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

During the month, two PEDU tests were completed. PEDU Tests 57 and 58 were conducted on September 8 and 23, 1971, respectively. Results of Tests 54, 55, and 56 were evaluated.

The general objective of the PEDU tests is to continue optimization of 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 is described under the "Data and Results" section for the specific test.

The data and results for PEDU Tests 55 and 56, which were not processed in time for Progress Report No. 92, will be presented and discussed in this report.

1. Data and Results for PEDU Test 54 with "As-used" Lignite (1963-8016-49) at 1,000 psig Using Long Coal Feed Nozzle: The primary purpose and significant details of PEDU Test 54 were presented in Section B-2, page 3896, Progress Report No. 92.

Data and results for PEDU Test 54 were given in Table 1057. Chromatographic and monitor analyses were given in Table 1058. Data and results for coal feeding were given in Table 1059, and C-14 analyses were given in Table 1060.

2. Data and Results for PEDU Test 55 with "As-used" Lignite (1963-8016-49) at 500 psig Using Long Coal Feed Nozzle: The primary purpose and significant details of PEDU Test 55 were presented in Section B-3, page 3901, Progress Report No. 92.

Data and Results for PEDU Test 55, not then completed, are given in Table 3, chromatographic and monitor analyses are given in Table 4, data and results for coal feeding are given in Table 5, and C-14 analyses are given in Table 6.

3. Data and Results for PEDU Test 56 with "As-used" Lignite (1963-8016-49) at 1,000 psig Using Long Coal Feed Nozzle: The primary purpose and significant details of PEDU Test 56 were presented in Section B-4, page 3906, Progress Report No. 92.

Data and results for PEDU Test 56, not then completed, are given in Table 7, chromatographic and monitor analyses are given in Table 8, data and results for coal feeding are given in Table 9, and C-14 analyses are given in Table 10.

4. 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 of PEDU Test 57, with Pittsburgh seam coal, was to determine the effect on the performance criteria, particularly carbon conversion to methane, of the use of the long coal feed nozzle. During PEDU Tests 54, 55, and 56 the discharge port of the long coal feed nozzle was located 4 inches below the center line of Stage 1. For PEDU Test 57, the port was retracted from 4 to 1 inch below the center line of Stage 1. This was done to increase the temperature in the

TABLE 3. DATA AND RESULTS OF PEDU TEST 55

		Period Number					
		1	2	3	4	5	6
Time	Start	2:40	3:05	4:10	4:30	4:45	5:50
	End	3:00	3:17	4:25	4:45	5:00	6:10
Feed Rates, lb/hr							
(Coal)		--	--	--	70.3	70.3	--
Cyclohexane C_8H_{12}		54.2	54.1	54.1	54.3	54.3	54.2
Saturated Steam		94.5	94.5	94.5	94.5	94.5	94.5
Oxygen		104.7	97.2	105.5	105.5	105.5	105.5
Superheated Steam		26.2	26.2	26.2	26.2	26.2	26.2
Total Steam		120.7	120.7	120.7	120.7	120.7	120.7
Ratios lb/lb							
Oxygen/C_8H_{12}		1.93	1.80	1.95	1.94	1.94	1.93
Saturated Steam/C_8H_{12}		1.74	1.75	1.75	1.74	1.74	1.74
Purge Nitrogen, cfh							
Stage 1		176	176	174	258	262	176
Stage 2		597	585	242	181	186	585
Total		773	761	416	439	448	761
*Hydrogen		0	0	1182	1184	1184	0
**Hydrogen		0	0	880	882	882	0
Total		0	0	2062	2066	2066	0
Products							
Product Gas, cfh		3528	3611	5001	5833	5796	3486
System Leak		18	18	18	18	18	18
Sample		26	26	26	26	26	26
Flash Gas		65	31	20	26	26	36
Total		3637	3686	5065	5903	5866	3566
Stage 1							
Temperature, °F							
UV Pyrometer ℄ Flame	Max	NA	NA	NA	NA	NA	NA
Thermocouple TIC-3E	Min	NA	NA	NA	NA	NA	NA
Stage 2 Outlet Temp. (F_1 and F_2 Avg.)		1710	1670	1650	1490	1470	1750
Reactor Pressure, psig		520	520	520	520	520	520
Quench Water, lb/hr		1016	1016	1152	1152	1152	1152

℄ - Center line of NA - Not Available

* Transport Line ** Rupture Disc

TABLE 4. GAS ANALYSES FOR PEDU TEST 55

Volume, Percent

Gas Analyses (by Chromatograph)	1 3:00	2 3:15	3 4:20	3F 4:21	3 4:23	4 4:40	4F 4:41	4 4:42	5 4:55	5F 4:56	5 4:56	6 6:10	6 6:11
	Period Number												
Hydrogen	36.70	39.08	63.41	37.16	63.20	59.71	39.72	59.53	59.24	39.91	58.82	37.11	36.94
Oxygen	0.08	0.06	0.04	0.34	0.07	0.04	0.42	0.05	0.06	0.36	0.05	0.05	0.06
Nitrogen	23.22	21.80	7.72	4.61	7.88	7.27	4.04	7.56	7.88	3.96	7.94	22.62	22.76
Carbon Monoxide	17.16	17.29	17.80	8.95	17.79	15.99	8.61	15.91	15.80	8.32	15.71	16.80	16.83
Carbon Dioxide	22.84	20.91	10.74	48.94	10.75	13.53	45.29	13.56	13.48	45.18	13.83	23.42	23.41
Methane	--	0.86	0.29	--	0.31	3.19	1.76	3.14	3.18	2.01	3.28	--	--
Ethane	--	--	--	--	--	0.16	0.15	0.15	0.23	0.25	0.24	--	--
Ethylene	--	--	--	--	--	--	--	--	--	--	--	--	--
Hydrogen Sulfide	--	--	--	--	--	0.11	0.01	0.10	0.13	0.01	0.13	--	--
Gas Analyses (by Monitor)													
Hydrogen	36.5	38.0	*	*	*	*	*	*	*	*	*	37.3	--
Carbon Monoxide	18.5	19.0	19.0	19.0	19.0	17.2	17.2	17.2	16.6	16.6	16.6	17.2	--
Carbon Dioxide	25.0	23.4	11.5	11.5	11.5	16.0	16.0	16.0	16.0	16.0	16.0	25.0	--
Methane	0	0.80	0.30	0.30	0.30	3.1	3.1	3.1	3.0	3.0	3.0	0	--

* Hydrogen was greater than 50 percent.

TABLE 5. DATA AND RESULTS FOR COAL FEEDING PEDU TEST 55
(Reactor Nominal Operating Pressure = 500 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	--	24.6	6.9	25.0	11.4	--
2	0	--	24.6	6.9	25.0	11.4	--
3	0	--	19.5	19.7	71.5	32.5	--
4	70.3	106	39.9	21.2	71.6	32.5	2.2
5	70.3	106	48.0	21.2	71.5	32.0	2.2
6	0	--	24.6	6.9	25.0	11.4	--

* 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 6. RADIOACTIVE GAS AND LIQUID ANALYSIS FOR PEDU TEST 55

GAS

DPH Per Standard Cubic Foot (x 10^6)

	Period Number												
	1	2	3	3	3	4	4	4	5	5	5	6	6
Time	3:00	3:15	4:20	4:21	4:23	4:40	4:41	4:42	4:55	4:56	4:56	6:10	6:11
Sample Number	5531	5532	5533	5541	5534	5535	5542	5536	5537	5543	5538	5539	5539A
Sample Point	2	2	2	F	2	2	F	2	2	F	2	2	2
DPH/cu ft	202.4	196.8	147.1	287.0	147.9	124.1	231.9	125.2	121.7	223.4	124.1	*	*
DPH/cu ft CuO	200.8	192.3	--	--	146.2	125.6	--	--	123.5	--	--	--	--

Liquid (C_6H_{12} only)
DPH per lb (x 10^5)

	Period Number				
	1-2	3-4	5	6	
Time	2:58	4:27	5:00	5:50	
Date	8-5-71	8-5-71	8-5-71	8-5-71	
Sample Number	5521	5522	5523	5524	
Sample Point	2	2	2	2	
DPH/lb	13,760	13,820	13,790	13,820	(Avg. 13,800)

* Results not required

TABLE 7. DATA AND RESULTS OF PEDU TEST 56.

		Period Number			
		1	2	3	4
Time	Start	2:50	3:45	5:00	5:50
	End	3:10	4:05	5:40	6:40
Feed Rates, lb/hr					
(Coal)		0	0	67.1	69.0
Cyclohexane C_6H_{12}		55.5	55.4	55.4	55.4
Saturated Steam		92.0	92.0	92.0	92.0
Oxygen		107.7	107.7	107.2	107.5
Superheated Steam		9.2	9.2	9.2	9.2
Total Steam		101.2	101.2	101.2	101.2
Ratios lb/lb					
Oxygen/C_6H_{12}		1.94	1.94	1.94	1.94
Saturated Steam/C_6H_{12}		1.66	1.66	1.66	1.66
Purge Nitrogen, scfh					
Stage 1		228	225	228	226
Stage 2		786	588	598	596
Total		1014	813	826	822
Hydrogen scfh		0	231	228	228
Products					
Product Gas, cfh		3627	3570	4369	4340
System Leak		21	21	20	20
Sample		26	26	26	26
Flash Gas		63	66	65	66
Total		3737	3683	4480	4452
Stage 1					
Temperature, °F					
UV Pyrometer ℄ Flame	Max	NA	NA	NA	NA
Thermocouple TIC-3E	Min	NA	NA	NA	NA
Stage 2 Outlet Temp.					
(F_1 and F_2 Avg.)		1720	1760	1600	1580
Reactor Pressure, psig		1020	1020	1020	1020
Quench Water, lb/hr		1002	1010	1002	1010

℄ - Center line of NA - Not Available

TABLE 8. GAS ANALYSES FOR PEDU TEST 56

Volume, Percent

Gas Analyses (by Chromatograph)	Period Number									
	1 / 3:10	2 / 4:00	2F / 4:01	2 / 4:04	3 / 5:30	3F / 5:32	3 / 5:33	4 / 6:30	4F / 6:31	4* / 6:33
Hydrogen	33.80	38.93	19.12	38.89	38.00	19.84	37.49	37.67	19.24	39.63
Oxygen	.08	.06	.03	0.10	0.13	0.04	.09	0.11	0.15	0.09
Nitrogen	28.16	21.48	5.86	21.50	18.33	5.87	18.34	17.99	6.03	15.78
Carbon Monoxide	17.90	19.68	7.29	19.64	17.91	7.14	17.77	17.37	7.05	18.06
Carbon Dioxide	20.06	19.85	67.70	19.87	21.02	64.98	21.62	22.08	65.21	22.23
Methane	--	--	--	--	4.50	2.12	4.57	4.66	2.31	4.11
Ethylene	--	--	--	--	--	--	--	--	--	--
Ethane	--	--	--	--	--	--	--	--	--	--
Hydrogen Sulfide	--	--	--	--	0.11	.01	0.12	0.12	0.01	0.10
Gas Analyses (by Monitor)										
Hydrogen	33.0	39.5	39.5	39.5	38.0	38.0	38.0	38.0	38.0	38.0
Carbon Monoxide	18.5	20.0	20.0	20.0	18.5	18.5	18.5	18.0	18.0	18.0
Carbon Dioxide	22.5	21.5	21.5	21.5	23.4	23.4	23.4	24.0	24.0	24.0
Methane	0	0	0	0	4.2	4.2	4.2	4.7	4.7	4.7

* Coal feed rate decreased. Omit from calculation

TABLE 9. DATA AND RESULTS FOR COAL FEEDING PEDU TEST 56
(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	16.3	7.4	--
2	0	--	--	8.7	16.3	7.4	--
3	67.1	21.6	--	8.8	16.3	7.4	9.1
4	69.0	21.6	--	8.8	16.2	7.4	9.4

* 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 10. RADIOACTIVE GAS AND LIQUID ANALYSIS FOR PEDU TEST 56

Gas

DPH Per Standard Cubic Foot (x 10^6)

	Period Number									
Time	1 3:10	2 4:00	2 4:01	2 4:04	3 5:30	3 5:32	3 5:33	4 6:30	4 6:37	4 6:33
Sample Number	5631	5632	5641	5633	5634	5642	5635	5636	5643	5637
Sample Point	2	2	F	2	2	F	2	2	F	2
DPH/cu ft	189.7	202.4	381.7	197.5	167.6	308.7	169.5	168.7	306.0	177.8
DPH/cu ft CuO	--	--	--	200.7	--	--	169.2	168.4	--	--

Liquid (C_8H_{12} only)
DPH Per lb (x 10^6)

	Period Number			
Time	1-2 3:13	3-4 5:19	- 8:43	
Date	8-12-71	8-12-71	8-12-71	
Sample Number	5621	5622	5623	
Sample Point	2	2	2	
DPH/lb	13,720	13,770	13,900	(13,800 Avg.)

* Coal feed rate decreased, omit for calculations

Stage 1 and 2 mixing zones, since on inspection after PEDU Test 56 no significant deposits of ash or slag were found in Stage 1 or on the Stage 1 burner nozzles.

Operating Data for PEDU Test 32 (see Table 583, page 3297, Progress Report No. 84) were duplicated as closely as possible, such that any improvement due only to the change in the locations of the coal feed nozzle could be observed. One variation from normal operating procedure was the use of about 2 scfm of hydrogen through the "dutchman" and the safety disc purge line. This was found necessary to prevent steam condensation and consequently high heat loss to the section of the long coal feed nozzle in the "dutchman" enclosure.

Secondary Procedures: No secondary procedures were scheduled for this test.

Data and results for PEDU Test 57, as well as computer processing of the data and results, are incomplete. The information will be presented and discussed in the next report.

5. 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 of PEDU Test 58 with Pittsburgh seam coal was to determine the effect of reduced residence time on the performance criteria, particularly carbon conversion to methane. Lower residence time was obtained by reducing the normal volume of Stage 2, as measured below the center line of Stage 1, from 1.92 to 0.76 cubic feet, or about 40 percent.

The volume of Stage 2 was reduced by placing refractory cement (Harbison and Walker Co., Castolast G) around a 2-inch OD cardboard tube which was centered in the lower 40 inches of the original 66 inch long, 8-inch ID refractory shaft of Stage 2. Figure 12, Vertical Cross Section of Reactor With Reduced Stage 2 Volume, illustrates the modifications made to reduce the volume.

Assuming a normal residence time of 10 seconds, the reduced residence time after modification of Stage 2 would be 3.9 seconds. This time excludes the void volume of the 2-inch ID hole in the 40-inch length of the new refractory, which amounts to 0.073 cubic feet. If this residual void volume is included, the reduced volume of Stage 2 would be 0.830 cubic feet, or 43.3 percent of the normal volume, and the residence time would be reduced to about 4.3 seconds.

Pittsburgh seam coal (2734-8016-19) was used as feedstock, and operating conditions employed for PEDU Test 57 were duplicated as nearly as possible. In PEDU Test 57, the long coal feed nozzle was used and the discharge port of the unit was located 1 inch below the center line of Stage 1; this was not altered for Test 58.

In Test 57 hydrogen purges of about 2 scfm each were used in the "dutchman" and safety disc purge line. Because of a lesser supply of hydrogen for this test, only one hydrogen purge to the "dutchman" was used at about 1.5 scfm.

The normal transport gas by-pass line to the top of the coal tank was not used in Test 58. A measured amount of nitrogen, about 2.0 scfm to the top of

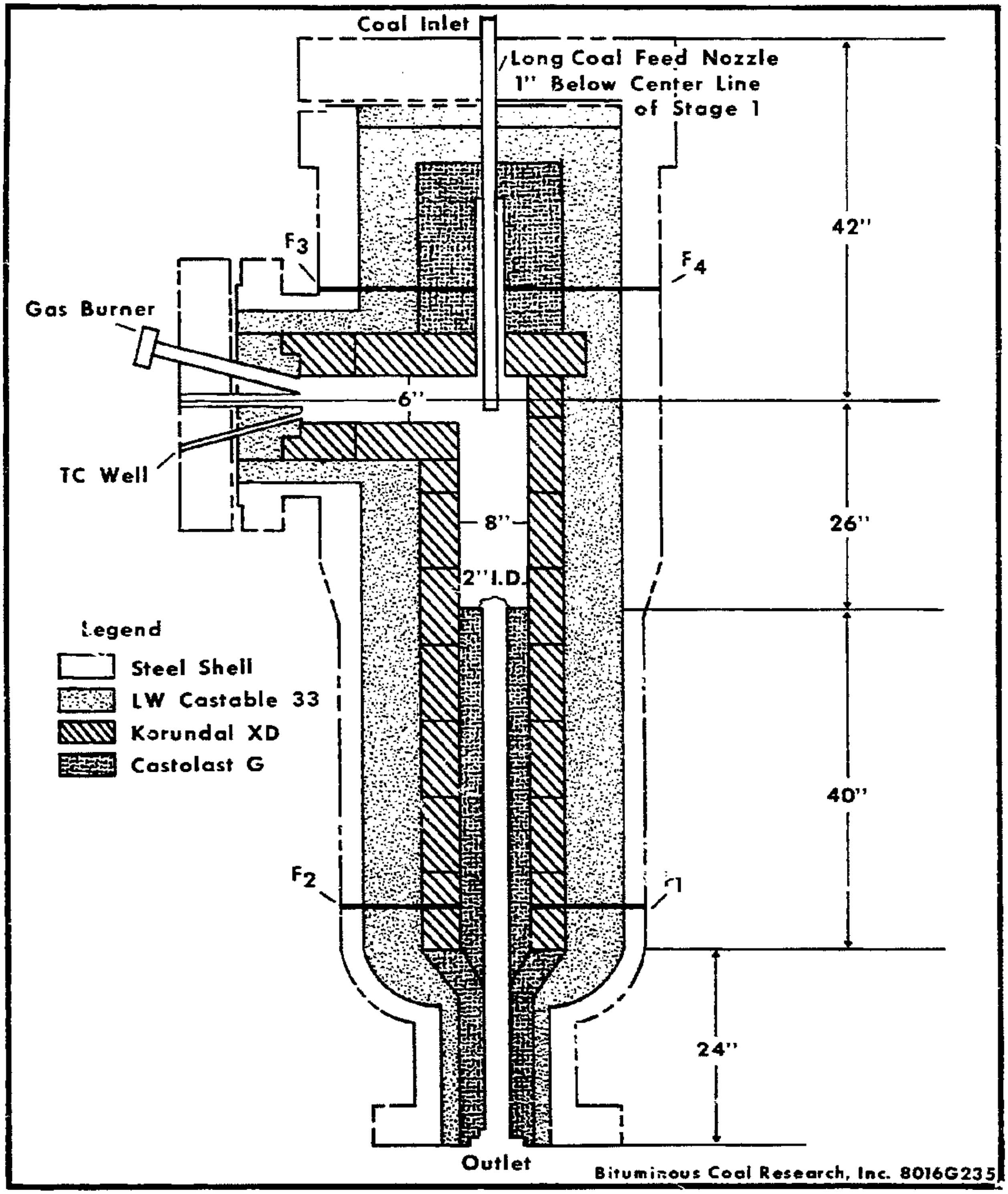


Figure 12. Vertical Cross Section of Reactor with Reduced Stage 2 Volume

the tank was employed to replace the actual volume of coal removed. Both means were employed in Test 57 and the latter proved to be most effective.

Attainment of operating conditions, comparable to those used in Test 57, depends primarily on the amount of cyclohexane that can be used in Stage 1, about 55 lb/hr was the aim in this test. However, the insulating effect of the 3-inch thick added refractory decreases the heat absorption in the lower 40-inch section of Stage 2 and thus imposes a higher heat load on the quench pipe system. Thus, the maximum cyclohexane rate depends on the capability of the latter. If operation is restricted to less than 55 lb/hr of cyclohexane, the coal feed rate can be lowered to provide comparable ratios to those obtained in Test 57.

The locations of Thermocouples 6 and 12 (F1 and F2, respectively, in Figure 12) were also changed. T.C. 12 is located at the gas refractory interface. T.C. 6 is located about 1/4 inch into the gas stream. Test data of temperature versus T.C. 6 location in the gas stream were obtained to provide a correction to the 1/4-inch location versus a center line temperature.

Secondary Procedures: No secondary procedures were scheduled for this test.

Data and results for PEDU Test 58, as well as computer processing of the data and results, are incomplete. The information will be presented and discussed in the next report.

Discussion of Operation During PEDU Test 58: During the first "coal-on" period of PEDU Test 58, which essentially duplicated operation obtained in PEDU Test 57, that is, with a coal feed rate of about 60 lb per hour and a cyclohexane rate of about 55 lb per hr, the black liquor from the flash tank showed a lemon-yellow tinge and a distinct odor of naphthalene. Also, the differential temperature of the cooling water in the circuit to the Stage 1 cyclohexane burner dropped abruptly and indicated insufflation of char into Stage 1. From the foregoing it was concluded that the coal feed rate was too great for the reduced volume of the reactor.

During the second "coal-on" period, the coal feed rate was reduced to about 44 lb per hr with no other system changes. Operation was continued over a period of about 33 minutes, after which it was necessary to quickly discontinue operation because of rapidly increasing water leakage from the seal of the scrubber pump (41003). Coal was shut off and the system pressure was reduced to about 100 psig, at which time the pump seal failed completely. However, the unit was shut down satisfactorily even under these conditions.

Preliminary evaluation of the raw data shows carbon conversion to methane for the first and second "coal-on" periods of 18.5 and 22.2 percent, respectively. Further discussion of the final data will be presented in the next report, as will the findings from an inspection of the seal of the scrubber pump.

6. Discussion of Results for PEDU Tests 54, 55 and 56 Using "As-used" Lignite and Long Coal Feed Nozzle: Summary data for various operating periods of PEDU Tests 54, 55, and 56, using "as-used" lignite and with the long coal feed nozzle located 4 inches below the center line of Stage 1, and at 1,000,

500, and 1,000 psig, respectively, are given in Table 11. For comparative purposes, the results of PEDU Test 17, with "as-used" lignite at 1,000 psig and the regular coal feed nozzle, are included.

Figure 13, Effect of Outlet Hydrogen Partial Pressure on Methane Yield, shows the average results of the present series of tests, PEDU Tests 54, 55, and 56, as well as those from earlier operations with lignite. Comparison will be made particularly with the results of PEDU Test 17.

Figure 13 shows that the carbon conversion to methane for PEDU Test 54 is lower than that for Test 17, namely, 16.2 vs 17.1 percent. (Note that carbon in the ethane is included in the methane percentages for PEDU Tests 17, 54 and 55.) It was also conducted at a lower hydrogen partial pressure, namely 14.3 atmospheres and at a lower exit temperature, namely, 1440 F. The latter was attributed to the higher heat loss to the long coal feed nozzle as compared to the regular coal feed nozzle. It also resulted in a lower Stage 1 and 2 mixing temperature.

The appearance of 1.2 percent carbon as ethane for Test 54, a substantial amount as compared to 0.1 percent for Test 17, tends to confirm the low Stage 1 and 2 mixing temperature, as does the lower percentage of carbon in the carbon oxides produced, namely, 16.8 vs 24.9 percent, respectively, for PEDU Tests 54 and 17.

Comparison of results from the two tests does not indicate a definite effect due alone to a decrease in insufflation of product gases into Stage 1. However, post test inspection of the various nozzles and Stage 1 proper showed little indication of increased accumulation of char or slag.

Further analyses of the data are indicated, with parameters that incorporate such other variables as residence time and temperature, to determine any definite effect. However, it is believed that increased carbon conversion to methane with lignite, as indicated by the exit temperature, occurs in the range from 1500 to 1600 F.

In PEDU Test 55, the coal feed was maintained as for Test 54, but the cyclohexane rate was increased to compensate for heat loss to the long coal feed nozzle. The pressure was lowered to 520 psig to provide for decreased residence time and auxiliary hydrogen was used to maintain the hydrogen partial pressure. The residence time obtained was 5.4 seconds; this compares to about 13.5 seconds for all other PEDU tests listed in Table 11.

Evaluations of the Stage 2 performance criteria, as given in Table 11, were found to be in error. The computer program as devised does not compensate for carbon in the methane that may be produced from Stage 1 operation. Chromatographic analyses for Stage 1, with auxiliary hydrogen added, as given in Table 4 for period 3, shows an average value of 0.30 percent methane. The radioactive gas analyses for the catalytic and copper oxide evaluations for Period 3, as given in Table 6, show a decided difference that also indicates methane from cyclohexane. Calculations based on both of these sources show that carbon in the methane from cyclohexane amounts to 1.4 percent of the carbon in the coal for the "coal-on"

TABLE 11. SUMMARY DATA FOR VARIOUS OPERATING PERIODS OF PEDU T
"AS USED" NORTH DAKOTA LIGNITE WITH LONG COAL FEED NOZZ

	17*		54					
Period Number	2	3	1	2	3	4	1	2
Operating Conditions								
System Pressure, psia	1035	1035	1035	1035	1035	1035	535	535
C_8H_{18} (lb/hr)	51.2	51.2	51.4	51.4	51.4	51.4	54.2	54.1
Temperature, F								
Stage 1 Inlet	3000**	3000**	3000**	3000**	3000**	3000**	3000**	3000
Stage 2 Outlet	1500	1510	1570	1460	1440	1440	1710	1670
Feed Rate								
Coal, lb/hr	80.0	81.0	0.0	70.5	70.5	70.5	0.0	0.0
Saturated Steam, lb/hr	90.9	89.6	91.9	91.9	91.9	91.9	94.5	94.5
Total Steam, lb/hr	112.1	110.8	122.4	122.2	122.2	122.4	120.7	120.7
Hydrogen Pressure, P_{H_2}								
Stage 2 Outlet, psia	247	257	215.4	208.7	210.7	207.7	109.4	120.0
Stage 2 Performance Criteria								
Preformed CH_4, percent	73.8	71.6	0.0	79.2	76.5	78.3	0.0	0.0
Carbon - as percent in coal								
C in $CO + CO_2$	25.2	24.6	--	17.3	12.6	16.3	--	--
C in $CO + H_2$	0.0	0.0	--	0.0	0.0	0.0	--	--
C in CH_4	17.2	16.8	--	15.1	15.0	14.9	--	--
C in C_2H_6	0.1	.1	--	1.0	1.4	1.4	--	--
C in Gas	42.5	41.5	--	33.4	29.0	32.6	--	--
Btu - as percent Btu in coal								
Btu in $(CO + CO_2)$	0.0	0.0	--	0.0	0.0	0.0	--	--
Btu in $(CO + H_2)$	14.9	16.3	--	7.3	7.8	6.8	--	--
Btu in (CH_4)	33.1	32.4	--	29.1	28.9	28.6	--	--
Btu in (C_2H_6)	0.1	0.1	--	1.7	2.5	2.4	--	--
Btu in Gas	48.1	48.8	--	38.1	39.2	37.8	--	--
Residence Time, secs	13.5	13.5	14.6	13.3	13.2	13.3	7.6	7.6

* Regular coal feed nozzle
‡ Data for performance criteria in erro
** Estimated

S OF PEDU TESTS 17*, 54, 55, AND 56 USING
L FEED NOZZLE 500 AND 1,000 psig

55#						56			
1	2	3	4	5	6	1	2	3	4
35	535	535	535	535	535	1035	1035	1035	1035
2	54.1	54.1	54.3	54.3	54.2	55.5	55.4	55.4	55.4
00**	3000**	3000**	3000**	3000**	3000**	3000**	3000**	3000**	3000**
10	1670	1650	1490	1470	1750	1720	1760	1600	1580
0	0.0	0.0	70.3	70.3	0.0	0.0	0.0	67.1	69.0
5	94.5	94.5	94.5	94.5	94.5	92.0	92.0	92.0	92.0
7	120.7	120.7	120.7	120.7	120.7	101.2	101.2	101.2	101.2
4	120.0	211.4	209.0	206.3	110.0	204.6	240.3	249.9	249.0
0	0.0	--	--	--	0.0	0.0	0.0	74.0	76.7
-	--	--	--	--	--	--	--	27.0	26.4
-	--	--	--	--	--	--	--	0.0	0.0
-	--	--	15.9	16.3	--	--	--	19.7	19.6
-	--	--	1.8	2.6	--	--	--	0.0	0.0
-	--	--	44.7	44.7	--	--	--	46.7	46.0
-	--	--	--	--	--	--	--	0.0	0.0
-	--	--	--	--	--	--	--	17.1	14.7
-	--	--	--	--	--	--	--	38.0	37.7
-	--	--	--	--	--	--	--	0.0	0.0
-	--	--	--	--	--	--	--	55.1	52.4
[illegible]	7.6	6.0	5.4	5.4	7.7	15.0	15.4	13.5	13.6

in error - to be corrected in next report

2

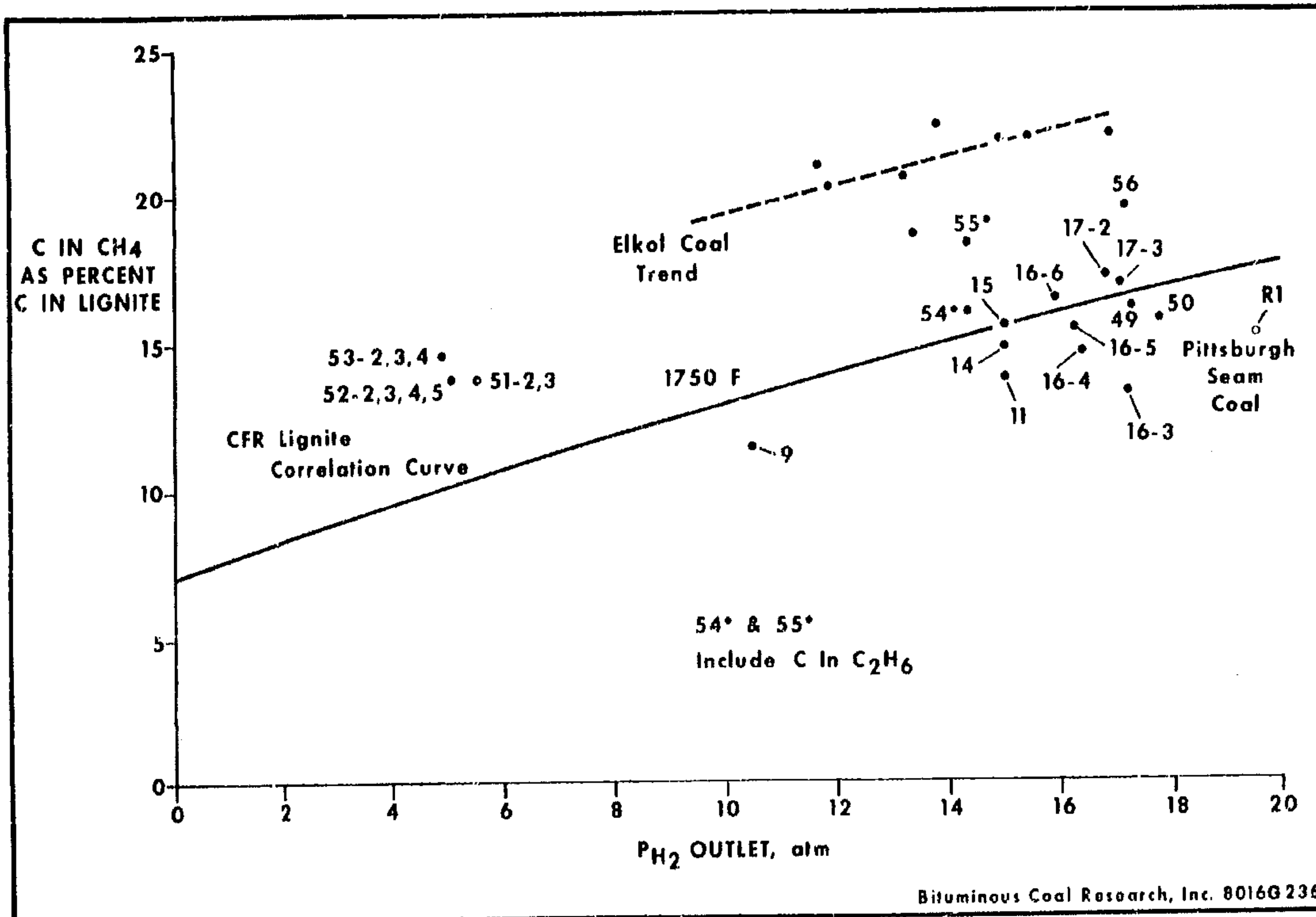


Figure 13. Effect of Outlet Hydrogen Partial Pressure on Methane Yield

time during Periods 4 and 5. Thus, the values as shown in Table 11 for carbon in the methane for Periods 4 and 5 have been corrected to read 15.9 and 16.3 percent, respectively. Since many other values for the Stage 2 performance criteria will be changed, the other data will be corrected and entered as such in the next progress report. For the present discussion, only the corrected values of carbon in methane and ethane as percent carbon in the coal will be used. The corrected average value of 18.3 percent carbon in methane plus ethane was employed in Figure 13.

During Period 2 of Test 55, the secondary procedure for evaluation of methane formed from cyclohexane by means of the C-14 technique, and as outlined for secondary procedures under Section B.3, page 3901 of Progress Report 92, was carried out. The oxygen supply to the Stage 1 burner was decreased such that the product gas contained 0.86 percent methane. Evaluation of carbon in the methane from the gas flow and methane percentage gave 1.00 lb carbon. Evaluation by means of the C-14 values of the catalytic and copper oxide determinations, as given for Period 3 in Table 6, amounted to 1.06 lb carbon. This is a very good check on the procedure for this particular case. However, inspection for other periods, where comparative evaluations are listed in Table 6, also shows variations in the two methods of evaluation, i.e., catalytic and copper oxide.

The average variation in comparative results on the same sample using the catalytic or copper oxide procedures were reported to be ± 1 percent. To illustrate the maximum differences obtainable, values of the catalytic and copper oxide C-14 determinations will be compared using the average variation.

Assume the true C-14 value to be 100 DPH/cu ft, and assume the catalytic value to be 1 percent high, or 101 DPH/cu ft, and copper oxide value to be low by 1 percent, or 99 DPH/cu ft. Also, assume no carbon as methane from cyclohexane and a cyclohexane rate equivalent to 50 lb carbon per hr. Calculation would then indicate

$$\frac{101 - 99}{101} \times 50 = 1.0^{+}$$

lb carbon in methane from cyclohexane. Further, assume that the uncorrected computer analysis for the Stage 2 performance criteria gives 20 percent C in methane, based on 30 lb carbon in coal, or 6.0 actual lb carbon. The calculated, correct value would actually be:

$$\frac{6.0 - 1.0}{30} \times 100 = 16.7$$

percent carbon in methane as percent carbon in coal.

For the purpose of evaluating the PEDU results, it has been the practice to neglect corrections when the difference between the catalytic and copper oxide C-14 values has been less than two percent. This has been the accepted procedure in all cases where the chromatographic analysis of the Stage 1 gas showed zero percent methane.

Figure 13 shows that the point for Test 55 is above the lignite correlation curve about 2.1 percentage points above the point for Test 54, and about 1.2 percentage points above the points for Test 17. It is concluded from the above that short residence time, even at reduced total system pressure, has definite influence on increasing the carbon conversion to methane. However, the effect of decreased insufflation into Stage 1, due to the location of the discharge port of the long coal feed nozzle, may also have had similar influence. Inspection of the various feed nozzles and Stage 1 proper indicated very little if any added accumulations of solid residues, i.e., char or slag, in the respective areas. These observations tend to indicate much less insufflation into Stage 1 when compared to the findings from similar previous inspections made during earlier operations with the regular coal feed nozzle. In these earlier operations char deposits were found on the various nozzles and definite increases in slag accumulation were found in Stage 1 proper.

The increase in carbon in the ethane to about 2.2 percent may again be attributed both to a lower Stage 1 and 2 mixing temperature, as indicated by the exit temperature of 1480 F, and to the decrease in residence time. However, a comparison of the exit temperature with that of Test 17, namely 1500 F, and of the carbon in the carbon oxides for the two tests, namely 24.9 and 25.0 percent, respectively, for Tests 17 and 55, leads to the conclusion that the reduced residence time may be the major contributing factor for the increase in carbon in the ethane.

The effect of increased superficial velocity of the transport gas (20 scfm hydrogen) at about 71 ft/sec, as compared to normal velocities of about 15 to 20 ft/sec, must also be given further consideration.

In PEDU Test 56, the coal feed rate was about the same as for the previous two tests, but the cyclohexane rate was increased about 2 percent to provide for an exit temperature above that obtained for PEDU Test 54, namely about 1600 vs 1440 F, respectively, for Tests 56 and 54. A small amount of purge hydrogen, about 4 scfm, was used to cool the coal feed nozzle and to provide for higher hydrogen partial pressure.

Figure 13 shows the point for Test 56 to be at the same hydrogen partial pressure as for Test 17, namely 17.0 atm. However, the carbon conversion to methane was increased from 17.1 to 19.6 percent for Tests 17 and 56, respectively.

No ethane was found in the product gases; this was attributed to the higher exit temperature and concomitant higher Stage 1 and 2 mixing temperature. Higher average carbon oxides formation, 26.7 vs 16.8, and 24.9 percent for Tests 56, 54, and 17, respectively, tends to confirm this latter observation.

Inspection of the various nozzles and Stage 1 proper indicated no insufflation of solid materials into Stage 1. On the basis of this and the foregoing observations, it is tentatively concluded that operating conditions for maximizing methane formation in the PEDU with "as used" lignite at 1,000 psig have been optimized as closely as practicable. However, further analyses of the data, including other system variables, are indicated to arrive at final, definite conclusions.

7. Extension and Termination of Stage 2 PEDU Test Program: Approval was received from OCR (letter of 9/24/71 from Paul Towson) for extension of the program through September, 1971 (letter of 9/16/71 from Glenn to Towson).

Following failure of the seal in the quench pump during PEDU Test 58, the decision was made to terminate the Stage 2 PEDU Test program. Verbal approval (via phone Glenn to Cochran) was obtained from OCR on September 28, 1971. Letter of confirmation (Glenn to Cochran) was sent to OCR on September 30, 1971.

8. Fluidized Weighing Tests: In a memorandum dated May 21, 1971, Dr. Donath suggested that particle fluidization could be used to measure the weight of char in the recycle hoppers of the BI-GAS pilot plant. This weighing method, if practicable, would have the advantage of replacing product gas with steam and thus avoid the loss of product gas surrounding the char going to Stage 1. It was suggested that the feasibility of such a scheme could be tested in the existing PEDU coal feed tank.

A gas distributing tube was added to the bottom of the coal feed tank to conduct the fluidization tests. Nitrogen was used as the fluidizing medium and weighing tests were conducted before and after PEDU Tests 53, 54, and 55. Figure 14 is a plot of the pressure drops through the coal feed tank obtained at minimum fluidization, and Table 12 is a comparison of the fluidization results and the coal feed tank weight loss. Because of pressure fluctuations in the coal

TABLE 12. COMPARISON OF FLUIDIZATION TEST RESULTS WITH COAL FEED TANK WEIGHT LOSS

PEDU Test No.	Fluidized* Weighing, lb	Tank Weight loss, lb
53	148	160
54	88	110
55	45	40

* Calculations based on mean Δp.

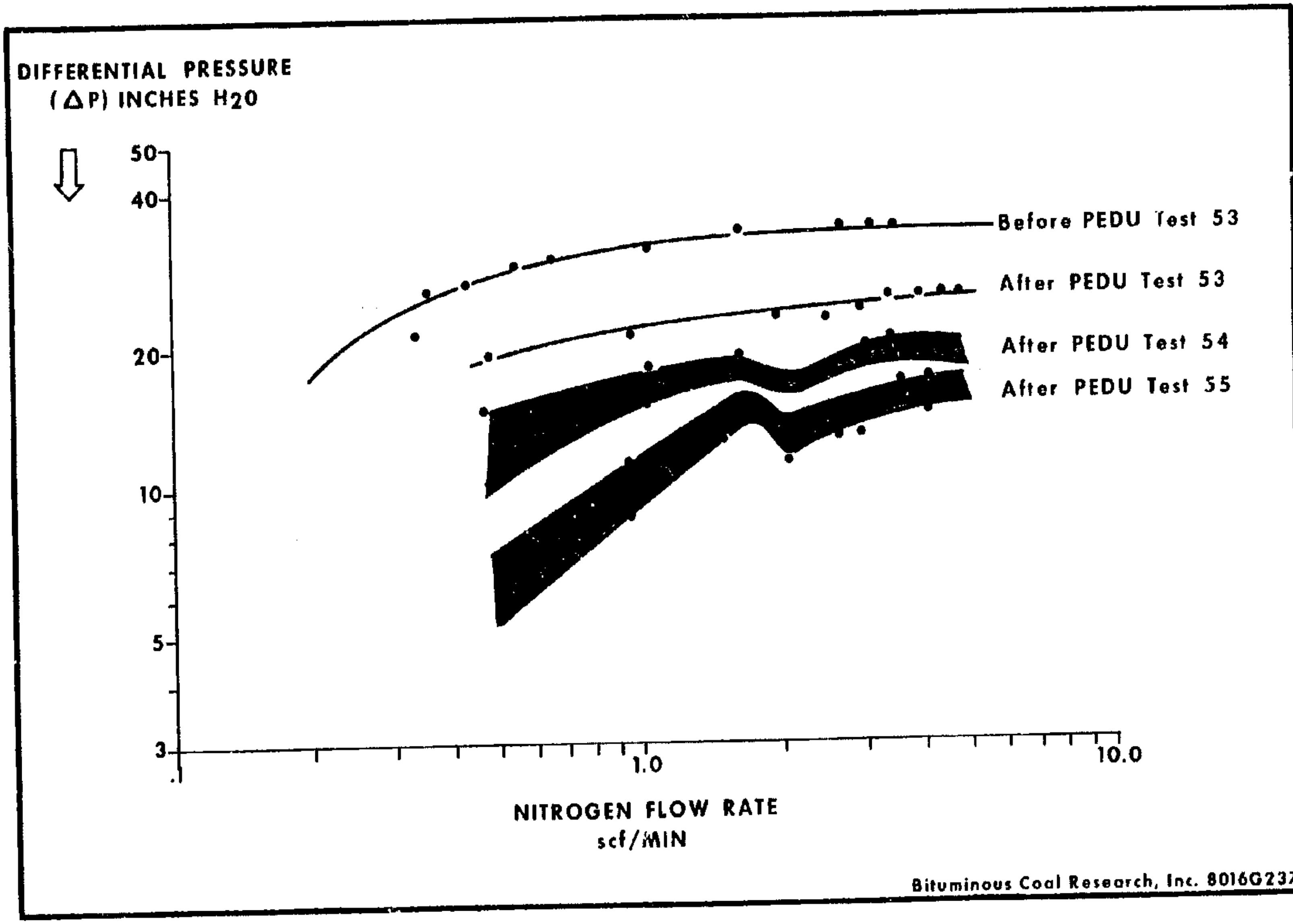


Figure 14. Coal Feed Tank Pressure Drop at Minimum Fluidization

tank under fluidized conditions, the results are significant only with ± 15 pounds of coal. With this in mind, there is close agreement between the test results and the weight loss values.

The minimum fluidization velocity for the lignite particles was calculated in the manner shown below:

ESTIMATION OF MINIMUM FLUIDIZING
VELOCITY FOR WEIGHING TESTS

Lignite average particle size .0029 inches
= .00024 feet

$$V = \frac{g\ (Pp-Pg)\ Dp^2\ EM^3}{150\ \mu\ (1-EM)} = ft/sec$$

Dp = diameter particle = .00024 feet
EM = fraction voidage = 0.6
g = 32 ft/sec^2
Pp = apparent particle density = 40 lb/cu ft
Pg = nitrogen density (@ 1 atm, 70 F) = 0.069 lb/cu ft
μ = nitrogen viscosity = 11.4×10^{-6} lb/ft sec

$$V = \frac{32\ (40 - 0.069)\ (.00024)^2\ (.6)^3}{150\ (11.4 \times 10^{-6} (\ (1-.6)}$$

= .02 ft/sec

= .06 acf/sec

= approximately 3.6 cu ft/min needed to fluidize lignite in coal feed tank

It should be noted that the coal feed tank was not designed for fluidized weighing. However, the results were encouraging and it is suggested that particle fluidization should be considered as an alternate method of weighing the recycle char.

9. Inspection of Long Coal Feed Nozzle, Creosote and Gas Burners After PEDU Tests 57 and 58: The long coal feed nozzle, 50002-3, was removed and inspected following PEDU Tests 57 and 58. After PEDU Test 57, the plastic cement around the top of the cooling water ring was missing. The Kaowool insulation for 2-1/2 inches from the tip was gone. Approximately 6 inches from the tip, the plastic cement was red in color and the remaining portion was black. The long coal feed nozzle was repaired. The condition of the unit after PEDU Test 58 was the same as that found after PEDU Test 57, except all the Kaowool insulation was present.

The modified creosote burner, 50001-2, was removed and inspected after PEDU Tests 57 and 58. The burner tip after both PEDU Tests 57 and 58 had the usual small deposits of slag. After PEDU Test 57, the burner had the usual buildup of carbon and char. Following PEDU Test 58, the top back half of the burner had an excessively large buildup of carbon and char in comparison to prior PEDU tests. The pitting around the face of the tip had increased slightly.

The gas burner, 50003, was not removed after PEDU Test 57. Following PEDU Test 58, the burner was covered with the usual amount of carbon and the ceramic tube was broken.

10. Inspection of Reactor After PEDU Tests 57 and 58: The condition of the reactor following PEDU Test 57 was the same as for PEDU Test 56 (see Progress Report 92, page 3909, Section B-7). Following PEDU Test 58, no additional slag buildup was found in Stage 1. Agglomerated slag was found on the shelf around the 2-inch diameter port of the poured refractory. Slag amounting to about 300 grams was removed.

11. Oxygen and Nitrogen Deliveries: Oxygen, amounting to 41,113 scf, was delivered on September 8, 1971. About 57,789 scf were used for PEDU tests. Cumulative oxygen to date amounts to 877,719 scf.

The 91st and 92nd deliveries of liquid nitrogen, amounting to 166,800 scf and 129,500 scf, respectively, or a total of 296,300 scf, were made on September 8 and 23, 1971, respectively; 294,000 scf were used for PEDU tests. Cumulative nitrogen use to date amounts to 14,907,625 scf.

12. Benzene, Coal, and Cyclohexane Deliveries: No deliveries of benzene, coal or cyclohexane were made during the month of September 1971.

13. System Changes and Additions

a. The teflon asbestos gasket of the sight glass on the ball valve on the gas burner, 50003, was replaced.

b. The "lo shut down" reed switch on the rotameter in the gas burner cooling system was lodged in the closed position. The sealed unit was replaced.

c. The inside diameter of Stage 2 of the reactor was reduced from 8.0 inches to 2.0 inches, beginning 26 inches below the center line of Stage 1, and ending at the outlet of Stage 2. This was accomplished by placing a two inch OD cardboard tube in Stage 2, then pouring a "High Alumina Castable," (Harbison Walker Castolast G,) around the cardboard tube.

During this operation, Thermocouples TC-6 and TC-12 were repositioned. TC-6 was placed into the gas stream 1/4 inch from castable surface and TC-12 was positioned at the gas-castable refractory inner fare.

14. Future Work: Since the Stage 2 PEDU (100 lb/hr) test program was officially terminated after PEDU Test 58, (see Section B.7 of this report) future work will include.

a. Assembly and analyses of data and results for PEDU Tests 57 and 58.

b. Revision and analyses of corrected data for PEDU Test 55.

c. Necessary work to place the PEDU equipment in "moth-ball" condition for future dismantling operations.

d. Preparation of final summary report.

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

1. Preliminary Studies for Model Tests: The preliminary studies have been completed and the Phase I and initial Phase III tests will soon be undertaken.

For Phase I tests, the burner shown in Figure 840 (see page 3914, Progress Report No. 92) will be used with different annuli to determine the design with the most favorable downstream mixing of the steam-char and oxygen streams. Air will be used to simulate the steam-char stream admitted down the center, and air with a 12 to 15 percent carbon dioxide content will be used to simulate oxygen.

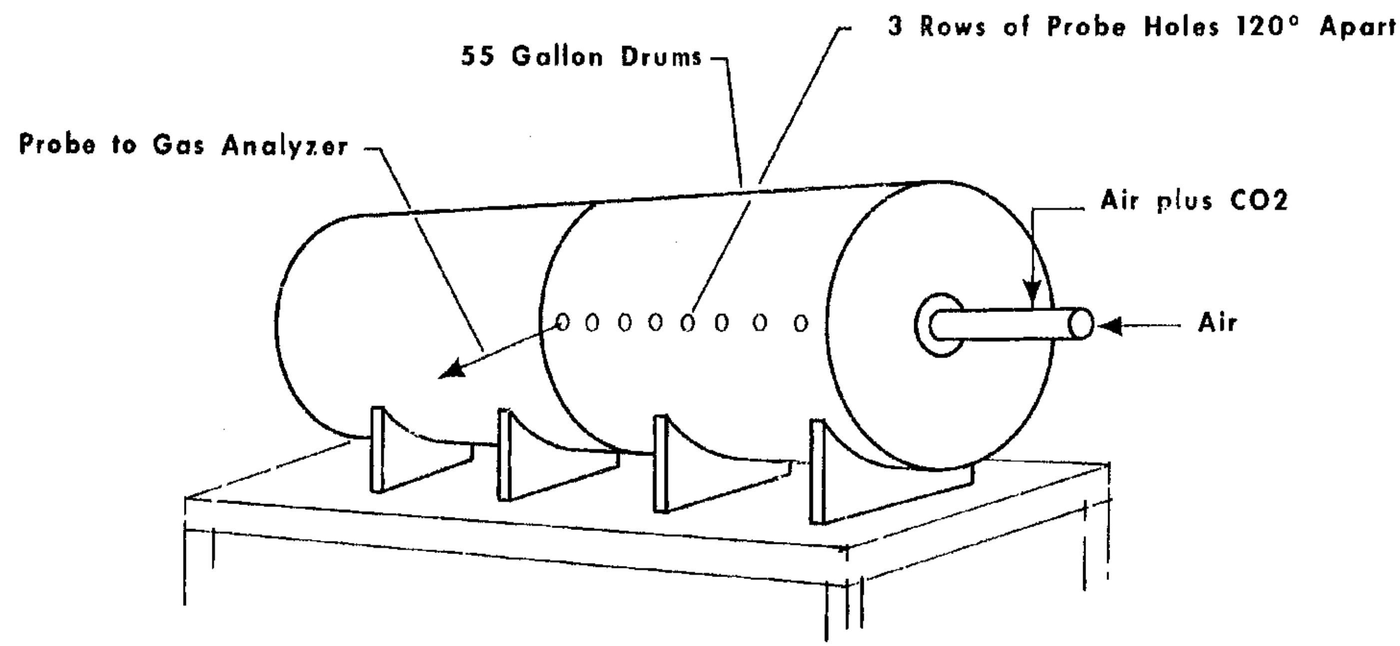
The test set-up will be as shown schematically in Figure 15. The burner, with the annulus to be tested, will be installed in the center of the bottom of a 55-gallon drum. Air at 14 scfm will be admitted down the center and air plus carbon dioxide at 5.6 scfm will be admitted through the annulus. The downstream mixing will be determined by sampling the gases at regular points along the axis of the burner and a regular distance from the center line at each point. The gases will be sampled for carbon dioxide content only, so as to determine a burner design that minimizes the chances of high oxygen content either near the burner entrance or near the opposite wall of the slag chamber.

A low-pressure blower, with a filter at the inlet, will be used to supply air, which will be measured using orifice meters. The carbon dioxide will be supplied from tanks and will be metered by rotameters. The MSA Lira carbon dioxide detector, presently used on the 100 lb/hr Stage 2 PEDU, will probably be used for rapid initial evaluations. The Gow Mac gas chromatography unit will be used for determination where higher accuracy is required.

For the initial Phase III tests, the set-up shown schematically in Figure 16 will be used. A 2-ft diameter chamber 4 ft high with 45 degree conical ends will be used to simulate the Stage 1 reactor. A provisional location of three burners will be made close to the base. A single burner will be equipped for air and oil injection, and air only will be used on the other two. Tests will be run first to simulate char injection with an atomizing nozzle and then to determine the effects of burner angle on the de-entrainment of the oil droplets before the air leaves the reactor outlet.

A Sonicore compressed air, oil nozzle has been selected for the initial tests. This nozzle will be used first with relatively low viscosity SAE 90 oil and then with SAE 250 gear oil which has the desired 30 poise viscosity at 85 F. It may be necessary to heat the latter oil to reduce its viscosity at the nozzle prior to atomization. However, any heating above 120 F is undesirable because additional means will then be necessary to cool the oil-air mixture at 85 F.

2. Preparation for Model Studies: The work area has been cleared. Much of the equipment to be used--blower, benches, scales, manometers, etc., -- is BCR equipment. This equipment is being moved to the work area. The plastic spool



Bituminous Coal Research, Inc. 8016G238

Figure 15. Schematic Layout of Equipment to Test Mixing Patterns from Prototype Steam-Oxygen Burner

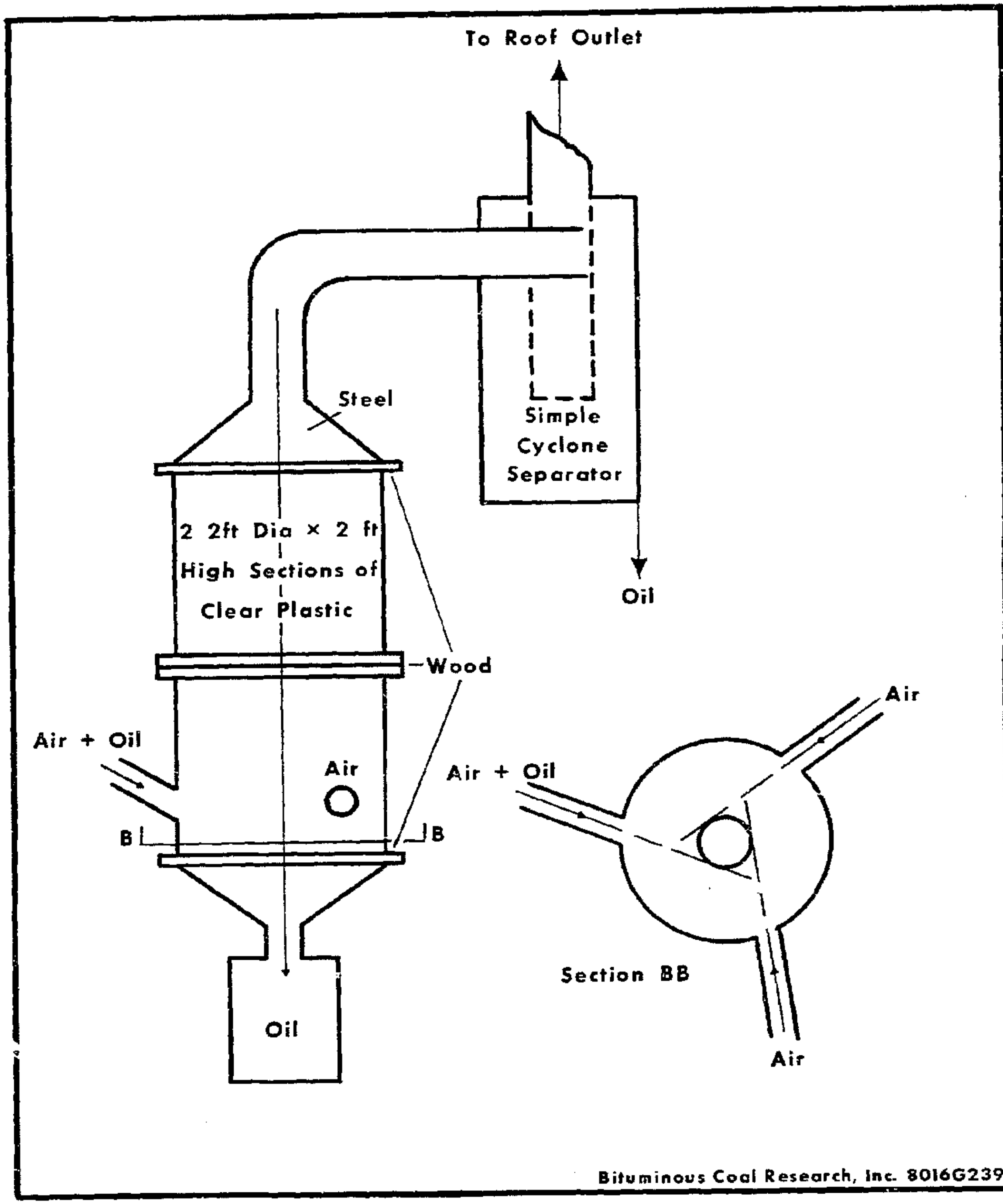


Figure 16. Schematic Layout of Equipment to Test Techniques for Evaluating Particulate Deentrainment from Stage 1 Reactor

pieces, sheet metal conical sections, atomizing nozzle, and fittings for the stack outlet have been ordered. Assembly of the equipment for Phase I testing has begun.

It is felt that most of the information required can be obtained from conventional steady state tests. However, it will be necessary to compare particulate injection through a 5/8-inch diameter tube with droplet injection from an orifice smaller than 1/8 inch, and it will also be necessary to determine the true residence time of the reactants. It is felt that such determination can best be made with the aid of stop-action photography. A series of pictures was taken of a water spray, and, as shown in Figure 17, the results are encouraging. It is felt that such pictures will be useful in future attempts to compare a cloud of atomized oil particles with a dust cloud.

3. Future Work: For the Phase I study, test work can be undertaken as soon as the components are set up.

Equipment for initial Phase III work has been ordered and early delivery has been promised. Installation will begin as the material is received.

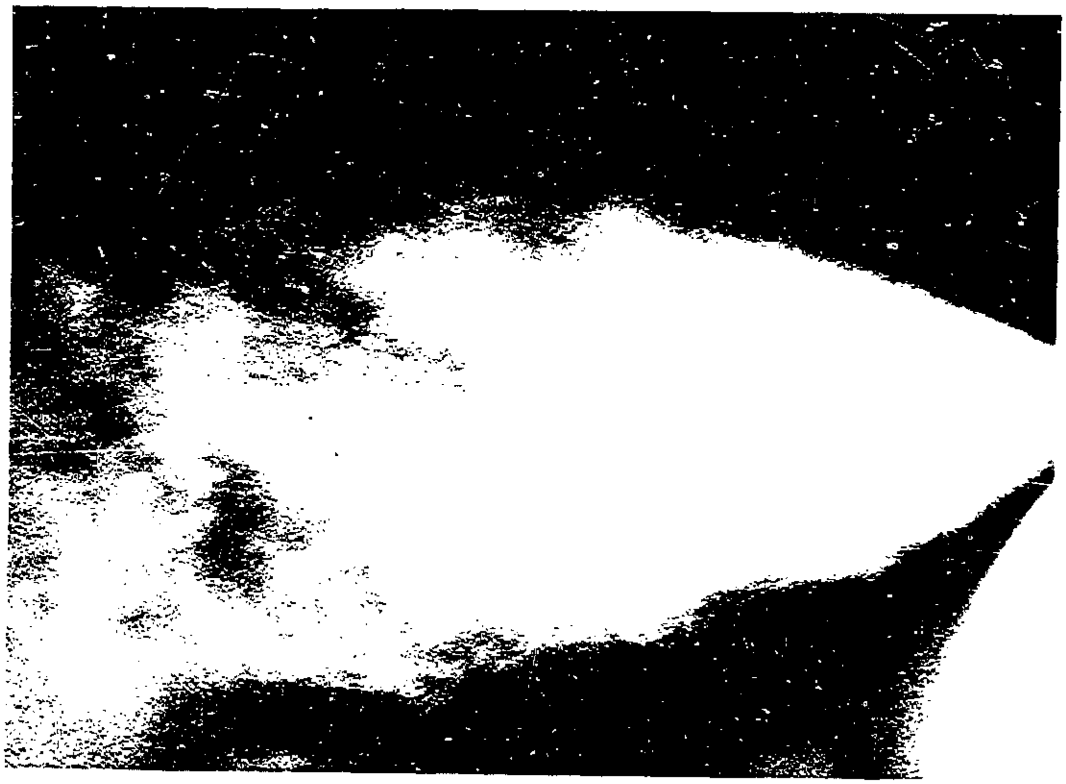


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Figure 17. View of Water Droplets at 3 to 4 Feet Illuminated by Single 500 Watt Floodlight

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

1. Stage 2 PEDU: All data through PEDU Test 56 have been processed.

2. Commercial Gasifier Modeling: As indicated in Progress Report No. 92, subroutine GASIFY was used to generate yield data for gasification of West Kentucky No. 11 seam coal. These test runs show that the subroutine is performing properly.

Revised gas yield expressions will be incorporated into the computer program prior to making gasifier simulation runs for Pittsburgh Seam, Elkol, and Lignite coals.

3. Automated Data Acquisition: Approval for purchase of the PDP8/E computer and peripherals from Digital Equipment Corporation was received. This equipment was ordered, and delivery is expected in late December, 1971.

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

a. Processing data from Stage 2 PEDU Tests 57 and 58.

b. Making several gasifier simulation runs for Pittsburgh seam, Elkol, and lignite coals using subroutine GASIFY.

E. Engineering Design and Evaluation

1. BI-GAS Process: The commercial gasifier computer program (subroutine GASIFY) is functioning properly; however, revised gas yield expressions based on recent data will be incorporated into the program. Subsequently, additional data will be generated on West Kentucky No. 11 seam coal as well as Pittsburgh, Elkol, and lignite coals.

As mentioned in last month's report, calculations had been made showing BI-GAS Stage 1 temperatures with complete char recycle. These calculations are presented in Appendix B. In addition, data on oxygen costs for the BI-GAS process, as computed from the Air Products report, are presented in Appendix C.

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. 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 are included in Appendix D.

3. Fischer-Tropsch System: No further work was done in this area this month. Also, no comments have been received from OCR concerning the evaluation included in Progress Report No. 90.

4. Electric Energy for Heat to Stage 1: As reported last month, the calculations given in Progress Report No. 90 for the complete gasification of coal were extended to a case with char withdrawal.

A char yield of 20 percent and methane yields of 20 and 27.5 percent on a carbon basis were assumed and the hydrogen partial pressure for these points obtained. Correlations from PEDU operation for methane yield and hydrogen partial pressure gave a 22.3 percent methane yield for the oxygen case and 26.1 percent for the electrothermal case. Using a coal price and char credit at 15 cents/MM Btu, $5/ton oxygen, 0.4 cents/kwh, and the unit operating cost from the 1970 Air Products and Chemicals, Inc., report, a cost advantage of about 8 cents/Mscf methane was indicated for the process using oxygen.

The complete data are included as Appendix E to this report.

F. Multipurpose Research Pilot Plant Facility (MPRF)

Design engineering for the research facility by Koppers Company, Inc., is to be completed by the end of November, 1971, according to present planning. At OCR's request, every assistance is being given to Koppers to ensure attainment of this objective. 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 F.)

A meeting with representatives of OCR and of AGA is scheduled for October 1, 1971, in the Koppers downtown Pittsburgh office; at this time progress achieved is to be reviewed and means for expediting the bid package discussed.

Discussions continue with American Lurgi and with Parsons Company concerning the licensing of the Purisol process, and with suppliers concerning the availability of catalysts for the CO-shift and methanation steps. In keeping with an understanding reached on August 17, 1971, Parsons is beginning to supply needed information on the Purisol process for the bid package.

The technical paper outlining the pilot plant design characteristics and status was presented at the Fall Meeting of the ACS Division of Fuel Chemistry, Symposium on Gasification of Coal, September, 1971, Washington, D. C.

G. Literature Search (V. E. Gleason)

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

H. Other

1. Prime Contract Matters: During the present report period, the necessary papers for transfer of work to the new contract were completed.

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.

The review of the performance under Subcontract No. 2, in accordance with Amendment No. 6, has been completed and a draft of a proposed Amendment No. 7 has been submitted to Koppers for their review and execution prior to submission to OCR for approval and subsequent counter-signature by BCR.

3. Brigham Young University: The project entitled "Study of High Rate, High Temperature Pyrolysis of Coal" with joint funding by Brigham Young University and BCR, is now in its sixth month. The letter report of progress by BYU is as follows:

During the past month, several test runs with hydrogen as the carrier gas for the powdered coal were carried out and initial tests with a shorter unheated reactor were made.

The use of hydrogen as a carrier gas in place of nitrogen has resulted in a substantially higher yield of hydrocarbon gases. Table 13 compares the data from a set of runs completed this month with that from runs with nitrogen carrier reported last month. The coal feed rate for these runs was 3.1 lb per hour. These data show that the dry, carrier gas-free concentration of hydrocarbon gases obtained with hydrogen carrier is nearly double that obtained previously with nitrogen carrier.

With hydrogen as the carrier gas, char buildup inside the reactor occurs at a lower rate than with nitrogen. With a coal/oxygen feed ratio of 2.4, the reactor would plug after approximately 8 minutes of operation whereas previously, plugging occurred after approximately 4 minutes.

Table 14 presents data showing the effects of increasing the feed rate to the reactor. Doubling the feed rate through the reactor was found to have the effect of decreasing the amount of carbon gasified by approximately 25 percent. It also had the effect of reducing the fraction of gasified carbon converted to hydrocarbon gases by approximately 40 percent.

Also shown in Table 14 are data showing the effect of operating the hydrogen/oxygen burner oxidizer rich. The overall gasification of carbon was

TABLE 13. DATA AND RESULTS FOR TESTS WITH NITROGEN AND HYDROGEN AS CARRIER GAS

Carrier Gas	Nitrogen	Hydrogen
Feed Rates, lb/hr		
Coal	3.1	3.1
Oxygen	1.3	1.3
Hydrogen	0.2	0.4
Nitrogen	0.8	0.4
Reactor Temperature*, F	2089	2048
Gas Analysis**, Mole percent		
Hydrogen	55.5	42.7
Carbon Monoxide	29.5	35.1
Carbon Dioxide	5.2	4.4
Methane	5.6	9.8
Ethane	--	0.2
Ethylene	1.5	2.7
Acetylene	2.7	5.2

* Measured at location A, 2-1/4" below point of coal injection.

** Samples withdrawn at location A. Analysis is dry, carrier-free basis.

TABLE 14. DATA AND RESULTS FOR TESTS WITH INCREASED COAL FEED RATE AND OXIDIZER-RICH BURNER OPERATION

Feed Rates, lb/hr			
Coal	3.1	5.8	5.8
Oxygen	1.3	2.4	2.4
Hydrogen	0.2	0.4	0.2
Nitrogen	0.4	0.4	0.4
Reactor Temperature*, F	2043	2282	2102
Gas Analysis**, Mole percent			
Hydrogen	59.4	55.7	48.3
Oxygen	0.5	0.7	0.4
Nitrogen	7.5	6.1	5.6
Carbon Monoxide	20.2	28.3	36.3
Carbon Dioxide	2.4	2.3	4.0
Methane	6.0	4.4	3.6
Ethylene	1.4	0.5	0.5
Acetylene	2.6	2.0	1.3

* Measured at location A, 2-1/2" below point of coal injection.

** Samples withdrawn at location C, 4-3/4" below point of coal injection. Analysis is dry basis.

only slightly changed; however, the conversion to carbon monoxide was greatly increased at the expense of hydrocarbon gases. Thus, it appears to be important that the oxygen be reacted prior to injection of the coal.

Initial tests were made with a shorter length reactor. In place of the 8-inch long alumina reactor which has been used to obtain the data reported last month and also that discussed above, a 4-inch graphite lined reactor was employed. This reactor was not electrically heated. When the reactor was operated at a coal feed rate of 3.1 lb per hour and a coal/oxygen ratio of 2.4, as employed previously with an 8 inch reactor, the hydrogen/oxygen flame was observed to be unstable and the temperature reached inside the reactor was reduced from 2048 to 1527 F. It was concluded that this reactor configuration was unsuitable.

Plans for the month of October include preparation of the first semi-annual report and redesigning the reactor to provide a longer residence time for the hydrogen-oxygen flame and a shorter residence time for the coal.

4. Reports and Papers: The revised manuscript of the paper entitled "Gasification of Lignite by the BCR Two-stage Super-pressure Process," by R. J. Grace, R. A. Glenn, and R. L. Zahradnik, has been 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: In August, 1970, BCR advised the solicitor of its desire to obtain patent protection on new processes in foreign countries. Conditions for BCR to obtain this protection were generally agreed upon by the parties concerned in October, 1970. A review of the files on OCR-866 and OCR-1078 and a new invention disclosure by E. E. Donath of December 11, 1970, revealed that Donath's process of December 11, 1970, was distinguishable from the previously described process and a U.S. patent application based on the new process concept has now been prepared and approved by the solicitor for filing. The application, entitled "Gasification of Carbonaceous Solids," (nine claims) was mailed to the Patent Office September 21, 1971, by BCR patent attorney, Stanley J. Price, Jr. 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. On July 6, 1971, the Office of the Solicitor, U.S. Department of the Interior, acknowledged receipt of these invention disclosures and assigned case numbers as follows:

BCR Suggestion 178	"Low-sulfur Char from Coal Gasification"	OCR-1859
BCR Suggestion 182	"Coal Premethanation for BCR Two-stage Process"	OCR-1860
BCR Suggestion 183	"Coal Prehydrogenation for BCR Two-stage Process"	OCR-1861
BCR Suggestion 185	"Two-stage Downflow Gasifier with Connected Fluidized Char Bed"	OCR-1862
BCR Suggestion 186	"Two-stage Downflow Gasification"	OCR-1863
BCR Suggestion 189	"Two-stage Gasifier"	OCR-1864

Also, the Solicitor's Office, in the letter of July 6, took recognition of the fact that BCR might, under certain circumstances, be interested in filing for patents of the subject inventions.

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 to develop patent applications for filing in the U.S., first obtaining the approval of the Solicitor's Office.

I. Visitors During September, 1971

September 1, 1971

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

September 2, 1971

Mr. R. O. Parker
Mr. E. V. Schulte
Koppers Company, Inc.
Koppers Building
Pittsburgh, Pa. 15219

September 10, 1971

Mr. J. H. Robb
Koppers Company, Inc.
Koppers Building
Pittsburgh, Pa. 15219

September 22, 1971

Mr. Robert Smock
Electric Light & Power
221 Columbus Avenue
Boston, Massachusetts

September 23, 1971

Mr. J. F. Farnsworth
Koppers Company, Inc.
Koppers Building
Pittsburgh, Pa. 15219

September 30, 1971

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

J. Trips, Visitors, and Meetings During September

September 14, 1971	Division of Fuel Chemistry National ACS Meeting Washington, D. C.	R. A. Glenn
September 14-15, 1971	Office of Coal Research Washington, D. C.	R. A. Glenn
September 21, 1971	Office of Coal Research Washington, D. C.	R. A. Glenn

K. Requests for Information

Mr. Edward M. Petsonk
Electrical Contractors Associates, Inc.
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Mr. John Stekly
Magnetic Corp. of America
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Cambridge, Massachusetts 02142

Mr. A. D. Singh
Consulting Engineer
4015 N. Whipple Street
Chicago, Illinois 60618

Mr. J. B. Jasmin
DeLaval Turbine, Inc.
1910 Cochran Road
Pittsburgh, Pennsylvania 15220

Mr. Stephen R. Anderson
System Planning, 22nd Floor
Michigan Wisconsin Pipe Line Co.
One Woodward Avenue
Detroit, Michigan 48227

Lawrence Radiation Laboratory
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Livermore, California 94550

Mr. J. N. Baird
United Engineers and Constructors
1401 Arch Street
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Mr. Don Weinert
MAPCO, Inc.
1437 S. Boulder Avenue
Tulsa, Oklahoma 74119