BITUMINOUS COAL RESEARCH, INC.
SPONSORED RESEARCH PROGRAM

GAS GENERATOR RESEARCH AND DEVELOPMENT

Progress Report No. 7

(BCR Report L-462)

I. INTRODUCTION

This report summarizes progress achieved during the ninety-ninth month of work 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 seventh 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 MARCH 25, 1972

A. Laboratory-scale Process Studies

1. Coal Composition and Beneficiation Studies, and Laboratory Pyrolysis of Coal (R. G. Moses, R. D. Saltsman, and J. E. Noll): The summary report (Special Report No. 1, BCR Report L-436) covering the work performed since September 1970 was mailed on March 6, 1972. This completes the work on this phase of the project.

2. Fluidized-bed Gasification (E. K. Diehl and J. T. Stewart): Work continued on the project with emphasis on arriving at a PEDU concept that would be consistent with the objectives of the experimental program. Laboratory work on char reactivity included the development of data for BI-GAS Stage 1 studies.

a. Fluidized-bed PEDU: OCR response to our letter of February 25, 1972, (ref. page 314, Progress Report No. 6) requested substantiation of the cost estimate which accompanied the preliminary flow diagram (Koppers Drawing No. 2415-2A438) of the most recent PEDU concept. The nature of the information required to meet OCR's request is such that a complete engineering design must be made. The design engineering package would supply equipment specifications, materials of construction, and performance criteria for the complete PEDU. In addition, sufficient data would be available to permit a more accurate estimate of the total erected cost of the unit.

In subsequent correspondence, OCR reemphasized the desire to have the PEDU as part of a continuing supporting effort for work on the production of low-Btu fuel gas. It was further indicated that OCR desires to have a flexible system designed with a nominal capacity of 100 lb/hr of coal. Specifically, the unit should handle either coal or char as a feed, with air or oxygen, or a mixture, as the oxidant, and with carbon dioxide and steam as the moderators. An additional alternate to be studied would be the use of carbon dioxide only as a source of oxygen.

In line with the above, OCR suggested that we obtain proposals from two firms for engineering the system, and submit our recommendations for approval. Discussions have been held with representatives of two companies, and both will submit proposals for the design engineering job.

b. Laboratory Investigations: The laboratory-scale fluidized-bed reactor described in last month's report has been used to demonstrate the applicability of the derived rate equation for the FMC char--carbon dioxide reaction. The TGA reactivity test was used to measure the reactivity of three chars from the BI-GAS Stage 2 PEDU relative to anthracite.

(1) Batch Reactor Tests: Six tests were made in the fluidized-bed batch reactor at a bed temperature of 1000 C and a system pressure of 70 psia, with FMC char (BCR Lot No. 2455) reacting with 100 percent carbon dioxide. Tests of 10, 20, 30, 40, 50, and 60-minute duration were made, at which time the reaction was quenched and the char was weighed to determine the weight loss. Figure 104 shows a curve drawn through the experimental data. The bottom curve is a plot of the previously derived rate equation for a reaction temperature of 1000 C:

$$(1-x) = ash + (1-ash)\ e^{-k\,(C_{CO_2})^{.52}t}$$

$$\text{and}\quad k = 3.96 \times 10^{6}\ e^{\frac{-2.36 \times 10^{4}}{T}}$$

where x = fraction of char reacted

T = temperature in °K = 1273

C = mole percent of reacting gas = 1.0

t = time in minutes

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

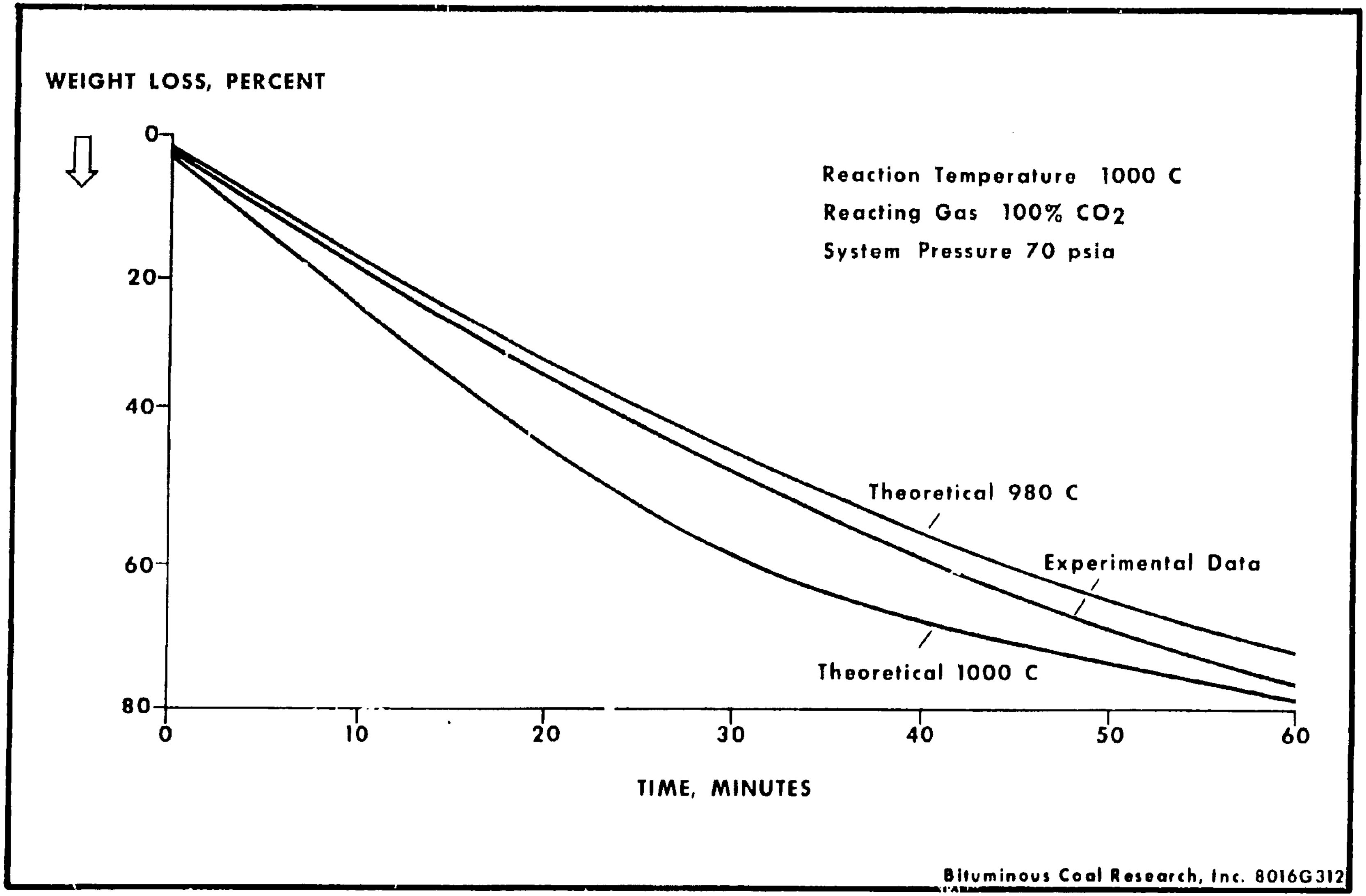
ash = weight fraction of ash in unreacted char = 0.15

The experimental data are closely approximated by the rate equation, with the experimental rate being always less than that predicted. This can be explained by examining the upper curve in Figure 104, a plot of the rate equation for a reaction temperature of 980 C. This plot follows the experimental data very closely. As explained in last month's report, the reaction temperature is measured by a thermocouple immersed in the dense phase fluidized bed. However, at any given time, some finite, but unmeasured, fraction of the char is in the cooler disengaging zone above the bed. Since the average temperature of char in the bed is postulated to be approximately 980 C, the derived rate equations may be used with confidence as design equations for char gasification reactors operating at low pressures and at non-slagging temperatures.

(2) TGA Tests: Twenty-one tests were made on the TGA during the month to determine the reactivity of chars from coals of different rank relative to anthracite. The chars investigated were from the Stage 2 PEDU tests on Pittsburgh seam coal (BCR Lot No. 2655), Elkol (BCR Lot No. 2280), lignite (BCR Lot No. 1963), and a Pennsylvania anthracite (BCR Lot No. 2985). (See Section II-C, Cold Flow Model Experiments, of this report for a discussion of the measured reactivities. See also Figures 111, 112, and 113 in that section for typical experimental data.) Figure 105 is an Arrhenius plot of the measured reactivity data. It is interesting to note that the Pittsburgh seam char, the Elkol char, and anthracite all gave an apparent activation energy of approximately 33 kcal/g mole, while the lignite char gave an activation energy of 16 kcal/g mole. The measured reaction rate coefficient was based on the continuous reaction model which has been described in previous reports. The low apparent activation energy of the lignite char suggests that this char cannot be adequately described by the continuous reaction model, but rather its reaction rate is determined by both kinetic and diffusion resistances of the same order. Additional tests will be conducted to investigate this possibility.

c. Future Work: As soon as proposals are received, an organization will be selected to prepare the design package for the PEDU.

Reactivity studies will continue using both the TGA and the batch reactor.



Bituminous Coal Research, Inc. 8016G312

Figure 104. Comparison of Fluidized-bed Reaction Rate Data with Derived Rate Equation for FMC Char

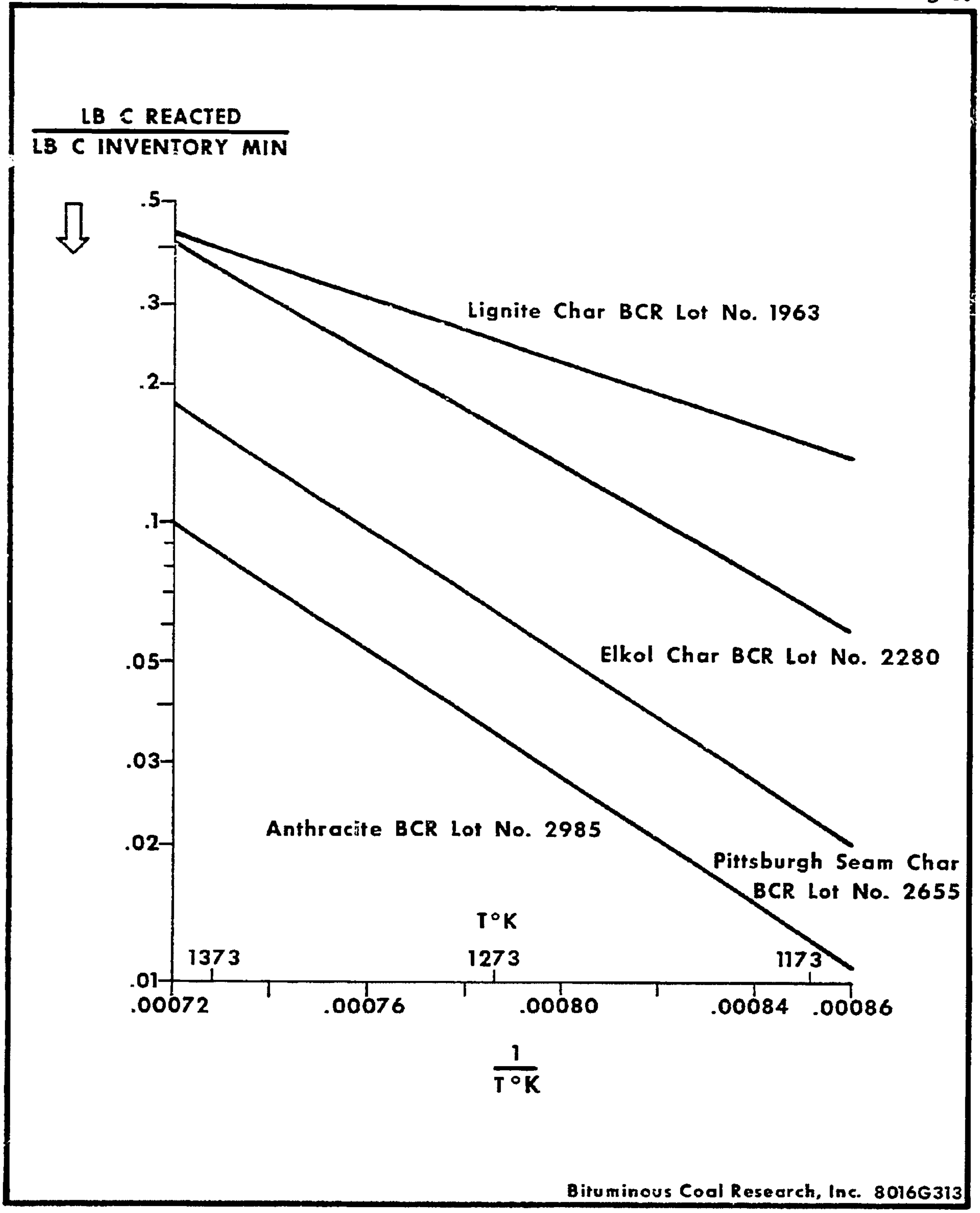


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Figure 105. Arrhenius Plot of Char Reactivity Data

3. 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 106. The revisions reflect changes in the scheduling of the PEDU studies. The model studies program has been extended six weeks due to a delay in receipt of an alumina-based catalyst to be used in place of the pulverized sand. The material is now available and tests are again proceeding. The PEDU engineering and procurement schedule has been slightly revised to reflect current Koppers' scheduling. This report summarizes progress achieved in the bench-scale and PEDU gas processing programs during the month of March.

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. 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, five exploratory BSM tests, Numbers 56 through 60, 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. In addition, raw test date from BSM Test 55, reported last month, were analyzed.

(a) BSM Test 55: BSM Test 55 was conducted with 125 grams of Lot 2903 molybdenum 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	57.65
Carbon Monoxide	20.61
Carbon Dioxide	14.30
Methane	7.44

Catalyst 2903 has a minimum fluidization velocity of 0.004 fps at reactor conditions, and a poured bulk density of 38 lb per cu ft.

Test Conditions: Test 55 was conducted at 830 to 835 F and 1000 psia throughout four test periods. The sample from Period 2 was lost. All periods were conducted at a relative velocity of about five times that at minimum fluidization.

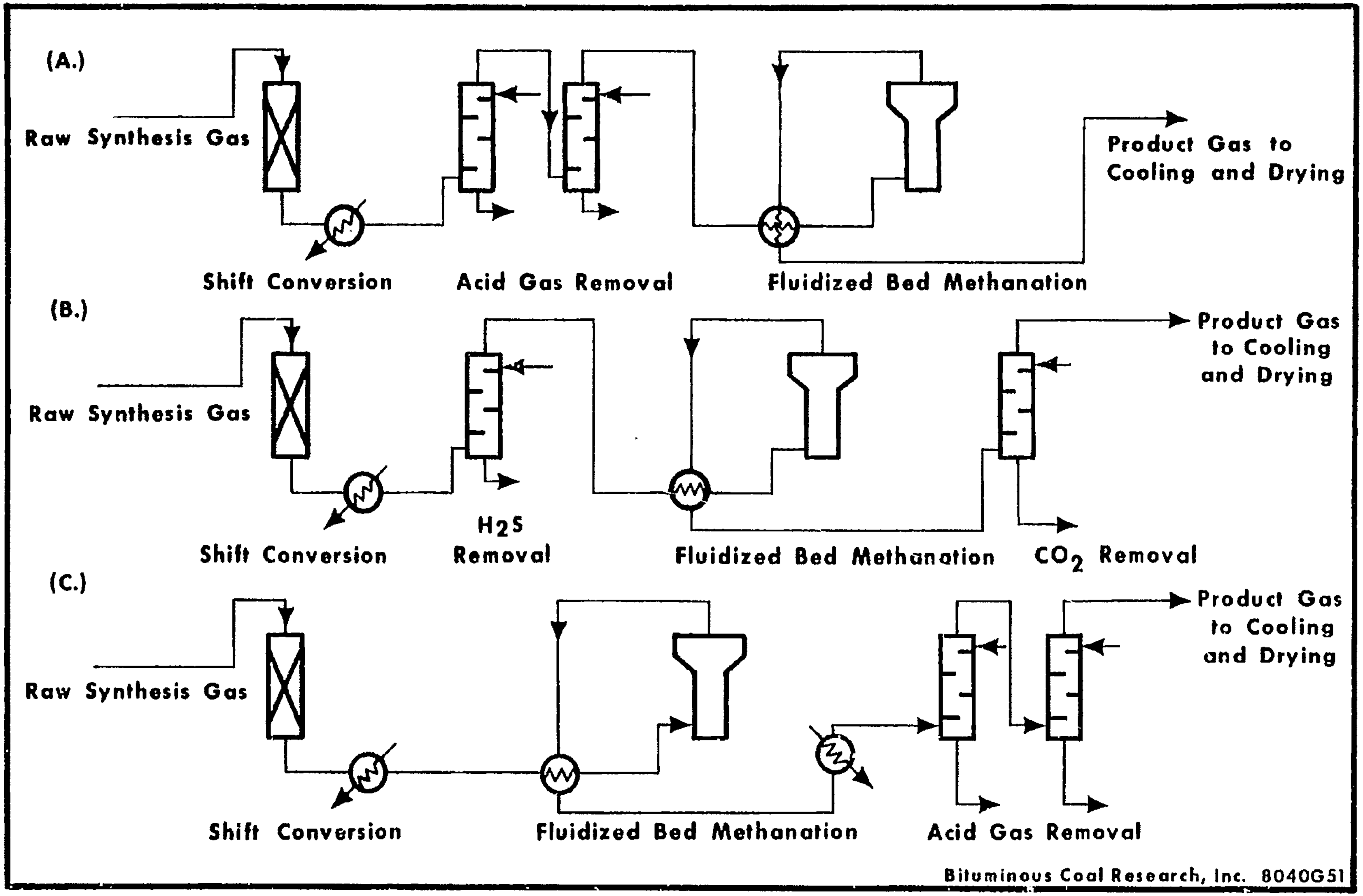

Figure 107. BI-GAS Gas Processing Systems

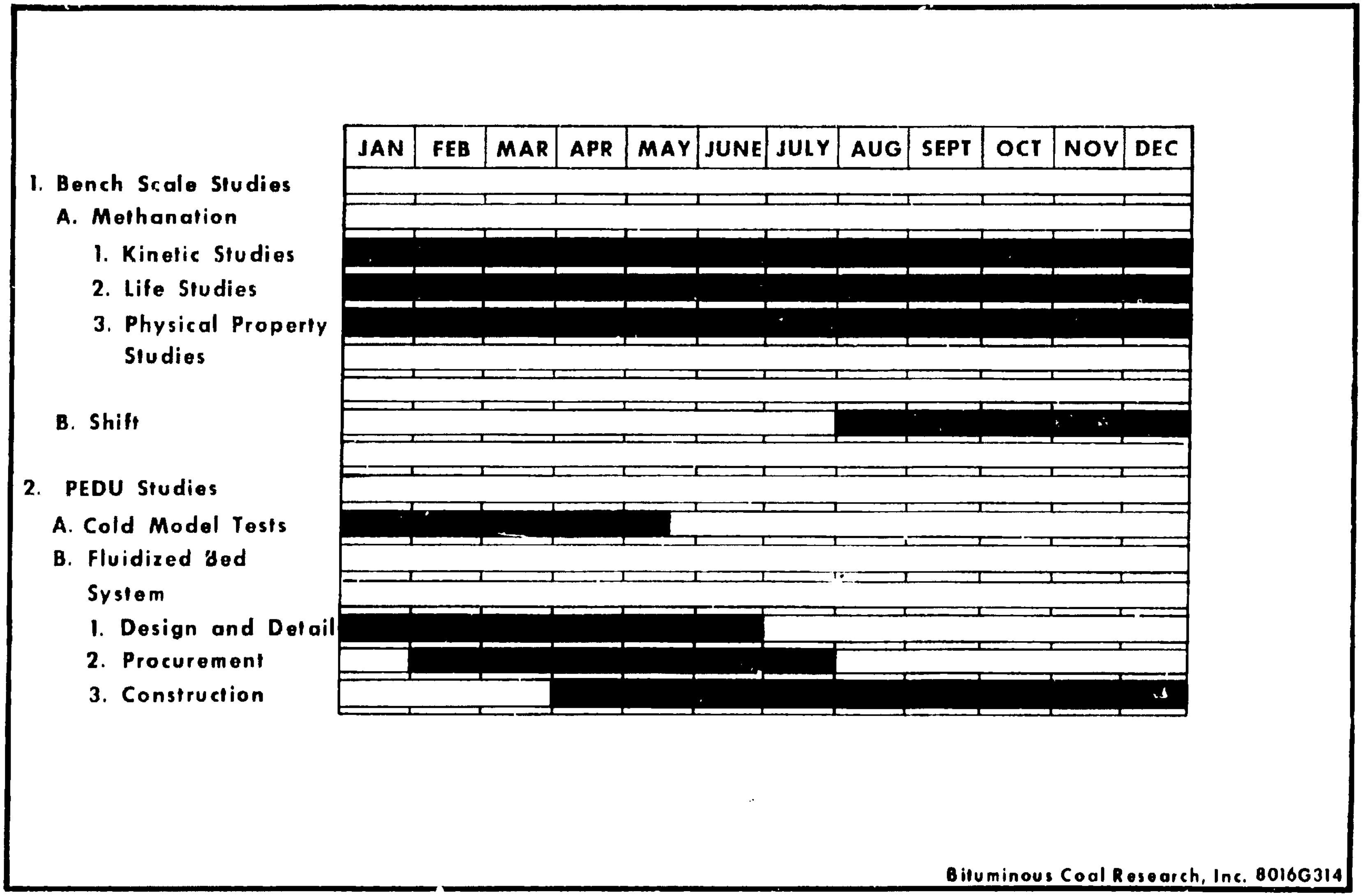

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Figure 106. Gas Processing Work Schedule for Calendar 1972

Results for Test 55: Material balance data for Test 55, Periods 1, 3, and 4, are given in Table 81. Yield data are summarized in Table 82.

In Test 55, a hydrogen to carbon monoxide ratio of 2.8/1 was used successfully without carbon deposition. Shift conversion drove the exit ratio to about 5/1. At these conditions, methane was the prime product, but significant amounts of ethane and propane were also present. Literature data on the iso-synthesis, (work conducted by the Germans in the 1930's pertaining to the production of isobutane from carbon monoxide and hydrogen) indicate that even at low hydrogen to carbon monoxide ratios, a temperature of 900 F, and a pressure of 100 atmospheres, methane was the prime product over mixed oxides of molybdenum or chrome and aluminum; traces of aromatic hydrocarbons were also found. That work also indicated that the chrome or molybdenum oxide tended to retard carbon formation, which is promoted on an alumina surface.

Data in Tables 81 and 82 indicate that shift equilibrium has been achieved and that reasonable useful conversion of ($CO + H_2$) has been accomplished.

Comparison of Tests 53, 54, and 55: Tests 53, 54, and 55 were all conducted on Lot 2903 molybdenum oxide catalyst. In each instance, a different feed gas composition and different test conditions were used. Table 83 summarizes the results of these studies.

In Table 83, the effects of temperature and feed gas composition are indicated. For Tests 53 and 54, where no carbon dioxide was present in the feed gas, high yields of carbon dioxide were obtained and, consequently, the conversion of carbon monoxide was above 90 percent. The useful conversion of ($CO + H_2$) was higher in Test 53 than in Test 54, even though the space velocity was higher. This indicates the effect of gas composition on conversion. The gas from Test 54, which simulates 1/1 product to fresh feed recycle, is suitable for fixed-bed cleanup methanation. Data from Test 53 show no increased efficiency of methanation with temperature in this region. Reconsideration of Test 52, which was conducted at non-isothermal conditions, indicates that above 800 F, temperature does not affect the methanation rate. It does, however, alter the shift reaction rate and, therefore, the system hydrogen to carbon monoxide ratio.

In Test 55, the temperature and the space velocity were lower than in Test 53. The ($CO + H_2$) content of the fresh feed was the same. Assuming no affect of temperature, it would seem that carbon dioxide in the feed depresses conversion over molybdenum oxide-alumina catalysts. This may be due to the fact that shift conversion is faster than water desorption on the catalyst surface; the reaction rate is depressed by steam. No data are available currently to support this supposition.

TABLE 81. DATA AND RESULTS FOR ESM TEST 55, PERIOD 1, CONDUCTED AT 835 F AND 985 PSIG MOLYBDENUM OXIDE CATALYST NO. 2903

A. Material Balance

Component	Feed		Product	
	mole percent	g moles/hr	mole percent	g moles/hr
Carbon Monoxide	20.61	4.64	7.48	1.09
Carbon Dioxide	14.30	3.22	25.82	3.76
Hydrogen	57.65	12.97	37.57	5.48
Nitrogen	0.00	0.00	0.00	0.00
Methane	7.44	1.67	26.81	3.91
Ethane	0.00	0.00	1.69	0.25
Propane	0.00	0.00	0.63	0.09
Water	0.00	0.00	0.00	2.45
Total	100.00	22.50	100.00	17.03

	In	Out
Total Moles Carbon	9.53	9.53
Total Moles Hydrogen	32.64	33.70
Total Moles Oxygen	11.07	11.07

B. Conversion Data

	Raw Data g moles/hr	H_2 Normalized g moles/hr
$CO \rightarrow$ Products	3.55	3.55
$H_2 \rightarrow$ Products	7.50	8.07
Reactants $\rightarrow H_2O$	2.45	2.45
$CO \rightarrow CH_4$	2.23	2.23
$CO \rightarrow C_2H_6$	0.49	0.49
$CO \rightarrow C_3H_8$	0.28	0.28
$CO \rightarrow CO_2$	0.56	0.56
α, Percent	65.7	63.5
β, Percent	25.6	25.6
K_{shift} (experimental)	7.70	7.70
K_{shift} (theoretical at outlet)	7.69	7.69

TABLE 81. DATA AND RESULTS FOR BSM TEST 54, PERIOD 3,
CONDUCTED AT 835 F AND 985 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	20.61	4.85	8.40	1.30
Carbon Dioxide	14.30	3.36	25.55	3.96
Hydrogen	57.65	13.55	38.22	5.93
Nitrogen	0.00	0.00	0.00	0.00
Methane	7.44	1.75	25.89	4.02
Ethane	0.00	0.00	1.41	0.22
Propane	0.00	0.00	0.51	0.08
Water	0.00	0.00	0.00	2.34
Total	100.00	23.51	100.00	17.85

	In	Out
Total Moles Carbon	9.96	9.96
Total Moles Hydrogen	34.11	34.55
Total Moles Oxygen	11.57	11.57

B. Conversion Data

	Raw Data g moles/hr	H_2 Normalized g moles/hr
CO → Products	3.54	3.54
H_2 → Products	7.63	7.85
Reactants → H_2O	2.34	2.34
CO → CH_4	2.27	2.27
CO → C_2H_6	0.44	0.44
CO → C_3H_8	0.24	0.24
CO → CO_2	0.60	0.60
α, Percent	62.1	61.60
β, Percent	23.0	23.0
K_{shift} (experimental)	7.71	7.71
K_{shift} (theoretical at outlet)	7.69	7.69

TABLE 81. DATA AND RESULTS FOR BSM TEST 55, PERIOD 4, CONDUCTED AT 830 F AND 965 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	20.61	4.72	8.69	1.32
Carbon Dioxide	14.30	3.27	25.40	3.87
Hydrogen	57.65	13.20	38.73	5.90
Nitrogen	0.00	0.00	0.00	0.00
Methane	7.44	1.70	25.31	3.86
Ethane	0.00	0.00	1.36	0.20
Propane	0.00	0.00	0.51	0.08
Water	0.00	0.00	0.00	2.20
Total	100.00	22.89	100.00	17.43

	In	Out
Total Moles Carbon	9.70	9.70
Total Moles Hydrogen	33.21	33.49
Total Moles Oxygen	11.27	11.26

B. Conversion Data

	Raw Data g moles/hr	H_2 Normalized g moles/hr
CO → Products	3.39	3.39
H_2 → Products	7.30	7.44
Reactants → H_2O	2.20	2.20
CO → CH_4	2.15	2.15
CO → C_2H_6	0.41	0.41
CO → C_3H_8	0.23	0.23
CO → CO_2	0.60	0.60
α, Percent	61.50	61.20
β, Percent	22.50	22.50
K_{shift} (experimental)	7.82	7.82
K_{shift} (theoretical at outlet)	7.69	7.69

TABLE 82. SUMMARY OF RESULTS FOR BSM TEST 55. MOLYBDENUM OXIDE 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	835	985	2600	5.7	4.5	63.5	25.6	7.7	56.0
2	--	--	--	--	--	--	--	--	--
3	835	985	2570	5.8	4.6	61.6	23.0	7.7	53.0
4	830	985	2500	5.6	4.4	61.2	22.5	7.8	54.5

[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 hydrocarbons 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 83. SUMMARY OF RESULTS FOR BSM TESTS 53, 54, and 55 MOLYBDENUM OXIDE CATALYST, LOT NO. 2903

Test	Temp, F	Pressure, psig	Feed Gas $CO/H_2/CO_2$	Inlet Space Velocity[1]	Conversions α[a]	CO	H_2	$CO \rightarrow CO_2$
53	870	1010	20/60/0	4960	76.9	95.3	69.5	20.2
	875	1010	20/60/0	4400	75.4	95.4	69.1	21.0
	970	1010	20/60/0	4300	77.4	94.6	71.8	18.0
54	865	1015	10/30/0	1850	63.5	93.1	55.6	20.5
	865	1015	10/30/0	2050	63.8	92.3	55.2	22.5
	865	1015	10/30/0	1980	63.1	91.4	53.8	23.6
	865	705	10/30/0	1460	63.8	91.2	53.2	24.0
55	835	985	20/60/15	2600	63.5	76.5	62.2	15.7
	835	985	20/60/15	2570	61.6	73.0	57.9	16.9
	830	985	20/60/15	2500	61.2	71.9	56.4	17.7

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

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

(b) BSM Test 56: BSM Test 56 was conducted with 100 grams of 2904 chromic oxide catalyst. The experimental unit consisted of the 1.25 inch fluidized-bed system used in the past several tests on Lot 2903 catalyst.

Test Conditions: The feed gas for Test 56 was the following, on a nitrogen-free basis:

Component	Volume, Percent
Hydrogen	62.96
Carbon Monoxide	20.92
Methane	16.05
Ethane	0.07

Two test periods were conducted at 825 F and 980 psig.

The catalyst used in Test 56 has a bulk density of 56 lb per cu ft and a minimum fluidizing velocity of 0.010 fps at reactor conditions. Under test flow rates, the superficial bed velocity was equivalent to about 3 times that of minimum fluidization.

Results for Test 56: Material balance data for Test 56, Periods 1 and 2, are given in Table 84. Yield data are summarized in Table 85.

The material balances in Table 84 are computed and presented on a nitrogen-free basis. Two reasons caused this:

1. The feed gas sample showed 11.4 percent nitrogen. Subsequent review of the sampling procedure for the feed gas revealed inadequate purging prior to sampling. Since nitrogen was used for pressurizing, trapped nitrogen was thus a contaminant in the sample.

2. The product gas showed a decreasing nitrogen content with time. Based on the known nitrogen content of the feed, both samples were contaminated to some extent with trapped pressurization gas.

The remaining component balances are good, as evidenced in Table 84.

Data in Table 85 indicate the activity and selectivity of 2904 catalyst at process conditions typical of those planned for PEDU tests. Since the catalyst charge is fresh, it might be expected, as indicated in life tests, that some initial deactivation would occur. Test periods were conducted at velocities which would produce little slugging. In addition, high space velocities were used.

The useful conversion for 2904 catalyst is comparable in magnitude to that obtained for catalyst 2903. Shift reaction equilibrium has been fairly well established at processing conditions. Overall comparison of

TABLE 84. DATA AND RESULTS FOR BSM TEST 56, PERIOD 1, CONDUCTED AT 825 F AND 980 PSIG CHROMIC OXIDE CATALYST NO. 2904

A. Material Balance

Component	Feed		Product	
	mole percent	g moles/hr	mole percent	g moles/hr
Carbon Monoxide	20.92	7.23	1.31	0.24
Carbon Dioxide	0.00	0.00	6.98	1.30
Hydrogen	62.96	21.76	32.33	6.02
Nitrogen	0.00	0.00	0.00	0.00
Methane	16.05	5.55	58.36	10.87
Ethane	0.07	0.02	0.81	0.15
Propane	0.00	0.00	0.21	0.04
Water	0.00	0.00	0.00	4.28
Total	100.00	34.56	100.00	22.90

	In	Out
Total Moles Carbon	12.82	12.83
Total Moles Hydrogen	65.84	65.34
Total Moles Oxygen	7.23	7.12

B. Conversion Data

	Raw Data g moles/hr
CO → Products	6.99
H_2 → Products	15.74
Reactants → H_2O	4.28
CO → CH_4	5.32
CO → C_2H_6	0.26
CO → C_3H_8	0.12
CO → CO_2	1.30
α, Percent	78.0
β, Percent	6.7
Kshift (experimental)	7.4
Kshift (theoretical at outlet)	8.0

TABLE 84. DATA AND RESULTS FOR BSM TEST 56, PERIOD 2,
CONDUCTED AT 825 F AND 980 PSIG
CHROMIC OXIDE CATALYST NO. 2904
(Continued)

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	20.92	7.20	1.53	0.29
Carbon Dioxide	0.00	0.00	7.17	1.35
Hydrogen	62.96	21.68	33.12	6.23
Nitrogen	0.00	0.00	0.00	0.00
Methane	16.05	5.53	57.32	10.78
Ethane	0.07	0.02	0.65	0.12
Propane	0.00	0.00	0.21	0.04
Water	0.00	0.00	0.00	4.10
Total	100.00	34.44	100.00	22.91

	In	Out
Total Moles Carbon	12.77	12.78
Total Moles Hydrogen	65.60	64.82
Total Moles Oxygen	7.20	7.09

B. Conversion Data

	Raw Data g moles/hr
CO → Products	6.91
H_2 → Products	15.23
Reactants → H_2O	4.10
CO → CH_4	5.25
CO → C_2H_6	0.20
CO → C_3H_8	0.12
CO → CO_2	1.35
α, Percent	76.8
β, Percent	5.7
K_{shift} (experimental)	6.9
K_{shift} (theoretical at outlet)	8.0

TABLE 85. SUMMARY OF RESULTS FOR BSM TEST 56. CHROMIC OXIDE CATALYST NO. 2904

Period	Temp, F	Pressure, psig	Space Velocity[1]	U/U$_{mf}$ Inlet	U/U$_{mf}$ Outlet	α[2]	[illegible][3]	K_s[4]	τ, sec[5]
1	825	982	7300	3.6	2.4	78.0	6.7	7.4	20
2	825	982	7300	3.5	2.4	76.5	5.7	6.9	20

[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] [illegible], moles CO to hydrocarbons 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 $U = (U_{in} + U_{out})/2$

the experimental shift ratio with thermodynamic data indicates that the system temperature ranged between 840 and 855 F rather than the measured 825 F. Overall products included ethane and propane along with the high methane yield.

(c) BSM Test 57: BSM Test 57 was conducted using 150 grams of Lot 2904 chromic oxide catalyst under test conditions similar to Test 56. The feed gas used for Test 57 was the following:

Component	Volume, Percent
Carbon Monoxide	20.20
Hydrogen	61.02
Nitrogen	3.12
Methane	15.56
Ethane	0.07
Carbon Dioxide	0.03

Test Conditions: Test 57 was conducted at 830 F and 990 psig through two test periods. Runs were made at three times minimum fluidization velocity.

Results for Test 57: Material balance data for Test 57 are given in Table 86, Periods 1 and 2. Yield data are summarized in Table 87.

Error in the feed gas composition, due to the improper sampling techniques as discussed in Test 56, caused the balances to be normalized for carbon with subsequent hydrogen adjustment.

Data for Test 57 indicate lower conversion than for Test 56 with increased residence time. The selectivity towards higher hydrocarbons is greater for Test 57. Useful conversions of 70 percent were achieved. In Test 57, the U/U_{mf} ratio, as in Test 56, was probably low enough to retard slugging in the catalyst bed. The shift constants from Test 57 are significantly higher than those in Test 56. This indicates that while the same temperature was being read in the bed, the actual reaction temperature was somewhat lower in Test 57. In fact, the shift constant difference indicates 25 F to be the differential. The higher selectivity is also an indication of lower temperature.

(d) BSM Test 58: BSM Test 58 was conducted using 150 grams of Lot 2904 chromic oxide catalyst. The test conditions, temperature and pressure, were the same as for Tests 56 and 57. In Test 58, the synthesis gas composition was altered to Scheme B conditions. In addition, the hydrogen to carbon monoxide ratio in the fresh feed was reduced to 2/1 as follows:

Component	Volume, Percent
Carbon Monoxide	24.98
Carbon Dioxide	17.94
Hydrogen	47.92
Nitrogen	0.15
Methane	9.01

TABLE 86. DATA AND RESULTS FOR BSM TEST 57, PERIOD 1, CONDUCTED AT 830 F AND 990 PSIG CHROMIC OXIDE CATALYST NO. 2904

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	20.20	6.01	2.03	0.36
Carbon Dioxide	0.03	0.01	7.29	1.31
Hydrogen	61.02	18.16	38.10	6.85
Nitrogen	3.12	0.93	5.24	0.94
Methane	15.56	4.63	45.09	8.11
Ethane	0.07	0.02	1.75	0.32
Propane	0.00	0.00	0.50	0.09
Water	0.00	0.00	0.00	3.05
Total	100.00	29.76	100.00	21.04

	In	Out
Total Moles Carbon	10.69	10.69
Total Moles Hydrogen	54.96	54.88
Total Moles Oxygen	6.03	6.03

B. Conversion Data

		Raw Data g moles/hr
CO	→ Products	5.65
H_2	→ Products	11.31
Reactants	→ H_2O	3.05
CO	→ CH_4	3.48
CO	→ C_2H_6	0.60
CO	→ C_3H_8	0.27
CO	→ CO_2	1.30
α, Percent		70.0
β, Percent		20.0
K_{shift} (experimental)		8.1
K_{shift} (theoretical at outlet)		7.8

TABLE 86. DATA AND RESULTS FOR BSM TEST 57, PERIOD 2,
CONDUCTED AT 830 F AND 990 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	20.20	6.08	1.85	0.33
Carbon Dioxide	0.03	0.01	7.31	1.32
Hydrogen	61.02	18.37	37.09	6.67
Nitrogen	3.12	0.94	5.34	0.96
Methane	15.56	4.68	46.25	8.32
Ethane	0.07	0.02	1.76	0.32
Propane	0.00	0.00	0.40	0.07
Water	0.00	0.00	0.00	3.14
Total	100.00	30.11	100.00	21.13

	In	Out
Total Moles Carbon	10.81	10.82
Total Moles Hydrogen	55.58	55.28
Total Moles Oxygen	6.10	6.06

B. Conversion Data

	Raw Data g moles/hr
CO → Products	5.75
H_2 → Products	11.70
Reactants → H_2O	3.14
CO → CH_4	3.64
CO → C_2H_6	0.60
CO → C_3H_8	0.21
CO → CO_2	1.31
α, Percent	71.0
[illegible], Percent	18.2
K_{shift} (experimental)	8.4
K_{shift} (theoretical at outlet)	8.0

TABLE 87. SUMMARY OF RESULTS FOR BSM TEST 57. CHROMIC OXIDE CATALYST NO. 2904

Period	Temp, F	Pressure, psig	Space Velocity[1]	U/U_{mf} Inlet	U/U_{mf} Outlet	α[2]	ρ[3]	K_s[4]	τ, sec[5]
1	830	998	4250	3.0	2.1	70.0	20.0	8.1	40
2	830	998	4250	3.0	2.1	71.0	18.2	8.5	40

[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] ρ, moles CO to hydrocarbons 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 $U = (U_{in} + U_{out})/2$

Test Conditions: Test 58 was conducted at temperatures of 820 F and 920 F and at a nominal pressure of 1000 psig for four test periods. Run conditions maintained a U/U_{mf} ratio between 2.0 and 3.0.

Results for Test 58: Material balance data for Test 58 are given in Table 88, Periods 1, 2, 3, and 4. Yield data are summarized in Table 89.

The overall test results from Table 89 indicate 80 percent useful conversion of $(CO + H_2)$ under test conditions. This is about 5 percent higher in conversion than for tests containing a 3/1 hydrogen to carbon monoxide ratio. Gas residence times to achieve this conversion were relatively low. Under test conditions, the yield of C_2- and C_3-hydrocarbons was relatively uneffected by temperature. This is different from the trend noticed at the higher hydrogen content. At the lower system temperature, shift equilibrium indicated that the exit temperature was 855 F, or 35 degrees higher than observed. At 920 F, there was no difference between the theoretical and experimental shift ratios.

In Test 58, the exit hydrogen to carbon monoxide ratio was between 2 and 2.5. This indicates that at the processing conditions, an even split of water and carbon dioxide is being achieved in the methanation reaction. Lowering the hydrogen to carbon monoxide ratio might be possible over this catalyst; this would further favor carbon dioxide as the by-product of methanation.

(e) BSM Test 59: BSM Test 59 was conducted with the same 150 grams of Lot 2904 chromic oxide catalyst used in previous tests. The purpose of the test was to duplicate the conditions of Test 57 to see if repeated heating and cooling cycles would depress the activity of the catalyst.

In Test 59, the following feed gas was used:

Component	Volume, Percent
Carbon Monoxide	20.36
Carbon Dioxide	0.05
Hydrogen	61.88
Nitrogen	2.24
Methane	15.39
Ethane	0.06

Test Conditions: The test was conducted at 845 F and a nominal pressure of 1000 psig over three test periods. Run conditions maintained a U/U_{mf} ratio between 2.0 and 3.0.

Results for Test 59: Material balance data for Test 59 are given in Table 90, Periods 1, 2, and 3. Yield data are summarized in Table 91.

Conversion data for Test 59 indicate good yields of methane. Little higher hydrocarbons were formed. In comparison with Test 57, the overall

TABLE 88. DATA AND RESULTS FOR BSM TEST 58, PERIOD 1, CONDUCTED AT 820 F AND 995 PSIG CHROMIC OXIDE CATALYST NO. 2904

A. Material Balance

	Feed		Product	
Component	mole percent	g moles/hr	mole percent	g moles/hr
Carbon Monoxide	24.98	7.84	6.03	1.16
Carbon Dioxide	17.94	5.63	38.93	7.50
Hydrogen	47.92	15.05	16.40	3.16
Nitrogen	0.15	0.05	0.23	0.04
Methane	9.01	2.83	37.33	7.20
Ethane	0.00	0.00	0.88	0.17
Propane	0.00	0.00	0.20	0.04
Water	0.00	0.00	0.00	2.96
Total	100.00	31.40	100.00	22.24

	In	Out
Total Moles Carbon	16.30	16.32
Total Moles Hydrogen	41.42	41.64
Total Moles Oxygen	19.10	18.85

B. Conversion Data

	Raw Data g moles/hr
CO → Products	6.68
H_2 → Products	11.89
Reactants → H_2	2.96
CO → CH_4	4.37
CO → C_2H_6	0.34
CO → C_3H_8	0.12
CO → CO_2	1.87
α, Percent	83.3
β, Percent	9.5
K_{shift} (experimental)	6.9
K_{shift} (theoretical at outlet)	8.2

TABLE 88. DATA AND RESULTS FOR BSM TEST 58, PERIOD 2, CONDUCTED AT 820 F AND 995 PSIG CHROMIC OXIDE CATALYST NO. 2904 (Continued)

A. Material Balance

Component	mole percent	g moles/hr	mole percent	g moles/hr
Carbon Monoxide	24.98	7.44	7.02	1.30
Carbon Dioxide	17.94	5.34	38.06	7.06
Hydrogen	47.92	14.26	17.82	3.31
Nitrogen	0.15	0.04	0.23	0.04
Methane	9.01	2.68	35.70	6.63
Ethane	0.00	0.00	0.97	0.18
Propane	0.00	0.00	0.20	0.04
Water	0.00	0.00	0.00	2.71
Total	100.00	29.77	100.00	21.27

	In	Out
Total Moles Carbon	15.46	15.47
Total Moles Hydrogen	39.24	39.99
Total Moles Oxygen	18.12	18.11

B. Conversion Data

	Raw Data g moles/hr
CO → Products	6.14
H_2 → Products	10.95
Reactants → H_2O	2.71
CO → CH_4	3.95
CO → C_2H_6	0.36
CO → C_3H_8	0.12
CO → CO_2	1.72
α, Percent	80.5
β, Percent	10.9
K_{shift} (experimental)	6.7
K_{shift} (theoretical at outlet)	8.2

TABLE 28. DATA AND RESULTS FOR BSM TEST 58, PERIOD 3,
CONDUCTED AT 920 F AND 1000 PSIG
CHROMIC OXIDE CATALYST NO. 2904
(Continued)

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	24.98	7.30	8.16	1.48
Carbon Dioxide	17.94	5.24	36.91	6.71
Hydrogen	47.92	14.01	17.30	3.14
Nitrogen	0.15	0.04	0.25	0.04
Methane	9.01	2.63	36.43	6.62
Ethane	0.00	0.00	0.75	0.13
Propane	0.00	0.00	0.20	0.03
Water	0.00	0.00	0.00	2.87
Total	100.00	29.25	100.00	21.04

	In	Out
Total Moles Carbon	15.17	15.16
Total Moles Hydrogen	38.54	39.36
Total Moles Oxygen	17.79	17.77

B. Conversion Data

	Raw Data g moles/hr
CO → Products	5.82
H_2 → Products	10.87
Reactants → H_2O	2.87
CO → CH_4	3.99
CO → C_2H_6	0.26
CO → C_3H_8	0.09
[illegible], Percent	80.6
[illegible], Percent	8.1
K_{shift} (experimental)	5.0
K_{shift} (theoretical at outlet)	5.2

TABLE 88. DATA AND RESULTS FOR BSM TEST 56, PERIOD 4, CONDUCTED AT 920 F AND 1000 PSIG CHROMIC OXIDE CATALYST NO. 2904
(Continued)

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	24.98	6.73	8.37	1.40
Carbon Dioxide	17.94	4.83	36.73	6.15
Hydrogen	47.92	12.90	17.31	2.90
Nitrogen	0.15	0.04	0.24	0.04
Methane	9.01	2.43	36.38	6.09
Ethane	0.00	0.00	0.77	0.13
Propane	0.00	0.00	0.20	0.03
Water	0.00	0.00	0.00	2.71
Total	100.00	26.93	100.00	19.46

	In	Out
Total Moles Carbon	13.99	13.99
Total Moles Hydrogen	35.52	36.68
Total Moles Oxygen	16.38	16.41

B. Conversion Data

	Raw Data g moles/hr
CO → Products	5.33
H_2 → Products	10.00
Reactants → H_2O	2.71
CO → CH_4	3.66
CO → C_2H_5	0.26
CO → C_3H_8	0.09
CO → CO_2	1.32
α, Percent	80.8
β, Percent	8.8
K_{shift} (experimental)	4.7
K_{shift} (theoretical at outlet)	5.2

TABLE 89. SUMMARY OF RESULTS FOR BSM TEST 58. CHROMIC OXIDE CATALYST NO. 2904

Period	Temp, F	Pressure, psig	Space Velocity[1]	U/U_{mf} Inlet	U/U_{mf} Outlet	c^{2}	α^{3}	K_s^{4}	τ, sec[5]
1	820	995	4430	3.1	2.2	83.3	9.5	6.9	35
2	820	995	4220	2.9	2.0	80.5	10.9	6.7	37
3	920	1000	4160	3.1	2.2	80.6	8.1	5.0	35
4	920	1000	3830	3.0	2.1	80.8	8.8	4.7	35

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

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

[3] α, moles CO to hydrocarbons 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 20% bed expansion and $U = (U_{in} + U_{out})/2$

TABLE 90. DATA AND RESULTS FOR ESM TEST 59, PERIOD 1, CONDUCTED AT 845 F AND 1000 PSIG CHROMIC OXIDE CATALYST NO. 2904

A. Material Balance

Component	Feed		Product	
	mole percent	g moles/hr	mole percent	g moles/hr
Carbon Monoxide	20.36	4.25	1.22	0.15
Carbon Dioxide	0.05	0.01	6.98	0.79
Hydrogen	61.88	12.91	33.53	4.10
Nitrogen	2.24	0.47	5.82	0.71
Methane	15.39	3.21	52.32	6.40
Ethane	0.06	0.01	0.63	0.08
Propane	0.00	0.00	0.00	0.00
Water	0.00	0.00	0.00	2.55
Total	100.00	20.86	100.00	14.78

	In	Out
Total Moles Carbon	7.49	7.50
Total Moles Hydrogen	38.72	39.38
Total Moles Oxygen	4.27	4.28

B. Conversion Data

	Raw Data g moles/hr
CO → Products	4.10
H_2 → Products	8.81
Reactants → H_2O	2.55
CO → CH_4	3.19
CO → C_2H_6	0.14
CO → C_3H_8	0.00
CO → CO_2	0.78
α, Percent	77.0
γ, Percent	4.2
K_{shift} (experimental)	8.5
K_{shift} (theoretical at outlet)	7.2

TABLE 9C. DATA AND RESULTS FOR ESM TEST 59, PERIOD 2, CONDUCTED AT 845 F AND 996 PSIG CHROMIC OXIDE CATALYST NO. 29C4 (Continued)

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	20.36	4.85	1.44	0.20
Carbon Dioxide	0.05	0.01	6.93	0.95
Hydrogen	61.88	14.76	33.59	4.67
Nitrogen	2.24	0.53	5.38	0.75
Methane	15.39	3.67	52.04	7.23
Ethane	0.06	0.01	0.62	0.09
Propane	0.00	0.00	0.00	0.00
Water	0.00	0.00	0.00	2.78
Total	100.00	23.85	100.00	100.00

	In	Out
Total Moles Carbon	8.55	8.56
Total Moles Hydrogen	44.26	44.36
Total Moles Oxygen	4.87	4.88

B. Conversion Data

	Raw Data g moles/hr
CO → Products	4.65
H_2 → Products	10.09
Reactants → H_2O	2.78
CO → CH_4	3.56
CO → C_2H_6	0.16
CO → C_3H_8	0.00
CO → CO_2	0.94
α, Percent	75.3
β, Percent	4.3
K_{shift} (experimental)	8.0
K_{shift} (theoretical at outlet)	7.2

TABLE 90. DATA AND RESULTS FOR BSM TEST 59, PERIOD 3,
CONDUCTED AT 845 F AND 1002 PSIG
CHROMIC OXIDE CATALYST NO. 2904
(Continued)

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	20.36	5.03	1.54	0.22
Carbon Dioxide	0.05	0.01	7.06	1.03
Hydrogen	61.88	15.30	34.25	4.98
Nitrogen	2.24	0.55	5.33	0.78
Methane	15.39	3.80	51.21	7.45
Ethane	0.06	0.01	0.61	0.09
Propane	0.00	0.00	0.00	0.00
Water	0.00	0.00	0.00	2.79
Total	100.00	24.72	100.00	17.34

	In	Out
Total Moles Carbon	8.86	8.88
Total Moles Hydrogen	45.86	45.88
Total Moles Oxygen	5.05	5.07

B. Conversion Data

		Raw Data g moles/hr
CO	Products	4.81
H_2	Products	10.32
Reactants	→ H_2O	2.79
CO	→ CH_4	3.65
CO	→ C_2H_6	0.16
CO	→ C_3H_8	0.00
CO	→ CO_2	1.02
[illegible], Percent		74.8
[illegible], Percent		4.3
K_{shift} (experimental)		8.4
K_{shift} (theoretical at outlet)		8.2

TABLE 91. SUMMARY OF RESULTS FOR BSM TEST 59. CHROMIC OXIDE CATALYST NO. 2904

Period	Temp, F	Pressure, psig	Space Velocity[1]	U/U_{mf} Inlet	U/U_{mf} Outlet	α[2]	[illegible][3]	K_s[4]	τ, sec[5]
1	845	1000	2950	2.1	1.5	77.0	4.2	9.5	49
2	845	996	3370	2.4	1.7	75.3	4.3	8.0	43
3	845	1002	3500	2.5	1.7	74.8	4.3	8.4	43

[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] [illegible], moles CO to hydrocarbons 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

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

yields are higher but the amount of ethane and propane formed was greatly decreased. The system temperature in Test 59 was 15 degrees higher by thermocouple reading, but the shift constant indicates that the outlet gas was at the same temperature. The major difference between Tests 57 and 59 was the inlet space velocity, or, more accurately, the fluidization velocity ratio used. In both tests, it is possible that the entire bed was not fluidized due to low throughput ratios. In Test 59, the probability of this occurring was greater due to the lower outlet ratio.

The main conclusion that can be drawn from Tests 57 and 59 is that repeated startups and shutdowns do not harm the activity of Lot 29C4 catalyst.

(f) BSM Test 60: BSM Test 60 was conducted with the 150 gram charge of Lot 29C4 catalyst used in previous tests under conditions somewhat the same as Tests 57 and 59. Higher feed rates, simulating Test 57 conditions, were used along with higher reaction zone temperatures.

The feed gas composition was the following:

Component	Volume, Percent
Carbon Monoxide	20.27
Carbon Dioxide	0.08
Hydrogen	62.02
Nitrogen	2.22
Methane	15.33
Ethane	0.08

Test Conditions: Test 60 was conducted at 970 and 855 F and 990 psig over four test periods. The nominal fluidization velocity ratio was between 2.0 and 3.0.

Results for Test 60: Material balance data for Test 60 are given in Table 92, Periods 1, 2, 3, and 4. Yield data are summarized in Table 93.

Data in Table 93 again show good conversions at 855 and 970 F. Results obtained are similar to those from Tests 57 and 59 and indicate that above a lower critical temperature, about 800 to 820 F, temperature has no effect on degree of conversion. However, temperature enhances the rate of cracking of higher hydrocarbons formed, thus increasing the yield of methane.

The high conversions being achieved in short residence times is extremely encouraging. It appears that the approach to follow now is to determine the optional feed gas composition for the synthesis. As Test 58 indicates, a reduction in hydrogen to carbon monoxide ratio may improve the overall yield by better controlling the outlet hydrogen to carbon monoxide ratio. In tests where the feed gas contains a 3/1 hydrogen to carbon monoxide ratio and no carbon dioxide, there is little chance of carbonization; however, the concentration of carbon monoxide is reduced drastically and thus conversion suffers. Future work will, therefore, involve effects of gas composition on conversion at the optimal temperatures (820 to 1000 F) found in these past studies.

TABLE 92. DATA AND RESULTS FOR BSM TEST 60, PERIOD 1, CONDUCTED AT 970 F AND 990 PSIG CHROMIC OXIDE CATALYST NO. 2904

A. Material Balance

	Feed		Product	
Component	mole percent	g moles/hr	mole percent	g moles/hr
Carbon Monoxide	20.27	6.67	1.94	0.35
Carbon Dioxide	0.08	0.03	6.02	1.09
Hydrogen	62.02	20.41	31.43	5.70
Nitrogen	2.22	0.73	4.04	0.73
Methane	15.33	5.04	55.98	10.14
Ethane	0.08	0.03	0.59	0.11
Propane	0.00	0.00	0.00	0.00
Water	0.00	0.00	0.00	4.20
Total	100.00	32.91	100.00	22.32

	In	Out
Total Moles Carbon	11.80	11.80
Total Moles Hydrogen	61.16	61.02
Total Moles Oxygen	6.73	6.73

B. Conversion Data

	Raw Data g moles/hr
CO → Products	6.32
H_2 → Products	14.71
Reactants → H_2O	4.20
CO → CH_4	5.10
CO → C_2H_6	0.16
CO → C_3H_8	0.00
CO → CO_2	1.06
α, Percent	77.3
β, Percent	3.1
K_{shift} (experimental)	4.2
K_{shift} (theoretical at outlet)	4.2

TABLE 92. DATA AND RESULTS FOR BSM TEST 60, PERIOD 2,
CONDUCTED AT 970 F AND 995 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	20.27	6.46	1.93	0.34
Carbon Dioxide	0.08	0.03	6.12	1.08
Hydrogen	62.02	19.78	31.47	5.54
Nitrogen	2.22	0.71	4.09	0.72
Methane	15.33	4.89	55.92	9.85
Ethane	0.08	0.03	0.47	0.08
Propane	0.00	0.00	0.00	0.00
Water	0.00	0.00	0.00	4.01
Total	100.00	31.89	100.00	21.62

	In	Out
Total Moles Carbon	11.44	11.43
Total Moles Hydrogen	59.03	58.98
Total Moles Oxygen	6.52	6.51

B. Conversion Data

	Raw Data g moles/hr
CO → Products	6.12
H_2 → Products	14.24
Reactants → H_2O	4.01
CO → CH_4	4.96
CO → C_2H_6	0.10
CO → C_3H_8	0.00
CO → CO_2	1.05
α, Percent	77.0
β, Percent	2.0
K_{shift} (experimental)	4.4
K_{shift} (theoretical at outlet)	4.2

TABLE 92. DATA AND RESULTS FOR BSM TEST 60, PERIOD 3, CONDUCTED AT 855 F AND 998 PSIG CHROMIC OXIDE CATALYST NO. 2904 (Continued)

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	20.27	6.25	1.86	0.33
Carbon Dioxide	0.08	0.02	6.97	1.22
Hydrogen	62.02	19.13	33.61	5.90
Nitrogen	2.22	0.68	3.84	0.12
Methane	15.33	4.73	53.24	9.34
Ethane	0.08	0.02	0.48	0.08
Propane	0.00	0.00	0.00	0.00
Water	0.00	0.00	0.00	3.53
Total	100.00	30.85	100.00	21.07

	In	Out
Total Moles Carbon	11.04	11.05
Total Moles Hydrogen	57.30	56.70
Total Moles Oxygen	6.29	6.30

B. Conversion Data

	Raw Data g moles/hr
CO → Products	5.92
H_2 → Products	13.23
Reactants → H_2O	3.53
CO → CH_4	4.61
CO → C_2H_6	0.12
CO → C_3H_8	0.00
CO → CO_2	1.20
α, Percent	74.2
β, Percent	2.5
K_{shift} (experimental)	6.2
K_{shift} (theoretical at outlet)	6.7

TABLE 92. DATA AND RESULTS FOR BSM TEST 60, PERIOD 4, CONDUCTED AT 855 F AND 980 PSIG CHROMIC OXIDE CATALYST NO. 2904 (Continued)

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	20.27	6.32	1.89	0.34
Carbon Dioxide	0.08	0.02	6.96	1.23
Hydrogen	62.02	19.34	33.82	6.02
Nitrogen	2.22	0.69	3.85	0.68
Methane	15.33	4.78	53.01	9.43
Ethane	0.08	0.02	0.47	0.08
Propane	0.00	0.00	0.00	0.00
Water	0.00	0.00	0.00	3.56
Total	100.00	31.19	100.00	21.36

	In	Out
Total Moles Carbon	11.16	11.16
Total Moles Hydrogen	57.92	57.36
Total Moles Oxygen	6.36	6.36

B. Conversion Data

	Raw Data g moles/hr
CO → Products	5.98
H_2 → Products	13.32
Reactants → H_2O	3.56
CO → CH_4	4.65
CO → C_2H_6	0.12
CO → C_3H_8	0.00
CO → CO_2	1.21
α, Percent	74.3
β, Percent	2.5
K_{shift} (experimental)	6.1
K_{shift} (theoretical at outlet)	6.7

TABLE 93. SUMMARY OF RESULTS FOR TEST 60. CHROMIC OXIDE CATALYST NO. 2904

Period	Temp, F	Pressure, psig	Space Velocity[1]	U/U_{mf} Inlet	U/U_{mf} Outlet	c'[3]	[illegible]	K_s	τ, sec[5]
1	970	990	4640	3.6	2.4	77.3	3.1	4.2	30
2	970	995	4510	3.5	2.4	77.0	2.0	4.4	30
3	855	998	4370	3.1	2.1	74.2	2.5	6.2	34
4	855	980	4370	3.2	2.2	74.3	2.5	6.1	33

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

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

[illegible], moles CO to hydrocarbons 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 $U = (U_{in} + U_{out})/2$

(2) Catalyst Life Tests: During the past month, life testing of Lot 2904 chromic oxide catalyst was completed and the final results were evaluated. In addition, the new life tester was constructed and placed on-stream.

Test 2904: Catalyst life testing of Lot 2904 chromic oxide catalyst was concluded at 1260 hours. The conversion data are shown in Figure 108. It is evident that after 200 hours, the useful conversion, α, over the chrome catalyst stabilized. These data, and those for Lot 2903, molybdenum oxide catalyst, indicate that further testing of these catalysts is warranted.

New Life Test Unit: The new life test system, discussed last month, has been constructed and placed on-stream. Figures 109 and 110 show the unit under construction and completed. The four catalyst tubes were charged with different catalysts. These were:

Tube No.	Catalyst	Bed Depth, Inches
1	2903 (molybdenum oxide)	23.0
2	2904 (chromic oxide)	24.0
3	2906 (iron oxide)	23.0
4	2687 (cobalt oxide - molybdenum oxide)	22.5

The volumes of the catalysts charged were the same; thus, at comparable flow rates, equivalent space velocities will be present in the system.

Data will be reported next month.

b. PEDU Studies: Progress continued on the methanation PEDU during the month of March.

(1) Design Engineering: No major changes were made in the PEDU design during March. Koppers conducted some limited design work on the effluent gas treatment system; however, this work has not been completed. A plot plan change was made. The carbon dioxide and hydrogen sulfide storage facilities were relocated as an addition to the present gas storage facility.

(2) Detail Engineering: Based on the Koppers "preliminary work outline" discussed last month, the detail engineering requirements were reviewed. On that basis, Koppers was given authorization (March 8) to proceed with the detailing of the methanator. In addition, where required, Koppers was given authorization (March 10) on BCR request to assist in evaluation of quotations.

In the area of vessel and equipment detailing, Koppers has provided services in reviewing specifications for bidding purposes and supplying necessary

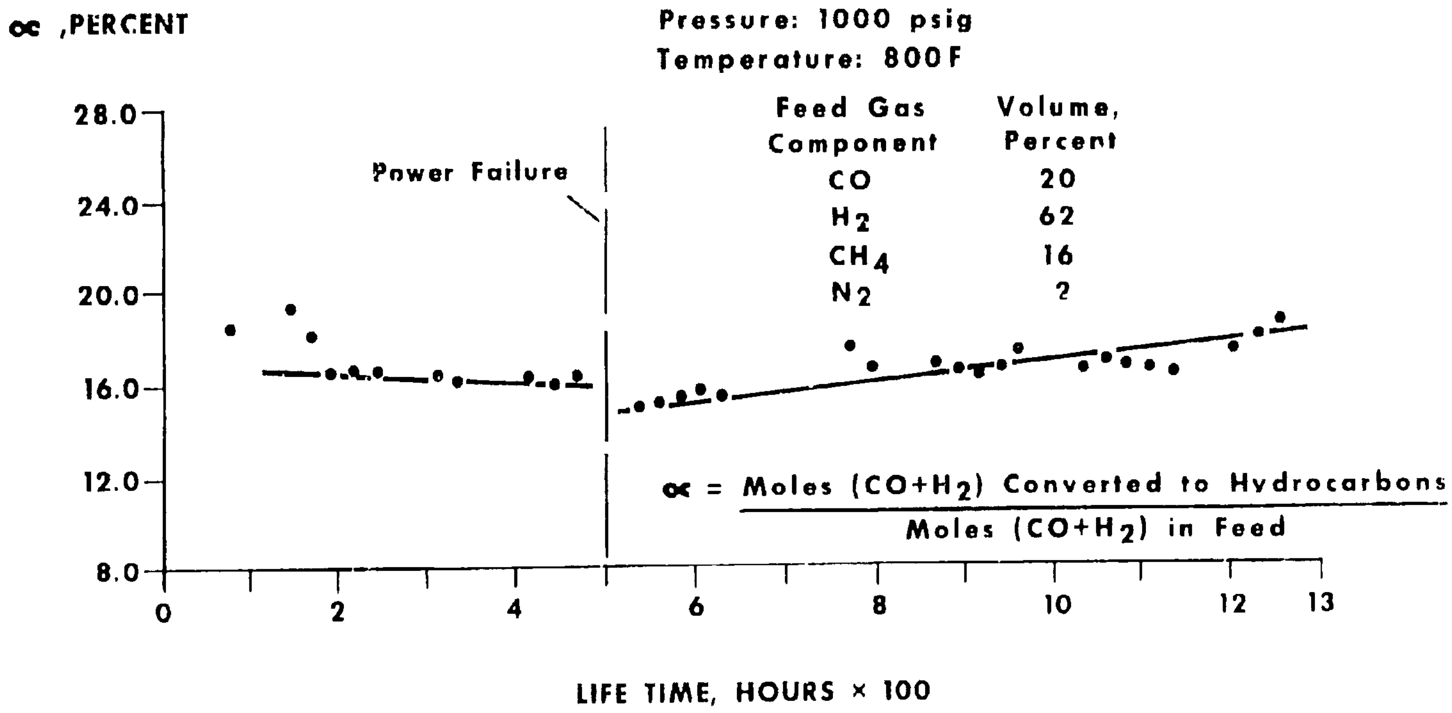

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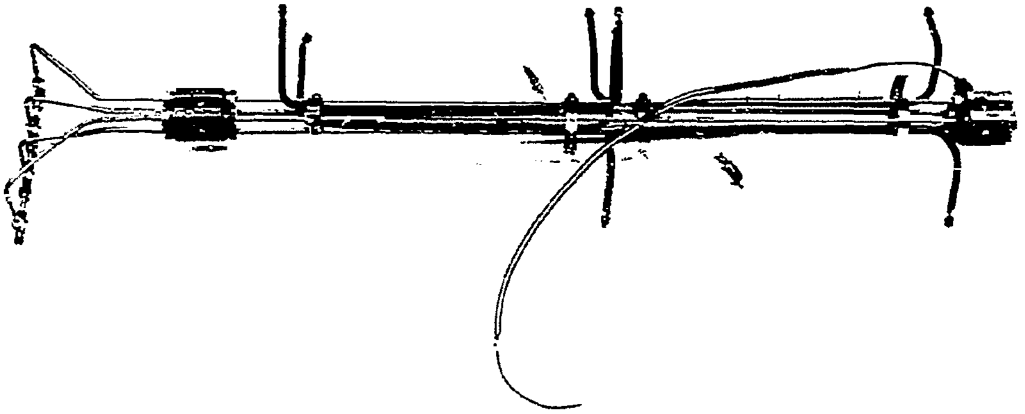
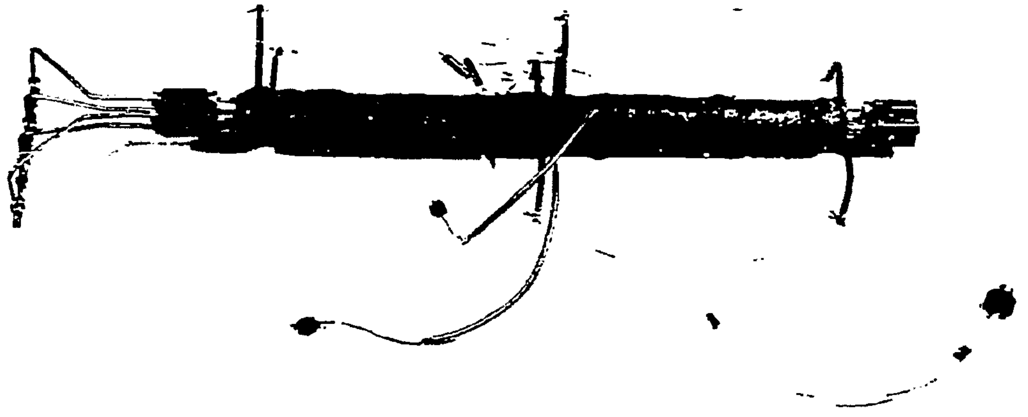
Figure 108. Extended Activity Data for Life Test 2904 Using Chromic Oxide on Alumina Catalyst (BCR Lot 2904)



8040P14

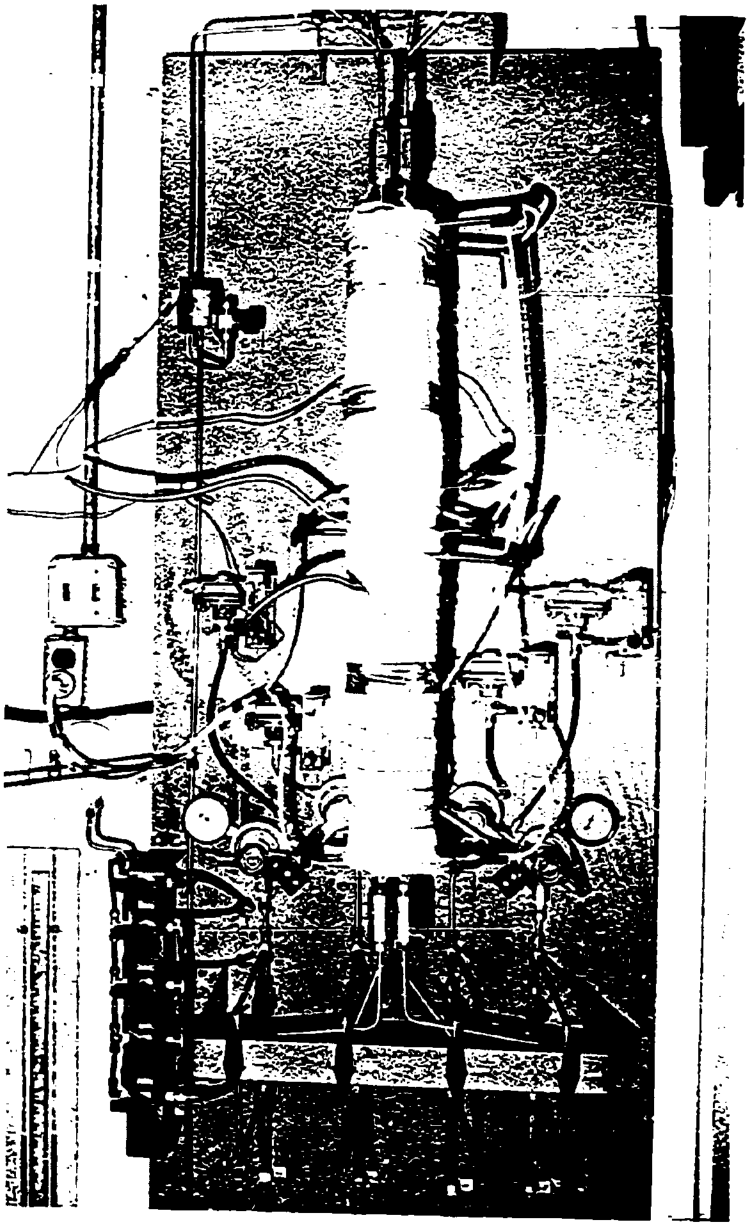
Reactor Tubes and Heaters



8040P15

Reactor Tubes and Heaters Encased in Heat Transfer Cement

Figure 109. Methanation Multitube Life Test Reactor Under Construction



8040P16

Figure 110. Methanation Multitube Life Test Reactor Unit

sketches to be included with quotes. The following drawings were received during March for quotation purposes:

2415-2A725 - Reformer Feed Gas Receiver
2415-2A726 - Methanator Feed Gas Receiver
2415-2A729 - Hydrogen Sulfide Flash Tank
2415-9F303 - Annunciator
2415-9F308 - Local Pressure Indicators

(3) Status of Quotations: Bids on fourteen items have been received, and are listed in Table 94. To date, a number of request letters have been submitted to OCR for procurement approval; however, no approvals have been received.

(4) Other Work:

(a) The excavation permit has been acquired and quotations have been solicited.

(b) The required forms for the building permit have been acquired. Koppers is currently firming the specifications for the reformer shed so that application can be made.

(c) The air pollution permit application is being held up pending the receipt of a quotation for the thermal oxidizer system. Koppers still has engineering work to complete in this area before quotations can be solicited.

(d) A meeting with a BCR underwriter representative has been arranged to discuss insurance requirements for the PEDU.

c. Cold Model Studies: The alumina-based catalyst for the cold model studies was received and some testing was conducted. Data currently have not been analyzed and will be presented next month.

d. Other Work: A draft report for BCR Suggestions 193, 194, and 196 was prepared and submitted for review to BCR staff.

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

At the bench-scale level, fluidization tests of Lot 2904 chromic oxide catalyst will continue under Scheme A and B conditions. Life testing of four catalysts will continue.

PEDU work will continue. Bids on equipment will continue to be solicited and evaluated. Procurement will begin. Detail engineering work will proceed based on the finalized scope of work. Continued emphasis will be placed on acquisition of the necessary permits for construction.

Cold model studies will be continued.

TABLE 94. SUMMARY OF METHANATION PEDU EQUIPMENT ITEMS HAVING FIRM QUOTATIONS

Index	Equipment Item
ME-405 A & B	Feed Gas Heaters
ME-605[1]	Cooler Condenser
ME-700	Water Cooler
MK-102	Natural Gas Compressor
MK-305	Methanator Feed Compressor
MP-710	Cooling Water Pump
MV-610	Water Metering Tank
MV-710	Cooling Water Tank
MX-100	Reformer
MX-500	Therminol System
MX-720	Steam Boiler
MX-750	Demineralizer
ANN-MR-420	Annunciator
Panel-MR-420	Instrument Panel

[1] Quotation to be revised

4. Analytical Services (J. E. Noll): During the past month, 37 samples were analyzed by gas chromatography. The types of analyses requested were as follows:

Type of Analysis Requested	No. of Samples Analyzed
Gas Chromatography	
Methanation Unit Gas Samples	37
Total	37

5. Gas Chromatographic Procedures (J. E. Noll): The Gow Mac 69-500 gas chromatograph was standardized for analyses of C_2- and C_3-hydrocarbons. The amounts of these gases in the gas samples from the methanation unit have become more important for carbon balances. A more accurate result, as well as a shorter analytical time, was needed.

Future Work: Performing samples 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)

No experimental work has been conducted on this section of the program since completion of the test schedule in September, 1971. Dismantling operations of the equipment are essentially completed, and preparation of the draft of the final Summary Report, Phase II, Process and Equipment Development, has been completed.

1. Dismantling of 100 lb/hr PEDU: Disposition of the four major items of equipment located in the safety cubicle, as discussed in last month's report, has been resolved. The four units will be removed and stored outside in the vicinity of Building 3. Means to protect the equipment from the weather will be provided.

2. Inspection of Stage 1 Refractories: The refractory samples from Stage 1, as reported last month, were submitted to Koppers Company for inspection. Results of their and the manufacturer's inspection are not available at this time.

3. Status of Phase II Summary Report: Editing and assembly of the final draft of the Phase II Summary Report are progressing. The completed report should be issued in April.

4. Future Work: Future work will include:

a. Report of Koppers Company inspection of refractories removed from Stage 1.

b. Disposition of any surplus equipment.

c. Issuance of Phase II Summary Report.

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 further modifying the equipment to allow operation of both stages of the model at high air rates which will simulate the expected pilot plant characteristics. A large capacity blower is being installed to enable the model testing program to be expanded. Reactivity studies were conducted on selected PEDU chars and on a sample of anthracite. In addition, a test method was developed for determining the grindability of the coarser fractions of PEDU chars.

The model studies to be carried out in the following months are expected to indicate both the location and size of nozzles and the shape of the reactor which will avoid excessive localizing of extreme temperatures near the reactor walls. Stages 1 and 2 of the gasifier are to be studied independently at first, followed by tests of the two stages together.

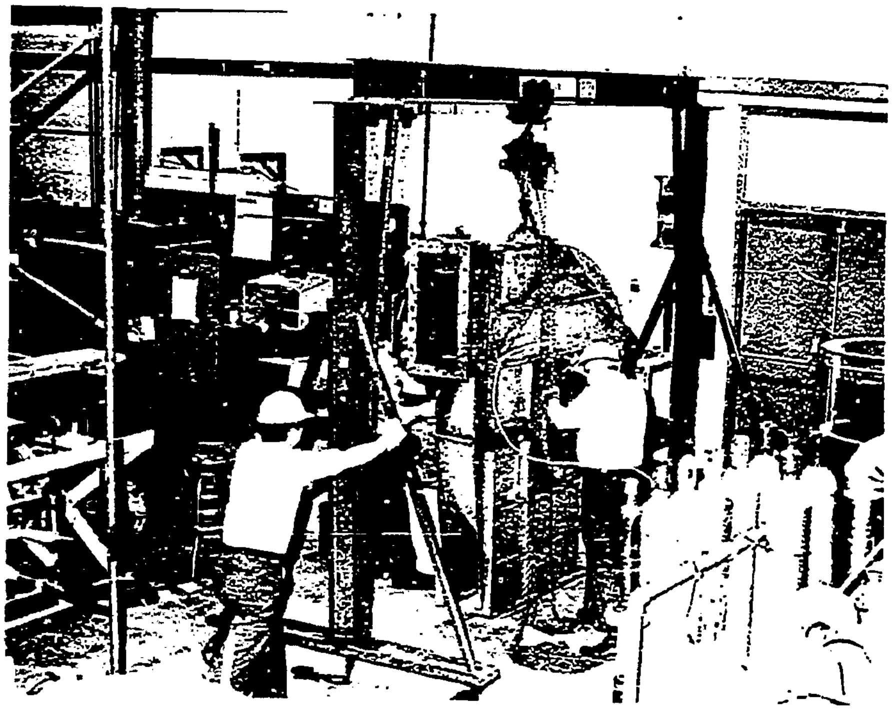
The Stage 1 studies have been divided into three phases, now underway: (I) single-burner tests, (II) multiple-burner tests, and (III) multiple-burner tests.

The Phase II and III studies for Stage 1 of the two-stage gasifier were proceeding as planned and satisfactorily when it appeared advisable to review some of the assumptions on steam and char flow rates. In addition to physical analysis of the chars, reactivity tests were scheduled in the TGA.

An important observation in the PEDU program was the significant increase in the size of char produced by the gasification of Pittsburgh seam coal in the simulated Stage 2. This char appeared to be as soft as coals having a Hardgrove Grindability Index of 100, but, due to its low bulk density, its grindability could not be assessed using the procedures developed for coal. Modified grindability tests are therefore being carried out so that the grindability of any char can be more accurately assessed.

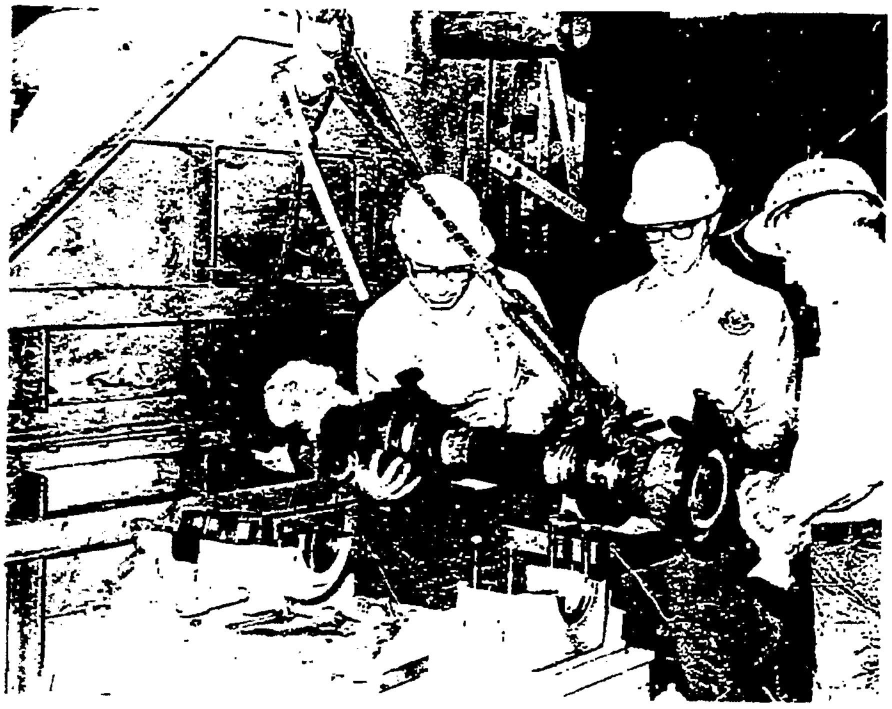
1. Further Model Tests: The modification shown in Figure 101, page 349 of Progress Report No. 6, provided enough air to test Stage 1 at the equivalent of 50 percent of rating of the pilot plant unit. This arrangement was suitable for providing some needed information. However, to test Stage 1 at the equivalent of full rating and both stages simultaneously, it was necessary either to use smaller than full-scale models or to purchase an additional blower having a capacity of 2000 cfm of air at 30 inches of water, or higher, manifold pressure.

Fortunately, BCR was able to locate a 6000 cfm blower from a previous test installation. The restored blower is shown in Figures 111 and 112.



8022P18

Figure 111. Housing of 6000 cfm Blower in Process of Installation



8022P19

Figure 112. Drive Train for 6000 cfm Blower

2. Determination of Reactivity of PEDU Chars: Four materials were tested in the TGA--chars from PEDU Tests 23 (Elkol, subbituminous), 27 (Pittsburgh seam), and 54 (lignite), and a Blue Coal Co. anthracite supplied by the U. S. Bureau of Mines, Morgantown. The PEDU chars were described previously (Progress Report No. 5, pp 279-285) and the anthracite was similar to coals used in the atmospheric pressure gasifier tested at Morgantown.[1]

The PEDU chars were screened at 50, 100, 200, and 325 mesh U.S. sieve sizes, and the anthracite sample was crushed and screened at the same sizes. Two samples of each material, 50 x 100 mesh and 200 x 325 mesh, were tested in the TGA at 1000 and 1100 C in an atmosphere containing 100 percent steam.

The reactivities of the materials were significantly different as shown in Figures 113 to 116. Figures 113 and 114, for tests at 1000 C, show that lignite char has the highest reactivity, subbituminous and Pittsburgh seam chars have comparable lower reactivities and anthracite is even less reactive.

In comparing Figures 113 and 114, it is interesting to note that there is no measurable change in reactivity with size for the PEDU char samples or the anthracite. However, there was more non-reactive material in the coarser anthracite fraction.

Figures 115 and 116 indicate higher reaction rates at 1100 C than at 1000 C, but no relative change in reactivities of the different materials.

3. Development of Grindability Test for Low Density Chars: The increased size of the PEDU char from Pittsburgh seam coal could be an asset in a commercial-scale reactor designed specifically for that coal. In the pilot plant, however, where a number of different coals will be tested, it may be expedient to cool the char from Stage 2, reduce its size, and then reinject it into Stage 1. Such a size reduction may also be desirable in a commercial installation if the size reduction could be effected without cooling or removing the char from the system.

An attempt was made (Progress Report No. 4, page 233) to apply a tentative Hardgrove Grindability Index (HGI) determination to characterize the hardness of these chars.

A revised procedure was devised after consultation with Mr. F. Walker of the U.S. Bureau of Mines, Pittsburgh. Samples of coals with known HGI's were obtained and characterized according to ASTM. The results show the correlation given in Figure 117.

The tests were repeated with 50 percent reduced charges (25 grams) for 50 percent fewer revolutions (30 revolutions) using finer 16 x 100 mesh material

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[1] Strimbeck, C. R., et al, "Gasification of Pulverized Coal at Atmospheric Pressure" U.S. Bur Mines, R of I 5559, 1960.

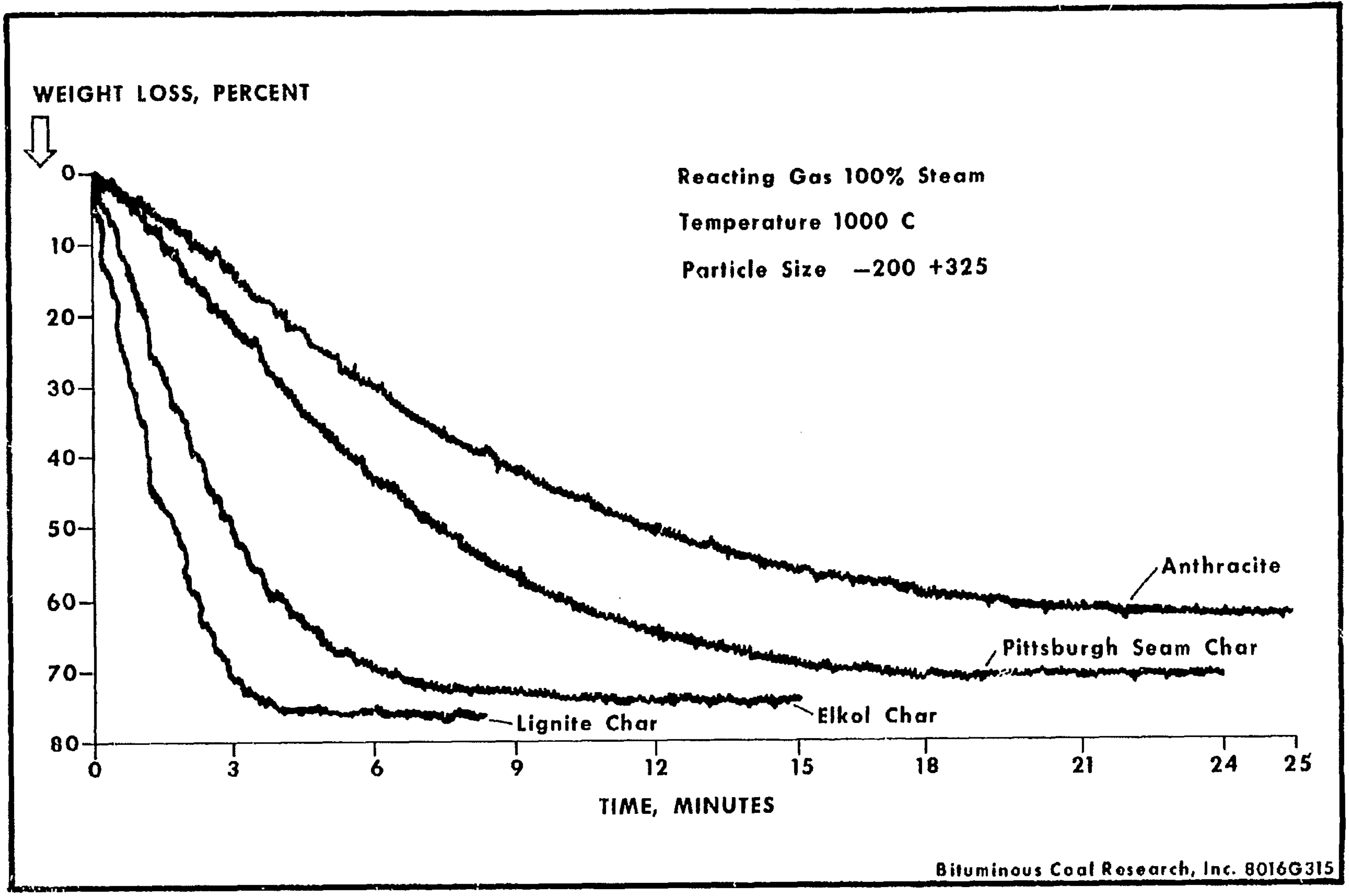


Figure 113. Rate of Weight Loss of —200 +325 Mesh Materials at 1000 C in 100 Percent Steam

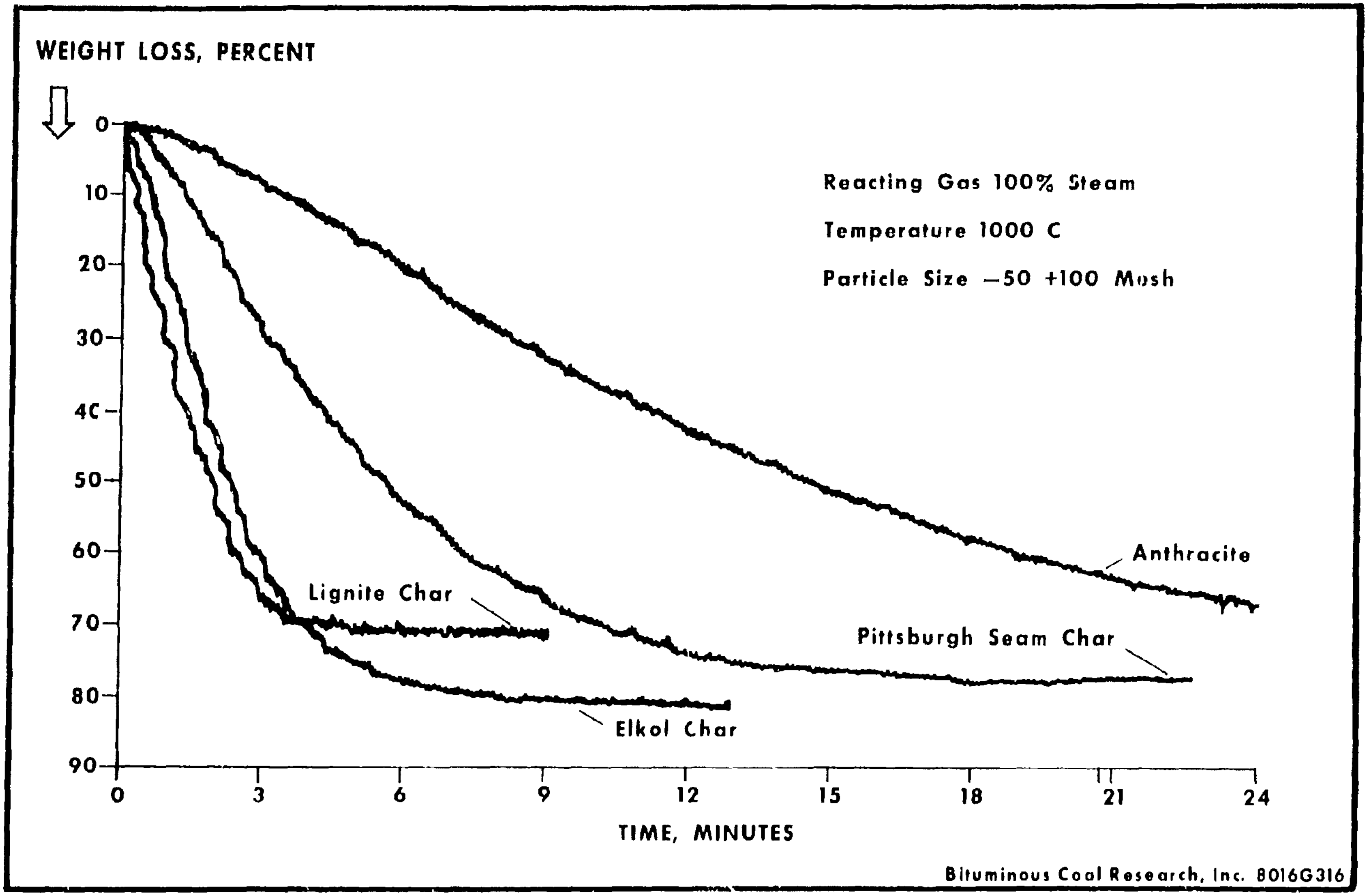
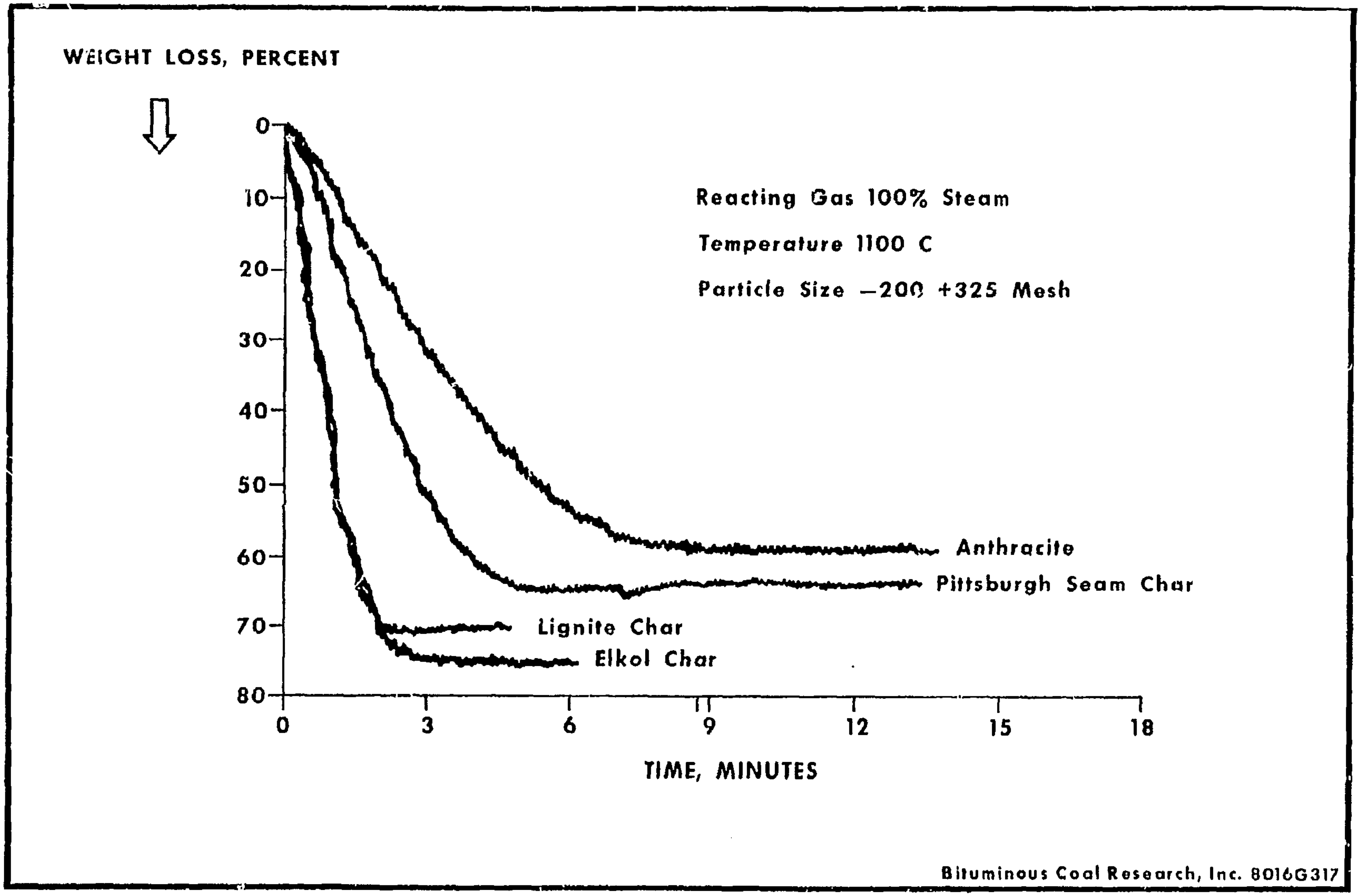


Figure 114. Rate of Weight Loss of −50 +100 Mesh Materials at 1000 C in 100 Percent Steam



Bituminous Coal Research, Inc. 8016G317

Figure 115. Rate of Weight Loss of −200 +325 Mesh Materials at 1100 C in 100 Percent Steam

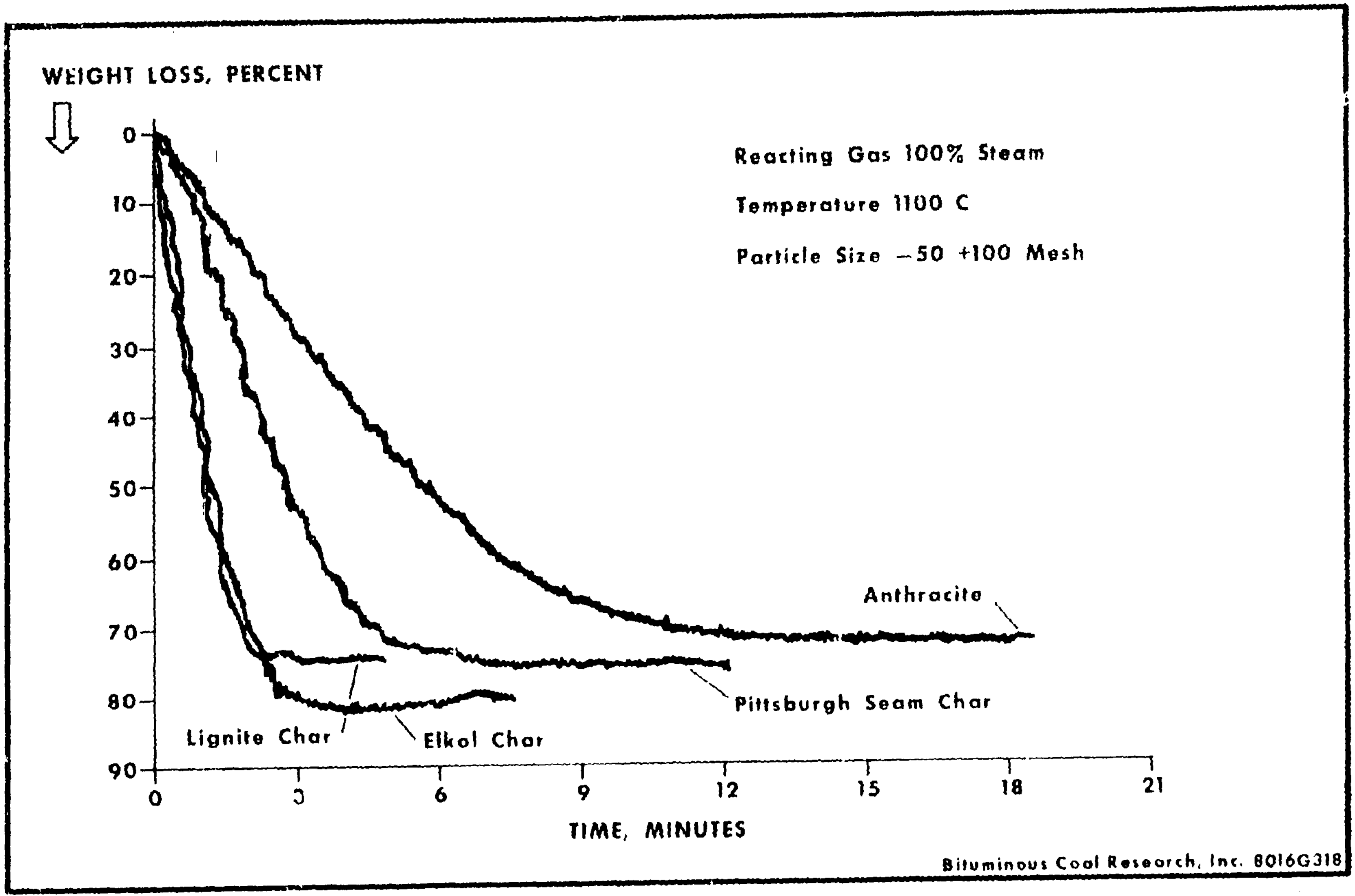


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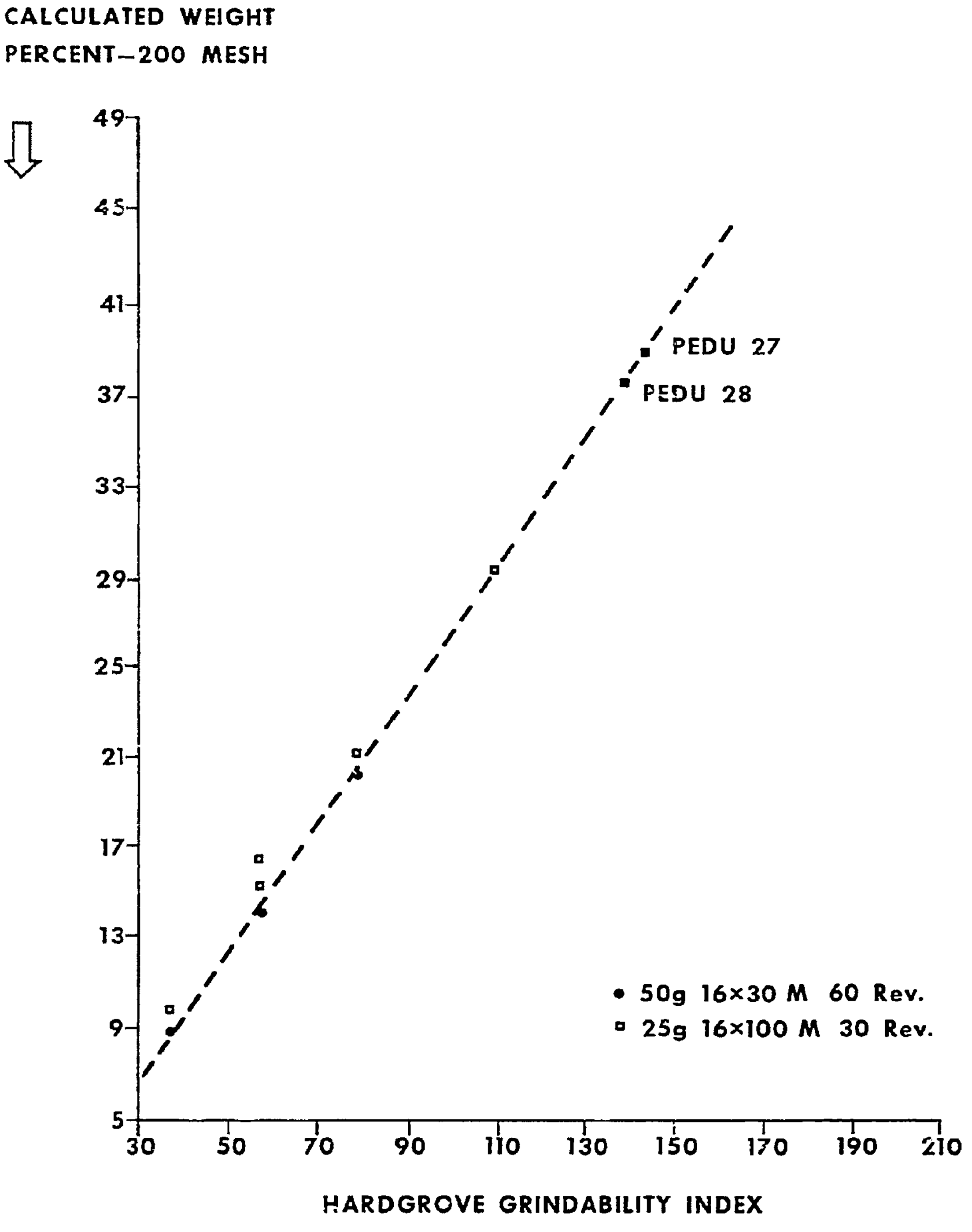
Figure 116. Rate of Weight Loss of −50 +100 Mesh Materials at 1100 C in 100 Percent Steam



Bituminous Coal Research, Inc. 8016G319

Figure 117. Results from Standard and Modified Test Procedures in Hardgrove Machine

instead of the standard 16 x 30 mesh size. The results showed that almost identical percentages of minus 200 mesh material were produced under the revised conditions.

Samples of chars were then crushed and screened to produce 25 gram samples of 16 x 100 mesh material. These samples were pulverized for 30 revolutions in the Hardgrove machine.

Tests with chars from PEDU Tests 27 and 28 indicated that these chars have an HGI of the order of 140. However, tests with PEDU char from Test 23 (Elkol coal) were inconclusive because the grinding chamber was overloaded with the low density char. Further tests are therefore being conducted with 15 gram charges. Tests so far conducted indicate that the Hardgrove machine produces a smaller percentage of fines when 15 grams are pulverized for 18 revolutions instead of 25 grams being pulverized for 30 revolutions. Since the fines production at 30 revolutions was also lower than expected, it appears that the Hardgrove machine does not pulverize efficiently during the initial revolutions.

4. Future Work

a. Modifications to Model Test Equipment: The installation of the 6,000 cfm blower will be completed and tests will begin.

b. Test of Char Reactivity: Char reactivity tests will continue on all sizes of char. Kinetic data will be summarized. Tests of materials that may be useful for start-up fuel will also be conducted.

c. Test of Grindability of Elkols: It is felt that a useful procedure will soon be available. An attempt will also be made to determine if size reduction is possible by using impacting jets to supply the feed steam.

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

1. Automated Data Acquisition: Installation and initial checkout of the PDP8/E computer and peripherals was completed.

Three programs were written to demonstrate some of the computer's capabilities. The first program illustrates procedures for permanently storing information on magnetic tape and the second describes how to retrieve it at operator's command. The other program shows how an electrical analog signal from any selected device is fed into the computer, is then converted to the appropriate engineering units, and finally printed out by the teletype.

The software system (computer programs) necessary for interfacing the bench-scale methanation unit with the computer is being written. This phase of work should be completed by April 30, 1972. Work will then be initiated on the data logging, data processing, and storage programs.

2. Commercial Gasifier Modeling: Subroutine GASIFY was utilized to generate 200 gasifier simulation runs for both Pittsburgh Seam and Elkol coals. These computer runs were made under various conditions in order to examine the following:

a. Operation of the gasifier under air-blown conditions.

b. Feasibility of operation with coal-water slurry feeding.

c. Energy and material balances under conditions simulating fluidized bed gasification.

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

a. Continue writing the software system for interfacing the bench-scale methanation unit with the computer.

b. Construct and install appropriate ductwork and wiring to accommodate individual signal lines from the bench-scale methanation unit to the computer system.

c. 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 200 sets of data. The following general areas were examined:

a. operation under air blown conditions,

b. feasibility of coal-water slurry feeding, and

c. conditions simulating fluidized bed gasification.

2. OCR/BCR Gasification--Power Generation: On March 3, 1972, representatives of Westinghouse Electric, Bechtel, Consolidation Coal Company, OCR, and BCR, met to discuss incorporation of the BI-GAS gasifier into a gas-turbine power generation system. Westinghouse is developing a proposal to OCR for a 50 ton/hr plant to demonstrate the system. An air-blown version of the BI-GAS unit has been suggested as a means of producing gaseous fuel for the gas turbine.

The main purpose of the meeting was to acquaint the other members of the group with the current status of the overall BI-GAS program. A further purpose was to determine what data are currently available for direct application to the air-blown gasifier system, and what data would have to be developed before a 50 ton/hr plant could be designed.

Following the meeting, Mr. S. Lemezis, Manager, Coal Gasification Project, for Westinghouse, submitted to BCR a list of some 21 items for which information is desired in order for the design of a plant to be initiated. BCR is currently preparing an analysis of that list, with an estimate of the amount of work required to supply the desired information.

BCR has been asked to discuss the BI-GAS unit with representatives of Foster Wheeler Corporation for yet another application of an air-blown version of the gasifier. A meeting has been scheduled for Wednesday, April 7, 1972.

F. Multipurpose Research Pilot Plant Facility (MPRF)

At the bidders conference on January 19, 1972, bidders were advised that questions submitted in writing would be distributed, together with BCR's answers, to all bidders. By letter dated March 3, 1972, another question and answer-type letter was distributed to all bidders with a copy to OCR.

Preparations are being made to set up a method of evaluating the various bids to be received. Technical as well as economic factors will be included.

1. Materials Evaluation Program: No meetings of the Task Group on material data for coal gasification equipment were held this month.

2. Desk-top Model: Visual Industries of Indianola, Pennsylvania, completed construction of the desk-top model (1/32 inch = 1 foot) on February 26, 1972. The model was delivered to OCR in Washington, D. C., on February 28, 1972.

Data sheets explaining piping and color coding for the model were mailed to OCR on February 28, 1972. Photographs and 35 mm slides were sent to Mr. Cochran on March 14, 1972.

3. Pollution Control Permits - Homer City, Pa.: Notice of intention to apply for a permit to discharge and treat industrial waste has been advertised in the Indiana, Pennsylvania, newspaper for the prescribed time of once a week for four weeks. Proof of publication to show the actual dates published is required at the time the application is filed with the Pennsylvania Department of Environmental Resources. The application for permit is being prepared.

G. Literature Search (V. E. Gleason)

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

H. Other

1. Prime Contract Matters: By letter dated March 6, 1972, BCR requested OCR instructions regarding disposal of radioactive carbon-14 samples. Mr. R. Stewart, U.S. Bureau of Mines, Morgantown, West Virginia, called BCR advising that he was requesting shipment of these samples to him. We are awaiting OCR authorization and approval.

On March 9, 1972, a final list of surplus equipment available was sent to OCR, including OCR inventory tag number and condition of equipment. By letter dated March 15, 1972, OCR requested the costs for this equipment. A list of surplus equipment including the cost of each item was mailed to OCR on March 21, 1972.

By letter dated March 24, 1972, BCR received authorization from Mr. Howard Thunberg to remove the reactor and associated surplus equipment from their present location for outside storage. The equipment is to be protected from the elements.

In accordance with an OCR request, information relating to that portion of expenditures on Contract No. 14-01-0001-324 and Contract No. 14-32-0001-1207 which has been carried out by small businesses was transmitted to Mr. G. E. Larson on March 15, 1972. In addition, more detailed backup information was sent to Mr. Larson on March 21, 1972, listing names and addresses of all small business companies from whom BCR purchased supplies or equipment.

Under date of March 1, 1972, proposed Amendment No. 1 to OCR Contract No. 14-32-0001-1207 was received from Mr. Larson, together with a copy of the Agreement with the American Gas Association and the Guidelines to implement that Agreement. Six signed copies of the proposed amendment were returned to Mr. Larson on March 9, 1972. Revised Amendment No. 1 was received from Mr. Larson on March 22, 1972. Six signed copies of the revised Amendment No. 1 were returned to Mr. Larson on March 27, 1972.

2. Outside Engineering and Services: Koppers continues to provide engineering assistance as required and as reported in their Progress Report No. 32 in Appendix C.

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 twelfth month. Figure 118, Monthly Progress Chart, Expenditures, shows the current budget status. The letter report of progress by BYU is as follows:

During March, the 3/4-inch diameter alumina tubes in the reactor were replaced with 1-1/4-inch diameter tubes in an attempt to avoid the serious

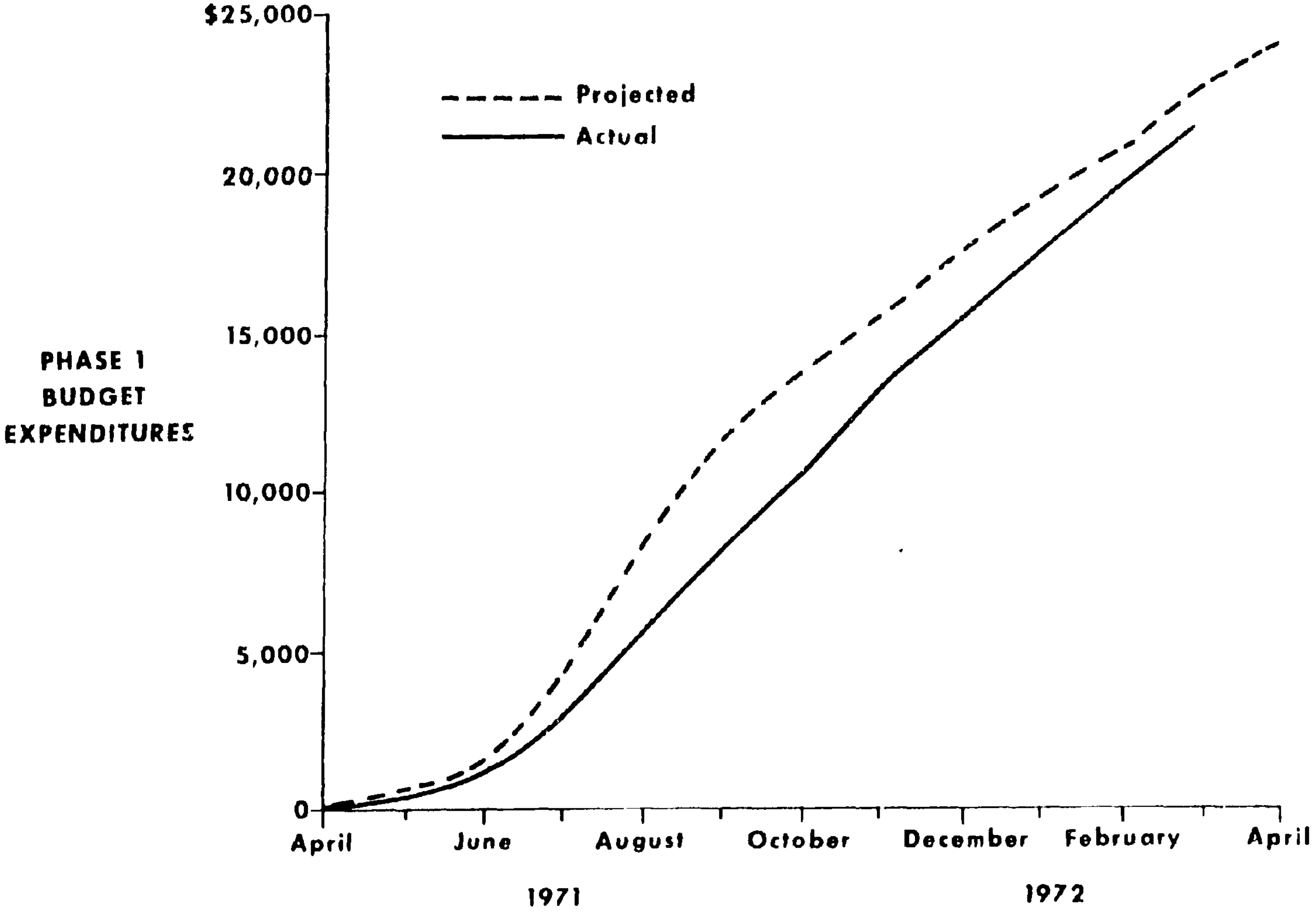


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Figure 118. Monthly Progress Chart, Expenditures, Brigham Young University

plugging problems encountered in the smaller diameter reactor. A total of nine test runs was made with this reactor configuration. The plugging problem was found to be considerably reduced. Six of these runs were made with hydrogen as the combustion gas fuel and the coal carrier, and three of the runs were made with methane as the fuel and carrier.

The results of the hydrogen runs are summarized in Table 95. Three variations were made in feed rates in these runs. The coal feed rate in the first two runs was 0.8 lbs/hr and the coal/oxygen ratio was 1:1. In the next three runs the coal feed rate was doubled, the gas feed rates remaining the same. The final run was made with a coal feed rate of 2.2 lbs/hr and a coal/oxygen ratio of 1.4:1. Gas samples were taken at the mid-point of the reactor and char samples were taken from the reactor effluent stream below the quench spray. Yields of carbon and hydrogen in the hydrocarbon gases and in carbon monoxide and carbon dioxide were computed using nitrogen as the tie compound. The coal gasification yield was also computed on the basis of the ash content of the coal and the char.

The data clearly show a decreasing yield of gasification products with increasing feed to the reactor. They also show a substantial yield of the hydrocarbon gases, methane, ethylene, and acetylene.

The tests with methane as the combustion fuel gas and coal carrier gas were unsatisfactory due to the instability of the methane-oxygen flame during injection of the coal. There is apparently insufficient residence time upstream of the point of coal injection for complete combustion of the methane and oxygen. The flame could be stabilized by increasing the combustion gas flow relative to the coal feed rate. However, the product gases then contained excessive amounts of carbon dioxide due to oxidation of the coal.

Some difficulty has been encountered with the gas filters used in the effluent sample collection system. The pressure drop across these filters is excessive at the higher feed rates, reaching 5 to 6 psi after only two minutes of effluent collection time at feed rates of 4 to 5 pounds per hour. Approaches are being considered for increasing the filtration area to eliminate this problem.

Some plugging problems in the effluent valve and lines have been encountered, and consequently these have been replaced with a larger diameter valve and piping.

During April our second semi-annual report will be prepared, and testing continued with the 1-1/4-inch reactor. Tests with a 2-inch diameter reaction tube are also planned.

4. FPC National Gas Survey - Economics of Manufacturing SNG From Coal: A meeting was held on Friday, March 10, 1972, at 10:00 a.m., at the Office of Coal Research Conference Room, Department of the Interior, Washington, D. C. The purpose of the meeting was to review a preliminary draft of the "Compilation of Gas Costs for Various Coal Gasification Processes," prepared by Esso Research and Engineering Co.

As a result of this meeting, the Synthetic Gas-Coal Task Force Group appointed two sub-groups to revise the breakdown of the process on-site costs given in the preliminary compilation of costs of pipeline gas from coal for the FPC National Gas Survey.

TABLE 95. RESULTS FROM HYDROGEN RUNS IN 1 1/4-INCH REACTOR

Number of Runs Averaged:	2	3	1
Feed Rates, lbs/hr			
Hydrogen, combustion	0.09	0.09	0.13
Hydrogen, carrier	0.08	0.08	0.12
Oxygen	0.78	0.78	1.57
Nitrogen	0.40	0.40	0.40
Coal	0.77	1.59	2.18
Total	2.12	2.94	4.40
Reactor Temperature, F*	1900	2050	2100
Gas Analysis Uncorrected,* Percent			
Hydrogen	57.3	57.7	39.4
Oxygen	2.1	0.9	0.4
Nitrogen	16.8	17.7	29.1
Methane	3.1	4.5	3.3
Carbon Monoxide	11.4	13.7	17.2
Ethane	0.1	0.1	--
Ethylene	0.8	1.8	0.7
Carbon dioxide	3.0	2.1	2.9
Acetylene	1.3	1.8	1.8
Feed Ratio lbs Coal/lb Oxygen	0.99	2.04	1.39
Yield lbs C, H in gas/lb Coal, Percent			
Methane	5.0	3.8	1.2
Carbon monoxide	16.5	5.5	4.6
Ethane	0.2	0.1	--
Ethylene	2.5	1.8	0.4
Carbon Dioxide	4.7	1.9	0.8
Acetylene	3.9	2.4	1.0
Ash Analysis, Percent			
Coal	7.5	7.4	7.3
Char	14.4	12.1	10.9
Yield = 100 (1-Coal Ash/Char Ash)	47.9	38.8	33.0

* The temperature was measured and the gas samples were taken at a point 3 inches below the point of coal injection.

On March 15, 1972, one sub-group met in Pittsburgh and prepared Table 96, which presents the revised breakdown of the process on-site costs. The table shows an increase in the number of sections from four to nine. Coal storage and preparation was separated into two sections--Raw Coal Cleaning and Sizing, and Sized Coal Storage and Preparation. This was done to distinguish between the numbers for BI-GAS, which include costs for the first category, and the other processes, which apparently do not. Because of different methods of solids feeding, which are not necessarily characteristic of a particular gasification process, this is shown as a separate item. For Synthane and CO_2 Acceptor, the figures were extracted from their reports. A separate pretreatment step is used for HYGAS with bituminous coal, and this is also shown for these cases. A better measure of the costs of gasification, per se, results from separation of feeding and pretreatment. CO shift is now shown as a separate operation, but was included with purification in the original. In the original table the quench system was included with gasification; now it is in purification. The CO_2 Acceptor design includes cost for compression from below 100 psig to 1000 psig (low pressure case). A current cost of $6.6 million was extracted from their report and subtracted from the original figure of $21.1 million. This brings methanation more in line with the others. A small compressor is used for the Synthane design (920 to 1000 psig).

The totals are as before. Only the total is given for Lurgi because the only individual process on-site numbers available are the same as used in the preliminary draft of the FPC report. Continental Oil will fill in the numbers when the new breakdown is decided on.

The factors necessary to change plant capacity for each process to 250 billion Btu per day were discussed; i.e., whether to change the investment by direct proportion, by 0.6 or 0.7 power of capacity ratio, or by consideration of individual plant sections.

In the preliminary compilation, $2 million was added for particulate emissions during coal preparation. Synthane was exempted from this, perhaps because of the inclusion of a section on dust removal, which follows gasification. From a study of the cost breakdown for coal preparation, it appears that about $700,000 is included for dust control. Therefore, the addition of $1.3 million, as shown in footnote (a, Table 96, was recommended.

On the other hand, it appears that the CO_2 Acceptor estimate included about $4.5 million for dust collection during drying and grinding, so it was thought that the $2 million should be removed, and this is also shown in footnote (b, Table 96.

The next meeting of the task force was set for March 27, 1972, at OCR in Washington, D. C.

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

TABLE 96. REVISED INVESTMENT BREAKDOWN PREPARED BY THE SUBGROUP FOR PROCESS ONSITE GAS COSTS, FPC NATIONAL GAS SURVEY

Process	Lurgi	BI-GAS	HYGAS Electrothermal	HYGAS Steam-Oxygen	HYGAS Steam-Iron	Synthane	C.S.G. CO_2 Acceptor
	All Costs in $ million						
Raw Coal Cleaning and Sizing	--	8.1	-	--	--	--	--
Sized Coal Storage and Preparation	--	13.9	9.7	9.3	11.3	6.9 (8.2)[a]	19.2 (17.2)[b]
Pretreatment	--	--	5.1	4.6	6.3	--	--
Feed System	--	6.6	11.7	8.5	12.0	5.8	2.0
Gasification	--	7.7	29.7	26.0	59.1	26.2	49.0
CO Shift	--	13.1	4.5	5.7	0.3	2.7	--
Gas Purification	--	41.3	28.5	33.1	21.9	20.7	7.1
Methanation	--	12.4	8.6	9.5	6.3	16.5	14.5
Compression	--	--	--	--	--	0.6	6.6
Total Process Onsite	107.1	103.1	97.8	96.7	117.2	79.4 (80.7)	98.4 (96.4)
Capacity Ratio $\frac{250 \times 10^9 \text{ Btu/SD}}{\text{Actual}}$	1.054	1.059	0.987	1.011	0.987	1.079	1.000

[a] $2 million not added in original. Synthane economics include $0.7 million for dust collection; we suggest adding $1.3 million to be on same basis as the others.

[b] CO_2 Acceptor original economics include $4.6 million for dust recovery; we suggest subtraction of the $2 million.

Solids," contains nine claims. The appropriate document assigning rights to the U.S. Government was filed with the patent application on September 22, 1971. BCR has applied for and received a license for foreign filing. On February 23, 1972, patent applications were forwarded for filing in Australia, India, South Africa, 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
Great Britain	- No. 9589/72

On March 10, 1972, patent application was forwarded for filing in Canada. 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, under date of January 12, 1972.

b. OCR-1860 and OCR-1861: As previously reported, Disclosures 1860 and 1861 have been combined into a single patent application entitled "Two-stage Gasification of Pretreated Coal." A copy of this application was mailed to Mr. 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.

This patent application was reviewed again by the inventor and certain revisions have been made. On March 20, 1972, a revised patent application, together with the appropriate document assigning rights to the government, was mailed to the U.S. Patent Office for filing. This application contains twelve claims. Confirmatory license will be prepared after a serial number is received.

c. OCR-1862: As previously reported, a U.S. patent application has been prepared on Disclosure 1862 entitled "Three Stage Gasification of Coal." A copy of this application was sent to Mr. 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, certain revisions have been made in this application. A revised application and Assignment form were mailed on March 20, 1972, to the U.S. Patent Office for filing. This application contains eight claims. Confirmatory license will be prepared after a serial number is received.

d. OCR-1863: A U.S. patent application has also been prepared on Disclosure 1863 entitled "Two-stage Downflow Gasification of Coal." A copy of this application was forwarded to Mr. Howard 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.

This application has also been reviewed again by the inventor and certain revisions have been made. A revised application and Assignment form were mailed on March 20, 1972, to the U.S. Patent Office for filing. The application contains seven claims. Confirmatory license will be prepared after a serial number is received.

e. CCR-1864: A U.S. patent application was prepared on Disclosure 1864 entitled "Two-stage Gasification of Coal with Forced Reactant Mixing and Steam Treatment of Recycled Char." A copy of this application was mailed to Mr. 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.

Revisions have also been made in this application after further review by the inventor. On March 20, 1972, a revised application and Assignment form were mailed to the U.S. Patent Office for filing. The application contains thirteen claims. Confirmatory license will be prepared after a serial number is received.

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 March, 1972

March 1, 1972

Mr. M. R. Jester
Mr. K. W. Deem
Processes Research, Inc.
2912 Vernon Place
Cincinnati, Ohio 45219

Mr. Paul Spaite
A. M. Kinney, Inc.
2912 Vernon Place
Cincinnati, Ohio 45219

March 2, 1972

Mr. Paul Towson, Engineer
Mr. Jack E. Ryan, Engineer
Division of Utilization
Office of Coal Research
U.S. Department of the Interior
Washington, D. C. 20240

March 3, 1972

Mr. A. T. Stewart
Bechtel Corporation
50 Beale Street
San Francisco, California 94119

Mr. Charles C. Ferguson
Bechtel Corporation
485 Lexington Avenue
New York, New York 10017

Mr. E. H. Reichl
Mr. G. P. Curran
Mr. Everett Gorin
Consolidation Coal Company
Library, Pennsylvania 15129

March 3, 1972

Mr. Raymond Durante
Mr. Robert Giardini
Mr. Dale L. Keairns
Mr. S. Lemizis
Mr. J. P. Morris
Westinghouse Electric Corp.
Beulah Road
Pittsburgh, Pennsylvania 15235

Mr. Paul Towson, Engineer
Mr. Jack E. Ryan, Engineer
Division of Utilization
Office of Coal Research
U.S. Department of the Interior
Washington, D. C. 20240

Mr. R. W. Whiteacre
Koppers Company, Inc.
Koppers Building
Pittsburgh, Pennsylvania 15219

March 7, 1972

Mr. Frank Chalmers
Arthur G. McKee & Co.
6200 Oak Tree Boulevard
Independence, Ohio 44131

March 8, 1972

Mr. Allan Benton
Chem Systems, Inc.
866 Third Avenue
New York, New York 10022

March 13, 1972

Mr. M. R. Jester
Mr. D. P. Miller
Processes Research, Inc.
2912 Vernon Place
Cincinnati, Ohio 45219

March 14, 1972

Mr. James R. Byron
Fluor Corporation
589 Fifth Avenue
New York, New York

Dr. I. Stephen Tuba, President
Mr. Leon V. Kulasa
Basic Technology, Inc.
201 Penn Center Boulevard
Pittsburgh, Pennsylvania 15235

March 15, 1972

Mr. J. Boiseau
Mr. Peter Loux
Computer Sciences Corp.
6728 Colesville Road
Silver Spring, Maryland 20910

March 22, 1972

Mr. Russell G. Ellis
Mr. Arthur J. Serrin
Arthur G. McKee & Co.
6200 Oak Tree Boulevard
Independence, Ohio 44131

March 28, 1972

Mr. D. C. Strimbeck
Mr. David Sherren
Mr. D. W. Gillmore
U.S. Bureau of Mines
Morgantown, West Virginia

March 29, 1972

Mr. Robert J. Rush
Air Products and Chemicals, Inc.
P.O. Box 538
Allentown, Pennsylvania 18105

Mr. L. J. Pieroni
The Rust Engineering Co.
850 Third Avenue
New York, New York 10022

Mr. Harrison Walker
Badger Company, Inc.
One Broadway
Cambridge, Mass. 02142

Mr. Frank Cannon
Mr. J. F. Farnsworth
Koppers Company, Inc.
Koppers Building
Pittsburgh, Pennsylvania 15219

Mr. R. B. Kilpatrick
Swindell-Dressler Co.
441 Smithfield Street
Pittsburgh, Pennsylvania 15222

Mr. B. A. Campbell
Foster Wheeler Corp.
909 Oliver Building
Pittsburgh, Pennsylvania 15222

March 29, 1972

Mr. E. J. Vidt
Mr. S. Kasper
Blaw-Knox Chemical Plants, Inc.
One Oliver Plaza
Pittsburgh, Pennsylvania 15222

March 29 and 30, 1972

Mr. Paul Towson, Engineer
Mr. Jack E. Ryan, Engineer
Division of Utilization
Office of Coal Research
U.S. Department of the Interior
Washington, D. C. 20240

March 30, 1972

Mr. Roger Detman
Mr. Frank J. Young
Mr. R. W. Hospodarec
C. F. Braun & Co.
Alhambra, California

Mr. W. J. Taylor
Procon, Inc.
30 UOP Plaza
Algonquin & Mt. Prospect Roads
Des Plaines, Illinois 60016

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

March 10, 1972	Office of Coal Research U.S. Department of the Interior Washington, D. C. 20240	E. K. Diehl J. P. Tassoney
March 27, 1972	Office of Coal Research U.S. Department of the Interior Washington, D. C. 20240	J. P. Tassoney

K. Requests for Information

Mr. Gary C. Ashley
Research Engineer
Northern States Power Company
414 Nicollet Mall
Minneapolis, Minnesota 55401

Mr. C. Halpin
Halpin Engineers
561 Hollywood
Grosse Point, Michigan 48236

III. WORK PLANNED FOR APRIL, 1972

The work planned for April 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 CCR 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 in both the TGA and the batch reactor.

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. As soon as approval is obtained for the expenditure of funds for removal of equipment, this work will begin, followed by the necessary excavation.

The draft of the final summary report on the Stage 2 PEDU (100 lb/hr) has been prepared for final typing. An early mailing date is planned.

Installation of the 6,000 cfm blower for the cold model studies of the 5 ton/hr two-stage gasifier will be completed and tests are planned. Char reactivity and grindability 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 BCR during the construction of the Homer City pilot plant. Preparations for bid evaluations will continue.

A. Trips and Meetings Planned

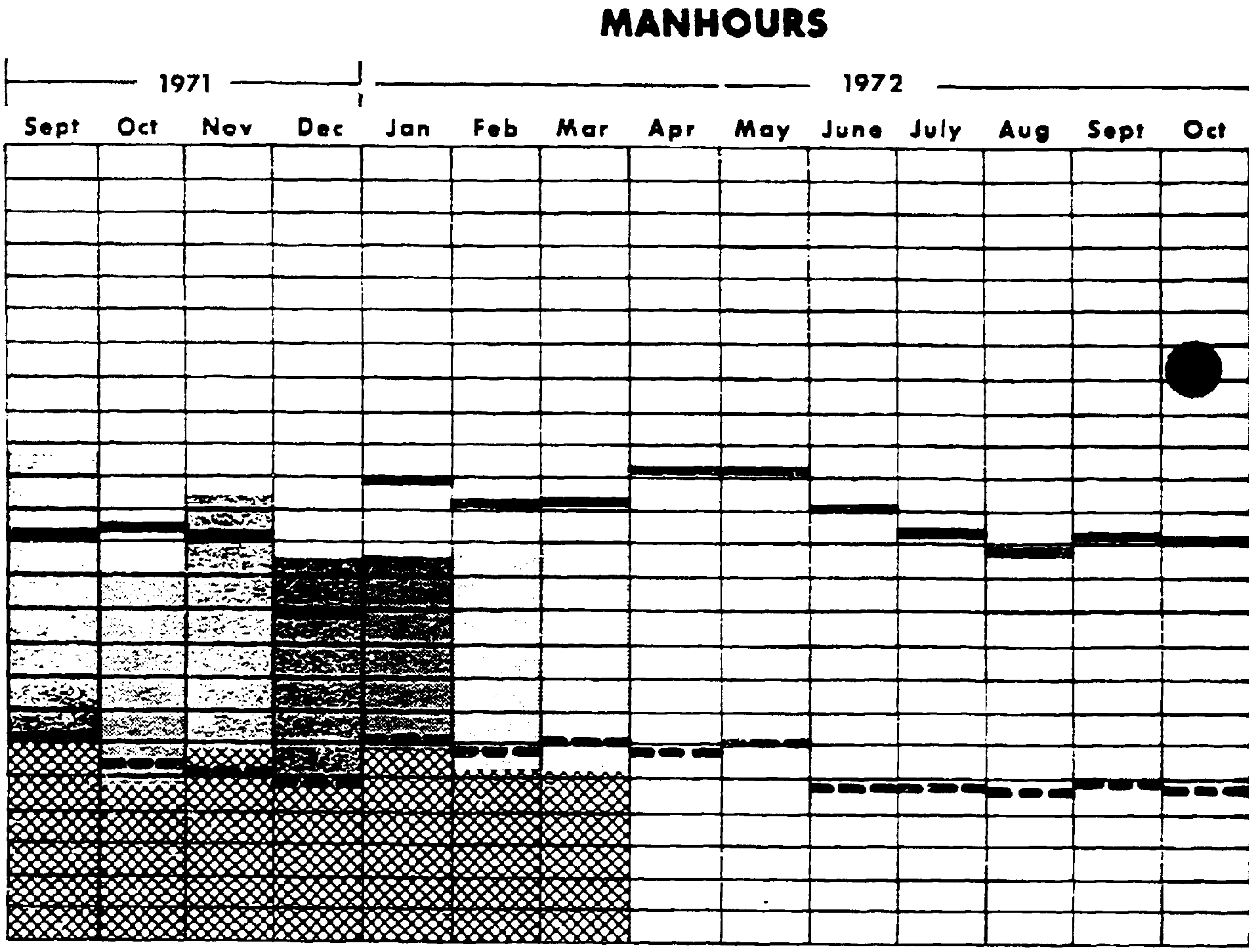
April 10-14, 1972	163rd National Meeting of American Chemical Society Division of Fuel Chemistry Boston, Massachusetts	J. P. Tassoney

B. Papers to be Presented

None

C. Visitors Expected

None

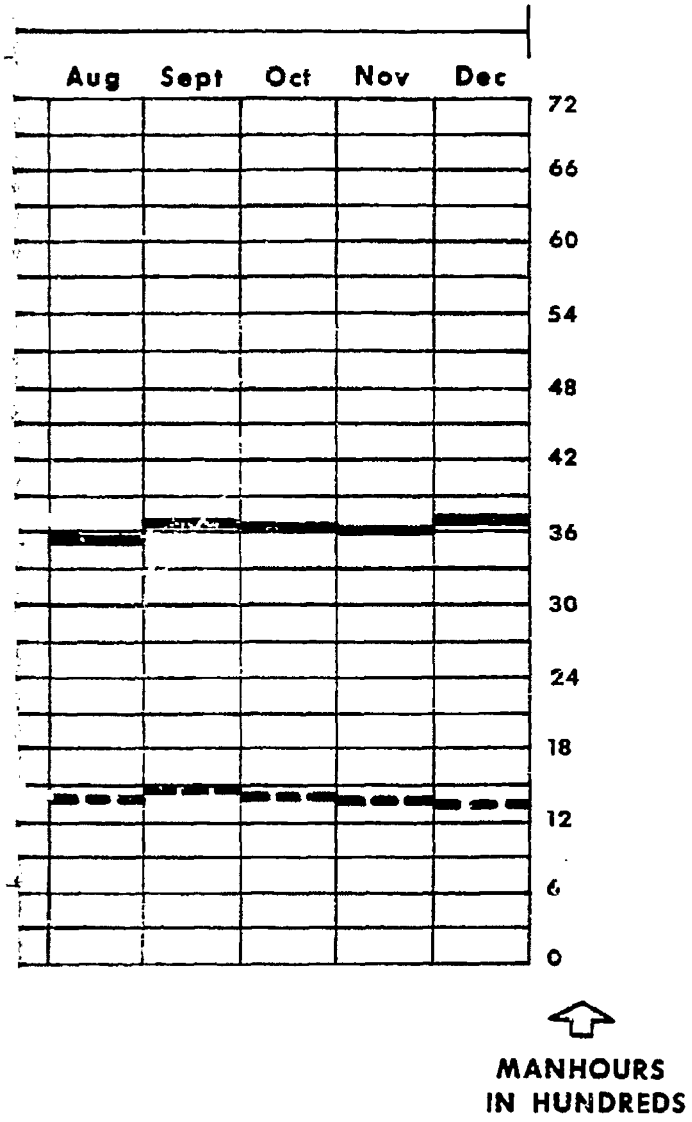

MANHOURS
1971
1972
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct

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



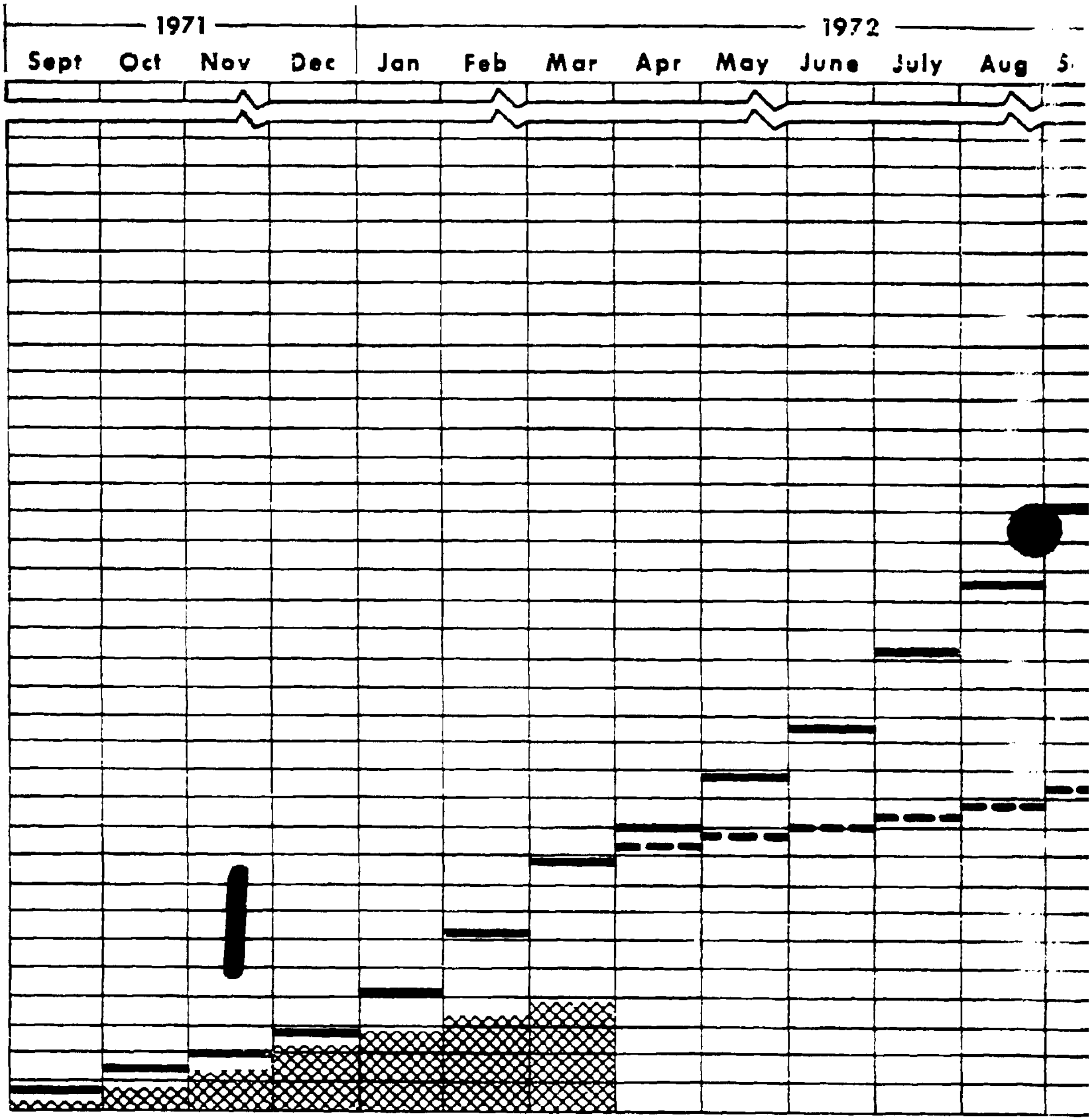
▬ Predicted Professional and Non-professional

▬ ▬ Predicted Professional

☐ Actual Non-professional

▨ Actual Professional

2



MONTHLY EXPENDITURES (All Costs, in Doll

		Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	M
Monroeville	**Predicted**	129,991	129,991	129,991	129,991	323,486	382,228	558,454	105,058	86,
	Actual	63,610	121,696	146,834	144,590*	103,147	86,250*	113,036		
Homer City	**Predicted**								154,00[illegible]	[illegible]15
	Actual									
Total	**Predicted**	129,991	129,991	129,991	129,991	323,486	382,228	558,454	259,058	301
	Actual	63,610	121,696	146,834	144,590*	103,147	86,250*	113,036		

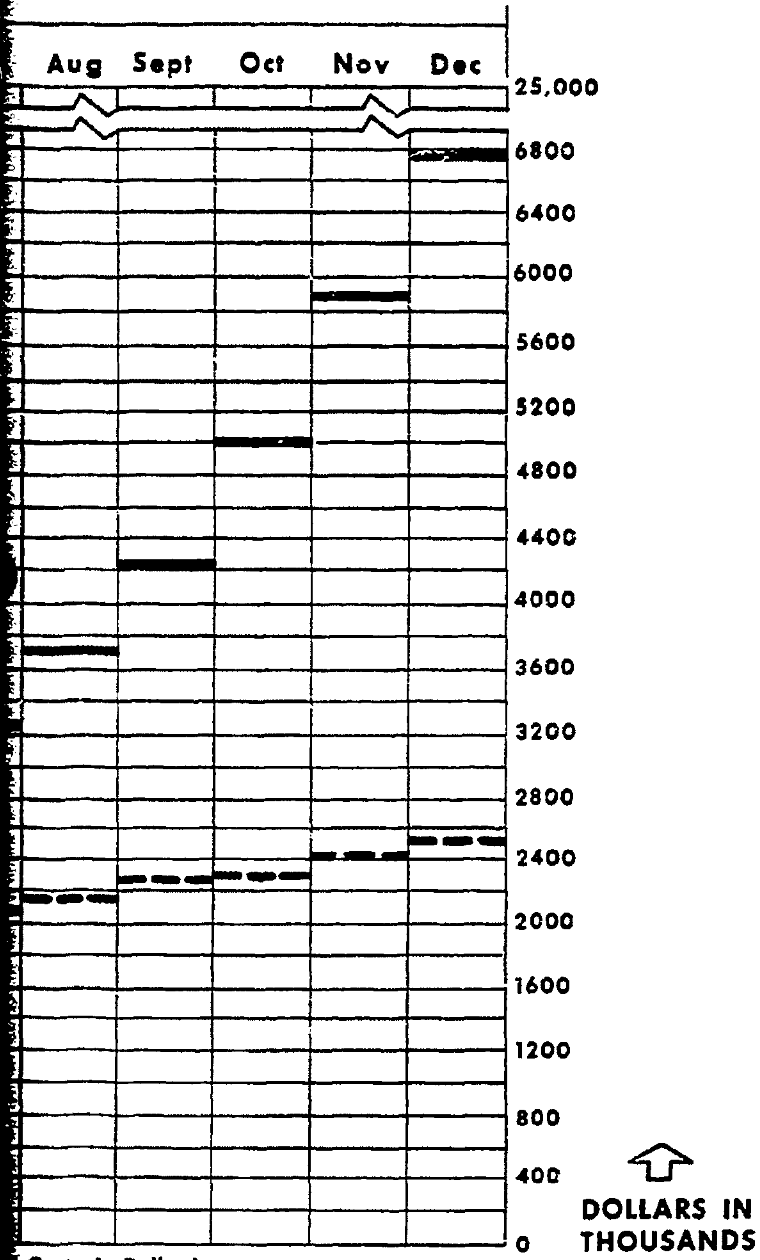
CUMULATIVE EXPENDITURES

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

Costs, in Dollars)

Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
5,058	86,238	86,240	65,813	65,813	74,746	62,273	62,273	62,275
4,000	215,600	280,400	444,300	444,300	444,400	760,600	760,600	760,800
9,058	301,838	366,640	510,113	510,113	519,146	822,873	822,873	823,075

2

* Estimated

APPENDIX B

ADDITIONS TO ABSTRACT FILE, MARCH 1972

Booth, N., Wilkins, E. T., Jolley, L. J., and Tebboth, J. A., "Catalytic synthesis of methane: experimental work at the Fuel Research Station," The Gas Research Board, Publ. GRB 21/11 (1948). 44 pp. 540.000 Gas Res. Bd.

> This paper describes the results of an investigation of the production of gas rich in methane from water gas by conversion with nickel catalysts. A detailed survey of the performance of nickel catalysts supported on kieselguhr and promoted with thoria and magnesia has been carried out with water gas-hydrogen mixtures of varied compositions, and the conditions necessary for producing catalysts of high activity and for obtaining a long working life from such catalysts have been determined. (from Authors' Summary)

Dent, F. J., Moignard, L. A., Eastwood, A. H., Blackburn, W. H., and Hebden, D., "An investigation into the catalytic synthesis of methane for town gas manufacture," The Gas Research Board, Publ. GRB 20 (1945). 104 pp. 540.000 Gas Res. Bd.

> This report covers six years of study at the University of Leeds under the direction of the Joint Research Committee. The immediate aim of the research was to develop methods of controlling the highly exothermic synthesis of methane from carbon monoxide and hydrogen so that it could be used at high space velocity for enriching the gas produced by both normal and high-pressure gasification processes. The reaction was studied over the range of 1 to 50 atmospheres pressure with attention to the variation in ratio of hydrogen to carbon monoxide in the synthesis gas produced by gasification at different pressures. Particular concerns of the report are control of carbon deposition and of catalyst sintering. (from Authors' Introduction and Summary)

Ertel, C. W. and Metcalf, J. T., "New fuels - old coal," Mech. Eng. 94 (3), 24-7 (1972). 540.000 Journal

> The article deals with problems to be faced in conversion of coal to meet fuel needs. Liquid fuel production processes of Consolidation Coal Co.,

Hydrocarbon Research, Inc., and The Pittsburgh and Midway Coal Mining Co. and coal gasification processes of U.S. Bureau of Mines, Bituminous Coal Research, Inc., Institute of Gas Technology, and Consolidation Coal Co. are discussed.

Forney, A. J., Haynes, W. P., Elliott, J. J., and Kenny, R. F., "Clean automotive fuel: laboratory-scale operation of the Synthane Process," U.S. Bur. Mines, TPR49 (1972). 6 pp. 540.000 Bur. Mines

> A high-Btu gas was made at the Bruceton, Pa. laboratories of the Bureau of Mines to demonstrate the feasibility of using the gas as a nonpolluting fuel for automobiles. The pilot plants at Bruceton were revised to combine the processes of coal gasification, gas purification, and catalytic methanation in one overall system. The gasification was carried out at 600 psig; a pilot plant sized amine scrubber was used as the purifier; and the purified synthesis gas, with hydrogen added to give H_2/CO ratio slightly above 3 to 1, was methanated over a Raney nickel reactor at 1000 psi. (from Authors' Abstract and Experimental Procedure)

Hall, C. C. and Taylor, A. H., "Chemical engineering aspects of the Fischer-Tropsch process," Trans. Inst. Chem. Eng. (Jan. 7, 1947). 15 pp. 540.000 47-1

> This paper describes data collected by Allied investigators on construction and operation of German plants producing hydrocarbon oils and waxes by the Fischer-Tropsch process during the period from 1939 to 1945.

Haynes, W. P., Elliott, J. J., and Forney, A. J., "Experience with methanation catalysts," ACS Div. Fuel Chem. Preprints <u>16</u> (2), 47-63 (1972). 540.000 ACS

> The Bureau of Mines, Pittsburgh Energy Research Center, has conducted bench-scale and pilot-plant studies of the methanation reaction with a variety of catalysts and reactors. This report discusses some of the work, comments on the preparation of the various types of catalysts and their performance, and outlines results of a recent tube-wall reactor pilot-plant test. (from Authors' Introduction)

Hoffman, E. J., Cox, J. L., Hoffman, R. W., Roberts, J. A., and Willson, W. G., "Behavior of nickel methanation catalysts in coal-steam reactions," ACS Div. Fuel Chem. Preprints <u>16</u> (2), 64-7 (1972). 540.000 ACS

The principal objective of the investigation at the Natural Resources Research Institute at the University of Wyoming is the direct conversion of coal-steam systems on to hydrocarbons in a single-stage reactor using multiple catalysts. In this reporting, gasification to produce methane is the overriding consideration. In addition to the conversion of coal and lignite, other carboniferous materials have been gasified. (Authors' Introduction Adapted)

King, J. G., "The synthesis of methane," The Gas World, 122, 196-200,209 (1945). 540.000 45-1

The problems encountered in the Gas Research Board study of catalytic synthesis of methane from mixtures of carbon monoxide and hydrogen are reviewed.

Long, G., "Quality requirement for SNG," ACS Div. Fuel Chem. Preprints 16 (1), 51-60 (1972). 540.000 ACS

Four gas compositions from naphtha gasification and one from coal gasification by IGT's HYGAS process were used in actual appliance combustion tests in a wide variety of burners. The results confirmed the validity of the use of AGA interchangeability indices and the Wobbe number to predict whether an SNG can be substituted for high methane natural gas.

Mills, G. A., "Future catalytic requirements for synthetic energy fuels," ACS Div. Fuel Chem. Preprints 16 (2), 107-23 (1972). 540.000 ACS

Catalysts for coal gasification, shift conversion, methanation, naphtha reforming, and coal liquefaction, particularly as studied by U.S. Bureau of Mines, are discussed.

Wen, C. Y., "Optimization of coal gasification processes," West Virginia University, Rept. to U.S. Office Coal Res., R & D Rept. 66, Interim Rept. No. 1, Vol. 1 - Chap. I thru VII, Vol. 2 - Chap. VIII plus Appendices, (undated, released 1972). 540.000 OCR

Coal gasification schemes to manufacture pipeline gas can be represented by five separate phases of operation, namely: coal preparation and pretreatment, coal gasification, shift conversion, gas purification, and methanation. This report deals with each of the five phases, presenting the pertinent technical information, examining the constraints and alternate processes, and formulating models for computer simulation and optimization. The results are interpreted in practical terms specifying the characteristics of coal used, the capital and operating costs of the plants as a whole, and of sections of such plants, including the necessary benefit/cost relationships. Thus, the most attractive processes or alternatives are recommended, and those areas of coal gasification technology are identified where further research and development are likely to produce beneficial results. (From Author's summary)

PATENT

"Synthesis of hydrocarbons and oxygen-containing organic compounds," (Rheinpreussen Akt.-Ges. für Bergbau und Chemie) Brit. Pat. 762,704 (Dec. 5, 1956). 4 pp. 540.000 Brit. Pat.

The reactions of carbon monoxide and water vapor discussed in the claims are carried out at temperatures from 150 to 350 C and at pressures ranging from 1 to 100 atmospheres. Catalyst compositions and methods of preparation are specified. In one claim, hydrogen is added to the mixture of carbon monoxide and water to produce synthesis products by the simultaneous reactions of carbon monoxide and hydrogen and of carbon monoxide and water vapor.

APPENDIX C

PROGRESS REPORT #32

Bituminous Coal Research, Inc.
Coal Gasification

March 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 March 1, 1972, revised Methanation Flow Diagrams and Material Balance Drawings incorporating the use of H_2S and CO_2 to the Methanator Feed Gas, were transmitted to BCR for their use in the application for a pollution permit for the subject PEDU.

2. Koppers received on March 8, 1972 Mr. E. K. Diehl's letter advising Koppers to proceed with the detail engineering of the Methanation PEDU on the basis of the revised 900 manday schedule.

3. Koppers drawings and specifications pertaining to the reformer feed gas receiver, methanator feed gas receiver and H_2S flash tank were transmitted to BCR on March 8, 1972.

4. Mr. Igoe, BCR, advised Koppers Company in a letter March 10, 1972 that the Bid Evaluation costs are to be charged to Part "C" of Contract 2415.

5. The following Bid Evaluations were made and transmitted to BCR:

   a. Compressor Bids - March 22, 1972

b. Steam Boiler - (Telephone conversation between R. W. Whiteacre and M. S. Graboski).

c. Instrument Panel - March 29, 1972

6. Reformer instrumentation was reviewed by Messrs. Graboski, Dorsey and Whiteacre at a meeting held in Koppers offices on March 15, 1972.

7. A meeting was held March 27, 1972 at Koppers offices between Gas Atmospheres, BCR and Koppers Company to discuss Gas Atmospheres' proposal dated February 28, 1972 (Conference Report No. 218). On the basis of this meeting, Gas Atmospheres will submit a revised proposal.

Fluid Bed Gasification PEDU

1. No further work is being performed on the Char 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