BITUMINOUS COAL RESEARCH, INC.

OCR-SPONSORED
GAS GENERATOR RESEARCH AND DEVELOPMENT

Progress Report No. 14-A
(BCR Report L-491)

I. INTRODUCTION

This report summarizes progress during October, 1972, 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 sponsored solely 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 OCTOBER 25, 1972

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

Design work on the fluidized-bed gasification PEDU neared completion. The fluidized-bed batch reactor was modified to permit the study of the Stage 1 coal pretreatment step.

1. Fluidized-bed PEDU: The following drawings were received from Foster Wheeler during the month:

Drawing Number	Title
OP-721-432	Engineering Flow Diagram Reactor Section, Sheet 1 of 2
OP-721-434	Engineering Flow Diagram Reactor Section, Sheet 2 of 2
OP-421-592	Proposed Plot Plan

These drawings were reviewed and discussed with Foster Wheeler personnel on October 19, 1972. The design and operation of each major piece of process equipment was reviewed with the following changes being agreed to:

a. The 1-inch line connecting the coal lock hopper (D-102) and Stage 1 (R-101) was removed. Nitrogen will be used to maintain the pressure in D-102 a few pounds higher than in R-101.

b. The equalization lines between Stages 1 and 2 and between Stages 2 and 3 will not be open for gas flow. These lines will be used to measure the differential pressure between the reactors and thus serve as an operational guide for regulating the gas flow between stages.

c. Filter F-102, located on top of the coal lock hopper, was changed in size. As originally designed, this filter allowed approximately 1 ton of coal to be transferred to the lock hopper in 30 minutes. At this capacity, the filter became one of the largest pieces of equipment in the entire PEDU. The filter was thus reduced in capacity such that it will require 2 hours to fill the lock hopper.

d. The coal lock hopper will be provided with an internal conical bottom to facilitate solids flow.

e. Electric heat tracing was provided for all process gas piping upstream of the heaters. This will prevent the condensation of a large amount of steam at the mixing point. In addition, electric heating was provided for the Stage 1 off-gas piping to Stage 2, and for the bypass line from Stage 1 to the scrubber-cooler. This is to insure that the tars and oils generated in Stage 1 do not condense and plug these lines.

f. Connections for level controllers on the reactors will be across the entire height of the reactor.

g. Fluffing nitrogen will be used on all solids flow lines.

The engineering flow diagrams will be revised to reflect the above-listed changes.

Figure 27 is a process flow diagram for the PEDU.

Stage 1 receives raw coal and functions as the pretreatment step. The devolatilized coal flows by gravity to Stage 2 and then to Stage 3, which operates as the final carbon burn-up reactor. Several pretreatment mediums have been investigated by others and have been shown to be effective. These include air alone, and steam or carbon dioxide diluted with nitrogen and containing small amounts of air. In this scheme, Stage 3 flue gas is used as the fluidizing medium for the first stage.

Stage 2 is the major gasification stage. The devolatilized coal is gasified with air and either steam or carbon dioxide to generate the desired product gas. In addition, Stage 1 flue gas is fed to Stage 2 where the entrained tars and oils are gasified. Stage 3 operates at the highest temperature

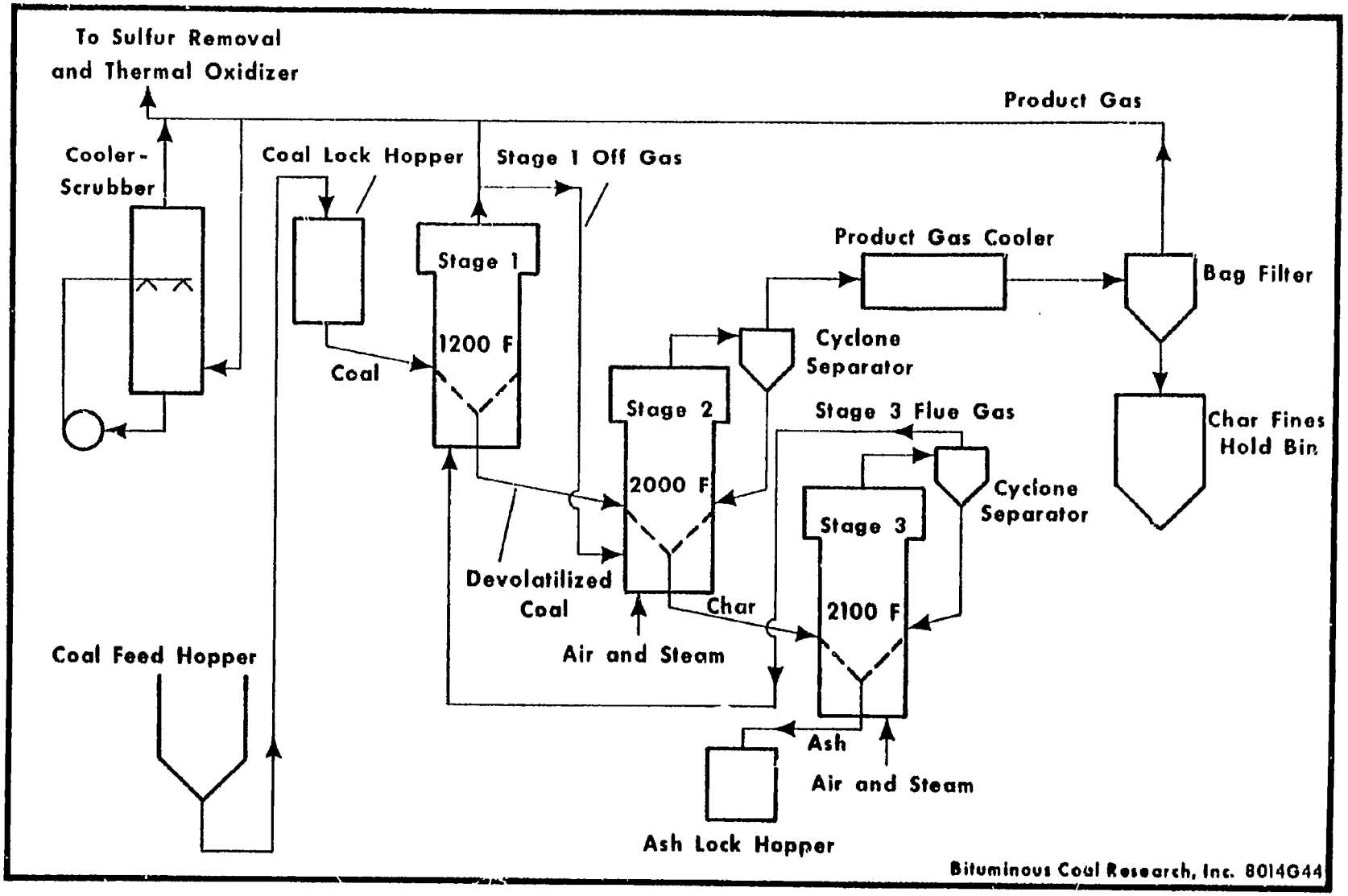


Figure 27. Fluidized-bed Gasification PEDU Process Flow Diagram

and serves to maximize carbon utilization. The ash discharged from Stage 3 will contain a minimum amount of carbon. Hot flue gas from Stage 3 flows to Stage 1 and completes the cycle.

Stage 1, the smallest reactor, has a reaction zone inside diameter of 10 inches and a disengaging zone of 16 inches. Stage 2 is the largest reactor with a reaction zone inside diameter of 16 inches and a 24-inch disengaging zone. The reaction zone diameter of Stage 3 is 12 inches with a 16-inch disengaging zone. All three reactors are approximately eleven feet high.

Refractory-lined cyclones are provided for the second and third stages to recycle entrained solids to the bed. Solids are scrubbed from the product gas stream in a venturi scrubber, and the gas flows through iron oxide boxes for hydrogen sulfide removal and thence to a thermal oxidizer for disposal.

The PEDU design package, originally scheduled for completion by the end of October, is now due by the middle of November. The engineering design package will include a cost estimate for detail engineering and construction, as well as an overall schedule for the project.

2. Laboratory Investigations: Stage 2 and Stage 3 kinetic studies are complete. The fluidized-bed batch reactor was modified to study the Stage 1 pretreatment step.

a. Char Reactivity Studies: No TGA tests were made during the month.

b. Fluidized-bed Gasification Batch Reactor: The FBBR system was modified to study fluidized-bed coal pretreatment. The modifications included the addition of a tar condenser and mist eliminator. These are shown in Figures 28 and 29. A preliminary test showed the system to be functional. Experimental tests should begin during the next report period.

3. Future Work: The FBBR will be used to study the PEDU Stage 1 reactor. The engineering design package, including the cost estimate for the PEDU, will be completed.

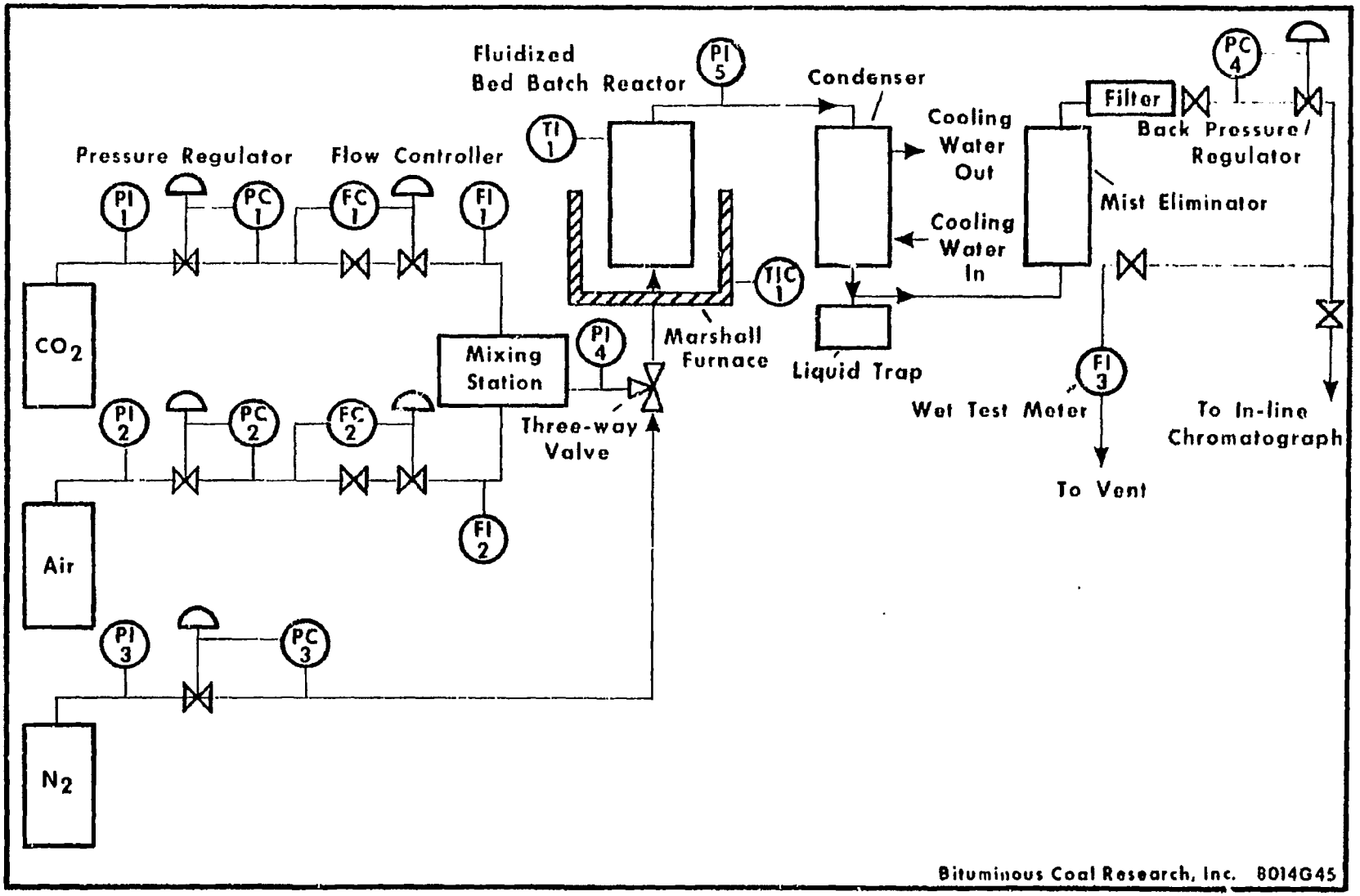


Figure 28. Flow Scheme for Modified Fluidized-bed Batch Reactor

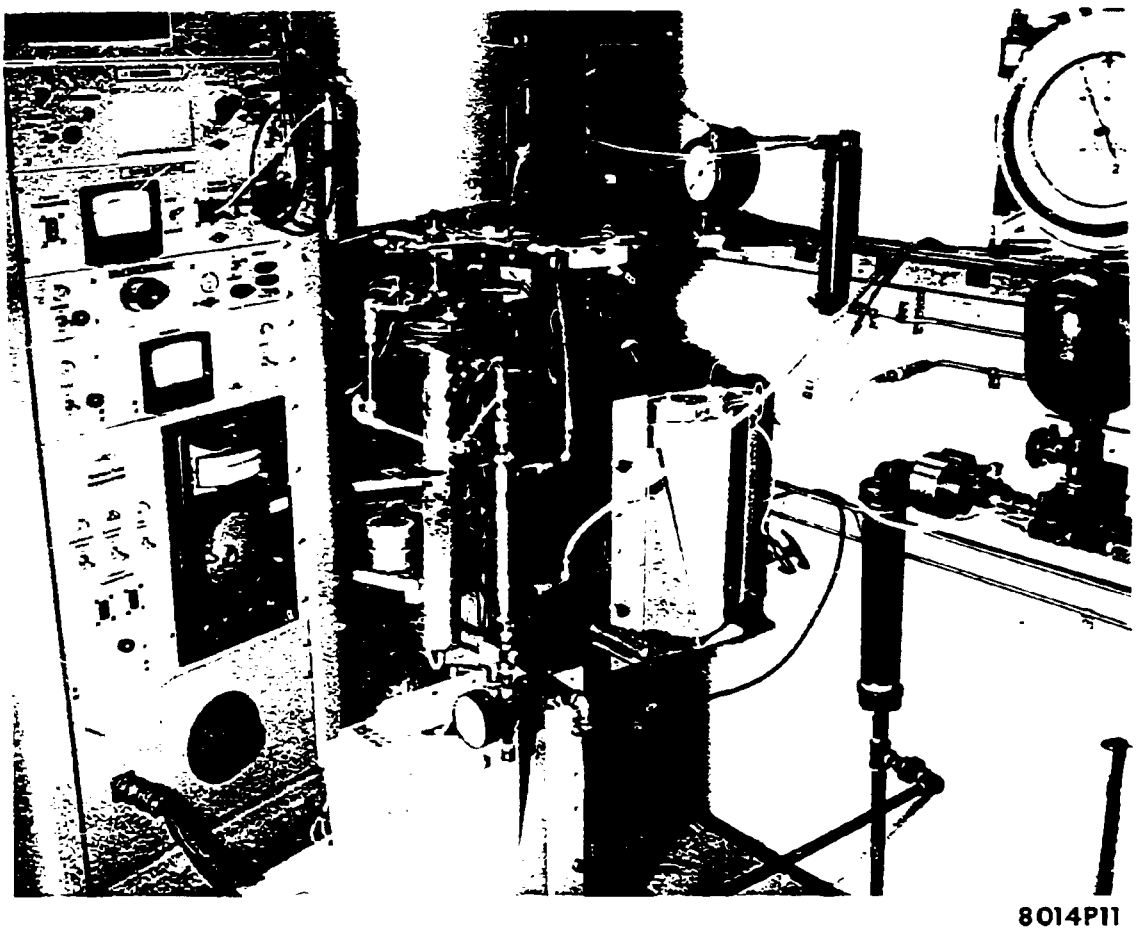


Figure 29. Fluidized-bed Batch Reactor System

B. Brigham Young University

The project entitled "Study of High Rate, High Temperature Pyrolysis of Coal" with joint funding by Brigham Young University and OCR is now in its nineteenth month. Figure 30, Monthly Progress Chart, Expenditures, shows the current budget status. The letter report of progress made during October is as follows:

Efforts during this report period were devoted to analysis of the data accumulated during the past six months and preparation of a paper and a report. A computer program was developed to seek optimum kinetic parameters for an assumed kinetic model of the gasification reactions occurring in the entrained flow reactor. Several simplified models were employed in attempts at correlating the yields of the principal gases with the reactor operating variables. However, none of these was found to provide a better correlation of the data than a simple graphical correlation of yields versus reactor temperature. The effects of reactor residence time, hydrogen concentration, and steam concentration were found to be small except for the yields of carbon dioxide.

A draft of a paper based on the data obtained during the past six-month period was prepared and submitted for approval by BCR and OCR. This paper is intended for presentation at the ACS Division of Fuel Chemistry Symposium on Coal Gasification which is planned for April, 1973.

A copy of the proposed paper, entitled "Coal Gasification in Low Pressure, Low Residence Time Entrained Flow Reactor," was submitted to OCR for approval by letter dated October 24, 1972. Verbal approval for Professor Coates to present the paper was received October 30, 1972, from Mr. Jack Ryan.

The third Semi-Annual Technical Progress Report of work performed on this subcontract was prepared and published. Included in this report are tables summarizing all the experimental data obtained during the past six-month period and graphs illustrating the trends observed from an analysis of the data.

During November, design studies will be carried out for apparatus to permit preheating the combustion gases that are fed to the reactor. In addition, further computer analysis of the data will be carried out with the objective of finding suitable models to account for all operating variables on the gas yields.

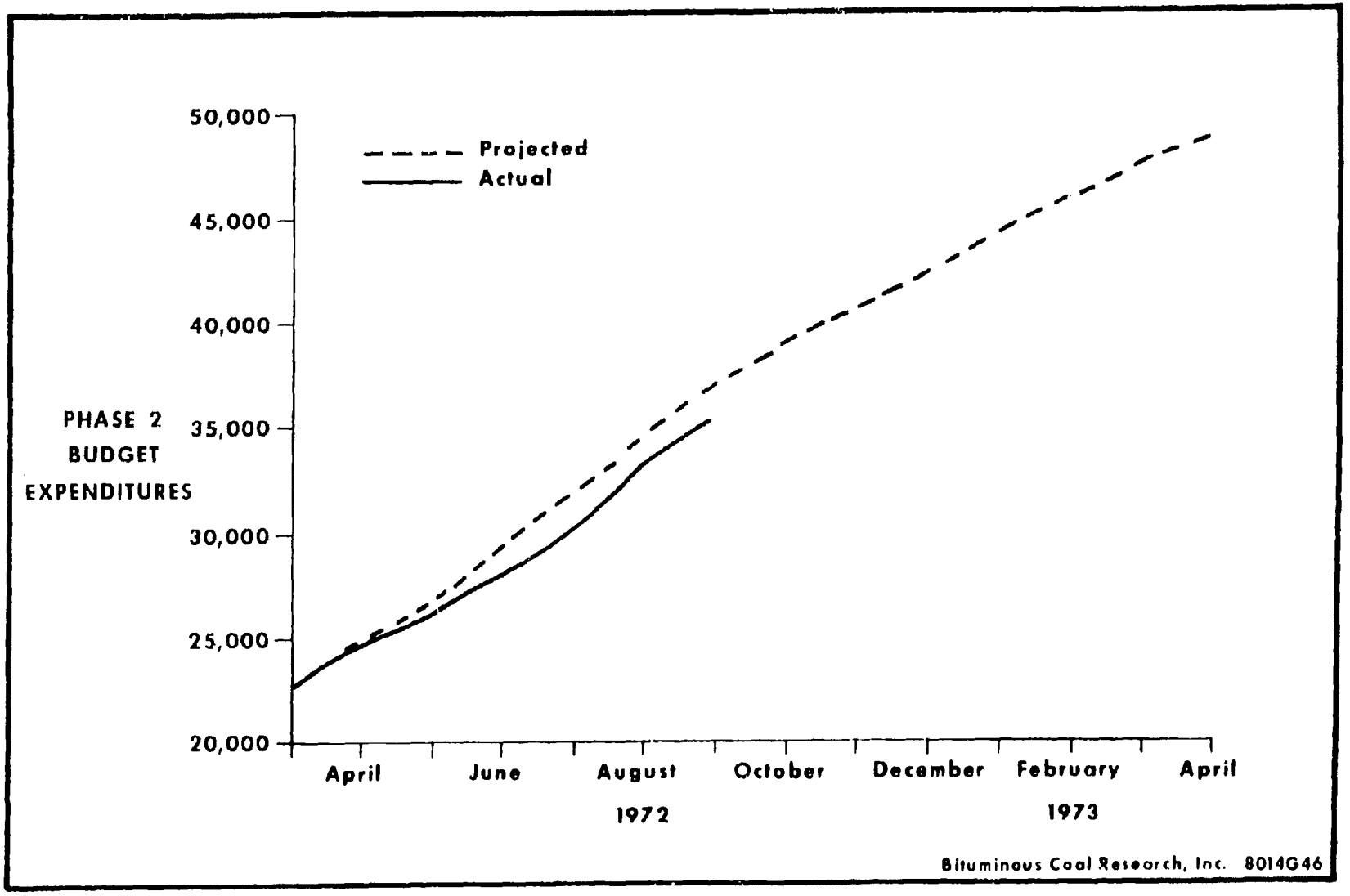


Figure 30. Monthly Progress Chart, Expenditures, Brigham Young University

C. Engineering Design and Evaluation

1. OCR/BCR Gasification--Power Generation: As reported last month, the BCR computer gasifier simulation program was given to Foster Wheeler Corporation. Communications with Foster Wheeler have continued since that time to further clarify procedures for utilizing the calculational schemes in the program. In particular, additional information regarding thermal properties of coal was transmitted to Foster Wheeler on October 27, 1972.

On October 17, 1972, personnel from Combustion Engineering, Inc., and the Lummus Company visited BCR to discuss various aspects of air-blown gasification. They were particularly interested in the mathematical model developed for the BI-GAS process, and in how it might assist them in their own gasification work.

Combustion may request a copy of the computer program in order to run their own calculations. They indicated that they would like to have further discussions with BCR as their program develops.

D. Literature Search (V. E. Gleason)

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

E. Other

1. Prime Contract Matters: By telephone request of Mr. Larson, and OCR letters of October 13 and October 17, 1972, BCR was requested to submit a proposal to OCR covering those research activities related to the low-Btu gasification program not funded jointly by OCR and AGA.

In order to expedite contract execution, BCR developed a contract draft paralleling the form of the prime contract. BCR feels that the contract draft makes preparation of a proposal unnecessary. This draft, submitted to OCR by letter dated October 23, 1972, incorporates the scope of work approved and underway at BCR on the fluidized-bed gasification systems development and related studies, as well as activities currently underway at Brigham Young University under subcontract to BCR.

Upon receipt from Foster Wheeler of estimated detail engineering and erection costs and time schedule for construction of the fluidized-bed gasification PEDU, dollar figures will be provided which were not available at the time the contract draft was submitted.

2. Patent Matters: Worthwhile ideas continue to be written as invention disclosures for submission to OCR for consideration. The 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. By letter dated January 26, 1972, OCR acknowledged receipt of this disclosure and forwarded it for processing.

F. Visitors During October, 1972

October 4, 1972

Mr. Paul Williams
Lord Electric Co.
2 Gateway Center
Pittsburgh, Pa. 15222

October 5, 1972

Mr. Calvin Walker
Lord Electric Co.
2 Gateway Center
Pittsburgh, Pa. 15222

October 10, 1972

Mr. Jack G. Marshall
Steel Bilt Construction Co.
P. O. Box 397
Bridgeville, Pa. 15017

October 11, 1972

Mr. Roy Beitle
Lord Electric Co.
2 Gateway Center
Pittsburgh, Pa. 15222

October 17, 1972

Mr. Richard Borio
Mr. C. R. Bozzuto
Mr. H. J. Blaskowski
Mr. R. W. Koucky
Combustion Engineering, Inc.
Windsor, Connecticut 06095

Mr. R. T. Whitehead
Mr. J. F. Frith
Lummus Division
Combustion Engineering, Inc.
1515 Broad Street
Bloomfield, New Jersey 07003

October 19, 1972

Mr. L. W. Zahnstecher
Mr. Vasant Lambu
Foster Wheeler Company
110 S. Orange Avenue
Livingston, New Jersey

October 20, 1972

Mr. J. M. Bialosky
Koppers Company, Inc.
Koppers Building
Pittsburgh, Pa. 15219

G. Papers Presented

October 29-November 1, 1972	Third International Conference on Fluidized Bed Combustion Hueston Woods, Ohio	"Fluidized Bed Gasification--Process and Equipment Development" J. T. Stewart E. K. Diehl

III. WORK PLANNED FOR NOVEMBER, 1972

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

Design work on the fluidized-bed PEDU should be completed by the middle of the month. Laboratory work will continue using the fluidized-bed batch reactor to study the PEDU Stage 1 reactor.

Brigham Young will conduct design studies for apparatus to permit pre-heating the combustion gases that are fed to the reactor. In addition, computer analyses of the data collected will be continued.

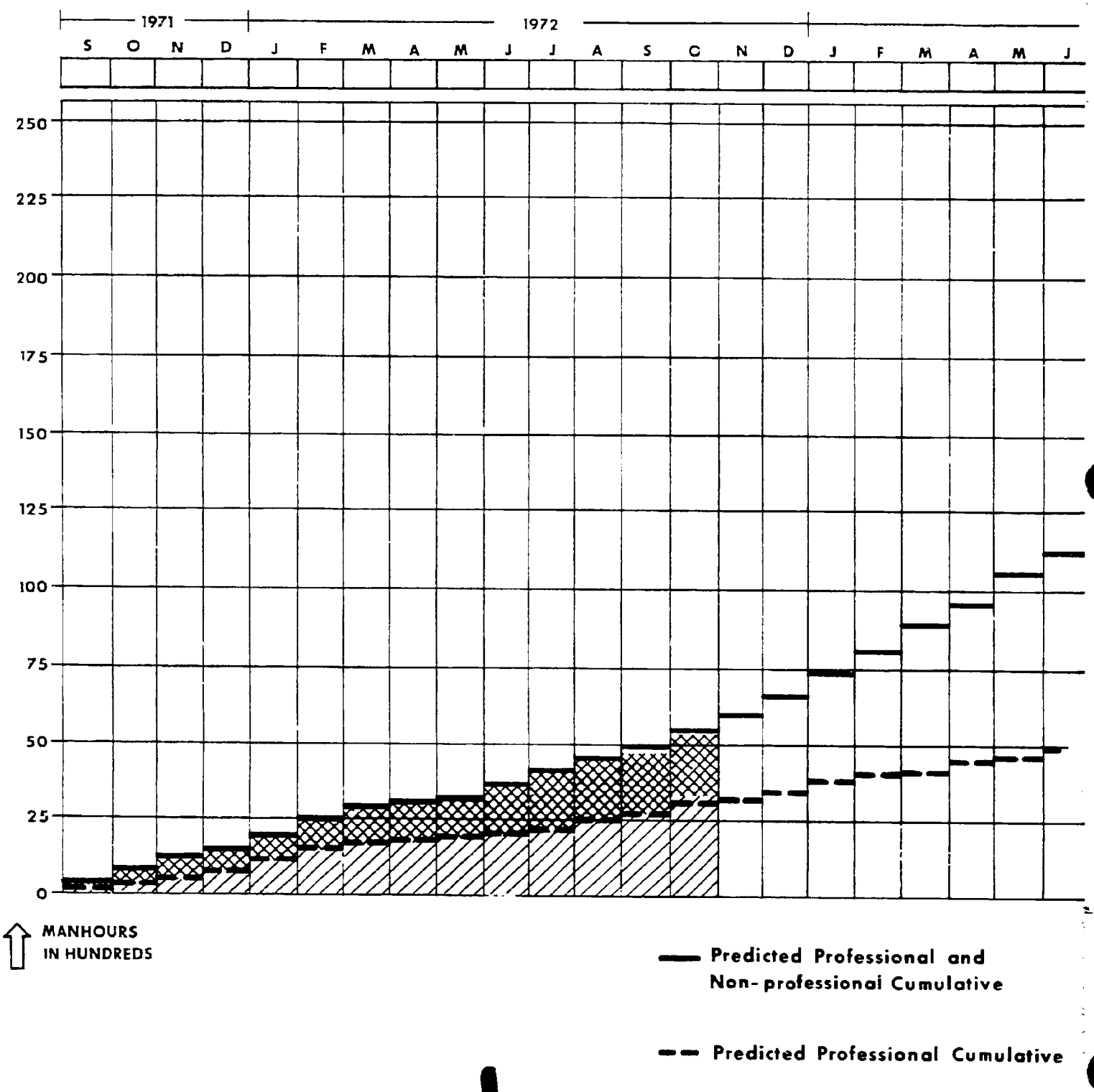
Discussions concerning power generation using the BCR/OCR gasifier will continue as requested and approved.

A. Papers to be Presented

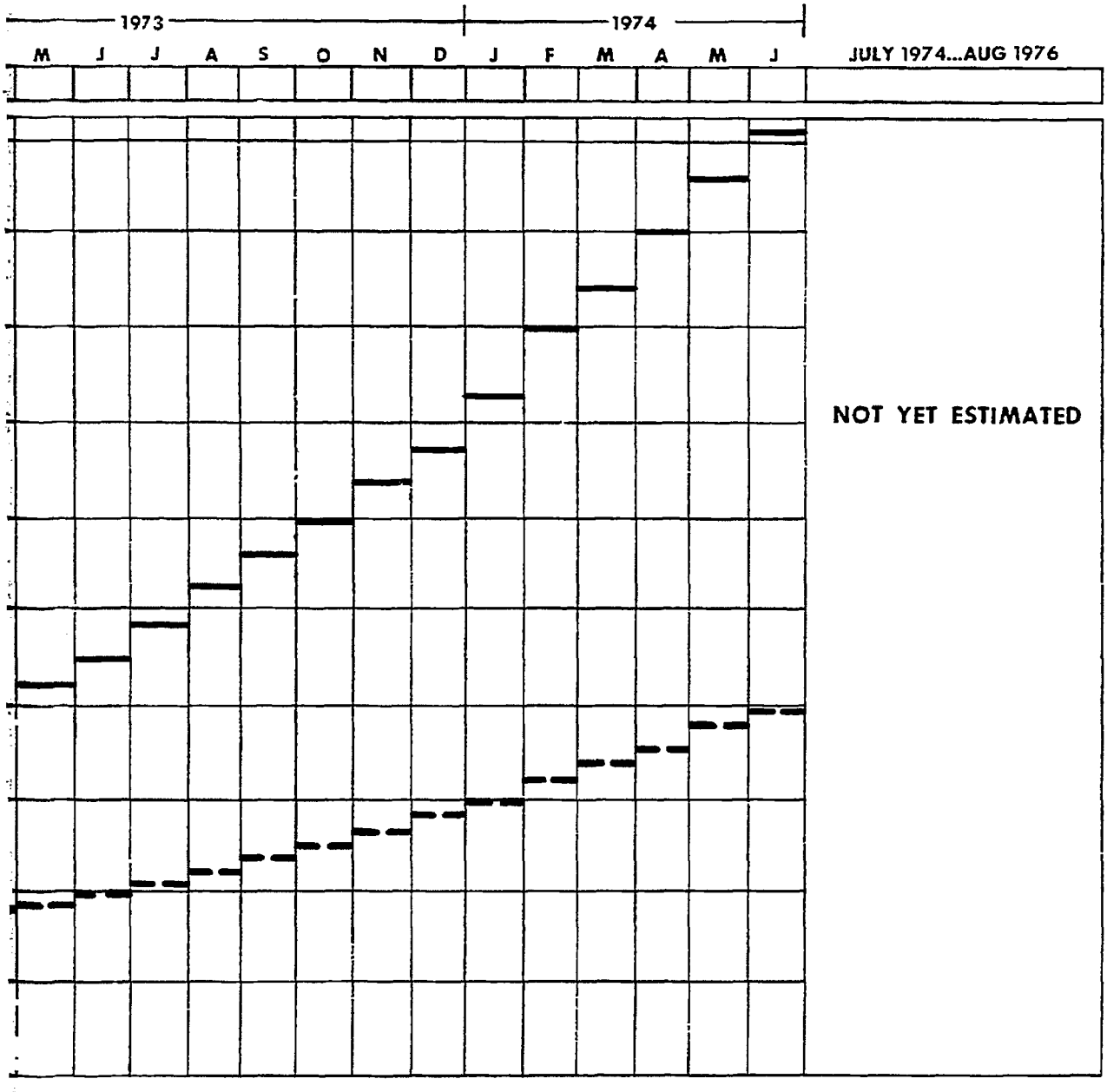
April 1973	Meeting of American Chemical Society, Division of Fuel Chemistry Symposium on Coal Gasification Dallas, Texas	"Coal Gasification in Low Pressure, Low Residence Time Entrained Flow Reactor" R. L. Coates C. L. Chen B. J. Pope

OCR-SPONSORED GAS GENERATOR RESEARCH AND DEVELOPMENT

CUMI



CUMULATIVE MANHOURS



Actual Non-professional Cumulative

ulative Actual Professional Cumulative

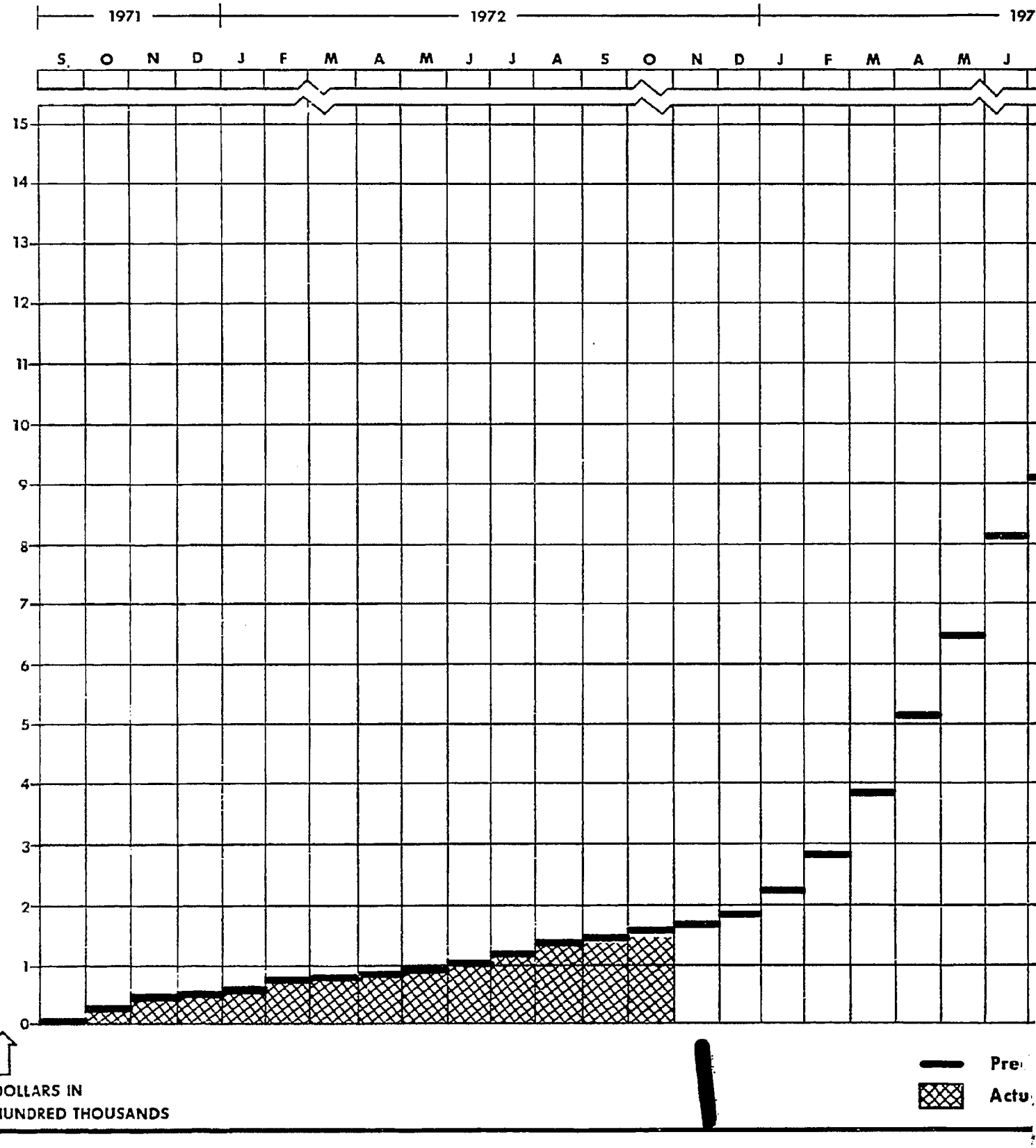
2

OCR-SPONSORED 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	240.0	249.0	160.5	2,770.0	2,782.0	2,206.0	2,056.5
Oct. '72	240.0	322.0*	251.0	218.5*	3,010.0	3,104.0*	2,457.0	2,275.0*
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							

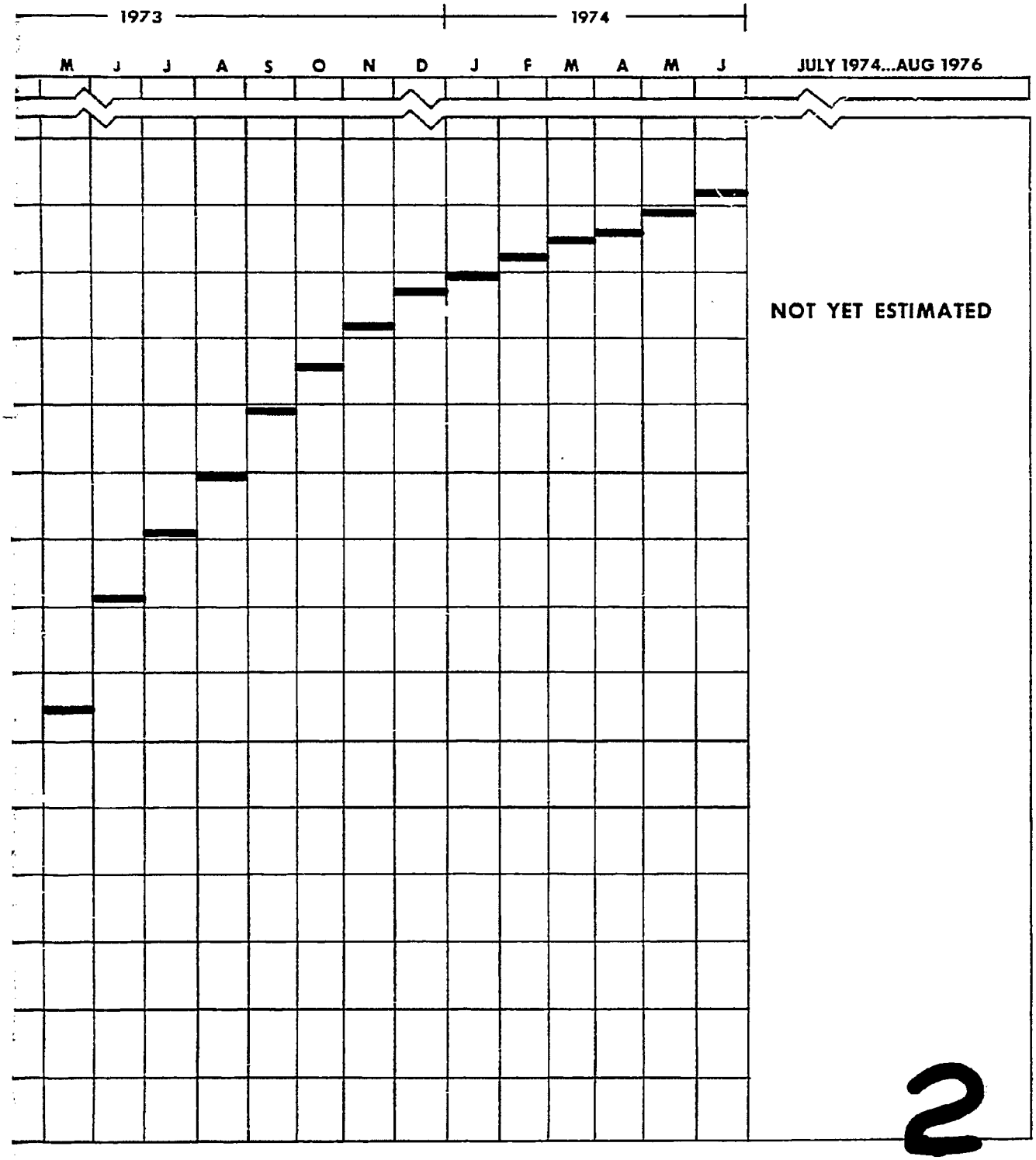
* Estimated

OCR-SPONSORED GAS GENERATOR RESEARCH AND DEVELOPMENT



BLANK PAGE

CUMULATIVE EXPENDITURES



Predicted Expenditures, Cumulative

Actual Expenditures, Cumulative

OCR-SPONSORED 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		6,189		114,062
Aug.	13,840	8,115	135,553	122,177
Sept.	13,840	12,747	149,393	134,924
Oct.	10,980	11,344*	160,373	146,268*
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	167,693		812,093	
July	93,077		905,170	
Aug.	93,077		998,247	
Sept.	93,076		1,091,323	
Oct.	61,410		1,152,733	
Nov.	61,410		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			

* Estimated

APPENDIX B

ADDITIONS TO ABSTRACT FILE, OCTOBER 1972

Bishop, J. W., Ehrlich, S., and Gordon, J. S., "Development of coal fired fluidized-bed boilers," Pope, Evans and Robbins, Final Rept. Vol. II to U.S. Office Coal Res., R&D Rept. 36 (1972). 60 pp. +

> The work covered in this report was carried out between February 1971 and February 1972. It includes the development of the coal feeding system and the preliminary optimization of fluidized-bed boiler designs which incorporate air pollution control by SO_2 sorption.

PATENTS

Parr, G. E., (to Sun Oil Co.), "Continuous, fluidized process and system for thermal recovery of hydrocarbonaceous materials from solids," U.S. Pat. 3,663,421 (May 16, 1972). 4 pp.

> The invention relates to a new process and apparatus for the thermal recovery of valuable liquid and gaseous hydrocarbon products from hydrocarbonaceous materials. The process is conducted within a vessel which has contiguous thermal treatment zones and spent solids combustion zones separated by a gas seal; the thermal treatment zone is characterized by maintaining a fluidized bed of the hydrocarbonaceous material on shallow-bed concatenated, slanting trays; a plurality of sidestream outlets to remove condensable hydrocarbon products and a plurality of hot gas inlets which serves to maintain fluidization and give temperature control. (Abstract of the disclosure)

Tusson, J. R., (to Standard Oil of Indiana), "Catalytic contacting apparatus," U.S. Pat. 2,550,948 (May 1, 1951). 4 pp.

> The apparatus described is a rotatable kiln-type vessel designed to be operated at elevated temperatures and pressures, and with several types of coal feeding. It can also be adapted to fluidization.

Voorhees, V., (to Standard Oil of Indiana), "Method and means for pressuring fluidized solids," U.S. Pat. 2,495,152 (Jan. 17, 1950). 5 pp.

> Specifically, the invention relates to a centrifugal-type transfer mechanism which provides continuous introduction of finely divided solids into a contacting zone operating under pressure. (From text of disclosure)