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

The Stage 2 PEDU test program was officially terminated after completion of PEDU Test 58 and after September 30, 1971. (ref. Section B.7, p. 41, Progress Report No. 1).

As indicated under Future Work in last month's report, assembly and analyses of data and results for PEDU Tests 57 and 58 were not completed. They are presented and discussed in this report; along with corrected results for PEDU Test 55.

The general objective of the PEDU tests was to optimize the operating parameters to provide for maximizing methane production and thus implement the design of equipment for the 5 ton/hr pilot plant. The primary objective of each test was described under the "Data and Results" section for the specific test.

1. Corrected Results for Stage 2 Performance Criteria for PEDU Test 55 with "As-used" Lignite (1963-8016-49) at 500 psig Using Long Coal Feed Nozzle: Data for the performance criteria, being in error, were not entered in Table 11, page 37, Progress Report No. 1. Correct values along with complete summary data are given in Table 29.

2. Data and Results for PEDU Test 57 with Pittsburgh Seam Coal (2734-8016-19) at 1,000 psig Using Long Coal Feed Nozzle (1 inch below center line Stage 1): The primary purpose and significant details of PEDU Test 57 were presented in Section B-4, page 24, Progress Report No. 1 (September 1971).

Data and results for PEDU Test 57 are given in Table 30. Chromatographic and monitor analyses are given in Table 31. Data and results for coal feeding are given in Table 32, and C-14 analyses are given in Table 33.

3. Data and Results for PEDU Test 58 with Pittsburgh Seam Coal (2734-8016-19) at 1,000 psig Using Long Coal Feed Nozzle with Short Residence Time: The primary purpose and significant details of PEDU Test 58 were presented in Section B-5, page 33, Progress Report No. 1.

Data and results for PEDU Test 58 are given in Table 34. Chromatographic and monitor analyses are given in Table 35. Data and results for coal feeding are given in Table 36, and C-14 analyses are given in Table 37.

4. Discussion of Results for PEDU Test 57 with Pittsburgh Seam Coal at 1,000 psig Using Long Coal Feed Nozzle (1 inch below center line of Stage 1): Summary data for various operating periods of PEDU Test 57, using Pittsburgh seam coal at 1,000 psig and with the long coal feed nozzle discharge port located 1 inch below the center line of Stage 1, are given in Table 38, along with similar data for PEDU Test 32.

TABLE 29. CORRECTED SUMMARY DATA FOR VARIOUS OPERATING PERIODS OF PEDU TEST 55 USING NORTH DAKOTA LIGNITE
(1963-8016-52)

Period Number	PEDU Test 55					
	1	2	3	4	5	6
Operating Conditions						
System Pressure, psia	535	535	535	535	535	535
C_6H_{12} (lb/hr)	54.2	54.1	54.1	54.3	54.3	54.2
Temperature, F						
Stage 1 Inlet	3000*	3000*	3000*	3000*	3000*	3000*
Stage 2 Outlet	1710	1670	1650	1490	1470	1750
Feed Rate						
Coal, lb/hr	0.0	0.0	0.0	70.3	70.3	0.0
Saturated Steam, lb/hr	94.5	94.5	94.5	94.5	94.5	94.5
Total Steam, lb/hr	120.7	120.7	120.7	120.7	120.7	120.7
Hydrogen Pressure, P_{H_2}						
Stage 2 Outlet, psia	109.4	120.0	211.4	209.0	206.3	110.0
Stage 2 Performance Criteria						
Preformed CH_4, percent	0.0	0.0	0.0	61.9	64.0	0.0
Carbon - as percent in coal						
C in $CO + CO_2$	--	--	--	27.35	26.11	--
C in $CO + H_2$	--	--	--	0.0	0.0	--
C in CH_4	--	--	--	15.92	16.23	--
C in C_2H_6	--	--	--	1.76	2.63	--
C in Gas	--	--	--	45.03	44.97	--
Btu - as percent Btu in coal						
Btu in $(CO + CO_2)$	--	--	--	0.0	0.0	--
Btu in $(CO + H_2)$	--	--	--	19.82	16.02	--
Btu in (CH_4)	--	--	--	30.65	31.25	--
Btu in (C_2H_6)	--	--	--	3.00	4.48	
Btu in Gas	--	--	--	53.47	51.75	

* Estimated

TABLE 30. DATA AND RESULTS OF PEDU TEST 57

		Period Number			
		1	2	3	4
Time	Start	3:00	4:30	5:00	6:15
	End	4:00	4:45	5:20	6:40
Feed Rates, lb/hr					
(Coal)		0	0	52.8	65.1
Cyclohexane C_6H_{12}		55.3	55.2	55.1	55.2
Saturated Steam		91.2	91.2	91.2	91.2
Oxygen		107.2	107.3	107.4	108.2
Superheated Steam		12.5	12.5	12.5	12.5
Total Steam		103.7	103.7	103.7	103.7
Ratios, lb/lb					
Oxygen/Cyclohexane		1.94	1.94	1.95	1.96
Saturated Steam/Cyclohexane		1.65	1.65	1.65	1.65
Purge Nitrogen, cfh					
Stage 1		416	331	319	325
Stage 2		570	584	610	697
Total		986	915	929	1022
Hydrogen, cfh		0	240	241	242
Products					
Product Gas, cfh		3608	3698	4309	4605
System Leak		19	20	18	18
Sample		26	26	26	26
Flash Gas		60	69	68	53
Total		3713	3813	4421	4702
Stage 1 Temperature, °F					
UV Pyrometer ℄ Flame		NA	NA	NA	NA
Thermocouple TIC-3E	Max	NA	NA	NA	NA
	Min				
Stage 2 Outlet Temp. (F_1 and F_2 Avg.)		1750	1770	1780	1800
Reactor Pressure, psig		1015	1015	1015	1015
Quench Water, lb/hr		1010	1002	1012	1002

℄ - Center line of

NA - Not Available

TABLE 31. GAS ANALYSES FOR PEDU TEST 57

Volume, Percent

Gas Analyses (by Chromatograph)	Period Number 1 3:50	1F 3:51	2 4:40	2F 4:43	2 4:45	3 5:10	3F 5:13	3 5:15	4 6:25	4F 6:29	4 6:31
Hydrogen	35.28	17.38	38.54	20.66	38.99	34.11	19.05	34.02	32.73	18.48	32.63
Oxygen	0.09	0.15	0.03	0.20	0.18	0.10	0.10	.03	0.04	0.08	0.03
Nitrogen	25.55	7.05	23.01	6.97	22.56	20.07	6.40	20.21	21.17	6.23	21.29
Carbon Monoxide	18.21	6.58	18.37	6.74	18.88	19.61	8.05	19.69	19.60	7.77	19.38
Carbon Dioxide	20.87	68.84	20.05	65.43	19.45	18.82	62.84	18.58	18.24	63.97	18.46
Methane	--	T	--	--	--	7.28	3.56	7.47	8.12	3.47	8.09
Ethane	--	--	--	--	--	--	--	--	T	--	--
Ethylene	--	--	--	--	--	--	--	--	--	--	--
Hydrogen Sulfide	--	--	--	--	--	0.01	T	T	0.10	T	0.12
Gas Analyses (by Monitor)											
Hydrogen	36.0	36.0	39.5	39.5	39.5	35.3	35.3	35.3	31.8	31.8	31.8
Carbon Monoxide	19.0	19.0	20.0	20.0	20.0	21.0	21.0	21.0	21.0	21.0	21.0
Carbon Dioxide	22.5	22.5	21.5	21.5	21.5	20.8	20.8	20.8	18.5	18.5	18.5
Methane	0	0	0	0	0	7.2	7.2	7.2	7.6	7.6	7.6

TABLE 32. DATA AND RESULTS FOR COAL FEEDING PEDU TEST 57
(Reactor Nominal Operating Pressure = 1000 psig)

Period	Feed Rate, Net lb/hr	C.F. Nozzle* and Trans Line d/p,**psi	Tank vs Line d/p**In. H_2O	Transport Gas Rate, Net scfm	Transport Gas Sup. Vel.† ft/sec	Transport Gas Acfh	Trans Density‡ lb/acf
1	0	--	--	8.5	16.1	7.3	--
2	0	--	--	8.5	16.1	7.3	--
3	52.8	26.1	--	9.2	16.9	7.7	6.9
4	65.1	35.4	--	10.5	19.1	8.7	7.5

* Coal Feed Nozzle and Transport Line - See Figure 501, Page 2227, Progress Report No. 63

** Differential Pressure

† Superficial Velocity

‡ Transport Density = $\frac{\text{lbs of coal/hr}}{\text{net Acf gas/hr}} = \frac{\text{lb coal}}{\text{Acf}}$

TABLE 33. RADIOACTIVE GAS AND LIQUID ANALYSIS FOR PEDU TEST 57

Gas

DPH Per Standard Cubic Foot ($\times 10^5$)

	Period Number										
Time	1 3:50	1 3:51	2 4:40	2 4:43	2 4:45	3 5:10	3 5:13	3 5:15	4 6:25	4 6:29	4 6:31
Sample Number	5731	5741	5732	5742	5733	5734	5743	5735	5736	5744	5737
Sample Point	2	F	2	F	2	2	F	2	2	F	2
DPH/ft^3	196.5	376.9	197.0	373.1	214.5	174.5	325.6	174.6	167.6	326.1	168.5
DPH/ft^3 CH0	--	--	--	--	--	173.7	--	--	--	--	168.4

Liquid (C_8H_{12} only)

DPH Per lb ($\times 10^5$)

	Period Number			
Time	1 3:48	2-3 4:49	4 7:04	
Date	9-9-71	9-9-71	9-9-71	
Sample Number	5721	5722	5723	
Sample Point	2	2	2	
DPH/lb	14,070	14,150	14,070	(14,100 Avg.)

TABLE 34. DATA AND RESULTS OF PEDU TEST 58

		Period Number				
		1	2	3	4	5
Time	Start	3:10	4:15	5:03	6:11	6:29
	End	4:10	4:45	5:23	6:29	6:46
Feed Rates, lb/hr						
(Coal)		0	0	59.5	43.7	43.7
Cyclohexane C_6H_{12}		55.6	55.6	55.6	55.6	55.6
Saturated Steam		92.0	92.0	92.0	92.0	92.0
Oxygen		107.4	107.4	107.4	107.2	107.2
Superheated Steam		29.3	29.3	28.8	29.7	29.7
Total Steam		121.3	121.3	120.8	121.7	121.7
Ratios lb/lb						
Oxygen/Benzene		1.93	1.93	1.93	1.93	1.93
Saturated Steam/Benzene		1.65	1.65	1.65	1.65	1.65
Purge Nitrogen, cfh						
Stage 1		237	239	250	249	249
Stage 2		626	627	732	750	750
Total		1013	866	982	999	999
Hydrogen, cfh		0	122	123	123	123
Products						
Product Gas, cfh		3747	3674	4386	4257	4258
System Leak		19	19	19	19	19
Sample		26	26	26	26	26
Flash Gas		69	68	70	68	65
Total		3861	3787	4501	4370	4368
Stage 1 Temperature, °F						
UV Pyrometer ℄ Flame		NA	NA	NA	NA	NA
Thermocouple TIC-3E	Max	NA	NA	NA	NA	NA
	Min					
Stage 2 Outlet Temp. (F_1 and F_2 Avg.)		2150	2160	2090	2140	2140
Reactor Pressure, psig		1020	1020	1020	1020	1020
Quench Water, lb/hr		1136	1136	1136	1136	1136

℄ - Center line of NA - Not Available

TABLE 35. GAS ANALYSES FOR PEDU TEST 58

Volume, Percent

Gas Analyses (by Chromatograph)	Period Number 1 4:00	1F 4:02	1 4:04	2 4:35	2F 4:35	2 4:38	3 5:15	3F 5:17	3 5:18	4 6:25
Hydrogen	35.95	18.84	35.54	38.62	19.44	38.61	33.40	18.72	35.68	33.71
Oxygen	0.04	0.15	0.03	T	0.18	0.02	0.04	0.07	0.06	.02
Nitrogen	26.10	7.97	26.77	22.42	7.05	22.73	22.69	7.62	21.37	23.60
Carbon Monoxide	16.91	7.01	16.86	17.90	7.04	17.71	18.52	7.67	19.61	18.14
Carbon Dioxide	21.00	66.03	20.80	21.06	66.29	20.93	19.03	62.91	17.64	19.41
Methane	--	--	--	--	--	--	6.21	3.01	5.54	5.00
Ethylene	--	--	--	--	--	--	--	--	--	--
Ethane	--	--	--	--	--	--	--	--	--	--
Hydrogen Sulfide	--	--	--	--	--	--	0.11	T	0.10	0.12
Gas Analyses (by Monitor)										
Hydrogen	35.3	35.3	35.3	39.0	39.0	39.0	33.0	33.0	33.0	33.8
Carbon Monoxide	17.5	17.5	17.5	18.5	18.5	18.5	19.0	19.0	19.0	19.0
Carbon Dioxide	22.5	22.5	22.5	23.4	23.4	23.4	20.8	20.8	20.8	20.8
Methane	0	0	0	0	0	0	5.9	5.9	5.9	5.0

TABLE 35. GAS ANALYSES FOR PEDU TEST 58
(continued)

Gas Analyses (by Chromatograph)	Volume, Percent Period Number 4F 6:29	4 6:28	5 6:40	5F 6:44	5 6:42
Hydrogen	19.15	34.00	33.84	18.88	34.09
Oxygen	0.18	0.04	0.01	0.07	0.04
Nitrogen	7.70	23.38	23.18	7.57	23.21
Carbon Monoxide	7.68	18.20	18.35	7.62	18.41
Carbon Dioxide	62.90	19.37	19.55	63.36	19.30
Methane	2.35	4.94	4.92	2.49	4.86
Ethylene	--	--	--	--	--
Ethane	--	--	--	--	--
Hydrogen Sulfide	0.04	0.07	0.15	0.01	0.09
Gas Analyses (by Monitor)					
Hydrogen	33.8	33.8	33.8	33.8	33.8
Carbon Monoxide	19.0	19.0	19.0	19.0	19.0
Carbon Dioxide	20.8	20.8	20.8	20.8	20.8
Methane	5.0	5.0	4.8	4.8	4.8

TABLE 36. DATA AND RESULTS FOR COAL FEEDING PEDU TEST 58
(Reactor Nominal Operating Pressure = 1000 psig)

Period	Feed Rate, Net lb/hr	C.F. Nozzle* and Trans Line d/p,**psi	Tank vs Line d/p**In. H_2O	Transport Gas Rate, Net scfm	Transport Gas Sup. Vel.‡ ft/sec	Transport Gas Acfh	Trans Density‡ lb/acf
1	0	--	--	8.7	16.4	7.5	--
2	0	--	--	8.7	16.4	7.5	--
3	59.5	26.7	124	10.3	18.9	8.6	6.9
4	43.7	25.8	124	10.7	19.5	8.9	4.9
5	43.7	25.8	124	10.7	19.5	8.9	4.9

* Coal Feed Nozzle and Transport Line - See Figure 501, Page 2227, Progress Report No. 63

** Differential Pressure

‡ Superficial Velocity

‡ Transport Density = $\frac{\text{lbs of coal/hr}}{\text{net Acf gas/hr}} = \frac{\text{lb coal}}{\text{Acf}}$

TABLE 37. RADIOACTIVE GAS AND LIQUID ANALYSIS FOR PEDU TEST 58

Gas

DPH Per Standard Cubic Foot (x 10^5)

	Period Number														
Time	1 4:00	1 4:02	1 4:04	2 4:35	2 4:35	2 4:38	3 5:15	3 5:17	3 5:18	4 6:25	4 6:29	4 6:28	5 6:40	5 6:44	5 6:42
Sample Number	5831	5841	5832	5833	5842	5834	5835	5843	5836	5837	5844	5838	5839	5845	5839A
Sample Point	2	F	2	2	F	2	2	F	2	2	F	2	2	F	2
DPH/cu ft	190.4	367.4	192.2	200.2	376.1	199.1	170.3	324.3	159.8	177.8	332.5	175.9	176.4	330.6	174.3
DPH/cu ft CuO	--	--	--	--	--	--	170.4	--	--	177.4	--	--	--	--	175.0

Liquid (C_8H_{18} only)

DPH Per lb (x 10^5)

	Period Number			
	1	4	5	
Time	3:56	6:26	6:45	
Date	9-22-71	9-22-71	9-22-71	
Sample Number	5821	5822	5823	
Sample Point	2	2	2	
DPH/lb	14,040	14,110	14,040	(14,060 Avg.)

TABLE 38. SUMMARY DATA FOR VARIOUS OPERATING PERIODS OF PEDU TESTS 32, 57, AND 58 USING PITTSBURGH SEAM COAL

	PEDU Test 32				PEDU Test 57				PEDU Test 58				
Period Number	1	2	3	4	1	2	3	4	1	2	3	4	5
Operating Conditions													
System Pressure, psia	1010	1010	1010	1010	1030	1030	1030	1030	1035	1035	1035	1035	1035
C_8H_{18} (lb/hr)	54.3	54.3	54.3	54.4	55.3	55.2	55.1	55.2	55.6	55.6	55.6	55.6	55.6
Temperature, F													
Stage 1 Inlet	3000*	3000*	3000*	3000*	3000*	3000*	3000*	3000*	3000*	3000*	3000*	3000*	3000*
Stage 2 Outlet	1750	1780	1800	1800	1750	1770	1780	1800	2150	2160	2090	2140	2140
Feed Rate													
Coal, lb/hr	0	57.4	56.4	56.4	0.0	0.0	52.8	65.1	0.0	0.0	59.5	43.7	43.7
Saturated steam, lb/hr	98.0	98.6	98.6	98.0	91.2	91.2	91.2	91.7	92.0	92.0	92.0	92.0	92.0
Total steam, lb/hr	123.1	121.9	122.3	151.6	103.7	103.7	103.7	104.2	121.3	121.3	120.8	121.7	121.7
Hydrogen Pressure, P_{H_2}													
Stage 2 Outlet, psia	196.2	224.0	224.3	210.6	217.4	241.0	231.1	228.5	213.4	228.4	224.0	217.9	217.9
Stage 2 Performance Criteria													
Preformed CH_4, percent	--	63.3	62.9	67.6	0.0	0.0	87.5	84.5	0.0	0.0	77.8	84.6	83.3
Carbon - as percent in coal													
C in CO + CO_2	--	31.02	32.16	30.52	--	--	17.73	19.7	--	--	14.02	15.04	15.88
C in CO + H_2	--	0.0	0.0	0.0	--	--	0.0	0.0	--	--	0.0	0.0	0.0
C in CH_4	--	20.32	21.07	22.27	--	--	25.41	24.11	--	--	18.28	20.42	20.10
C in C_2H_6	--	0.0	0.0	0.0	--	--	0.0	0.0	--	--	0.0	0.0	0.0
C in Gas	--	51.34	53.23	52.79	--	--	43.13	43.38	--	--	32.31	35.46	35.98
Btu - as percent Btu in coal													
Btu in (CO + CO_2)	--	0.0	0.0	0.0	--	--	0.0	0.0	--	--	0.0	0.0	0.0
Btu in (CO + H_2)	--	27.02	28.44	24.44	--	--	8.29	10.07	--	--	11.91	8.52	9.24
Btu in (CH_4)	--	36.32	37.68	39.81	--	--	45.32	43.00	--	--	32.62	36.42	35.85
Btu in (C_nH_6)	--	0.0	0.0	0.0	--	--	0.0	0.0	--	--	0.0	0.0	0.0
Btu in Gas	--	63.35	66.11	64.26	--	--	53.61	53.07	--	--	44.52	44.94	45.09

* Estimated

Operating conditions in PEDU Test 57 duplicated those of PEDU Test 32 as closely as possible such that any improvement due only to the change in location of the discharge port of the coal feed nozzles could be observed. In PEDU Test 32 the regular coal feed nozzle was used, with its discharge port located just above the entrance to Stage 1.

Figure 42, "Effect of Outlet Hydrogen Partial Pressure on Methane Yield," shows that the points for PEDU Test 57 are above all of those for previous tests at 1,000 psig, except for PEDU Test 43. The latter was conducted with added hydrogen which increased the hydrogen partial pressure to about 21.5 atm and thus is not directly comparable to the others.

The coal feed rates used in PEDU Test 57, namely 52.8 and 65.1 lb/hr, bracketed those used in PEDU Test 32, namely 56.4 lb/hr. These data and other items given under operating conditions in Table 38 shows that the two tests are reasonably comparable; the major variable being the location of the discharge port of the coal feed nozzle.

The average values of carbon in the methane as percent carbon in the coal for the two tests were 21.7 and 24.8 percent for PEDU Tests 32 and 57, respectively. Thus the definite increase of 3.1 percentage points in the carbon conversion to methane for PEDU Test 57 can be attributed to the decrease in insufflation of the product gases into Stage 1.

Notable too, is the decrease in carbon oxides formation, average values for Tests 32 and 57 being 31.4 and 18.5 percent, respectively. The 12.9 percentage difference may indicate a lower mixing temperature, since the carbon-steam reaction is temperature dependent. Carbon oxides formation is an important item, since it will affect the amount of carbon in the char returning to Stage 1 in the integrated gasifier. The effect is also indicated in the preformed methane, average values of which are 65.3 and 86.0 percent for PEDU Tests 32 and 57, respectively.

5. Discussion of Results for PEDU Test 58 with Pittsburgh Seam Coal at 1,000 psig Using Long Coal Feed Nozzle with Short Residence Time: Summary data for the various operating periods of PEDU Test 58, using Pittsburgh seam coal at 1,000 psig and with the long coal feed nozzle discharge port located 1 inch below the center line of Stage 1, and with the volume of Stage 2 reduced to 40 percent of its initial volume to decrease the residence time, are given in Table 38.

A preliminary discussion of operating details during PEDU Test 58 was given in Section II B-5, page 35 of Progress Report No. 1. The arrangement of the reduced Stage 2 volume also was described and illustrated in Figure 12, page 34 of Progress Report No. 1

Inspection of Stage 1 of the reactor following the test showed no additional slag build-up. However, agglomerated (sintered) slag was found on the flat shelf which surrounded the 2-inch diameter entrance port of the added refractory.

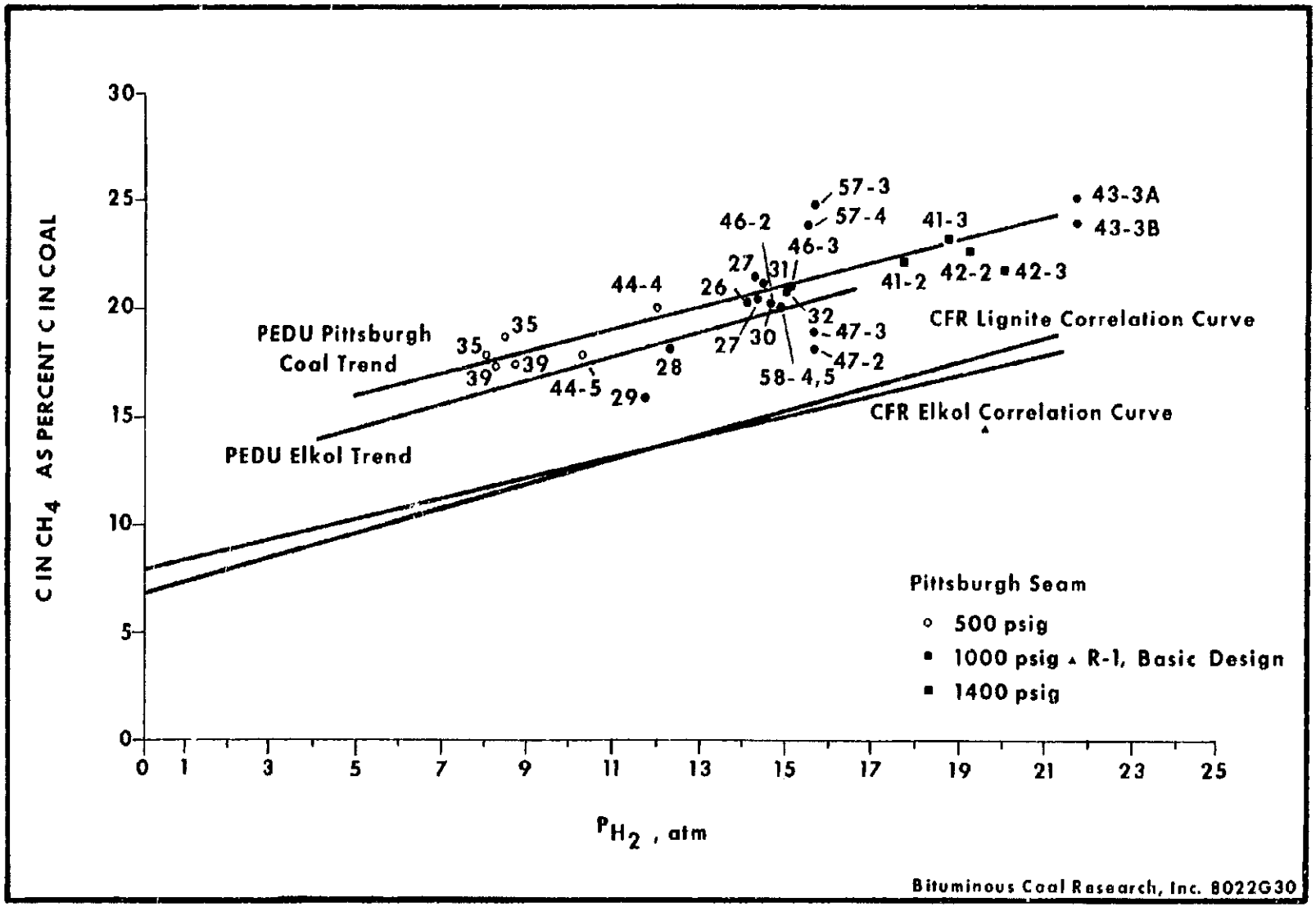


Figure 42. Effect of Outlet Hydrogen Partial Pressure on Methane Yield

Table 38 shows for PEDU Test 58 that all of the Stage 2 outlet temperatures were much higher than those for PEDU Test 57, approximately 2140 vs 1800 F for the respective tests.

Because of apparent overfeeding of coal in Period 3, as discussed in Progress Report No. 1, the results were inconclusive and will not be discussed further.

During Periods 4 and 5, with reduced residence times of 5.4 seconds as compared to about 14 seconds in PEDU Test 57, average carbon conversion to methane, as shown in Table 38 and Figure 42, amounted to 20.3 percent. This is much less than the average carbon conversion of 24.8 percent obtained in PEDU Test 57. The lower result of Test 58 was most likely due to a higher Stage 1 and 2 mixing temperature as well as recirculation of the product gases and char in the "turbulent" zone at the 2-inch diameter entrance port of the added refractory. Both of these conditions tend to decompose methane. Consequently, any improvement due to decreased residence time alone, which was the primary aim in Test 58, was adversely effected by the incompatible operating conditions which were obtained. Thus, definite conclusions as to the effect of short residence time in this particular test cannot be made. However, previous tests indicate that residence time is a very important factor in maximizing methane formation in Stage 2 of the 100 lb/hr PEDU. It should be noted that PEDU Test 58 was the only test with any coal that was conducted with short residence time at 1,000 psig. Short residence times were obtained in several other tests but at pressures below 1,000 psig.

6. Pittsburgh Seam High Volatile A Bituminous Coal, Fifth Feedstock Preparation: Two drums, Numbers 4 and 6, of Pittsburgh seam high volatile A coal, were obtained from the original shipment of eight drums of BCR Lot No. 2734. This portion of coal was designated 2734-8016-16. The coal, weighing 647 pounds, was air dried and processed through the Jeffrey crusher. The final product, designated 2734-8016-18, was processed through the Patterson ball mill and Williams classifier. The 600 pounds of final product, designated 2734-8016-19, were transferred to the coal feed tank on August 31, 1971. A representative sample of the final product was taken for screen, proximate, and ultimate analyses. The wet screen analysis is given in Table 39. The proximate and ultimate analyses are given in Table 40.

TABLE 39. WET SCREEN ANALYSIS OF PITTSBURGH SEAM HIGH VOLATILE A BITUMINOUS COAL, FIFTH FEEDSTOCK PREPARATION (SAMPLE 2734-8016-19)

Screen Size Mesh	Weight Percent Retained, Cumulative
+ 50	4.1
+ 100	31.6
+ 200	62.9
+ 325	75.6
- 325	100.0

TABLE 40. ANALYSES OF PITTSBURGH SEAM HIGH VOLATILE A BITUMINOUS COAL FEEDSTOCK
(Sample 2734-8016-19)
(Air Drying Loss 2.4 Percent)

Proximate, Percent	As Received	As Used	Dry	Dry Ash-free
Moisture	3.8	1.4	--	--
Volatile Matter	36.0	36.9	37.4	40.3
Fixed Carbon	53.4	54.7	55.5	59.7
Ash	6.8	7.0	7.1	--
Ultimate, Percent				
Moisture	3.8	1.4	--	--
Carbon	74.6	76.5	77.6	83.6
Hydrogen	5.3	5.4	5.5	5.9
Nitrogen	1.6	1.6	1.6	1.7
Sulfur	1.6	1.6	1.6	1.7
Ash	6.8	7.0	7.1	--
Oxygen (by difference)	6.3	6.5	6.6	7.1
Heating Value (Btu/lb)	13,370	13,700	13,890	14,950

7. Oxygen and Nitrogen Deliveries: No deliveries of oxygen were made during the month of October 1971. About 42,250 scf were used for PEDU operations. Cumulative oxygen to date amounts to 919,969 scf.

The 93rd delivery of liquid nitrogen, amounting to 155,500 scf, was made on October 5, 1971; 71,500 scf were used for PEDU operations. Cumulative nitrogen used to date amounts to 14,775,275 scf.

8. Benzene, Coal, and Cyclohexane Deliveries: No deliveries of benzene, coal, or cyclohexane were made during the month of October.

9. Future Work: Future work will include:

a. Evaluation and consolidation of the results for the complete series of 58 PEDU TESTS.

b. Preparation of a summary report.

c. Necessary work to expedite dismantling of the 100 lb/hr PEDU.

d. Completion of the design of the 5 ton/hr pilot plant gasifier and of equipment for the integrated gasification system.

e. Development of appropriate patent disclosures and preparation of technical papers.

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 continued during the month on the cold flow model studies in accordance with the schedule presented in Progress Report No. 92, page 3912. The model studies are expected to indicate both the location and size of nozzles and the shape of the reactor which will avoid excessive localizing of temperatures near the reactor walls, confining the high temperatures to the reactor center. 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: (1) single-burner tests, (2) multiple-burner tests, and (3) multiple-burner tests plus simulated slag. The experimental requirements for the third phase are considered to be more difficult than those for the other phases. Provisional Phase III work is therefore being undertaken to solve some of the experimental problems so that Phase III data can be obtained immediately following Phase II tests.

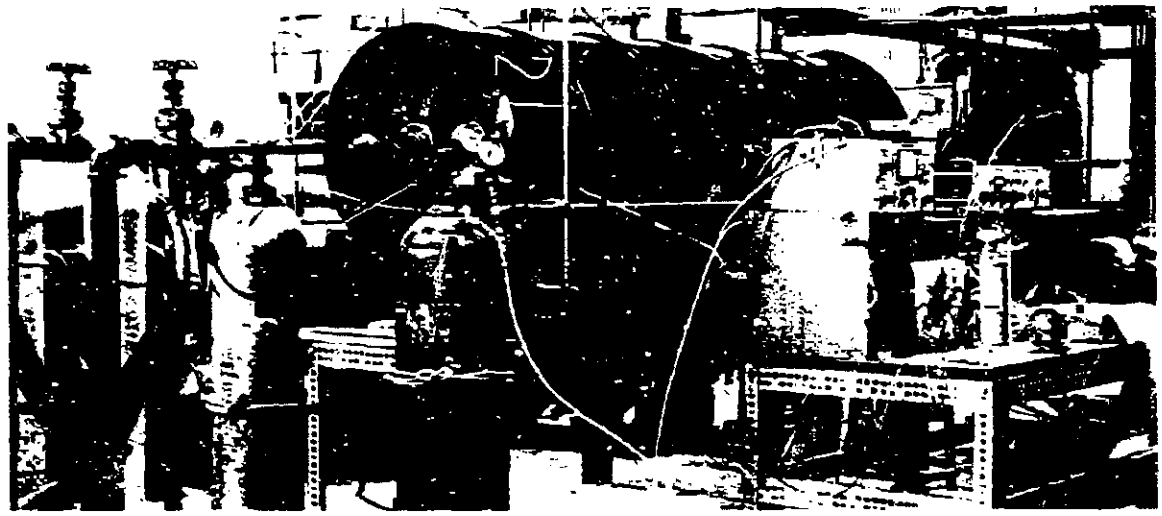
1. Phase I Model Tests: For the Phase I tests, a single-prototype burner is being tested with three different annular rings for directing the oxygen stream around the stream of steam and char being fed to Stage 1 of the two-stage gasifier. The test setup was shown schematically in Figure 15, page 47 of Progress Report No. 1, and the actual setup is shown in Figure 43.

The annular rings, shown in Figure 44, consist of twelve 5/32-inch ports drilled parallel to the steam flow, 15 degrees to the steam flow, and 30 degrees to the steam flow. The rings fit into the prototype burner shown in Figure 840, page 3914, Progress Report No. 92.

With the burner mounted, as shown in Figure 43, the rings were initially characterized using air only at 13.9 cfm through the center (steam-char) port, and at 5.6 cfm through the ring (oxygen) ports. Determinations of the air velocities were made at the centerline of the burner and at points one and two inches below the centerline using a standard pitot tube. These measurements were taken at a point 2-1/4 inches from the burner outlet and were repeated at 4-inch intervals to a total distance of 22-1/4 inches. The data, as shown in Figure 45, indicate essentially similar flow patterns regardless of the ring used.

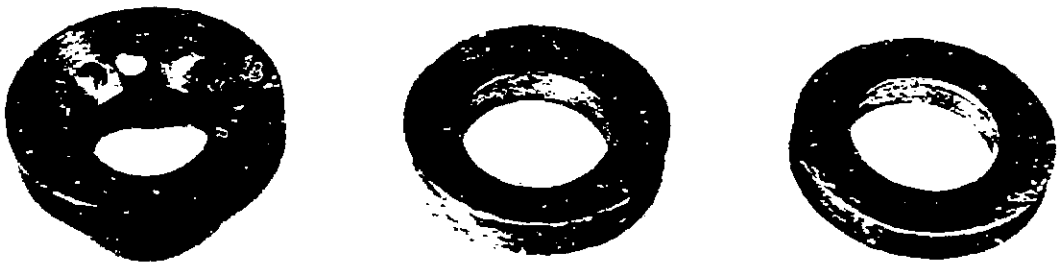
The rings are presently being characterized using air only at 13.9 cfm through the center port, and a mixture of air and 10 to 11 percent carbon dioxide content at 5.6 cfm through the rings. Carbon dioxide concentrations are being measured over a wide area of the drum.

2. Gas Analyzing Procedure and Equipment: To measure the carbon dioxide content in the air stream, during the model tests, a probe of 1/8-inch stainless steel tubing is placed in the air stream at set positions from the source and from the centerline. The air-carbon dioxide mixture is drawn through the tube, a Drierite drying tower, and the sample loops of the gas chromatograph by a diaphragm pump at a rate of approximately two liters per minute.



8016P259

Figure 43. Test Set-up for Phase 1 Model Testing



8016P258

Ports Facing 30° Inwards	Ports Parallel to Steam Flow	Ports Facing 15° Inwards

Figure 44. Three Oxygen Rings to be Tested with Prototype Steam-Char and Oxygen Burner

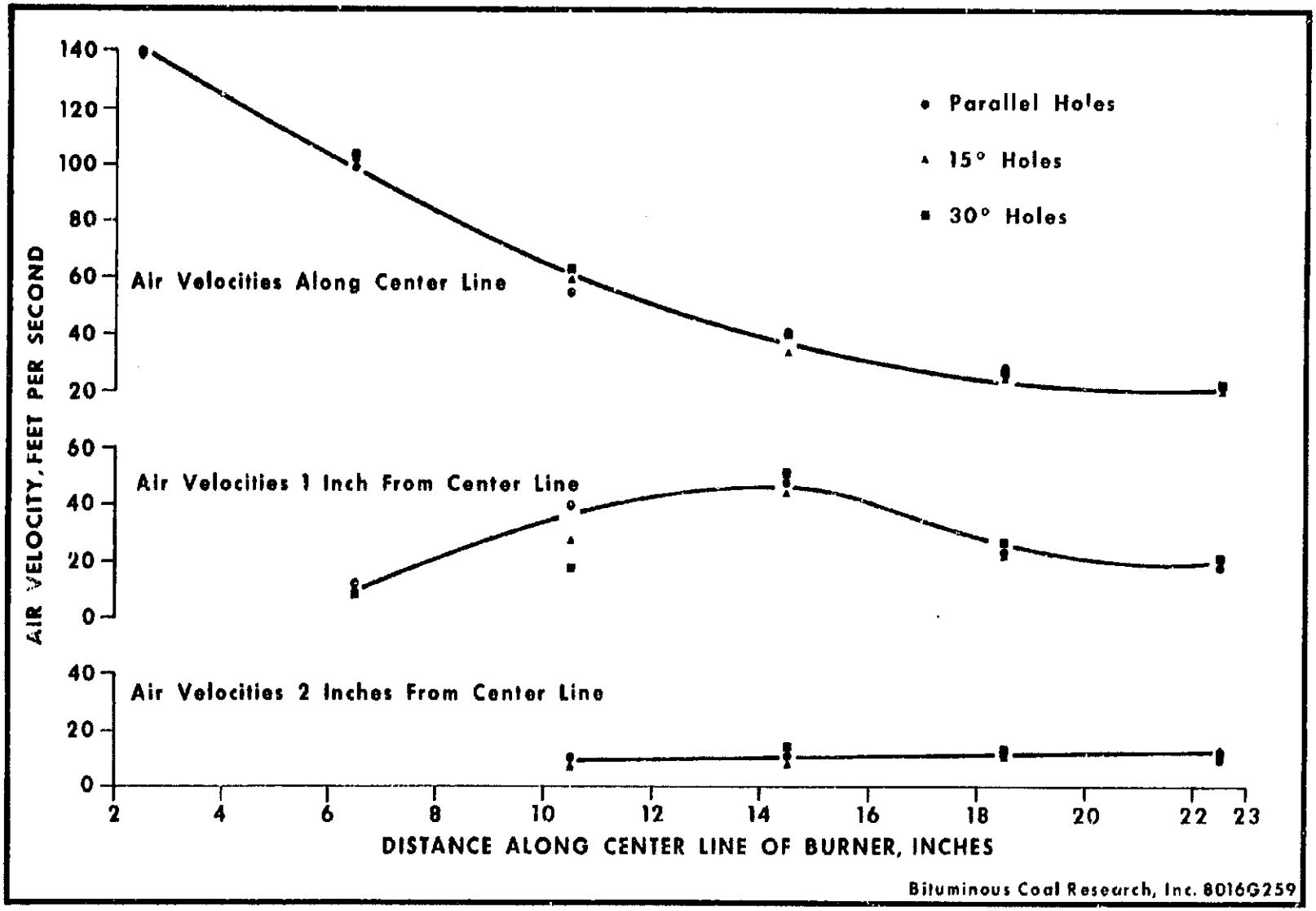


Figure 45. Gas Velocities Near Center Line of Simulated Steam-Oxygen Burner

The gas chromatograph is a Gow Mac 69-500 with a thermal conductivity detector operated at an oven temperature of 125 C and a block temperature of 120 C. The separation column is a 7-foot length of 1/4-inch copper tubing packed with Porapak Q at a density of 1.8 grams per foot. Helium flow through the gas chromatograph is maintained at 500 milliliters per minute.

The output of the gas chromatograph is put into a Vidar Autolab 6300 integrator, which determines the area under the curves produced by each gas present in the mixture. The area under the curves is related to the carbon dioxide concentration by a constant, which is determined using standard carbon dioxide samples.

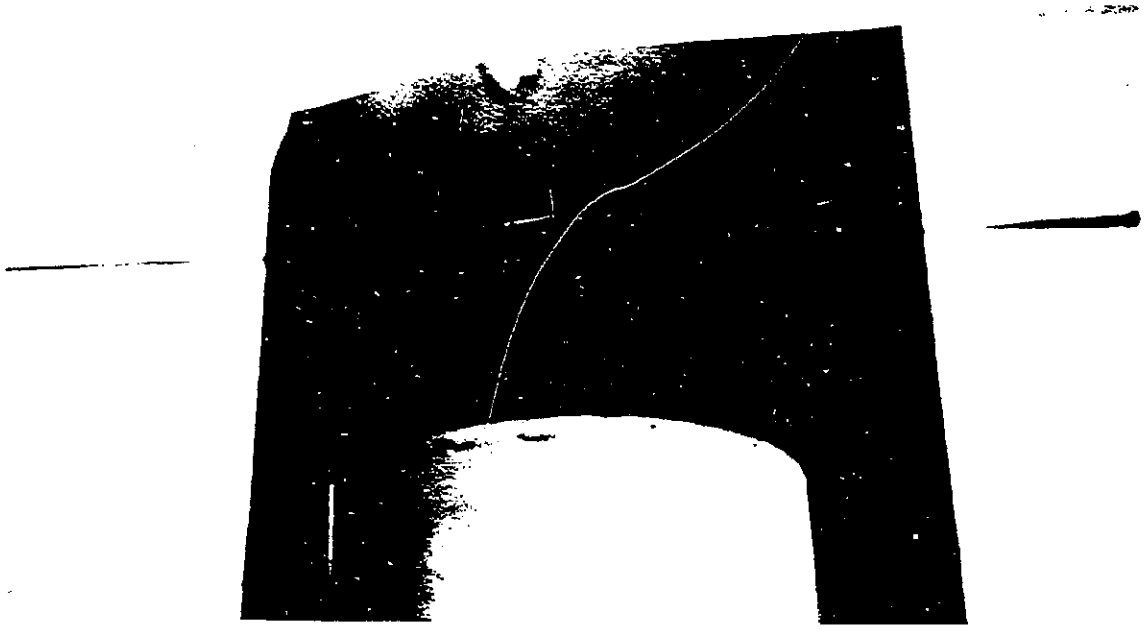
3. Phase III Model Tests: To date, the supporting scaffold has been erected, for the Phase III equipment, a roof outlet has been provided, and the oil separator has been installed in the stack. A baffled drum was built for the oil separator rather than using the cyclone described in last month's report. This drum was tested with the air and water spray shown in Figure 46. With the oil separator in place, the emission shown in Figure 47 was produced at the outlet.

Most of the components for the model have been received; the oil-air injection burner has been made and swivels for changing burner angles have been designed.

4. Future Work: The operation of the prototype burner with three different annular rings will be characterized using air and air with carbon dioxide. Other burner configurations will be tested as required. Assembly of Phase III equipment will continue.

8016P257

Figure 46. Air-Water Spray Used to Test Oil Separator



8016P256

Figure 47. Residual Mist at Oil Separator Outlet

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

1. Stage 2 PEDU: All data through PEDU Test 58 have been processed.

2. Commercial Gasifier Modeling: Gas yield expressions which will be incorporated into subroutine GASIFY have not yet been satisfactorily revised. It is hoped that these revisions will be completed during the next report period so that simulation runs for Pittsburgh seam, Elkol, and lignite coals can be made.

3. Automated Data Acquisition: Delivery of the PDP8/E computer and peripherals is expected in late December, 1971.

A thorough study of PDP8/E operational procedures is now in progress. This study will include two weeks of formal schooling at Digital Equipment Corporation's home office during the next report period.

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

a. Generate gasification yield expressions to be incorporated in subroutine GASIFY.

b. Continue study of the operation of the PDP8/E computer and peripherals.

E. Engineering Design and Evaluation

1. BI-GAS Process: Gas yield expressions which will be incorporated into the commercial gasifier program (subroutine GASIFY) have not yet been satisfactorily revised. Upon satisfactory revision of these expressions, data will be generated on West Kentucky No. 11 seam coal as well as Pittsburgh, Elkol, and lignite coals.

2. OCR/BCR Gasification--Power Generation: A special report (BCR-L-417), summarizing the two engineering evaluations and cost studies prepared by Koppers and Blaw-Knox, was submitted to OCR on July 19, 1971. These studies were based on the use of air-blown two-stage gasification as a retrofit process for inplant production of fuel gas to feed a conventional boiler.

As a result of the wide interest in the economics of desulfurized fuel gas from coal, OCR decided to issue the report as one of their publications. On August 6, 1971, an edited version of the special report was submitted to OCR for publication. This report has now been released as OCR R&D Report No. 20. Also, a paper is being prepared for the forthcoming 1972 Spring Meeting of the ACS Division of Fuel Chemistry.

Discussions continue with industry on this application of the two-stage gasifier.

Details of the cost of fuel gas by the BI-GAS process were included in Appendix D of Progress Report No. 1 for September, 1971.

3. Fischer-Tropsch System: No further developments occurred in this area this month.

F. Multipurpose Research Pilot Plant Facility (MPRF)

Every assistance is being given to Koppers to ensure that design engineering for the research facility by Koppers Company, Inc., is completed by the end of November, 1971. Progress achieved in preparation of the engineering bid package for the 5 ton/hr oxygen-blown system (BI-GAS Process) and the MPRF general facilities is given in Koppers Progress Report. (See Appendix B.)

A meeting with representatives of OCR and AGA was held October 1, 1971, in the Koppers downtown Pittsburgh office. Progress achieved was reviewed and means for expediting the bid package were discussed.

Discussions continue with American Lurgi and with Parsons Company concerning the licensing of the Purisol process. In keeping with an understanding reached on August 17, 1971, Parsons has been supplying needed information on the Purisol process for the bid package. Written confirmation of the understanding reached on August 17, 1971, is being sought from American Lurgi.

G. Literature Search (V. E. Gleason)

There were no literature references completed during the month.

H. Other

1. Prime Contract Matters: There were no new developments during this report period.

2. Outside Engineering and Services: In addition to working on the bid package for the MPRF, Koppers continues to provide engineering assistance as required and as reported above.

Copies of a proposed Amendment No. 7 to Subcontract No. 2 have been signed by Koppers and submitted to OCR for approval prior to counter-signature by BCR.

3. Brigham Young University: During the past month, the greater part of the time was spent preparing the first semi-annual report. Five copies of this report were forwarded to BCR. Figure 48, Monthly Progress Chart, Expenditures, shows the current budget status.

The reactor was redesigned to achieve shorter residence time of the coal particles and longer residence time of the hydrogen-oxygen flame. To accomplish this, the diameter of the reactor was reduced to 3/4 inches and the distance

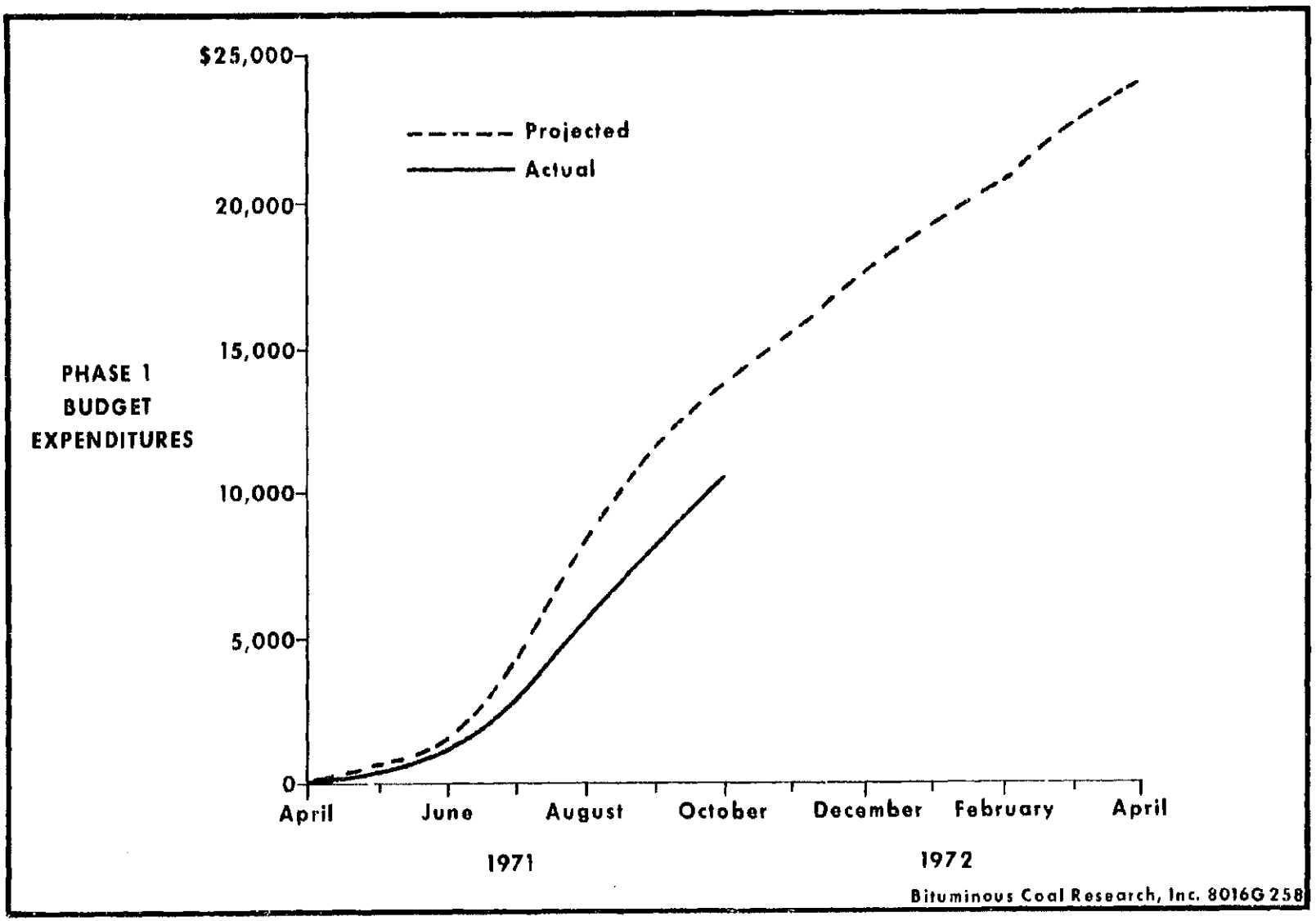


Figure 48. Monthly Progress Chart, Expenditures Brigham Young University

between the point of injection of the premixed hydrogen and oxygen and the point injection of the coal was lengthened by 50 percent. Shop drawings have been prepared to carry out these changes to the reactor design. Fabrication of the new parts will be carried out during the coming month.

Additional tests are also planned with the present reactor during November. These tests will be made with mixtures of coal and char to obtain pyrolysis data at lower temperatures than tested heretofore.

It is suggested that the concept of pyrolysing coal by injecting it into a premixed flame of oxygen and a fuel gas such as hydrogen or methane, or the design of equipment for doing this, may be patentable.

4. Reports and Papers: As reported last month, the revised manuscript of the paper entitled "Gasification of Lignite by the BCR Two-stage Superpressure Process," by R. J. Grace, R. A. Glenn, and R. L. Zahradnik, was returned to INDUSTRIAL & ENGINEERING CHEMISTRY Quarterlies. Early publication is expected.

5. Patent Matters: As reported in Progress Report No. 84, December, 1970, all worthwhile ideas are being written up as invention disclosures for submission to OCR for consideration.

a. OCR-866 and OCR-1078: A U.S. patent application based on the new process concept (E. E. Donath, December 11, 1970) has now been filed and given Serial Number 182,652. The application, entitled "Gasification of Carbonaceous Solids," contains nine claims. The appropriate document assigning rights to the U.S. Government has been prepared.

b. New Invention Disclosures: Formal Invention Disclosures (Form DI 1217) for six individual BCR suggestions were submitted to OCR on May 7, 1971. These were listed in last month's report.

Inasmuch as 90 days have elapsed since the submission of these invention disclosures, in accordance with the patent clause under Contract 14-01-0001-324, BCR is proceeding, as reported last month, to develop patent applications for filing in the U.S., first obtaining the approval of the Solicitor's Office.

I. Visitors During October, 1971

October 1, 1971

Mr. Neal P. Cochran
Chief, Division of Utilization
Office of Coal Research
U.S. Department of the Interior
Washington, D. C. 20240

October 5, 1971

Mr. H. M. Mitchell
Mr. E. H. D. Gibbs
Koppers Company, Inc.
Koppers Building
Pittsburgh, Pennsylvania 15219

Mr. Carl A. Bolez
Gilbert Associates, Inc.
525 Lancaster Avenue
Reading, Pennsylvania

October 6, 1971

Mr. C. J. Neuhoff
H. F. Lenz Co.
Lyter Drive
Johnstown, Pennsylvania

October 7, 1971

Mr. H. F. Leonard
Koppers Company, Inc.
Koppers Building
Pittsburgh, Pennsylvania 15219

Professor C. Y. Wen
West Virginia University
Morgantown, West Virginia

Dr. Paul Yavorsky
U.S. Bureau of Mines
4800 Forbes Avenue
Pittsburgh, Pennsylvania 15213

October 8, 1971

Dr. C. A. Johnson
Mr. H. H. Stotler
Mr. D. H. Tulhall
Hydrocarbon Research, Inc.
Box 1416
Trenton, New Jersey 08607

October 12, 1971

Mr. Walter Kuehn
Mr. W. A. Clayton
Mr. H. J. Blaskowski
Mr. R. C. Ulmer
Combustion Engineering, Inc.
Windsor, Connecticut

Mr. S. M. Tymiak
Mr. J. F. Farnsworth
Koppers Company, Inc.
Koppers Building
Pittsburgh, Pennsylvania 15219

October 18, 1971

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

October 18, 19, 20, 1971

Dr. Frederick A. Zenz
P. O. Box 363
Roslyn, Long Island, New York

October 19, 1971

Mr. J. W. Lindstrom
Mr. D. M. Mitsak
Mr. H. F. Leonard
Koppers Company, Inc.
Koppers Building
Pittsburgh, Pennsylvania 15219

October 19, 1971

Mr. Ravindra M. Nadkarni
Mr. Charles Bliss
Arthur D. Little, Inc.
Acorn Park
Cambridge, Mass. 02140

October 20, 1971

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

October 22, 1971

Mr. D. M. Mitsak
Mr. R. O. Parker
Koppers Company, Inc.
Koppers Building
Pittsburgh, Pennsylvania 15219

October 27, 1971

Mr. A. Kroeber
Mr. W. J. Kerr
Mr. D. M. Mitsak
Mr. S. M. Tymiak
Koppers Company, Inc.
Koppers Building
Pittsburgh, Pennsylvania 15219

October 28, 1971

Mr. R. D. Lutze
Mr. Leonard J. Pieroni
Mr. Emmett J. Ferretti
Rust Engineering Company
Division of Litton Industries
P. O. Box 101
Birmingham, Alabama 35202

J. Trips, Visits, and Meetings During October

October 1, 1971	Koppers Company, Inc. Pittsburgh, Pa.	Neal P. Cochran R. A. Glenn Ab Flowers Koppers Staff

K. Requests for Information

Mr. Lee H. Bowser
Gannett, Fleming, Corddry,
and Carpenter, Inc.
P. O. Box 1963
Harrisburg, Pennsylvania

Mr. H. F. Ferguson
Energy Technology Division
Department of Trade and Industry
Thames House, South Millbank
London SW1, ENGLAND

Mr. Emmett Ferretti
Rust Engineering
P. O. Box 101
Birmingham, Alabama 35201

Mr. Frederic de Hoffmann
P. O. Box 1814
La Jolla, California 92037

Mr. John R. Heizelman
Manager of Construction Sales
Kaighin-Hughes-Paulin, Inc.
2852 South Avenue
Toledo, Ohio 43601

III. WORK PLANNED FOR NOVEMBER, 1971

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

The final summary report on the coal composition and beneficiation studies is being edited and should be completed soon.

The review of the bid package from Koppers for the fluidized-bed gasification PEDU will continue. A list of usable instrumentation and equipment from the Stage 2 PEDU will be compiled with the idea of using as many of these items as possible in the new PEDU installation. Reactivity studies of the Consol char will continue.

Tests will continue in the bench-scale methanator to evaluate suitable catalysts. Emphasis will be placed on non-nickel catalysts as a result of previous experience. Evaluation and review of the bid package from Koppers for the methanation PEDU is planned, as well as continued work on the model studies.

The test work on the Stage 2 PEDU (100 lb/hr) was officially terminated on September 30, 1971. Data are being compiled in preparation for writing a final summary report to cover work completed since September 20, 1970. A schedule is being developed for the dismantling of the Stage 2 PEDU equipment.

Tests in the Phase I program of the cold flow model studies for the 5 ton/hr two-stage gasifier will continue. Erection of the equipment for Phase III tests is also planned.

Gas yield expressions will be revised and incorporated into subroutine GASIFY in order to obtain simulation runs for Pittsburgh seam, Elkol, and lignite coals. Operation of the PDP8/E computer will be studied.

Assistance will be given to Koppers to ensure completion of the bid package for the multipurpose research pilot plant facility at an early date.

A. Trips and Meetings Planned

November 8, 1971	Office of Coal Research Washington, D. C. 20240	R. A. Glenn

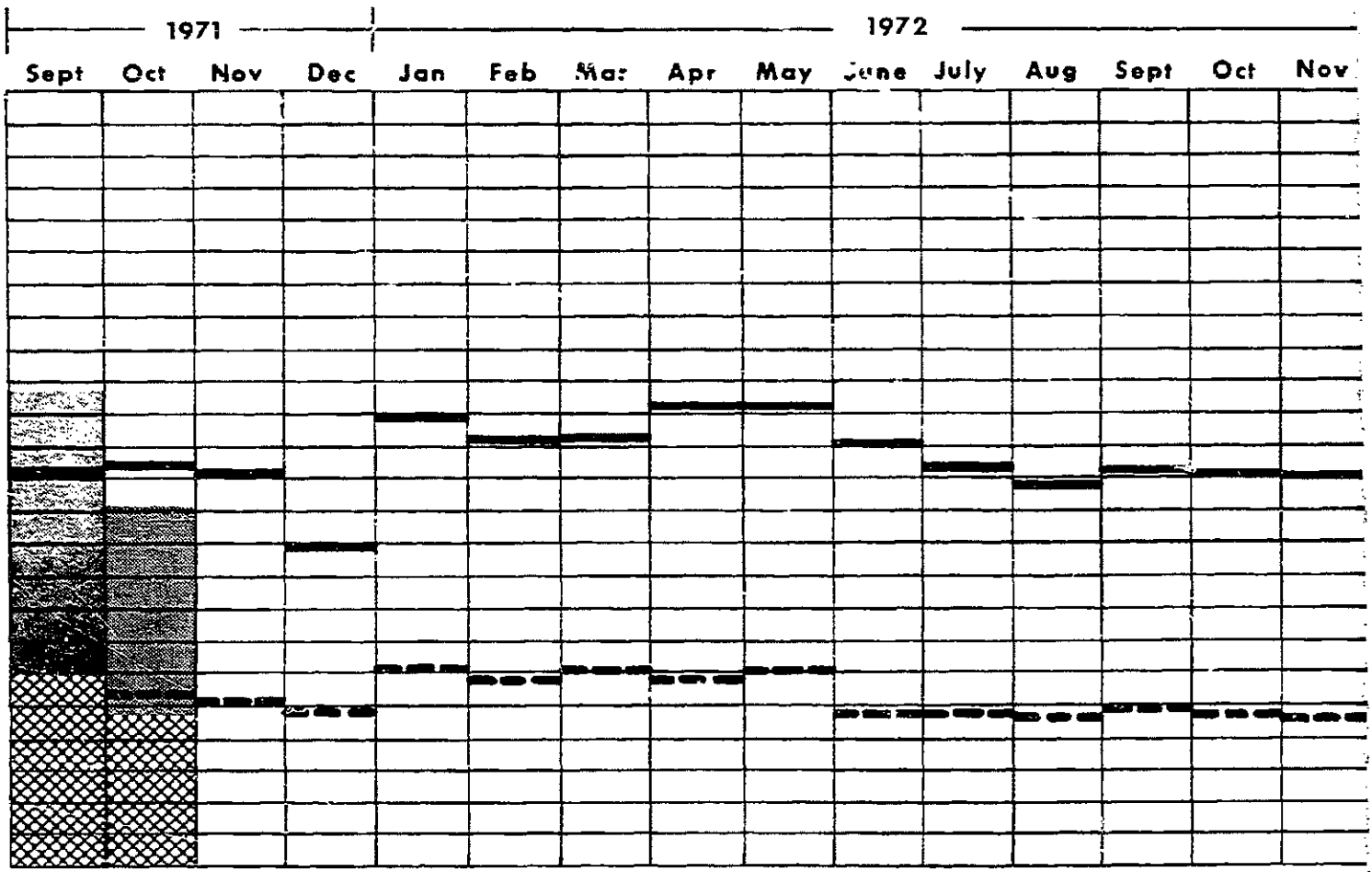
B. Visitors Expected

None

C. Papers to be Presented

April, 1972	Symposium on Quality of Synthetic Fuels ACS Division of Fuel Chemistry Boston, Massachusetts	"Economics of Generating Clean Fuel Gas from Coal using an Air-blown Two-stage Gasifier" E. K. Diehl J. T. Stewart R. A. Glenn

MANHOURS

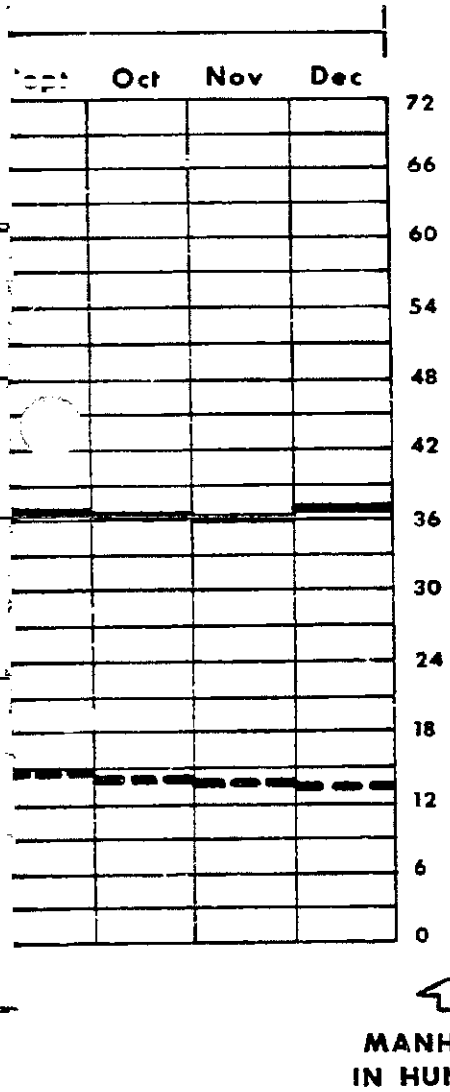

1971
1972
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov

MONTHLY PROGRESS CHART
PART 1 MANHOURS

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

OFFICE OF COAL RESEARCH
DEPARTMENT OF THE INTERIOR

CONTRACT NO. 14-32-0001-1207



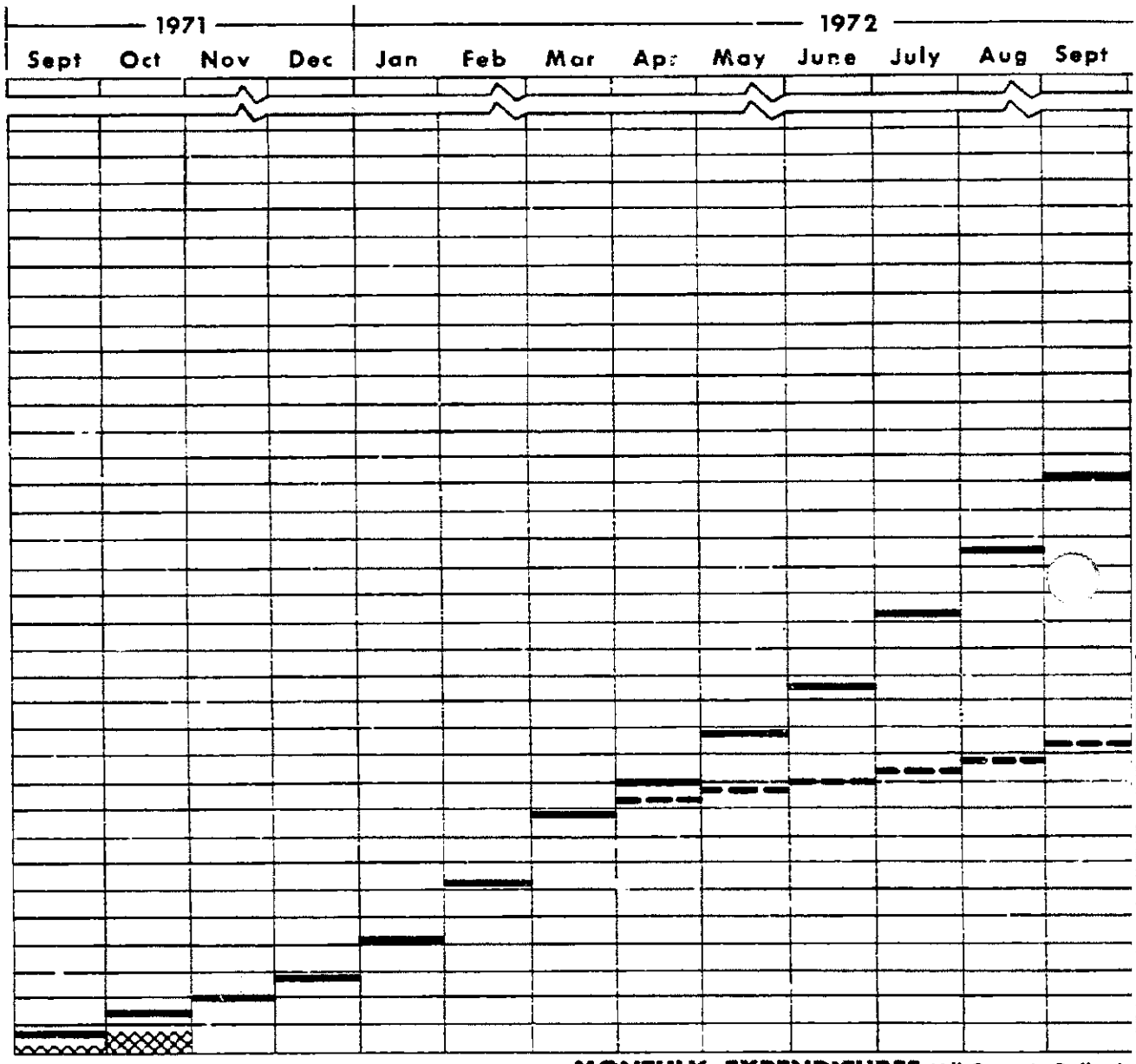
Predicted Professional and Non-professional

Predicted Professional

Actual Non-professional

Actual Professional

2



MONTHLY EXPENDITURES (All Costs, in Dollars)

		Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Monroeville	Predicted	129,991	129,991	129,991	129,991	323,486	382,228	558,454	105,058	86,238
	Actual	63,610	121,696							
Homer City	Predicted								154,000	215,60
	Actual									
Total	Predicted	129,991	129,991	129,991	129,991	323,486	382,228	558,454	259,058	83
	Actual	63,610	121,696							

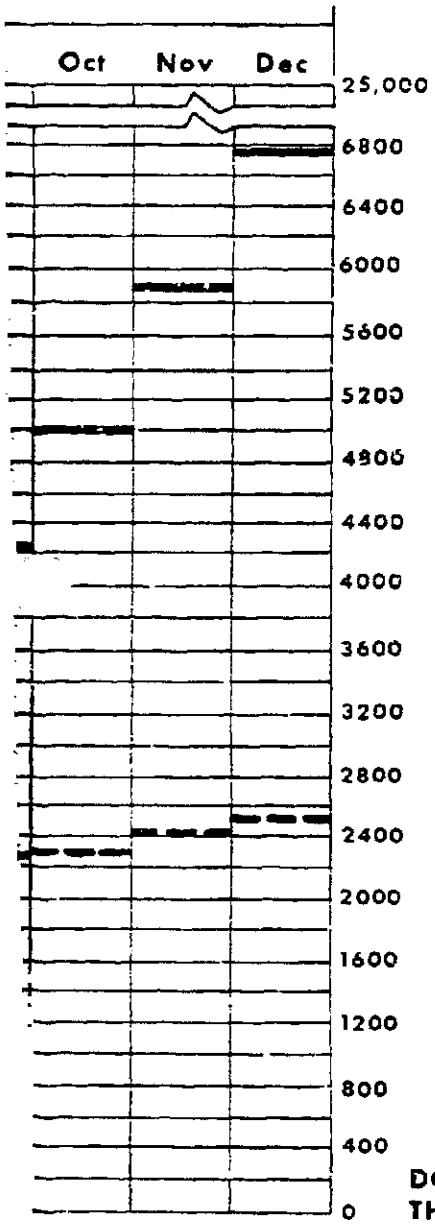
CUMULATIVE EXPENDITURES

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

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

2

APPENDIX B

PROGRESS REPORT #27

BITUMINOUS COAL RESEARCH, INC.
COAL GASIFICATION

OCTOBER 1971

KOPPERS CONTRACT 2415

I. STATUS OF CONTRACT

A. PILOT PLANT ENGINEERING BID PACKAGE

(1) A meeting was held on October 1, 1971 in Koppers offices in Pittsburgh, attended by representatives of OCR, AGA, BCR and Koppers. The purpose of the meeting was to review the concept, basic design and related costs of the 5 ton per hour OCR/BCR BI-GAS pilot plant.

Following the review, Dr. Ab Flowers, AGA, explained that it was urgent to the gas industry that the process be proved as quickly as possible in order that commercialization could be started by 1975.

Messrs. Flowers and N. Cochran, OCR, requested that Koppers submit, as quickly as possible, a proposal covering the detailed engineering, procurement, construction and operations of the 5 ton per hour pilot plant, to be based on a simplified version of the oxygen blown gasifier facility, including only those facilities and services necessary to prove the process.

Work on the proposal was to be conducted independently of the contract and was not to delay completion of the engineering bid package.

(2) Effluent Treatment Flow Diagrams for the pilot plant were submitted for BCR's approval in our letter C-174 dated October 8, 1971.

(3) Water treatment recommendations were submitted in our letter C-176 dated October 11, 1971.

(4) An estimate of the electric power requirements for the pilot plant operations was submitted to BCR in Koppers letter C-179 dated October 12, 1971.

(5) Transmittal of three (3) proposals from outside soils engineering firms for site soils investigations to be performed at Homer City plant site (letter C-180 dated October 13, 1971).

(6) Transmittal to BCR of limited data and process description covering Parsons-Lurgi PURISOL unit for acid gas removal facilities (C-181 dated October 15, 1971). Supplier advised that no further engineering data will be supplied without prior execution of the secrecy agreement (C-201 dated November 2, 1971).

(7) Review and discussions of the proposed Amendment #7, scope of initial site work, revised process descriptions were made at the meeting held at BCR on October 12, 1971, and reported in the Conference Report #197.

(8) Specifications for the recommended scope of work for clearing and grubbing at the Homer City pilot plant were submitted to BCR in letter C-193 dated October 27, 1971.

B. ENGINEERING ASSISTANCE AND RECOMMENDATIONS FOR PEDU PROGRAM

(1) A review of the Char Fluidized Bed Gasification PEDU was made at the meeting held at BCR on October 19, 1971 and attended by BCR's representatives, Dr. F. A. Zenz (Consultant, Fluid Particle Technology) and Koppers personnel. For additional information please refer to Conference Report #198 (transmitted in Koppers letter C-194 dated October 27, 1971).

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 2415-C183 dated October 18, 1971. Receipt of these copies was acknowledged by BCR in their letter dated October 18, 1971.

Koppers is proceeding in accordance with the scope of work stated in proposed Amendment No. 7.

J. F. Farnsworth
Project Manager

SMT:jp