v	0.9
16	G	41.2	1	max	nil	60 vx	1.7
17	G	42.2	1	max	nil	45 vx	1.8

[1] v indicates vanes in top cone, x indicates short stage 2 added

was collected from the mist separator during either test, but in Test 1 the droplet separation appeared superior because the top 12 inches of the reactor were dry.

It was concluded that if slag could be separated as effectively as water at 15 gph, it would be feasible to locate the burner near the top of the reactor. This higher location would allow a longer residence time for the reaction of char that might stick to the slag film flowing down the walls.

Tests 3 and 4 were therefore conducted with the model spools reversed so that the burners were 3 ft from the bottom of the cylindrical portion of the model. During Tests 3 and 4, no water was collected from the mist separator. There was, however, more evidence of moisture in the connection to the mist separator in Test 3 than in Test 4.

After Test 4 the installation was modified to include atomizing nozzles for all three burners. Tests 5 and 6 were duplicates of Tests 3 and 4 except that higher water injection rates were used. In Test 5 some water was collected in the mist separator, and in Test 6 there was evidence of moisture in the connection to the mist separator.

The water tests indicated possible significant differences between different burner deflections and locations. However, since that water which deposited near the top of the reactor tended to evaporate, it was not possible to identify possible troublesome slag accumulation near the gas exit. It was, therefore, decided that further tests would be conducted with more viscous and less volatile glycerine.

For Test 7 a flat top was installed on the model in place of the cone-shaped top. With the flat top, the Stage 1 reactor configuration tends to resemble a cyclone separator; and, as such, it might be a more effective slag separator. The results of Test 7 showed promise in eliminating the glycerine mist. However, observations showed that some glycerine, which was deposited on the top, tended to creep towards the gas outlet. This creep of glycerine towards the outlet was considered a serious deterrent to the use of a flat top despite its apparent effectiveness for removing a slag mist.

For Test 8, the conditions of Test 6 with water were repeated with a glycerine spray. During this test, droplets adhering to the 45° top were sheared off and the smaller droplets thus produced were often entrained in the air leaving the model. Despite the 7 percent glycerine loss, as shown in Table 115, only a few grams were drained from the mist collector.

It was decided that the air flow patterns which induced the glycerine drops to flow up the 45° top could be modified by installing vanes in the top. The installation of six such vanes was simulated with wooden shapes. At the same time, a 60° top with similar vanes was also made. Figure 136 compares the profiles of the two tops and Figure 137 shows the vanes.

The vanes appeared to eliminate most of the problem of slag creeping toward the gas outlet. Tests 9 through 13 were conducted to evaluate

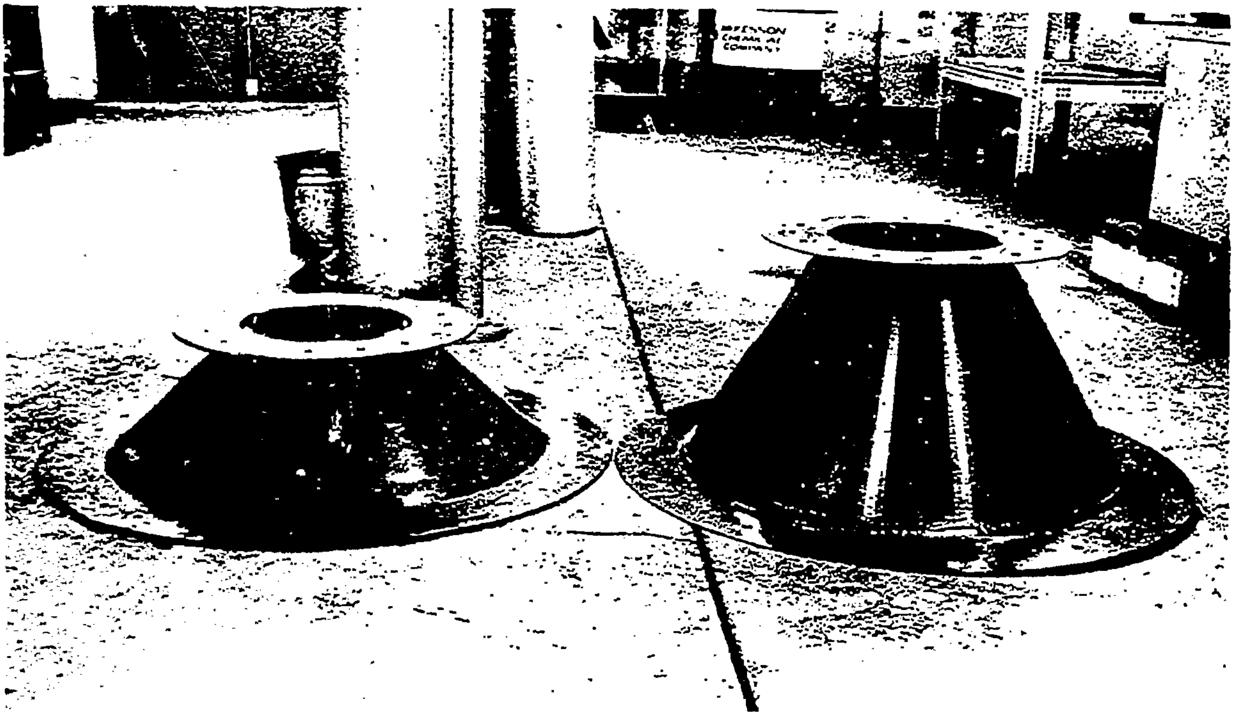

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Figure 136. Top Sections of Stage 1 for Cold Flow Model

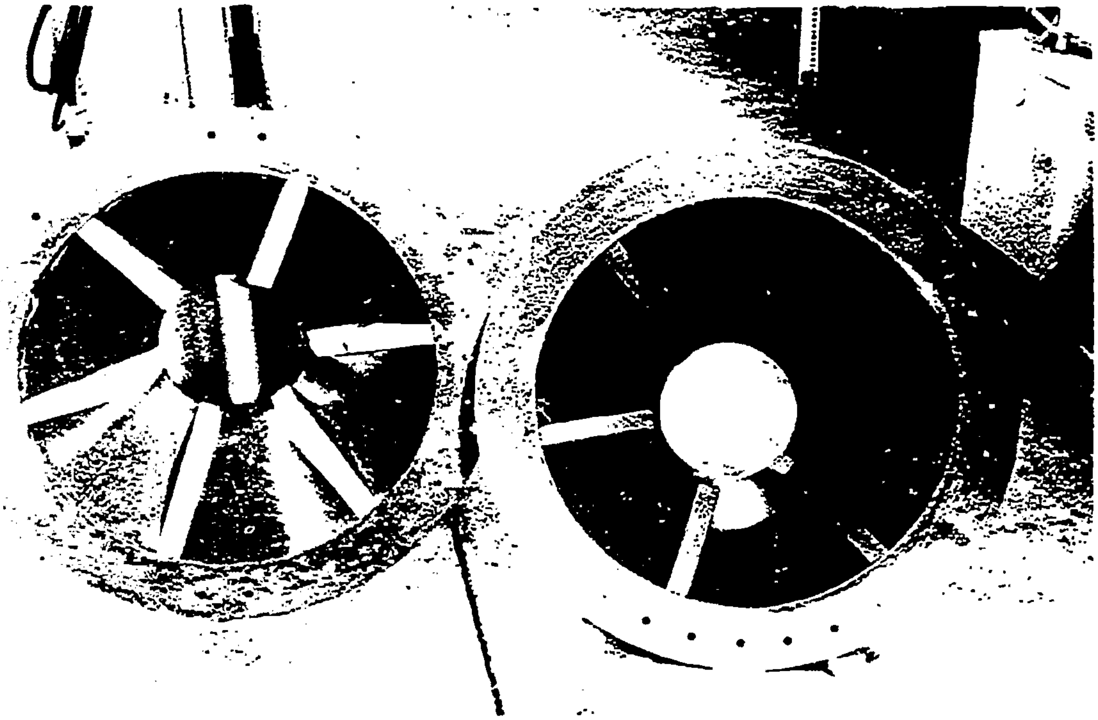

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Figure 137. Inside View of Top Sections Showing Simulated Vanes

the difference in slag separation between maximum and minimum deflection of the burners and between a horizontal and a depressed setting of the burners.

The tests indicated that the horizontal setting of the burners with maximum deflection (approximately 2-3/4 inches from the axis) produced a significantly higher glycerine loss than the other three combinations.

Tests 14 and 15 were made with the 60° top and with the burner settings that produced higher losses in Tests 9 and 14. The results did not duplicate closely, but of greater concern was the observation that some of the glycerine which deposited on the top crept towards the exit despite the vanes.

In Tests 7 through 15, some glycerine always collected at the air outlet. It appeared that most of this glycerine was part of the mist particles that agglomerated in the duct leading to the mist separator. However, a slag mist entrained into Stage 2 should be no problem since the droplets would freeze while still entrained and be removed with the fines or recycled with the char.

In order to separate mist droplets deposited at the throat from droplets conveyed out of Stage 1 and returned by running down the exit duct, a short Stage 2 section was installed as shown in Figure 138. Not apparent in Figure 138 is a 1-inch ring placed 2 inches above the throat for the purpose of collecting droplets deposited in the short Stage 2 section.

Tests 16 and 17 were conducted with the short Stage 2 section in place. During both tests, little glycerine was deposited or induced into the throat area. However, the throat was somewhat freer of glycerine during Test 17 with the 45° top.

(2) <u>Conclusions from Phase III Tests</u>: The following conclusions have been drawn:

(a) A harmless mist of slag will be carried into Stage 2 with the synthesis gas from Stage 1.

(b) Most of the liquid droplets were deposited in and drained out of Stage 1.

(c) The creep of droplets out of Stage 1 was essentially stopped by vanes installed in the 45° top.

(d) The 45° top with vanes appeared superior to the 60° top.

(e) Some residual slag will be deposited at the throat. These deposits could be troublesome but arrangements for steam admission to clear such deposits will probably be beneficial.

2. <u>Determination of Properties of Chars</u>: A procedure for modifying the standard Hardgrove grindability tests for processing low bulk density, friable

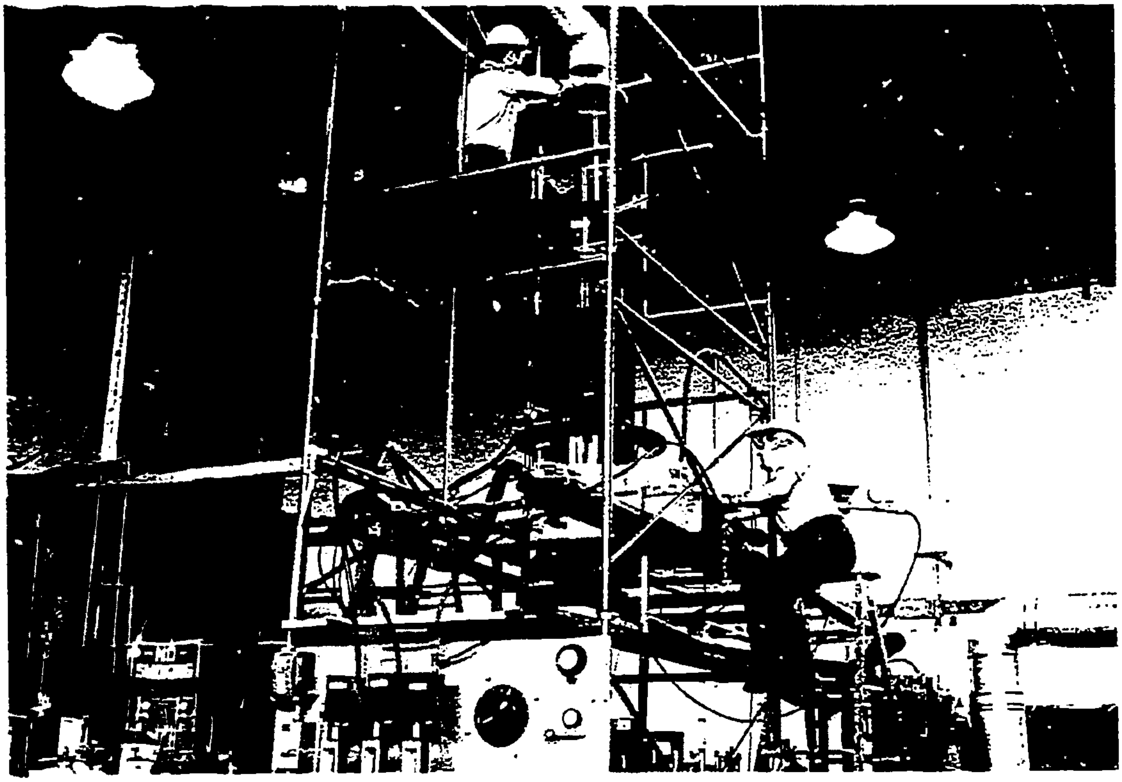

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Figure 138. Cold Flow Model with Short 2 ft Stage 2 Section Installed

chars is described in Appendix B. Using the revised procedure, it is apparent that the PEDU chars have a significantly higher grindability than the softest available bituminous coals.

3. Future Work: Stage 1 model studies are being concluded with tests of a simulated steam ring. The ring will be installed in the throat between Stages 1 and 2 for the purpose of eliminating slag deposits in this critical area.

Studies of particulate feeds to a prototype Stage 2 will also be undertaken.

C. Data Processing (R. K. Young and D. R. Hauck)

1. Automated Data Acquisition: The software executive system necessary for real time data acquisition has been written and entered in the computer. This software system should be completely debugged by mid-June.

The hardware interfacing (wiring) between the methanation unit and the PDP8-E computer has been completed.

The programs required to log, process, and store data from the methanation unit are presently being written and should be debugged by June 30. At that time, the computer will be able to acquire data directly from the bench-scale methanation unit and process it as necessary.

2. Future Work: Plans for the next report period are as follows:

a. Complete the data acquisition programs for the methanation unit and begin to acquire data from that unit.

b. Generate simulation runs with subroutine GASIFY as requested and authorized.

D. Engineering Design and Evaluation

1. BI-GAS Process. No commercial gasifier simulation runs were made during May. Plans for the next report period include several simulation runs with char withdrawal rates greater than the normal 25 percent.

2. OCR/BCR Gasification--Power Generation: On May 15, 1972, representatives of Combustion Engineering, Inc., visited BCR to discuss potential application of an air-blown version of the BI-GAS gasifier for the production of low-Btu fuel gas. They were primarily interested in the background to the development of the gasifier, and in the state of our knowledge regarding novel features of the unit.

E. Multipurpose Research Pilot Plant Facility (MPRF)

1. Pilot Plant Bid Evaluation: To provide as complete information as possible in completing the evaluation of proposals, AGA, OCR, BCR, and C. F. Braun and Co., met with selected bidders in the bidders' facilities. This gave the evaluators opportunity to assess creative design capability,

general engineering capability, backup services, and management of the proposing companies. Results of these visits will be combined with the earlier evaluation of written proposals to permit BCR to recommend a constructor to the program sponsors.

Evaluation of proposals submitted by companies seeking to assist BCR in the construction project have been evaluated and a recommendation has been prepared for submission to the sponsors.

2. Materials Evaluation Program: On May 15, 1972, the Task Group on Materials Design Data for Coal Gasification Process Equipment met at the United Engineering Center, 345 East 47th Street, New York City. The following were in attendance.

Task Group Members

W. Hulsizer	The International Nickel Co., Inc.
F. Schora	Institute of Gas Technology
J. Tassoney	Bituminous Coal Research, Inc.
C. Schulz	Consolidation Coal Company
E. Pirsh	Babcock and Wilcox
A. Flowers	American Gas Association

Guests

J. J. Moran (part-time)	The International Nickel Co., Inc.
A. O. Schaefer	The Metal Properties Council

The purposes of this meeting were to review the technical aspects of the various proposals submitted to the Metal Properties Council in response to MPC Inquiry No. 72-18, entitled, "Corrosion of Materials at Temperatures and Environments Expected in Proposed Processes for the Gasification of Solid Fuels" and to recommend to MPC which proposal(s) should be pursued. Those submitting proposals were Foster Wheeler Corp., Battelle Memorial Institute, Southwest Research Institute, IIT Research Institute, C. F. Braun and Co., and United States Steel Corporation.

The Task Group reviewed in detail each proposal with emphasis on reactor design. It was concluded that the vessel and recirculating gas system design submitted by IIT could be made to work, and of all the designs was more likely to provide the same gas analysis exposure at any given instant to all samples. On this basis, those present agreed that the IIT proposal was currently favored and with some modifications, such as means of introduction of water vapor, could be made acceptable to the Task Group.

It was decided that F. Schora and A. O. Schaefer should meet with those concerned at IIT to outline requirements that should be included in their final proposal. Among these are:

a. The addition of a second test vessel (time is critical and second vessel will significantly reduce testing time).

b. As part of Phase I, an additional 1000 hr test at 2000 F to include those materials performing favorably at 1800 F.

c. As part of Phase I, an additional 1000 hr test at 1800 F to include welded samples of those materials performing favorably at 1800 F. (Type of welding procedure, sample form, product form, etc., to be defined at future date.)

d. As part of Phase I, an additional two 1000 hr runs, one to include uncoated alloys, the other coated alloys under the following conditions:

Temperature: 1950 F

Pressure: 350 psig

Atmosphere:

	Volume, Percent
Hydrogen	0.01
Nitrogen	79.40
Carbon monoxide	3.00
Carbon dioxide	16.60
Hydrogen sulfide	0.001
Sulfur	0.01
Sulfur dioxide	0.01
Moisture	0.97

This is to be conducted as final part of Phase I.

e. Due consideration should be given as to eventual conversion of the system to include erosion/corrosion tests, fluid bed approach, etc.

Concerning the ceramic coated materials for testing in Phase I, Hulsizer, Pirsh, Schora, Schaefer and Crowly (of American Oil, a new member of the Task Group) will meet to decide what is to be included.

A report prepared by M. E. Komp on "Corrosion in Aqueous Ammonia - Acid Gas Systems" was distributed for review and will be a topic of discussion at the next Task Group Meeting.

F. Literature Search (V. E. Gleason)

Annotated literature references completed during the month are listed in Appendix C.

G. Outside Engineering and Services

1. Koppers Company, Inc.: Koppers continues to provide engineering assistance as required and as reported in their Progress Report No. 34 in Appendix D.

2. Brigham Young University: The project entitled "Study of High Rate, High Temperature Pyrolysis of Coal" with joint funding by Brigham Young University and BCR is now in its fourteenth month. Figure 139, Monthly Progress

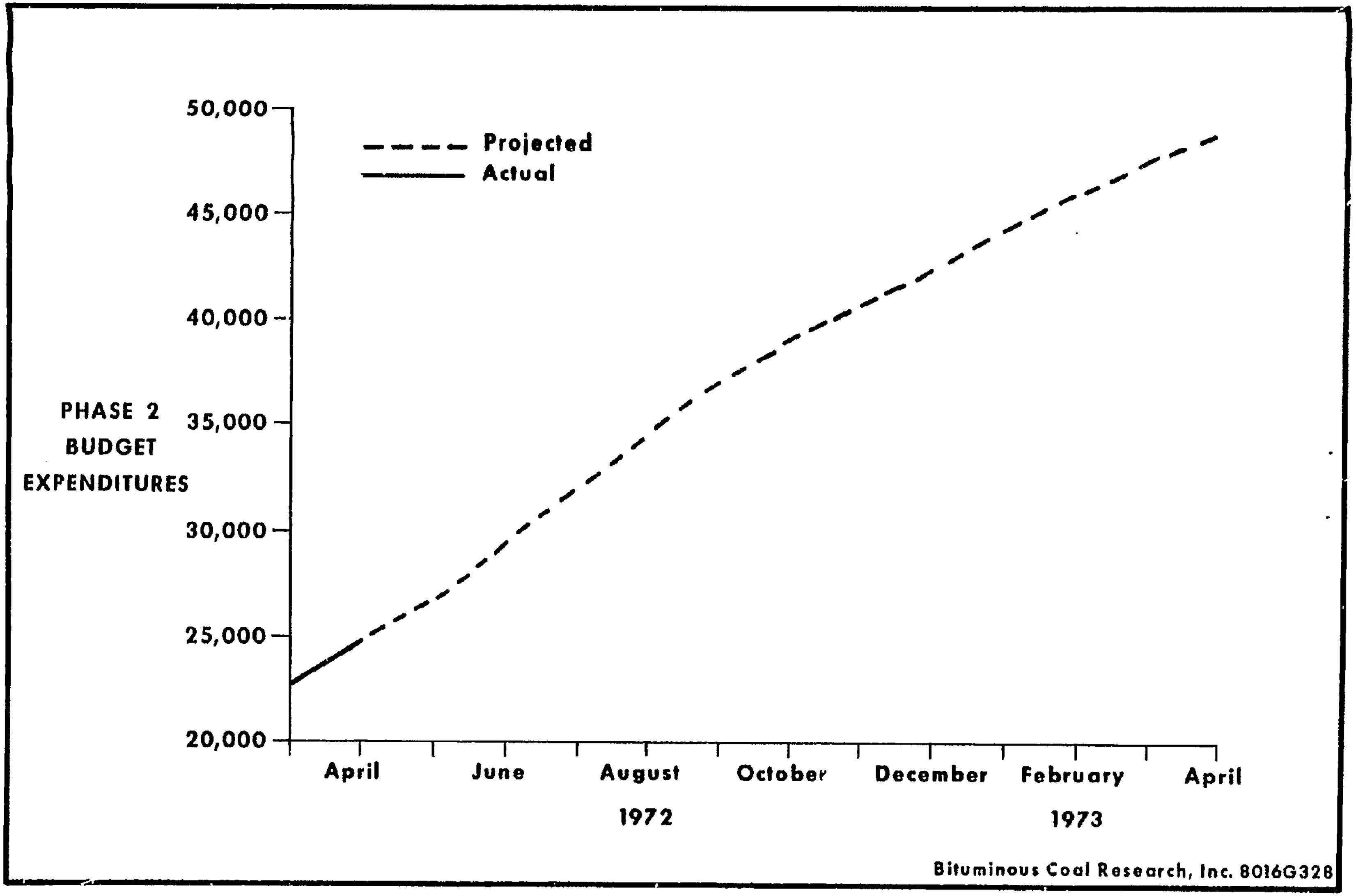

Figure 139. Monthly Progress Chart, Expenditures, Brigham Young University

Chart, Expenditures, shows the current budget status. The letter report of progress made during May is as follows:

Testing was continued with the 2 x 4-5/8 inch reactor equipped with a gas filtration system and a meter to measure the volume of gas produced. A total of twenty-eight tests were made. Five of the tests were made with a 50/50 mixture of coal and spent cracking catalyst and the remainder with straight coal.

The coal presently being used is from the same source but from a different lot of material. Since the ash analysis is higher than in the previous lot, 7.1 percent compared with 6.6 percent, the composition is not the same as previously reported. An ultimate analysis will therefore be made of the coal presently being used.

The tests with the coal/catalyst mixture produced gases very similar in composition to those from tests with straight coal, indicating very little effect of the catalyst. Tests with catalyst made during April indicating high concentrations of acetylene and ethylene in the product gas could not be reproduced.

For the straight coal tests, a procedure was devised in which a series of tests was made at a fixed coal feed rate with the combustion gas flow rate being systematically varied. Coal feed rates of 0.7, 1.06, 1.26, 1.59, and 2.05 pounds per hour were tested at combustion oxygen/coal ratios ranging from 0.33 to 1.00. Product gas volumes were measured and char samples were collected during a two or three-minute portion of the test. Raw data from all of the tests completed during the period are reported in Table 116.

Because of the time required to reduce the large amount of test data being accumulated, a computer program is being developed for data reduction. This program is nearly operational, and a detailed analysis of the data obtained during this period will be presented in the next report. Preliminary analysis of the data shows that the optimum yield of hydrocarbon gases (methane, ethylene, and acetylene) is approximately 20 percent by weight of the carbon fed. Approximately 10 percent is converted to methane, 8 percent to acetylene, and 2 percent to ethylene. The combustion oxygen/coal ratio at the optimum conversion point is 0.67. The conversion of carbon to carbon monoxide at this ratio is approximately 40 percent. The preliminary analysis has also shown that a substantial fraction of the steam resulting from the combustion of hydrogen and oxygen is decomposed to carbon monoxide and hydrogen.

Some difficulty was encountered during the latter part of this period with the electrical heaters which are employed to reduce energy loss from the reactor. The heating elements of one section became shorted out. Replacement elements have been received and testing will be resumed during the week of June 5.

During the next period, a long duration test at optimum feed conditions is planned to provide accurate material balance data and verify the data from the 3-minute duration runs. Further testing of the 1-1/4 inch reactor is also planned to provide additional data for residence time effects.

TABLE 116. SUMMARY DATA FOR TESTS IN 2 x 4-5/8

Test No.	4/28/1		5/1/1	5/1/2	5/3/1		
Reactor Size	2		2	2	2		
Objective:	Mixed coal and catalyst (50/50) in coal feeder bin. Check high yields of ethylene and acetylene in prior runs		Obtain gas sample with comb. gas off	Use same gas setting as 4-28 increase coal and catalyst (50/50) feed rate	Inject coal and catalyst mixture (50/50) at low oxygen/coal ratio		R g U c
Feed Rates lbs/hr							
Coal	1.49		1.77	2.20	1.47		
Hydrogen Carrier	0.12		0.12	0.12	0.12		
Hydrogen Combustion	0.15		0.00	0.15	0.082		
Oxygen	1.20		0.00	1.2	0.80		
Catalyst	1.49		1.77	2.20	1.47		
Ratio Oxygen/Coal	0.81		0.00	0.55	0.54		
Reactor Temp. °F	1845	1875	2400-2200		1790 -	1740	
Run Time Minutes	9		1	2	1.5+2		
Char Amount, lbs.	0.097*				0.0606		
Dry Gas Volume, SCF	2.51*				1.25		
Gas Sample Port	Reactor	Quench	Reactor bottom	Reactor bottom	Reactor	Quench	F
Gas Analysis (uncorrected)							
Hydrogen	69.03	66.89	71.88	69.03	71.16	64.76	
Oxygen	0.80	1.18	0.28	2.13	1.28	1.84	
Nitrogen	2.60	3.85	1.11	2.15	0.45	6.63	
Methane	3.49	3.39	9.43	4.62	4.62	3.77	
Carbon Monoxide	17.39	16.09	7.75	13.48	15.07	12.32	
Ethane	.01	.03	0.36	0.13	0.06	0.04	
Ethylene	1.04	1.09	2.78	1.39	1.63	1.35	
Carbon Dioxide	3.44	3.22	1.47	9.99	1.92	2.00	
Acetylene	1.51	1.57	0.25	0.19	1.48	1.29	
Ash Analysis							
Coal + Catalyst	50.0				7.1*		
Char	70.2				67.0		
Comments:	*Char and gas volume resulting from 3 minutes of run time. No plugging apparent.		Heated reactor to 2400°F, injected coal for 1 min. Took gas sample from bottom of reactor. No char sample taken.	Ran for 2 minutes during which took gas sample from bottom of reactor. No char sample taken.	Shut down for one minute to burn out reactor. Restarted coal/cat feed for char sample, gas meter reading. Ran for 2 min. Temp. 1690-1680°F.		

* Coal only

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IN 2 x 4-5/8 INCH REACTOR, MAY, 1972

5/3/1 2		5/3/2 2		5/4/1 2		5/4/2 2		5/4/3 2
, coal and -t mixture) at low /coal ratio		Reduce combustion gas feed further. Use same coal/catalyst feed.		Put straight coal back in feeder to feed coal at constant rate and vary combustion gas feed rate in steps.		Same feed as 5/4/1, but reduced combustion flow.		Same coal feed as 5/4/1, but reduced combustion flow.
1.47		1.47		2.05		2.05		2.05
0.12		0.12		0.082		0.082		0.082
0.082		0.066		0.155		0.129		0.083
0.80		0.52		1.38 (rich)		1.04		0.68
1.47		1.67						
0.54		0.35		0.68		0.51		0.33
-	1740	1680 -	1390	2110		2140 -	1980	
1.5+2		1 +	1'10"	3		3	3	2
.0606		0.0254		0.041		0.039	0.039	0.0247
1.25		0.62		3.25		3.36	3.36	1.24
or	Quench	Reactor	Quench	Reactor bottom	Quench	Reactor bottom	Quench	Quench
5	64.76	70.7	71.6	58.36	57.63	64.63	40.62	64.19
3	1.84	1.10	0.12	0.94	0.99	0.50	8.78	0.30
[illegible]	6.63	4.20	0.76	3.07	3.31	2.03	30.71	0.98
[illegible]	3.77	4.62	4.05	2.32	3.16	4.11	2.32	6.33
	12.32	8.26	10.06	28.69	29.52	19.24	11.94	16.42
5	0.04	0.24	0.23		0.02			0.11
3	1.35	1.78	1.67	0.05	0.42	0.50	0.4	1.69
[illegible]	2.00	1.47	1.69	3.17	3.26	2.16	1.17	1.58
3	1.29	0.31	0.58	0.88	1.64	2.26	1.33	1.30
7.1* 67.0		7.1* 64.7			7.1*		7.1* 14.41	7.1* 10.6
down for one to burn ctor. Re- coal/cat r char , gas reading. or 2 min. 1690-1680°F.		Ran for 1 minute; took gas from reactor. Repeat with char valve on. Ran for 1 minute, 10 sec. gas meter reading. Took quench gas and char samples.					Pressure started to raise, shut off, change gas filter, turn back on for 1 1/2 min.	

2

TABLE 116. SUMMARY DATA FOR TESTS IN 2 x 4-5/8 INC

Test No. Reactor Size	5/5/1 2	5/5/2 2	5/5/3 2	5/5/4 2	5/8/1 2
Objective:	Reduce coal feed rate to 8 gm/min. Run series similar to 5-4.				Feed coal at 12 gm/min. Reduce oxygen coal ratio in steps
Feed Rates lbs/hr					
Coal	1.06	1.06	1.06	1.06	1.59
Hydrogen Carrier	0.082	0.082	0.082	0.082	0.082
Hydrogen Combustion	0.086	0.071	0.057	0.051	0.133
Oxygen	0.67	0.55	0.44	0.38	1.05
Ratio Oxygen/Coal	0.67	0.50	0.40	0.33	0.66
Reactor Temp. °F	1980-1950	1570-1520	1540-1480	1540-1510	1980-
Run Time Minutes	3	3	3	3	3
Char Amount, lbs.	0.0194	0.0172	0.01455	0.01146	.0275
Dry Gas Volume, SCF	1.605	1.45	1.319	1.265	2.302
Gas Sample Port	Quench	Quench	Quench	Quench	Quench
Gas Analysis (uncorrected)					
Hydrogen	63.96	67.40	68.50	68.37	69.54
Oxygen	1.61	0.56	0.46	0.61	0.16
Nitrogen	3.75	1.12	0.88	1.68	0.45
Methane	4.28	4.62	5.18	5.07	3.85
Carbon Monoxide	18.57	15.79	12.92	12.06	20.79
Ethane	0.02	0.07	0.08	0.12	0.01
Ethylene	0.85	1.34	1.35	1.43	0.64
Carbon Dioxide	1.21	1.33	1.13	1.06	2.51
Acetylene	1.34	0.96	0.75	0.68	1.80
Ash Analysis					
Coal	7.1	7.1	7.1	7.1	7.1
Char	9.9	10.9	11.8	9.5	15.8

Comments:

2 x 4-5/8 INCH REACTOR, MAY, 1972 (Continued)

5/8/1	5/8/2	5/8/3	5/8/4	5/11/1	5/11/2
2	2	2	2	2	2
Feed coal at 12 gm/min. Reduce oxygen/coal ratio in steps				Test feed rate lower than 1 lb/hr of coal	
1.59	1.59	1.59	1.59	0.697	0.697
0.082	0.082	0.082	0.082	0.052	0.052
0.133	0.101	0.073	0.063	0.0805	0.062
1.05	0.80	0.60	0.54	0.7	0.47
0.66	0.50	0.38	0.33	1	0.67
1980-1930	1820-1680	1680-1450	1510-1380	2020	1870-1740
3	3	3	3	3	3
.0275	.0253	.0262	.0251	0.0139	0.00948
2.302	1.884	1.597	1.551	1.675	1.017
Quench	Quench	Quench	Quench	Quench	Quench
69.54	69.84	71.38	71.38	54.34	72.92
0.16	0.42	0.32	0.20	0.16	0.15
0.45	1.33	1.15	0.79	23.90	0.26
3.85	5.03	5.46	5.14	1.73	4.66
20.79	18.40	15.57	14.79	14.69	16.04
0.01	0.05	0.15	0.16		0.025
0.64	1.26	1.79	1.56	0.11	1.176
2.51	2.07	1.75	1.50	1.61	1.66
1.80	1.59	1.17	0.86	0.94	1.23
7.1	7.1	7.1	7.1	7.1	7.1
15.8	12.2	13.3	9.3	12.2	8.11

2

TABLE 116. SUMMARY DATA FOR TESTS IN 2 x 4-5/8 IN

Test No. Reactor Size	5/11/3 2	5/11/4 2	5/12/1 2	5/12/2 2	5/12/3 2
Objective:			Obtain data at oxygen/ coal ratio of 0.8,0.7		Obtain data at reduced coal feed rate
Feed Rates lbs/hr					
Coal	0.697	0.697	1.59	1.59	1.26
Hydrogen Carrier	0.052	0.052	0.082	0.082	0.082
Hydrogen Combustion	0.051	0.0415	0.155	0.133	0.1545
Oxygen	0.38	0.32	1.26	1.05	1.25
Ratio Oxygen/Coal	0.55	0.46	0.79	0.67	1.0
Reactor Temp. °F	1740-1540	1600-1360	2250-2230	2080-2070	2120-2[illegible]
Run Time Minutes	3	3	3	3	3
Char Amount, lbs.	0.00893	0.0086	0.0212	0.0256	0.022
Dry Gas Volume, SCF	0.940	0.847	2.689	2.286	2.488
Gas Sample Port	Quench	Quench	Quench	Quench	Quench
Gas Analysis (uncorrected)					
Hydrogen	74.45	74.76	68.00	68.77	73.84
Oxygen	0.19	0.17	0.21	0.26	0.81
Nitrogen	0.51	0.73	0.58	0.75	2.80
Methune	4.98	5.48	2.67	3.27	2.73
Carbon Monoxide	13.80	12.21	23.82	19.68	23.86
Ethane	0.08	0.19	0.01	--	--
Ethylene	1.29	1.70	0.23	0.92	0.22
Carbon Dioxide	1.79	1.68	2.81	2.54	4.37
Acetylene	0.53	0.37	1.26	1.21	1.69
Ash Analysis					
Coal	7.1	7.1	7.1	7.1	7.1
Char	13.8	9.1	18.0	15.5	17.0

Comments:

2 x 4-5/8 INCH REACTOR, MAY, 1972 (Continued)

5/12/3	5/12/4	5/12/5	5/16/1	5/16/2	5/16/3
2	2	2	2	2	2
Obtain data at reduced coal feed rate			Repeat of 5/12 tests		
1.26	1.26	1.26	1.26	1.26	1.26
0.082	0.082	0.082	0.082	0.082	0.082
0.1545	0.113	0.106	0.14	0.113	0.094
1.25	1.0	1.86	1.26	1.00	0.84
1.0	0.80	0.67	1.0	0.79	0.67
120-2100	2060-2050	2080-2010	2220-2240	2040-2070	1990-1970
3	3	3	2	2	3
0.022	0.0236	0.0207	0.0075	0.0126	0.0167
2.488	2.015	1.087	2.144	2.113	1.811
Quench	Quench	Quench	Quench	Quench	Quench
73.84	26.10	82.89	70.56	69.84	76.32
0.81	13.28	0.54	0.36	0.58	0.55
2.80	46.30	1.90	1.06	2.04	2.00
2.73	2.93	3.51	1.82	3.32	4.18
23.86	16.17	18.94	23.86	19.66	22.01
--	--	0.01	--	--	--
0.22	0.44	0.41	0.07	0.40	0.80
4.37	2.21	2.81	2.07	1.75	3.31
1.69	1.19	2.17	0.83	1.52	2.69
7.1	7.1	7.1	7.1	7.1	7.1
17.0	13.8	14.8	15.4	13.0	14.3
			Gas meter reading questionable	Gas meter reading questionable	Gas meter reading questionable

2

H. Other

1. Prime Contract Matters: In accordance with Mr. Thurberg's letter of April 18, we are proceeding to develop a list of all nonexpendable equipment on the inventory as of the expiration date of Contract No. 14-01-0001-324. This list will indicate which equipment should be transferred to Contract No. 14-32-0001-1207 or declared as scrap.

2. FPC National Gas Survey - Economics of Manufacturing SNG from Coal: In the meeting of March 27, 1972, OCR requested that BCR work up new total plant investment and gas costs for a non-caking, low-sulfur western coal such as Montana subbituminous coal. IGT supplied to BCR for this engineering study the following Montana subbituminous coal analysis:

Proximate Analysis, as-received, Wt Percent

Moisture	22.0
Volatile Matter	29.4
Fixed Carbon	42.6
Ash	6.0
	100.0

Ultimate Analysis (dry), Wt Percent

Carbon	67.70
Hydrogen	4.61
Nitrogen	0.85
Oxygen	18.46
Sulfur	0.66
Ash	7.72
	100.00

Dry Heating Value, Btu/lb	11,290 observed
	11,300 calculated

After receiving the above coal analysis, BCR calculated the material and energy balance using BCR computer program printout as shown in Table 117. Using the BCR computer printout as a basis to prepare a plant design and gas cost estimates for the manufacture of SNG from coal using the BCR/OCR BI-GAS coal gasification process to produce 250 MM scfd of pipeline gas, Air Products and Chemicals, Inc. (APCI) was contacted on April 7, 1972. A visit was made to APCI on April 25, 1972, to review and confirm the engineering study to date using the Montana subbituminous coal.

On May 1, 1972, Air Products issued the completed report[1] to BCR and copies were mailed on May 5, 1972, to OCR for review. In this study, the

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[1] "Economics of Manufacturing SNG by BCR/OCR BI-GAS Coal Gasification Process Using Montana Subbituminous Coal."

TABLE 117. RESULTS FOR GASIFICATION OF MANTANA SUBBITUMINOUS COAL

```
MAR. 31, 1972                                                    REQUEST NO. 34

==============================================================================
                       STAGE 1,   SET YIELD  MODEL
                   YIELD= 60.0 %,   COMBUSTION TEMP.= 2700. F

   STREAM                  TEMP. F        FLOW, LBS         ENERGY, BTU/1000
                                                         SENSIBLE      FORMATION
IN  CHAR                     800.            86.7          11.88          24.40
    TRANSPORT                  0.             0.0           0.0            0.0
    STEAM                   1000.            42.8          19.05        -247.87
    OXIDIZER                 800.            49.2           8.31           0.0
    TOTAL                                   178.8          39.24        -223.46

OUT GAS                     2700.           135.7         135.89        -373.51
    CHAR                    2700.            34.7          32.61           9.76
    SLAG                    2700.             8.4           6.02           0.0
    LOSS                                                    5.00
    TOTAL                                   178.8         179.52        -363.75

==============================================================================
                       STAGE 2,   SET YIELD  MODEL
            CH4 YIELD= 20.5 %, CO YIELD= 20.0 %, RES. TIME=  0. SEC.

   STREAM                  TEMP. F        FLOW, LBS         ENERGY, BTU/1000
                                                         SENSIBLE      FORMATION
IN  STAGE 1 GAS             2700.           135.7         135.89        -373.51
    STAGE 1 CHAR            2700.            34.7          32.61           9.76
    STEAM                   1000.            27.2          12.07        -157.08
    COAL(AS REC'D)           260.           109.8           6.34        -129.20
    TRANSPORT                  0.             0.0           0.0            0.0
    TOTAL                                   307.3         186.92        -650.03

OUT GAS                     1550.           220.6         135.82        -660.59
    CHAR                    1550.            86.7          36.76          24.40
    LOSS                                                    0.50
    TOTAL                                   307.3         173.08        -636.19

==============================================================================
                       SOLIDS ANALYSES, WT. PERCENT                  BTU/LB
                   H      O      C      N      S     ASH   H2O   V.M.  GROSS   NET

CHAR              0.0    0.0   83.9    0.0    0.0   16.1   0.0    0.0 12120. 12120.
COAL(AS REC'D)    4.5   18.2   66.8    0.8    0.6    7.6   1.3    0.0 11150. 10706.
==============================================================================
                       GASEOUS ANALYSES, VOL. PERCENT
                     M.W.  H2     O2     CO     CO2    CH4    H2O    N2     H2S

    STAGE 1 GAS     22.52 21.24   0.0   48.68 11.69   0.0   18.26   0.13   0.0
    STAGE 2 GAS     21.82 23.28   0.0   29.89 18.17 12.39   15.64   0.40   0.22
    TRANSPORT        0.0   0.0    0.0    0.0   0.0    0.0    0.0    0.0    0.0
    TRANSPORT        0.0   0.0    0.0    0.0   0.0    0.0    0.0    0.0    0.0
    OXIDIZER        31.98  0.0   99.50   0.0   0.0    0.0    0.0    0.50   0.0
==============================================================================

                 TOTAL DRY GAS, SCF                        3234.
                 GROSS DRY GAS HEATING VALUE, BTU/SCF       422.
                 NET DRY GAS HEATING VALUE, BTU/SCF         386.

          PRESSURE=  80. ATM.          WITHDRAWL=  0. %
```

Rectisol acid gas removal system was substituted for the Benfield hot carbonate system and the subbituminous coal was received at the plant battery limits cleaned and crushed to a size of 1-1/2 inch x 0.

The substitution in this study of the Rectisol acid gas removal system for the Benfield hot carbonate system has eliminated the need for the molecular sieve system proposed in APCI's original study[2] on West Kentucky No. 11 bituminous coal. This results from the high selectivity of the Rectisol solution, which reduces the sulfur dioxide equivalent contamination in the acid gas effluent to a permissible level. In addition, because of the increased concentration of hydrogen sulfide in the feed to the Claus plant, a reduction in the investment costs for the Claus and Wellman-Lord plants results. Likewise, a more precise cost estimate was made by APCI for oxygen compression requirements.

In view of the pronounced cost reduction in the on-site investment costs by the substitution of the Rectisol acid gas removal system for the Benfield hot carbonate system in the Montana coal study, BCR requested Air Products to make a revised investment and capital requirements cost of an earlier study[3] made by BCR using Western Kentucky No. 11 coal. Using the results of APCI study as shown in Table 118, BCR has calculated the operating costs and average gas price for the Western Kentucky No. 11 coal at 30 cents/MM Btu and submitted the results in a report[4] to OCR with a letter of transmittal dated May 19, 1972.

The results of the engineering cost study by APCI and BCR are summarized in Table 119 and Table 120 for the plant investment, capital requirements, and summary of gas costs for the manufacture of SNG from Montana subbituminous and Western Kentucky No. 11 coal using the BCR/OCR BI-GAS coal gasification process to produce 250 MM scfd of pipeline gas.

3. Patent Matters A report on the status of BCR suggestions and invention disclosures was submitted to Mr. George Fumich on March 27, 1972. Worthwhile ideas continue to be written as invention disclosures for submission to OCR for consideration. Action taken on Disclosures is as follows:

a. OCR-866 and OCR-1078: A U.S. patent application entitled "Gasification of Carbonaceous Solids," and containing nine claims, was filed together with Assignment on September 22, 1971, and given Serial No. 182,652.

Patent applications have been filed in Australia, India, South Africa, Canada, and Great Britain, and applications are being prepared for filing in France, Japan, and West Germany. Confirmatory license to the government was executed by BCR on January 12, 1972.

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[2] "Engineering Study and Technical Evaluation of the Bituminous Coal Research, Inc., Two-stage Super Pressure Gasification Process," R and D Report No. 60. Available from Superintendent of Documents, GPO, Washington, D. C.

[3] BCR report "Economics of Manufacturing SNG by BCR/OCR BI-GAS Coal Gasification Process," Feb. 1, 1972.

[4] BCR report "Economics of Manufacturing SNG by BCR/OCR BI-GAS Coal Gasification Process using Western Kentucky No. 11 Bituminous Coal," May 18, 1972.

TABLE 118. REVISED INVESTMENT & CAPITAL REQUIREMENTS OF THE BCR TWO-STAGE SUPER-PRESSURE GASIFICATION PROCESS UTILIZING A RECTISOL ACID GAS SYSTEM

TASK FORCE EVALUATION METHOD OF COST ANALYSIS
COST BASIS: 30¢/MM BTU COAL - W. KENTUCKY NO. 11 BITUMINOUS

A. TOTAL PLANT INVESTMENT AND CAPITAL REQUIREMENTS - MID-1971

1. Process Onsite Investment	
Coal Storage and Preparation*	$ 14,300,000
Pretreatment	--
Feed System	6,600,000
Gasification & CO Shift	20,300,000
Gas Purification	21,800,000
Methanation	12,400,000
Compression	--
2. Auxiliary Onsite Investment	
Oxygen Manufacture	32,000,000
Sulfur Recovery	5,900,000
Water Pollution Control	10,000,000
3. Steam and Power Investment	17,800,000
4. General Utilities Investment	14,000,000
5. General Offsites Investment	10,000,000
Subtotal Ex. Contingencies	$165,600,000
Project Contingency	24,800,000
Development Contingency	11,600,000
Total Plant Investment	$202,000,000
6. Capital Requirement Breakdown	
Total Plant Investment	$202,000,000
Interest During Construction	34,100,000
Startup Costs	10,900,000
Working Capital	11,300,000
Total Capital Requirement	$258,300,000
Adjustment to 250 MMM BTU/SD	$273,500,000

* Kentucky No. 11 Bituminous Coal cleaned and crushed to a size of 1 1/2 inch x 0 at the battery limits and includes added $2 MM allowance for particulate emission control.

TABLE 119. PLANT INVESTMENTS AND CAPITAL REQUIREMENTS -- BCR/OCR BI-GAS PROCESS FOR SYNTHETIC GAS-COAL TASK FORCE REVIEW

Timing: Mid-1971 Startup Completion

	Montana Subbituminous Coal	West Kentucky No. 11 Bituminous Coal
Plant Size, Billion Btu/SD Pipeline Gas	237.0	236.1
Investment Breakdown, MM$:		
Process Onsites Investment		
Coal Storage & Preparation*	14.3	14.3
Pretreatment	--	--
Feed System	6.6	6.6
Gasification & CO Shift	20.6	20.8
Gas Purification	21.8	21.8
Methanation	12.4	12.4
Compression	--	--
Auxiliary Onsites Investment		
Oxygen Manufacture	32.0	32.0
Sulfur Recovery	2.0	5.9
Water Pollution Control	10.0	10.0
Steam and Power Plant Investment	17.8	17.8
General Utilities Investment	14.0	14.0
General Offsites Investment	10.0	10.0
Subtotal Ex. Contingencies	161.5	165.6
Project Contingency	24.1	24.8
Development Contingency	11.3	11.6
Total Plant Investment	196.9	202.0
Capital Requirement Breakdown, MM$:		
Total Plant Investment	196.9	202.0
Interest During Construction	33.2	34.1
Startup Costs	8.1	10.9
Working Capital	8.1	11.3
Total Capital Requirement	246.3	$ 258.3
Adjusted for 250 Billion Btu/SD	259.8	$ 273.5

* Coal storage and preparation investment includes added $2 MM allowance for particulate emission control and coal cleaned and crushed to a size of 1 1/2 inch x 0 at the battery limits.

TABLE 120. SUMMARY OF GAS COSTS--BCR/OCR BI-GAS PROCESS FOR SYNTHETIC GAS-COAL TASK FORCE REVIEW

Gas Costs, $/MM Btu	Montana Subbituminous Coal	West Kentucky No. 11 Bituminous Coal
For Mid-1971 Startup Completion		
20-year Average Cost without escalation	.843	1.086
20-year Average Cost with escalation	.981	1.293
Constant Cost @ 12% DCF return without escalation	1.058	1.312
with escalation	1.161	1.465
For Mid-1975 Startup Completion		
20-year Average Cost without escalation	.954	1.238
20-year Average Cost with escalation	1.070	1.410
Constant Cost @ 12% DCF return without escalation	1.189	1.485
with escalation	1.272	1.606
For Mid-1980 Startup Completion		
20-year Average Cost without escalation	1.070	1.384
20-year Average Cost with escalation	1.198	1.574
Constant Cost @ 12% DCF return without escalation	1.338	1.666
with escalation	1.430	1.801

b. OCR-1860 and OCR-1861: These disclosures were combined into a single patent application entitled "Two-stage Gasification of Pretreated Coal." This application, containing 12 claims, was filed together with Assignment on March 23, 1972, and given Serial No. 237,332.

Patent applications are being prepared for filing in France, West Germany, and Japan. Confirmatory license was executed by BCR on May 8, 1972.

c. OCR-1862: A U.S. patent application entitled "Three Stage Gasification of Coal," and containing eight claims, was filed together with Assignment on March 23, 1972, and assigned Serial No. 237,333.

Patent applications are being prepared for filing in France, West Germany, and Japan. Confirmatory license was executed by BCR on May 8, 1972.

d. OCR-1863: A U.S. patent application was prepared for this disclosure entitled "Two-stage Downflow Gasification of Coal." This application, containing seven claims, was filed together with Assignment on March 23, 1972, and given Serial No. 237,454.

Applications are being prepared for filing in France, West Germany, and Japan. Confirmatory license was executed by BCR on May 8, 1972.

e. OCR-1864: A U.S. patent application entitled "Two-stage Gasification of Coal with Forced Reactant Mixing and Steam Treatment of Recycled Char," was prepared for this disclosure. The application contains 13 claims and was filed on March 23, 1972, together with the Assignment, and assigned Serial No. 237,360.

Patent applications are being prepared for filing in France, West Germany, and Japan. Confirmatory license to the government was executed by BCR on May 8, 1972.

f. Invention Disclosure--Brigham Young University: During the course of work under Subcontract No. 3, Professor R. L. Coates, Brigham Young University, developed a new concept of pyrolyzing coal which may be patentable.

An Invention Disclosure (Form DI-1217) entitled "Process for High Temperature Pyrolysis of Coal," was submitted to Mr. George Fumich for his consideration on January 6, 1972. OCR has acknowledged receipt of this disclosure and forwarded it for processing.

4. Reports and Papers. At the request of George Bolton, Columbia Gas, BCR has consented to present a paper on the status of the BI-GAS process at the forthcoming AGA Synthetic Pipeline Gas Symposium, October 30, 1972, at Chicago, Illinois. OCR approval to present this paper was received by letter dated May 22, 1972. An advance copy of the paper will be submitted to OCR when available.

Another request was received from Dr. Everett Gorin, Consolidation Coal Company, for BCR to consider presentation of a paper at the Third International Conference on Fluidized Bed Combustion to be held at Hueston Woods State Park, Ohio, October 29 - November 1, 1972. By letter dated May 30 we apprised OCR of this contact and enclosed a copy of our letter to Dr. Gorin wherein we advised we might be able to present an informative-type paper on the design and experimental plans for the fluidized-bed gasification PEDU that we propose to build at Monroeville. We will await further word from Dr. Gorin as to whether this type of a paper would fit in the program.

I. Visitors During May, 1972

May 1, 1972

Mr. R. A. Wylie
Mr. John Wappler
Mr. R. W. Whiteacre
Mr. S. S. Nakles
Koppers Company, Inc.
Koppers Building
Pittsburgh, Pa. 15219

May 3, 1972

Mr. J. A. Craig
Chevron Research Company
576 Standard Avenue
Richmond, California 94802

Mr. John Mills
El Paso Natural Gas Co.
P.O. Box 1492
El Paso, Texas 79901

May 5, 1972

Mr. R. McGowan
Mr. John Wappler
Koppers Company, Inc.
Koppers Building
Pittsburgh, Pa. 15219

May 8, 1972

Mr. D. M. Mitsak
Koppers Company, Inc.
Koppers Building
Pittsburgh, Pa. 15219

May 11, 1972

Mr. John Rose
Northern Natural Gas Co.
2223 Dodge Street
Omaha, Nebraska 68102

May 15, 1972

Mr. G. Edward Larson
Office of Coal Research
U.S. Department of the Interior
Washington, D. C. 20240

Mr. R. W. Borio
Dr. R. W. Koucky
Combustion Engineering, Inc.
Windsor, Connecticut 06095

May 18, 1972

Mr. Roy Carpe
Mr. R. D. Howell
C. F. Braun and Co.
Alhambra, California

J. Trips, Visits, and Meetings During May, 1972

May 15, 1972	Meeting of Task Group on Materials Evaluation New York, New York	J. P. Tassoney
May 23-25, 1972	INCO Petroleum and Petrochemical Materials and Corrosion Conference Wrightsville, North Carolina	J. P. Tassoney

K. Requests for Information

Mr. K. Nishio
Manager, Coal Department
Nichimen Co., Ltd.
P.O. Box Central 1136
Tokyo, JAPAN

Miss Meribeth Kish
206 McGregor Hall
Indiana, Pennsylvania

Mr. F. H. Cary
Research and Development Division
Grinnell Corporation
Providence, Rhode Island 20901

Dr. James K. Kindig
Senior Research Engineer
Hazen Research, Inc.
4601 Indiana Street
Golden, Colorado

Processes Research, Inc.
2912 Vernon Place
Cincinnati, Ohio 45219

Asst. Professor C. J. Hahn
University of Kentucky
Lexington, Kentucky

III. WORK PLANNED FOR JUNE, 1972

The work planned for June will basically be a continuation of the on-going program which has been underway for the past few months.

The bench-scale methanator will continue to be used to evaluate suitable catalysts. The new life-test unit will be put into operation to evaluate four different catalysts. Cold model studies will be continued using the new catalyst. Bids on equipment for the PEDU will continue to be solicited and evaluated. As approval for purchase is obtained, procurement will begin. Continued emphasis will be placed on acquisition of the necessary permits for construction.

The 6,000 cfm blower for the cold model studies of the 5 ton/hr two-stage gasifier will be used for tests as planned. Char reactivity tests will continue to characterize the various chars to be used in the pilot plant.

The software system for interfacing the bench-scale methanation unit with the PDP8/E computer will continue to be written. Ductwork and wiring will be installed to accommodate the individual signal lines from the methanation unit to the computer system. Simulation runs with subroutine GASIFY will be generated as requested.

Evaluation of bids will continue to obtain a contractor for the 5 ton/hr BI-GAS pilot plant.

Plans will be made for a groundbreaking ceremony on June 23, 1972.

A. Trips and Meetings Planned

None

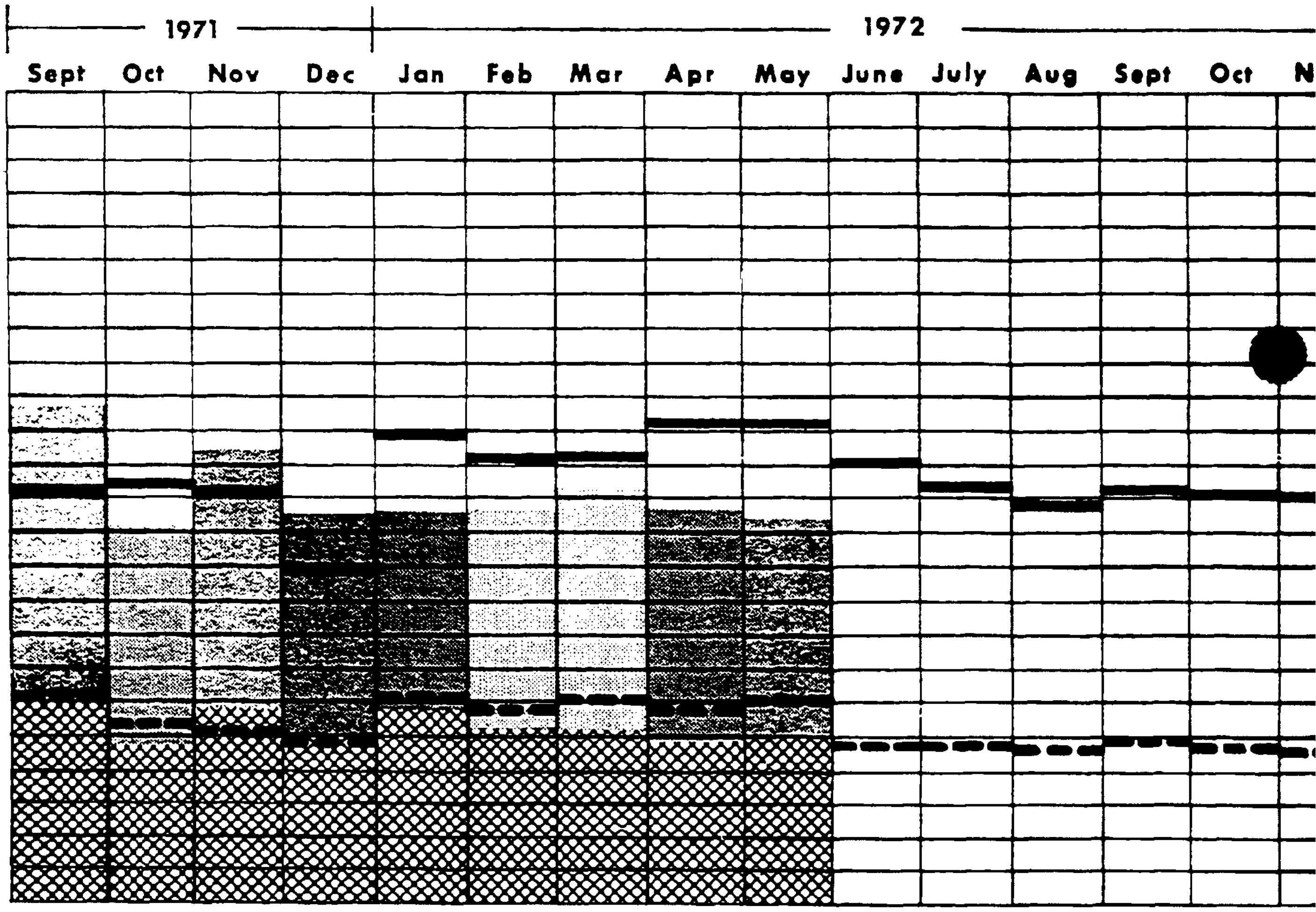
B. Papers to be Presented

October 30, 1972	AGA Synthetic Pipeline Gas Symposium	Chicago, Illinois

C. Visitors Expected

June 5, 1972	Office of Coal Research U.S. Department of the Interior Washington, D. C. 20240	G. E. Larson
June 8, 1972	Office of Coal Research U.S. Department of the Interior Washington, D. C. 20240	Jack E. Ryan Dr. C. L. Miller

MANHOURS


1971
1972
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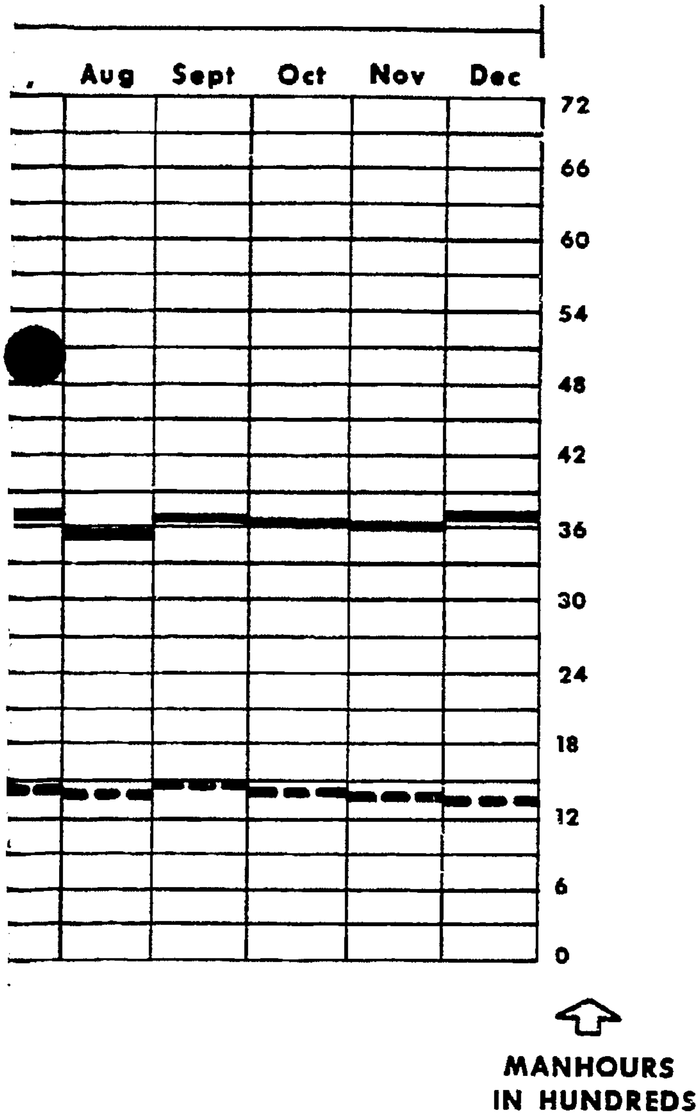
MONTHLY PROGRESS CHART
PART 1 MANHOURS

Bituminous Coal Research, Inc.
350 Hochberg Road Monroeville, Pa.

OFFICE OF COAL RESEARCH
DEPARTMENT OF THE INTERIOR

CONTRACT NO. 14-32-0001-1207



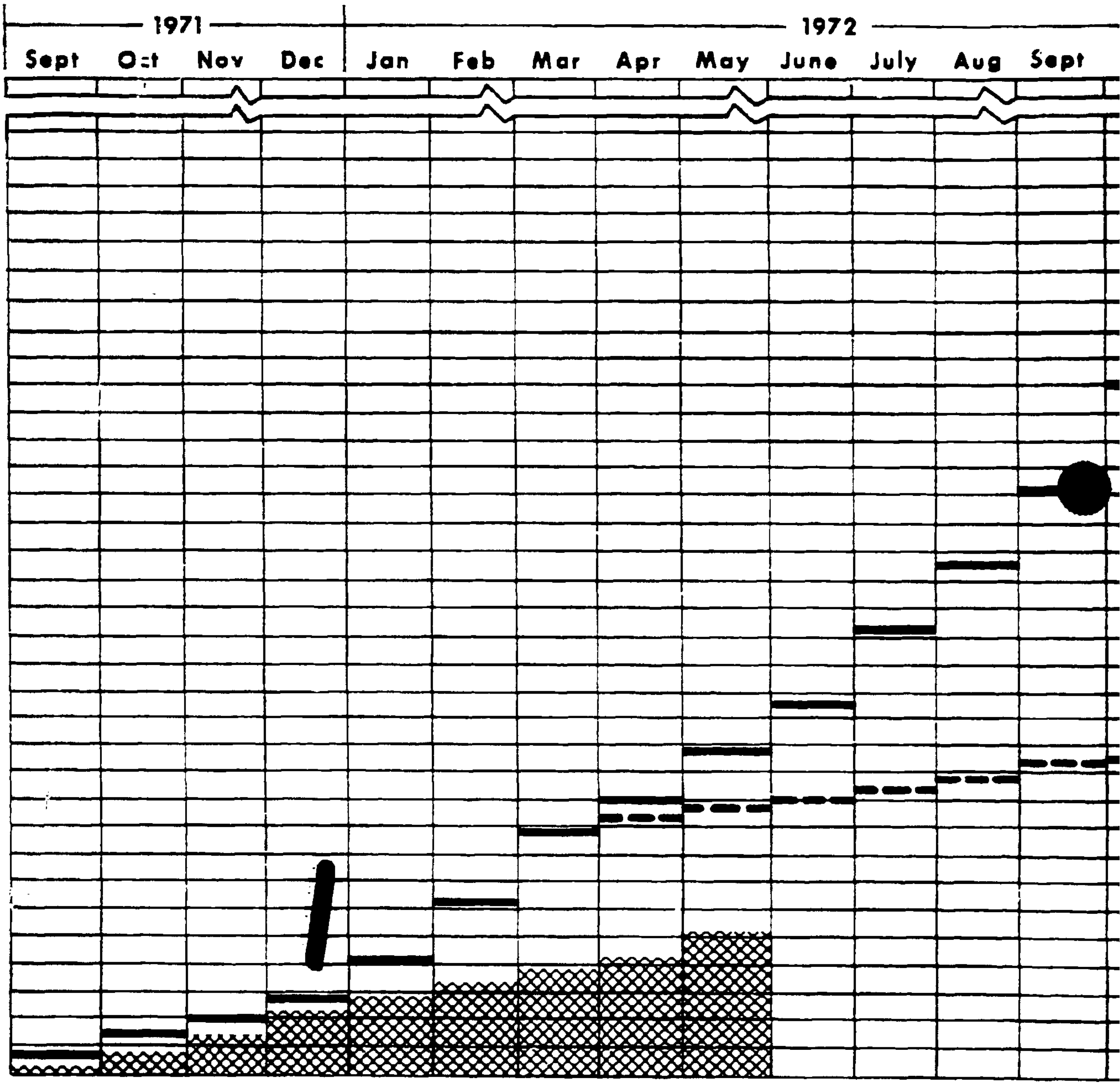
▬ Predicted Professional and Non-professional

▬ ▬ Predicted Professional

☐ Actual Non-professional

▨ Actual Professional

2



MONTHLY EXPENDITURES (All Costs, in Dollars)

		Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Monroeville	**Predicted**	129,991	129,991	129,991	129,991	323,486	382,228	558,454	105,058	86,238
	Actual	63,610	121,696	146,834	144,590*	103,147	86,250*	113,036	50,685*	73,[illegible]
Homer City	**Predicted**								154,000	215,600
	Actual									
Total	**Predicted**	129,991	129,991	129,991	129,991	323,486	382,228	558,454	259,058	301,838
	Actual	63,610	121,696	146,834	144,590*	103,147	86,250*	113,036	50,685*	73,400*

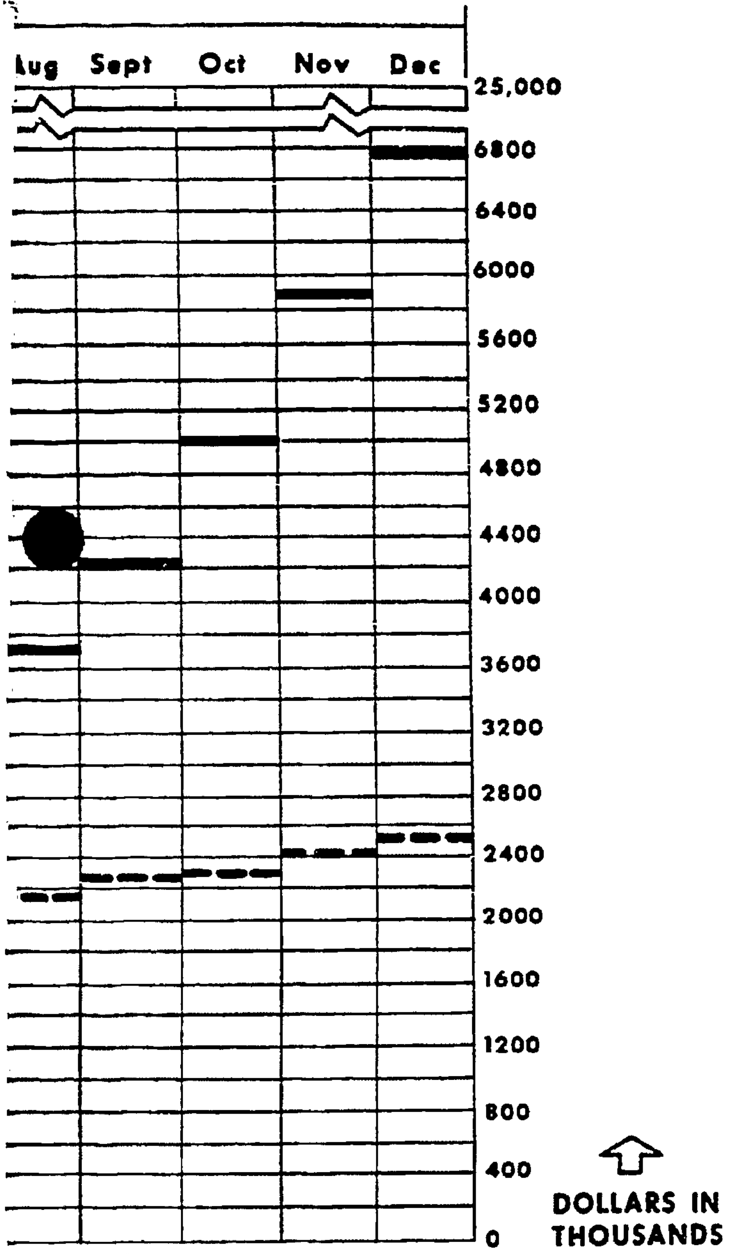
CUMULATIVE EXPENDITURES

MONTHLY PROGRESS CHART
PART 2 EXPENDITURES

Bituminous Coal Research, Inc.
350 Hochberg Road Monroeville, Pa.

OFFICE OF COAL RESEARCH
DEPARTMENT OF THE INTERIOR

CONTRACT NO. 14-32-0001-1207



Expenditures, Cumulative

▨ Actual, Monroeville

☐ Actual, Homer City

Predicted Expenditures, Cumulative

— Total, Monroeville and Homer City

--- Monroeville

2

osts, in Dollars)

	May	June	July	Aug	Sept	Oct	Nov	Dec
[illegible]	86,238	86,240	65,813	65,813	74,746	62,273	62,273	62,275
[illegible]	73,400*							
000	215,600	280,400	444,300	444,300	444,400	760,600	760,600	760,800
,058	301,838	366,640	510,113	510,113	519,146	822,873	822,873	823,075
35*	73,400*							

* Estimated

Appendix B

DEVELOPMENT OF A GRINDABILITY TEST FOR LOW-DENSITY CHARS

Summary

A usable test has been devised to compare the apparent grindability of low-density chars with the ASTM Hardgrove Grindability Index of standard coals. The test consists of grinding a 15 gram, 16 x 100 mesh charge for 22 revolutions in the standard Hardgrove machine. The apparent HGI is determined by comparing the percent minus 200 mesh in the modified tests with the extrapolated curve obtained under ASTM conditions in the Hardgrove machine.

Description of Grindability Index

The ASTM method for determining the Hardgrove Grindability Index (HGI) of a coal consists of grinding a 50 gram, 16 x 30 mesh sample for 60 revolutions in a standard Hardgrove machine in order to determine the amount of minus 200 mesh material produced. Each machine is calibrated with four coals of known HGI which produced amounts of minus 200 mesh material that increase with increasing grindability. The amounts are plotted against the known HGI of the coals to give a calibration curve from which the HGI of unknown coals is determined.

Problems with Low Density Chars

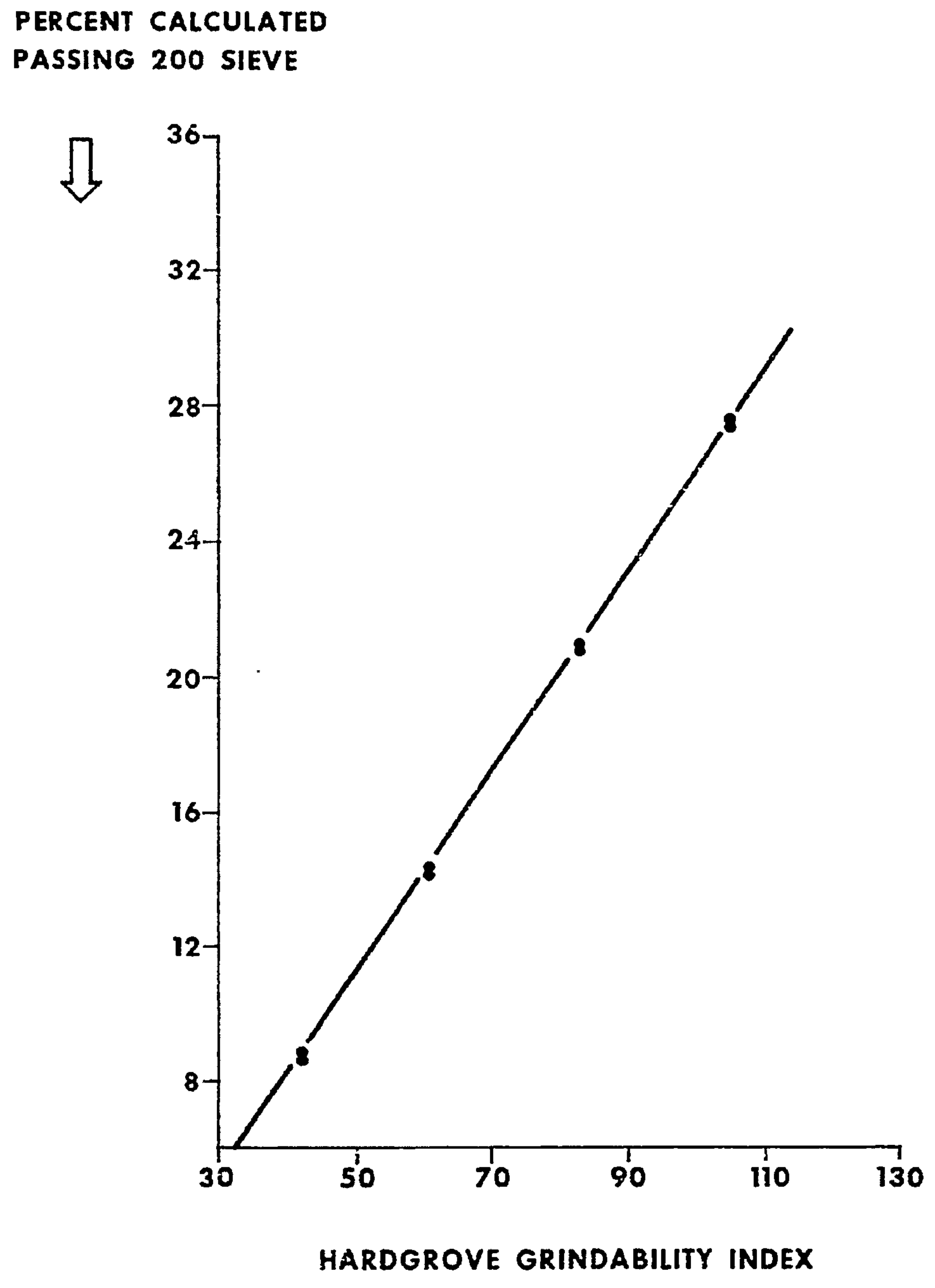
The ASTM procedure was not suitable for determining the HGI of chars produced in the 100 lb/hr PEDU because: (1) a 50 gram charge overfilled the grinding chamber and, (2) some of the chars produced were mostly minus 30 mesh. It was, however, important to try to determine the grindability of these chars to assess the feasibility of pulverizing them while hot and under pressure using jet impact or other applicable techniques.

Details of Test Conducted

1. Calibration of BCR Machine: Standard samples with HGI's of 105, 83, 61, and 42 were prepared, pulverized, and evaluated according to ASTM procedures. The resulting calibration curve is given in Figure 140.

2. Tests with 25 Gram Loads: The standard samples were prepared in 25 gram increments of 16 x 100 mesh material. The samples were pulverized for 30 revolutions to yield "Percent calculated passing 200 size" that matched closely the calibration curve shown in Figure 140.

Samples of PEDU chars produced from the Stage 2 gasification of Pittsburgh seam coal were similarly processed. The "Percent calculated passing 200 size" exceeded 30 percent and gave extrapolated HGI's of approximately 140. A sample of PEDU char produced from subbituminous Elkol seam coal was prepared for similar processing but, due to its lower density, it overflowed the bowl. Therefore, further tests were conducted with 15 gram charges.

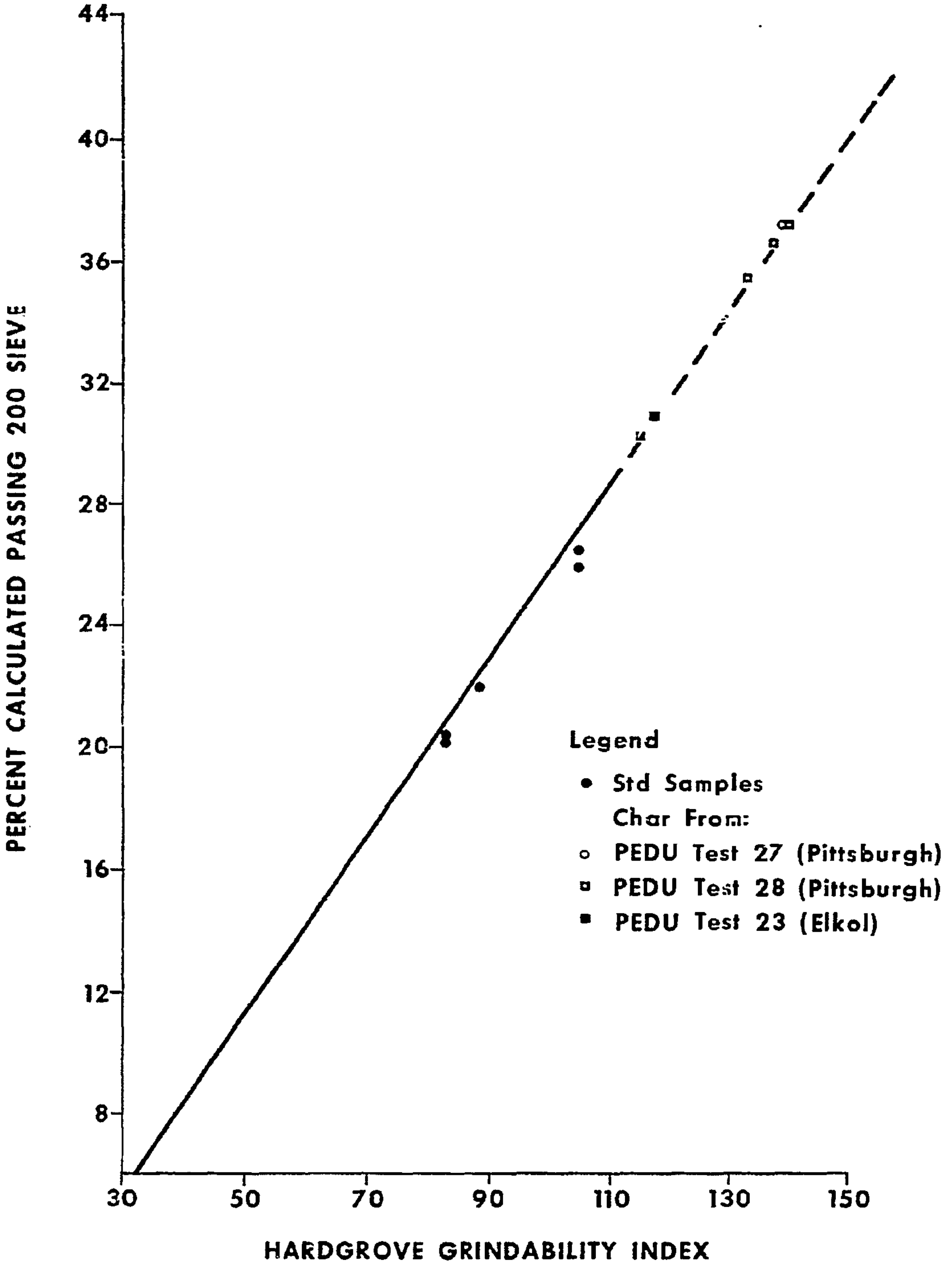


Bituminous Coal Research, Inc. 8016G328

Figure 140. Calibration Curve for BCR Hardgrove Machine

3. Tests with 15 Gram Loads: Tests with 15 gram charges of PEDU chars were pulverized for 18, 25, 23, and 22 revolutions. The product after 22 revolutions of pulverization matched closely the values obtained when 25 grams of the same char was pulverized for 30 revolutions. Additional samples of PEDU chars and standard coals with 105 and 83 grindabilities were then pulverized using the same 15 gram, 30 x 100 mesh size and 22-revolution operation. The results are plotted against the extrapolated calibration curve as shown in Figure 141.

The data from all tests are summarized in Table 121.



Bituminous Coal Research, Inc. 8016G329

Figure 141. Operation of Hardgrove Machine with 15 g Samples

TABLE 121. SUMMARY DATA OF TESTS WITH STANDARD COALS AND PEDU CHARS IN BCR HARDGROVE MACHINE

Test No.	Feed	Weight, Grams	Size	Revolutions	Calculated Percent Passing 200 Sieve
1	STD HGI 105	50	16 x 30	60	27.68
2	STD HGI 105	50	16 x 30	60	27.57
3	STD HGI 83	50	16 x 30	60	20.73
4	STD HGI 83	50	16 x 30	60	20.89
5	STD HGI 67	50	16 x 30	60	14.11
6	STD HGI 67	50	16 x 30	60	14.22
7	STD HGI 42	50	16 x 30	60	8.95
8	STD HGI 42	50	16 x 30	60	8.85
9	STD HGI 105	25	16 x 100	30	27.56
10	STD HGI 105	25	16 x 100	30	27.76
11	STD HGI 83	25	16 x 100	30	21.15
12	STD HGI 83	25	16 x 100	30	21.22
13	STD HGI 61	25	16 x 100	30	15.12
14	STD HGI 61	25	16 x 100	30	16.12
15	STD HGI 61	25	16 x 100	30	16.70
16	STD HGI 61	25	16 x 100	30	15.97
17	STD HGI 42	25	16 x 100	30	10.00
18	STD HGI 42	25	16 x 100	30	10.02
19	PEDU Test 28	25	16 x 100	30	38.74
20	PEDU Test 27	25	16 x 100	30	37.84
21	PEDU Test 23	15	16 x 100	18	27.27
22	PEDU Test 27	15	16 x 100	18	31.65
23	PEDU Test 27	15	16 x 100	18	31.67
24	PEDU Test 28	15	16 x 100	18	31.47
25	PEDU Test 27	15	16 x 100	25	40.73
26	PEDU Test 27	15	16 x 100	23	38.36
27	PEDU Test 27	15	16 x 100	22	37.44
28	PEDU Test 28	15	16 x 100	22	35.81
29	PEDU Test 28	15	16 x 100	22	37.76
30	PEDU Test 28	15	16 x 100	22	36.91
31	PEDU Test 23	15	16 x 100	22	30.99
32	PEDU Test 23	15	16 x 100	22	30.43
33	STD HGI 105	15	16 x 100	22	26.03
34	STD HGI 105	15	16 x 100	22	26.39
35	STD HGI 83	15	16 x 100	22	20.51
36	STD HGI 83	15	16 x 100	22	20.53

Evaluation of the data showed that the PEDU chars had the following HGI's:

PEDU Test 27 (Pittsburgh seam) - 139
PEDU Test 28 (Pittsburgh seam) - 137.
PEDU Test 23 (Elkol) - 117.

Appendix C

ADDITIONS TO ABSTRACT FILE, MAY 1972

Chopey, N. P., "Coal gasification: can it stage a comeback," Chem. Eng. 79 (7), 44-6 (1972). 540.000 Journal

> Both publicly and privately supported programs in development of coal gasification technology are summarized.

Hart, F. E., Baker, N. C., and Williams, I., "CRG route to SNG," Hydrocarbon Process. 51 (4), 94-6 (1972). 540.000 Journal

> Two modifications of the British Gas Council's catalytic rich gas process which produces methane from light hydrocarbon feedstocks are described. In one method all the feed is charged to the first stage reactor yielding a methane rich gas which goes through further reaction stages to produce more methane. In the other method the feed is split equally between a conventional first stage reactor operating in series with a hydro-gasifier.

Jenkins, R. G., Nandi, S. P., and Walker, P. L., Jr., "The reactivity of heat treated coals in air," ACS 163rd National Meet., Boston, Mass., 1972. 17 pp. 023.101 72-1

> A large series of U.S. coals, of widely varying rank, has been carbonized under controlled conditions to 1000° C, and the reactivity in air at 500° C of the resulting chars has been measured by a gravimetric method. The results obtained are found to lie within a quite well-defined band when plotted against the rank of the parent coal. The lower rank coal chars are more reactive than those prepared from high rank coals. In extreme cases the value found for a Montana lignite char is 100 times greater than that obtained for a char of a Pennsylvania low volatile coal. An examination has been made of the variation of reactivity with different heat treatment temperatures (600° C to 1000° C) for three coals. As heat treatment temperature increases there is a decrease in reactivity. Some results are reported of investigations into the effects which mineral matter and pore structure have on the reactivity parameter. It has been found that the partial removal of the mineral matter from low rank coals by acid washing causes the resulting chars to be less reactive. In some cases, as much as a four-fold decrease is reported. (Authors' abstract)

Klingman, G. E. and Schaaf, R. P., "Make SNG from coal?" Hydrocarbon Process. 51 (4), 97-101 (1972). 540.000 Journal

> The gasification technology being used and being developed in the United States is reviewed.

Kunugi, T., Saki, T., and Nishimura, T., "Hydrogenation of CO in a gas/liquid/solid fluidized bed by an iron catalyst," Kogyo Kagaku Zasshi 71, 497-501 (1968). Trans-Chem T111432, Ind. Chem. and Technol. 1971-1. 540.000 68-31

> The synthesis of hydrocarbons by hydrogenation of CO was carried out in a g/l/s fluidized bed which was prepared by suspending precipitated iron catalysts in a heavyweight Fischer synthetic oil. The reactant gases at 1.3-1.5 CO/H_2 mole ratio were blown into the catalyst in the oil suspension at 200-250° C and 3-10 kg/cm^2 gas pressure. Compared to the reaction in a fixed bed using the same catalyst, the reaction in the g/l/s fluidized bed showed no initial activity drop and the activity remained at the level which was observed during the early stage of the reaction. The apparent activation energy, 5-7 kcal/mole, was smaller than that obtained from the fixed bed, which was about 20 kcal/mole. The methane yield in the fluidized bed was very small. The results are attributed to the different rate controlling steps in the two reaction methods and to the degree of local overheating of the catalyst layers. (Author's abstract adapted.)

"Process route: interchangeable SNG-CRG methanation process," The Gas Council Midlands Res. Sta., External Rept. No. 174 (March 1971). 3 pp. 540.000 71-12

> The production of high-methane, low inert gas from LPG and straight-run naphthas boiling up to 365 F is described. Operating conditions and economics are summarized.

"Process route: SNG-recycle hydrogenation process," The Gas Council Midlands Res. Sta., External Rept. No. 175 (March 1971). 4 pp. 540.000 71-13

> The report describes a non-catalytic process for production of purifiable gaseous hydrocarbons which can be catalytically hydrogenated, treated cryogenically or reformed to produce SNG, hydrogen or synthesis gas from crude petroleum distillate fractions boiling up to about 620 F. Yields from butane, light naphtha, and heavy naphtha for SNG containing about 10 percent hydrogen are tabulated. (Adapted from text)

"Process route: SNG-fluidized bed hydrogenation process," The Gas Council Midlands Res. Sta., External Rept. No. 176 (March 1971). 4 pp. 540.000 71-14

This process operates in the pressure range 750-1000 psi depending on the nature of the feedstock. The high heating value gas, after purification, can be catalytically hydrogenated, treated cryogenically or reformed with steam to yield SNG, hydrogen, or synthesis gas. Yields for SNG containing about 10 percent hydrogen are tabulated. (adapted from text)

Robson, F. L., "Electric power - via marriage of chemical and aerospace industries," Chemtech, April, 239-49 (1972).

Clean low-Btu/scf gaseous fuel made from high-sulfur coal or residual oil is proposed for use in advanced cycle power systems. This will help meet both the demand for increased inexpensive electric power and the requirement to conform to stringent emission standards for air pollutants.

PATENTS

Benson, H. E. (to Consolidation Coal Co.) "Method and apparatus for producing mixtures of methane, carbon monoxide, and hydrogen," U.S. Pat. 3,503,724 (March 31, 1970). 7 pp. 540.000 70-26

The invention uses two reaction zones for making high Btu gas at elevated temperatures and pressures from carbonaceous material by the steam-iron process.

Benson, H. E. (to Consolidation Coal Co.) "Gasification of carbonaceous material," U.S. Pat. 3,615,298 (Oct. 26, 1971). 5 pp. 540.000 71-15

The reaction of steam with iron, or lower iron oxides, is conducted in the presence of carbonaceous solids by circulating the steam upwardly in countercurrent flow relationship with downwardly moving iron or lower iron oxides in a fluidized bed of the carbonaceous solids. (Abstract of the disclosure)

Padovani, C., "Process for the production of rich fuel to replace natural gas by means of catalytic hydrogasification under pressure of fluid hydrocarbons," U.S. Pat. 3,625,664 (Dec. 7, 1971). 9 pp. 540.000 71-16

A mixture of methane and hydrogen, which is interchangeable with natural gas, is obtained from liquid hydrocarbons by means of a two step catalytic hydrogenation process under pressure. In the first step a complete gasification, but not a complete hydrogenation, is effected by contacting the liquid hydrocarbons with a mild-hydrogenating catalyst in such a controlled condition of temperature, pressure, hydrogen-to-carbon ratio as to obtain a gas containing 10-60 percent by volume of free hydrogen. In the

second step the gas obtained in the first step is practically completely hydrogenated to methane on a catalyst having high hydrogenating and methanating activity. The resultant product is essentially methane with up to 12 volume percent hydrogen. (Abstract of the disclosure)

APPENDIX D

D-553.

PROGRESS REPORT #34

Bituminous Coal Research, Inc.
Coal Gasification

May 1972

Koppers Contract 2415

I. STATUS OF CONTRACT

A. Pilot Plant Engineering Bid Packages

Step No. 1: Pilot Plant for oxygen-blown, two stage coal gasification system, including general facilities: design and models. For additional information see Part II: Contract Evaluation.

(Work Completed)

Step No. 2: Fluidized bed system.

(Work Deferred)

B. Engineering Assistance And Recommendations For PEDU Program

Methanation PEDU

1. On May 1, 1972 Koppers Structural, Electrical and Project personnel visited BCR to inspect the Methanation PEDU plant site for additional information as regards Structural and Electrical detail engineering. The details of this visit are reported in Conference Report No. 223, dated May 1, 1972.

2. Messrs. E. K. Diehl and M. S. Graboski of BCR visited Koppers offices on May 4, 1972 for an electrical requirements discussion with Koppers personnel, J. DeNelle, J. T. Wappler and R. W. Whiteacre. This meeting is covered in Conference Report No. 224.

3. Mr. M. S. Graboski, BCR, and R. C. Dorsey and R. W. Whiteacre, Koppers, met May 19, 1972 in Koppers offices to review the operation of the Methanation PEDU to determine what changes, if any, would be required to the present design. Major areas of interest concerned the addition of nitrogen purge connections and vent lines at various parts of the system, addition of valves in the gas line from the methanator feed gas receiver to the Thermal Oxidizer

and minor changes to some of the instrument control valves. The hydrogen sulfide feed system was reviewed in the light of providing a means of keeping the storage cylinder at a temperature in excess of 38° F. since at lower temperatures there will be insufficient pressure generated in the H_2S system for introduction into the process gas stream. Details of this meeting are covered in Conference Report No. 225.

4. The following Fluid Bed Methanation PEDU drawings and specifications were transmitted by Koppers Company, Inc., to BCR:

Drawing No.	Rev. No.	Title	Date Trans.
2415-9F304 Shts. 1 to 12 incl.	0	Flow Elements	5/2/72
2415-9F-306	0	Flow Integrator-Pneumatic	5/2/72
2415-9F323	0	Flow Computing Devices	5/2/72
2415-2A725	1	Reformer Feed Gas Receiver (M-V104)	5/2/72
2415-2A729	2	Hydrogen Sulfide Flash Tank	5/2/72
2415-2A735	0	H_2S Removal Towers	5/2/72
2415-2A700	5	PEDU Fluid Bed Methanator Sheet 1 of 2	5/4/72
2415-2A733	2	Plot Plan	5/4/72
2415-9F603 Shts 1 to 4 incl.	0	Temperature Recorders (MV) Alterations	5/4/72
2415-2A722	1	Demister (M-V620)	5/8/72
2415-9F313 Shts. 1 and 2	0	Temperature Indicators - Local	5/8/72
2415-9F305 Shts. 1 and 2	0	Flow Transmitters-Pneumatic	5/8/72
2415-9F307	0	Flow Totalizing Meters	5/9/72
2415-9F317	0	Temperature Transmitters-Electrical	5/9/72

Drawing No.	Rev. No.	Title	Date Trans.
2415-9F600 Shts. 1 to 5 incl.	0	Flow Transmitters-Pneumatic	5/9/72
2415-9F601	0	Flow Totalizing Meter Alterations	5/9/72
2415-6A701	0	Electrical Wiring Grounding	5/9/72
2415-2A723	1	Filter Blow Back Heater (M-E410)	5/10/72
2415-9F315	0	Temperature Elements Multiple Probe	5/12/72
2415-9F606 Shts. 1 to 6 incl.	0	Indicating Controllers Pneumatic-Alterations	5/12/72
2415-2A736	0	Water Let-Down Tank (M-V615)	5/12/72
2415-2A739	0	Water Head Tank(M-V766)	5/12/72
M-V615	0	Water Let-Down Tank	5/15/72
M-V766	0	Water Head Tank	5/15/72
M-V764	0	Drip Pot	5/15/72
2415-9F303 Shts. 1 to 3 incl.	1	Annunciator	5/17/72
2415-9F314 Shts. 1 to 3 incl.	0	Thermocouple	5/17/72
2415-4F701	1	General Notes For Steel Design	5/17/72
2415-6A700	0	Electrical Wiring Lighting	5/17/72
2415-2A730	0	H. P. Stall Equipment General Arrangement And Piping And Steel Design Sheet 1 of 3	5/17/72

Drawing No.	Rev. No.	Title	Date Trans.
2415-2A731	0	H. P. Stall Equipment General Arrangement And Piping And Steel Design Sheet 2 of 3	5/17/72
2415-2A732	0	H. P. Stall Equipment General Arrangement And Piping And Steel Design Sheet 3 of 3	5/17/72
2415-2A712	1	General Piping Specifications Sheet 1 of 2	5/18/72
2415-2A713	1	General Piping Specifications Sheet 2 of 2	5/18/72
2415-2A733	2	Plot Plan	5/19/72
2415-2A718	2	Reformer Structure And Cooling Tower General Arrangement	5/19/72
2415-6A702	0	Electrical Wiring Single Line Diagram	5/23/72
2415-9F317	1	Temperature Transmitters-Electrical	5/23/72
2415-9F601	1	Flow Totalizing Meter-Alterations	5/23/72
2415-9F604	0	Recorders-Miniature Pneumatic Alterations	5/23/72
2415-9F611	0	Pressure Differential Transmitters -Pneumatic Alterations	5/23/72
2415-2A718	2	Reformer Structure And Cooling Tower General Arrangement	5/23/72
2415-9F305	1	Flow Transmitters-Pneumatic	5/25/72

Drawing No.	Rev. No.	Title	Date Trans.
2415-2A734	0	Vent Gas And Hydrogen Sulfide Removal Flow Diagram	5/25/72
2415-2A737	0	Hydrogen Sulfide Removal Towers General Arrangement And Piping, Steel And Concrete Design	5/25/72
B/M2415-2A737 Shts 1 to 6 incl.	0	Bill Of Material Hydrogen Sulfide Removal Towers General Arrangement And Piping, Steel And Concrete Design	5/25/72
2415-6A703	0	Electrical Wiring Specification, Schematics And Connection Diagrams	5/25/72

Drawing Approval

The following drawings were approved by BCR:

Drawing No.	Rev. No.	Title	Approval Date
2415-2A700	4	Fluid Bed Methanator	4/27/72
2415-2A700	5	Fluid Bed Methanator	5/5/72
2415-2A714	3	Fluid Bed Methanator Details	4/27/72
2415-2A715	1	Utilities Flow Diagram Sheet 1 of 3	4/27/72
2415-2A716	2	Utilities Flow Diagram Sheet 2 of 3	4/27/72
2415-2A717	1	Utilities Flow Diagram Sheet 3 of 3	4/27/72
2415-2A726	1	Methanator Feed Gas Receiver	4/27/72
2415-2A729	2	Hydrogen Sulfide Flash Tank	5/5/72

Drawing No.	Rev. No.	Title	Approval Date
2415-2A733	1	Plot Plan	4/27/72
2415-2A735	0	Hydrogen Sulfide Removal Tower	5/5/72
2415-2A718	1	Reformer Structure And Cooling Tower General Arrangement	5/9/72
2415-2A722	1	Fluid Bed Methanation PEDU Demister (M-V620)	5/9/72
2415-2A733	2	Plot Plan	5/9/72
2415-9F305 Sheets 1 and 2	0	Flow Transmitters-Pneumatic	5/9/72
2415-9F313 Sheets 1 and 2	0	Temperature Indicators-Local	5/9/72
2415-9F603 Shts. 1 to 4 incl.	0	Temperature Recorders (MV) Alterations	5/9/72
M-V763 A & B	0	Hydrogen Sulfide Removal Towers	5/9/72
2415-9F304	0	Flow Elements	5/23/72
2415-9F306	0	Flow Integrator-Pneumatic	5/23/72
2415-9F308	0	Pressure Indicators-Local	5/23/72
2415-9F309	0	Pressure Transmitters-Pneumatic	5/23/72
2415-9F323	0	Flow Computing Devices	5/23/72
2415-9F333	0	Instrument Panels	5/23/72
2415-9F602	0	Pressure Transmitters-Alterations	5/23/72
2415-2A701	2	Material Balance Sheet 1 of 2	5/23/72

Drawing No.	Rev. No.	Title	Approval Date
2415-2A702	2	Material Balance Sheet 2 of 2	5/23/72
2415-2A703	2	Process And Utility Flow Diagram Sheet 1 of 4	5/23/72
2415-2A704	2	Sheet 2 of 4	5/23/72
2415-2A705	2	Sheet 3 of 4	5/23/72
2415-2A706	2	Sheet 4 of 4	5/23/72
2415-2A721	0	Cooling Water Hold Tank (M-V710)	5/23/72
2415-2A724	0	Water Metering Tank (M-V610)	5/23/72
2415-2A725	1	Reformer Feed Gas Receiver (M-V104)	5/23/72
2415-2A727	0	Material Balance (with H_2S and CO_2 Addition) Sheet 1 of 2	5/23/72
2415-2A728	0	Sheet 2 of 2	5/23/72
2415-9A701	1	Graphic Panel Layout	5/23/72
2415-9A702	0	Recorder and Analyzer Panels	5/23/72

The following is a list of drawings transmitted to BCR without a previous request for approval. Under letter 2415-C378 dated May 19, 1972, Koppers requested this approval.

Drawing Nos.
2415-2A701, 2A702, 2A703, 2A704, 2A705, 2A706, 2A721, 2A724,

2A727, 2A728, 9A701, 9A702, 9F308, 9F309, 9F333, 9F602

BCR approved these on May 23, 1972, as shown in the report under Drawing Approval.

The following memoranda were transmitted by Koppers Company, Inc. to BCR:

Date	Letter No.	Title	Remarks
5/5/72	C357	Hydrogen Sulfide Removal Towers (M-V763 A & B)	Soliciting bids from vessel fabricators.
5/12/72	C366	Hydrogen Sulfide/ Removal System (M-X763)	Used to remove hydrogen sulfide from the effluent gas stream fed to the Thermal Oxidizer (M-X770)
5/17/72	C371	Air Compressor (M-K770)	Soliciting bids from compressor vendors.
5/19/72	C377	Memorandum Equipment Inspection	Inspection of the Methanator Reactor and other high pressure, high temperature code vessels which will be fabricated for the Methanation PEDU
5/24/72	C383	Memorandum Comments On Nooter Corporation Inquiries	In Relation to the use of ultrasonic testing of the Methanator Reactor welds and the necessity of stress relieving the reactor.
5/26/72	C386	Memorandum Code Welding	Information pertaining to the need of a certified code welder for the installation of Methanation PEDU

During this period, at BCR's request, Koppers reviewed and approved certain portions of vendor drawings and information, which BCR received through their procurement.

C. Fluid Bed Gasification PEDU

1. A proposal for the design engineering package for a coal and/or char Fluid Bed Gasification PEDU was submitted to BCR on April 25, 1972.

2. No further work is being performed on the Fluid Bed Gasification PEDU pending receipt of further direction from BCR.

II. CONTRACT EVALUATION

Four (4) copies of Amendment No. 7 to Amended Subcontract No. 2, including Appendices I through VIII, signed by Mr. J. D. Rice, Vice President, Engineering and Construction Division, Koppers Company, Inc., were transmitted to BCR in our letter C-183 dated October 18, 1971. Receipt of these copies was acknowledged by BCR in their letter dated October 18, 1971.

Pilot Plant Engineering Bid Package (Volumes I through VI) was completed in accordance with the scope of work specified under Appendix I - Revised Appendix A, Par. IIIA - 5. Step a.: "General Facilities Plus Oxygen - Blown Two-Stage System" of Amendment No. 7 to Amended Subcontract No. 2 (originated under OCR Contract No. 14-01-0001-324 and transferred to OCR Contract No. 14-34-0001-1207) between Bituminous Coal Research, Inc., and Koppers Company, Inc.

J. F. Farnsworth
Project Manager