BITUMINOUS COAL RESEARCH, INC.

OCR-SPONSORED
GAS GENERATOR RESEARCH AND DEVELOPMENT

Progress Report No. 12-A
(BCR Report L-482)

I. INTRODUCTION

This report summarizes progress during the month on a part of the general program, "Gas Generator Research and Development," being conducted by Bituminous Coal Research, Inc., for the Office of Coal Research. This represents that portion of progress under Contract No. 14-32-0001-1207 being solely sponsored by the Office of Coal Research.

The overall objective of the program continues to be to develop processes for gasifying coal with emphasis on the production of a fuel gas. Laboratory-scale coal gasification experimentation is to be continued, together with process and equipment development.

A. Monthly Progress Charts

Monthly progress charts reflecting proposed rate of effort and expenditures on projects sponsored solely by the Office of Coal Research are shown in Appendixes A-1 and A-2.

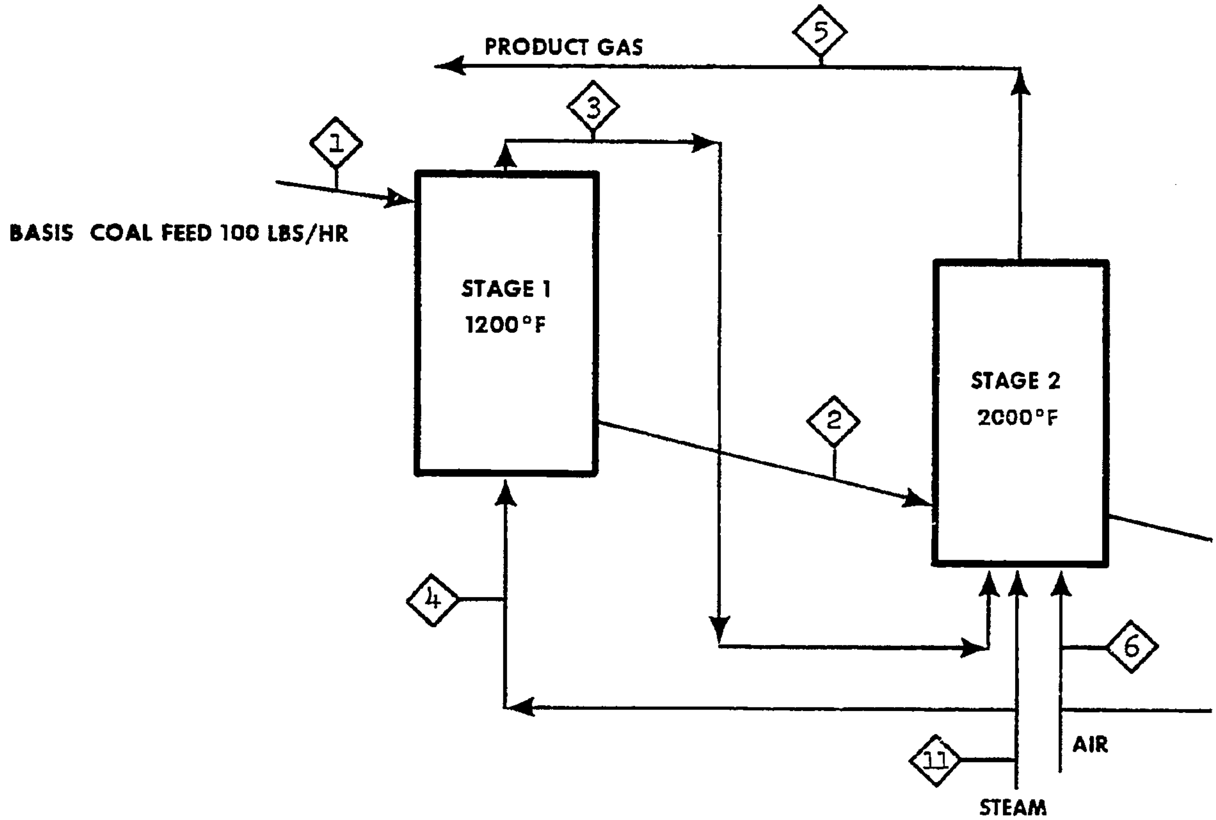
II. PROGRESS ACHIEVED DURING THE MONTH ENDING AUGUST 25, 1972

A. Fluidized-bed Gasification Studies (J. T. Stewart)

Design work on the fluidized-bed gasification PEDU progressed with receipt of preliminary vessel drawings from Foster Wheeler. Data from the fluidized-bed batch reactor continue to substantiate assumptions that were made during the development of the PEDU material balance.

1. Fluidized-bed PEDU: The material balance for the air-blown gasification of coal in the fluidized-bed PEDU has been completed. This was received from Foster Wheeler as Drawing No. 11-22334 and is shown in Figure 18. Preliminary sketches of the following vessels were also received:

1.	R-101, R-102, R-103	Stage 1, Stage 2, and Stage 3 Reactors, respectively.
2.	D-101	Coal Feed Hopper
3.	D-102	Coal Lock Hopper
4.	D-103	Ash Lock Hopper
5.	D-104	Char Fines Hold Bin
6.	Specifications for the natural gas compressor.	



STREAM NO.	1		2		3		4		5		6
STREAM	COAL FEED		CHAR FROM STAGE 1		STAGE 1 FLUE GAS		STAGE 3 FLUE GAS		PRODUCT GAS		AIR TO STAGE 2
	LBS	WT, %	LBS	WT, %	MOLS	VOL, %	MOLS	VOL, %	MOLS	VOL, %	MOLS
COAL (ASH FREE)	93.8	93.8	72.6	92.1							
ASH	6.2	6.2	6.2	7.9							
H_2					0.95	13.7	0.95	16.2	4.7	21.3	
CO					1.53	22.0	1.53	26.0	5.16	23.4	
CO_2					0.37	5.3	0.37	6.3	1.04	4.7	
H_2O					0.55	7.9	0.55	9.4	2.00	9.0	
N_2					2.48	35.7	2.48	42.1	9.14	41.4	
H_2S									0.05	0.2	
STAGE 1 OFF GAS					1.06	15.4					
TOTAL	100.0	100.0	78.8	100.0	6.94	100.0	5.88	100.0	22.1	100.0	8.43
AVG MOL WT					23.3		23.9		22.3		29
TEMP, °F	77		1200		1200		2100		2000		1000
PRESS, PSIA					250		250		250		300
SCFM					43.8		37.1		140.0		53.0
ACFM					8.2		10.7		38.9		7.3

Figure 18. Material Balance for Gasification

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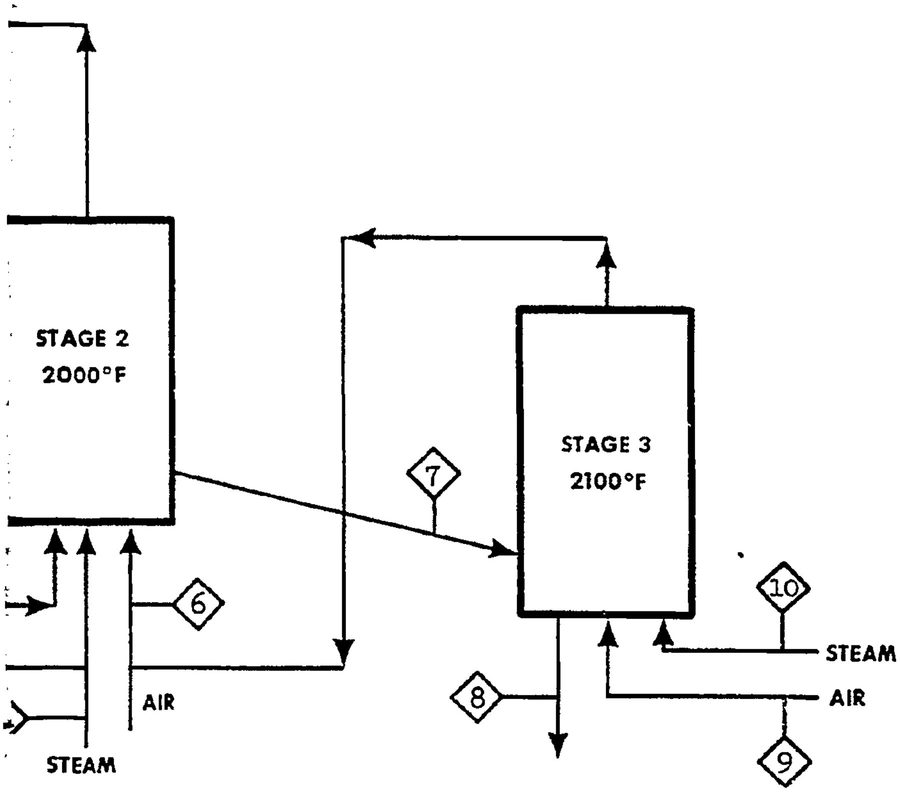

5		6	7		8		9	10	11
..T GAS		AIR TO STAGE 2	CHAR FROM STAGE 2		CHAR FROM STAGE 3		AIR TO STAGE 3	STEAM TO STAGE 3	STEAM TO STAGE 2
	VOL, %	MOLS	LBS	WT, %	LBS	WT, %	MOLS	MOLS	MOLS
			26.4	81	3.6	37			
			6.2	19	6.2	63			
7	21.3								
6	23.4								
4	4.7								
0	9.0								
4	41.4								
5	0.2								
1	100.0	8.43	32.6	100	9.8	100	3.14	1.50	2.5
22.3		29					29	18	18
2000		1000	2000		2100		1000	1000	1000
250		300	250				300	300	300
40.0		53.0					19.8	9.5	15.8
38.9		7.3					2.7	1.31	2.17

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for Gasification with Air and Steam

Figure 19 is a projected work schedule for the fluidized-bed gasification studies through fiscal year 1975, based upon our best current predictions.

Laboratory studies will continue, as required, to provide data in support of PEDU design and operation.

PEDU design engineering by Foster Wheeler is expected to be essentially complete by the end of October. The projected detailing, procurement, and construction phases are contingent upon acceptance of the PEDU design and cost estimate, and upon authorization by OCR to proceed with construction of the unit. Time required for these latter phases is only an estimate, but reflects, in part, our current experience regarding progress on the methanation PEDU.

2. Laboratory Investigations: Eleven test runs were made with the fluidized-bed batch reactor (FBBR) during the month using the new flow scheme shown in Figure 16 of Progress Report No. 11-A. The system worked satisfactorily with the only problem being the short life expectancy of the gas distributor.

a. Char Reactivity Studies: No TGA tests were made during the month. No immediate tests are planned pending further collection and interpretation of data from the batch reactor.

b. Fluidized-bed Gasification Batch Reactor: The study of air-blown fluidized-bed gasification continued during the month using the batch reactor. Eleven tests were made at a pressure of approximately 65 psia and a temperature of 940 C. For convenience, these tests used air and carbon dioxide as the gasifying medium, rather than air and steam. The two chars chosen for these tests were thought to be reasonably similar to the partially devolatilized coal that will leave the PEDU Stage 1 reactor. Thus, the fluidized-bed batch reactor is being used to simulate the second stage of the three-stage, air-blown, fluidized-bed concept. The second stage is the major gasification step in the three-stage concept. Laboratory-scale batch reactor studies are being conducted for the purpose of predicting the product gas analysis, the extent of steam or carbon dioxide decomposition, and the required solids residence time. Tables 8 through 19 summarize the results of the first series of FBBR air-blown tests.

(1) FBBR Test 3: This was the first test in which the complete FBBR system, including the inline gas chromatograph, was used. The purpose of this test was to establish reasonable feed rates and to calibrate the flow controllers. Earlier char reactivity tests (as summarized in Appendix A, Progress Report No. 9-A) gave kinetic data for the char-carbon dioxide reaction. Based on the gas residence time in the FBBR, the carbon dioxide feed rate was initially set such that the time needed for the complete reduction of the carbon dioxide equalled the residence time. The air rate was set based on two assumptions:

(a) The carbon dioxide utilization would be 50 percent.
(b) Half of the carbon would be gasified with carbon dioxide, and half with oxygen.

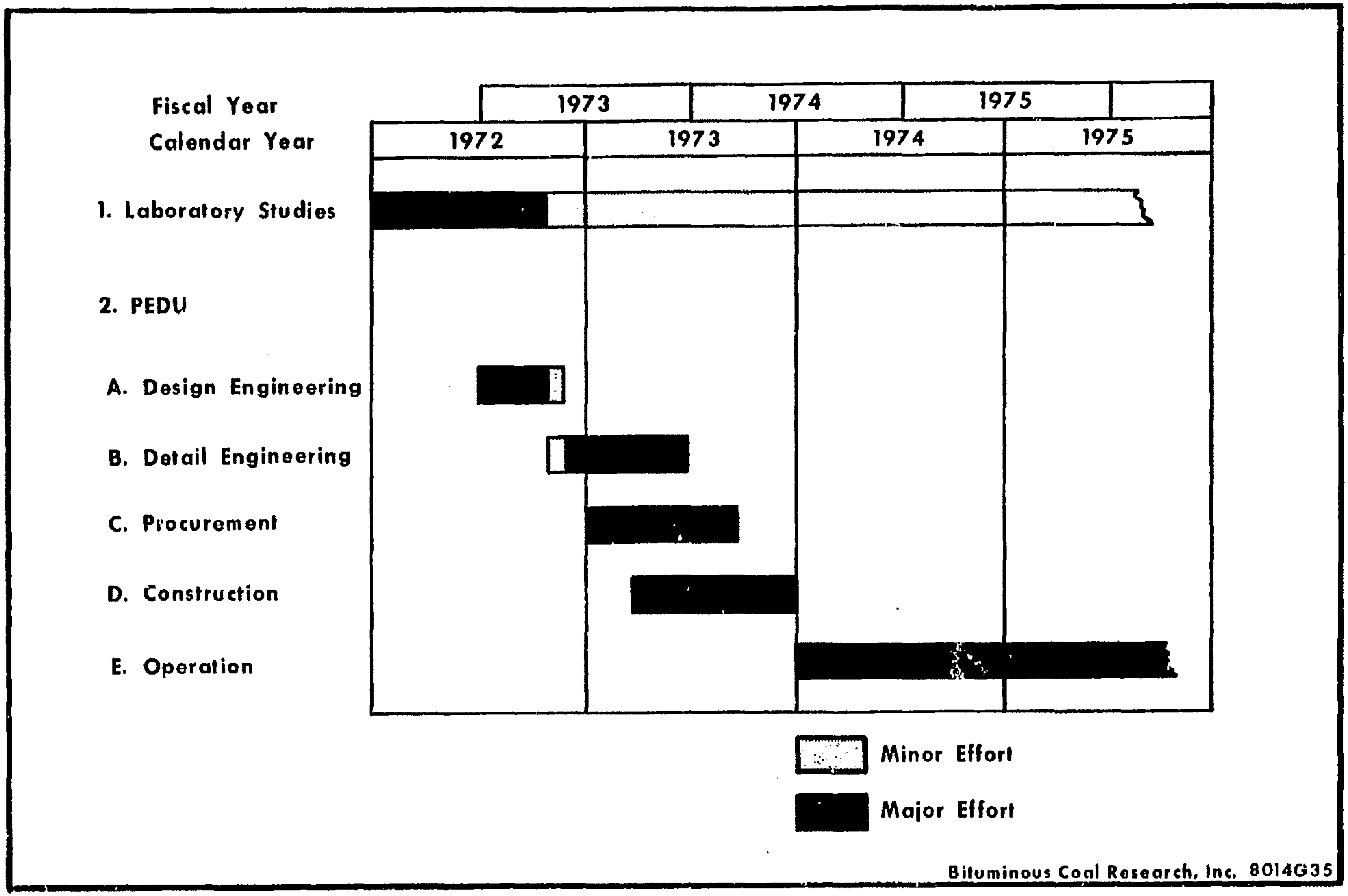


Figure 19. Fluidized-Bed Gasification Schedule

TABLE 8. MATERIAL BALANCE FOR FLUIDIZED-BED BATCH REACTOR AIR-BLOWN GASIFICATION TEST NUMBER 3

Reactor Pressure 72 psia
Reactor Temperature 940 C
Initial Charge to Reactor 20 grams FMC char, BCR Lot 2455

Component	Feed		Product	
	mole percent	g moles/min	mole percent	g moles/min
Oxygen	11.5	0.0084	0.20	0.0002
Nitrogen	43.5	0.0316	31.85	0.0316
Carbon Dioxide	45.0	0.0330	31.52	0.0313
Carbon Monoxide	0	0	36.43	0.0361
Hydrogen	0	0	0	
TOTAL	100.0	0.0730	100.00	0.0992

Feed gas rate 1650 sml/min
Product gas rate 2225 sml/min

	In	Out
Total g moles Carbon*	0.033	0.0674
Total g moles Oxygen	0.0414	0.0490
Total g moles Nitrogen	0.0316	0.0316

* Carbon gasification rate 0.0344 g moles/min
Carbon Dioxide utilization 5 percent

TABLE 9. MATERIAL BALANCE FOR FLUIDIZED-BED BATCH REACTOR AIR-BLOWN GASIFICATION TEST NUMBER 4

Reactor Pressure 68 psia
Reactor Temperature 940 C
Initial Charge to Reactor 20 grams FMC char, BCR Lot 2455

	Feed		Product	
Component	mole percent	g moles/min	mole percent	g moles/min
Oxygen	12.4	0.00846	0.12	0.0001
Nitrogen	46.4	0.03160	30.72	0.0316
Carbon Dioxide	41.2	0.02824	21.45	0.0221
Carbon Monoxide	0	0	47.71	0.0491
Hydrogen	0	0	0	0
TOTAL	100.0	0.06830	100.00	0.1029

Feed gas rate 1530 sml/min
Product gas rate 2300 sml/min

	In	Out
Total g moles Carbon*	0.02824	0.0712
Total g moles Oxygen	0.03770	0.0467
Total g moles Nitrogen	0.03160	0.03160

* Carbon gasification rate 0.0429 g moles/min
Carbon Dioxide utilization 21.7 percent

TABLE 10. MATERIAL BALANCE FOR FLUIDIZED-BED BATCH REACTOR AIR-BLOWN GASIFICATION TEST NUMBER 5

Reactor Pressure 68 psia
Reactor Temperature 940 C
Initial Charge to Reactor 20 grams FMC char, BCR Lot 2455

Component	Feed		Product	
	mole percent	g moles/min	mole percent	g moles/min
Oxygen	12.4	0.00846	0.46	0.0005
Nitrogen	46.4	0.03160	36.15	0.0316
Carbon Dioxide	41.2	0.02824	25.59	0.0224
Carbon Monoxide	0	0	37.80	0.0330
Hydrogen	0	0	0	0
TOTAL	100.0	0.06830	100.00	0.0875

Feed gas rate 1530 sml/min
Product gas rate 1960 sml/min

	In	Out
Total g moles Carbon*	0.02824	0.05540
Total g moles Oxygen	0.03770	0.0394
Total g moles Nitrogen	0.0316	0.0316

* Carbon gasification rate 0.02716 g moles/min
Carbon Dioxide utilization 21 percent

TABLE 11. MATERIAL BALANCE FOR FLUIDIZED-BED BATCH REACTOR AIR-BLOWN GASIFICATION TEST NUMBER 6

Reactor Pressure 66 psia
Reactor Temperature 940 C
Initial Charge to Reactor 20 gram FMC char, BCR Lot 2455

	Feed		Product	
Component	mole percent	g moles/min	mole percent	g moles/min
Oxygen	12.4	0.00846	0.62	0.0006
Nitrogen	46.4	0.03160	37.42	0.0316
Carbon Dioxide	41.2	0.02824	23.43	0.0197
Carbon Monoxide	0	0	38.53	0.0326
Hydrogen	0	0	0	0
TOTAL	100.0	0.06830	100.00	0.0845

Feed gas rate 1530 sml/min
Product gas rate 1892 sml/min

	In	Out
Total g moles Carbon*	0.02824	0.0523
Total g moles Oxygen	0.03770	0.0366
Total g moles Nitrogen	0.0316	0.0316

* Carbon gasification rate .02406 g moles/min
Carbon Dioxide utilization 30 percent

TABLE 12. MATERIAL BALANCE FOR FLUIDIZED-BED BATCH REACTOR AIR-BLOWN GASIFICATION TEST NUMBER 7

Reactor Pressure 66 psia
Reactor Temperature 940 C
Initial Charge to Reactor 20 grams FMC char, BCR Lot 2455

Component	Feed mole percent	Feed g moles/min	Product mole percent	Product g moles/min
Oxygen	12.4	0.00846	0.20	0.0003
Nitrogen	46.4	0.03160	34.70	0.0316
Carbon Dioxide	41.2	0.02824	27.10	0.0247
Carbon Monoxide	0	0	38.00	0.0346
Hydrogen	0	0	0	0
TOTAL	100.0	0.06830	100.00	0.0912

Feed gas rate 1530 sml/min
Product gas rate 2040 sml/min

	In	Out
Total g moles Carbon*	0.02824	0.0593
Total g moles Oxygen	0.03770	0.0423
Total g moles Nitrogen	0.03160	0.03160

* Carbon gasification rate .03106 g moles/min
Carbon Dioxide utilization 12.5 percent

TABLE 13. MATERIAL BALANCE FOR FLUIDIZED-BED BATCH REACTOR AIR-BLOWN GASIFICATION TEST NUMBER 8

Reactor Pressure 66 psia
Reactor Temperature 940 C
Initial Charge to Reactor 20 grams FMC char, BCR Lot 2455

	Feed		Product	
Component	mole percent	g moles/min	mole percent	g moles/min
Oxygen	12.4	0.00846	0.5	0.0004
Nitrogen	46.4	0.03160	37.4	0.0316
Carbon Dioxide	41.2	0.02824	24.0	0.0203
Carbon Monoxide	0	0	38.0	0.0321
Hydrogen	0	0	0.1	0
TOTAL	100.0	0.06830	100.0	0.0844

Feed gas rate 1530 sml/min
Product gas rate 1890 sml/min

	In	Out
Total g moles Carbon*	0.02824	0.0524
Total g moles Oxygen	0.03770	0.0367
Total g moles Nitrogen	0.03160	0.03160

* Carbon gasification rate 0.02416 g moles/min
Carbon Dioxide utilization 28 percent

TABLE 14. MATERIAL BALANCE FOR FLUIDIZED-BED BATCH REACTOR AIR-BLOWN GASIFICATION TEST NUMBER 9

Reactor Pressure 66 psia
Reactor Temperature 940 C
Initial Charge to reactor 20 grams FMC char, BCR Lot 2455

	Feed		Product	
Component	mole percent	g moles/min	mole percent	g moles/min
Oxygen	21.0	0.00846	0.22	0.00011
Nitrogen	79.0	0.03160	65.29	0.03160
Carbon Dioxide	0	0	2.91	0.00141
Carbon Monoxide	0	0	31.30	0.01515
Hydrogen	0	0	0.28	0.00013
TOTAL	100.0	0.04006	100.00	0.04840

Feed gas rate 900 sml/min
Product gas rate 1065 sml/min

	Feed	Product
Total g moles Carbon*	0.0	0.01656
Total g moles Oxygen	0.00846	0.00909
Total g moles Nitrogen	0.0316	0.0316

* Carbon gasification rate 0.01656 g moles/min
Carbon Dioxide utilization Not applicable percent

TABLE 15. MATERIAL BALANCE FOR FLUIDIZED-BED BATCH REACTOR AIR-BLOWN GASIFICATION TEST NUMBER 10

Reactor Pressure 66 psia
Reactor Temperature 940 C
Initial Charge to Reactor 20 grams FMC char, BCR Lot 2455

Component	Feed mole percent	Feed g moles/min	Product mole percent	Product g moles/min
Oxygen	21.0	0.00846	.05	0.00012
Nitrogen	79.0	0.03160	66.88	0.03160
Carbon Dioxide	0	0	2.62	0.00124
Carbon Monoxide	0	0	30.45	0.01444
Hydrogen	0	0	0	0
TOTAL	100.0	0.04006	100.00	0.04740

Feed gas rate 900 sml/min
Product gas rate 1060 sml/min

	In	Out
Total g moles Carbon*	0.0	0.01568
Total g moles Oxygen	0.00846	0.00848
Total g moles Nitrogen	0.0316	0.0316

* Carbon gasification rate 0.01568 g moles/min
Carbon Dioxide utilization Not applicable percent

TABLE 16. MATERIAL BALANCE FOR FLUIDIZED-BED BATCH REACTOR AIR-BLOWN GASIFICATION TEST NUMBER 11

Reactor Pressure 66 psia
Reactor Temperature 940 C
Initial Charge to Reactor 20 grams FMC char, BCR Lot 2455

Component	Feed		Product	
	mole percent	g moles/min	mole percent	g moles/min
Oxygen	0	0	0.11	.0002
Nitrogen	0	0	0.27	.0005
Carbon Dioxide	100.0	0.0335	41.58	.0192
Carbon Monoxide	0	0	58.04	.0275
Hydrogen	0	0	0	0
TOTAL	100.0	0.0335	100.00	.0474

Feed gas rate 750 sml/min
Product gas rate 1060 sml/min

	In	Out
Total g moles Carbon*	.0335	.0467
Total g moles Oxygen	NA	NA
Total g moles Nitrogen	NA	NA

* Carbon gasification rate .0132 g moles/min
Carbon Dioxide utilization 42.7 percent

TABLE 17. MATERIAL BALANCE FOR FLUIDIZED-BED BATCH REACTOR AIR-BLOWN GASIFICATION TEST NUMBER 12

Reactor Pressure 66 psia
Reactor Temperature 940 C
Initial Charge to Reactor 20 grams FMC char, BCR Lot 2455

Component	Feed mole percent	Feed g moles/min	Product mole percent	Product g moles/min
Oxygen	0	0	0.05	0.0001
Nitrogen	0	0	0.36	0.0001
Carbon Dioxide	100.0	0.0335	42.61	0.0201
Carbon Monoxide	0	0	56.98	0.0269
Hydrogen	0	0	0	0
TOTAL	100.0	0.0335	100.00	0.0472

Feed gas rate 750 sml/min
Product gas rate 1057 sml/min

	In	Out
Total g moles Carbon*	0.0335	0.0470
Total g moles Oxygen	NA	NA
Total g moles Nitrogen	NA	NA

* Carbon gasification rate 0.0135 g moles/min
Carbon Dioxide utilization 40 percent

TABLE 18. MATERIAL BALANCE FOR FLUIDIZED-BED BATCH REACTOR AIR-BLOWN GASIFICATION TEST NUMBER 13

Reactor Pressure 66 psia
Reactor Temperature 940 C
Initial Charge to Reactor 20 grams Consolidated char, BCR Lot 2469

	Feed		Product	
Component	mole percent	g moles/min	mole percent	g moles/min
Oxygen	0	0	.06	0.0001
Nitrogen	0	0	.32	0.0002
Carbon Dioxide	100.0	0.0335	37.67	0.0175
Carbon Monoxide	0	0	61.95	0.0309
Hydrogen	0	0	0	0
TOTAL	100.0	0.0335	100.00	0.0487

Feed gas rate 750 sml/min
Product gas rate 1090 sml/min

	In	Out
Total g moles Carbon*	0.0335	0.0484
Total g moles Oxygen	NA	NA
Total g moles Nitrogen	NA	NA

* Carbon gasification rate 0.0149 g moles/min
Carbon Dioxide utilization 47.8 percent

TABLE 19. MATERIAL BALANCE FOR FLUIDIZED-BED BATCH REACTOR AIR-BLOWN GASIFICATION TEST NUMBER 14

Reactor Pressure 65 psia
Reactor Temperature 940 C
Initial Charge to Reactor 20 grams Consolidated char, BCR Lot 2469

Component	Feed mole percent	Feed g moles/min	Product mole percent	Product g moles/min
Oxygen	0	0	.05	0.00002
Nitrogen	0	0	.35	0.00015
Carbon Dioxide	100.0	0.0335	26.10	0.01392
Carbon Monoxide	0	0	73.50	0.03921
Hydrogen	0	0	0	0
TOTAL	100.0	0.0335	100.00	0.05330

Feed gas rate 750 sml/min
Product gas rate 1195 sml/min

	In	Out
Total g moles Carbon*	0.0335	0.0531
Total g moles Oxygen	NA	NA
Total g moles Nitrogen	NA	NA

* Carbon gasification rate 0.0196 g moles/min
Carbon Dioxide utilization 58.5 percent

The results of Test 3, which are summarized in Table 8, show that the carbon dioxide utilization was only 5 percent. This implied that the carbon dioxide-char reaction rate was less than that predicted by the derived rate equations. Since the char reactivity studies have already shown that at a reaction temperature of 940 C, internal diffusion is not rate controlling, i.e., chemical reaction at the internal surfaces is rate controlling, the reaction rate in the FBBR must be limited by external diffusion from the bulk gas phase to the exterior of the particles. The external diffusion limitation is a consequence of the very low gas velocities in the FBBR.

(2) FBBR Tests 4 through 8: In FBBR Test 4, the carbon dioxide feed rate was lowered and the gas residence time was increased. The carbon gasification rate increased from 0.0344 g moles/min in Test 3 to 0.429 g moles/min in Test 4. The carbon dioxide utilization rose to 21.7 percent. This was such a dramatic improvement that four more tests were made at the same conditions. Tables 9 through 13 show that the carbon dioxide utilization ranged from 20 to 30 percent. The product gas generated in Test 4 had a net heating value of approximately 153 Btu/cu ft.

(3) FBBR Tests 9 through 12: Tests 9 through 12 were made to verify the assumption that half the coal would be gasified with oxygen and half with carbon dioxide or steam. Tests 9 and 10 were run using air alone as the gasifying medium. The product gas contained 65.29 percent nitrogen and 31.30 percent carbon monoxide, with the remaining 3.41 percent being carbon dioxide. Approximately 0.016 g moles of carbon were gasified per minute. Tests 11 and 12 were made using carbon dioxide only. The carbon dioxide utilization was 42.7 percent with the product gas composed of 58 percent carbon monoxide and 42 percent carbon dioxide. Approximately 0.013 gram moles of carbon were gasified per minute. The average gasification rate in Tests 3 through 8 was 0.03 g moles carbon/min. The sum of the gasification rates for Tests 9 and 12 is 0.03 g moles/min, which verifies the basic assumptions.

The carbon gasification rate is calculated from measured product gas flow rates and product gas analysis. This was checked during Test 7 by quenching the reaction after 15 minutes and weighing the carbon left in the reactor. Twenty grams of char were charged to the reactor initially. After 15 minutes, 13.89 grams remained, giving a reaction rate of 0.4 grams/minute, or 0.033 g moles/min. The calculated value for Test 7 was 0.036 g moles/min.

(4) New FBBR Reactor: The batch reactor was initially made from a type 316 SS pipe that was on hand. The first distribution grids were made from type 304 stainless steel. After a few hours operation, the distribution grids would burn up. Grids were then made from type 316 SS. These grids failed at about the same time as the reactor failed, which was after 80 hours of actual operation. A new batch reactor and distribution plate were made from type 310 stainless steel. Type 310 is a high temperature alloy that should withstand the constant temperature cycling imposed on the FBBR.

3. Future Work: Design work on the fluidized-bed PEDU will continue. Foster Wheeler's rate of effort on this project should continue to increase.

Air-blown gasification studies with different chars will continue, using the fluidized-bed batch reactor.

B. 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 seventeenth month. The letter report of progress made during July, which was forwarded from Brigham Young University on August 4, was received on August 21, 1972. These data for July, along with those for August, are presented in this report. Figures 20 and 21 show the current budget status for June and July. The letter reports of progress during the two months are as follows:

1. July Report: Twenty test runs were completed during July. Ten of these runs were made using the 2 x 4-5/8 inch reactor with methane as the combustion gas fuel rather than hydrogen. The remaining runs were made with a 1-1/4 x 4-5/8 inch reactor, using hydrogen as the combustion gas fuel and the coal carrier gas.

Although prior testing with methane as the combustion gas fuel had resulted in an unstable flame, it was found that stable operation could be achieved at low methane feed rates. The tests were conducted with methane feed rates ranging from 0.1 to 0.3 pounds/hour. The corresponding oxygen feed rates were stoichiometrically balanced for combustion products consisting of water and carbon monoxide. Five of the test runs were made feeding only the combustion gases and nitrogen to the reactor. The remaining five were made with a coal feed rate of 0.77 pounds/hour. Raw data from these tests are listed in Table 20. Analysis of these data to obtain yields is still in progress.

The objectives of the tests with the 1-1/4 x 4-5/8 inch reactor was to obtain yield data at shorter residence times for comparison with the data obtained previously in the 2 x 4-5/8 inch reactor. Eight tests were made with a coal feed rate of 0.78 pounds per hour and with oxygen/coal ratios ranging from 0.4 to 1.5. Plugging of the reactor was encountered only at the lowest oxygen/coal ratio. Two additional tests were made with a coal feed rate of 1.64 pounds/hour and with an oxygen/coal ratio of 0.82. Raw data from these tests are listed in Table 21. Yield analysis of these results is also still in progress.

The data obtained between April 28 and June 14 as generated by a computer data reduction program have been summarized. This "Summary of Test Data" is quite large (68 pages), consequently it will be reported and retained only in the master file copy for the project. Each page of this summary lists data for a single test run, including the feed rates, observed gas yields, gas compositions, char yield, and char ash content. An explanation of each item of these data sheets follows.

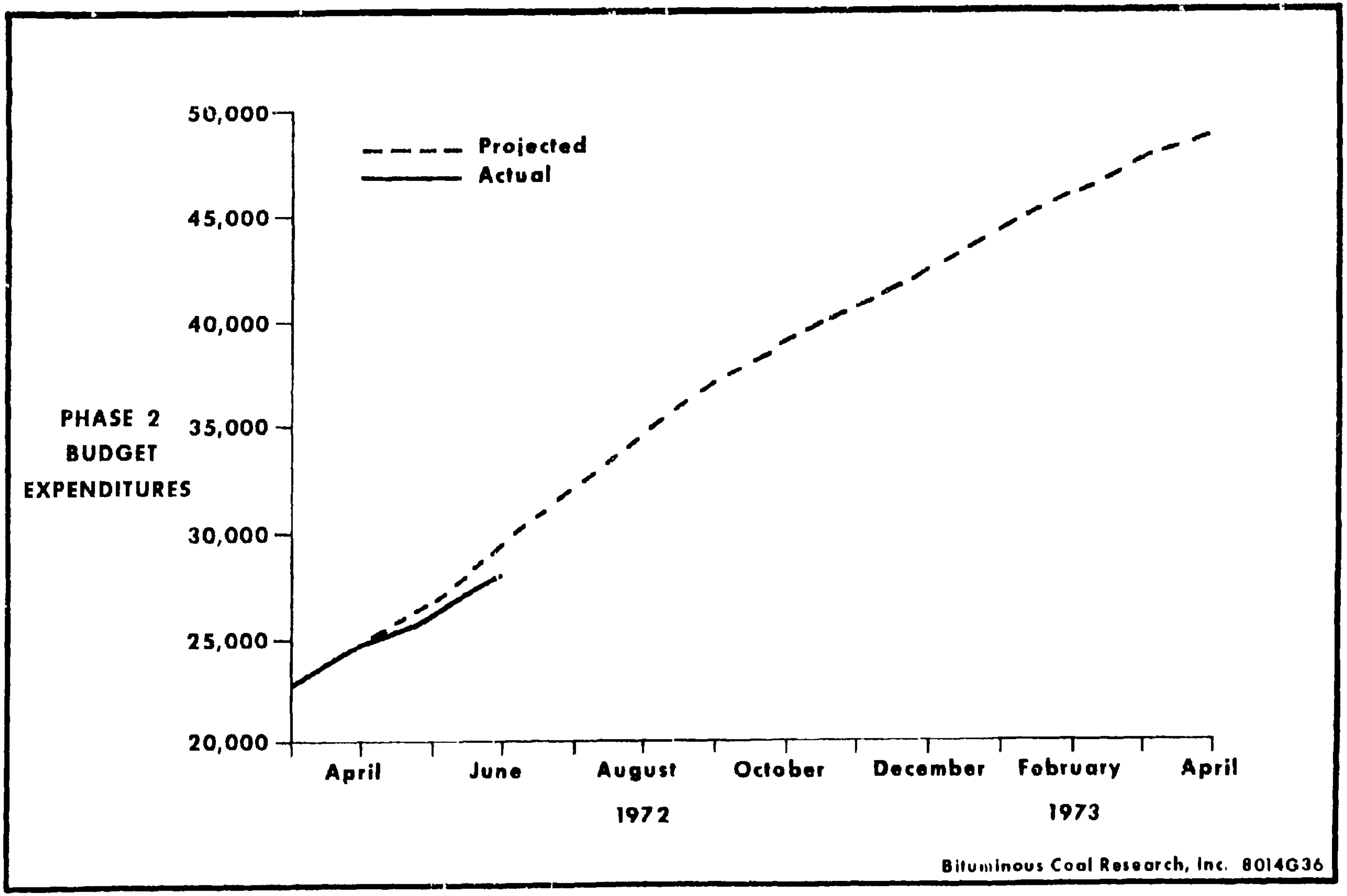


Figure 20. Monthly Progress Chart, Expenditures, Brigham Young University

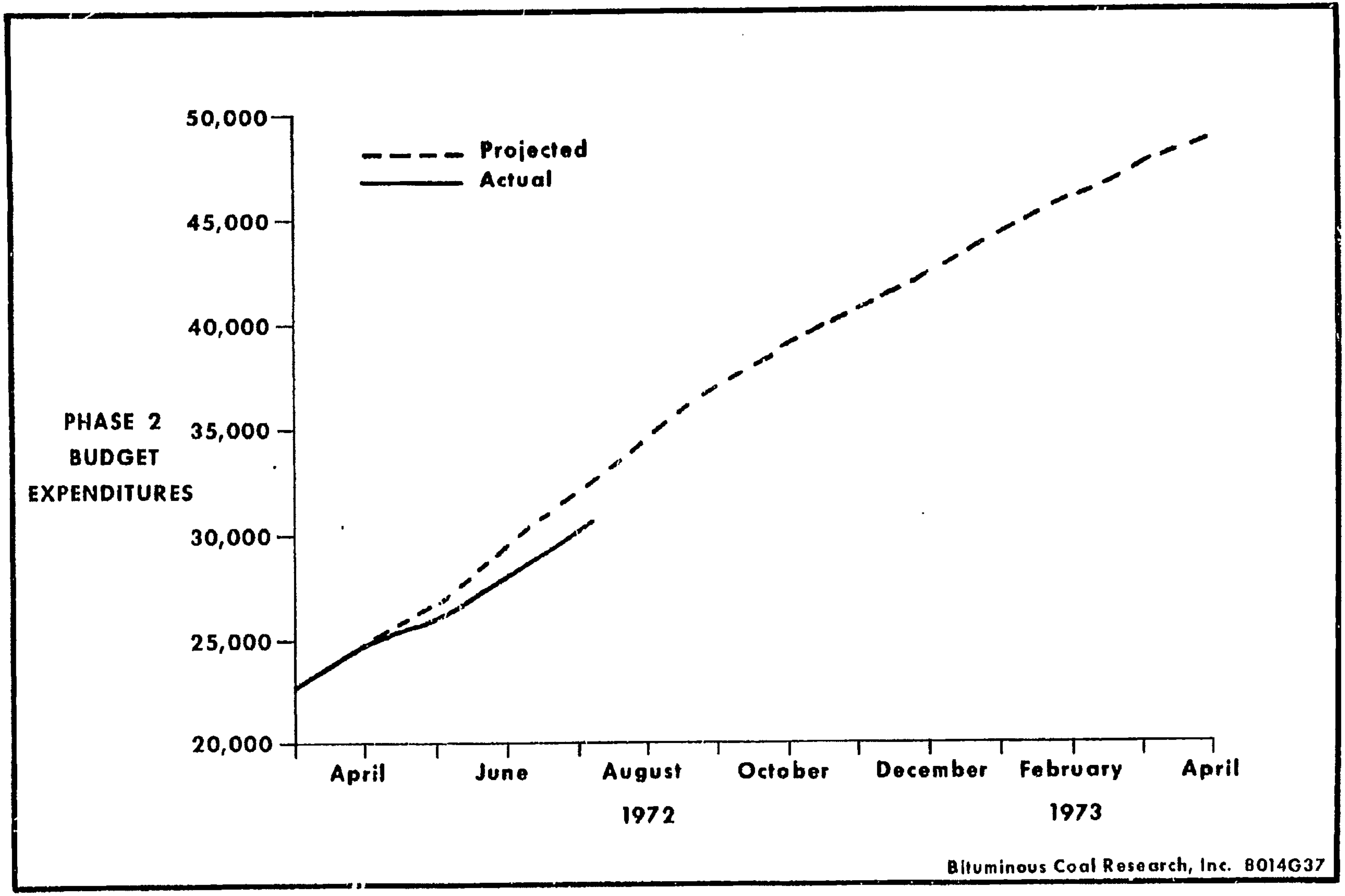


Figure 21. Monthly Progress Chart, Expenditures, Brigham Young University

TABLE 20. DATA OBTAINED USING METHANE AS COMBUSTION GAS FUEL, 2 x 4-5/8 INCH REACTOR

Run No.	7-18-1	7-17-1	7-18-2	7-17-2	7-18-3	7-18-8	7-18-7	7-18-6	7-18-5	7-18-4
Feed Rates, lb/hr										
Coal	--	--	--	--	--	0.77	0.77	0.77	0.77	0.77
Methane	0.10	0.15	0.20	0.26	0.32	0.10	0.16	0.20	0.26	0.32
Oxygen	0.31	0.46	0.61	0.78	0.44	0.31	0.47	0.61	0.78	0.94
Nitrogen	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
Uncorrected Gas Composition Volume Percent										
Hydrogen	--	5.8	9.0	11.6	11.3	12.4	4.1	4.3	7.7	9.5
Oxygen	14.9	4.3	0.3	0.6	0.4	3.3	5.1	6.8	5.5	1.5
Nitrogen	75.6	71.1	66.0	57.4	47.5	67.0	55.1	51.7	45.0	42.8
Methane	--	--	0.1	--	--	2.6	13.3	12.9	10.9	11.1
Carbon Monoxide	9.4	8.6	9.9	11.6	12.8	10.7	8.9	11.3	15.7	17.6
Ethylene	--	--	--	--	--	0.9	1.0	1.0	0.8	0.8
Carbon Dioxide	--	10.2	14.6	18.8	28.0	2.8	12.3	11.8	13.9	16.3
Acetylene	--	--	--	--	--	0.3	--	--	0.3	0.4
Product Gas Volumetric Flow Rate, SCF/hour	23.8	16.4	21.7	23.9	26.0	24.2	27.2	29.9	33.2	36.2
Reactor Temp., °F	1115	2000	1609	1970	1993	1354	1566	1645	1708	1757

TABLE 21. DATA OBTAINED USING HYDROGEN AS COMBUSTION GAS FUEL, 1-1/4 x 4-5/8 REACTOR

Run No.	7-28-1	7-28-2	7-28-3	7-28-4	7-28-5	7-28-6	7-28-7a	7-28-7b
Feed Rates, lb/hr								
Coal	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Hydrogen Carrier	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Hydrogen Combustion	0.15	0.14	0.12	0.10	0.08	0.06	0.04	0.04
Oxygen	1.20	1.12	0.96	0.80	0.64	0.48	0.32	0.32
Oxygen/Coal Ratio	1.53	1.43	1.22	1.02	0.82	0.61	0.41	0.41
Uncorrected Gas Composition Volume Percent								
Hydrogen	65.86	67.40	69.54	59.40	69.38	59.05	63.26	59.41
Oxygen	1.90	2.23	1.49	5.44	3.03	6.79	2.32	9.55
Nitrogen	5.80	6.62	4.74	16.17	9.23	20.18	6.46	22.37
Methane	0.79	1.06	1.94	2.02	2.90	2.70	1.34	2.54
Carbon Monoxide	23.10	19.75	18.78	14.25	12.58	8.96	20.17	4.66
Ethylene	0.02	0.06	0.17	0.23	0.61	0.81	0.33	0.82
Carbon Dioxide	2.20	2.41	2.23	1.33	1.07	0.58	5.96	0.17
Acetylene	0.29	0.43	1.08	1.12	1.14	0.85	0.11	0.33
Product Gas Volumetric Flow Rate, SCF/hour	44.7	39.8	39.2	34.4	29.0	25.4	18.8	21.0
Reactor Temp., °F	2094	1926	1872	1859	1658	1331	1329	1193
Char Collection, lbs. Char/100 lb. coal	16.58	19.89	28.06	28.31	26.53	---	11.73	20.79
Percent Ash in Char	18.45	17.48	15.51	14.79	14.67	14.67	9.18	8.05

The top line of the data sheet lists the run date and number and a brief description of the objectives. Runs where more than one gas sample was taken are indicated by a -2 or -3 following the run number, for example run 4/28/72 1-4 indicates the results according to gas sample number four for run number one made on April 28. The column listing reactor data indicates the Combustion Ratio and the Space Time. The Combustion Ratio is the ratio of the moles of Hydrogen (H_2) fed as combustion fuel to the moles of atomic oxygen fed. The Space Time is computed from the following equation:

$$\text{Space Time} = \frac{\text{Reactor Volume}}{(V_g + V_{H_2O})\ (T/492)}$$

where V_g is the measured volumetric flow rate of the dry product gas, V_{H_2O} is the computed volumetric flow rate of steam at the exit of the reactor based on an oxygen balance, and T is the observed reactor temperature in Rankine degrees.

The column headed by PRODUCTS lists the observed dry product flow rate corrected to 0°C and 1 atmosphere. The volume of Carrier Free Product Gas per pound of coal is computed by subtracting the volumetric flow rate of the carrier gas, either hydrogen or nitrogen, from the observed Total Gas flow rate and dividing by the coal feed rate. The Carrier Free Heating Value is computed by multiplying the High Heating Values as listed in Table 9-16 of the Chemical Engineers Handbook, 4th Edition, times the volume fractions of the various product gases on a carrier-free basis.

Under the heading GAS COMPOSITION, the Uncorrected column lists the measured dry composition of the product gas uncorrected for air contamination of the gas sample. The Corrected column lists the composition assuming there is no nitrogen or air present. The Yield is computed by the following equation:

$$\text{Yield} = \frac{Y_C V_{GCF}}{359 \times 0.74/12}$$

where Y_C is the Corrected volume percent of the gas and V_{GCF} is the Carrier Free Product Gas per pound of coal.

Under the heading CHAR, the Char Yield is simply the observed production rate of dry char divided by the coal feed rate and multiplied by 100. The heading GASIFICATION is the percent coal gasified according to the equation

$$\text{GASIFICATION} = 100(1 - \text{Ash In Coal/Ash in Char})$$

The Steam Decomposed is computed from the equation

$$\text{STEAM DECOMPOSED} = 100[1-(M_s)_{out}/(M_s)_{in}]$$

where $(M_s)_{out}$ is the computed mass flow rate of steam at the reactor exit based on an oxygen balance and $(M_s)_{in}$ is the mass flow rate of hydrogen and oxygen combustion gases fed to the reactor. In computing $(M_s)_{out}$, all of the oxygen in the coal fed to the reactor is assumed to be gasified.

The interpretations of these data which have been made to date were summarized on page 588 of Progress Report No. 10, June, 1972. Further analysis is underway to attempt to separate the effects of temperature and residence time on the product yields.

2. August Report: Eighteen runs were completed during August. Eleven runs were made using the 1-1/4 x 4-5/8 inch reactor and seven runs with a 3/4 x 4-5/8 inch reactor. The objective of the tests made with these reactors was to obtain yield data at shorter residence times for comparison with the data obtained previously in the 2 x 4-5/8 inch reactor. Plugging of the reactor was encountered with most of runs made with 3/4 x 4-5/8 inch reactor, especially with high coal feed rates and low oxygen/coal ratios, but only at the lowest oxygen/coal ratio with 1-1/4 x 4-5/8 inch reactor. However, it was possible to obtain useful data by using short run times.

Of the eleven runs made with 1-1/4 x 4-5/8 inch reactor, six were made with a coal feed rate of 1.64 pounds per hour and with oxygen/coal ratios ranging from 0.41 to 0.82, and five were made with a coal feed rate of 1.18 pounds per hour and with oxygen/coal ratios ranging from 0.41 to 1.15. Raw data from these tests are listed in Table 22.

Four of the seven runs made with the 3/4 x 4-5/8 inch reactor were made with a coal feed rate of 0.68 pounds per hour and with oxygen/coal ratio ranging from 0.51 to 1.53, and three runs were made with a coal feed rate of 1.16 pounds per hour and oxygen/coal ratios ranging from 0.52 to 1.02. Raw data from these tests are listed in Table 23.

Preliminary analysis of the data from these runs shows that the residence time has only a small effect on the yield. Analysis of these results is still in progress.

A tank of a standard gas mixture has been received from the Matheson Co. The gas mixture will be used as a standard in the gas chromatograph analysis. Previously, the standard gas mixtures were prepared in the laboratory in quantities of 100 ml. A syringe filter holder has also been obtained which will improve the gas sample by reducing possible air contamination because of its small volume and large filtering area. A product gas holder of 3.5 cu ft. capacity, made of Plexiglas, submerged in a 19 x 19 x 26 inch glass tank, is being constructed.

During the next month plans have been made to make additional tests with the 2-inch diameter reactor using substantially higher feed rates to verify the small residence time effects noted from the tests carried out during this month.

The char collected from these runs will be used for ultimate char analysis. Ultimate analysis of the coal will also be made.

TABLE 22. DATA OBTAINED WITH 1-1/4 x 4-5/8 INCH REACTOR

Run No.	7/31/1-1	7/31/1-2	8/7/1	8/7/2	8/7/3	8/7/4	8/8/1	8/8/2	8/8/3	8/8/4	8/8/5
Feed Rates, lb/hr											
Coal	1.64	1.64	1.64	1.64	1.64	1.64	1.18	1.18	1.18	1.18	1.18
Hydrogen Carrier	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082
Hydrogen Combustion	0.167	0.167	0.167	0.137	0.105	0.084	0.167	0.149	0.121	0.090	0.059
Oxygen	1.340	1.340	1.350	1.080	0.830	0.670	1.350	1.190	0.960	0.710	0.480
Oxygen/Coal Ratio	0.82	0.82	0.82	0.66	0.51	0.41	1.15	1.01	0.82	0.60	0.41
Uncorrected Gas Composition Volume Percent											
Hydrogen	64.20	60.98	58.31	65.09	64.16	74.32	68.79	69.24	70.62	72.59	57.72
Oxygen	1.65	2.99	2.32	2.67	3.23	0.31	0.42	0.23	0.35	0.22	6.06
Nitrogen	4.11	7.25	7.08	6.76	9.90	1.17	1.27	0.77	1.02	0.81	18.46
Methane	2.34	1.70	0.48	0.93	1.14	1.48	1.36	1.74	2.78	3.86	4.14
Carbon Monoxide	23.47	22.76	27.37	20.46	17.02	17.53	24.76	23.28	20.41	17.91	9.99
Ethane	0.00	0.00	0.06	0.01	0.04	0.05	0.00	0.00	0.00	0.02	0.07
Ethylene	0.19	0.14	0.44	0.61	0.99	1.63	0.06	0.13	0.30	0.94	1.36
Carbon Dioxide	2.39	2.96	2.80	1.54	1.53	1.52	2.62	3.61	2.88	2.16	1.16
Acetylene	1.60	1.16	1.09	1.89	1.95	1.94	0.67	0.96	1.61	1.44	0.99
Product Gas Volumetric Flow Rate, SCF/hour	60.3	60.3	61.0	48.8	40.2	34.5	55.9	48.8	42.2	38.0	28.3
Reactor Temp. °F	2157	2215	2284	1892	1790	1706	2202	2183	2170	1797	1616
Char Collection, lb/hr *	--	0.54	0.51	0.59	0.66	0.54	0.345	0.356	0.381	0.390	0.36
Char/100 lb. Coal *	--	32.99	30.90	35.89	40.33	33.08	29.33	30.27	32.39	33.16	30.61
Percent Ash in Char *	--	15.68	16.59	13.87	12.26	11.86	18.44	17.18	15.27	12.27	10.89
Percent Gasified *	--	55.10	57.56	49.24	42.57	40.64	61.82	59.02	53.89	42.62	35.35

* No Char Sample Collected.

TABLE 23. DATA OBTAINED WITH 3/4 x 4-5/8 INCH REACTOR

Run No.	8/22/1	8/22/2	8/22/3	8/22/4	8/23/1	8/23/2	8/23/3
Feed Rate, lb/hr							
Coal	0.68	0.68	0.68	0.68	1.156	1.156	1.156
Hydrogen Carrier	0.082	0.082	0.082	0.082	0.082	0.082	0.082
Hydrogen Combustion	0.131	0.087	0.065	0.026	0.149	0.113	0.074
Oxygen	1.040	0.695	0.520	0.347	1.180	0.900	0.600
Oxygen/Coal Ratio	1.53	1.02	0.76	0.51	1.02	0.78	0.52
Uncorrected Gas Composition Volume Percent							
Hydrogen	73.79	70.41	81.91	69.30	67.64	67.11	34.77
Oxygen	0.17	1.95	0.30	3.51	0.67	1.39	9.64
Nitrogen	0.70	7.88	1.48	16.58	3.08	4.65	45.23
Methane	1.81	2.47	2.80	3.05	2.54	3.22	2.26
Carbon Monoxide	20.29	14.22	10.90	5.59	21.43	18.82	6.28
Ethane	0.00	0.02	0.01	0.08	0.01	0.01	0.01
Ethylene	0.16	0.44	0.61	1.11	0.34	0.52	0.76
Carbon Dioxide	1.99	1.69	0.89	0.25	2.53	2.57	0.29
Acetylene	1.06	0.89	1.06	0.49	1.72	1.66	0.71
Product Gas Volumetric Flow Rate, SCF/hour	39.4	30.8	25.4	21.4	44.4	39.7	31.5
Reactor Temp. °F	2189	2019	1832	1399	2286	1913	1722
Char Collection, lb/hr	0.19	0.23	0.13	0.21	0.40	0.32	0.37
Char/100 lb. Coal	27.64	34.49	19.40	30.87	34.79	28.13	31.71
Percent Ash in Char	17.21	14.91	13.34	10.63	15.05	13.94	11.18
Percent Gasified	59.09	52.78	47.22	33.77	53.22	49.49	37.03

C. Engineering Design and Evaluation

1. OCR/BCR Gasification--Power Generation: Representatives from Foster Wheeler Corporation and Pittsburg & Midway Coal Mining Company visited BCR on August 16, 1972, to discuss aspects of the air-blown gasifier in relation to work they are pursuing on a combined-cycle demonstration plant.

D. Literature Search (V. E. Gleason)

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

E. Other

1. Patent Matters: Worthwhile ideas continue to be written as invention disclosures for submission to OCR for consideration. Status of invention disclosures is as follows:

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

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

F. Visitors During August, 1972

August 16, 1972

Professor R. L. Coates
Department of Chemical Engineering Science
176 FELB
Brigham Young University
Provo, Utah 84601

Mr. Robert A. McCallister
Mr. Robert J. Zoschak
Foster Wheeler Corporation
110 S. Orange Avenue
Livingston, New Jersey 07039

Mr. George E. Chenoweth
The Pittsburg & Midway Coal Mining Co.
9009 West 67th Street
Merriam, Kansas 66202

August 22, 1972

Mr. M. L. Spector
Mr. Robert Ziemer
Air Products and Chemicals Inc.
P. O. Box 538
Allentown, Pennsylvania 18104

Mr. Robert Maddocks
Catalytic, Inc.
1528 Walnut Street
Philadelphia, Pa.

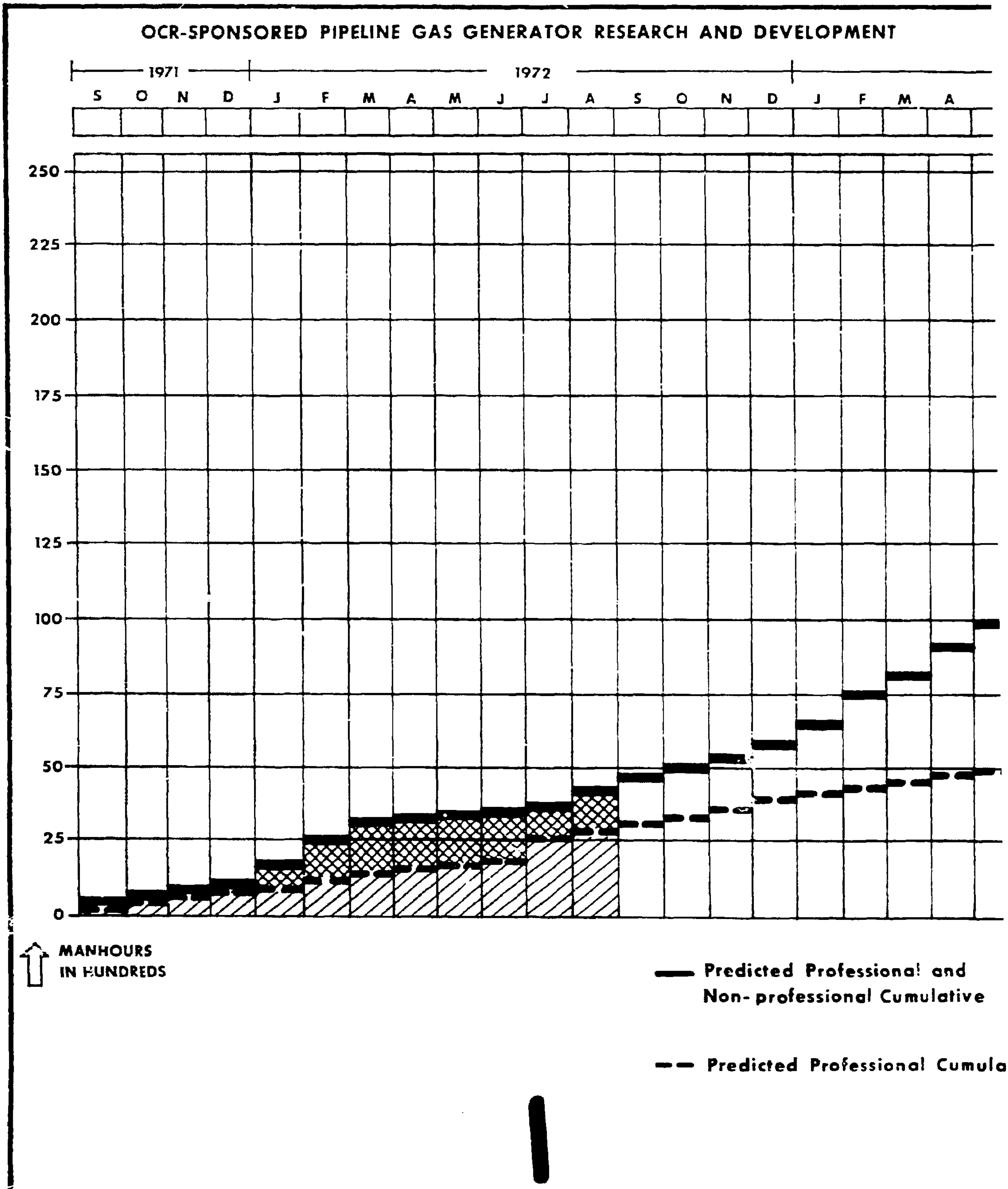
III. WORK PLANNED FOR SEPTEMBER, 1972

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

Design work on the fluidized-bed PEDU will continue with Foster Wheeler's rate of effort continuing to increase. Laboratory work will continue using the fluidized-bed batch reactor to study air-blown gasification with different chars.

Brigham Young will conduct additional tests at higher feed rates in the two-inch diameter reactor to verify the small residence time effects noted previously.

Discussions concerning power generation using the BCR/OCR gasifier will continue as requested.



OCR-SPONSORED PIPELINE GAS GENERATOR RESEARCH AND DEVELOPMENT
1971
1972
S O N D J F M A M J J A S O N D J F M A
250
225
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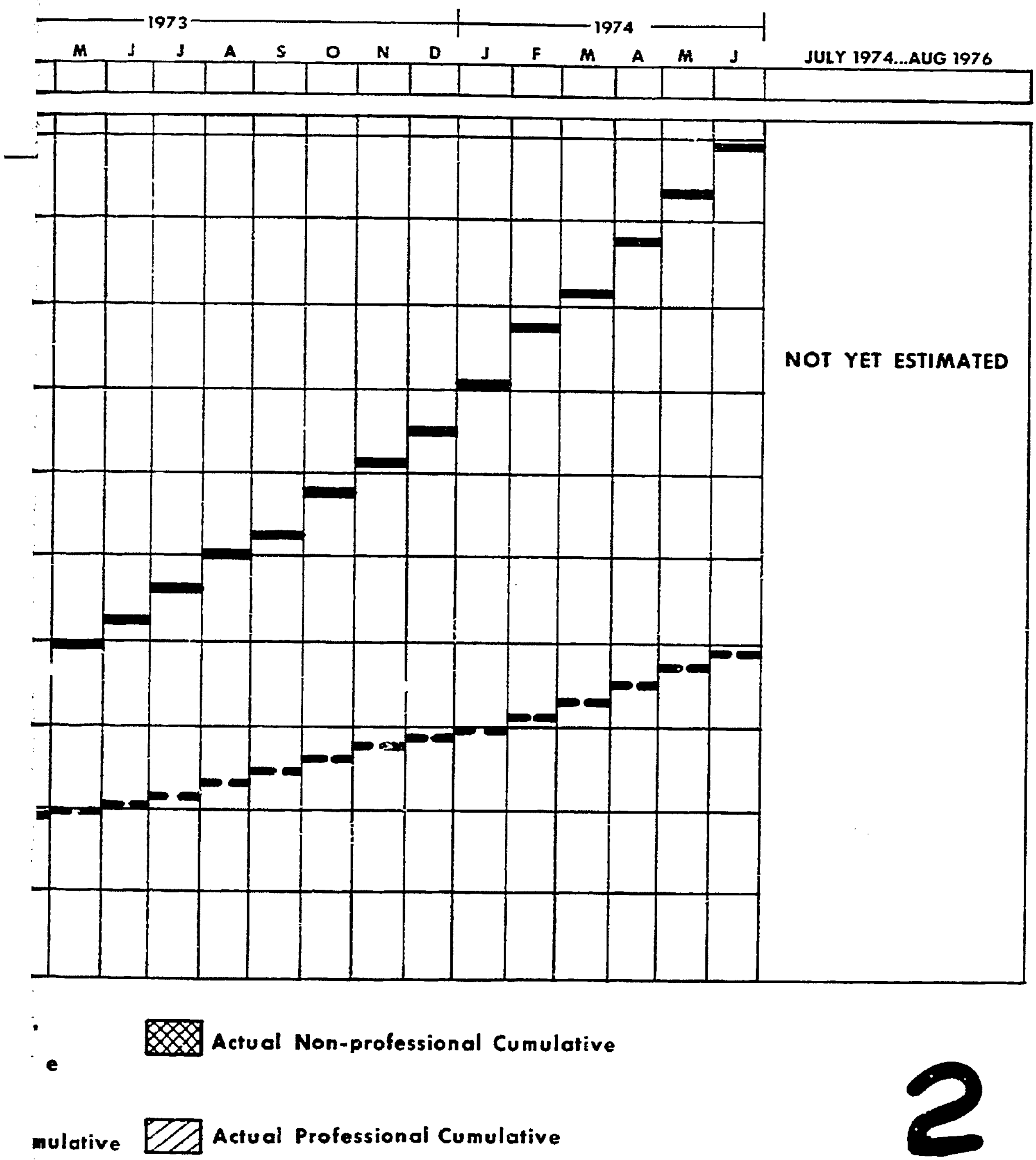
Predicted Professional and Non-professional Cumulative
Predicted Professional Cumula

CUMULATIVE MANHOURS



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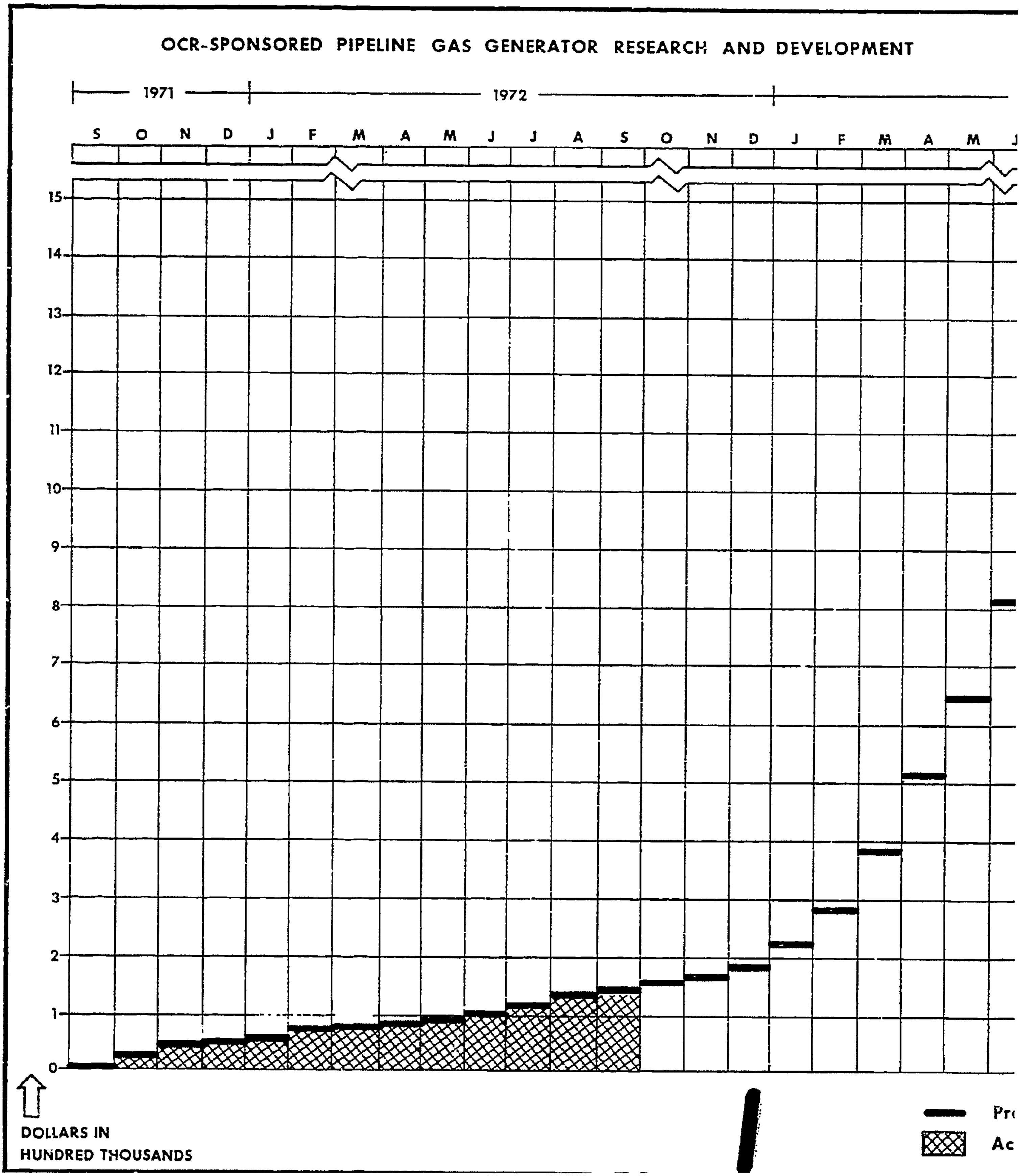
OCR-SPONSORED PIPELINE GAS GENERATOR RESEARCH AND DEVELOPMENT

Schedule of Predicted and Actual Manhours

Month	This Month				Cumulative			
	Professional		Non-Professional		Professional		Non-Professional	
	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual
Sept. '71		284.5		239.5		284.5		239.5
Oct. '71		289.5		152.0		574.0		391.5
Nov. '71		231.5		186.5		805.5		578.0
Dec. '71		201.0		91.0		1,006.5		669.0
Jan. '72		244.0		152.5		1,250.5		821.5
Feb. '72		285.0		218.5		1,535.5		1,040.0
Mar. '72		223.0		109.0		1,758.5		1,149.0
Apr. '72		75.0		21.5		1,833.5		1,170.5
May '72		108.0		162.5		1,941.5		1,333.0
June '72		214.0		209.0		2,155.5		1,542.0
July '72		139.5		167.0		2,295.0		1,709.0
Aug. '72	237.0	247.0	248.0	187.0	2,532.0	2,542.0	1,957.0	1,896.0
Sept. '72	238.0		249.0		2,770.0		2,206.0	
Oct. '72	240.0		251.0		3,010.0		2,457.0	
Nov. '72	240.0		251.0		3,250.0		2,708.0	
Dec. '72	240.0		250.0		3,490.0		2,958.0	
Jan. '73	238.0		557.0		3,728.0		3,515.0	
Feb. '73	238.0		557.0		3,966.0		4,072.0	
Mar. '73	237.0		558.0		4,203.0		4,630.0	
Apr. '73	240.0		566.0		4,443.0		5,196.0	
May '73	240.0		566.0		4,683.0		5,762.0	
June '73	240.0		564.0		4,923.0		6,326.0	
July '73	304.0		581.0		5,227.0		6,907.0	
Aug. '73	304.0		582.0		5,531.0		7,489.0	
Sept. '73	304.0		581.0		5,835.0		8,070.0	
Oct. '73	397.0		589.0		6,232.0		8,659.0	
Nov. '73	397.0		590.0		6,629.0		9,249.0	
Dec. '73	398.0		589.0		7,027.0		9,838.0	
Jan. '74	474.0		933.0		7,501.0		10,771.0	
Feb. '74	475.0		934.0		7,976.0		11,705.0	
Mar. '74	475.0		933.0		8,451.0		12,638.0	
Apr. '74	480.0		949.0		8,931.0		13,587.0	
May '74	480.0		950.0		9,411.0		14,537.0	
June '74	464.0		939.0		9,875.0		15,476.0	
July '74 to Aug. '76	N O T Y E T E S T I M A T E D							


OCR-SPONSORED PIPELINE GAS GENERATOR RESEARCH AND DEVELOPMENT
1971
1972
S O N D J F M A M J J A S O N D J F M A M J
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DOLLARS IN
HUNDRED THOUSANDS

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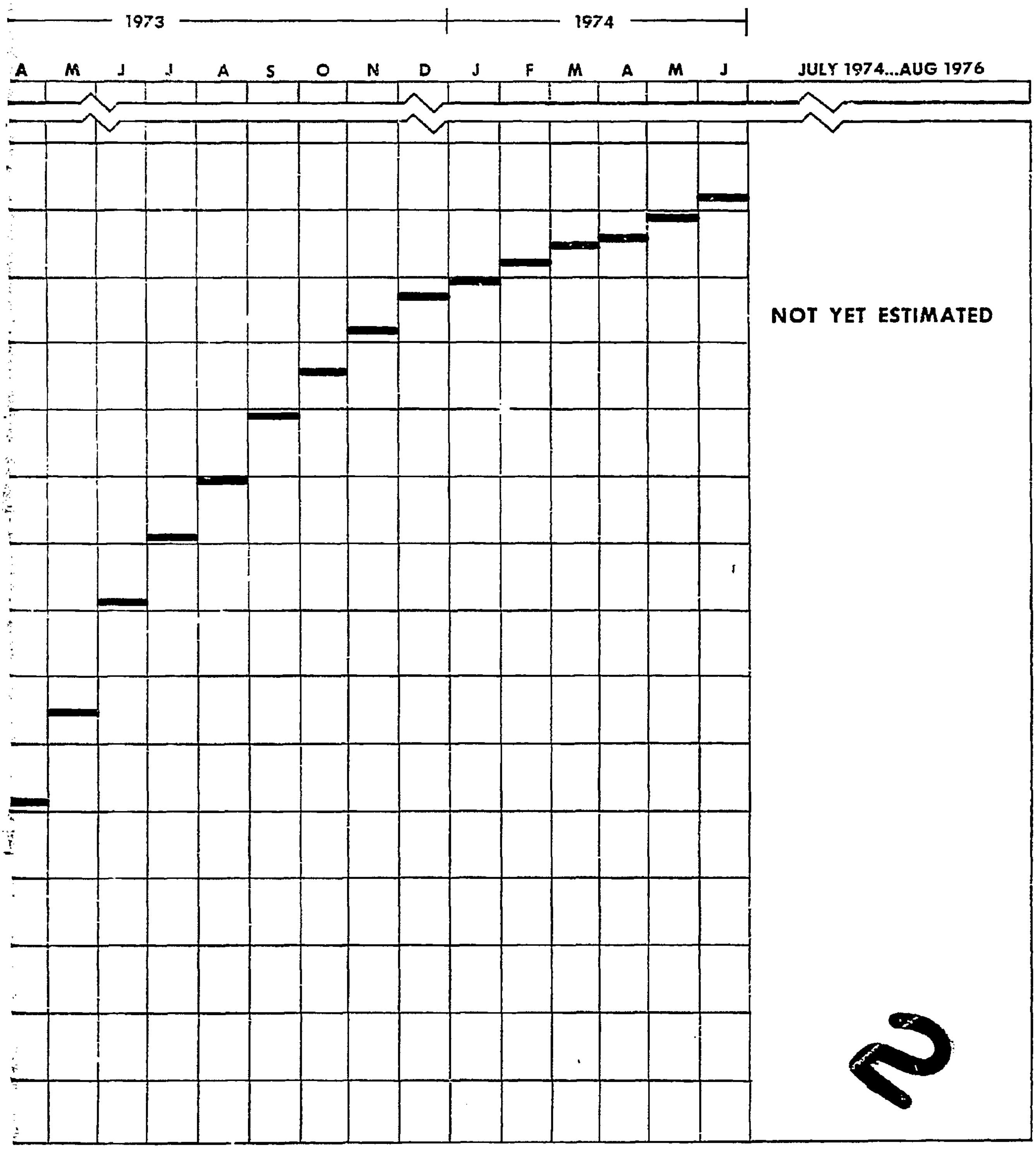
CUMULATIVE EXPENDITURES



Predicted Expenditures, Cumulative

Actual Expenditures, Cumulative

OCR-SPONSORED PIPELINE GAS GENERATOR RESEARCH AND DEVELOPMENT
Schedule of Predicted and Actual Expenditures

	Current Month		Cumulative to Date	
Month	Predicted	Actual	Predicted	Actual
1971				
Sept.		5,710		5,709
Oct.		22,720		28,429
Nov.		17,751		46,180
Dec.		6,161		52,340
1972				
Jan.		7,986		60,327
Feb.		15,328		75,655
March		16,354		92,009
April		3,432		95,441
May		4,352		99,793
June		8,080		107,873
July		13,840		121,713
Aug.	13,840	8,110	135,553	129,823
Sept.	13,840		149,393	
Oct.	10,980		160,373	
Nov.	10,980		171,353	
Dec.	10,980		182,333	
1973				
Jan.	46,060		228,393	
Feb.	56,060		284,453	
March	102,560		387,013	
April	128,694		515,707	
May	128.693		644,400	
June	16[illegible]3		812,093	
July	93,[illegible]7		905,170	
Aug.	93,[illegible]7		998,247	
Sept.	93[illegible]6		1,091,323	
Oct.	[illegible]10		1,152,733	
Nov.	[illegible],410		1,214,143	
Dec.	61,410		1,275,553	
1974				
Jan.	22,810		1,298,363	
Feb.	22,809		1,321,172	
March	22,810		1,343,982	
April	22,694		1,366,676	
May	22,693		1,389,369	
June	22,693		1,412,062	
July to Aug. '76	N O T	Y E T	E S T I M A T E D	

APPENDIX B

ADDITIONS TO ABSTRACT FILE, AUGUST 1972

Jain, L. K. and Hixson, T. J., "Applicability study - coal gasification process," Catalytic, Inc., Rept. No. APTD-1103 to EPA, Office Air Programs (March 1972). 20 pp. NTIS No. PB-208 944. 535.000 72-1

The objective of this study is to determine the applicability of the Applied Technology Corporation Coal Gasification Process to electric utility and industrial boiler facilities for new installations and for the "retrofit" of existing installations. The costs, space limitations, and operational, maintenance and safety aspects are evaluated. In addition, a number of technical difficulties and unresolved problems are outlined. The primary product of the combustion of crushed coal in a mass of molten iron is a high temperature (2500°-2700°F) gas rich in carbon monoxide and hydrogen, with approximately 175 Btu/std. cu. ft. available heat of combustion. Conclusions developed during this study are based on preliminary technical and cost information without actual pilot tests and are subject to this qualification. (Adapted from text)

APPENDIX B

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