BITUMINOUS COAL RESEARCH, INC.
SPONSORED RESEARCH PROGRAM

GAS GENERATOR RESEARCH AND DEVELOPMENT

Progress Report No. 10

(BCR Report L-474)

I. INTRODUCTION

This report summarizes progress achieved during the month on the general program, "Gas Generator Research and Development," being conducted by Bituminous Coal Research, Inc., for the Office of Coal Research. The program which was initiated under Contract No. 14-01-0001-324, December 20, 1963, was transferred to Contract No. 14-32-0001-1207 on August 19, 1971. Thus, this report represents the tenth 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 JUNE 25, 1972

A. Laboratory-scale Process Studies

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

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

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

(1) BSM Tests: During the month, seven exploratory BSM tests, Numbers 69 through 75, were conducted. The system configuration used was that described in detail in Progress Report No. 6, page 318. The reactor vessel used was a 1.25 inch ID fluidized bed.

(a) BSM Test 69: BSM Test 69 was conducted using a 100-gram charge of nickel-tungsten, Lot No. 2905, catalyst. Two periods were conducted. In the first, the standard synthesis gas composition, as shown below, was fed to the reactor at 977 F, while in Period 2 a gas with a 1/1 hydrogen to carbon monoxide ratio was fed along with steam to the reactor.

Dry Feed Gas Component	Volume, Percent Period 1	Volume, Percent Period 2
Carbon Monoxide	20.40	37.73
Carbon Dioxide	0.04	15.98
Hydrogen	61.81	44.84
Nitrogen	2.20	0.21
Methane	15.48	1.24
Ethane	0.07	---

Period 1 simulated conversion under Scheme A conditions. Period 2 was conducted under Scheme B conditions with no prior shift conversion.

Results for Test 69: Material balance data for Test 69 are given in Table 122. Overall results are summarized in Table 123.

In Period 1, gas was fed at a rate of 23.5 scfh or about two times minimum fluidizing velocity. With the small catalyst charge present, the resulting space velocity was high (4000). Under these conditions, a large

TABLE 122. DATA AND RESULTS FOR BSM TEST 69, PERIOD 1,
CONDUCTED AT 977 F AND 1020 PSIG
NICKEL-TUNGSTEN CATALYST NO. 2905

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	20.40	5.74	4.19	0.66
Carbon Dioxide	0.04	0.01	5.04	0.79
Hydrogen	61.81	17.38	31.44	4.93
Nitrogen	2.20	0.62	3.87	0.61
Methane	15.48	4.35	55.43	8.69
Ethane	0.07	0.02	0.00	0.00
Propane	0.00	0.00	0.00	0.00
Water	0.00	0.00	-	3.52
Total	100.00	28.12	100.00	19.20
Total Moles Carbon		10.14		10.14
Total Moles Hydrogen		52.28		51.67
Total Moles Oxygen		5.76		5.76

B. Conversion Data

	Raw Data g moles/hr
CO → Products	5.08
H_2 → Products	12.45
Reactants → H_2O	3.52
CO → CH_4	4.34
CO → C_2H_6	-0.04
CO → C_3H_8	0.00
CO → CO_2	0.78
α, Percent	74.5
β, Percent	-0.9
K_{shift} (experimental)	1.68
K_{shift} (theoretical at outlet)	-

TABLE 122. DATA AND RESULTS FOR BSM TEST 69, PERIOD 2, CONDUCTED AT 624 F AND 1024 PSIG NICKEL-TUNGSTEN CATALYST NO. 2905 (Continued)

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	37.73	[illegible]	37.46	6.28
Carbon Dioxide	15.98	2.86	18.83	3.16
Hydrogen	44.84	8.03	40.81	6.84
Nitrogen	0.21	0.04	0.45	0.08
Methane	1.24	0.22	2.45	0.41
Ethane	0.00	0.00	0.00	0.00
Propane	0.00	0.00	0.00	0.00
Water	0.00	7.71	-	8.52
Total	100.00	17.91	100.00	16.67
Total Moles Carbon		9.84		9.84
Total Moles Hydrogen		32.37		32.37
Total Moles Oxygen		20.19		21.11

B. Conversion Data

	Raw Data g moles/hr
CO → Products	0.48
H → Products	1.19
Reactants → H_2O	-0.10
CO → CH_4	0.19
CO → C_2H_6	0.00
CO → C_3H_8	0.00
CO → CO_2	0.29
α, Percent	5.1
γ, Percent	0.00
K_{shift} (experimental)	-32.91
K_{shift} (theoretical at outlet)	-

TABLE 123. SUMMARY OF RESULTS FOR BSM TEST 69. CATALYST NO. 2905

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	977	1020	4049	2.14	1.43	74.5	0.00	1.68	27.2
2	824	1024	2580	1.74	1.71	5.1	0.00	0.40	28.3

1 Standard volumes/volume catalyst/hr at inlet conditions

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

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

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

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

temperature gradient was present across the bed (810 to 980 F). The yield using the nickel tungsten catalyst was high for the relatively short residence time of the test.

Period 2 was run to determine the effect of steam addition on a simulated unshifted gasifier effluent. In that period, a steam to dry gas ratio of 0.75 was used at a reaction temperature of 805 to 830 F. Products from this test period indicated that possibly a little reaction was occurring but that the steam had essentially poisoned the reaction surface.

BSM Test 70: BSM Test 70 was conducted using the same charge of catalyst used in Test 69. The purpose of Test 70 was to duplicate the results of Test 69 with the additional feature of being able to measure the water feed rate. The same feed gases were used in Periods 1 and 2 as in Test 69.

Results for Test 70: Material balance data are given in Table 124 while overall results are reported in Table 125.

In Period 1, the mean reaction temperature was somewhat lower than in Test 69. The feed space velocity was slightly higher. Conversion was slightly lower (71 percent as opposed to 74 in Test 69) but agreed relatively well.

In Period 2, a steam to dry gas ratio of 0.95 was used with the simulated unshifted gas. Conversion of carbon monoxide to hydrocarbon, as in Period 2 of Test 69, was questionable.

Tests 69 and 70 indicate that the nickel-tungsten catalyst favors the formation of methane as there was no evidence of appreciable quantities of higher hydrocarbons in the test sample analyses.

BSM Test 71: BSM Test 71 was conducted with the same 100-gram charge of Lot 2905 catalyst used in Test 69. In Test 71, the feed gas simulating Scheme B conditions, as shown for Test 69, was fed to the reactor along with steam in a 0.15/1 ratio.

Results for Test 71: Material balance data for Test 71 and summary data are given in Tables 126 and 127. At the steam to gas ratio of 0.15/1, substantial conversion of carbon monoxide took place. The useful conversion amounted to 64 percent. No change in catalyst activity was apparent. The indication from this result is that combined shift and methanation under Scheme B conditions is possible with current commercially available catalysts.

BSM Test 72: BSM Test 72 was conducted using the same 100-gram lot of catalyst charged in Test 69. After establishing activity with the standard synthesis gas (Scheme A conditions), the following gas, simulating Scheme B conditions with no shift conversion, was fed to the reactor. In Periods 1 and 2, steam was added along with the dry gas; in Period 3, the steam flow was discontinued.

TABLE 124. DATA AND RESULTS FOR BSM TEST 70, PERIOD 1, CONDUCTED AT 930 F AND 1001 PSIG NICKEL-TUNGSTEN CATALYST NO. 2905

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	20.32	4.27	5.14	5.01
Carbon Dioxide	0.07	0.01	4.92	2.15
Hydrogen	62.12	13.05	33.49	5.19
Nitrogen	2.22	0.47	3.88	0.02
Methane	15.24	3.20	52.48	0.04
Ethane	0.03	0.01	0.09	0.00
Propane	0.00	0.00	0.00	0.00
Water	0.00	0.00	-	2.51
Total	100.00	21.01	100.00	14.92
Total Moles Carbon		7.50		7.50
Total Moles Hydrogen		38.93		38.17
Total Moles Oxygen		4.30		4.30

B. Conversion Data

	Raw Data g moles/hr
CO → Products	3.65
H_2 → Products	9.04
Reactants → H_2O	2.51
CO → CH_4	3.07
CO → C_2H_6	0.01
CO → C_3H_8	0.00
CO → CO_2	0.57
α, Percent	71.1
[illegible], Percent	0.3
K_{shift} (experimental)	1.53
K_{shift} (theoretical at outlet)	-

TABLE 124. DATA AND RESULTS FOR BSM TEST 70, PERIOD 2,
CONDUCTED AT 830 F AND 1011 PSIG
NICKEL-TUNGSTEN CATALYST NO. 2905
(Continued)

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	40.35	5.01	37.44	4.64
Carbon Dioxide	17.29	2.15	19.52	2.42
Hydrogen	41.87	5.19	41.90	5.20
Nitrogen	0.17	0.02	0.11	0.01
Methane	0.32	0.04	1.03	0.13
Ethane	0.00	0.00	0.00	0.00
Propane	0.00	0.00	0.00	0.00
Water	0.00	11.91	-	11.74
Total	100.00	24.22	100.00	24.14
Total Moles Carbon		7.19		7.19
Total Moles Hydrogen		34.37		34.38
Total Moles Oxygen		21.21		21.22

B. Conversion Data

	Raw Data g moles/hr
CO → Products	0.36
H_2 → Products	-0.001
Reactants → H_2O	11.74
CO → CH_4	0.09
CO → C_2H_6	0.00
CO → C_3H_8	0.00
CO → CO_2	0.28
α, Percent	3.5
β, Percent	0.0
K_{shift} (experimental)	-14.46
K_{shift} (theoretical at outlet)	-

TABLE 125. SUMMARY OF RESULTS FOR BSM TEST 70. CATALYST NO. 2905

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	930	1001	4453	1.57	1.08	71.1	0.3	1.53	24.8
2	830	1011	2631	1.68	1.68	3.5	0.0	0.23	19.9

1 Standard volumes/volume catalyst/hr at inlet conditions

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

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

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

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

TABLE 126. DATA AND RESULTS FOR BSM TEST 71, PERIOD 1, CONDUCTED AT 1023 F AND 1013 PSIG NICKEL-TUNGSTEN CATALYST NO. 2905

A. Material Balance

Component	Feed mole percent	Feed g moles/hr	Product mole percent	Product g moles/hr
Carbon Monoxide	38.80	7.41	22.14	3.69
Carbon Dioxide	18.05	3.22	40.17	5.01
Hydrogen	42.22	9.22	18.07	3.08
Nitrogen	0.34	0.14	0.46	0.10
Methane	0.59	0.32	19.14	2.24
Ethane	0.00	0.00	0.02	0.00
Propane	0.00	0.00	0.00	0.00
Water	0.00	3.67	0.00	4.39
Total	100.00	23.98	100.00	18.61
Total Moles Carbon		10.96		10.96
Total Moles Hydrogen		24.60		24.60
Total Moles Oxygen		18.56		18.75

B. Conversion Data

	Raw Data g moles/hr
CO → Products	4.61
H_2 → Products	5.86
Reactants → H_2O	-
CO → CH_4	2.56
CO → C_2H_6	0.01
CO → C_3H_8	0.00
CO → CO_2	2.04
α, Percent	63.8
β, Percent	0.2
K_{shift} (experimental)	0.96
K_{shift} (theoretical at outlet)	3.43

TABLE 127. SUMMARY OF RESULTS FOR BSM TEST 71. CATALYST NO. 2905

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	1023	1013	4993	1.87	1.46	63.8	0.2	0.96	19.8

1 Standard volumes/volume catalyst/hr at inlet conditions

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

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

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

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

Component	Volume, Percent
Carbon Monoxide	36.98
Carbon Dioxide	16.08
Hydrogen	45.45
Nitrogen	0.55
Methane	0.94

Results for Test 72. Composition data for Test 72 are given in Table 128 and summary data in Table 129.

TABLE 128. COMPOSITION DATA FOR BSM TEST 72, PERIODS 1, 2, AND 3

Conducted at 990 F and 1015 psig
Nickel-tungsten Catalyst No. 2905

Component	Volume, Percent, Dry Basis		
	Period 1	Period 2	Period 3
Feed			
Steam	7.0	7.0	0.0
Product			
Carbon Monoxide	22.96	20.89	21.07
Carbon Dioxide	40.62	43.39	45.01
Hydrogen	14.26	12.22	8.14
Nitrogen	0.57	0.70	0.70
Methane	21.57	22.77	25.03
Ethane	0.02	0.03	0.05

Based on these product compositions, reasonable material balances could not be achieved. The catalyst showed a substantial weight gain, which can be attributed to carbon deposition. This is a result of the very low steam concentration in the feed gas. The product composition does indicate that substantial methane was being formed and that shift conversion was proceeding well. Table 129 shows that approximate yields of 60 to 70 percent were achieved. This catalyst shows potential merit for combined shift and methanation if, for example, it were promoted with an alkalai for suppression of carbon deposition.

BSM Test 73: BSM Test 73 was conducted to determine the effect of sulfur on the 2905 catalyst. The test simulated Scheme C conditions. The feed gas contained 0.5 percent hydrogen sulfide, a 1/1 hydrogen to carbon monoxide ratio, and a water feed rate corresponding to a steam to gas ratio of 0.1/1. No activity of the catalyst was apparent, indicating sulfur poisoning had occurred.

BSM Tests 74, 75, and 76. Data for these tests will be reported next month.

TABLE 129. SUMMARY OF RESULTS FOR BSM TEST 72. CATALYST NO. 2905

Period	Temp, F	Pressure, psig	Space Velocity[1]	U/U_{mf} Inlet	U/U_{mf} Outlet	α[2,3]
1	985	1017	5100	1.64	1.42	61.9
2	988	1015	5050	1.62	1.39	64
3	1030	1012	5210	1.63	1.30	68

[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] Approximate values due to poor material balance results

(2) Life Test Data: No new data are available from the life test unit. The multitube reactor system was shut down and lined with copper to reduce the catalytic activity of the reactor wall. Further results will be reported next month.

(a) Catalyst Vendors: BCR has negotiated a secrecy agreement with the Harshaw Chemical Company pertaining to methanation catalysts. A meeting was held between BCR and Harshaw in Cleveland on June 1, 1972, to transfer information pertaining to the methanation project.

b. PEDU Studies: Progress continued to be made on the methanation PEDU during June in all areas.

(1) Engineering: During the month, a large number of PEDU drawings and specifications was received from Koppers.

(a) Vessels: Engineering on vessels has been completed. No new vessel specifications were received in June.

(b) Buildings: Drawings 2415-4A700 and 701 detailing the alterations to Building 3 were reviewed and approved.

(c) Piping and General Arrangement: The following list indicates the new P and A material received and processed during June:

Drawing	Title	Status*
2415-2A730	High Pressure	AN
2415-2A731	Stall Equipment	
2415-2A732	Details	
2415-2A734	Vent Gas and H_2S Removal Flow Diagram	A
2415-2A737	H_2S Removal Tower Details and Bill of Material	AN
2415-2A740	Boiler Room Details and Bill of Material	AN
2415-2A741	Yard Rack Piping Details and Bill of Material	R
2415-2A742	Gas Storage Area Details and Bill of Material	R

*A Approved
AN Approved as Noted
R Under Review

(d) Electrical: The electrical wiring specification, schematic and connection diagram 2415-6A703 was reviewed and approved.

(e) Instrumentation: The instrumentation portion of the engineering has been essentially completed. The following items were received and processed.

DRAWING	TITLE	STATUS*
I. New Instruments		
2415-9F300	Infrared analyzers	A
2415-9F302	Analyzers, CO alarms	A
2415-9F304-R1	Flow elements	A
2415-9F307	Flow totalizers	R
2415-9F308-R1	Local pressure indicators	A
2415-9F319	Miniature recorders	A
2415-9F32A	Panel mounted indicators	A
2415-9F329	Relief valves	A
2415-9F330	Solenoid valves	A
2415-9F332	Timers	A
2415-9F336	Pneumatic temperature transmitters	A
2415-9F337	Pressure switches	A
2415-9A338	Electric panel indicators	A
2415-9A339	Current controllers	A
2415-9F341	Reversing relay	A
2415-9F342	Pneumatic switch	A
2415-9F343	Differential pressure indicators	A
II. Instrument Alterations		
2415-9F603-R1	Temperature recorders	A
2415-9F608	Panel indicators	A
2415-9F609	Electronic recorder controller	A
2415-9F612	Analyzer recorder	A
2415-9F613	Clock	A

*A Approved
R Under Review

In addition, the revised panel drawings, 2415-9f701 and 702, and the instrument connection diagrams, 703 through 710, are under review.

(2) Procurement: Table 130 indicates the status of procurement of major items of PEDU equipment. Certified drawings have been received and reviewed for items MK-102, MK-305, MX-500, MX-720, MX-770 (plot plan only), MY-700 (plot plan only), ME-605, and MV-307. Little information has been received from Gas Atmospheres pertaining to the design of reformer unit. Delivery of the methanator feed gas compressor, MK-305, may be delayed because of severe flooding at the Ingersoll Rand manufacturing plant at Painted Post, New York. No word has been received regarding when the production facility will reopen.

(3) Permits: Approval from the Monroeville commissioners has been received for the erection of the reformer enclosure. No major progress has been achieved in obtaining the air pollution permit.

(4) Transformer: Certified drawings for the new 750KVA transformer and pole line have been approved as noted and transferred to Duquesne Light. Tentative delivery of the facility is set for October, 1972.

(5) PEDU Problem Areas

(a) Feed Gas Heater: Koppers is currently designing this unit. No manufacturer has been found who will produce the required duplex tubing for the heater.

(b) Reformer: Gas Atmospheres has not supplied sufficient information for Koppers to complete structural design.

(c) Feed Gas Compressor: A potential delivery problem exists due to a shutdown of the Ingersoll Rand manufacturing facility.

(6) Construction Work: Excavation has been completed, and the site area is currently being fenced in. Steelbilt, the local Armco Building representative, is currently being contacted with respect to Building 3 modifications. Concrete contractors are being contacted to obtain quotes on foundation work.

(a) Cold Model: No model results are available for reporting this month.

c. Future Work: Work planned for July is as follows:

At the bench-scale level, fluidized reactor tests will be continued. Testing of four new catalysts will begin.

PEDU work planned involves further detail engineering and procurement. Some construction will begin.

Cold model work will be continued as time permits.

2. Analytical Services (J. E. Noll): During the past month, 36 samples were analyzed by gas chromatography. The types of analyses requested were as follows:

TABLE 130. SUMMARY OF STATUS OF PEDU EQUIPMENT ITEMS

Index	Equipment Item	Status[1]	Estimated Delivery Date
ME-405	Feed Gas Preheater	D	--
ME-410	Filter Blowback Heater	P	9/14/72
ME-605	Cooler Condenser	P/A	10/06/72
ME-700	Water Cooler	P/A	6/30/72
MF-420	Catalyst Filters	Q	--
MK-102	Natural Gas Compressor	P/A	9/22/72
MK-305	Methanator Feed Gas Compressor	P	--
MK-770	Air Compressor	Q	--
MP-710	Cooling Water Pump	P/A	7/07/72
MR-420	Fluid Bed Methanator	P/A	12/04/72
MV-104	Reformer Feed Gas Receiver	P/A	6/11/72
MV-260	H_2S Flash Tank	P/A	7/17/72
MV-307	Oil Separator	P/A	7/12/72
MV-310	Methanator Feed Gas Receiver	P/A	7/28/72
MV-610	Water Metering Tank	P/A	6/01/72
MV-615	Water Letdown Tank	P	7/22/72
MV-620	Demister	P	8/25/72
MV-710	Cooling Water Tank	P/A	6/02/72
MV-763 A & B	H_2S Removal Towers	P	7/21/72
MV-764	Drip Pot	D	--
MV-766	Water Break Tank	P	7/28/72
MX-100	Reformer	P	11/08/72
MX-500	Therminol System	P/A	8/23/72
MX-720	Steam Boiler	P/A	9/20/72
MX-750	Demineralizer	P	--
MX-770	Thermal Oxidizer	P	10/20/72
MY-700	Reformer Enclosure	P	--

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

Type of Analysis Requested	Number of Samples Analyzed
Gas Chromatography	
Methanation Unit	
Gas Samples	36
Total	36

3. Gas Chromatographic Procedures (J. E. Noll): Neon is being investigated as a carrier gas for the analysis of the gas stream in the PEDU methanation unit. Since neon has a thermal conductivity value less than that of helium, the usual carrier gas, there is a greater difference between the thermal conductivity of hydrogen and neon than between hydrogen and helium. Hence, neon would yield a more favorable response factor for hydrogen than does helium and result in more reliable analytical data. However, since the thermal conductivity value for neon is close to that of methane, it may not be possible to obtain reliable analytical data for this gas.

Thermal conductivity data for several gases at the temperatures that can be used in gas chromatographic analysis of the gas stream are shown in Figure 142. The data for these curves are a compilation of data from the Chemical Engineers' Handbook, 3rd Ed.; Mechanical Engineers' Handbook, 5th Ed.; and calculations using the Chapman-Enskog formula.

Using helium as a carrier gas, 200 C is used for the analysis of the gases in the gas chromatograph. This temperature, however, would likely be too high with neon because the thermal conductivities of methane and neon would be very close. This would yield a very low response factor and hence poor analytical data. Table 131 shows a relative response factor, the ratio of the difference in the thermal conductivity of the gas being analyzed and the carrier gas to the carrier gas. The higher the ratio, the greater the response.

The table indicates that when neon is used as a carrier gas, there is an increase in the response factor to methane as the temperature decreases. The actual response of the gas chromatograph to a particular gas with a given carrier gas is a complex function involving flow, temperature, thermal conductivity, geometry of the detector, and current on the detector. Only experimental results will indicate if the response is sufficient to give satisfactory analytical data. Experiments are now being made to obtain these data and will be reported next month.

Future Work:

1. Gas samples will be analyzed as required.

2. The work on the use of neon as a carrier gas in the analysis of gas samples will be continued.

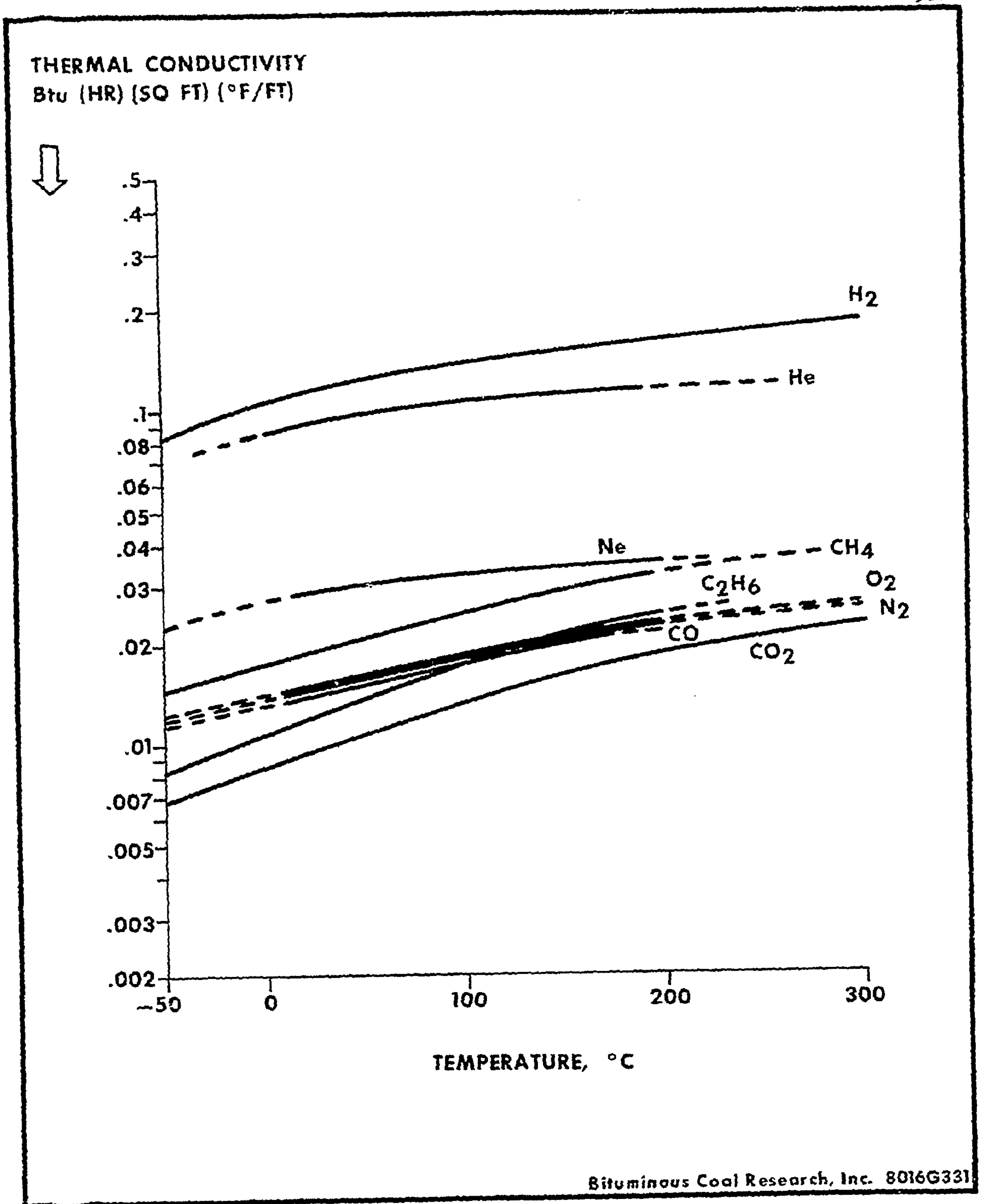


Figure 142. Thermal Conductivity of Some Fixed Gases as a Function of Temperature

TABLE 131. DIFFERENCES IN THERMAL CONDUCTIVITIES (K) OF GASES TO BE ANALYZED AND THE CARRIER GAS

Carrier Gas / Gas to be Analyzed	He at 200C		Ne at 200C		Ne at 75	
	K_g-K_{He}	$\frac{K_g-K_{He}}{K_{He}}$	K_g-K_{Ne}	$\frac{K_g-K_{Ne}}{K_{Ne}}$	K_g-K_{Ne}	$\frac{K_g-K_{Ne}}{K_{Ne}}$
H_2	+0.031	0.27	+0.1120	3.29	0.0932	3.02
N_2	-0.0922	0.80	-0.0112	0.33	0.0138	0.45
O_2	-0.0920	0.80	-0.0110	0.32	0.0136	0.44
CO	-0.0927	0.81	-0.0117	0.34	0.0142	0.46
CO_2	-0.0972	0.85	-0.0157	0.46	0.0189	0.61
CH_4	-0.0830	0.72	-0.0020	0.06	0.0075	0.24
C_2H_6	-0.0911	0.79	-0.0101	0.30	0.0154	0.50

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

During the month two more tests were made with glycerine sprayed into Stage 1 to simulate slag droplets. Most of the model tests conducted were made on Stage 2 - polystyrene, polyethylene, sugar, and cork dust were injected to simulate coal, the char product, and possible large size agglomerates. The model test program is currently being concluded.

The conclusion of this program coincides with imminent selection of a contractor for the final design and construction of the Homer City Pilot Plant. As a result of the model program, certain aspects of the Koppers design were evaluated and changes, listed in the letter of June 27, 1972 to OCR, were recommended. The contractor selected will be responsible for the final design of the pilot plant and may decide to deviate from the initial Koppers design. It is expected that such deviations may need to be evaluated with model tests and, consequently, a new model test program may be proposed.

1. Stage 1 Model Tests

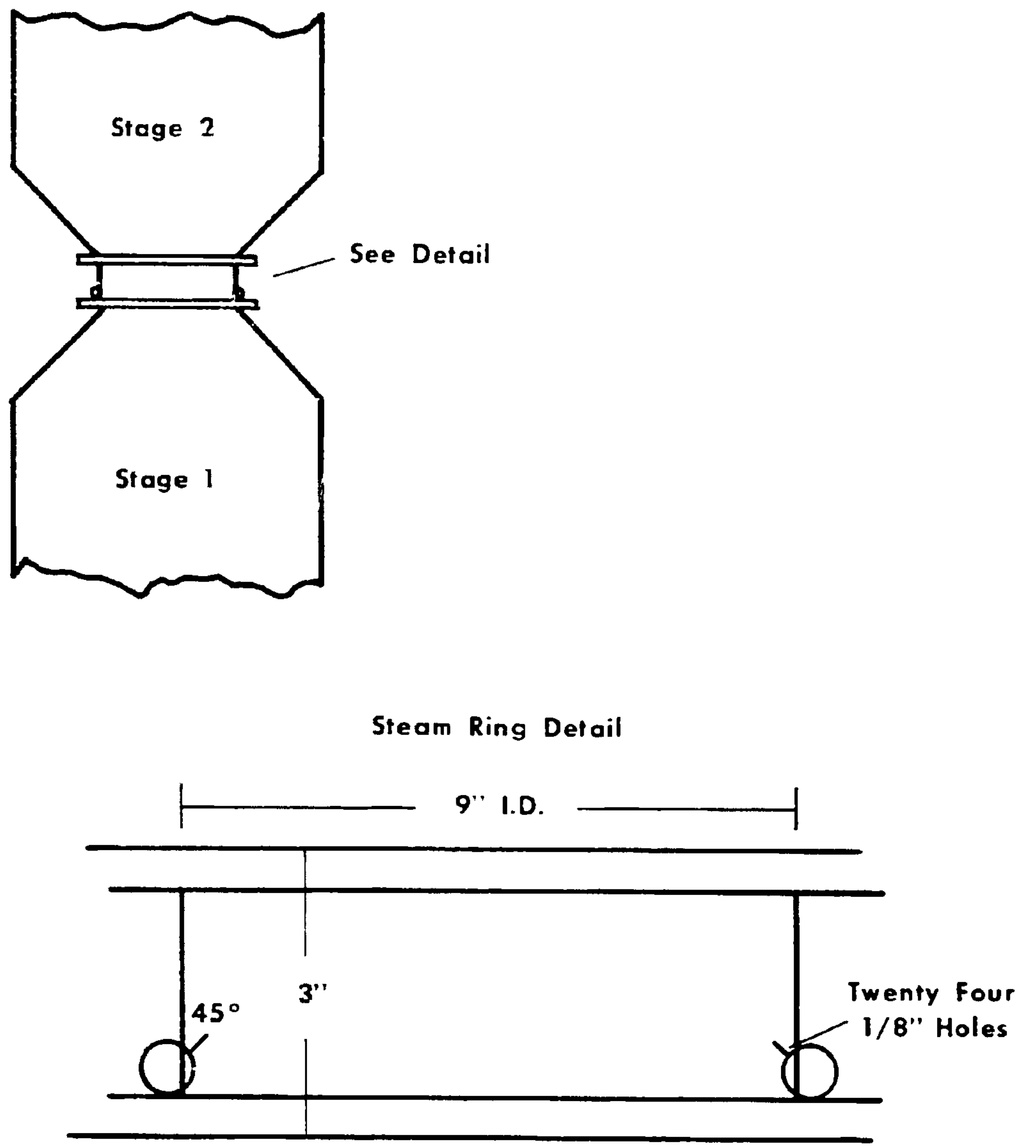
a. Review of Previous Tests: The cold model tests on Stage 1 were essentially completed in May and the results were reported in Progress Report No. 9, pages 516-524.

b. Test of Steam Ring in Throat: One of the concerns with the operation of a slagging Stage 1 is the migration and subsequent deposition of slag in Stage 2. The throat between Stages 1 and 2 is considered the most critical area since it is at the transition from the slagging to the non-slagging zone and since its opening could be seriously restricted by small amounts of slag deposits. The admission of some Stage 1 steam to the throat area was recommended as a means for minimizing possible slag problems. This steam would chill the Stage 1 gas and particulates below the ash softening temperature and would be admitted in such a way as to provide a scavenging effect at the throat.

It was decided that a ring of small steam jets located at the throat would be an effective means of quenching the gas and scavenging the critical throat area. Such a ring was modeled using the flanged assembly shown in Figure 143. The ring consists of a 9 in. ID. hoop of 1/2 in. pipe drilled to provide 24, 1/8 in. ports at 45° to the axis of the gasifier.

The flanged assembly was installed between Stage 1 and the short Stage 2, and was supplied with shop air to represent superheated steam. The test set-up was otherwise the same as in Test 17 with the vaned 45° top to Stage 1 and the plain 45° bottom with the gutter on the bottom of the short Stage 2. Tests 18 and 19 were run with air and glycerine, as in Test 17, to evaluate the effects of supplying some Stage 2 steam at the throat. Both tests were run with air rates of 600 cfm to Stage 1 and of 70 cfm to the steam ring. Glycerine was atomized at 40 gph from the Stage 1 burners.

In Test 18 a glycerine film was allowed to build up on the throat before the air was turned on the ring. In Test 19 the air ring was turned on before glycerine atomization was started. No significant differences were noted



Bituminous Coal Research, Inc. 8016G332

Figure 143. Schematic Arrangement of Simulated Steam Ring Installed in Throat Between Stages 1 and 2

with or without the additional air in Test 18. The throat did not remain completely clear for a significantly longer time in Test 19 than in Test 18. It appeared that the additional air did help to keep the throat a little clearer. However, under the conditions noted with the 45° vaned top, the small film of glycerine was not considered an indication of concern for plant operation.

c. Conclusions from Test with Steam Ring: The following conclusions were drawn from the tests with the steam ring:

(1) Tests with glycerine indicated no significant need for a steam scavenging system to keep the throat clear.

(2) Observation of the small glycerine film deposited during two tests indicated that steam scavenging might help minimize slag problems if they did occur.

(3) Installation of a steam ring at the throat of the pilot plant gasifier appears to have considerable merit because of its ability to quench the gas at a critical point and to allow superheated steam to be fed with a minimum of cooling.

2. Stage 2 Model Tests: The test program for Stage 2 was also divided in three phases - Phase IV, testing Stage 2 with gas alone; Phase V, testing with gas and simulated coal; and Phase VI, testing with gas and simulated slag and coal.

The test of a single protctype Stage 1 burner (Phase I) produced data that were also applicable to the similar burners proposed for Stage 2. From the test of the single Stage 1 burner it was concluded that the downstream mixing required would be obtained by burner action alone, hence, the Stage 1 gas mixing study (Phase II multiple burner test with gas only) was not conducted. Less intensive mixing is required in Stage 2 and it was assumed that the necessary gas mixing would be obtained by the action of the two Stage 2 burners alone. The study of gas mixing in Stage 2 (Phase IV) was therefore not conducted.

The tests with gas and simulated coal (Phase V) were essentially concluded in June. Operation with coal and the probable char to be produced was studied by injecting shreds of polystyrene, polyethylene beads, granulated sugar, and cork dust into the air stream provided in the Stage 2 model.

The tests showed conclusively that opposed burners located near the bottom of a 60° conical inlet to Stage 2 produced rapid dispersion of "coal" downstream from the point of jet impact. Figures 144, 145, and 146 show stop action photographs taken at short intervals after slugs of cork dust had been injected into Stage 2 of the model. The pictures show successive stages in the dispersion of a consolidated stream of "coal" by an opposing stream of air.

The Stage 2 work is essentially complete. The data will be reported more fully in the July progress report with a summary of the Stage 1 studies.

8016P277

Figure 144. Puff of Cork Dust at Instant of Initial Impact with Opposing Air Stream

8016P278

Figure 145. Puff of Cork Dust after Initial Impact Showing Dispersed Dust Cloud Above Point of Impact

8016P279

Figure 146. Near End of Puff View of Jet Being Obscured by Small Fraction of Cork Dust

3. Future Work: This program has essentially been completed. The findings will be consolidated and a report prepared to include the application of the Phase I tests to the Stage 2 burners, the summarization of the three-burner Stage 1 tests including a discussion of the criteria for modeling, and the summarization of the two-burner Stage 2 tests. This work should be completed in July.

4. Other Model Tests: The pilot plant program is moving into the stage where the contractor and his chosen subcontractors will be making final drawings of the pilot plant. In this stage, departures from the initial Koppers design will probably require model tests for their evaluation.

The model tests so are conducted were based on operation at a 5 ton/hr rating with a relatively low ash content coal. It will be appropriate, if time is available, to repeat certain previous tests at different air rates. There are also problems in the operation of Stage 1, such as the duration of entrainment of particles of different sizes and densities, the distribution of particles that adhere to the surface, the behavior of slag at the tap hole, and the flow of slag around the burner ports. These are all problems that can be more realistically appreciated with the aid of a model program. It is expected that a program will be recommended in the near future to include modeling required by the contractor and continued modeling of Stage 1.

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

1. Automated Data Acquisition: The software executive system for real time data acquisition has been debugged except for the DECtape handlers and the mathematics routines. This work should be completed during July, 1972.

The programs required to log, process, and store data from the methanation unit have been completely written. These routines will be entered into the computer and debugging will be initiated during July.

2. Commercial Gasifier Modeling: Subroutine GASIFY was utilized to generate 60 gasifier simulation runs on a Pittsburgh seam coal. The purpose of this work was to estimate maximum char withdrawal rates at constant methane yield, and constant temperature and pressure. These runs were made at OCR's request. Results were transmitted to OCR by letter on June 15, 1972.

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

a. Completion of debugging work on the software executive system.

b. Entry of data logging and data processing routines into the computer and initiation of debugging.

c. Acquisition of data from the methanation unit.

d. Generation of simulation runs with subroutine GASIFY as requested and authorized.

D. Engineering Design and Evaluation

1. BI-GAS Process: Subroutine GASIFY was used to generate 60 gasifier simulation runs on a Pittsburgh seam coal. The main purpose was to estimate maximum feasible char withdrawal rates. Results were transmitted by letter to OCR on June 15, 1972.

2. OCR/BCR Gasification--Power Generation: No inquiries were received this month concerning application of an air-blown version of the BI-GAS gasifier for the production of low-Btu fuel gas.

E. Multipurpose Research Pilot Plant Facility (MPRF)

1. Pilot Plant Bid Evaluation: Following the meetings with selected bidders in the bidders' facilities, the evaluation of proposals for a contractor to construct the pilot plant was completed. A recommendation was submitted to OCR on June 5, 1972.

BCR's recommendation of a company to perform project management services during construction and operation of the pilot plant was approved by OCR on May 16, 1972.

The groundbreaking ceremony scheduled for June 23, 1972 at the Homer City site was cancelled because of inclement weather. The ceremony has been rescheduled for July 27, 1972.

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

3. Permits - Industrial Waste Pollution Control Permit - Homer City, Pa.: A meeting was held on Tuesday, June 13, 1972, at the Pennsylvania Department of Environmental Resources, Regional Office IV, Pittsburgh, Pa., to discuss the procedure in filing of an application for an industrial waste permit for the Homer City Pilot Plant.

As a result of this meeting, BCR will submit to the Department of Environmental Resources of Pennsylvania, Section K - "Effluent Treatment" of Koppers' "Bid Package" for their exploratory review and comments at this point in time inasmuch as changes are anticipated in the final design of the effluent treatment plant for the Homer City Pilot Plant.

F. Literature Search (V. E. Gleason)

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

G. Outside Engineering and Services

1. Koppers Company, Inc.: Koppers continues to provide engineering assistance as required and as reported in their Progress Report No. 35 in Appendix B.

2. Brigham Young University: The project entitled "Study of High Rate, High Temperature Pyrolysis of Coal" with joint funding by Brigham Young University and BCR is now in its fifteenth month. Figure 147, Monthly Progress Chart, Expenditures, shows the current budget status. The letter report of progress made during June is as follows:

A total of thirty additional test runs with the 2 x 4 5/8 inch reactor were completed during this period. Nine of these runs were made with hydrogen as the carrying gas for the coal, extending the run conditions from the previous period and also increasing the duration of the runs. Fifteen tests were made with nitrogen as the coal-carrying gas to observe the effect of hydrogen partial pressure on the product yield. The remainder of the tests were made with only combustion gases and carrier gases fed to the reactor in order to measure the product composition without coal being present in the reactor.

The data from these runs as well as the data from the previous period were analyzed employing a computer data reduction program. The results of this analysis were used to prepare a series of plots illustrating the effects of various operating parameters. Revised copies of the initial plots will be presented in the next report. The conclusions drawn from this analysis are summarized as follows:

1. The operating parameter most strongly effecting the overall gasification of the coal is the combustion oxygen fed to the reactor per pound of coal.

2. The conversion of carbon in the coal to carbon monoxide increases linearly with the oxygen/coal ratio in the range of 0.3 to 1.6. The maximum observed carbon conversion to CO is 55 percent at an oxygen/coal ratio of 1.6.

3. The conversion of carbon to the hydrocarbon gases methane, ethylene, and acetylene, reaches a maximum of approximately 15 percent at an oxygen/coal ratio of approximately 0.67.

4. The conversion of carbon to methane is relatively insensitive to the oxygen/coal ratio over the range tested to date; however, it appears to increase with increasing residence time in the reactor. The maximum conversion observed is 8.7 percent.

5. The conversion of carbon to ethylene drops off sharply with increasing oxygen/coal ratio, or alternatively, with increasing temperature of the reactor. The maximum conversion observed is six percent at an oxygen/coal ratio of 0.52.

6. The conversion of carbon to acetylene increases with increasing oxygen/coal ratios between 0.3 and 1.0. The maximum conversion observed is 6.7 percent at an oxygen/coal ratio of 0.67.

7. Replacing hydrogen as the coal-carrying gas with nitrogen has only a small effect on the gasification product distribution except for the yield of carbon dioxide. The conversion of carbon to CO_2 with nitrogen as the carrier is roughly twice what it is with hydrogen as the carrier. However, even with

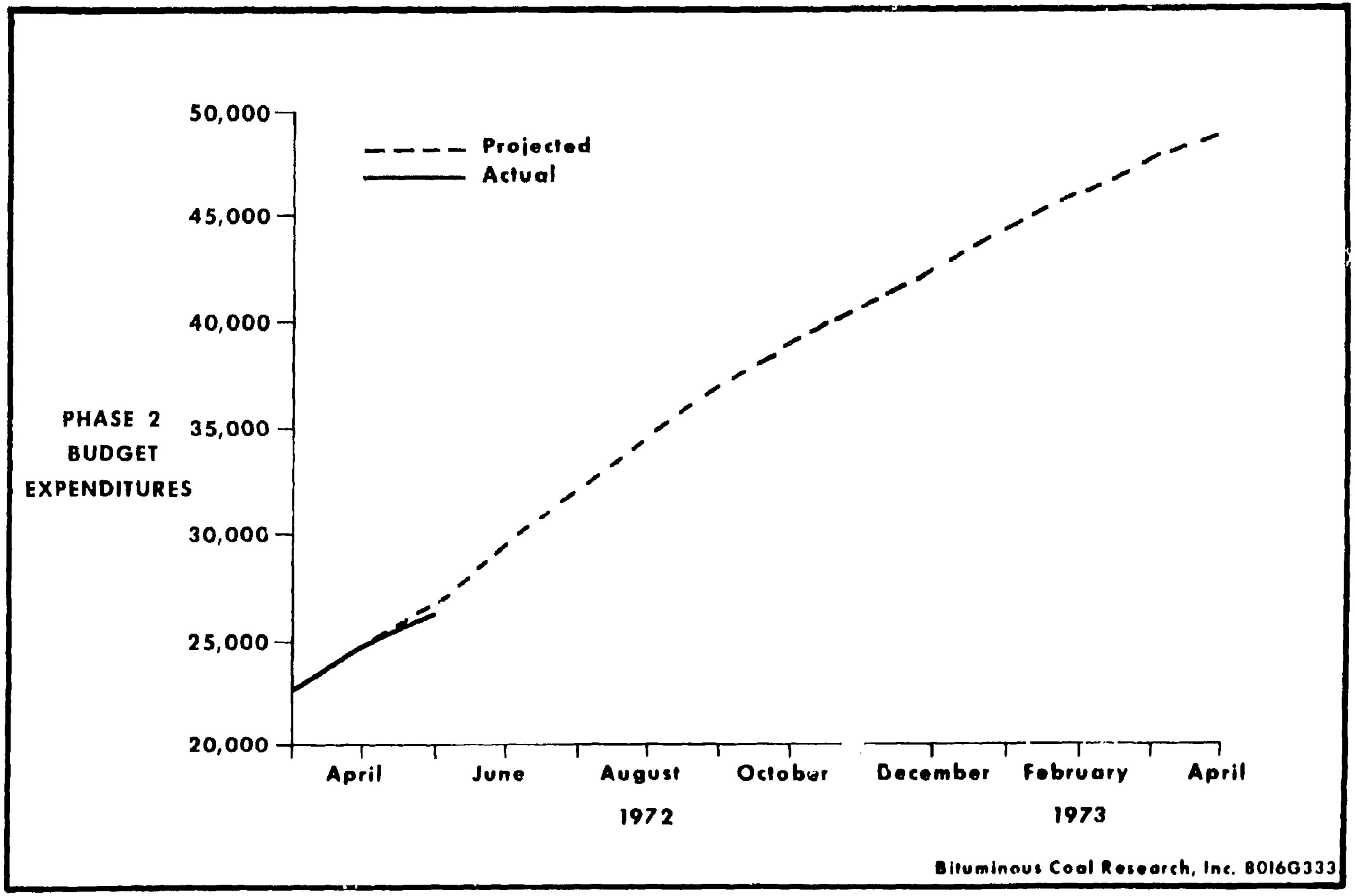


Figure 147. Monthly Progress Chart, Expenditures, Brigham Young University

the use of nitrogen carrier, the ratio of carbon dioxide yield to carbon monoxide yield is very small compared with other gasification processes.

8. A substantial portion of the hydrogen/oxygen combustion gas is decomposed to hydrogen and carbon monoxide through reaction with the coal. The decomposition reaches a maximum of approximately 46 percent with hydrogen carrier and approximately 60 percent with nitrogen carrier. The maximum decomposition occurs at an oxygen/coal ratio of 0.85.

9. The yield of hydrocarbon gases and the yield of carbon dioxide relative to carbon monoxide depends strongly on the stoichiometry of the combustion gas. Combustion gases lean in hydrogen fuel cause the hydrocarbon gas yield to be reduced and the ratio of CO_2 to CO to be increased from the yields with stoichiometric combustion gases.

10. The volume of gas produced per pound of coal increases uniformly with the oxygen/coal ratio. At the ratio corresponding to maximum hydrocarbon gas yield the volume produced is 24 SCF per pound of coal.

11. The carrier-free heating value of the product gas decreases uniformly with increasing oxygen/coal ratio. At the ratio corresponding to maximum hydrocarbon gas yield, the heating value is in the range of 370 to 420 BTU/SCF.

12. The yield data are independent of run time for run times ranging from 3 to 22 minutes.

Further analysis will be made of these data to determine if specific pyrolysis rate constant information can be derived from it. Further testing is planned in which methane will be substituted for the hydrogen as the combustion gas fuel. Further testing will also be carried out to extend the data showing the effects of reactor residence time.

H. Other

1. Prime Contract Matters: A list of all nonexpendable equipment on the inventory as of the expiration date of Contract No. 14-01-CCC1-324 is being developed. This list will indicate what equipment should be transferred to Contract No. 14-32-CCC1-1207 and what should be declared as scrap.

2. FPC National Gas Survey - Economics of Manufacturing SNG from Coal: In determining the onsite investment costs used for calculating the 20-year average gas costs for the FPC National Gas Survey, Synthetic Gas-Coal Task Force, Air Products and Chemicals, Inc., did not include the costs to recover sulfur from flue gases. Therefore, Tables 118, 119, and 120 presented in Progress Report No. 9, May 1972 (BCR Report L-467) will be revised accordingly and inserted into Progress Report No. 11. Likewise, the BCR report issued May 1?, 1972 entitled "Economics of Manufacturing SNG by BCR/OCR BI-GAS Coal Gasification Process Using Western Kentucky No. 11 Bituminous Coal" will be revised and re-issued to OCR for review.

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

a. OCR-666 and OCR-1078: A U.S. patent application entitled "Gasification of Carbonaceous Solids," containing nine claims, was filed together with Assignment on September 22, 1971, and given Serial No. 182,652.

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

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

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

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

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

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

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

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

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

f. New Invention Disclosure: An Invention Disclosure (Form DI 1217) entitled "Combined Methanation - Shift Reaction Process," was submitted to OCR on June 14, 1972. Use of this process simplifies and reduces the cost of making synthetic pipeline gas, especially from coal, using the BI-GAS or other coal gasification processes.

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

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

4. Reports and Papers: As approved by OCR, R. J. Grace will present a paper entitled "BI-GAS Program Enters Pilot Plant Stage" at the forthcoming AGA Synthetic Pipeline Gas Symposium, October 30, 1972, at Chicago, Illinois. Authors of the paper will be R. J. Grace and R. L. Zahradnik. An advance copy of the paper will be submitted to OCR when available.

On June 7, 1972, J. W. Tieman gave a status report on the gasification project to the Illinois Coal Gasification Committee in Chicago, Illinois.

I. Visitors During June, 1972

June 2, 1972

Mr. Ron McGowan
Mr. John Wappler
Koppers Company, Inc.
Koppers Building
Pittsburgh, Pennsylvania 15219

June 8, 1972

Dr. C. L. Miller
Office of Coal Research
U.S. Department of the Interior
Washington, D. C. 20240

June 12, 1972

Mr. Frank Wolf
U.S. Department of the Interior
Washington, D. C. 20240

June 16, 1972

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

June 22, 1972

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

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

None

K. Requests for Information

Mr. F. W. Fitzpatrick Bralorne Resources Limited 1005 Two Bentall Centre Vancouver 1, B.C., CANADA	Mr. John Mills Manager of Engineering Synfuels Division El Paso Natural Gas Company El Paso, Texas 79978

III. WORK PLANNED FOR JULY, 1972

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

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

The cold model studies of the 5 ton/hr two-stage gasifier have been essentially completed. A report will be prepared summarizing the results of the work.

The software system for interfacing the bench-scale methanation unit with the PDP8/E computer has been 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.

Plans will be made for a groundbreaking ceremony on July 27, 1972, since the ceremony on June 23, 1972 was cancelled because of inclement weather.

A. Trips and Meetings Planned

None

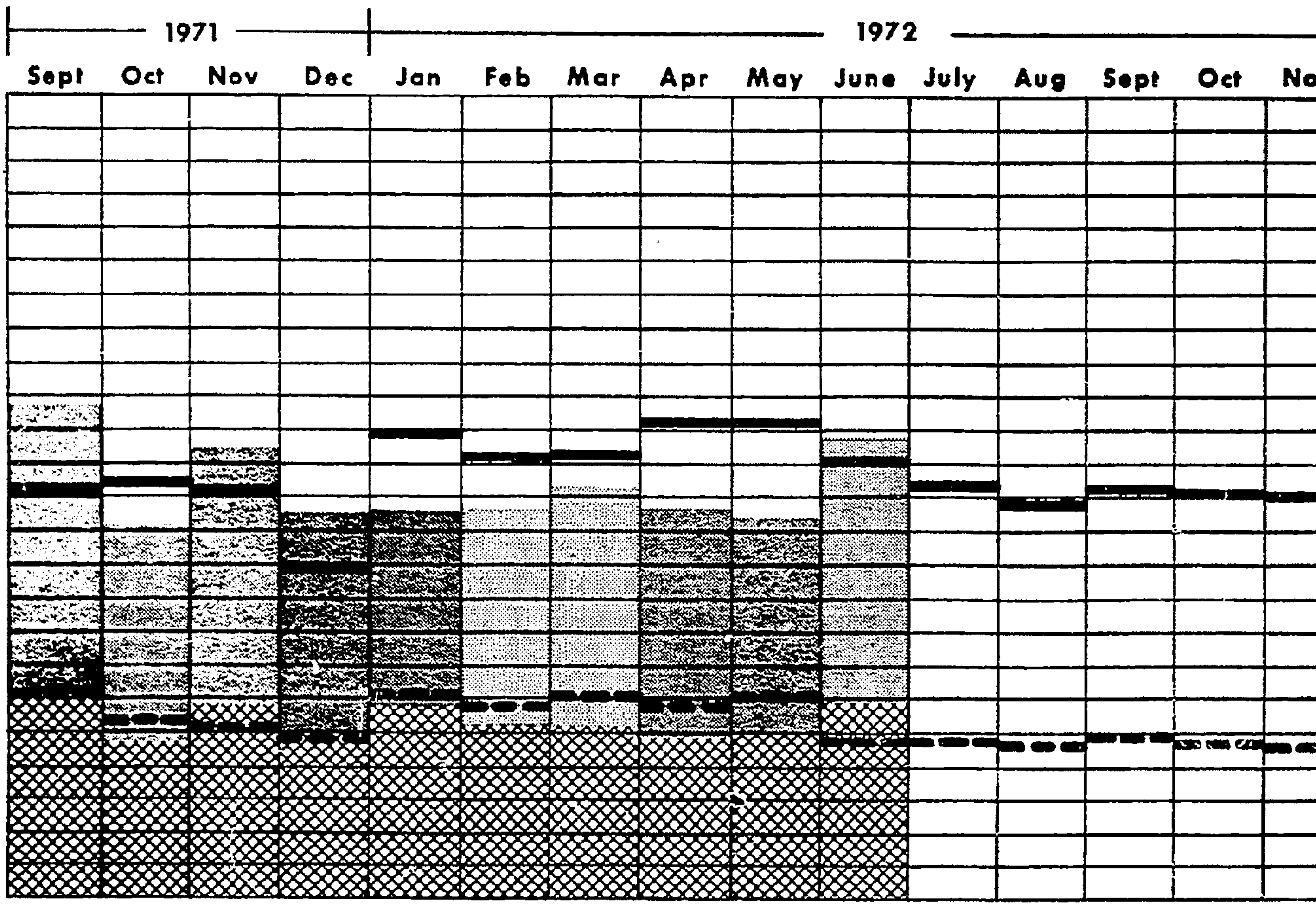
B. Papers to be Presented

October 30, 1972	AGA Synthetic Pipeline Gas Symposium Chicago, Illinois	"BI-GAS Program Enters Pilot Plant Stage" R. J. Grace R. L. Zahradnik

C. Visitors Expected

August 25, 1972	Brigham Young University Provo, Utah	R. L. Coates

MANHOURS


1971
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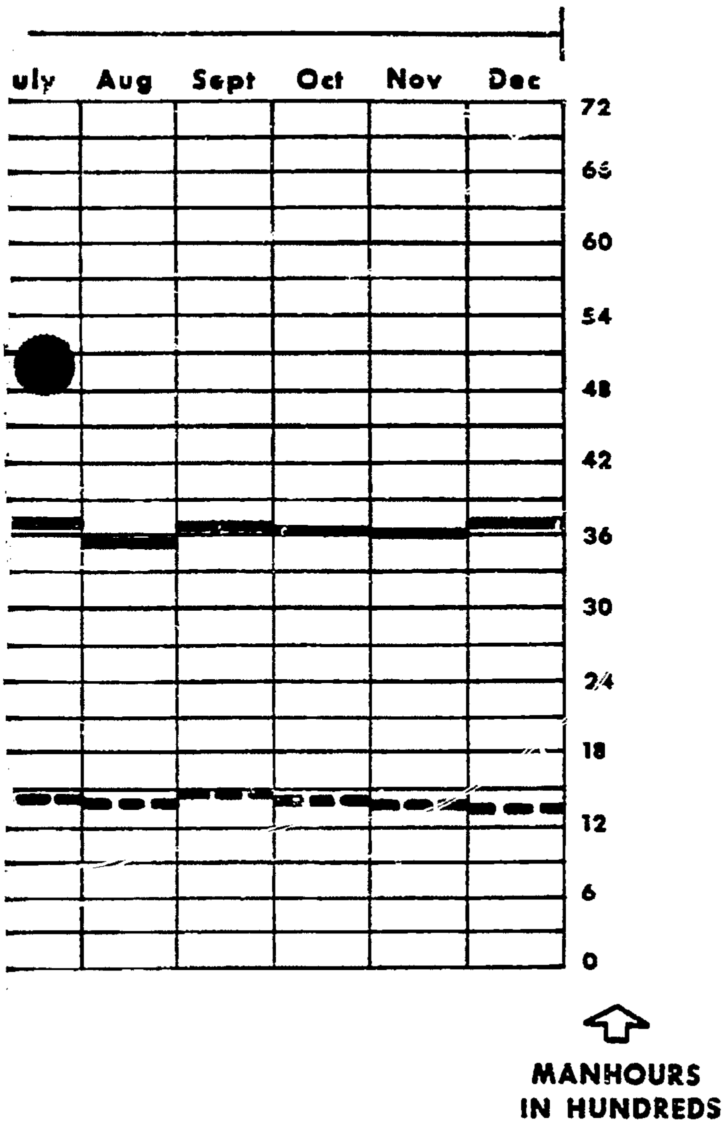
MONTHLY PROGRESS CHART
PART 1 MANHOURS

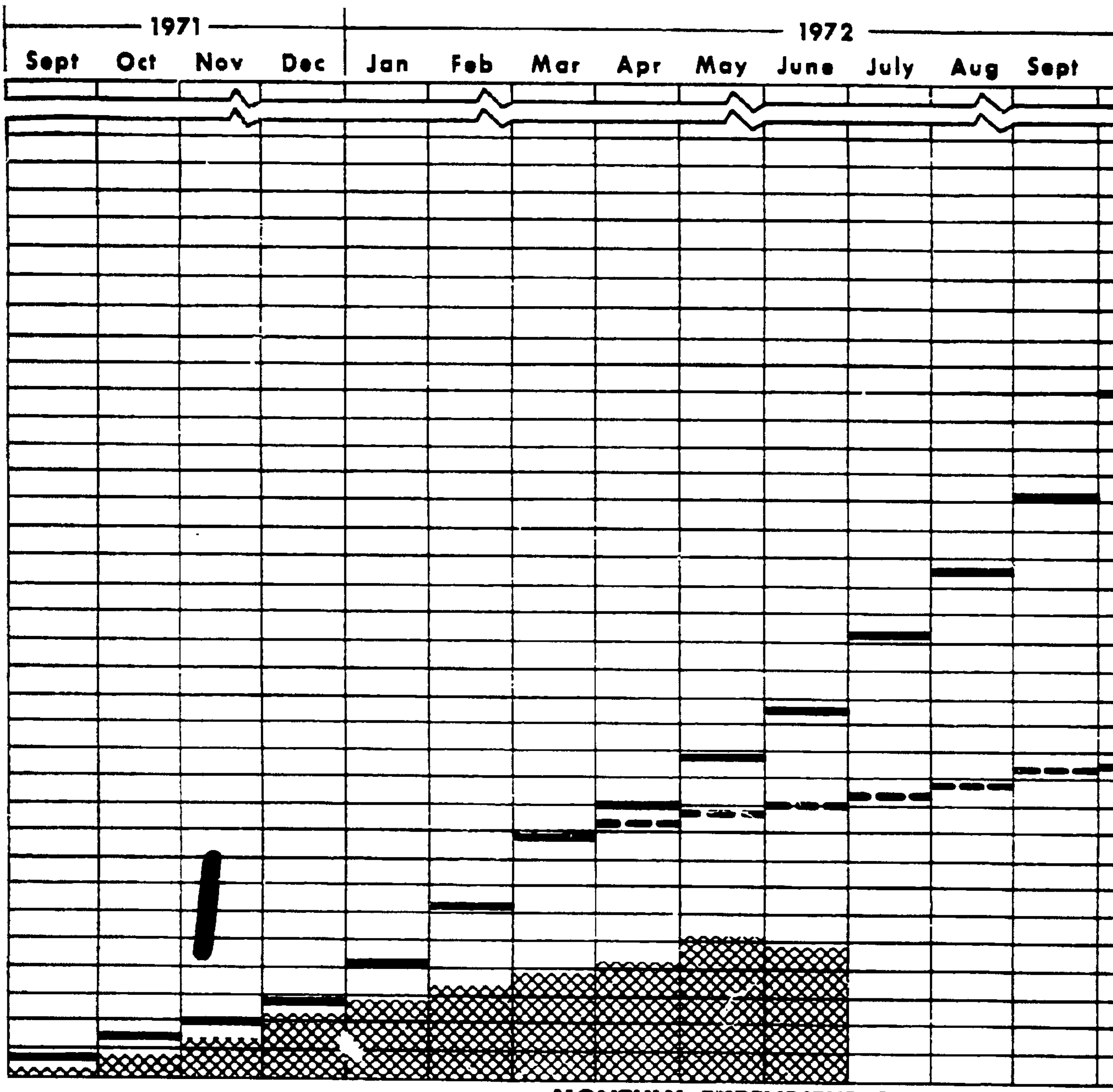
Bituminous Coal Research, Inc.
350 Hochberg Road Monroeville, Pa.

OFFICE OF COAL RESEARCH
DEPARTMENT OF THE INTERIOR

CONTRACT NO. 14-32-0001-1207



- Predicted Professional and Non-professional
- Predicted Professional
- Actual Non-professional
- Actual Professional



MONTHLY EXPENDITURES (All Costs, in Dollars)

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

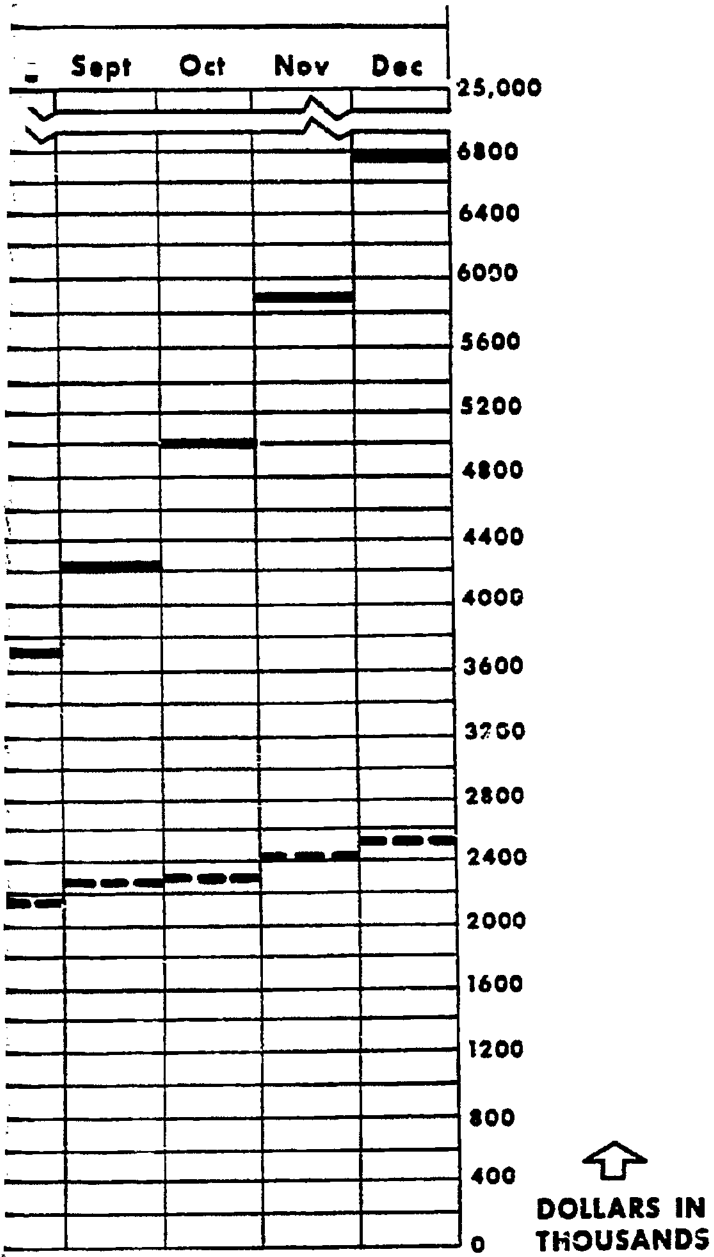
CUMULATIVE EXPENDITURES

MONTHLY PROGRESS CHART
PART 2 EXPENDITURES

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

OFFICE OF COAL RESEARCH
DEPARTMENT OF THE INTERIOR

CONTRACT NO. 14-32-0001-1207



Expenditures, Cumulative

Actual, Monroeville

Actual, Homer City

Predicted Expenditures, Cumulative

Total, Monroeville and Homer City

Monroeville

2

(... in Dollars)

	May	June	July	Aug	Sept	Oct	Nov	Dec
..3	86,238	86,240	65,813	65,813	74,746	62,273	62,273	62,275
..	73,400*	86,600						
..9	215,600	280,400	444,300	444,300	444,400	760,600	760,600	760,800
..8	301,838	366,640	510,113	510,113	519,146	822,873	822,873	823,075
5*	73,400*	86,600						

* Estimated

Appendix B

B-596.

PROGRESS REPORT #35

Bituminous Coal Research, Inc.
Coal Gasification

June 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. Messrs. M. S. Graboski, BCR, and R. C. Dorsey and R. W. Whiteacre, Koppers, met June 2, 1972 in Koppers offices to review the piping and instrumentation located in the high pressure stall area.

2. Messrs. E. K. Diehl and M. S. Graboski, BCR, and Messrs. D. M. Mitsak, R. W. Whiteacre and J. F. Farnsworth, Koppers, met June 30, 1972 at BCR's offices to discuss the status of the Methanation PEDU detail engineering. Details of this meeting are covered in Conference Report No. 226.

3. The following Fluid Bed Methanation PEDU drawings, bills of materials, and specifications were transmitted by Koppers Co., Inc. to BCR:

Drawing No.	Rev. No.	Title	Date Trans.
2415-2A744	0	Engineering & Purchasing Schedule	6/1/72
2415-9F-319 Shts. 1 and 2	0	Recorders - Miniature Pneumatic	6/2/72
2415-9F-324	0	Panel Mounted Indicators - Pneumatic	6/2/72
2415-9F-336	0	Temperature Transmitters-Pneumatic	6/2/72
2415-9F-608	0	Panel Mounted Indicators-Pneumatic -Alterations	6/2/72
2415-9F-302 Shts. 1 to 3 incl.	0	Analyzers - CO Alarms	6/2/72
2415-9F-304 Shts. 1 to 12 incl.	1	Flow Elements	6/2/72
2415-9F-307	1	Flow Totalizing Meters	6/2/72
2415-9F-337 Shts. 1 to 3 incl.	0	Pressure Switches	6/2/72
2415-9F-341	0	Reversing Relay - Pneumatic	6/2/72
2415-9F-609 Shts. 1 and 2	0	Recorder Controller - Electronic Alterations	6/2/72
2415-4A700	0	Existing Building No. 3 Alterations - Steel Design Sheet 1 of 2	6/5/72
2415-4A701	0	Existing Building No. 3 Alterations - Steel Design Sheet 2 of 2	6/5/72
2415-2A712	2	General Piping Specifications Sheet 1 of 2	6/5/72

	Drawing No.	Rev. No.	Title	Date Trans.
	2415-7A713	2	General Piping Specifications Sheet 2 of 2	6/5/72
	2415-2A740	0	Boiler Room - General Arrangement and Piping Design	6/5/72
B/M	2415-2A740 Shts. 1 to 6 incl.	0	Boiler Room - General Arrangement and Piping Design - Bill of Material	6/5/72
	2415-4F702	1	Reformer Enclosure Specifications	6/8/72
	2415-9F338	0	Panel Mounted Indicators - Electrical	6/8/72
	2415-9F339	0	Current Controllers	6/8/72
	2415-2A715	2	Utilities - Flow Diagram Sheet 1 of 3	6/8/72
	2415-2A716	3	Utilities - Flow Diagram Sheet 2 of 3	6/8/72
	2415-2A717	2	Utilities - Flow Diagram Sheet 3 of 3	6/8/72
	2415-9F332	0	Timers	6/12/72
	2415-9F342	0	Pneumatic Switch	6/12/72
	2415-9F603	1	Temperature Recorders (MV) Alterations	6/12/72
	2415-9F612	0	Analyzer Recorder Alterations	6/12/72
	2415-2A733	3	Plot Plan	6/12/72
	2415-2A741	0	Yard Rack Piping	6/12/72
B/M	2415-2A741 Shts. 1 to 14 incl.	0	Yard Rack Piping Bill of Material	6/12/72

	Drawing No.	Rev. No.	Title	Date Trans.
	2415-9F308 Shts. 1 to 4 incl.	1	Pressure Indicators-Local	6/13/72
	2415-9F329 Shts. 1 to 6 incl.	0	Relief Valves	6/13/72
	2415-9F337 Shts. 1 to 3 incl.	1	Pressure Switches	6/13/72
	2415-9F330 Shts. 1 and 2	0	Solenoid Valves	6/15/72
	2415-9F343	0	Differential Pressure Indicators	6/15/72
	2415-9F300 Shts. 1 and 2	0	Analyzers - Infrared	6/16/72
	2415-9F604 Shts. 1 to 4 incl.	1	Recorders - Miniature Pneumatic - Alterations	6/16/72
	2415-2A725	2	Reformer Feed Gas Receiver	6/22/72
	2415-9F333	1	Instrument Panels	6/22/72
	2415-2A737	1	H_2S Removal Towers General Arrangement and Piping, Steel and Concrete Design	6/22/72
B/M	2415-2A737	1	H_2S Removal Towers General Arrangement and Piping, Steel and Concrete Design - Bill of Materials	6/22/72
	2415-2A700	6	PEDU - Fluid Bed Methanator Sheet 1 of 2	6/22/72
	2415-2A740	2	Boiler Room General Arrangement and Piping Design	6/22/72

	Drawing No.	Rev. No.	Title	Date Trans.
B/M	2415-2A740 Shts. 1 to 7 incl.	2	Boiler Room General Arrangement and Piping Design - Bill of Materials	6/22/72
	Shts. 8 to 10 incl.	0	Boiler Room General Arrangement and Piping Design - Bill of Materials	6/22/72
B/M	2415-2A742	0	H_2S, CO_2 and Vent Gas from Storage Area Bill of Materials	6/22/72
	2415-9A701	1	Graphic Panel Layout	6/22/72
	2415-9A702	1	Recorder and Analyzer Panels	6/22/72
	2415-9A703	0	N. G. Comp., Reformer Unit and Add. Flows Interconnection Schematics	6/22/72
	2415-9A704	0	Meth. Flow, Feed Gas And Reactor Safety Ckt. Interconnection Schematic	6/22/72
	2415-9A705	0	Filter Blowback, Demister Level, Product Gas Press., Graphic Panel Elect. Power Distribution	6/22/72
	2415-9A706	0	Graphic Pnl. Annunciator and Air Supply Interconnection Schematic	6/22/72
	2415-9A707	0	Feed Gas Press. and Flow, Meth. Pressures, Product Gas Flow, Therminol Flows and Temp.	6/22/72
	2415-9A708	0	Meth. and Heat Windings Temps., Infrared Analyzers Recorders	6/22/72

Drawing No.	Rev. No.	Title	Date Trans.
2415-9A709	0	Heat Winding Ckt. and Record Panel Elect. Air Supply and H_2S Controls	6/22/72
2415-9A710	0	Electric Terminal and Pneumatic Bulkhead Arrangements	6/22/72
2415-9F313	1	Temperature Indicators - Local	6/27/72
2415-9F314 Shts. 1 to 3 incl.	1	Temperature Elements - Thermocouples	6/27/72
2415-9F326	0	Recorder - Large Case Elect.	6/27/72
2415-2A712	3	General Piping Specifications	6/27/72
2415-2A713	3	General Piping Specifications	6/27/72
2415-6A700	1	Electrical Wiring - Lighting	6/27/72
2415-6A701	1	Electrical Wiring - Grounding	6/27/72
2415-6A703	1	Electrical Wiring-Specifications, Schematics and Connection Diagrams Sheet 1	6/27/72
2415-6A704	0	Electrical Wiring-Specifications, Schematics and Connection Diagrams Sheet 2	6/27/72
2415-6A707	0	Electrical Wiring - 750 KVA Transformer and SWGR Pwr. and Cont. Embedded Conduits and Grd.	6/27/72

4. The following drawings were approved by BCR:

	Drawing No.	Rev. No.	Title	Approval Date
	2415-2A718	2	Fluid Bed Methanation PEDU Reformer Structure and Cooling Towers General Arrangement	6/6/72
	2415-2A734	0	Fluid Bed Methanation PEDU Vent Gas And Hydrogen Sulfide Removal Flow Diagram	6/5/72
	2415-2A737	0	Fluid Bed Methanation PEDU Hydrogen Sulfide Removal Towers - General Arrangement and Piping, Steel and Concrete Design	6/6/72
B/M	2415-2A737	0	Fluid Bed Methanation PEDU Hydrogen Sulfide Removal Towers - General Arrangement and Piping, Steel and Concrete Design - Bill of Materials	6/6/72
	2415-9F302	0	Analyzers - CO Alarms	6/12/72
	2415-9F304	1	Flow Elements	6/12/72
	2415-9F307	1	Flow Totalizing Meters	6/12/72
	2415-9F319	0	Recorders, Miniature Pneumatic	6/12/72
	2415-9F324	0	Panel mounted Indicators, pneumatic	6/12/72
	2415-9F336	0	Temperature transmitters-pneumatic	6/12/72
	2415-9F337	0	Pressure switches	6/12/72
	2415-9F341	0	Reversing relay, pneumatic	6/12/72
	2415-9F608	0	Panel mounted Indicators, pneumatic alterations	6/12/72

Drawing No.	Rev. No.	Title	Approval Date
2415-9F609	0	Recorder controller, electronic	6/12/72
2415-9F339	0	Panel Mounted Indicators	6/13/72
2415-9F338	0	Current Controllers	6/13/72
2415-9F612	0	Analyzer Recorder Alterations	6/13/72
2415-9F342	0	Pneumatic Switch	6/13/72
2415-9F332	0	Timers	6/13/72
2415-9F603	1	Temperature Recorders	6/13/72
2415-4F702	0	Reformer Enclosure	6/13/72
2415-2A715	2	Utilities Flow Diagram Sht. 1 of 3	6/13/72
2415-2A716	3	Utilities Flow Diagram Sht. 2 of 3	6/13/72
2415-2A717	2	Utilities Flow Diagram Sht. 3 of 3	6/13/72
2415-9F308	1	Pressure Indicators-Local	6/16/72
2415-9F329	0	Relief Valves	6/14/72
2415-9F337	1	Pressure Switches	6/16/72

5. During this period, at BCR's request, Koppers reviewed and approved certain portions of vendor drawings and information, which BCR received through their procurement. The following memoranda were transmitted by Koppers Company, Inc. to BCR:

Date	Letter No.	Title	Remarks
6/7/72	C-393	Electrical Wiring Classification	Recommendations for type electrical wiring for H_2S vaporizer

Date	Letter No.	Title	Remarks
6/12/72	C-396	BCR Reformer	Transmit R. W. Whiteacre's letter 6/9/72 to Gas Atmosphere Inc. requesting design information to permit Koppers to complete detail engineering of the PEDU
6/13/72	C-399	Approval Drawing	Duquesne Light Co. Transformer Pad and Location Plan Drawing. Weigand Steam Boiler (M-X720) and Gardner Denver Compressor (M-K102)
6/16/72	C-402	Instrument Information	Request for additional information from BCR for completion of loop schematics
6/16/72	C-404	Reformer Enclosure	Comments on review of Steel-Bilt Construction Corp. proposal for Reformer Enc. (M-Y700)
6/22/72	C-407	Approval Drawing	Comments on drawing of following units: Brown Fin-Tube Cooler Condenser (M-E605). Weigand Therminol Unit M-X500

Date	Letter No.	Title	Remarks
6/22/72	C-408	Reformer Approval Drawing	Reviewed Gas Atmosphere Drawing H 600-C1 Rev. C and H 600-C2

C. Fluid Bed Gasification PEDU

1. BCR's letter of June 26, 1972 relieved Koppers of the responsibility for fluidized-bed gasification engineering under Amendments No. 6 and No. 7, Subcontract No. 2, OCR Contract No. 14-32-0001-1207.

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

APPENDIX C

ADDITIONS TO ABSTRACT FILE, JUNE 1972

Fumich, G., Jr., "Overview of coal gasification programs," AIME Ann. Meet., San Francisco, Calif., 1972. 72-F-119. 6 pp. + app. 540.000 AIME

The programs for development of coal gasification processes supported by the Office of Coal Research are reviewed.

Gallo, P., "Synthane - a candidate for success," Gas World 175 (4575), 334-5 (1972). 540.000 72-3

The U.S. Bureau of Mines Synthane process is described.

Lewis, P. S., Liberatore, A. J., and McGee, J. P., "Strongly caking coal gasified in a stirred-bed producer," U.S. Bur. Mines, RI 7644 (1972). 11 pp. 540.000 Bur. Mines

The Bureau of Mines gasified strongly caking Pittsburgh bed coal over test periods lasting four days in an experimental gas producer located at Morgantown, W. Va. Mechanical stirring throughout the fuel bed was effective for keeping the fuel moving and this stirring made the operation successful. Nuclear density gages were applied as control instruments to indicate coal flow and fuel level, and to record the frequency and location of void spaces in the bed. The calorific value of the gas produced is about 140 to 165 Btu/scf. (From authors' abstract)

Schora, F. C., Jr., "Experience with design, start-up and operation of the IGT-HYGAS pilot plant," AIME Ann. Meet. San Francisco, Calif., 1972. 72-F-118. 7 pp. 540.000 AIME

The development of the HYGAS Process is reviewed and the status of the pilot plant is summarized.

Vallerschamp, R. E., "An evaluation of statistical methodology in the kinetic modeling of the methanation synthesis and water-gas shift reactions," Ph.D. Thesis, Univ. of Pa., 1969. 239 pp. Univ. Microfilms, Ann Arbor, Mich. 540.000 540.V184

Recently developed uni and multi-response statistical techniques were evaluated in an experimental kinetic modeling study. The kinetics of the two vapor-phase catalytic reactions studied were investigated using a non-porous type 316 stainless catalyst and a backmixed reactor. Data were taken in the temperature range of 880° to 1100° F and at total pressures up to 175 psig. (From author's abstract)

PATENTS

Thompson, B. H. (to The Gas Council, London, England), "Process for the production of methane containing gases," U.S. Pat. 3,625,665 (Dec. 7, 1971). 5 pp. 540.000 71-17

A process for the production of a gas containing a high proportion of methane (e.g. 90% or more) comprises: (i) introducing a preheated mixture of steam and the vapour of a predominantly paraffinic hydrocarbon feedstock having a final boiling point of not more than 300° C. (e.g. naphtha) into a first catalytic reaction zone in which the mixture reacts in the presence of a steam reforming catalyst to give a gas containing methane, hydrogen, carbon oxides and undecomposed steam; (ii) cooling the gas produced in stage (i) by adding a further quantity of at least one of the reactants; (iii) introducing the gaseous mixture formed in stage (ii) into a second catalytic reaction zone in which the constituents of the mixture react in the presence of a catalyst to increase the proportion of methane in the mixture; and (iv) removing steam and carbon dioxide from the gas leaving the second catalytic reaction zone. (From abstract of the disclosure)

Wenzel, W. and Schenck, H. (to Rheinische Braunkohleworke A. G., Cologne, Germany), "Method of gasifying water-containing coal," U.S. Pat. 3,647,379 (March 7, 1972). 5 pp. 540.000 Patent

For gasifying coal, a coal-water mixture is pumped in the form of a viscous mass into a treating chamber where the mixture is heated, causing, in immediately successive steps and in said chamber, first dehydration of the mixture by vaporizing its water content, second, gasification thereof and, third, endothermic reaction of the products precedingly obtained by the heat treatment. (Abstract of the disclosure)