BITUMINOUS COAL RESEARCH, INC.
SPONSORED RESEARCH PROGRAM

GAS GENERATOR RESEARCH AND DEVELOPMENT

Progress Report No. 8

(BCR Report L-465)

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 eighth 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 APRIL 25, 1972

A. Laboratory-scale Process Studies

1. Fluidized-bed Gasification (E. K. Diehl and J. T. Stewart): Work during the month consisted mainly of completing the reactivity studies on three BI-GAS chars. Data were developed to support on-going studies of Stage 1 reactions.

The scope of work to be included in the PEDU engineering design was formalized and provided to several organizations for their guidance in preparing an estimate of the cost for doing the job.

a. Fluidized-bed PEDU: The following information was submitted as background for the PEDU engineering design:

(1) The unit is to provide a flexible system designed with a nominal capacity of 100 pounds of coal per hour.

(2) Feed to the unit will be either coal or char, or a mixture of both.

(3) Oxidant will be air or oxygen, or a mixture, with carbon dioxide and/or steam as a moderator. An additional alternate will be the use of carbon dioxide alone as a source of oxygen.

(4) When complete, the design engineering package will include at least the following:

(a) Process description.

(b) Material and energy balance

(c) Design bases.

(d) Utility summary.

(e) Equipment specifications.

(f) Instrument specifications.

(g) Electrical specifications.

(h) General facility specifications.

(i) General specifications.

(j) P & I drawings, general arrangement drawings, and detail drawings of specialty vessels.

(k) Estimated erected cost.

(5) Specifications and drawings will be in sufficient detail to substantiate costs and to establish performance criteria.

Proposals for the design engineering work are expected early in May.

b. Laboratory Investigations: TGA reactivity tests were concluded for three chars from the BI-GAS Stage 2 PEDU.

As discussed in last month's report, tests were conducted to determine the reactivity of chars produced in the Stage 2 FEDU relative to anthracite. Figure 105 in Progress Report No. 7 was an Arrhenius plot of the char reactivity data based on partial completion of the factorially designed experiments. The experiments were completed this month on a lignite char, an Elkol char, and a Pittsburgh seam char, as well as the reference anthracite. The tentative data presented in Progress Report No. 7 were supported by this month's findings. The complete rate equations for the char-steam reactions may now be summarized as follows:

(1) Lignite char-BCR Lot No. 1963

$$(1 - x) = \text{ash} + (1 - \text{ash})\, e^{-k\,(C_{H_2O})^{.63}t}$$

$$\text{and } k = 2.19 \times 10^{2}\, e^{-\frac{1.008 \times 10^{4}}{T}}$$

(2) Elkol char-BCR Lot No. 2280

$$(1 - x) = \text{ash} + (1 - \text{ash})\, e^{-k\,(C_{H_2O})^{.66}t}$$

$$\text{and } k = 6.84 \times 10^{5}\, e^{-\frac{1.8 \times 10^{4}}{T}}$$

(3) Pittsburgh Seam char-BCR Lot No. 2655

$$(1 - x) = \text{ash} + (1 - \text{ash})\, e^{-k\,(C_{H_2O})^{.49}t}$$

$$\text{and } k = 8.57 \times 10^{6}\, e^{-\frac{1.96 \times 10^{4}}{T}}$$

(4) Anthracite-BCR Lot No. 2985

$$(1 - x) = \text{ash} + (1 - \text{ash})\, e^{-k\,(C_{H_2O})^{.97}t}$$

$$\text{and } k = 1.64 \times 10^{6}\, e^{-\frac{2.09 \times 10^{4}}{T}}$$

where x = fraction of char reacted

T = temperature in °K

C = concentration (mole percent) of reacting gas

t = time in minutes

k = apparent reactivity $\left(\frac{\text{lb C reacted}}{\text{lb C inventory-min.}}\right)$

ash = weight fraction of ash in unreacted char

As noted in last month's report, the Pittsburgh seam char, the Elkol char, and the anthracite all gave an apparent activation energy of approximately 36 kcal/mole, while the lignite char had an activation energy of 19 kcal/mole. The lignite, Elkol, and Pittsburgh seam chars all were approximately half-order reactions with respect to steam concentration, while the anthracite was first order. The derived rate equations are not meant to imply a precise reaction mechanism, but they may be used to adequately correlate the experimental data as shown in Figures 119, 120, 121, and 122.

c. Future Work: Upon receipt of the proposals for the PEDU the proposals will be evaluated and recommendations will be submitted to OCR. Reactivity studies will be completed for the Stage 1 studies.

2. Gas Processing (M. S. Graboski): Work continued in the area of gas processing methanation studies in accordance with the revised time schedule shown in Figure 123. Due to a major effort being placed on evaluation of bids for the Homer City pilot plant, work in the area of model studies was halted temporarily. This report summarizes progress achieved in the bench-scale and PEDU gas processing programs during the month of April.

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 are 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 61 through 64, were conducted on Lot 2904 chromic oxide catalyst. 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 61: BSM Test 61 was conducted with 250 grams of Lot 2904 chromic oxide catalyst. The purpose of the test was to investigate conversion under Scheme A conditions. Synthesis gas of the following composition was used:

Component	Volume, Percent
Hydrogen	62.55
Carbon Monoxide	20.13
Carbon Dioxide	0.04
Methane	15.00
Ethane	0.08
Nitrogen	2.20

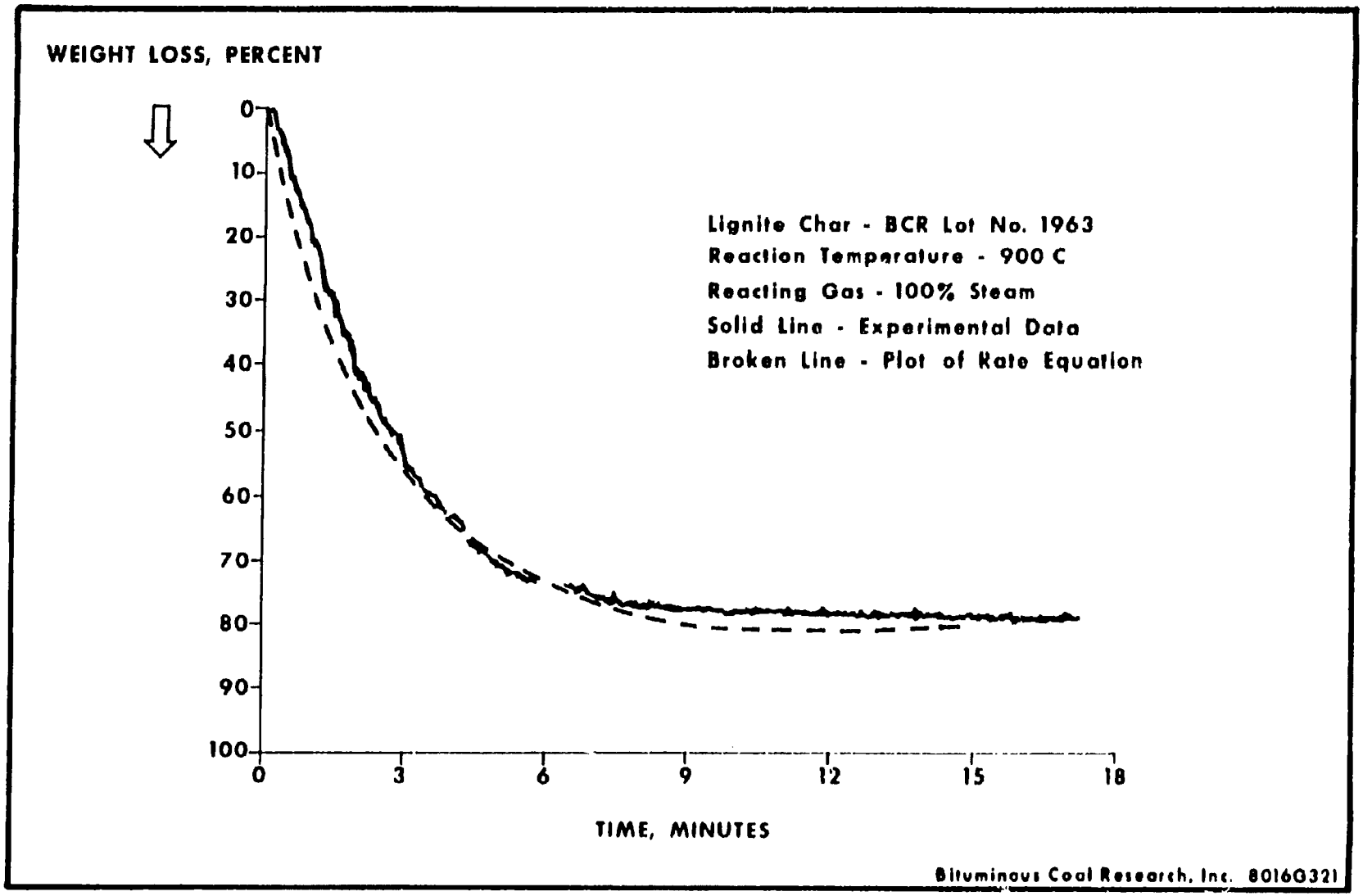

Figure 119. Correlation of Lignite Char Reactivity Data

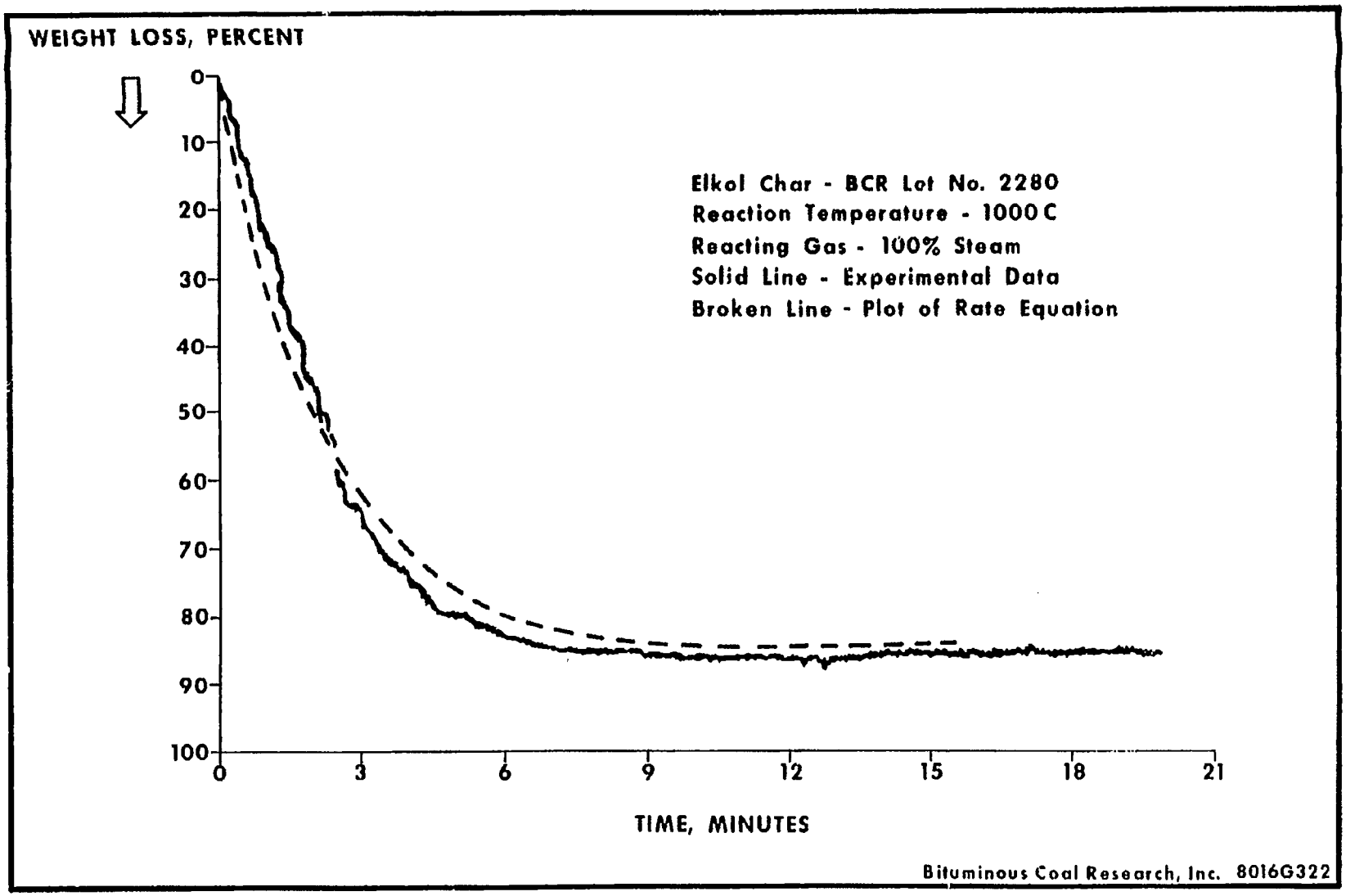

Figure 120. Correlation of Elkol Char Reactivity Data

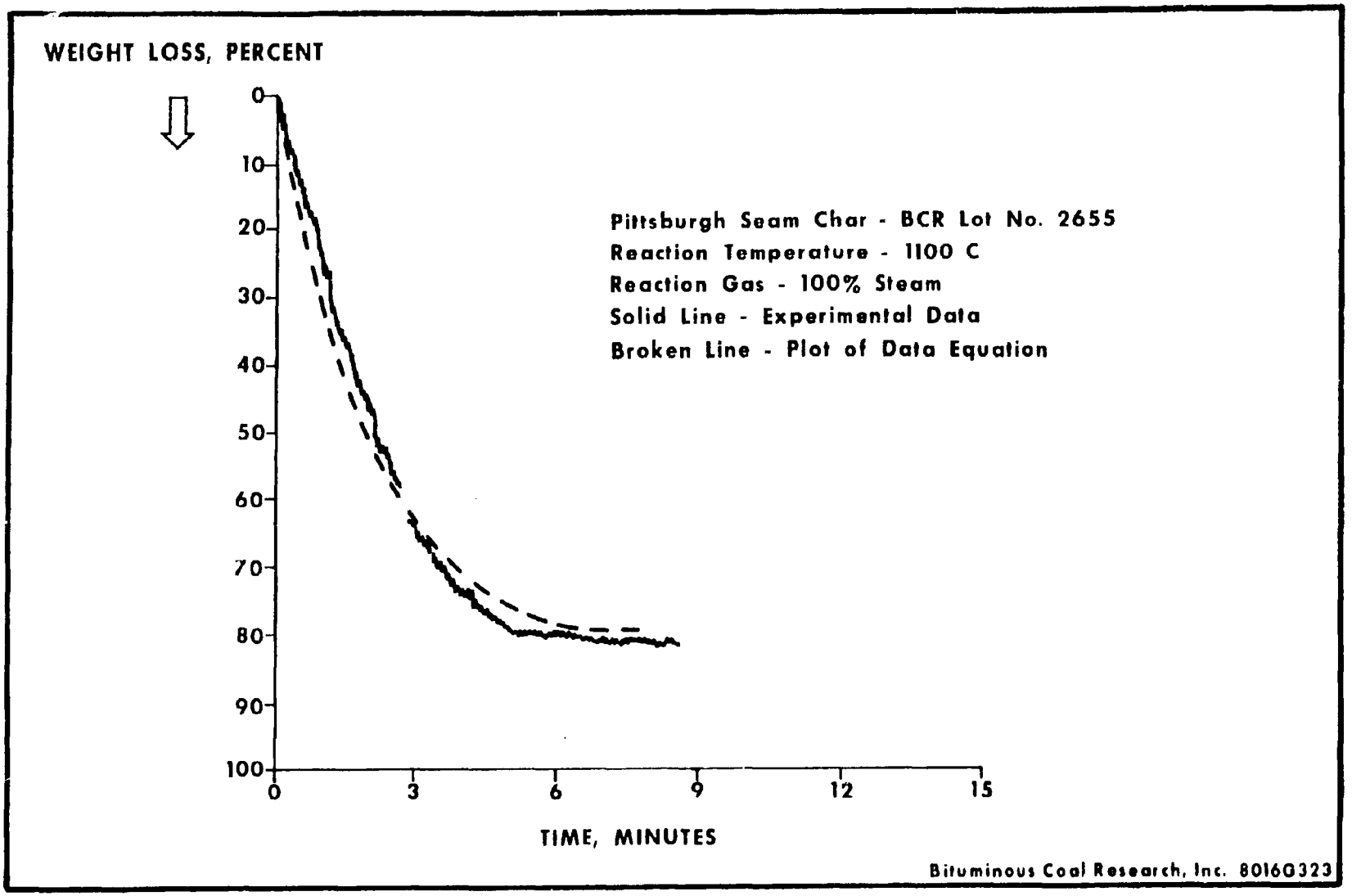

Figure 121. Correlation of Pittsburgh Seam Char Reactivity Data

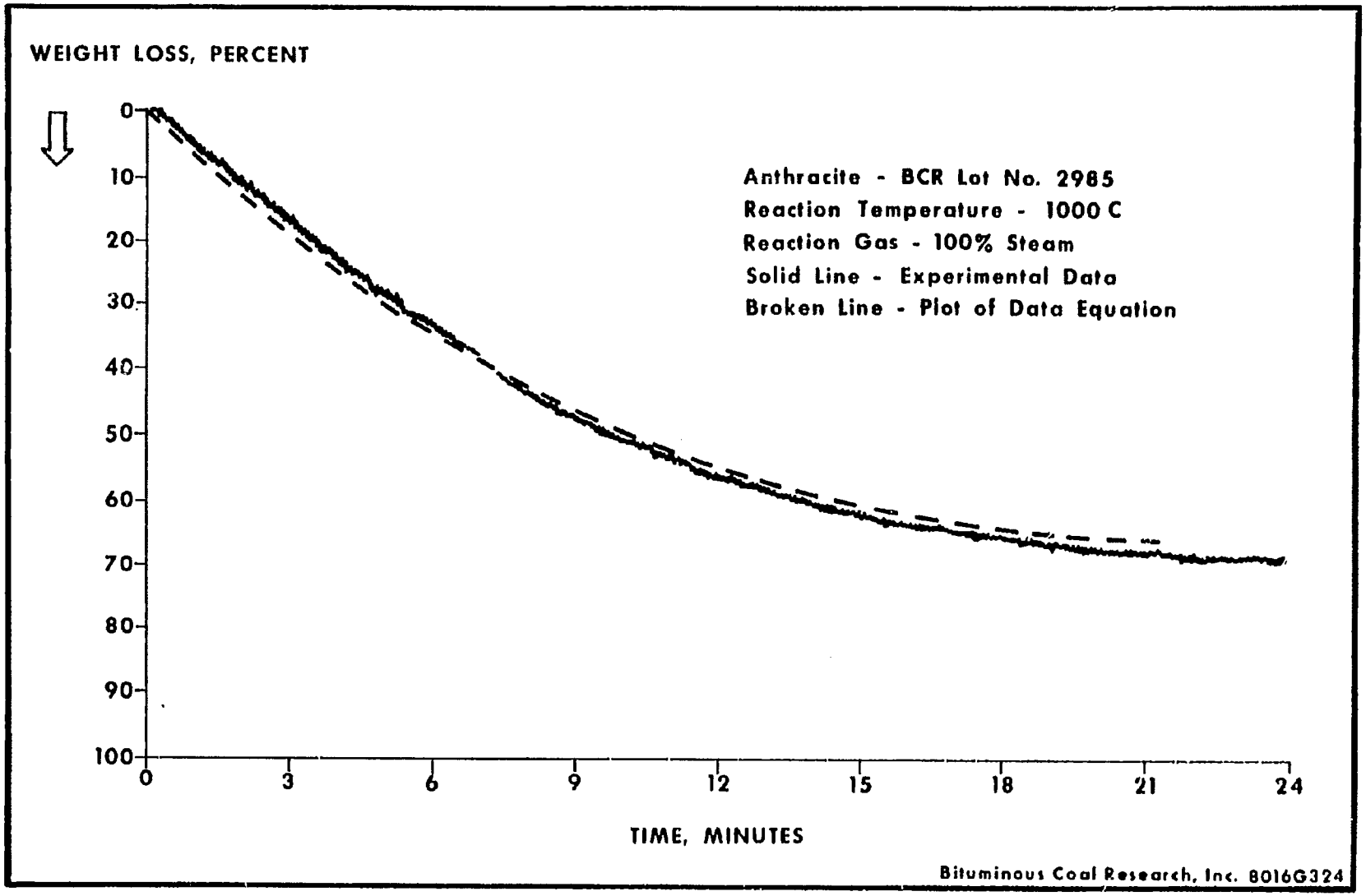

Figure 122. Correlation of Anthracite Reactivity Data

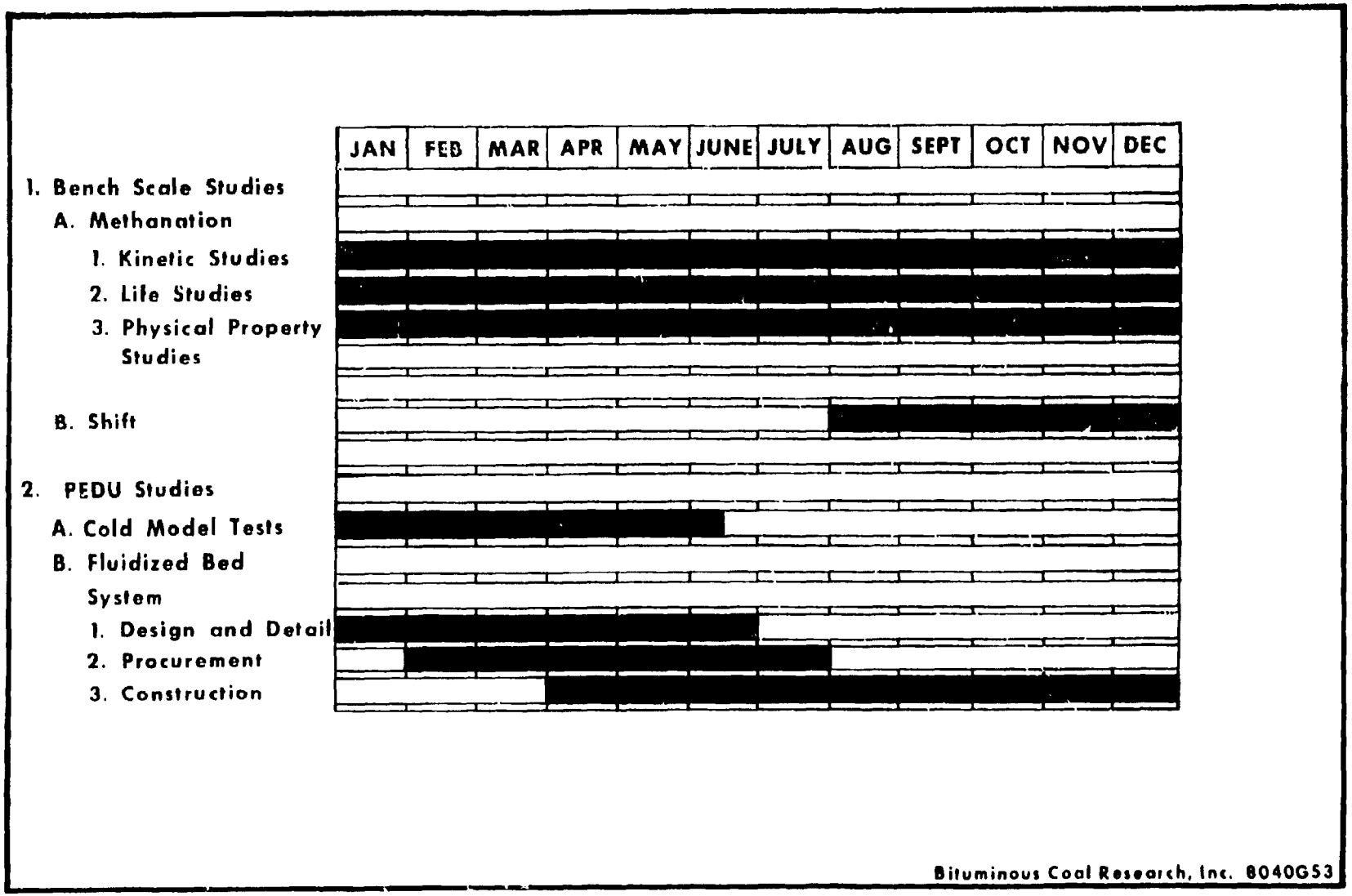

Figure 123. Gas Processing Work Schedule for Calendar 1972

Catalyst 2904 has a minimum fluidization velocity of 0.01 fps at reactor conditions, and a poured bulk density of 56 lb per cu ft.

Test Conditions: Test 61 was conducted at 872 F and 1017 psia throughout one test period. The period was conducted at a relative velocity of about 3.5 times that at minimum fluidization.

Results for Test 61: Material balance data for Test 61 are given in Table 97. Yield data are summarized in Table 98.

In Test 61, the purpose was to maintain the same feed space velocity while increasing the catalyst charge to determine whether the higher velocity, and hence slugging rate, would enhance conversion. The useful conversion, α, from the test sample collected was 71 percent. The exit shift constant from gas composition data was within 10 F of the measured reactor temperature. Test 60, run at the same velocity and approximately the same temperature, as evidenced by an exit shift ratio of 6.2, had a useful conversion of 74 percent. This agrees well and indicates that gas-solids contacting is not being improved by increasing the gas velocity further.

(b) BSM Test 62: BSM Test 62 was conducted with 250 grams of Lot 2904 chromic oxide catalyst. The purpose of the test was to investigate conversion under Scheme A conditions. Synthesis gas of the following composition was used:

Component	Volume, Percent
Hydrogen	61.84
Carbon Monoxide	20.02
Carbon Dioxide	0.00
Methane	15.88
Ethane	0.07
Nitrogen	2.19
TOTAL	100.00

Test Conditions: During Test 62, three samples were collected. The first two were at a reactor temperature of 850 F and a pressure of 1000 psig. The third was collected at 950 F and the same system pressure.

Results for Test 62: Material balance data for Test 62 are given in Table 99. Yield data are summarized in Table 100.

Data for Test 62 are comparable to the results obtained for Tests 60 and 61. In the first two periods, the yield of $(CO + H_2)$, α, is lower than for Tests 60 and 61 even though a lower space velocity was present. However, the exit shift ratio indicates that the reaction zone was at about 825 F, or about 60 F lower than for Tests 60 and 61. The conversion in Period 3 was increased by several percent when the temperature was raised about 70 F according to the shift ratio.

TABLE 97. DATA AND RESULTS FOR BSM TEST 61. PERIOD 1
CONDUCTED AT 872 F AND 1002 PSIG
CHROMIC-OXIDE CATALYST NO. 2904

A. Material Balance

Component	Feed		Product	
	mole percent	g moles/hr	mole percent	g moles/hr
Carbon Monoxide	20.13	9.35	2.20	0.60
Carbon Dioxide	0.04	0.02	6.99	1.92
Hydrogen	62.55	29.06	37.13	10.19
Nitrogen	2.20	1.02	3.74	1.03
Methane	15.00	6.97	49.26	13.52
Ethane	0.08	0.04	0.68	0.19
Propane	0.00	0.00	0.00	0.00
Water	0.00	0.00	--	4.95
Total	100.00	46.46	100.00	32.40
Total Moles Carbon		16.41		16.41
Total Moles Hydrogen		86.22		85.47
Total Moles Oxygen		9.39		9.39

B. Conversion Data

	Raw Data g moles/hr
$CO \rightarrow$ Products	8.75
$H_2 \rightarrow$ Products	18.87
Reactants $\rightarrow H_2O$	4.95
$CO \rightarrow CH_4$	6.55
$CO \rightarrow C_2H_6$	0.30
$CO \rightarrow C_3H_8$	0.00
$CO \rightarrow CO_2$	1.90
[illegible], Percent	71.0
[illegible], Percent	4.[illegible]
K_{shift} (experimental)	6.54
K_{shift} (theoretical at outlet)	6.36

TABLE 98. SUMMARY OF RESULTS FOR BSM TEST C1. CATALYST NO. 2904

Period	Temp, F	Pressure, psig	Space Velocity[1]	U/U_{mf} Inlet	U/U_{mf} Outlet	α[2]	θ[3]	K_s[4]	τ, sec[5]
1	872	1002	3940	4.7	3.2	71.0	4.0	6.54	29.0
2	--	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--	--

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

[2] α, useful conversion, 1CO x (moles ($CO + H_2$) converted to hydrocarbons)/(total moles ($CO + H_2$) fed)

[3] θ, 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 99. DATA AND RESULTS FOR BSM TEST 62. PERIOD 1
CONDUCTED AT 850 F AND 1002 PSIG
CHROMIC-OXIDE CATALYST NO. 2904

A. Material Balance

Component	Feed		Product	
	mole percent	g moles/hr	mole percent	g moles/hr
Carbon Monoxide	20.02	7.68	2.02	0.47
Carbon Dioxide	0.00	0.00	7.21	1.66
Hydrogen	61.84	23.74	37.25	8.58
Nitrogen	2.19	0.84	3.70	0.85
Methane	15.88	6.10	48.90	11.27
Ethane	.07	0.03	0.84	0.19
Propane	0.00	0.00	0.08	0.02
Water	0.00	0.00	--	3.89
Total	100.00	38.39	100.00	26.93
Total Moles Carbon		13.83		13.83
Total Moles Hydrogen		72.02		71.33
Total Moles Oxygen		7.68		7.68

B. Conversion Data

	Raw Data g moles/hr
CO → Products	7.22
H_2 → Products	15.16
Reactants → H_2O	3.89
CO → CH_4	5.17
CO → C_2H_6	0.33
CO → C_2H_8	0.06
CO → CO_2	1.66
α, Percent	70.1
η, Percent	7.0
K_{shift} (experimental)	7.86
K_{shift} (theoretical at outlet)	7.05

TABLE 99. DATA AND RESULTS FOR BSM TEST 62. PERIOD 2
CONDUCTED AT 850 F AND 998 PSIG
CHROMIC-OXIDE CATALYST NO. 2904 (Continued)

A. Material Balance

Component	Feed		Product	
	mole percent	g moles/hr	mole percent	g moles/hr
Carbon Monoxide	20.02	7.80	2.01	0.47
Carbon Dioxide	0.00	0.00	7.24	1.69
Hydrogen	61.84	24.08	37.24	8.68
Nitrogen	2.19	0.85	3.64	0.85
Methane	15.88	6.18	48.89	11.40
Ethane	0.07	0.03	0.88	0.21
Propane	0.00	0.00	0.10	0.02
Water	0.00	0.00	0.00	3.95
Total	100.00	38.94	100.00	27.27
Total Moles Carbon		14.04		14.04
Total Moles Hydrogen		73.07		72.28
Total Moles Oxygen		7.80		7.80

B. Conversion Data

	Raw Data g moles/hr
CO → Products	7.33
H_2 → Products	15.40
Reactants → H_2O	3.95
CO → CH_4	5.21
CO → C_2H_6	0.36
CO → C_3H_8	0.07
CO → CO_2	1.69
α, Percent	70.1
β, Percent	7.5
K_{shift} (experimental)	7.91
K_{shift} (theoretical at outlet)	7.05

TABLE 99. DATA AND RESULTS FOR BSM TEST 62. PERIOD 3
CONDUCTED AT 950 F AND 1008 PSIG
CHROMIC-OXIDE CATALYST NO. 2904 (Continued)

A. Material Balance

Component	Feed		Product	
	mole percent	g moles/hr	mole percent	g moles/hr
Carbon Monoxide	20.02	6.51	2.19	0.41
Carbon Dioxide	0.00	0.00	6.78	1.28
Hydrogen	61.84	20.10	34.57	6.50
Nitrogen	2.19	0.71	3.86	0.73
Methane	15.88	5.16	51.96	9.78
Ethane	0.07	0.02	0.61	0.11
Propane	0.00	0.00	0.03	0.01
Water	0.00	0.00	--	3.54
Total	100.00	32.50	100.00	22.36
Total Moles Carbon		11.71		11.71
Total Moles Hydrogen		60.97		59.94
Total Moles Oxygen		6.51		6.51

B. Conversion Data

	Raw Data g moles/hr
CO → Products	6.09
H_2 → Products	13.59
Reactants → H_2O	3.54
CO → CH_4	4.62
CO → C_2H_6	0.18
CO → C_3H_8	0.02
CO → CO_2	1.28
α, Percent	
β, Percent	4.0
K_{shift} (experimental)	5.69
K_{shift} (theoretical at outlet)	4.55

TABLE 100. SUMMARY OF RESULTS FOR BSM TEST 62. CATALYST NO. 2904

Period	Temp, F	Pressure, psig	Space Velocity[1]	U/U_{mf} Inlet	U/U_{mf} Outlet	α[2]	η[3]	K_s[4]	τ, sec[5]
1	850	1002	3250	3.46	2.41	70.1	7.0	7.86	35.6
2	850	998	3290	3.53	2.45	70.1	7.5	7.91	35.0
3	950	1008	2750	3.14	2.16	72.1	4.0	5.69	39.5
4	--	--	--	--	--	--	--	--	--

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

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

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

(c) BSM Test 63: BSM Test 63 was conducted with 250 grams of Lot 2904 chromic oxide catalyst. The purpose of the test was to investigate conversion under Scheme B conditions. Synthesis gas of the following composition was used:

Component	Volume, Percent
Hydrogen	62.08
Carbon Monoxide	18.38
Carbon Dioxide	12.72
Methane	6.69
Ethane	0.00
Nitrogen	0.13

Test Conditions: Test 63 was conducted at 820 F and 1000 psig for one test period.

Results for Test 63: No accurate material balance results are available for Test 63. The analytical chromatograph used to process samples malfunctioned and the sample was lost. Approximate data from the Lira and on-line chromatograph indicated that good conversion was being achieved.

	Volume, Percent	
Component	Feed	Product
H_2	62.2	50.0
CO	18.4	11.7
CH_4	6.7	22.0
CO_2 (Diff)	12.7	16.3
	100.0	100.0
Total C	37.8	50.0
$CO \rightarrow CH_4$		13.1
[illegible], Percent		65

After the completion of Period 1, the system temperature was increased to 920 F. A significant conversion increase was noted, but increased pressure drop in the system became apparent. At this point, the preheater had been raised from 750 F to 850 F. After shutdown, the system was inspected and a carbon plug was found in the preheater tube. The feed gas used could potentially deposit carbon as indicated by thermodynamic calculations, and apparently the preheater wall temperature was high enough to initiate reaction. An analysis of the deposit showed it to be 90 percent carbon and 10 percent iron. Thus, the 304 stainless tube wall had catalyzed the reaction. The tube was blown clean. No evidence of carbon was found on the catalyst.

(d) BSM Test 64: BSM Test 64 was conducted with 300 grams of Lot 2904 chromic oxide catalyst. The purpose of the test was to investigate conversion under Scheme B conditions with a low hydrogen to carbon monoxide ratio. The synthesis gas used in Test 64 had the following composition:

Component	Volume, Percent
Hydrogen	39.49
Carbon Monoxide	28.85
Carbon Dioxide	21.25
Methane	10.30
Ethane	0.04
Nitrogen	0.07

Test Conditions: Two test periods were conducted; both were at 850 F and 995 psig.

Results for Test 64: Material balance data are given in Table 101 and yield data are presented in Table 102.

Data for Test 64 do not reflect actual conversions across the catalyst bed. From the initiation of the test, carbon deposition was a serious problem. This is indicated in the material balance by the imbalance for hydrogen. (Balances are normalized for carbon, and oxygen is obtained from theoretical water.) During Test 64, significant methane was produced until the preheater plugged. Catalyst activity suffered from the severe test conditions.

(e) Preheater: To reduce carbon deposition problems, the gas heater was redesigned. Literature indicates that copper will not catalyze carbon deposition. Thus, 20 feet of 1/4-inch stainless tubing was lined with 5/16 copper and pressed out hydraulically to eliminate gas pockets. The "laminated" tube was then fitted into the current electrical preheater design.

(2) Life Tests: The new multi-tube life test unit, described in last month's report, was placed on stream and has now been operated for about 600 hours. Difficulty arose in early testing due to condensation of product water above the catalyst retaining plate at the base of the reactor. As water accumulated on the cooler plate, flow stoppage occurred. A heater was installed at the bottom end of the reactor and the blockage was alleviated by vaporization of the water.

Data for the four catalysts are shown in Figure 124. Conversion is slightly erratic with time, especially with respect to the last sample where all conversions have declined. This is probably due to the chromatographic analysis since operational difficulties with the machine have been encountered in the last several weeks.

In the current phase of the life test, the gas composition being used represents Scheme A processing. Comparison of the activities of the four catalysts, which are being processed at identical space velocities, indicates

TABLE 101. DATA AND RESULTS FOR RSM TEST 64. PERIOD 1
CONDUCTED AT 850 F AND 995 PSIG
CHROMIC-OXIDE CATALYST NO. 2904

A. Material Balance

Component	Feed		Product	
	mole percent	g moles/hr	mole percent	g moles/hr
Carbon Monoxide	28.85	6.74	8.40	1.50
Carbon Dioxide	21.25	4.96	37.58	6.73
Hydrogen	39.49	9.23	22.28	3.99
Nitrogen	.07	0.02	0.26	0.05
Methane	10.30	2.41	30.10	5.39
Ethane	.04	0.01	1.09	0.20
Propane	0.00	0.00	0.22	0.04
Water	0.00	0.00	--	1.71
Total	100.00	23.37	100.00	19.61
Total Moles Carbon		14.13		14.13
Total Moles Hydrogen		28.13		34.44
Total Moles Oxygen		16.67		16.67

B. Conversion Data

	Raw Data g moles/hr
CO → Products	5.24
H_2 → Products	5.24
Reactants → H_2O	1.71
CO → CH_4	2.98
CO → C_2H_6	0.37
CO → C_3H_8	1.76
CO → CO_2	0.12
α, Percent	85.0
β, Percent	14.1
K_{shift} (experimental	10.44
K_{shift} (theoretical at outlet)	7.05

TABLE 101. DATA AND RESULTS FOR BSM TEST 64. PERIOD 2
CONDUCTED AT 850 F AND 992 PSIG
CHROMIC-OXIDE CATALYST NO. 2904 (Continued)

A. Material Balance

	Feed		Product	
Component	mole percent	g moles/hr	mole percent	g moles/hr
Carbon Monoxide	28.85	7.36	9.24	1.65
Carbon Dioxide	21.25	5.42	42.31	7.57
Hydrogen	39.49	10.07	14.87	2.66
Nitrogen	.07	0.02	.21	0.04
Methane	10.30	2.63	32.20	5.76
Ethane	.04	0.01	.98	0.18
Propane	0.00	0.00	0.15	0.03
Water	0.00	0.00	--	1.39
Total	100.00	25.51	100.00	19.28
Total Moles Carbon		15.43		15.43
Total Moles Hydrogen		30.71		32.44
Total Moles Oxygen		18.20		18.20

B. Conversion Data

	Raw Data g moles/hr
CO → Products	5.70
H_2 → Products	7.41
Reactants → H_2O	1.39
CO → CH_4	3.14
CO → C_2H_6	0.33
CO → C_3H_8	2.16
CO → CO_2	0.08
α, Percent	80.2
β, Percent	11.6
K_{shift} (experimental)	8.75
K_{shift} (theoretical at outlet)	7.05

TABLE 102. SUMMARY OF RESULTS FOR BSM TEST 64. CATALYST NO. 2904

Period	Temp, F	Pressure, psig	Space Velocity[1]	U/U_{mf} Inlet	U/U_{mf} Outlet	α[2]	α[3]	K_s[4]	τ, sec[5]
1	850	995	1650	2.1	1.76	85.0	14.1	10.44	64.6
2	850	992	1800	2.3	1.77	80.2	11.6	8.75	61.4
3	--	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--	--

[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] α, 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 $U = (U_{in} + U_{out})/2$

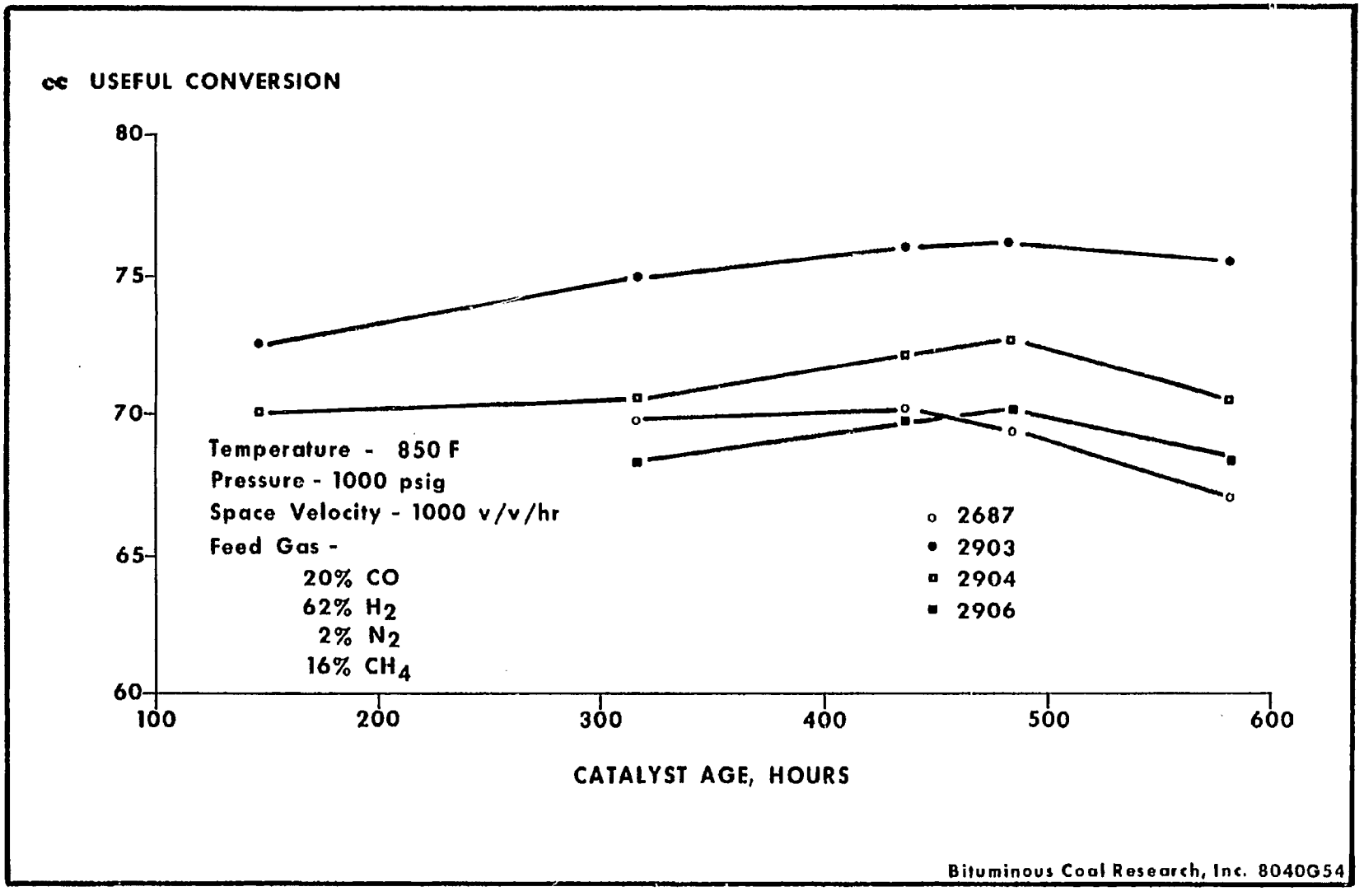

Figure 124. Catalyst Life Test Results

that Lot 2903 (molybdenum oxide) has the best activity followed by Lot 2904 (chromic oxide), Lot 2906 (iron oxide), and Lot 2687 (cobalt and molybdenum oxides.) The mean reaction rate over the reactor for Lot 2903 is about 0.06 g moles ($CO + H_2$) per hour per gram of catalyst. In the PEDU, which can hold 2 cubic feet of catalyst, this corresponds to a throughput of 2000 scfh, or a reactor superficial velocity in the range of 0.1 fps, which is 20 times minimum fluidizing velocity for that catalyst. For higher activity catalysts, a greater throughput may be achieved. This crude analysis confirms the basic PEDU design.

b. PEDU Studies: Progress continued to be made on the methanation PEDU during April.

(1) Design Engineering

(a) Site Plot Plan: A final site plot plan showing the entire facility was reviewed, finalized, and submitted as drawing 2415-2A733 by Koppers.

(b) Utilities Flow Diagram: The three utilities flow diagrams 2415-2A715, 716, and 717 were revised and submitted in final form by Koppers.

(c) Sulfur Removal System. Koppers presented a design for a twin iron oxide tower sulfur removal system to treat the effluent from the PEDU prior to incineration. The unit is capable of removing 95 percent of the sulfur in the effluent under test conditions where one percent hydrogen sulfide is incorporated into the feed gas.

(d) PEDU Feed Gas Heater: Because of carbon deposition problems encountered in the BSM feed gas heater, Koppers was asked to redesign the preheater so that the unit will have high surface area and a relatively low surface temperature for heating. In addition, it was suggested that copper cladding on the gas side of the exchanger would further minimize carbon formation. A system is currently being designed which will use molten lead as the heat transfer medium rather than high temperature electrical elements. The lead will be heated electrically and circulated by free convection.

(e) Effluent Cooler: Koppers was asked to check, through Brown Fintube Company, the design of the effluent cooler. In that unit, cooling fins were placed on the tube surface. However, the gas was forced through the tube side and glycol on the shell side. In such a situation fins should have no effect on heat transfer since the gas side offers the major resistance to heat flow. Brown rechecked the design and is currently eliminating the fins.

(f) Reformer: To investigate reformer flexibility, Gas Atmospheres Inc. was asked if hydrogen/carbon monoxide ratios lower than 3/1 could be obtained by carbon dioxide addition to the feed. A gas with as low as about a 1.5/1 hydrogen/carbon monoxide ratio can be made using a different catalyst than specified by Gas Atmospheres. Using Chemetron G-90B reforming catalyst, much greater flexibility is possible from the unit.

(2) Detail Engineering

(a) Schedule and Cost: Koppers presented a detailed work schedule and firm cost for the PEDU engineering. Work is scheduled to be completed by Koppers July 1, 1972.

(b) Vessel and Equipment Detailing: During the month, Koppers has continued to work on the detail engineering of vessels and equipment. The following have been completed:

MV-310 (Methanator Feed Gas Receiver): The vessel drawing (2415-2A-726) has been revised to show nozzle orientation for fabrication purposes.

MR-420 (Methanator Reactor): The vessel drawings 2415-2A-700 and 2415-2A-714 were revised to show nozzle orientation for fabrication purposes.

MX-770 (Thermal Oxidizer): Procurement specifications for the thermal oxidizer unit were prepared by Koppers. The design is based on handling either the methanation PEDU or the future gasification PEDU at full capacity or both units simultaneously at reduced throughput. Thus, while the system is designed to service the future PEDU as well as the unit currently under construction, the entire cost is being charged to the $850,000 blanket approval by OCR for the methanation unit.

Transformer: Duquesne Light submitted a quote on a separate transformer to serve both PEDU installations in Building 3. The entire cost is being charged to methanation.

Other Detail Work: Koppers is currently working on the equipment layout, piping, general electrical, and structural requirements for the unit. No definitive results are available.

(3) Procurement Status: Table 103 summarizes the status of some major items for the PEDU. It is anticipated that those items not currently procured and on the list will soon be processed through purchasing.

The major item not shown in Table 103 is the reactor, MR-420, itself. Currently, about one dozen fabricators have been contacted. All but two have refused to quote; we are still awaiting word from these vendors on the cost of the vessel.

(4) Other Work

(a) Dismantling of the cubicle stall equipment was completed in April. The contractor's fee for this work was charged against the OCR-approved funds for the PEDU. This was an unanticipated expense in the budget since all previous dismantling expense had been approved and budgeted to the 100 pound per hour coal gasification PEDU project.

TABLE 103. SUMMARY OF METHANATION PEDU EQUIPMENT ITEMS HAVING FIRM QUOTATIONS

Index	Equipment Item	Status[2]
ME-605[1]	Cooler Condenser	
ME-700	Water Cooler	P
MF-420	Catalyst Filters	
MK-102	Natural Gas Compressor	P
MK-305	Methanator Feed Compressor	P
MP-710	Cooling Water Pump	P
MV-104	Reformer Feed Gas Receiver	P
MV-260	H_2S Flash Tank	
MV-310	Methanator Feed Gas Receiver	
MV-610	Water Metering Tank	P
MV-620	Demister	
MV-710	Cooling Water Tank	P
MX-100	Reformer	P
MX-500	Therminol System	P
MX-720	Steam Boiler	P
MX-750	Demineralizer	P
ANN-MR-420	Annunciator	
Panel-MR-420	Instrument Panel	

(1) Quotation to be revised

(2) (P) Purchase order issued

(b) Excavation has been scheduled for the first week of May.

(c) A meeting was held with a BCR insurance representative. No difficulties are present in the PEDU system.

(d) No progress was made on acquiring air pollution and building permits.

c. Cold Model Studies: Due to Homer City bid evaluation studies, no time was available to be spent on the cold model program during April.

d. Future Work: The following work will be conducted during the coming month according to the gas processing schedule:

At the bench-scale level, fluidized reactor tests will be conducted on 2903 molybdenum oxide catalyst to supplement data developed in earlier tests. Life testing of four catalysts will continue.

PEDU work is planned as follows: (1) excavation will be completed in preparation for construction, (2) bid soliciting and purchasing will be continued, and (3) detail engineering by Koppers will proceed.

Cold model studies will be continued.

3. Analytical Services (J. E. Noll): During the past month, 45 samples were analyzed by gas chromatography. The types of analyses requested were as follows:

Type of Analysis Requested	Number of Samples Analyzed
Gas chromatography	
Methanation unit gas samples	45
TOTAL	45

4. Gas Chromatographic Procedures (J. E. Noll): No work was required in this area during the past month.

Future Work: Performing sample analyses is the only work planned.

B. Stage 2 Process and Equipment Development Unit--100 lb/hr (R. J. Grace, E. E. Donath, and R. L. Zahradnik)

On April 21, 1972, the Summary Report, "Direct Methanation of Coal in 100 lb/hr Process and Equipment Development Unit," Special Report No. 2 (ECR Report L-460), was submitted to the Office of Coal Research. Consequently, no further monthly reports on this section of the Phase II program will be made.

1. Inspection of Stage 1 Refractories: Portions of Stage 1 refractories which were removed from the reactor during dismantling operations were discussed and illustrated in Section B, Progress Report No. 4, December 1971.

Sections of a letter report of April 12, 1972, to the Koppers Company from the manufacturer, Harbison-Walker Refractories Company, concerning their visual examination of a sample of the Korundal XD bricks taken from Stage 1 follow:

"The sample of the KORUNDAL XD working lining brick was a 3-1/2 inch long piece from an original 9-inch arch brick. Of the original 4-1/2 inches working thickness of this brick about 3-3/4 inches remained, indicating approximately 3/4 inches of wear during service of unknown duration. The exact location of this sample in the lining was also not known. The examination of the broken face of this brick showed an average penetration of about 1/2 inch with a range of 3/8 to 5/8 inch. This penetrated area was dark brown to black in color, but the coarser white grains were evident in this zone. The hot face itself had a very thin dry black metallic looking skin not over about 1/8 inch in thickness. There was no evidence of cracking either perpendicular or parallel to the hot face in this sample. Below the hot face and penetrated zone the structure appeared entirely normal for KORUNDAL XD. A thin mortar joint was evident on the sides of this sample and there was no evidence of any preferential penetration of the joints suggesting a very tight and uniform installation job. The obvious source of the penetrants would be the ash derived from the coal being gasified. Coal ashes are typically high in silica, alumina, iron oxide and alkalies.

"The slag sample was a gray-green colored vesicular material approximately 1/4 inch thick. On one face there was evidence of some obvious white grains obviously derived from the brick hot face.

"The two possible modes of lining wear would be slow solution of the hot face through reaction of the coal ash with the brick, and based on the evidence of brick structure attached to the slag sample, peeling away of thin layers of the working face during the various up and down periods of operation or through any attempts to remove build-up slag coating. The difference in reversible thermal expansion of the refractory lining and the slag coating is often responsible for this type of peeling action. It is most likely that the wear of the lining is a combination of both the reaction between the ash and the refractory and the peeling action."

2. Future Work: This section of the Phase II program has been completed and no future work is planned.

C. 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)

Work on the cold flow model during the month consisted of completing the installation of the 6000 cfm blower. Four tests were conducted using water injection to simulate slag droplets.

The reactivity of a "green" petroleum coke was determined and compared to the PEDU chars and anthracite.

A satisfactory procedure for determining a grindability index of low bulk density materials, based on the Hardgrove grindability index procedure, has been developed.

1. Stage 1 Model Tests: Following the installation of the 6000 cfm blower, four tests were run using water to simulate slag output from Stage 1. Figure 125 shows the test setup schematically, and Figures 126 and 127 are photographs of the actual equipment used. The results will be reported next month.

2. Determination of Reactivity of Chars: A sample of "green" petroleum coke was obtained from a refinery in Lima, Ohio, and was tested in the TGA. The purposes of the test were to determine the reactivity of the coke, as compared with other materials tested, and evaluate the material for possible use in the Homer City pilot plant as an initial solid feed for startup of Stage 1.

Figure 128 shows that the reactivity of this petroleum coke was less than that of the anthracite and PEDU chars tested previously.

3. Development of Grindability Test for Low Density Chars: A revised procedure for the ASTM Hardgrove grindability index method was developed for use on low density chars. The results will be reported next month.

4. Future Work: Cold flow model tests will be conducted to obtain operation of the prototype Stage 1 reactor with various nozzle settings and burner locations. Slag separation will be evaluated using viscous liquids.

Reactivity tests will be continued in an attempt to find suitable startup materials for the pilot plant.

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

1. Automated Data Acquisition: The software system (computer programs) necessary for interfacing the bench-scale methanation unit with the PDP8/E computer will be completed by May 15, 1972. Work will then be initiated on several programs required to log, process, and store data from the methanation unit.

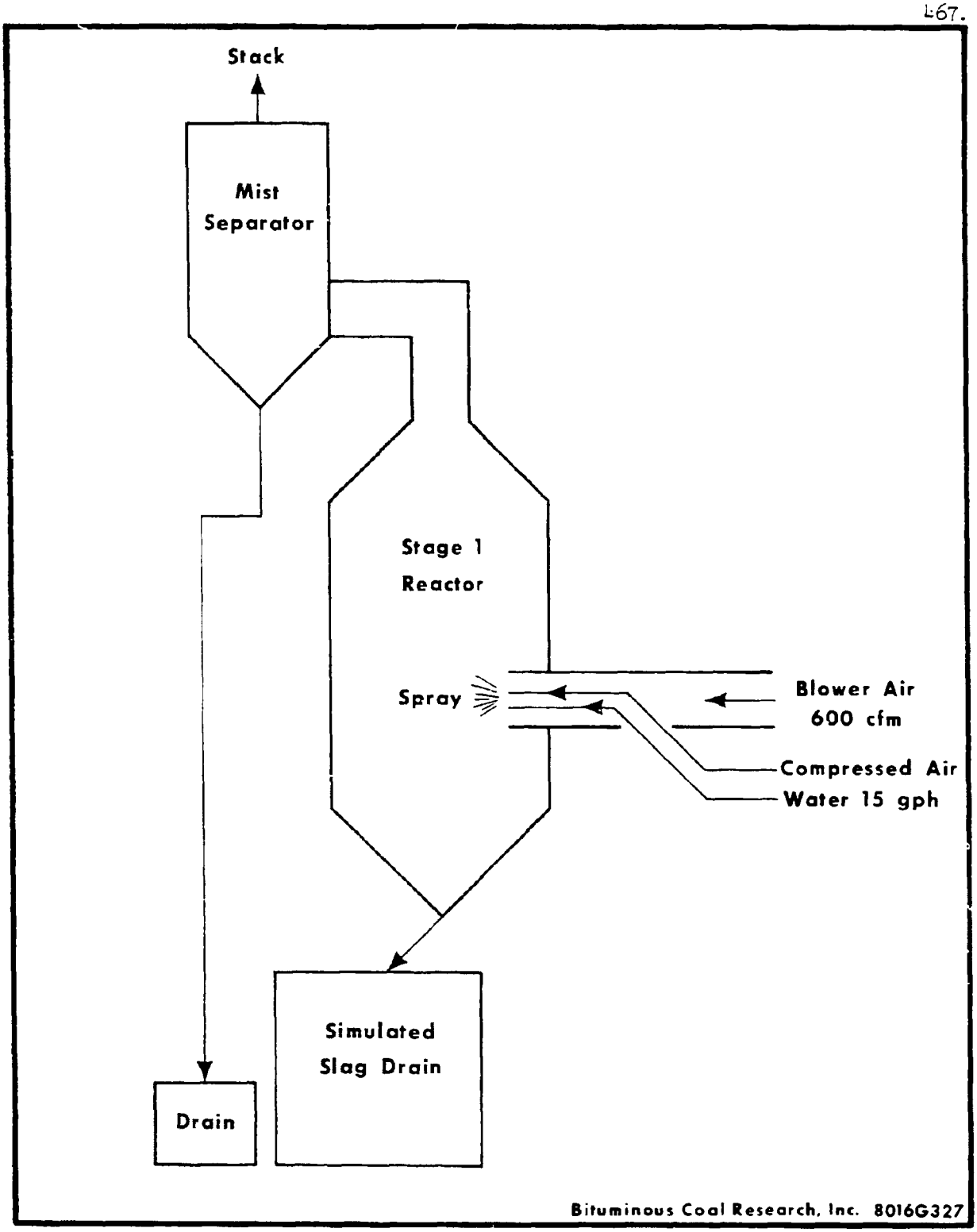

Figure 125. Schematic Setup for Testing Prototype Stage 1 Reactor for Simulated Slag Removal

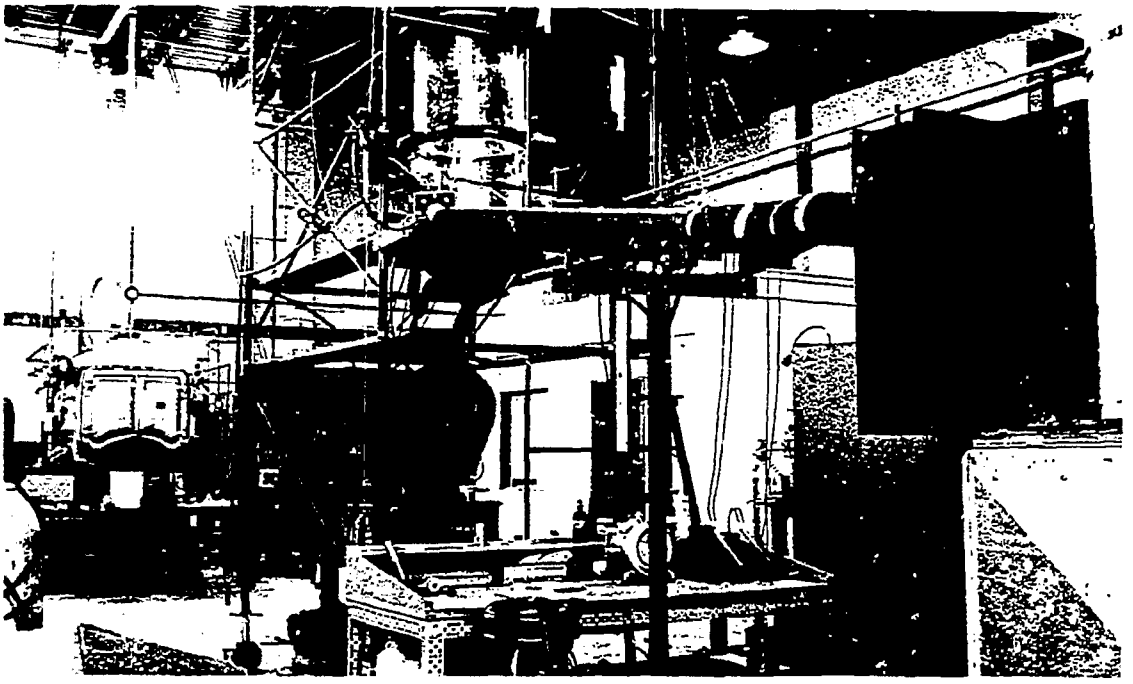

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Figure 126. View of Revised Model Installation from Newly Installed 6000 cfm Blower

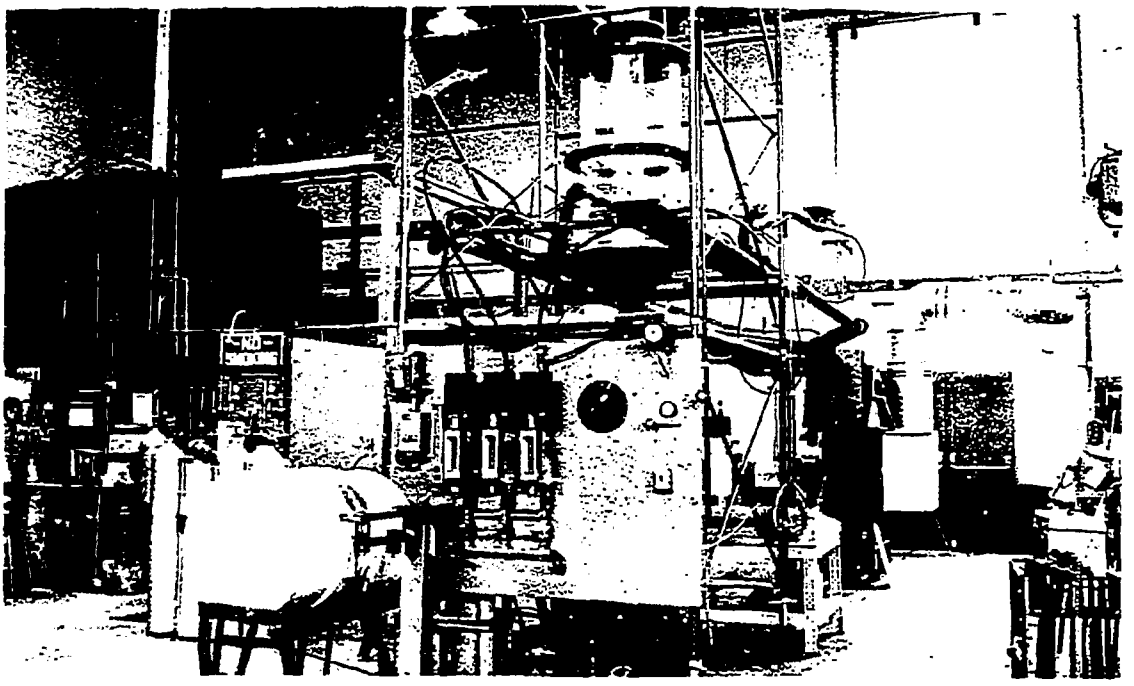

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Figure 127. View of Revised Model Installation Facing Panel Board

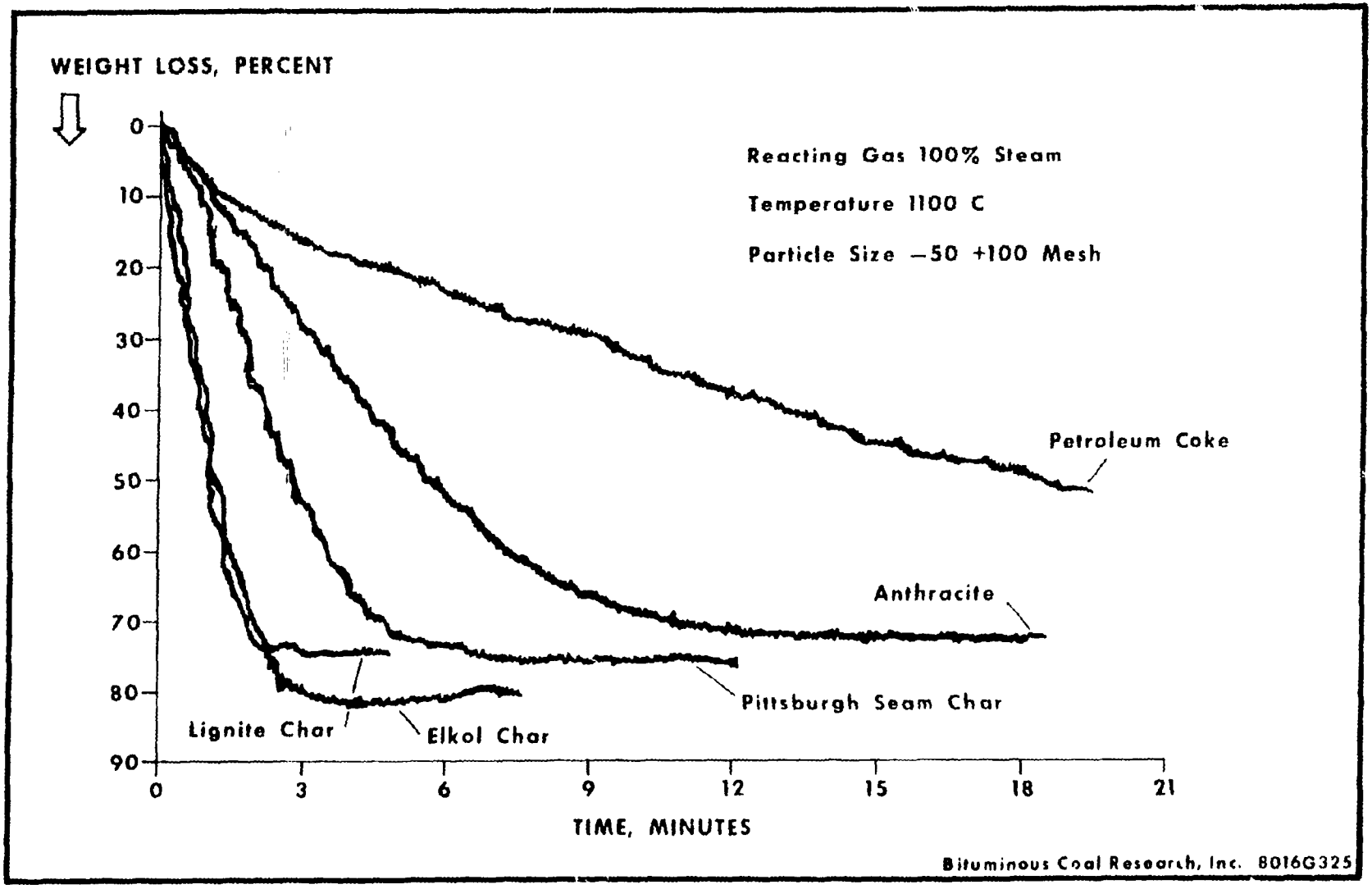

Figure 128. Rate of Weight Loss of 50 × 100 Mesh Materials at 1100 C in 100 Percent Steam

The hardware interfacing (wiring) between the methanation unit and the computer will be completed by May 30, 1972. This will include: (1) construction of a wire-way from the methanation unit to the computer room, and (2) connecting selected signal transmitters to the computer.

2. Commercial Gasifier Modeling: Subroutine GASIFY was utilized to generate 12 gasifier simulation runs on a Montana subbituminous coal. The set yield model was employed.

3. Future Work: Plans for the next report period include:

a. Completion of the software system for interfacing the bench-scale methanation unit with computer.

b. Begin writing data processing programs necessary for the methanation project.

c. Completion of the hardware interface between the computer and methanation unit.

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

E. Engineering Design and Evaluation

1. BI-GAS Process: The commercial gasifier simulation program (Subroutine GASIFY) was used to generate 12 sets of data on Montana subbituminous coal. Methane yield was set at 20 percent and carbon oxide yields were set at four levels; namely, 15, 20, 25, and 30 percent. Stage 2 exit temperature was set at 1550 F.

2. OCR/BCR Gasification--Power Generation: BCR submitted a letter to Mr. S. Lemezis, Westinghouse, outlining BCR's ideas concerning the ability to provide the sort of information requested by Westinghouse for the preliminary design of an advance power system. Much of the data would need to be developed specifically for Westinghouse's particular application. Therefore, BCR suggested that Westinghouse clear their request through OCR before BCR proceeds to do the work. It was further suggested that in the event BCR is to proceed with the work, it may be well to meet again with the appropriate Westinghouse people to define the specific data required.

On April 5, 1972, representatives of Foster Wheeler Corporation visited BCR to discuss yet another potential application of an air-blown version of the BI-GAS gasifier. It is understood that they intend to pursue further development of a combined-cycle concept. They may wish to call upon BCR for more information as their involvement in low-Btu gas generation increases.

F. Multipurpose Research Pilot Plant Facility (MPRF)

1. Pilot Plant Bid Evaluation: Evaluation of construction and/or operation bids, as received in response to BCR's "Invitation for Engineering and

Construction Proposal," is in progress. Technical as well as economic factors are being considered. To expedite bid evaluation, bidders were requested to submit a breakdown of their bid according to a cost estimate sheet supplied to them by letter dated April 4, 1972. Copies of these construction cost breakdowns were forwarded to OCR and AGA on April 17, 1972.

Effort is also being devoted to evaluation of proposals submitted by other organizations for project management services during construction.

2. Materials Evaluation Program: Proposals have been received in preparation for the meeting of the members of the task group on Materials for Coal Gasification - Subcommittee 8, scheduled for May 15, 1972, in New York, N. Y. The purpose of the meeting is to discuss the proposals received from C. F. Braun & Co., IIT Research Institute, Battelle-Columbus, and Foster Wheeler Corporation.

It is the primary function of the task group to decide, from a technical standpoint, the relative desirability of the proposals received.

G. Literature Search (V. E. Gleason)

No literature references were completed during the month.

H. Other

1. Prime Contract Matters: Two fully executed copies of Amendment No. 1, dated March 29, 1972, were received from OCR.

In accordance with Mr. Thunberg's letter of April 10, we are storing the surplus radioactive carbon-14 at BCR until such time as Mr. R. F. Stewart, USBM, Morgantown, West Virginia, can arrange for transfer. By letter dated April 18, Mr. Thunberg advised that all nonexpendable equipment on the inventory as of the expiration date of Contract 14-01-0001-324, should be transferred to the new contract or declared as scrap.

Confirmation was received by OCR letter of April 20 indicating that all subcontracts and consulting agreements which were in effect under Contract No. 14-01-0001-324 should be transferred to Contract No. 14-32-0001-1207.

2. Outside Engineering and Services: Koppers continues to provide engineering assistance as required and as reported in their Progress Report No. 33 in Appendix B.

Action by OCR on the request for approval of proposed Amendment No. 7 to Subcontract No. 2, signed by Koppers and submitted to OCR on October 20, 1971, still has not been received.

3. 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 thirteenth month. Five copies of the Second Semi-annual Technical Progress Report covering work completed during the second half of Phase I of the program were received. Figure 129, Monthly Progress Chart, Expenditures, shows the current budget status at the end of Phase I and that projected for Phase II through March 31, 1973. The letter report of progress made during April is as follows:

During the past month, in addition to preparing the Technical Report, efforts have been directed towards exploratory testing of the 1 1/4-inch diameter and 2-inch diameter reactors. A total of nine tests have been conducted, five of which were with the 1-1/4-inch reactor. Data from these runs are summarized in Tables 104 and 105, respectively.

The first two tests with the 1-1/4-inch reactor were repeats of feed conditions employed during the previous month to check char and gas analysis. These tests confirmed the prior results. At a coal feed rate of 1.6 lbs/hr and a coal/oxygen ratio of 2-1, only 37 percent of the coal was gasified. Increasing the coal feed to 2.0 lbs/hr and reducing the coal/oxygen ratio increased the gas yield, based on char analysis, to 48 percent but reduced the ratio of coal converted to hydrocarbon gases to that converted to carbon monoxide.

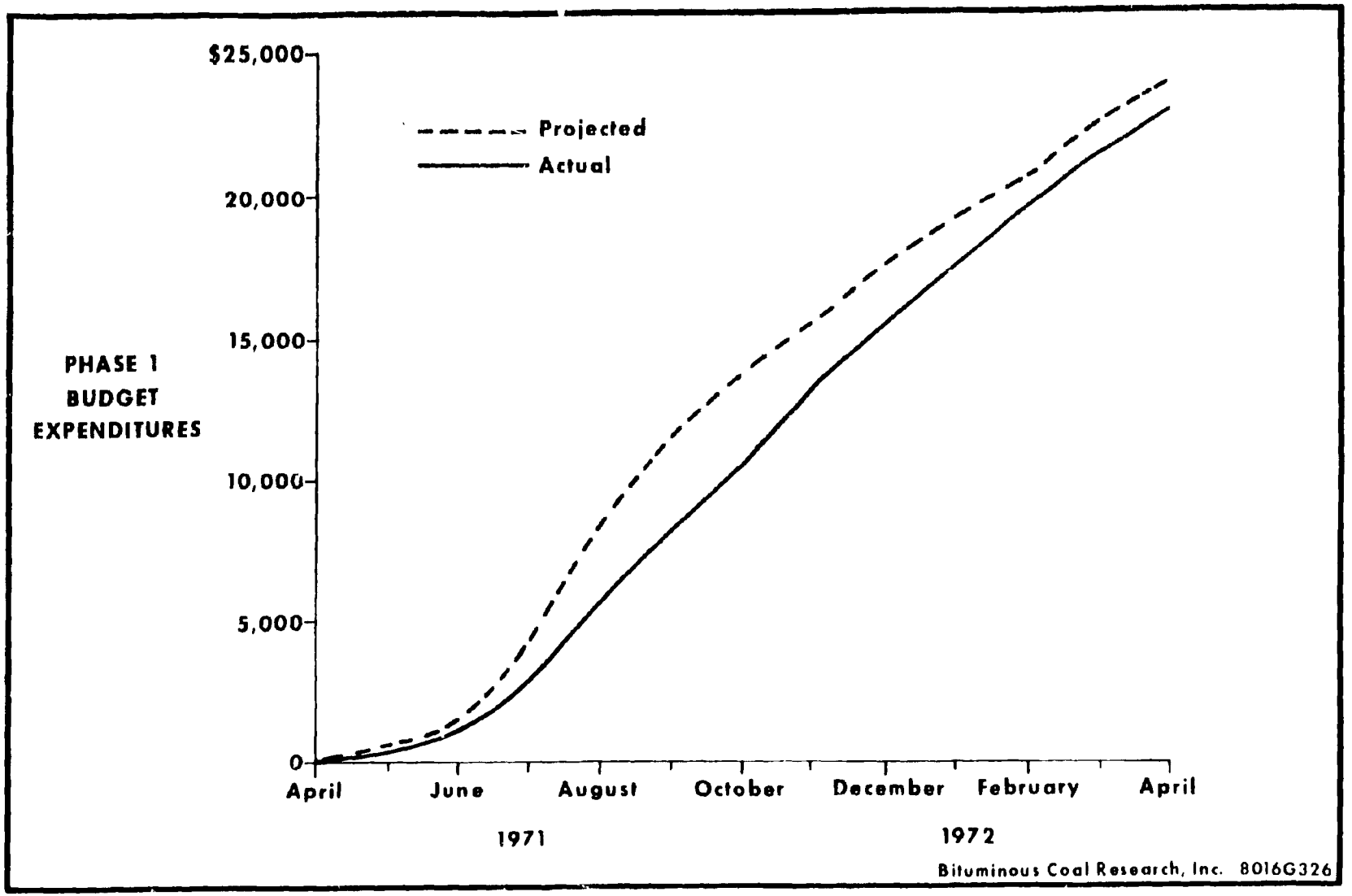

Figure 129. Monthly Progress Chart, Expenditures, Brigham Young University

TABLE 104. SUMMARY DATA FOR TESTS IN 1-1/4-INCH REACTOR, APRIL, 1972

Run No.	4-3-1	4-6-1	4-14-1	4-18-1	4-19-1	
Reactor Tube Size	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	
Objective	Repeat of 3-28-2 to check ash analysis	Repeat of 3-29 -1 to check gas analysis		Test of ceramic heat carrier concept. Catalyst injected at top, coal below.	Inject both catalyst and coal thru top feed port to determine catalyst effect.	Repeat of 4-18-1. Inject catalyst with coal. Check gas analysis.
Feed Rates lbs/hr						
Coal	1.62	1.98		1.00	1.89	1.85
Hydrogen carrier	0.082	0.12		0.082	0.105	0.105
Hydrogen combustion	0.057	0.13		0.088	0.150	0.150
Oxygen	0.78	1.56		0.88	1.19	1.204
Nitrogen	0.40	0.40		1.17	0.78	0.78
Catalyst	--	--		(7.5)	(4.73)	(4.63)
Ratio coal/oxygen	2.08	1.27		1.14	1.58	1.54
Reactor Temp. F		2160		--	1820	2100-2200
Gas Sample Port	--	Reactor Quench		Quench	Reactor	Reactor Mid / Reactor Bottom
Gas Analysis (N,D Free)						
Hydrogen	--	55.43	54.70	(95.63)	76.35	73.40 / 73.48
Methane	--	5.23	5.18	(0.67)	5.12	4.00 / 3.86
Carbon monoxide	--	34.10	36.93	(2.25)	14.96	16.50 / 17.70
Ethane	--	0.02	--	(0.04)	(0.14)	-- / --
Ethylene	--	1.19	0.89	(0.40)	(2.09)	0.31 / 0.28
Carbon dioxide	--	1.12	--	--	--	1.79 / 1.51
Acetylene	--	2.91	2.30	--	(1.33)	3.99 / 3.17
lbs C in HC/lbs C in CO	--	0.40	0.31		0.82	0.76 / 0.61
Char Collection Rate lbs/hr	0.57	0.99		3.58	3.23	1.56
Ash Analysis						
Coal	7.1	7.1		7.1	7.1	7.1
Char	11.3	13.7		94.6	65.3	65.6
Yield	37.1	48.1		--	--	--
Run Time, minutes	2	3 1/2		2 1/4	4 3/4	6
Comments:	Yield checks well with 3-28-2 run. Two minute run.	Hydrocarbons nearly same as before. CO higher. Some plugging encountered after 3 1/2 minutes.		No caking apparent in reactor except small amount opposite coal injection port.	Problems with catalyst feeding. Some caking opposite injectors. High conversion to HC.	Actual catalyst feed rate unknown; much lower than planned. High acetylene concentration.

TABLE 105. SUMMARY DATA FOR TESTS IN 2-INCH REACTOR, APRIL, 1972

Run No.	4-24-1	4-25-1	4-25-2	4-27-1
Reactor Tube Size	2	2	2	2
Objective	Repeat of 4-19-1. Feed rates, no catalyst, 2-inch reactor. Reactor length shortened from 7 3/4 to 4 5/8 inches.	Feed same coal rate as 4-24-1 but reduce oxygen feed to increase coal/oxygen ratio. No catalyst.	Inject coal and catalyst together	Increase alumina surface in reactor. Heat reactor then shut off combustion gas, inject coal only.
Feed Rates, lbs/hr				
Coal	1.92	1.92	1.98	1.98
Hydrogen carrier	0.082	0.09	0.082	0.082
Hydrogen combustion	0.150	0.10	0.126	--
Oxygen	1.21	0.78	0.89	--
Nitrogen	--	--	0.39	--
Catalyst	--	--	(3.31)	
Ratio Coal/oxygen	1.59	2.46	2.23	--
Reactor Temp. F	1830-1890	1770-2040	1500	2150-2450
Gas Sample Port	Reactor Bottom / Quench	Reactor Bottom / Quench	Reactor	Reactor Bottom / Quench
Gas Analysis (N,D, Free)				
Hydrogen	69.29 / 68.66	68.93 / 66.70	(44.16)	78.64 / 78.57
Methane	3.90 / 4.09	3.88 / 3.60	(8.72)	9.98 / 9.95
Carbon monoxide	20.52 / 20.70	20.96 / 23.46	(24.98)	6.55 / 6.96
Ethane	0.02 / 0.03	0.02 / 0.03	(2.15)	0.07 / 0.04
Ethylene	0.91 / 0.95	0.81 / 0.75	(10.46)	2.55 / 1.73
Carbon dioxide	3.80 / 3.85	3.99 / 4.33	(5.46)	0.63 / 0.76
Acetylene	1.59 / 1.71	1.42 / 1.13	(4.07)	1.69 / 1.98
lbs C in HC/lbs C in CO	0.43 / 0.46	0.40 / 0.32	1.68	2.64 / 2.51
Char Collection Rate	0.64			
Ash Analysis				
Coal	7.1			
Char	16.8			
Yield	57.7			
Run Time, minutes	10	2	5	3
Comments:	Without plugging. Lower conversion to ethylene and acetylene than in catalyst run.	Reactor plugged, stopped coal feed after 2 minutes. Slight decrease in yield of hydrocarbon gases.	After running five minutes the reactor plugged shutting off feed. Reactor completely full of char and catalyst. Gas samples badly contaminated with air. High hydrocarbons.	After heating injected coal for one minute, then burned out reactor with combustion gas only for 2 1/2 minutes then repeated cycle. Gas samples taken during coal injection. Highest concentration of methane to date.

Three tests were made with the 1-1/4-inch reactor in which spent cracking catalyst, obtained from the American Oil Refinery in Salt Lake City, was injected along with the coal. In the first test, the catalyst was injected at the top of the reactor and the coal was injected through the gas sampling port at the mid-point of the reactor. Problems were encountered in controlling the catalyst feed rate. Also, the gas analysis is uncertain because of problems with the silica-gel column of the chromatograph. The analysis showed a high conversion to ethylene.

The next two runs were carried out with the catalyst being injected along with the coal at the top of the reactor tube. Problems were again encountered in controlling the catalyst feed rate. The gas analysis for this run indicated low ethylene and high acetylene in the product gas. There was no caking apparent in the reactor during this run even though the coal rate was 2 lbs/hr and the coal oxygen ratio was 1.54.

The 2-inch diameter reactor tests were made by replacing the 1-1/4-inch alumina tubes with a single 2-inch tube, and using only the upper heater and housing, reducing the reactor length from 7-3/4 inches to 4-5/8 inches. The first test with this configuration was made with the same feed rates as in the previous test, but without injecting catalyst. The test was continued for 10 minutes with no apparent caking inside the reactor. The gas yield based on char analysis was high, 58 percent by weight of the coal fed, or 62 percent of the ash-free weight, being converted. Over 40 percent of the conversion was to methane, ethylene, and acetylene. The second test of the 2-inch reactor was with the same coal feed rate but with the coal/oxygen ratio increased to 2.5. However, severe plugging of the reactor was encountered at these conditions. The next run was made with a reduced coal/oxygen ratio and with catalyst being injected along with the coal. Again plugging was encountered, and again the catalyst feed rate was not properly controlled. The gas samples were contaminated with air due to plugging in the sampling probes and therefore the analysis is uncertain. However, it indicated extremely high conversion to ethylene and acetylene.

The final test with the 2-inch reactor was made to determine the product gas composition resulting from pyrolysis as a result of heating by radiation and contact with the reactor walls, with no convective heating by combustion products. Several short lengths of 3/4-inch alumina tube were placed at the bottom of the 2-inch reactor to increase the hot surface area, and the reactor was heated to 2500 F. Coal was then injected at a rate of 2 lbs/hr for one-minute periods separated by a period of 2-1/2 minutes during which the reactor was burned out with hydrogen-oxygen combustion gases. Gas samples were withdrawn during the coal injection periods. The analysis of these samples showed a high conversion to methane and ethylene, with little carbon monoxide or carbon dioxide, as anticipated.

Plans for the coming month include further testing with the catalyst. Also, a new gas filtration system will be put into operation which will permit measurement of the volume of gas produced during collection of the char samples.

4. FPC National Gas Survey - Economics of Manufacturing SNG from Coal: A meeting was held in Washington, D. C., on Monday, March 27, 1972, at the Office of Coal Research to review the breakdown of the process on-site invest-

ment costs given in the preliminary compilation of costs of pipeline gas from coal for the FPC National Gas Survey (2-10-72).

The following Task Force members and OCR Contractor Sub-group members were present:

Task Force Members

Mr. Neal P. Cochran
Office of Coal Research
Department of the Interior
Washington, D. C. 20240

Dr. A. B. Flowers
American Gas Association
1515 Wilson Blvd.
Arlington, Va. 22209

Mr. James R. Garvey
Bituminous Coal Research, Inc.
350 Hochberg Road
Monroeville, Pa. 15146

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P. O. Box 880
Collins Ferry Road
Morgantown, W. Va. 26505

Mr. James Landers
CONOCO
Research and Engineering
Ponca City, Okla. 74601

Mr. George Bolton
Columbia Gas System Service Corp.
20 Montchanin Road
Wilmington, Delaware 19807

Mr. Jack Ryan
Office of Coal Research
Department of the Interior
Washington, D. C. 20240

As a result of this meeting, the attached Table 106, "Revised Plant Investments and Capital Requirements - Bituminous Coal, for Synthetic Gas-Coal Task Force Review" was developed for presentation to OCR for review at the next meeting of the Task Group. In addition, it was requested by OCR that IGT, BCR, and the Bureau of Mines work up new total plant investment and gas costs for a non-coking, low-sulfur western coal. It was decided that a Montana subbituminous coal be used in this study. The purpose of this study is to verify the assumption used by Esso that a $20 million investment savings for a non-coking, low sulfur coal reflects a gas cost savings of 6.6 cents/MM Btu for western coal in the BI-GAS, three HYGAS cases, and Synthane. Likewise, CONOCO will prepare new total plant investment and gas costs for the CO_2-Acceptor process for a bituminous coal.

Finally, these cost data will be sent by each OCR contractor to OCR on or about April 28, 1972, for review. IGT will supply to BCR and the Bureau of Mines the coal analysis of Montana subbituminous coal.

TABLE 106. REVISED PLANT INVESTMENTS AND CAPITAL REQUIREMENTS--BITUMINOUS COAL FOR SYNTHETIC GAS-COAL TASK FORCE REVIEW

Timing: Mid-1971 Startup Completion

			HYGAS			
	Lurgi	BI-GAS	Electrothermal	Steam-Oxygen	Steam-Iron	Synthane
Plant Size, Billion Btu/SD Pipeline Gas	237.2	236.1	253.3	247.2	252.8	231.8
Investment Breakdown, MM$:						
Process Onsites Investment						
Coal Storage and Preparation	--	13.9(1)	9.7(1)	9.3(1)	11.3(1)	6.9
Pretreatment	--	--	5.1	4.6	6.3	--
Feed System	--	6.6	11.7	8.5	12.0	5.8
Gasification and CO Shift	--	20.8	34.2	31.7	59.4	34.1
Gas Purification	--	30.3	28.5	33.1	21.9	15.5
Methanation	--	12.4	8.6	9.5	6.3	16.5
Compression	--	--	--	--	--	0.6
Auxiliary Onsites Investment						
Oxygen Manufacture	38.1	35.3	--	19.1	--	22.2
Sulfur Recovery	18.1	22.0	20.5	20.6	19.7	4.4(2)
Water Pollution Control	10.0	10.0	10.0	10.0	10.0	10.0
Steam and Power Plant Investment	15.2	17.5	72.9	20.9	10.3	22.1
General Utilities Investment	17.7	13.1	15.0	12.5	10.1	12.9
General Offsites Investment	10.0	10.0	10.0	10.0	10.0	10.0
Subtotal Excl. Contingencies	216.2	191.9	226.2	189.8	177.3	161.0
Project Contingency	32.4	28.8	33.9	28.4	26.6	24.2
Development Contingency	--	13.4	15.8	13.3	12.4	11.3
Total Plant Investment	248.6	234.1	275.9	231.5	216.3	196.5
Capital Requirement Breakdown, MM$:						
Total Plant Investment	248.6	234.1	275.9	231.5	216.3	196.5
Interest During Construction	42.0	39.5	46.6	39.1	36.5	33.2
Startup Costs	13.3	11.7	13.5	12.3	14.1	11.6
Working Capital	12.6	11.8	13.6	12.7	14.5	11.8
Total Capital Requirement	316.5	297.1	349.6	295.6	281.4	253.1
Adjusted for 250 Billion Btu/SD	333.6	314.6	345.1	298.9	277.7	273.1

Notes:

(1) Coal storage and preparation investment includes added 2MM$ allowance for particulate emissions control in cases indicated.

(2) Synthane case assumes that the char used as boiler fuel is sufficiently low in sulfur to preclude the need for flue gas desulfurization.

5. 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 up 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 based on the new process concept (E. E. Donath, December 11, 1970) has been filed and given Serial No. 182,652. The application, entitled "Gasification of Carbonaceous Solids," contains nine claims. The appropriate document assigning rights to the U.S. Government was filed with the patent application on September 22, 1972. BCR has applied for and received a license for foreign filing. Patent applications have been filed in Australia, India, South Africa, Canada, and Great Britain. Official filing receipts have been received assigning the following numbers:

Australia	- Serial No. 39570
India	- No. 134,819
South Africa	- Serial No. 72/1284
Canada	- Serial No. 137,359
Great Britain	- No. 9589/72

Applications are also being prepared for filing in France, Japan, and West Germany.

Confirmatory license to the government was executed by BCR and returned to Mr. Ernest Cohen, Assistant Solicitor, Branch of Patents, on January 12, 1972.

b. OCR-1860 and OCR-1861: Disclosures 1060 and 1861 were combined into a single patent application entitled "Two-stage Gasification of Pretreated Coal." A copy of this application was mailed to Mr. M. Howard Silverstein, Branch of Patents, on December 6, 1971, for his review and authorization for filing by BCR. By letter dated December 28, 1971, Mr. George Fumich authorized BCR to file a foreign patent application on the subject invention.

After further review by the inventor, a revised patent application was filed under Serial Number 237,332, on March 23, 1972, together with the appropriate document assigning rights to the U.S. Government. This application contains 12 claims.

On April 6, 1972, copies of the application as filed and the assignment document were forwarded to Mr. M. Howard Silverstein, Branch of Patents. Mr. Silverstein was advised that BCR has received license for foreign filing and intends to file this application in France, West Germany, and possibly Japan. Confirmatory license will be prepared.

c. OCR-1862: A U.S. patent application was prepared for Disclosure 1862 entitled "Three Stage Gasification of Coal." A copy of this application was sent to Mr. M. Howard Silverstein, Branch of Patents, on December 13, 1971, for his review and authorization for filing by BCR. Authorization for BCR to file a foreign patent application on the subject invention was received from Mr. George Fumich by letter dated December 28, 1971.

After further review by the inventor, a revised patent application was filed under Serial Number 237,333, on March 23, 1972, together with the appropriate document assigning rights to the U.S. Government. This application contains eight claims.

On April 6, 1972, copies of the application as filed and the assignment document were forwarded to Mr. M. Howard Silverstein, Branch of Patents. Mr. Silverstein was advised that BCR has received license for foreign filing and intends to file this application in France, West Germany, and possibly Japan. Confirmatory license will be prepared.

d. OCR-1863: A U.S. patent application was prepared for Disclosure 1863 entitled "Two-stage Downflow Gasification of Coal." A copy of this application was forwarded to Mr. Silverstein, Branch of Patents, on December 13, 1971, for his review and authorization for filing by BCR. By letter dated December 28, 1971, Mr. George Fumich authorized BCR to file a foreign patent application on the subject invention.

After further review by the inventor, a revised patent application was filed under Serial Number 237,454, on March 23, 1972, together with the appropriate document assigning rights to the U.S. Government. This application contains seven claims.

Copies of the application as filed and the assignment document were forwarded to Mr. M. Howard Silverstein, Branch of Patents, on April 6, 1972. Mr. Silverstein was advised that BCR has received license for foreign filing and intends to file this application in France, West Germany, and possibly Japan. Confirmatory license will be prepared.

e. OCR-1864: A U.S. patent application was also prepared for Disclosure 1864 entitled "Two-stage Gasification of Coal with Forced Reactant Mixing and Steam Treatment of Recycled Char." A copy of the application was sent to Mr. M. Howard Silverstein, Branch of Patents, on December 8, 1971, for his review and approval for filing by BCR. Authorization for BCR to file a foreign patent application on the subject invention was received from Mr. George Fumich by letter dated December 28, 1971.

After further review by the inventor, a revised patent application was filed under Serial Number 237,360, on March 23, 1972, together with the appropriate document assigning rights to the U.S. Government. This application contains 13 claims.

Copies of the application as filed and the assignment document were forwarded to Mr. M. Howard Silverstein, Branch of Patents, on April 6, 1972. Mr. Silverstein was advised that BCR has received license for foreign filing and intends to file this application in France, West Germany, and possibly Japan. Confirmatory license will be prepared.

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 prepared and submitted to Mr. George Fumich for his consideration on January 6, 1972. OCR has acknowledged receipt of this disclosure and forwarded it for processing.

I. Visitors During April, 1972

April 4, 1972

Mr. J. F. Farnsworth
Mr. J. Frank Cannon
Mr. D. M. Mitsak
Koppers Company, Inc.
Koppers Building
Pittsburgh, Pa. 15219

April 5, 1972

Mr. R. C. Fritz
Chemetron Corporation
Catalysts Division
P. O. Box 337
Louisville, Kentucky 40201

Mr. R. J. Brocker
Mr. R. J. Zoschak
Foster Wheeler Corporation
110 S. Orange Avenue
Livingston, New Jersey 07039

April 6, 1972

Mr. Fred Callowhill
Mr. T. F. Sheehan
Mr. Carl A. Bolez
Gilbert Associates, Inc.
P. O. Box 1498
Reading, Pennsylvania 19603

April 12, 1972

Mr. R. E. Maples
Mr. R. G. Ellis
Arthur G. McKee and Co.
Cleveland, Ohio 44131

Mr. R. Whiteacre
Mr. H. Leonard
Koppers Company, Inc.
Koppers Building
Pittsburgh, Pa. 15219

April 14, 1972

Mr. T. F. Sheehan
Gilbert Associates, Inc.
P. O. Box 1498
Reading, Pennsylvania 19603

Mr. J. W. Colton
Mr. J. I. Jenks
Procon, Inc.
30 UOP Plaza
Algonquin and Mt. Prospect Roads
Des Plaines, Illinois 60016

April 17, 1972

Mr. S. M. Tymiak
Mr. D. M. Mitsak
Mr. R. W. Whiteacre
Koppers Company, Inc.
Koppers Building
Pittsburgh, Pa. 15219

April 18, 1972

Mr. A. E. Miller
Mr. R. W. Whiteacre
Koppers Company, Inc.
Koppers Building
Pittsburgh, Pa. 15219

April 20, 1972

Mr. T. F. Sheehan
Mr. Fred Callowhill
Mr. Carl A. Bolez
Gilbert Associates, Inc.
P. O. Box 1498
Reading, Pennsylvania 19603

April 24, 1972

Mr. R. P. O'Neal, Jr.
Mr. J. I. Jenks
Procon, Inc.
30 UOP Plaza
Algonquin and Mt. Prospect Roads
Des Plaines, Illinois 60016

April 28, 1972

Mr. William Malaxos
Matrix Engineering, Inc.
2961 W. Liberty Avenue
Pittsburgh, Pennsylvania 15216

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

None

K. Requests for Information

Mr. Ken Kridner
Editor
GAS Magazine
4151 Southwest Freeway
Houston, Texas 77027

Mr. M. M. Sen
Scientist
Central Fuel Research Institute
P. O. F.R.I.
Dhanbad, (Bihar)
INDIA

Mr. Harold Wing
Consulting Engineer
Kerr-McGee
P. O. Box 25861
Oklahoma City, Oklahoma 73125

III. WORK PLANNED FOR MAY, 1972

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

As a result of the discussions with OCR concerning the fluidized-bed PEDU, proposals have been solicited from two firms for the design engineering of a PEDU. As soon as proposals have been received, one organization will be selected to prepare the design package. Reactivity studies of various chars will continue.

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.

Meetings are planned with organizations interested in providing project management services to PCR during the construction of the Homer City pilot plant. Bid evaluations will continue.

A. Trips and Meetings Planned

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

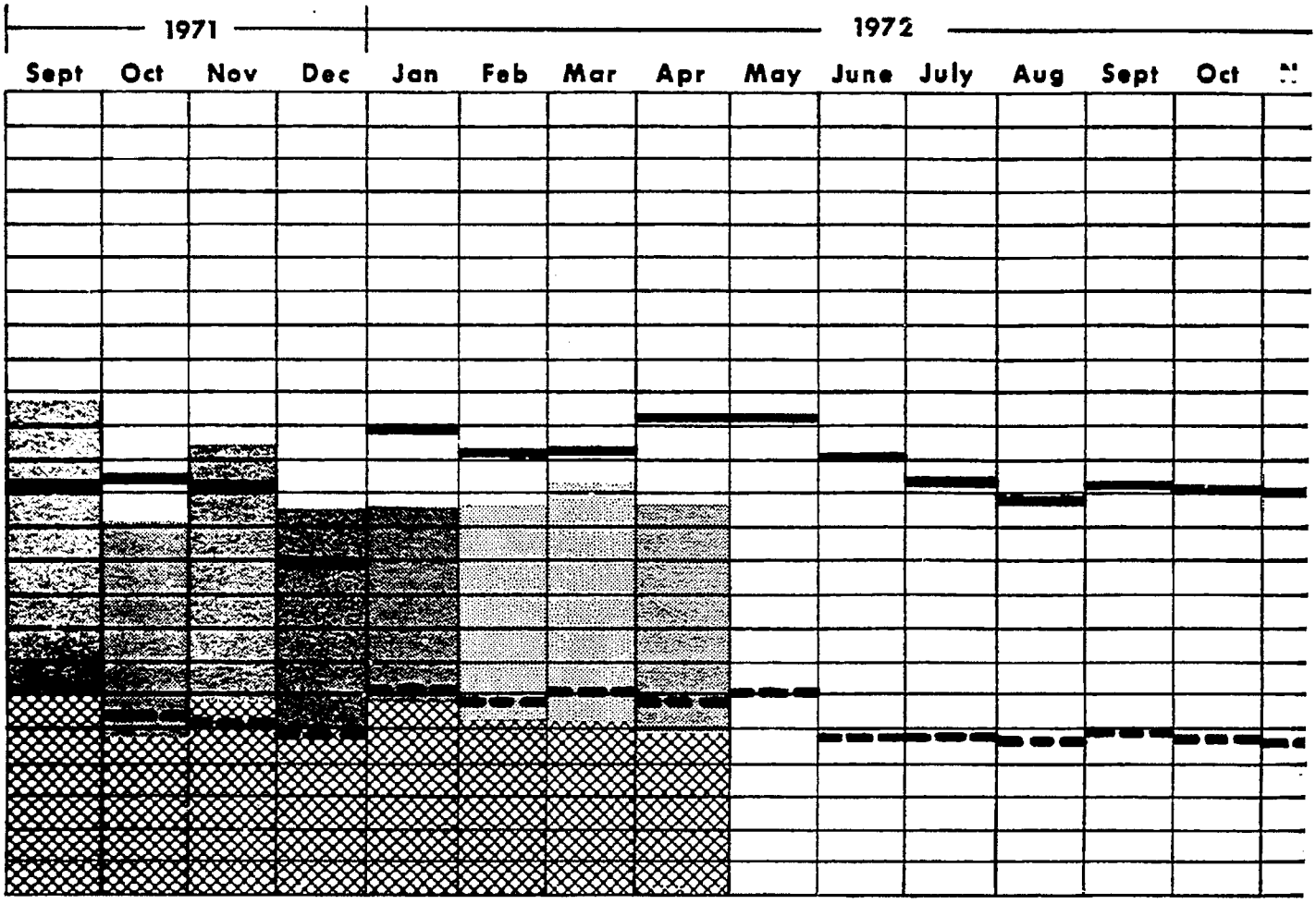
B. Papers to be Presented

None

C. Visitors Expected

May 3, 1972	Mr. John Mills El Paso Natural Gas Co. P. O. Box 1492 El Paso, Texas 79901
May 3, 1972	Mr. J. A. Craig Chevron Research Co. 576 Standard Avenue Richmond, California 94802
May 15, 1972	Mr. R. W. Borio Dr. R. W. Koucky Combustion Engineering, Inc. Windsor, Connecticut 06095

MANHOURS


1971
1972
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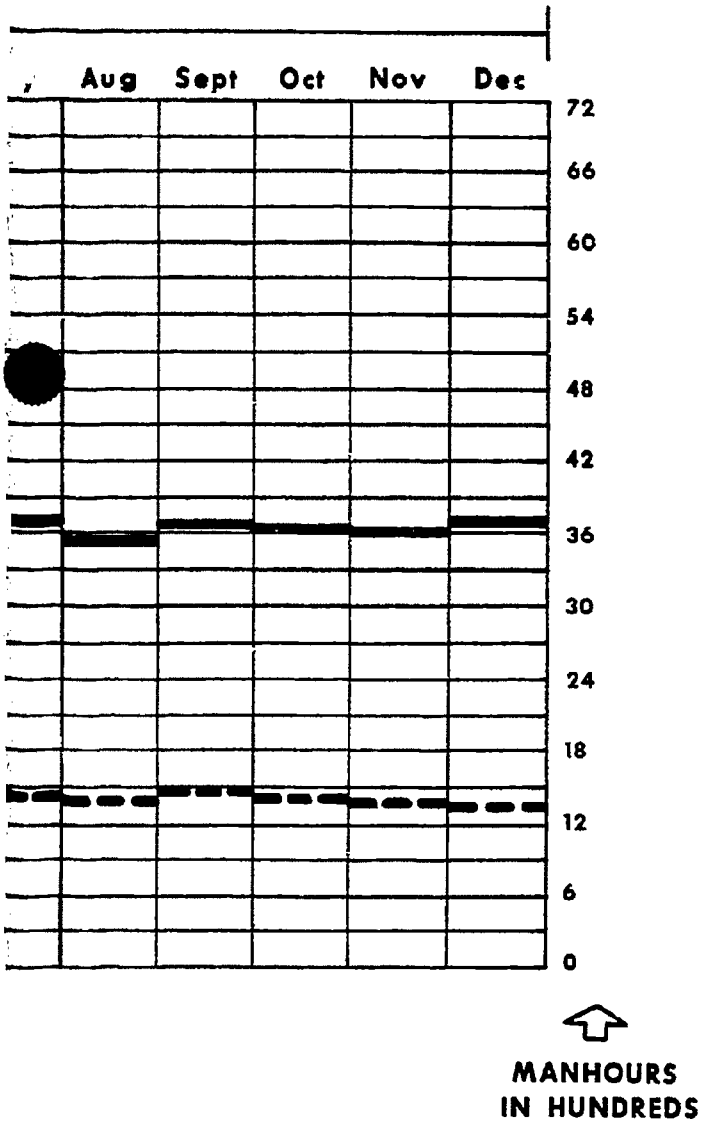
MONTHLY PROGRESS CHART
PART 1 MANHOURS

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

OFFICE OF COAL RESEARCH
DEPARTMENT OF THE INTERIOR

CONTRACT NO. 14-32-0001-1207



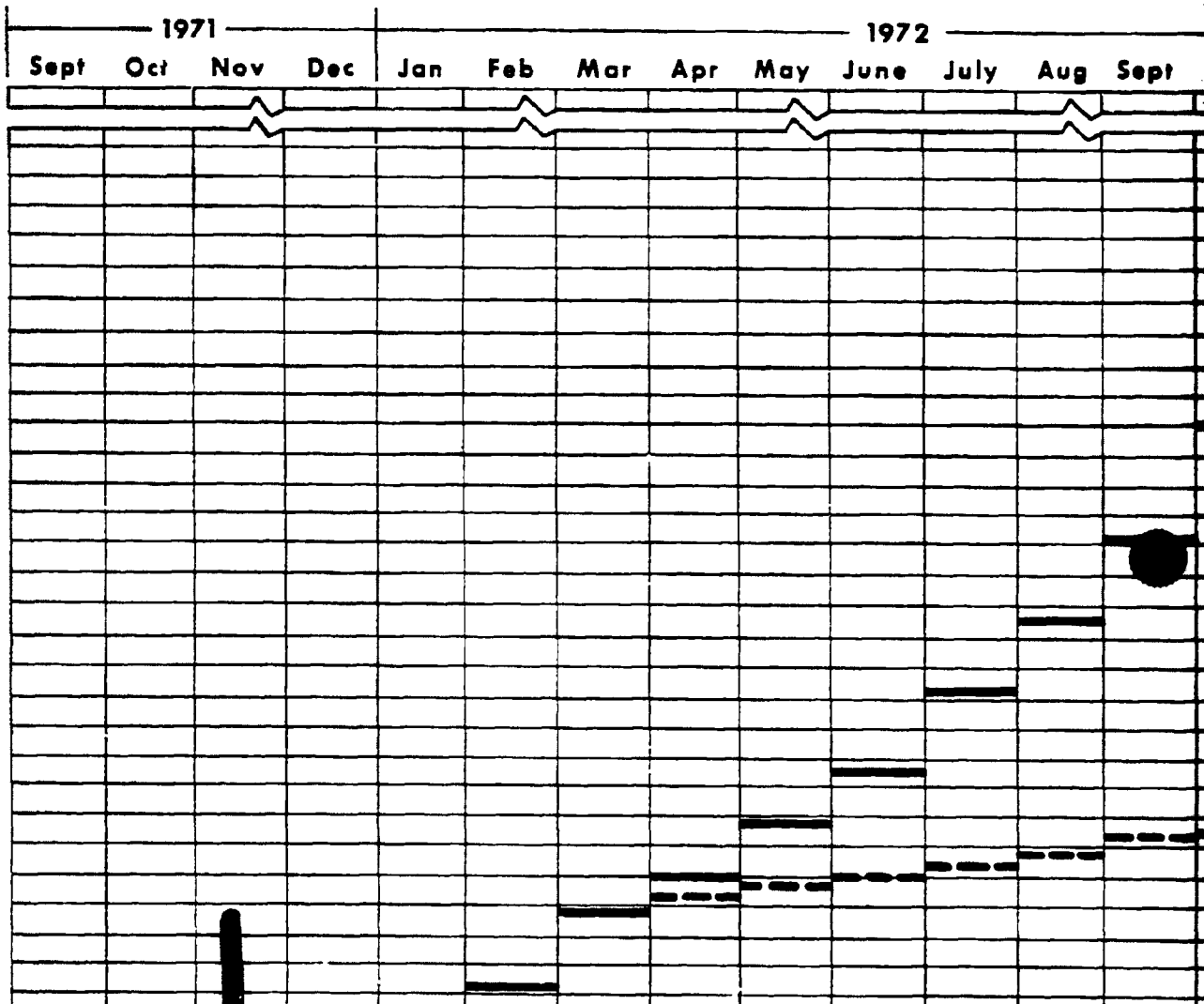
Predicted Professional and Non-professional

Predicted Professional

Actual Non-professional

Actual Professional

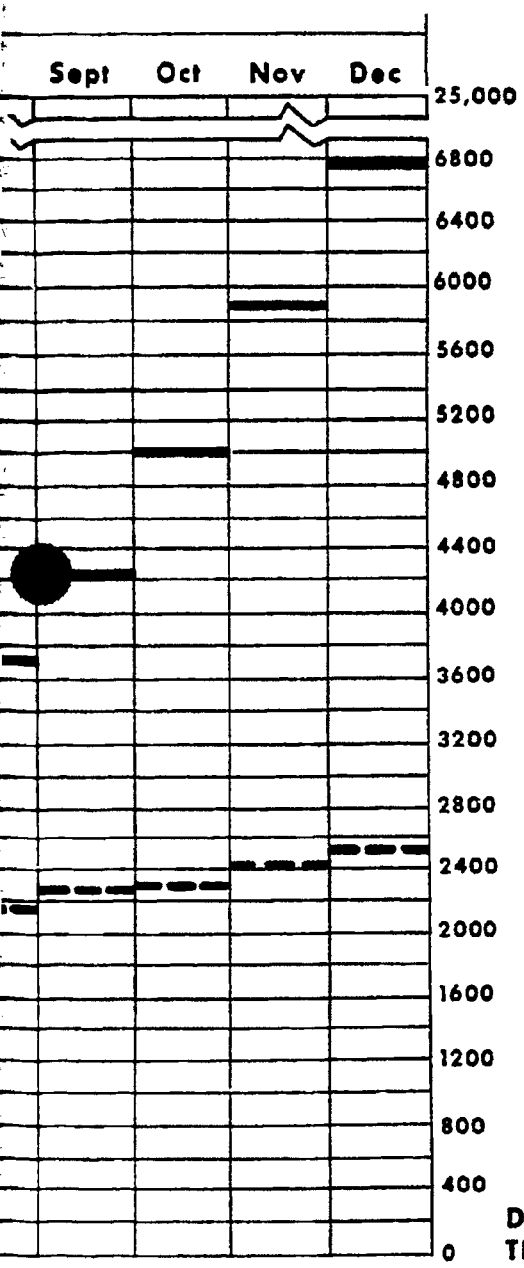
2



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*	
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*	

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

in Dollars)

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

* Estimated

APPENDIX B

B-486.

PROGRESS REPORT #33

Bituminous Coal Research, Inc.
Coal Gasification

April 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. A meeting was held on April 12, 1972, at BCR's offices (conference report no. 221) to discuss the redesign of the Methanator Feed Gas Heaters (M-E405 A & B), revised Plot Plan Drawing, design of the H_2S Removal Towers (M-V763 A & B), the Pressure Relief System and the Thermal Oxidizer Design.

   BCR requested that the Methanator Feed Gas Heaters be redesigned. They have recently experienced difficulties with severe fouling of their electrically heated lab units and suspect it is due to high surface temperatures, catalysis due to the stainless steel or a combination of these.

   BCR further requested that the H_2S Removal System design basis be modified to one which assumes an average H_2S Removal of 95% as being acceptable. The unit is to be designed to operate with a maximum feed of 10,000 SCFH of gas containing 1.0% H_2S. This flow is based on the assumption that only one (1) PEDU will be operated at a given time.

2. On April 17, 1972, a meeting was held at BCR (conference report no. 220) to review the construction schedule for the Methanation

PEDU and the rates of effort for engineering and procurement on this program.

3. A meeting was held April 18, 1972, at BCR (conference report no. 222) to discuss the plant General Arrangement; the location of the Thermal Oxidizer and the H_2S Removal Towers was established. Stakes were placed for locating the area of the hillside to be excavated.

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

Drawing No.	Rev.No.	Title	Date Transmitted
2415-2A733	0	Plot Plan	4/11/72
2415-2A701	2	Material Balance Sheet 1 of 2	4/17/72
2415-2A702	2	Material Balance Sheet 2 of 2	4/17/72
2415-2A727	0	Material Balance (with H_2S and CO_2 addition) Sheet 1 of 2	4/17/72
2415-2A728	0	Material Balance (with H_2S and CO_2 addition) Sheet 2 of 2	4/17/72
2415-2A715	1	Utilities Flow Diagram Sheet 1 of 3	4/20/72
2415-2A716	2	Utilities Flow Diagram Sheet 2 of 3	4/20/72
2415-2A717	1	Utilities Flow Diagram Sheet 3 of 3	4/20/72
2415-2A700	4	PEDU-Fluid Bed Methanator Sheet 1 of 2	4/20/72
2415-2A714	3	PEDU-Fluid Bed Methanator Details Sheet 2 of 2	4/20/72
2415-2A733	1	Plot Plan	4/20/72

Drawing No.	Rev. No.	Title	Date Transmitted
2415-2A726	1	Methanator Feed Gas Receiver	4/25/72
DS 2.13		Standards-Sheets 1 to 3 incl.	4/28/72
DS 4.12		Standards-Sheets 1 to 3 incl.	4/28/72
DS 4.22		Standards-Sheets 1 to 3 incl.	4/28/72
DS 4.31		Standards-Sheets 1 to 3 incl.	4/28/72
DX 2.21		Standards-Sheets 1 to 3 incl.	4/28/72
2415-4F-701	0	General Notes For Steel Design	4/28/72
2415-4F-702	0	Reformer Enclosure Specifications Sheets 1 and 2	4/28/72
2415-2A718	1	Reformer Structure and Cooling Tower General Arrangement	4/28/72

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

Date	Letter No.	Title	Remarks
4/4/72	C-337	Cost Estimate	Estimated Cost Of Additional Engineering for the modified Methanation PEDU program.
4/5/72	C-338	Meth. Feed Gas Compressor M-K305	Vendor's technical information pertaining M-K305 Peerless Vertical Absolute Separator
4/20/72	C-347	Review Of Annunciator Quotations	
4/21/72	C-348	Thermal Oxidizer M-X770	Spec. to solicit bids, also John Zink Co.'s letter of 4/18/72 confirming design and costs

Date	Letter No.	Title	Remarks
4/24/72	C-349	Water Cooler M-E700	Koppers suggested comments for revision to Vendor's approval drawing
4/26/72	C-351	Thermal Oxidizer	Two memoranda dated 4/14/72 and 4/21/72 pertaining to Thermal Oxidizer design

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