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FE--415-T2

MASTER

**CONSOL LIGNITE GASIFICATION
PROCESS DEVELOPMENT**

Monthly Progress Reports for the
Period January - December, 1965

Consolidation Coal Company
Library, Pennsylvania 15129

Prepared for
Office of Coal Research
U. S. Department of the Interior
OCR Contract No. 14-01-0001-415

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Monthly Progress Reports 8 through 19 covering each
month January through December, 1965, respectively

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CCDC-MPR--8

PROGRESS REPORT NO. 8
OCR Contract No. 14-01-0001-413
CONSOL LIGNITE GASIFICATION PROCESS DEVELOPMENT

January 1 to 31, 1965

A. Summary

Phase I - Feasibility Study

The feasibility study was completed and reported on January 13, 1965. A potential gas price of 40¢/MM BTU is indicated.

Phase II - Bench-Scale Experiments

The experimental program to determine the effect of pretreatment conditions and lignite source on char reactivity has been completed. Final calculations of the data are now in progress and will be completed by February 15, and the main experimental program on the kinetics of lignite char gasification will proceed shortly thereafter.

The unusually high reactivity of lignite char as compared with bituminous char reported earlier has been further confirmed during the above program.

The unusually high reactivity of South Dakota lignite char towards gasification with pure hydrogen was mentioned earlier. Analysis of the major constituents in the char ash did not reveal any obvious catalytic component which would be responsible for the high reactivity.

It is planned to make further studies in February on the effect of lignite ash on acceptor activity under regenerator conditions.

The correlation work on the fluidization properties of solids to be handled in the process has been completed. A detailed data report is being written covering this work.

Assembly of the model of the gasification unit has been completed. Feed materials have been prepared. Leak testing and calibrations of rotameters and solids feeders is in progress.

Financial

Estimated expenditures for January were \$12,000 vs. a budget figure of \$21,600. Cumulative expenses to date are \$65,837 vs. a budget of \$111,900.

Lignite Gasification
Progress Report No. 8

-2-

January, 1965

B. Technical Results and Program

Phase I - Feasibility Study (Project No. 180)

The lignite gasification feasibility study was issued in two sections. A Summary Report covering all the major elements was submitted to OCR on January 13 (100 copies). The Appendix to the report, covering all of the details, has been duplicated and is currently being assembled. It is anticipated that 100 copies of this Appendix will be mailed to OCR the week of February 8. Copies of both volumes will be distributed within the Company at the same time.

The conclusion from this study is that lignite-derived gas can be delivered to a substantial consuming area at a price of 44-49¢/MM Btu, if the technical assumptions in the study are proven to be valid by the experimental program. The projected 1975 city-gate price in this area is 50¢/acf.

Phase II - Bench Scale Program

1. Kinetic Studies (Project No. 530.00)

The experimental program to determine the effects of pretreatment and of lignite origin on char reactivity has been completed. Final calculations of the data from the 23 runs comprising the program are not yet complete. Considerable effort was required to refine the correlations of the calibrating factors for the on-line gas chromatograph used to measure the concentrations of CO, CO₂, and CH₄ in the product gas during the steam gasification portion of the run. A similar correlating effort was required for the thermal conductivity cell used to measure the concentrations during the pretreatment period and during the transition interval between the pretreatment and steam gasification periods. The revised computer program which will perform most of the run calculations is now fully operational. All final calculations, which lead to generation of differential reaction rates, will be completed by February 15.

The only series of runs which has been completely processed is that for the Renner's Cove char at 60% H₂ - 40% H₂O inlet gas composition at 16 atm. total pressure and 1500°F, conditions which correspond to those at the top of the commercial gasifier. The differential rate of total gasification at 20% burnoff is 170 times that of bituminous coal char at identical conditions and 3.5 times that of the bituminous coal char at 1700°F. The corresponding ratios of differential methane formation rates are 8 and 1.2.

Although they are not in final form, the data show that the Dakota Star and South Dakota (Firesteel Mine) char have about the same level of reactivity at the top-of-gasifier conditions up to 40% burnoff, and that this level is about 20% less than that of the Renner's Cove char.

The South Dakota char exhibits a remarkably high reactivity for methane production in pure hydrogen. The rates are higher at 6 atm. H₂ pressure and 1400°F than are the total gasification rates for Renner's Cove char at 16 atm. pressure, with 60% H₂ - 40% H₂O inlet gas composition at 1500°F. This high reactivity

persists after 9% of the ash has been removed by extraction with water. Analyses which are available to date of the ash from the three chars are tabulated below. They offer no obvious explanation of the differences in reactivity. The water extractions were not necessarily exhaustive, but were carried out under essentially the same conditions for all three chars.

Per Cent by Weight of Ash, SO₂-Free Basis

	Total Ash		
	Remmer's Cove	Dakota Star	South Dakota
Al ₂ O ₃	14.9	10.7	9.3
SiO ₂	17.6	14.4	33.3
Fe ₂ O ₃	8.7	18.1	8.8
CaO	26.0	37.3	35.2
MgO	8.7	10.6	2.7
K ₂ O	14.7	3.9	4.3
K ₂ CO ₃	.5	.2	.8
TiO ₂	.3	.3	.7
P ₂ O ₅	.8	.8	.1
Water-Soluble Ash			
Al ₂ O ₃	4.8	1.4	-
SiO ₂	18.7	21.7	-
Fe ₂ O ₃	.08	.14	<.1
CaO	3.8	3.9	3.0
MgO	.11	.06	.14
Na ₂ CO ₃ (1)	55.3	51.1	47.3
K ₂ CO ₃ (1)	1.7	2.3	3.9
TiO ₂	.4	.1	<.1
P ₂ O ₅	.3	1.3	-
lg. Loss (2)	14.9	18.0	-
% of Total Ash removed by water extraction	35	12	9

(1) Alkalies were assumed to be present as carbonates, not only because the sum of the components will not approach 100% without this assumption but because the water-soluble ash fuses at about 800°C.

(2) Assumed to be hydrate water. The values shown here are by difference from 100%. The measured value for the Remmer's Cove ash was 15.2%.

Further experimental work on steam-carbon kinetics will be deferred until the existing body of data has been worked up and the results studied from the viewpoint of evaluating the experimental technique to make sure that adequate accuracy and reproducibility have been achieved. In this interim period experiments to study the effect of lignite ash on acceptor activity at regenerator conditions will be resumed.

2. Design of the Continuous Gasification Unit (Project No. 531.01)

No work was done on this project during January.

3. Mockup Studies (Project No. 531.02)

Construction and Operation of the Model

Construction of the model has been completed. Flow calibrations and leak testing are underway. About 100 pounds of lignite char, carbonized at 1100°F, and sized to 35 x 100 mesh have been prepared. Since char is not consumed in the model, this amount will be sufficient for the entire operating program. Also, stocks of closely sized fractions of Greenfield dolomite in the size range 28 x 100 mesh have been prepared.

Initial operations of the model will be devoted to the study of the transfer lines, feeders, and level detectors. The relations among carrier gas velocity, feed rate, line diameter and particle size will be determined, as will the optimum static pressure difference between the regenerator and gasifier vessels at various acceptor recirculation rates.

The feeders will be dismantled periodically and the wear rates of the Tuffon rotors and stainless steel stators will be measured. The rate of acceptor particle attrition, caused by repeated passage through the feeders, also will be measured. During this phase of the program single stage fluidized beds will be used in the regenerator and gasifier vessels. Studies of acceptor retention time in the gasifier and of two-stage beds will be deferred until continuous, reproducible, trouble-free feeding and recirculation have been demonstrated.

Fluidization Studies

The correlation work has been completed and will be presented in a Data Report now being written. The equations developed enable the bed density (or fractional expansion) to be calculated for any material fluidized by any gas at any conditions of pressure and temperature. The correlations will be vital in the translation of data obtained during operation of the model with air at ambient conditions to the continuous gasification unit operated at elevated pressures and temperatures.

The ranges of the variables investigated were:

Particle Density	31 to 222 lb/ft ³
Particle Size	28 x 35 mesh to 200 x 35 mesh
Fluidizing Gases	N ₂ , H ₂ , CO ₂
Vessel Diameter	1" and 2"

The equations predict the fluidized bed densities with an average deviation of somewhat less than 5% of their values and with a maximum deviation of 15% over the entire range of the several hundred data points which were obtained.

4. Supporting Process and Economic Analyses (Project No. 533.00)

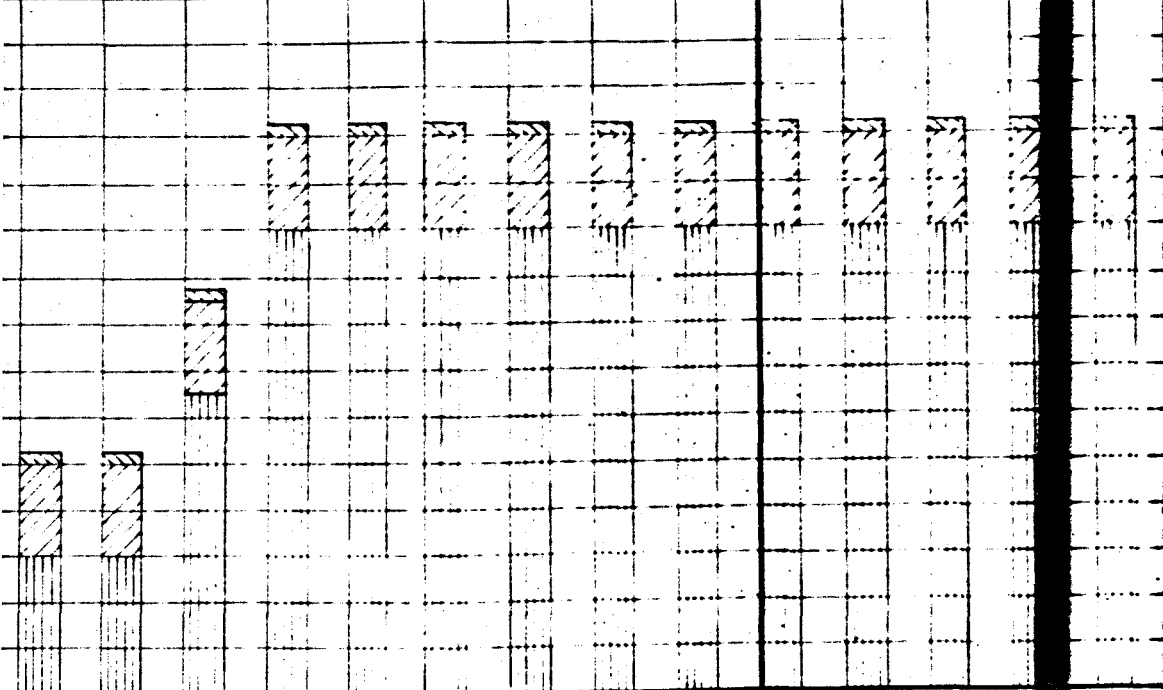
No work was done on this project.

MONTHLY PROGRESS CHART 2

CONTRACT No. 14-01-0001-415

1966

APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY



Complete Detailed Engineering Complete Construction Complete Installation & Commissioning

13.0M	13.0M	18.9M	19.4M	18.9M	17.4M	17.0M	17.4M	17.0M	17.4M	17.4M	17.4M	17.4M	17.4M	17.4M	17.4M
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148.5	171.4K	186.3M	199.7K	212.0M	230.5M	233.0M	270.9M	284.0M	305.4M	323.0M	330.0M	330.0M	377.5
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PROGRESS REPORT NO. 9
 OCR CONTRACT NO. 14-01-0001-415
 CONSOLIDATION COAL GASIFICATION PROCESS DEVELOPMENT
 February 1 to 28, 1965

A. Summary

Phase I - Feasibility Study

Complete.

Phase II - Bench Scale Experiments

Final calculations to determine differential rates from the initial series of kinetics runs have been completed. The technique used has been proved to be adequate, although experimental aberrations require that a few of the runs be repeated. On the basis of these results a comprehensive program of further kinetic studies is being planned.

Further investigations have been made into the nature of the high reactivity of South Dakota lignite to pure hydrogen. It was found that small amounts of steam addition, i.e., 9 vol. % was sufficient to reduce the rate to "normal" values. A catalytic component, possibly some form of iron, which is sensitive to steam is indicated.

The possible deactivation of dolomite acceptor by interaction with high alkali lignite ash under regeneration conditions was investigated. Little or no deactivation of acceptor was observed in spite of the fact that ash fusion occurred with the highest sodium content lignite (Benner's Cove) under the most severe conditions tested. The conditions which define the onset of ash fusion are being defined more sharply as a function of CO₂ partial pressure, temperature and ash alkali content. At the present time, it appears feasible to operate the process within the range of conditions where ash fusion will not occur.

The model of the gasification unit has been leak tested and flow calibrations completed. Circulation of acceptor between gasifier and regenerator vessels has been satisfactorily accomplished. The feeders operated with 100% volumetric efficiency. The major problem encountered to date has been a rapid rate of wear of the feeder rotors. This is being corrected and the program described in the last monthly report will then be carried out.

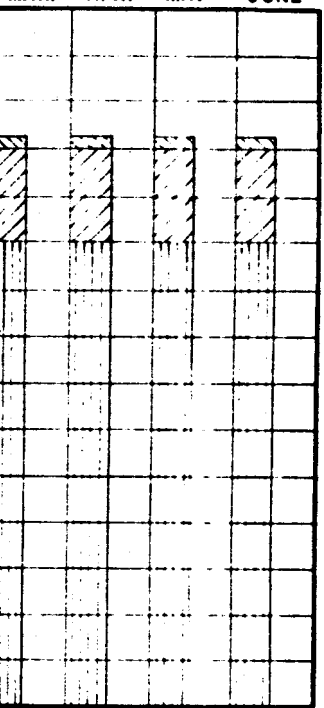
An additional measurement was made on the fluidization characteristics of dolomite under high CO₂ pressure and temperature to further check the correlation derived from past work. Satisfactory agreement was obtained. The fluidization correlation will be reported as a Data Report.

Financial:

Estimated expenditures for February were \$10,000 vs. a budget figure of \$10,500. Cumulative expenses to date are \$95,837 vs. a budget figure of \$122,400.

DATE: _____

MAR. APR. MAY JUNE



PREDICTED ACTUAL

SUPERVISING

PROFESSIONAL

TECHNICIAN

3

17.0M	17.0M	17.0M	17.0M
MAR.	APR.	MAY	JUNE
340.0M	338.0M	377.0M	384.0M

MONTHLY PROGRESS CHART

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CONTRACT No. 14-01-0001-415

B. Technical Results and Program**Phase I - Feasibility Study (Project No. 180)**

Completed.

Phase II - Bench Scale Program**1. Kinetic Studies (Project No. 530.00)**

Final calculations of the data from all the runs to date have been completed. A review of the results shows that the run procedure, control of the inlet gas composition, product gas analyses, and data workup procedure all are adequately accurate to give the desired differential reaction rates. Measures of the adequacy are given by the carbon and oxygen balances for the runs, which were made over fairly wide ranges of burnoffs, hydrogen and steam inlet flow rates, reactivity level, and carbon inventory. The balances are summarized below:

	% Deviation from 100% Closure	
	Average	Maximum
Carbon Balances	1.0	3.3
Oxygen Balances	1.8	4.8

The carbon and oxygen balances were influenced by a small and variable leak in the product gas sampling system which was found, and corrected, after the runs were made. Future runs will show even better closures.

Although the general experimental technique has been found suitable for production of reliable differential reaction rates, specific aberrations during 8 of the 17 runs involved have prevented the goal of reliability from being reached. The major difficulty stemmed from the inlet gas fluidizing velocity, which was chosen at a value about 20% too low to fluidize properly the char-diluent beds in the runs having the largest initial carbon inventory. In the runs, as subsequent investigation showed, the upper half of the bed was 10°-20°F hotter than the lower half, in which the control thermocouple was located. This situation led to the apparent anomaly where the integral rates for total gasification were greater for the runs having the larger initial carbon inventory than those for the companion runs having the smaller inventory. Other aberrations included: spurious burnoff caused by leakage of steam into the hydrogen stream used during the standardized pretreatment period, and a bed temperature error caused by a faulty thermocouple.

The inert diluent used was 200 x 325 mesh fused periclase. The char-diluent ratio was chosen to give a constant initial fluidized bed height, independent of the initial carbon inventory. The feed char was sized to 35 x 65 mesh.

The eight runs will have been repeated, and the final calculations completed by March 25th, at which time the experimental program for the 2nd Quarter can be formulated on a more sound basis than is now possible.

The South Dakota lignite char (Firesteel Mine) had shown a very high reactivity for methane production in pure hydrogen at 6 atm. pressure and 1400°F, conditions which correspond to those of the commercial devolatilizer. Yet, at gasification conditions in 60% H₂ - 40% steam its total gasification reactivity was somewhat less than that of the Kemmer's Cove char. If the high methane reactivity were to persist in the presence of a smaller amount of steam, advantage could be taken of the enhanced methane yields in the process devolatilizer. To check this possibility, Run 25 was made in which the inlet gas was 91% H₂ - 9% steam. The results showed that steam severely deactivates whatever catalytic substance (possibly metallic iron in the ash) which was responsible for the high methane rates in pure hydrogen. Run 24 showed that the catalytic substance was not removed appreciably by water extraction of the ash. The results are summarized below:

Run	1	10	9	25	24
Char	Kemmer's Cove	-----South Dakota-----			S. Dakota Water Extracted
°F	1500	1500	1400	1500	1400
Total Pressure, Atm.	16	16	6	16	6
Gas Composition					
% H ₂	60	60	100	91	100
% Steam	40	40	-	9	-
% Burnoff	35	35	11	35	11
Gasification Rate, gC Gasif./ gC in Bed, Min x 10 ⁴					
Total to all products	160	110	150	230	70
to methane, only	31	20	150	230	47

Equal volumes of lignite char ash and acceptor (25% ash by weight) were placed in a platinum capsule and exposed to regenerator conditions of temperature and O₂ partial pressure for 18 hours. The results are given below:

Run	Ash	Form of Acceptor	°F	P _{CO₂} , atm.	Fused?	Acceptor Activity Std. Carbonation Ratio
820	Kemmer's Cove	Carbonate	1910	11.0	No	.84
821	"	"	1950	11.0	Yes	.80
Q38	"	Oxide	1950	0.9	No	.94
822	Sakota Star	Carbonate	1950	11.0	No	.88

In all cases, the acceptor activities remained high and are comparable with those after exposure to bituminous coal ash at the same conditions. The Na₂O contents of the Renner's Cove and Dakota Star ashes are 15% and 4%, respectively.

The above data suggest that fusion of the ash is controlled by equilibrium in a reaction involving some silicate of sodium, such as



Another run will be made with Renner's Cove ash at 7 atm. CO₂ pressure and 1950°F - conditions which correspond more closely to the actual process regenerator conditions - to determine whether ash fusion will be eliminated under these conditions. If ash fusion still occurs, minor alterations of the process should be sufficient to resolve the problem. Some possibilities are:

1. Slightly lower the system pressure such that the regenerator temperature is reduced to 1900°F.
2. Operate with a slagging combustor and supply hot flue gas to a separate regenerator vessel.
2. Design of the Continuous Gasification Unit (Project No. 531.01)

No work was done on this project during February.

3. Mockup Studies (Project No. 531.02)

Operation of the Model

Leak testing and flow calibrations have been completed. Necessary revisions in hose piping diameters and locations have been made. In the absence of solids, tests on the feeders showed that they were leak-free up to at least a ΔP of 2.5 psi across the rotors.

Operations to date have involved recirculation of acceptor between the gasifier and regenerator vessels. Circulation rates of 2 to 30 lb/hr have been achieved at essentially 100% volumetric efficiency of the feeders. This range covers the entire range of recirculation rates anticipated during the operation of the continuous gasification unit.

The acceptor recirculation has been accomplished, so far, only by careful adjustment of the static pressures in the two vessels to make the pressure drop across the feeder rotors essentially zero. The rotors had been severely scored during preliminary testing. In this condition, even a mild pressure upset causes backflushing of gas through the standlegs above the feeders and consequent erratic feeding. After installation of new rotors, the program described in last month's Progress Report will be carried out. This program should be completed by the end of March, at which time studies of the retention time of acceptor in the gasifier and of two-stage beds will be started.

It is emphasized that continuous, trouble-free recirculation of the acceptor, in a manner relatively independent of process upsets, must be demonstrated in the model - if only to assure that explosions will not occur during operation of the continuous gasification unit.

Fluidization Studies

Data Report No. 1, covering the studies of retention times of particles falling through fluidized beds has been written.

As stated last month, the correlations of fluidized bed density with properties of the solids and fluidizing gas fit the observed data very well. However, the equations do not contain a term involving the gas density. This implies that the gas flow pattern has the nature of Poiseuille flow which generally is associated with particle Reynolds numbers of about 0.3 or less. Yet much of the data were taken at conditions where the Reynolds numbers were considerably above this level. Furthermore, all the data were obtained at ambient conditions, which precluded independent variation of gas density and viscosity. Completion of the Data Report covering this work was delayed until the correlations could be confirmed experimentally at high levels of gas density and Reynolds number. Measurements on a fluidized bed of 28 x 36 mesh acceptor (MgO.CaCO₃ form), made at 16 atm. CO₂ pressure and 1500°F, showed good agreement with the correlations. Apparently, the particle-particle interactions in a dense-phase fluidized bed fortuitously allow the use of equations having the Poiseuille form. Work on the Data Report has been resumed and it should be completed by March 15th.

4. Supporting Process and Economic Analyses (Project No. 533.00)

No work was done on this project.

5. Supporting Patent and Legal Activities (Project No. 534.00)

The current laboratory reports and memoranda were reviewed for determination of Subject Inventions.

C. Subject Inventions

None.

D. Financial Status

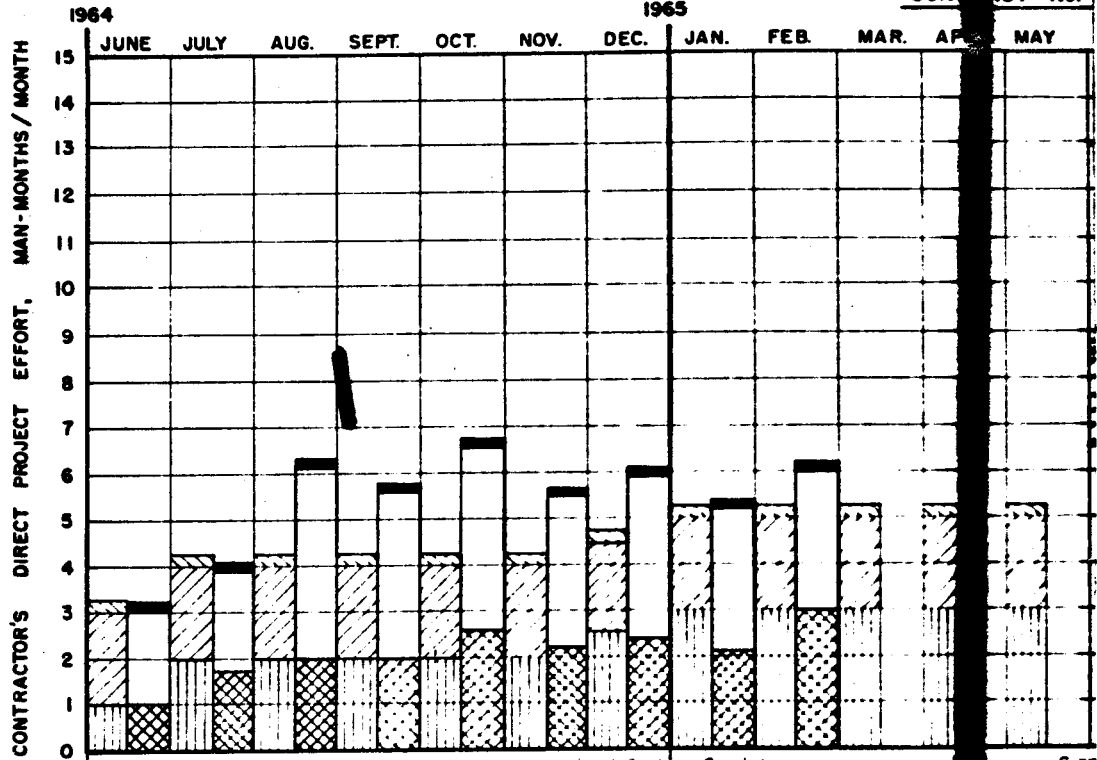
	<u>Actual</u>	<u>Budget</u>
Cumulative through January, 1965	\$ 85,837	\$ 111,500
Expended in Period	10,000	10,500
Cumulative through February, 1965	\$ 95,837	\$ 122,400

The indicated February expense is an estimate since accounting is not yet completed.

Att. Monthly Progress Chart
3/12/65

MONTHLY PRO

CONTRACT No.



Start Prelim. Eng'g Continuous Unit Start Test. Complete Prototype Unit C

FIGURES APPLY TO PHASE II PROGRAM ONLY

MONTHLY EXPENDITURES*

	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY
PREDICTED	3.9M	4.9M	9.3M	9.3M	19.4M	19.4M	27.1M	21.6M	10.3M	13.0M	13.0M	13.0M
ACTUAL	2.9M	4.3M	8.8M	8.3M	20.4M	10.7M	16.3M	12.8M	11.0M	13.0M	13.0M	13.0M

CUMULATIVE EXPENDITURES*

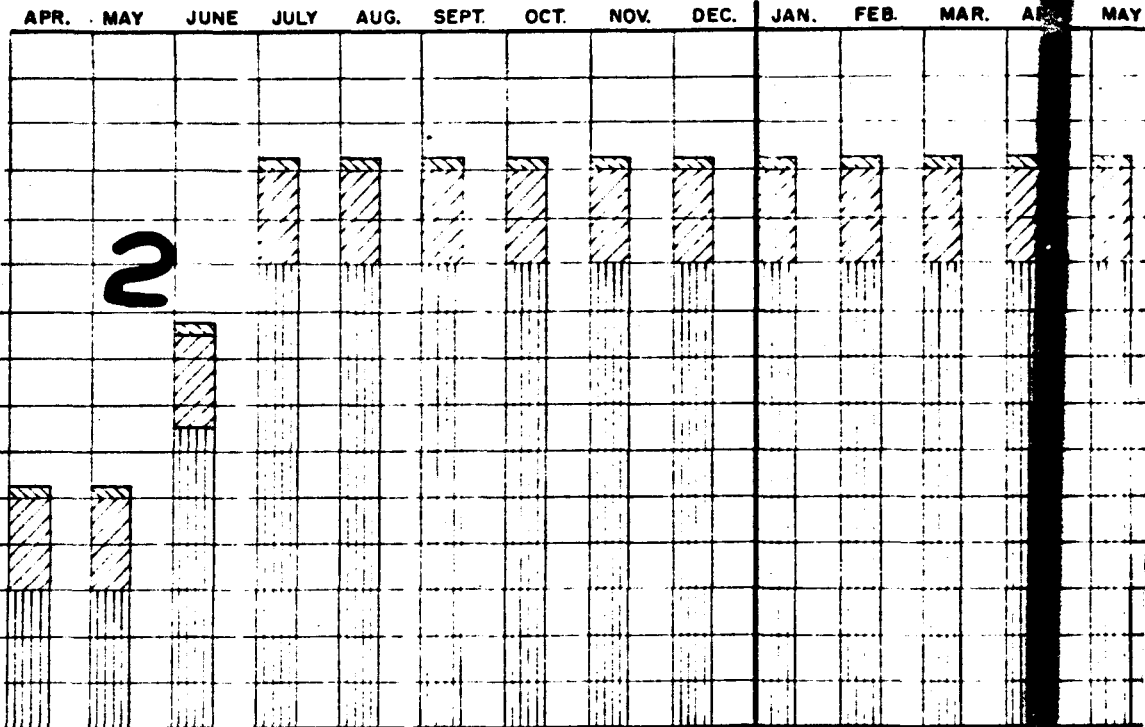
* Expenditures Include All Costs & Fees.

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MONTHLY PROGRESS CHART

CONTRACT No. 14-01-0001-415

1966









Complete Detailed Engineering Complete Construction Complete Break-in Runs & Revisions

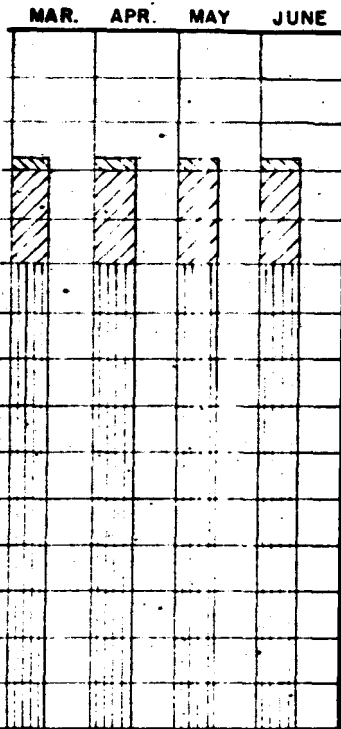
APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY
13.0M	15.0M	18.0M	19.0M	18.0M	17.5M	17.5M	17.0M	17.0M	17.0M	17.0M	17.0M	17.0M	17.0M

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CEDC-MPR--10

DATE: Feb. 1965

	PREDICTED	ACTUAL
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PROFESSIONAL		
TECHNICIAN		



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MONTHLY PROGRESS CHART

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RESEARCH DIVISION

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CONTRACT No. 14-01-0001-415

PROGRESS REPORT NO. 10
OCR CONTRACT NO. 14-01-0001-415
CONSOLIDATION COAL GASIFICATION PROCESS DEVELOPMENT

March 1 to 31, 1965

A. Summary

Phase I - Feasibility Study

Complete

Phase II - Bench-Scale Experiments

Some of the more important features of the kinetics behavior of the lignite char steam system have now been elucidated experimentally. A program has been formulated, based on these data, which will define the 1500°F isotherm in the above system.

The question of ash fusion under regenerator conditions of high alkaline content lignites was investigated further. No ash fusion occurs at temperatures up to 1950°F, if the CO₂ partial pressure does not exceed the value prevailing under process conditions, i.e., 7 atms at 20 atms total pressure.

Operation of the model continued to be the main experimental effort during the month. Attrition rate during circulation of dolomite through the unit was observed to be quite small. Wear on the rotors in the solids feeder continues to be a problem. Operations will be conducted with a pressure balance maintained across the feeders.

Char and calcined acceptor feeding have been successfully demonstrated. With char there is no wear on feed rotors. The calcined acceptor has been found to be subject to excessive attrition on passing through the feeders. The feeder in the acceptor return line to the gasifier has therefore been replaced by a plug valve.

The relationships between pressure drop, solids feed rates and carrier gas flows in the transfer lines has been determined. These data are needed for operation of the hot unit to maintain the proper pressure balance between the gasifier and regenerator.

Design work on all the hot vessels for the continuous gasification unit is well underway. Design and procurement of all items which are not contingent on the results of the cold model tests are being expedited.

Financial

Estimated expenditures in March were \$11,000 vs. a budget figure of \$13,000. Cumulative expenses to date are \$111,979 vs. a budget figure of \$135,450.

B. Technical Results and Program

Phase I - Feasibility Study (Project No. 180)

Completed.

Phase II - Bench Scale Program

1. Kinetic Studies (Project No. 530.00)

Char-H₂O Kinetic Studies

Final calculations leading to integral reaction rates for the repeat runs made during the month have been completed. Processing of the body of integral rate data to give differential reaction rates is in progress.

On the basis of the integral rate data, the operating program through July, 1965 was formulated. The program is of the minimum extent now thought necessary to define the kinetics behavior of the lignite char-H₂O system at 1500°F and features study of inhibition by CH₄ and CO. An outline of the program is given in EM-10813.

Inspection of the integral rate data showed that, for Renner's Cove char, the reaction rates increase by a factor of about two in going from top to bottom-of-gasifier conditions. This situation is favorable to the process since the carbon inventory per unit vessel volume decreases from top to bottom.

Char Ash - Acceptor Reactions at Regenerator Conditions

An ash-acceptor run (batch) made at 1950°F at 7 atm. CO₂ pressure with high-sodium Renner's Cove ash showed no fusion or agglomeration of the ash. The acceptor activity remained high at 0.85 Standard Carbonation Ratio. This result shows that if ash agglomeration is shown to be a problem in continuous operation, it can be alleviated by a small reduction in regenerator pressure and temperature.

Another approach is to remove sodium by extraction with water. A batch of raw Renner's Cove lignite currently is being extracted. Although no quantitative data are available yet, the alkalinity of the extract shows that a large proportion of the sodium is being removed.

2. Design of the Continuous Gasification Unit (Project No. 531.01)

Design work is nearly completed on all hot vessels that require coding, i.e., the gasifier, regenerator, steam generator, etc. Procurement is proceeding on long delivery items such as gas compressors. Design and procurement of all items which are not contingent upon the results of the cold model tests are being expedited.

3. Backup Studies (Project No. 531.02)

Acceptor Recirculation

About 30 hours of acceptor recirculation have shown that the attrition rate of raw dolomite and recarbonated acceptor (MgO.CaCO₃) is satisfactorily low at about 2% per day, and that attrition is caused solely by repeated passage through the rotary feeder. The calcined acceptor (MgO.CaO), although resistant to attrition in fluidized beds and transfer lines, is too soft to resist attrition by shearing which occurs during each passage through a rotary feeder. Therefore, the feeder in the acceptor return line to the gasifier was replaced by a plug valve. The flow rate of acceptor to the gasifier is now controlled by this valve, which is positioned by the regenerator level control circuit.

It is now apparent that rotor wear in the spent acceptor feeder will prevent a gas-tight seal from being maintained between the gasifier and regenerator. However, by holding an essentially zero pressure differential across the worn rotor and across the plug valve in the acceptor return line, the gas inventories of the regenerator and gasifier vessels can be isolated effectively from each other. Pressure balance is achieved by controlling the purge rate into the standlegs above the feeder and plug valve. The necessary flow rates were determined by injection of CO₂ into the purge lines, then analyzing the offgas from the appropriate vessel (regenerator or gasifier) for its CO₂ content. Instrumentation to maintain balanced pressure has been incorporated into the design of the continuous gasification unit.

The relationships among pressure drop, acceptor recirculation rate, and carrier gas flow rate in the transfer line between the gasifier and regenerator have been determined. Knowledge of these relationships is vital to the operation of the continuous gasification unit because the pressure drop across the transfer line must balance, approximately, the pressure drop across the fluid beds and standlegs of both process vessels.

Reliable recirculation of acceptor has now been demonstrated. Startups and shutdowns are accomplished smoothly. With pressure balance across the acceptor feeder and plug valve, safe operation during normal process upsets can be assured.

Char Feed and Withdrawal

Char feed to and withdrawal from the gasifier has been demonstrated successfully. Wear of the feeder rotors is slight and gas-tight seals can be maintained. Char attrition is not an issue since once-through operation is involved.

Pressure drop, char feed rate, carrier gas flow rate relationships for the transfer line from the feed hoppers to the gasifier were determined.

The level detector probes, whose operation depends upon the electrical conductivity of the char, could not be evaluated in the model, since char feedstock for operation of the model had been prepared at 1100°F and therefore is not a conductor. It was impractical to prepare a large batch of char at a temperature higher than 1100°F. Operation of prototypes of the probes, set up in the laboratory, with a small batch of char prepared at 1400°F has shown that they will perform satisfactorily.

4. Supporting Process and Economic Analyses (Project No. 533.00)

No work was done on this project.

5. Supporting Patent and Legal Activities (Project No. 534.00)

The current laboratory reports and memoranda were reviewed for determination of Subject Inventions.

C. Subject Inventions

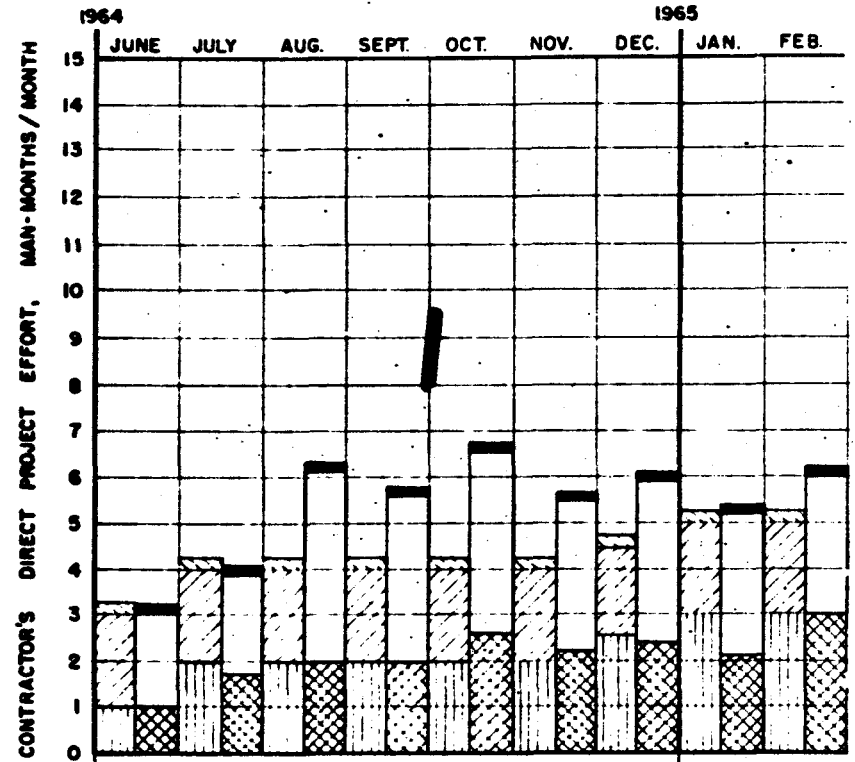
None.

D. Financial Status

	Actual	Budget
Cumulative through February, 1965	\$ 100,979	\$ 122,400
Expended in Period	11,000	13,000
Cumulative through March, 1965	\$ 111,979	\$ 135,400

The indicated March expense is an estimate since accounting is not yet completed.

JAP:vw
Att. - Monthly Progress Chart
4/14/65



Start Prelim. Cont. Continuous Unit Start Test Complete Prototype Unit
FIGURES APPLY TO TASK 11 PROGRAM ONLY

	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.
PREDICTED	3.0M	4.2M	9.3M	9.3M	19.4M	19.4M	20.1M	21.6M	17.5M
ACTUAL	2.9M	4.2M	8.2M	9.3M	20.4M	10.7M	16.3M	15.6M	11.6M
PREDICTED	3.0M	12.2M	22.1M	31.4M	50.8M	70.2M	90.3M	111.9M	122.4M
ACTUAL	2.9M	7.4M	17.1M	26.4M	46.8M	57.5M	73.8M	89.4M	101.0M

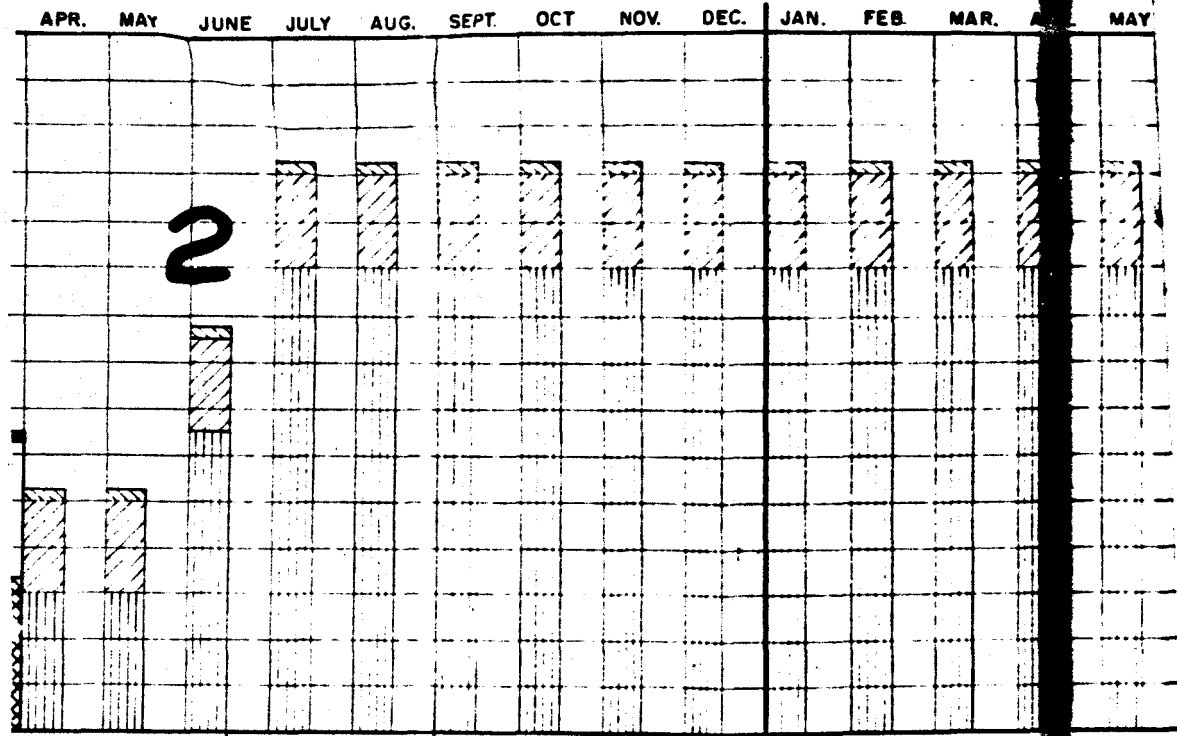
CUMULATIVE EXPENDITURES*

* Expenditures Include All Costs & Fees.

MONTHLY PROGRESS CHART

CONTRACT No. 14-01-0001-415

1966









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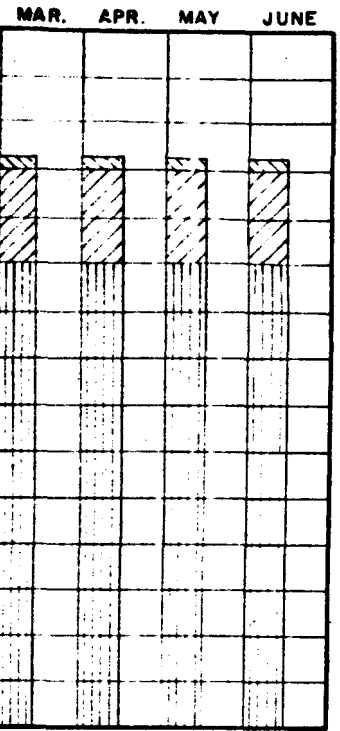
Complete Detailed Engineering Complete Construction Complete Treatment Runs & Retentions

13.0M	13.0M	18.0M	19.0M	18.0M	17.0M	17.0M	17.0M	17.0M	17.0M	17.0M	17.0M	17.0M	17.0M	17.0M
APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	
142.0M	141.0M	186.0M	199.0M	216.0M	230.0M	253.0M	270.0M	285.0M	300.0M	323.0M	340.0M	350.0M	370.0M	

CSDC-MPR--11

DATE: March 1965

	PREDICTED	ACTUAL
SUPERVISING		
PROFESSIONAL		
TECHNICIAN		



3

17,000	17,000	17,000	8,000
MAR.	APR.	MAY	JUNE
340,000	358,000	371,000	384,000

MONTHLY PROGRESS CHART
 OFFICE OF COAL RESEARCH
 DEPARTMENT OF THE INTERIOR
CONSOLIDATION COAL CO.
 RESEARCH DIVISION LIBRARY, PA.
 CONTRACT No. 14-01-0001-415

PROGRESS REPORT NO. 11
 OCR CONTRACT NO. 14-01-0001-415
CONSOLIDATION COAL COMPANY

April 1 to 30, 1965

A. Summary

Phase I - Feasibility Study

Complete.

Phase II - Bench-Scale Experiments

Kinetic investigations of the rate of gasification of lignite char have revealed that the rate is influenced to an unexpected degree by the partial pressure of carbon monoxide. A tentative explanation is that one is dealing here with sodium catalysis and the presence of CO influences the chemical state and activity of the catalyst. Munner's Cove lignite is the superior feedstock from the point of view of reaction rate.

Operation of the model of the continuous reaction system has continued successfully. Control of retention time of acceptor particles falling through the fluidized char bed has been adequately demonstrated. Previous correlations based on single particles falling through the bed have been found to be valid for quantitative predictions.

Reliable feeding, recirculation and withdrawal of solids as well as pressure drop relationships in the transfer lines has likewise been adequately demonstrated. Operation of the model will be completed by May 21 at which time it will be dismantled and construction of the hot unit begun.

All design work, drawings, and purchase orders for the hot unit will be completed in early June, 1965. Construction of the hot unit should be completed in August, 1965.

Financial

Estimated expenditures in April are \$11,500 vs. a budget figure of \$13,000. Cumulative expenses to date are \$124,161 vs. a budget figure of \$148,400.

B. Technical Results and Program

Phase I - Feasibility Study (Project No. 180)

Completed.

Phase II - Bench Scale Program

1. Kinetic Studies (Project No. 530.00)

Differential rate data for the four lignite chars at conditions of steam and hydrogen partial pressures corresponding to the top and bottom of the commercial gasifier have been obtained by extrapolating integral reaction rates from char beds having initial carbon contents of .67 and .33 gram atoms of carbon to zero carbon content. The Kemmer's Cove char clearly is the superior feedstock.

Closer study of the integral rates has revealed that the reaction rates are influenced by the partial pressure of carbon monoxide to an extent that cannot be accounted for by the procedure of extrapolation to zero carbon content. At some conditions CO seems to enhance, rather than inhibit, the reaction rates. This situation implies that a catalytic material of variable activity and/or variable concentration is present. The material presumably is sodium, present in some unknown state. The effects of CO are qualitatively the same for all four lignite chars, including the Kemmer's Cove char from which most of the sodium had been removed by extraction with water.

Further discussion will be deferred until rate data from runs in which CO is added to the inlet gas are available. The program is now underway.

2. Design of Continuous Gasification Unit (Project No. 531.01)

During the past month, the following has been completed:

1. Ordered J-2 and J-3 Recycle Gas Compressors. This is a long lead item and delivery is presently scheduled for the second week of August.
2. Ordered all the required instruments for hot operation of the unit. Delivery is expected in 7 to 11 weeks.
3. Construction was started on one new instrument board.
4. Arranged for fabrication of a new conical section of the lignite gasifier.
5. Designed the outer shells for the regenerator and gasifier. These vessels and the steam saturator should be code fabricated. Drawings have been sent out to obtain quotes on these items.
6. Ordered a boiler feed water pump.

7. Designed and completed drawings on the following vessels.

- (a) Char Let Down Drum (F-2)
- (b) Condensate Receiver (F-4)
- (c) Gasifier Cyclone
- (d) Dust Collector Cyclone (G-2)
- (e) Dust Collector Ropper (F-12)
- (f) Condensate Knock-Out Pot (F-14)

The following actions should be accomplished during the next month:

1. Order the following:

- (a) Demineralizer (L-8)
- (b) Chilled Water Supply (L-9)
- (c) Required Materials for Vessels
- (d) Required valves, fittings and tubing

2. Design and prepare drawings for the following:

- (a) Gasifier Inner Shell
- (b) Regenerator Inner Shell
- (c) Gas Cooler (C-1)
- (d) Char Cooler (C-2)
- (e) Acceptor Cooler (C-3)
- (f) Gas Cooler (C-4)
- (g) Acceptor Cooler (C-5)
- (h) Gas Cooler (C-6)
- (i) Gasifier Filters (L-6)
- (j) Regenerator Filters (L-7)

3. Prepare a revised equipment layout.

The majority of the required drawings can be prepared and the material required for fabrication can be ordered during May and the first part of June. Construction of the hot unit should start during the latter part of July and be completed around the middle of August.

3. Mockup Studies (Project No. 531.02)

Acceptor Retention Time

The retention time of acceptor particles showering downward through a fluidized bed of lignite char is predicted accurately by the correlation developed from measurements on single particles (RM-10500, Project 531.02). The presence of a cloud of particles is accounted for by basing the fluidized bed density on the weight of the char plus the weight of acceptor falling through the bed. The maximum deviation of the observed retention time from the predicted was 7%. Some typical results are given below. The lignite char was 48 x 100 mesh in all cases.

Size	Acceptor	Fluidized Bed		Retention Time at 4 ft Bed Height, min.
	Circulation Rate, lb/hr	Bed Density lb/ft ³	Wt. % Acceptor	
28 x 35 M	17.5	35.8	18.2	7.8
28 x 35 M	18.2	33.9	17.1	6.7
20 x 28 M	17.0	32.4	10.2	4.1
	8.40	31.0	5.1	4.0
	8.89	29.4	5.7	4.0
	18.8	28.4	10.5	3.8

The technique of timing the fall of a small slug of radioactive acceptor injected into the fluidized bed was abandoned because it was too time-consuming. The retention time of the slug of particles was strongly dependent on which portion of the fluid bed flow pattern the slug entered. Very short retention times occurred if the slug entered the downflowing stream at the vessel wall, and long retention times occurred if it entered the upflowing stream at the center of the bed. Several hundred slug injections would have been necessary to have obtained reliable average retention times over the ranges of the variables covered in the above table.

The method finally adopted was to establish steady-state recirculation of the acceptor through the bed of char at known values of recirculation rate and fluidized bed height, then by simultaneously shutting off all flows, the fluidized bed was "frozen". The bed was drained off above the char acceptor interface at the bottom of the vessel and the char and acceptor were separated by sieving. From the weights of each material and the recirculation rate and bed height, the average retention times were calculated.

Final Operations of the Model

To date, operation of the model has demonstrated reliable feeding, recirculation, and withdrawal of solids and that the acceptor retention time in the gasifier can be controlled. Sufficient data on the relationships in transfer lines and standlegs among pressure drop, flow rates, and line diameter have been obtained. The remaining studies fall into three categories and will be completed by May 21, at which time the model will be dismantled and construction of the hot unit begun:

1. The existing geometry of the bottom of the gasifier vessel is not adequate to provide a sharp interface between the char bed and the segregated acceptor. A new bottom, now being fabricated, increases the gas velocity through the segregated acceptor by reducing the vessel diameter from 4 to 2 inches. Performance will be tested during the second week of May.
2. During startup and major process upsets, it has been found that the inventory of acceptor falling through the gasifier bed changes rapidly. It is therefore necessary to test the operation of the probe which detects and controls the char-acceptor interface under these nonsteady-state conditions.

Several pounds of lignite char were made electrically conducting by heating to 1400°F. Performance of the probe and its circuitry will be tested by imposing purposeful upsets on the system.

3. Efforts so far to operate two-stage beds with overflow weirs and downcomers between the upper and lower beds have shown little success. Although stable inventories in both beds have been maintained during severe process upsets for a fixed throughput of solids, instability occurs when the throughput is changed. Some further experimentation is planned before staging is abandoned. The hot unit will operate satisfactorily with single-stage beds, although better bed temperature control would be possible if the beds were staged.

4. Supporting Process and Economic Analysis (Project No. 533.00)

No work was done on this project.

5. Supporting Patent and Legal Activities (Project No. 534.00)

The current laboratory reports and memoranda were reviewed for determination of Subject Inventions.

C. Subject Inventions

None.

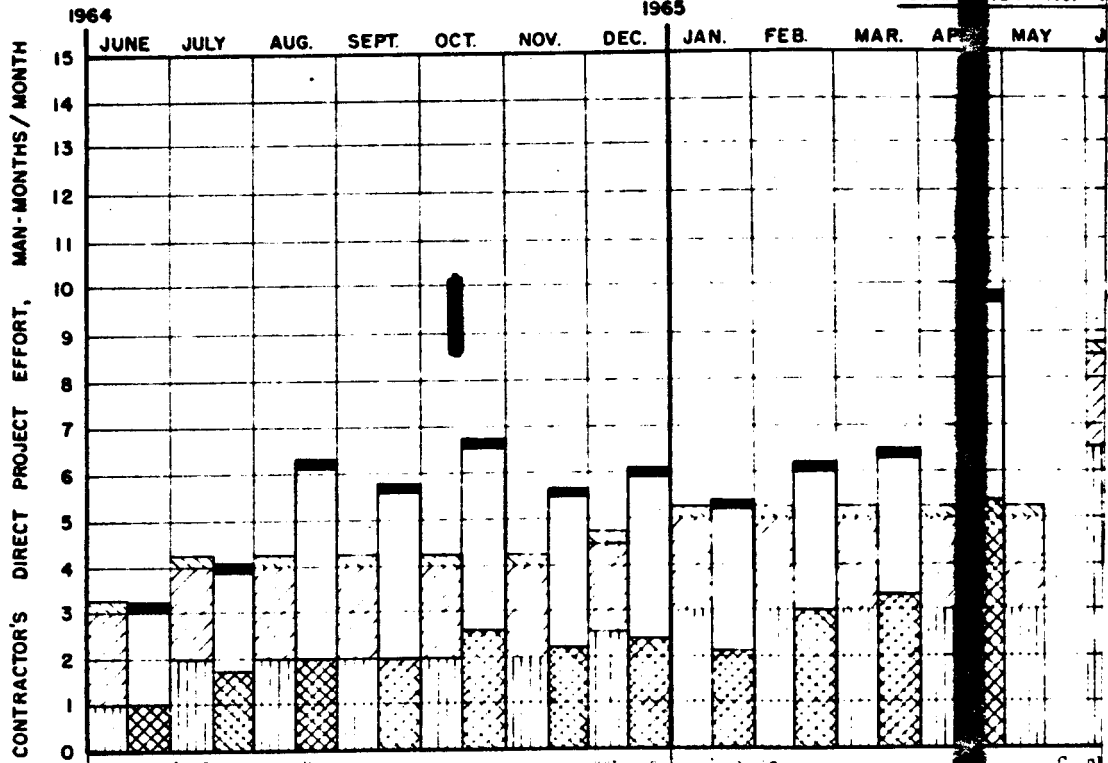
B. Financial Status

	<u>Actual</u>	<u>Budget</u>
Cumulative through March, 1965	\$ 112,661	\$ 128,400
Expended in Period	11,500	13,000
Cumulative through April, 1965	\$ 124,161	\$ 148,400

Att. Monthly Progress Chart

MONTHLY PRO

CONTRACT No. 1



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Start of Month, and for Contract Units

FIGURES ARE IN MILLIONS OF DOLLARS

		JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY
MONTHLY EXPENDITURES*													
PREDICTED		3.9M	4.9M	9.3M	9.3M	19.4M	19.4M	23.1M	11.6M	17.9M	13.0M	13.0M	13.0M
ACTUAL		2.9M	4.8M	8.8M	9.3M	23.4M	10.7M	10.3M	15.0M	11.0M	11.7M	11.7M	11.7M
CUMULATIVE EXPENDITURES*													
PREDICTED		3.9	12.1	22.1	31.4	50.8	70.2	93.3	111.4	122.3	135.3	148.3	161.3
ACTUAL		2.9	7.7	17.1	26.4	46.8	57.5	73.8	89.4	101.0	111.7	123.4	135.1

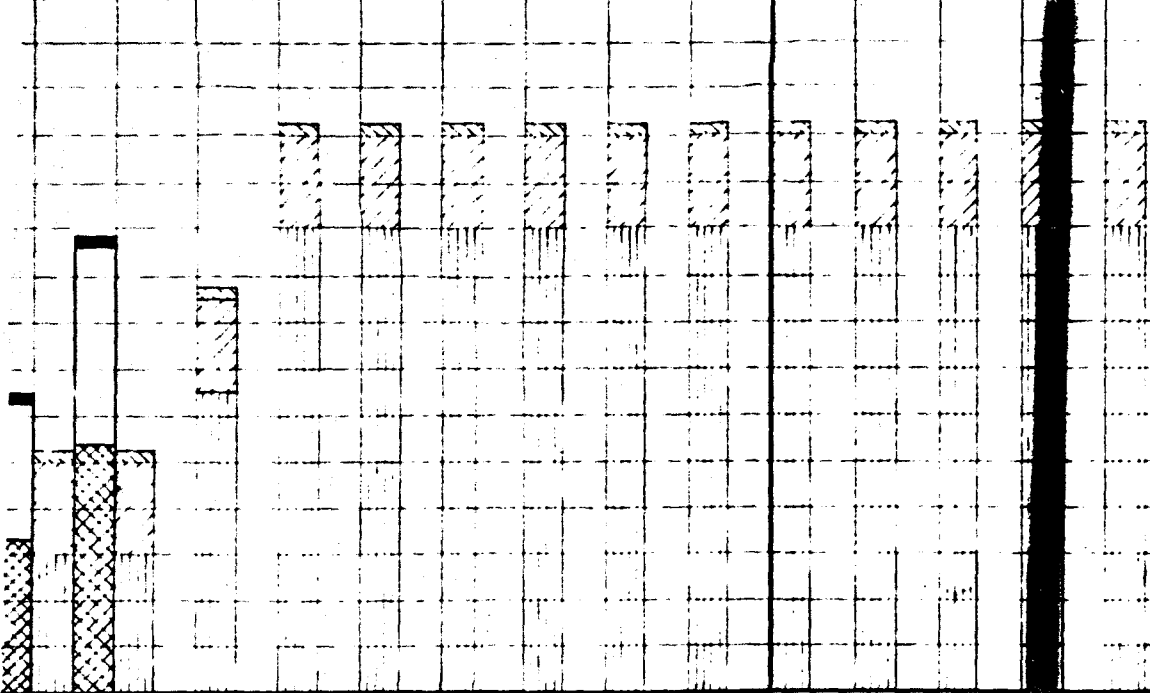
* Expenditures Include All Costs & Fees.

HLY PROGRESS CHART

CONTRACT No. 14-01-0001-415

1966

APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY



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	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY
Construction	13.0M	13.0M	18.9M	19.4M	18.2M	17.7M	17.1M	17.0M	17.1M	17.1M	17.1M	17.1M	17.1M	17.1M
Construction	11.0M													
Construction														
TOTAL	24.0M	13.0M	18.9M	19.4M	18.2M	17.7M	17.1M	17.0M	17.1M	17.1M	17.1M	17.1M	17.1M	17.1M

2

PROGRESS REPORT NO. 12
 OCE CONTRACT NO. 14-01-0001-415
CONSOLIDATION LIGNITE GASIFICATION PROCESS DEVELOPMENT
 May 1 to 31, 1965

A. Summary

Phase I - Feasibility Study

Complete.

Phase II - Bench-Scale Experiments

The peculiarly high rate of CH₄ formation in pure H₂ previously found with South Dakota char was also noted with Renner Cove char although the magnitude of the rate was less in the latter case. Addition of steam as in the case of the South Dakota char drastically lowered the CH₄ rate.

Peculiar reversals in integral reaction rates with decreasing bed height in runs with pure H₂ and in some cases with H₂-H₂O mixtures pointed to volatilization of a catalytic component, presumably a sodium salt, as a possible cause. A survey was therefore made of volatilization losses of sodium during previous kinetic runs. The results show that the sodium loss was roughly independent of the gas composition and was relatively small. Only 3% of the total sodium in Renner Cove ash was volatilized in 3 hours.

Auxiliary kinetic studies showed that the CH₄-H₂O reaction occurred at negligible rates under conditions used in the kinetic studies, and could be safely neglected in interpretation of results. Char ash was not a catalyst for this reaction but did effectively catalyze the water gas shift reaction.

Most of the problems foreseen in April in operation of the model have been favorably resolved. A method has been worked out for maintaining a stable interface between the char bed and the segregated acceptor. Detectors for maintenance of bed inventories and the acceptor-char interface were tested and found to perform satisfactorily. Successful demonstration of operation with two-stage beds was effected.

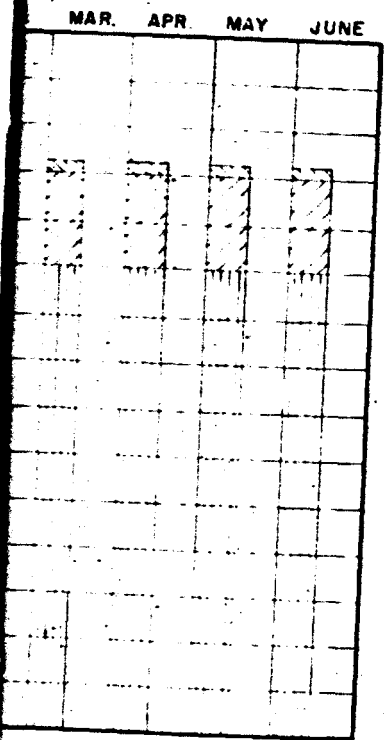
A few further tests are planned. Improved procedures for withdrawing a char stream uncontaminated with acceptor from the gasifier will be worked out. The rate of attrition of acceptor in the fully calcined form on circulation through the unit will also be determined. Operations of the model will cease on June 16 to permit full concentration on construction of the hot unit.

All design work on the hot unit has been completed. Purchase orders for all long delivery items have been placed. The target date for completion of construction remains late August, 1965.

Financial

Estimated expenditures in May are \$18,000 vs. a budget figure of \$13,000. Cumulative expenses to date are \$145,331 vs. a budget figure of \$161,400.

DATE: June 1965



PREDICTED ACTUAL

SUPERVISING

PROFESSIONAL

TECHNICIAN

3

MONTHLY PROGRESS CHART

OFFICE OF COAL RESEARCH
 DEPARTMENT OF THE INTERIOR

CONSOLIDATION COAL CO.
 RESEARCH DIVISION LIBRARY, PA.

CONTRACT No. 14-01-0001-415

MAR.	APR.	MAY	JUNE
		371.7	31.3

B. Technical Results and ProgramPhase I - Feasibility Study (Project No. 180)

Completed.

Phase II - Bench Scale Program1. Kinetic Studies (Project No. 530.00)Previously Scheduled Runs

Data from runs with 100% H₂ as the inlet gas show that the Renner Cove lignite char also has a peculiarly high reactivity toward pure H₂. The magnitude of the rate is considerably less than that shown by the South Dakota char, however.

The results also show that the integral rates are essentially the same at 11 atm and 16 atm and that the rates are lower for the run having the smaller initial charge of carbon. These apparently anomalous results can be explained on the basis of volatility of the catalytic ash component since the sweep gas rates as shown below decrease with increasing bed weight.

g Initial Bed Wt.	Total Press. atm.	1500°F Integral CH ₄ Rate, % Burnoff	gC gasif./gC in Bed/Min. x 10 ⁴					SCFH/g Initial Char
			5	15	25	35	45	
10	16	192	200	104	48	20	2.0	
10	11	204	172	112	48	20	1.4	
5	16	138	124	82	40	20	4.0	

Addition of 10% steam to the inlet hydrogen drastically decreased the integral CH₄ rates, as was the case with the South Dakota char. The rates are shown below, along with those for the other inlet hydrogen concentrations.

Total Pressure: 16 atm. Temperature: 1500°F
Integral CH₄ Rates for 5 g Initial Charge.

% H ₂ in Inlet Gas	% Burnoff	gC gasif./gC in Bed/Min. x 10 ⁴				
		10	20	30	40	50
32	60	56	53	51	48	
62	84	63	47	41	38	
90	40	24	14	8	-	
100	135	111	61	30	16	

Studies of Extraneous Reactions

The thermal conductivity cell used to monitor the exit gas composition during transition from the pretreatment to the gasification periods failed completely in early May. A new cell was ordered and delivery is expected during

the second week of June. In the interim, studies were made on possible reactions which could occur in the upper part of the reactor and the exit piping above the char bed.

(a) Reactions Involving CH₄

If CH₄ were formed or decomposed after the product gas leaves the char bed, interpretation of the kinetics of CH₄ formation would be difficult. Reactor temperatures above the char bed range from 1500°F to 800°F and the exit piping temperatures range from 800°F to 400°F. Gas retention times are about one second in the char bed and about 3 seconds above the bed.

Methane can be formed or decomposed by reactions such as



To determine the extent of methane decomposition in the kinetics reactor system, a steam-H₂-CH₄ mixture under the conditions shown below was passed through beds of various solids.

Total Pressure:	18.2 atm.
Dry Gas Composition:	23.9% CH ₄ in H ₂
Inlet Gas:	62% dry gas - 38% steam

It is concluded that Renner Cove ash has no specific catalytic effect on CH₄ decomposition. The results showed that the CH₄ formed from the steam-carbon reaction during a routine kinetics run is not appreciably decomposed while in the char bed, especially at temperatures of 1500°F or less.

In the experiments described below, mixtures of CO-CO₂-H₂-H₂O were passed through the system. In no case was CH₄ detected in the exit gas, showing that CH₄ is not synthesized in the upper, cooler parts of the reactor system where synthesis is favorable, thermodynamically.

(b) The Water Gas Shift Reaction

During the kinetics runs with steam-H₂ mixtures as inlet gas, the observed water gas shift ratio of the product gas never deviated by more than ± 5% from the equilibrium ratio, regardless of the initial bed weight, burnoff level, origin of the lignite, or inlet gas composition. In contrast, the Project II work with Disco char showed major deviations, predominantly toward the CO side of equilibrium.

To help determine the relative effect of the reactor walls and internals and of the Renner Cove ash toward catalysis of the reaction, a mixture of the four components was passed through the reactor system at conditions shown below:

Total Pressure: 16 atm.
Inlet Dry Gas Composition: 7.45% CO₂, 11.79% CO,
80.76% H₂
Inlet Gas: 32% dry gas - 68% steam

$$K = \frac{(CO_2)(H_2)}{(CO)(H_2O)}$$
$$K_{inlet} = .240$$

It was shown that water gas shift equilibrium was reached at 1600°F whether or not a bed of Renner Cove ash was present. The reactor internals clearly catalyze the water gas shift equilibrium. The Renner Cove ash, however, is a specific catalyst since a closer approach to water gas shift equilibrium was achieved when it was present, i.e., in the lower temperature runs at 1400 and 1500°F.

Volatilization of Sodium

It has been found that the kinetics of the lignite char-steam reaction are influenced strongly by the presence of a catalytic material in the ash (presumably sodium) of variable activity and/or concentration. The sodium lost by volatilization from the reacting bed of solids, at the conclusion of all the runs made during May, was determined by washing the reactor and external piping with water and analyzing the washings for recovered sodium.

The results have shown that for a given time and gas rate/unit of initial char the loss of sodium was essentially independent of the gas composition, which ranged from 100% H₂ containing no CO₂ to steam-H₂ mixtures containing CO₂ at .002 to .64 atm partial pressure. In three hours, 3% of the total sodium charged with the ash in Renner Cove char was volatilized. On continued exposure to process conditions, additional loss occurred. At the gas flow rates and system pressures used in the experiments, the amounts of volatile sodium recovered correspond to a compound having a vapor pressure of .03 mm Hg at 1500°F, assuming 2 atoms of sodium per mole.

The above information is inconclusive because it is not known whether the volatilized sodium, or any part of it, is the active catalyst. The variation in activity could also be caused by a change of the form in which the active sodium exists -- e.g., oxide, carbonate, silicate.

The issue cannot be resolved until data from the series of runs in which CO and CO₂ are added to the inlet gas are available. These run conditions will presumably stabilize the active sodium as Na₂CO₃.

2. Design of Continuous Gasification Unit (Project No. 531.01)

Designs of the solids coolers and inlet gas preheaters were completed. Heat balance and wall-to-fluid Δt calculations were made for high and low levels of feed rates and for the case where all the process heat is supplied electrically.

Purchase orders for essentially all the equipment and material for the hot unit have been placed. The exceptions are for powerstats and some miscellaneous piping fittings. These are short-delivery items.

3. Mockup Studies (Project No. 531.02)

The three problems, foreseen in April, were resolved during the month.

1. The proper geometry of the bottom of the gasifier vessel for maintenance of a sharp, stable interface between the char bed and the segregated acceptor was determined. The full (4") diameter 80° cone was retained but was modified by an insert positioned to extend partly into the cone and partly into the straight section. The optimum gas velocity between the insert and the reactor wall was found to be three times that in the 4" diameter section. The interface is held in the annular space between the insert and the reactor wall.
2. The three detectors which maintain the bed inventories in the gasifier and regenerator and the acceptor-char interface at the bottom of the gasifier were tested and found to perform well under conditions of severe upsets.
3. Successful operation of two-stage beds using overflow weirs and downcomers was demonstrated. The hot unit regenerator has been designed as a two-stage vessel. However, the gasifier will be operated as a single-stage vessel because it would be difficult to withdraw the spent char, substantially uncontaminated with acceptor, from a two-stage bed.

All operations with the model have been with raw Greenfield dolomite. The attrition rate with this material has been satisfactorily low. Fully calcined dolomite is much less resistant to attrition and has not been tested in the model since it slakes in the humidified air used as the fluid. Before the model is dismantled, an attempt will be made to recirculate calcined acceptor, using dry N₂, and to measure the attrition rate. The rotary feeder in the acceptor transfer line from the gasifier to the regenerator will be removed from the system, since laboratory experiments have shown that the feeder crushes the calcined acceptor at a rapid rate. All operations of the model will cease on June 16th, to permit installation of pressure equipment.

4. Supporting Process and Economic Analysis (Project No. 533.00)

A paper was prepared and presented at the AGA Operating Conference, Buffalo, New York, May 25, 1965.

5. Supporting Patent and Legal Activities (Project No. 534.00)

The current laboratory reports and memoranda were reviewed for determination of Subject Inventions.

C. Subject Inventions

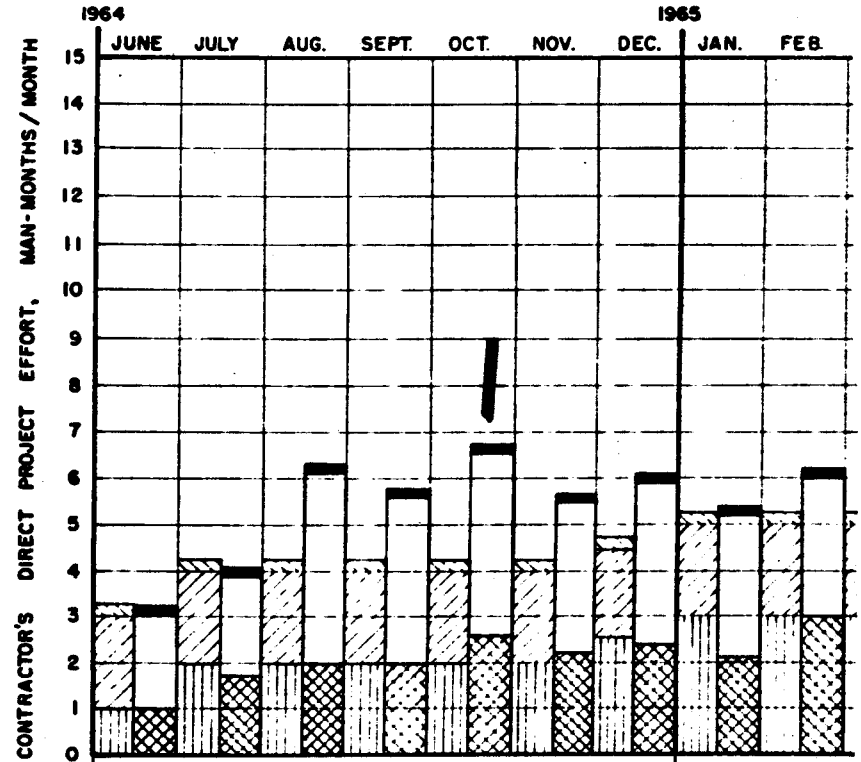
None.

D. Financial Status

<u>Expenses</u>	<u>Actual</u>	<u>Budget</u>
Cumulative through April, 1965	\$127,331	\$148,400
Expended in Period	18,000	13,000
Cumulative through May, 1965	\$145,331	\$161,400

Att. - Monthly Progress Chart
6/14/65

MC



Start Prelim. Eng'g Continuous Unit Start Testing Complete Prototype Unit
FIGURES APPLY TO PHASE II PROGRAM ONLY

	MONTHLY EXPENDITURES*									
	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	
PREDICTED	3.9M	8.9M	9.3M	9.3M	19.4M	19.4M	20.1M	21.6M	10.3M	
ACTUAL	2.9M	8.3M	8.8M	9.3M	20.4M	10.7M	16.3M	15.6M	11.6M	
PREDICTED	3.9M	12.8M	22.1M	31.4M	50.8M	70.2M	90.3M	111.9M	122.2M	
ACTUAL	2.9M	8.3M	17.1M	26.4M	46.8M	57.5M	73.8M	89.4M	101.0M	

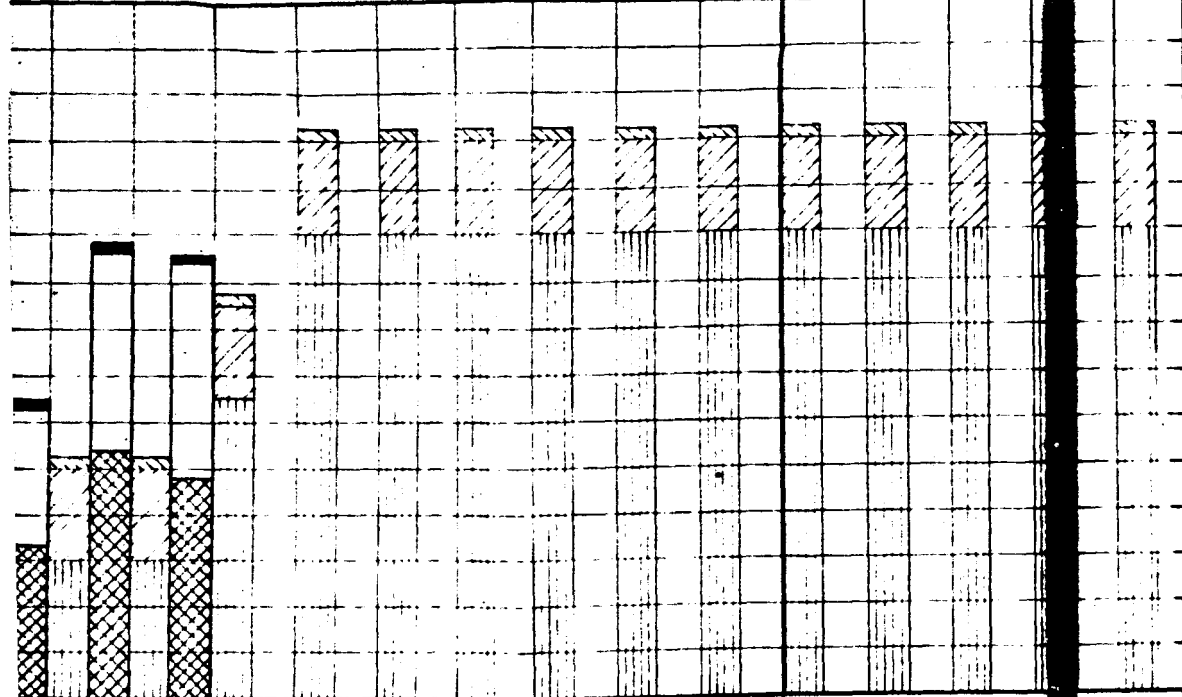
CUMULATIVE EXPENDITURES*
* Expenditures Include All Costs & Fees.

MONTHLY PROGRESS CHART 2

CONTRACT No. 14-01-0001-415

1966

APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY



Complete Detailed Engineering

Complete Construction

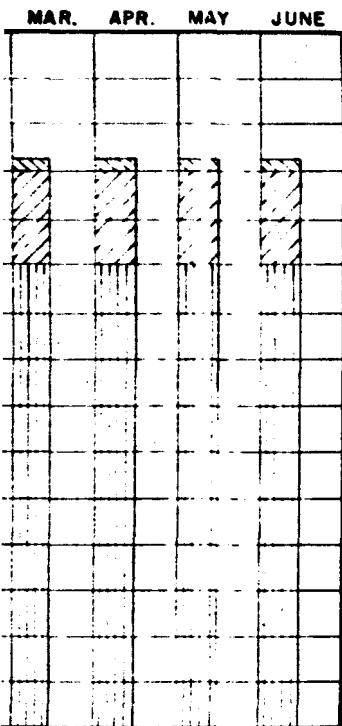
Complete Break-in Runs & Revisions

	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY
OM	13.0M	13.0M	18.9M	19.4M	18.3M	17.0M	17.5M	17.3M	17.7M	17.5M	17.5M	17.5M	17.5M	17.5M
7M	14.6M	18.0M												
T.	117.3	111.4K	180.3M	198.7M	218.0M	235.0M	253.0M	270.3M	288.0M	305.3M	323.0M	310.3M	310.3M	379.3M
M	127.3M	145.3M												

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CEOC-MPR--13

DATE: July 1965



PREDICTED **ACTUAL**

SUPERVISING

PROFESSIONAL

TECHNICIAN

3

MAR.	APR.	MAY	JUNE
310.00	338.00	375.00	381.00

MONTHLY PROGRESS CHART

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CONTRACT No. 14-01-0001-415

PROGRESS REPORT NO. 13

OCR CONTRACT NO. 14-01-0001-415
CONSOL LIGNITE GASIFICATION PROCESS DEVELOPMENT
June 1 to 30, 1965

A. Summary

Phase I - Feasibility Study

Complete.

Phase II - Bench-Scale Experiments

The lignite char-steam kinetics program in which CO and CO₂ will be added to the inlet gas was deferred while awaiting delivery of a new thermal conductivity cell. The program will get under way in July.

Lignite char from Husky-Dominion's Lurgi carbonizer in North Dakota has been chosen as the feedstock to be used during most of the operation of the hot unit. A kinetics run with this char showed that it is comparable in reactivity to Dakota Star char.

Preliminary testing for activity and physical strength of the commercially available dolomites from the North Central States showed that only one, from South Dakota, had the desired acceptor properties. This stone will be subjected to repeated cycles of regeneration and recarbonation to determine its suitability at process conditions.

Highly selective removal of sodium from Benser Cove ash has been demonstrated by extracting either the raw lignite or char with hot water.

The attrition rate of fully calcined acceptor while circulating through the model was measured. The rate was satisfactory, under the operating conditions required to overcome the strong electrostatic forces which developed.

The model has been dismantled and construction of the pressure unit is under way. All purchase orders and drawings for the unit have been issued, and deliveries are on schedule to date. The target date for cold pressure testing of the unit is August 23rd.

Financial

Estimated expenditures in June are \$26,500 vs. a budget figure of \$18,900. Cumulative expenditures to date are \$172,846 vs. a budget figure of \$180,300.

B. Technical Results and ProgramPhase I - Feasibility Study (Project No. 180)

Completed.

Phase II - Bench Scale Program1. Elastic Studies (Project No. 530.00)

Delay of delivery of the thermal conductivity cell again caused postponement of the char-steam kinetics program in which oxides of carbon are added to the inlet gas. However, the new cell has been received, calibrated, and is now in service.

Because of its ready availability, lignite char from Husky-Dominion's Lurgi unit at Dickinson, North Dakota, is a good potential source of feedstock for the continuous gasification unit. After pretreatment at standard conditions, a kinetics run with a sample of this char showed that it has about the same reactivity as Dakota Star char. The Husky char has been chosen as the feedstock to be used in the hot unit.

Samples of the potentially useful dolomites in commercial production in the North Central States were given a preliminary test for activity and size degradation. The results are shown below, along with those for the Greenfield dolomite which is the best stone found during our earlier studies of acceptor behavior.

Dolomite Source for South Dakota Pilot Plant

Origin	Activity Std. Carb. Ratio	% Fines Produced
Greenfield (Ohio)	.98	1.1
Pete Lien, site 2 (S.D.)	.95	4.3
Wheatland (Wyo.)	.71	4.5
Concrete Materials (Iowa)	.88	7.4
Fort Dodge (Iowa)	.88	8.0

Of the stones tested, only the Pete Lien sample shows promise from the standpoints of both activity and particle strength.

Analytical results for the extraction of Renner Cove ash with water are now complete. The samples were extracted exhaustively in a Soxhlet apparatus in which the water temperature was held at about 80°C. Alkalies are extracted preferentially, and to a high degree. The sodium exists in the ash mostly in the form of silico-aluminates. Water extraction of the lignite thus offers one possible solution to the problem of ash fusion at regenerator conditions. The results are summarized below.

Extraction of Renner Cove Ash with Water

	Char, Pretreated at 1400°F	Raw Lignite
% of Total Ash Removed	28.5	19.1
% of Component Removed		
SiO ₂	41	32
Al ₂ O ₃	37	8
Fe ₂ O ₃	14	28
MgO	90	98
K ₂ O	94	82
CaO + MgO	~0	~0
SiO ₂ + Al ₂ O ₃ MgO + K ₂ O, moles in soluble ash	.80	.74

2. Design of Continuous Gasification Unit (Project No. 531.01)

The design of the hot unit has been completed, and all purchase orders and drawings have been issued. The project was terminated on June 30th. Any further engineering or drafting work needed for revisions of equipment or layout will be charged to Project No. 531.03 (Construction of Continuous Gasification Unit).

3. Backup Studies (Project No. 531.02)

During final operations of the model, an effort was made to measure the attrition rate of fully calcined Greenfield dolomite while circulating it through the regenerator fluidized bed, the standlegs, and the transfer line. In dry N₂, circulation was not possible because of severe electrostatic effects. By "humidifying" the N₂ with methanol, electrification was reduced considerably, but continuous circulation still was not possible unless the rotary feeder was used to control the flow rate of the acceptor into the transfer line.

The measured attrition rate was 19%/24 hours, compared with 2%/24 hours at similar conditions with the raw dolomite. This rate is considered to be adequately low since most of the attrition is caused by crushing in the rotary feeder. In the hot unit, only the recarbonated acceptor passes through the feeder. Furthermore, even this rate is within the acceptable limits for the process as visualized in the feasibility study.

Operations with the model ceased on June 11th, and the model has been dismantled.

Workup and correlation of the data obtained with the model are currently under way.

4. Construction of Continuous Gasification Unit (Project No. 531.03)

Removal of the mockup unit was initiated on June 15th to permit the start of assembly of the pressure apparatus. Delivery of equipment is proceeding as scheduled. The target date for initiating of cold pressure testing is August 23rd.

5. Supporting Process and Economic Analysis (Project No. 533.00)

No work was done on this project.

6. Supporting Patent and Legal Activities (Project No. 534.00)

The current laboratory reports and memoranda were reviewed for determination of Subject Inventions.

C. Subject Inventions

None

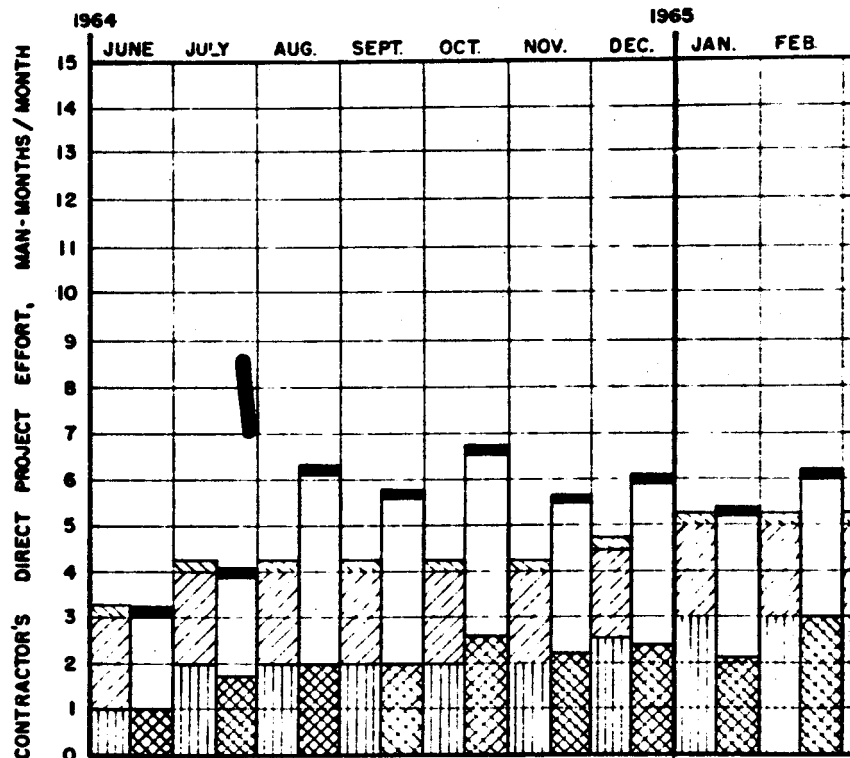
D. Financial Status

Expenses	Actual	Budget
Cumulative through May, 1965	\$ 146,346	\$ 161,400
Expended in Period	26,500	18,900
Cumulative through June, 1965	\$ 172,846	\$ 180,300

The indicated June expense is an estimate since accounting is not yet complete.

Att. - Monthly Progress Chart
 7/8/65

MO



Start Prelim. Eng. Continuous Unit
 FIGURES APPLY TO PHASE II PROGRAM ONLY
 Start Test. Complete
 Prototype Unit

MONTHLY EXPENDITURES*

	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.
PREDICTED	3.0M	4.9M	9.3M	9.3M	19.4M	19.4M	20.1M	21.6M	10.3M
ACTUAL	2.9M	5.0M	8.8M	9.3M	20.4M	10.7M	16.3M	15.6M	11.6M

	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.
PREDICTED	3.0M	12.4M	22.1M	31.4M	50.8M	70.2M	90.3M	111.9M	122.2M
ACTUAL	2.9M	8.3M	17.1M	26.4M	46.8M	57.5M	73.8M	89.4M	101.0M

CUMULATIVE EXPENDITURES*

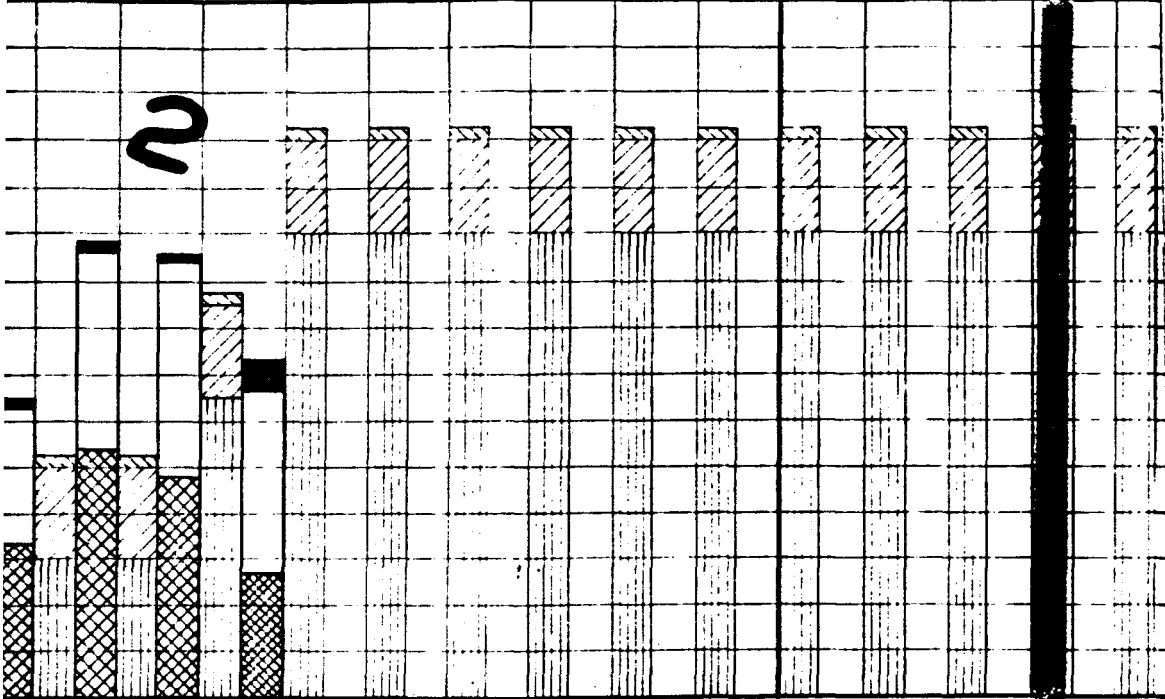
* Expenditures Include All Costs & Fees.

MONTHLY PROGRESS CHART

CONTRACT No. 14-01-0001-415

1966

R. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MA



Complete Detailed Engineering Complete Construction Complete Break-in Runs & Revisions

0M	13.0M	13.0M	18.0M	19.0M	18.0M	17.5M	17.5M	17.5M	17.5M	17.5M	17.5M	17.5M	17.5M	17.5M
7M	14.5M	19.0M	26.5M											

R. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY

9M	14.5M	19.0M	18.0M	19.7M	21.0M	23.5M	23.0M	27.0M	26.0M	30.5M	32.0M	31.0M	38.0M	37.5M
7M	127.3M	146.3M	172.4M											

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PROGRESS REPORT NO. 14
 OCR CONTRACT NO. 14-01-0001-415
CONSOLIDATION COAL GASIFICATION PROCESS DEVELOPMENT
 July 1 to 31, 1985

A. Summary

Phase I - Feasibility Study

Completed.

Phase II - Bench Scale Experiments

Initial results are now available on the effect of addition of CO and CO₂ on the gasification kinetics. The addition of oxides of carbon reduced the gasification rate for production of new oxides of carbon to roughly one-fourth the value with no carbon oxide addition. The effect is presumably due to a stabilization or reduction in activity of the sodium catalyst by interaction with CO₂.

Interestingly enough, the rate of formation of methane by the hydrogen carbon reaction was unaffected by the addition of carbon oxides.

The effect of cycling through simulated process conditions on activity was studied for the South Dakota dolomite (Pete Lien). The loss in activity was greater than for the standard Greenfield dolomite although its resistance to physical degradation was just as good.

Attempts at reconstituting dolomite fines by melting in a steam-carbon dioxide atmosphere under pressure were unsuccessful. The MgO did not melt and behaved as solid matrix which retained the molten lime.

Report writing and correlation of data in connection with fluidization behavior and the model studies is complete with one exception. The latter deals with the correlation of the friction factor in dilute phase transport.

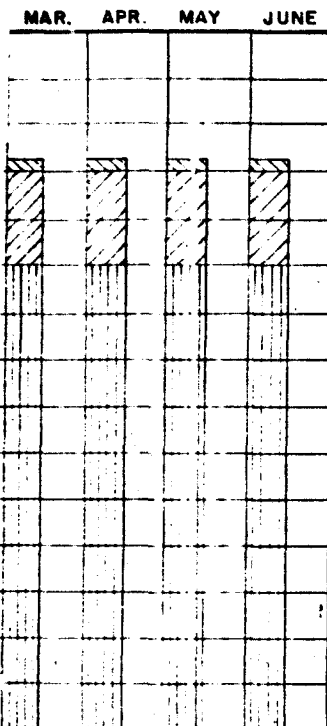
The construction of the continuous hot unit is slightly behind schedule. Initial testing of the unit should start on September 15th.

Financial

Estimated expenditures for July are \$25,000 vs. a budget figure of \$19,400. Cumulative expenditures to date are \$197,846 vs. a budget figure of \$199,700.

DATE: June 1985

	PREDICTED	ACTUAL
SUPERVISING		
PROFESSIONAL		
TECHNICIAN		



3

17.3M	17.3M	17.3M	16.8M
MAR.	APR.	MAY	JUNE
310.3M	308.0M	373.5M	384.3M

MONTHLY PROGRESS CHART

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CONSOLIDATION COAL CO.
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CONTRACT No. 14-01-0001-415

B. Technical Results and ProgramPhase II - Bench Scale Program1. Batch Kinetic Studies (Project No. 530.00)Steam - Char Kinetics

The first series of kinetic runs in which CO and CO₂ were added to the inlet gas has been completed. Steam and hydrogen partial pressures correspond to top-of-gasifier conditions and were kept the same as for the runs previously reported. Carbon oxides were added to the inlet gas to simulate the projected amounts at the outlet from a commercial gasifier as shown below:

	Partial Pressure, atm.	Mole % in Total Inlet Gas
CO	1.64	7.88
CO ₂	.96	5.34

Gasification rates for CO and CO₂ production were reduced to 20-30% of those observed with no carbon oxide addition, showing that the powerful catalytic action of sodium had been suppressed. This catalysis was shown to be specific for carbon oxides production since the rates of CH₄ formation were essentially unchanged. The results are summarized below:

Integral Gasification Rates for 15 g Initial Bed Weight
g C gasif./min/g C in Bed x 10⁴

Run	% Burnoff	R _{CO + CO₂}					R _{CH₄}				
		10	20	30	40	50	10	20	30	40	50
H ₂ + H ₂ O only		150	131	124	122	118	55	42	34	28	24
Oxides Added		48	38	32	28	23	53	37	33	27	23

In the oxide addition runs, the conversions were small enough so that the above integral rates are very nearly the differential rates. The study will be continued using lower levels of oxides addition and higher ratios of steam to hydrogen, i.e., to simulate the condition prevailing at the gasifier inlet.

Acceptor Studies

The Pete Lien dolomite (S. Dakota) was tested further by subjecting it to repeated calcining and recarbonation at process conditions. The results are shown below in comparison with those from other stones tested previously:

No. of Cycles	Total Time at Process Conditions, Hrs.	Activity, Standard Carbonation Ratio		
		Pete Lien	Virginia	Greenfield
5	3.80	.74	.60	.81
12	4.75	.62	.38	.81

All three stones were equally resistant to size degradation. If the acceptor activity at the level of the South Dakota stone proves to be uneconomical, reactivation by conversion to the Ca(OH)₂ form followed by calcining to CaO may be necessary. As time permits a brief study of reactivation of the South Dakota stone will be made.

A possible solution to the combined problems of activity loss and size degradation lies in the reconstitution of spent acceptor fines by forming a melt followed by cooling, crushing, and calcining. The Greenfield dolomite from Western Ohio could then be used, since the freight costs involved would be very small with the resulting "perpetual" acceptor.

In an effort to study the acceptor properties of such a melt, several attempts were made to form a liquid from the South Dakota dolomite, but without success. At a CO₂ partial pressure of 1.5 atm. and steam partial pressures of 13, 16, and 19.6 atm. at 1600°F. the acceptor agglomerated but did not form a liquid. The particles did not lose their identity and the agglomerates had the consistency of a sugar cube. Previous melts which were truly liquids had been made with calcined limestone, pure CaO, or mixtures of CaO and Ca(OH)₂. Possibly, melts which are truly liquid could be made from dolomite by starting with mixtures of MgO-Ca(OH)₂ and MgO-CaCO₃ or MgO-Ca(OH)₂ and MgO-CaO. Studies to determine the proper temperatures and partial pressures of steam and CO₂ probably would involve a major experimental program.

2. Mockup Studies (Project No. 531.02)

Data reports for the correlation of fluidized bed densities with fluid and particle properties and for the results of operation of the model have been written and will be issued in August.

3. Construction of Continuous Gasification Unit (Project No. 531.03)

The construction pace has been slowed somewhat by demands for shop time by the Gasoline Projects. However, the hot unit should be ready for initial testing by September 13th. Deliveries of materials and equipment have been adequate and should cause no delay.

4. Operation of Continuous Gasification Unit (Project No. 532.00)

An Operating Manual for the hot unit has been written and will be issued in August.

The initial shipment of lignite char from Husky-Dominion in North Dakota has been received. The char has been ground to minus 20 mesh and will be screened at 35 mesh in the Sweco Separator. The fines will be elutriated batchwise in the CC-2 pretreater vessel. These operations will provide about 3300 lbs. of feedstock for the hot unit, sized to 35 x 150 mesh and substantially free of minus 150 mesh material. This amount should be sufficient for operation of the unit until December. Additional char will be ordered from Husky, and processed, as requirements dictate.

Analyses of the 35 x 150 mesh fraction of the char showed:

Moisture to 500°F	-	3.4%
Volatile Loss - 500-1100°F	-	3.4%
Volatile Loss - 1100-1500°F	-	7.7%
		-14.5%

5. Supporting Process and Economic Analyses (Project No. 533.00)

No work was done on this project.

6. Supporting Patent and Legal Activities (Project No. 534.00)

The current laboratory reports and memoranda were reviewed for determination of Subject Inventions.

C. Subject Inventions

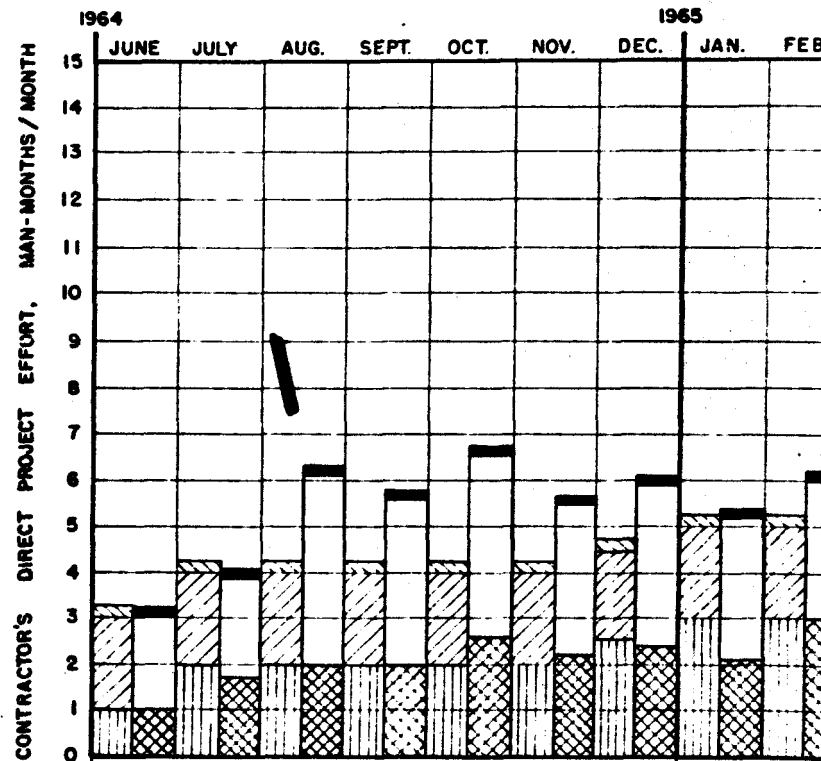
None.

D. Financial Status

<u>Expenses</u>	<u>Actual</u>	<u>Budget</u>
Cumulative through June, 1965	\$ 172,846	\$ 180,300
Expended in Period	25,000	19,400
Cumulative through July, 1965	\$ 197,846	\$ 199,700

The indicated July expense is an estimate since accounting is not yet complete.

Att: Monthly Progress Chart
8/13/65



Start Prelim. Engrg Continuous Unit Start Testing Complete Prototype Unit

FIGURES APPLY TO PHASE II PROGRAM ONLY

MONTHLY EXPENDITURES*

	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.
PREDICTED	3.9M	8.9M	9.3M	9.3M	19.4M	19.4M	20.1M	21.6M	13.9
ACTUAL	2.9M	5.0M	8.8M	9.3M	20.4M	10.7M	16.3M	15.6M	11.6M

	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.
PREDICTED	3.9M	12.8M	22.1M	31.4M	50.8M	70.2M	90.3M	111.9M	125.8M
ACTUAL	2.9M	7.9M	17.1M	26.1M	46.5M	57.2M	73.5M	89.1M	100.7M

CUMULATIVE EXPENDITURES*

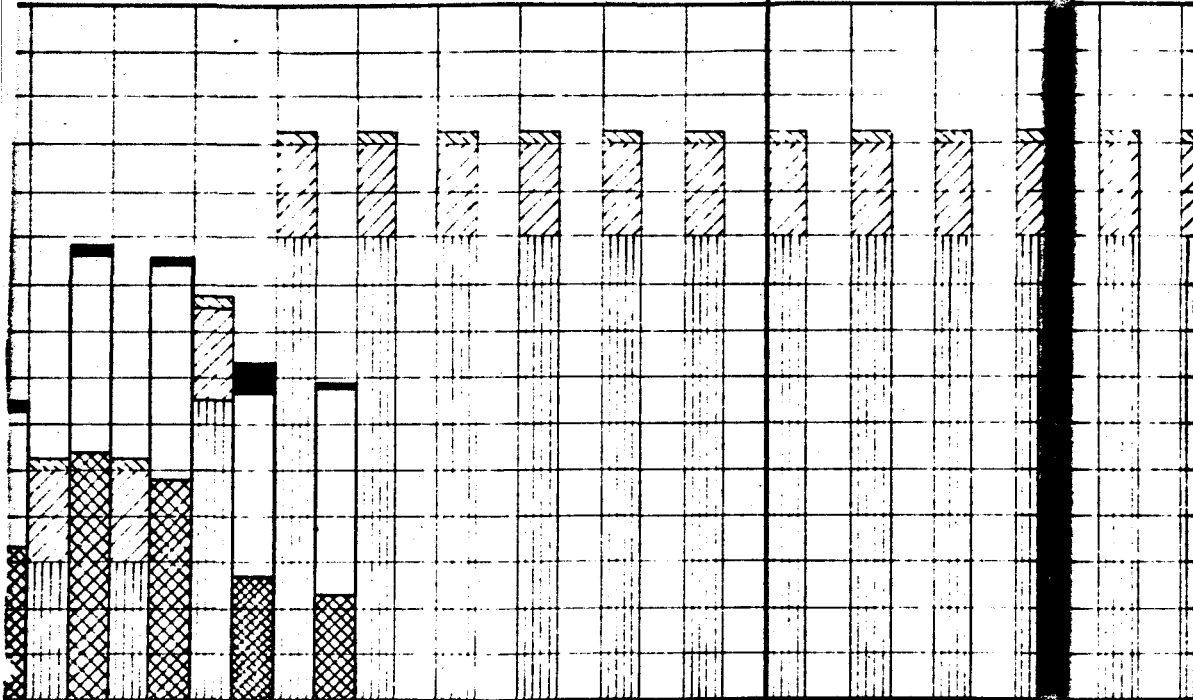
* Expenditures Include All Costs & Fees.

HLV PROGRESS CHART

CONTRACT No. 14-01-0001-415

1966

APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY



Complete Detailed Engineering

Complete Construction

Complete Break-in Runs & Revisions







13.0M	13.0M	18.9M	19.4M	18.2M	17.0M	17.3M	17.3M	17.0M	17.0M	17.0M	17.0M	17.0M	17.0M	17.0M
14.6M	19.9M	26.5M	25.0M											
APR	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	
147.3M	146.3M	172.8M	199.7M	218.0M	230.0M	253.0M	270.5M	288.0M	305.5M	323.0M	340.5M	358.0M	375.5M	
127.3M	146.3M	172.8M	197.8M											

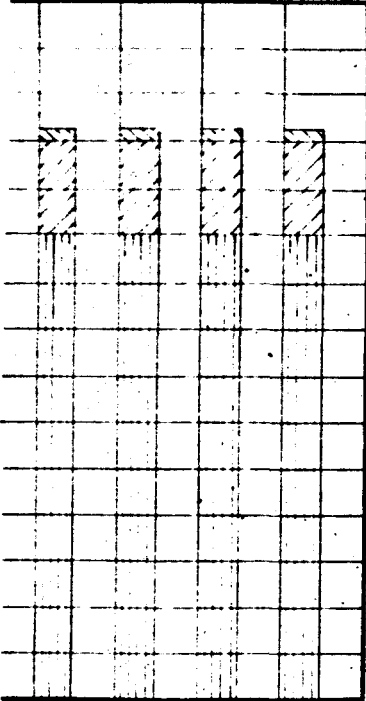
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DATE: _____

MAR. APR. MAY JUNE

	PREDICTED	ACTUAL
SUPERVISING		
PROFESSIONAL		
TECHNICIAN		



3

MONTHLY PROGRESS CHART

OFFICE OF COAL RESEARCH
DEPARTMENT OF THE INTERIOR

CONSOLIDATION COAL CO.
RESEARCH DIVISION LIBRARY, PA.

CONTRACT No. 14-01-0001-415

PROGRESS REPORT NO. 15
OCR CONTRACT NO. 14-01-0001-415
CONSOLIDATION COAL GASIFICATION PROCESS DEVELOPMENT

August 1 to 31, 1968

A. Summary

Phase I - Feasibility Study

Complete.

Phase II - Bench Scale Experiments

Further kinetic results are now available on the effect of addition of carbon oxides at gasifier inlet and exit conditions on gasification rates at 1500°F. The CH₄ formation rate is relatively unaffected in both cases by carbon oxide addition. The rate of formation of new carbon oxides is, however, reduced by factors of about 2 and 4 at the inlet and exit conditions respectively.

Difficulty associated with spurious methane formation by hydrogenation of carbon monoxide was corrected by using an all stainless steel reactor and poisoning the catalytic effect of the metal by presulfiding.

All data gathered during the operation of the cold model has been correlated including the solids friction factor in pneumatic transport.

The construction of the hot unit is behind schedule. Pressure testing of the unit is scheduled for September 15 and initial operator training runs should begin by September 30.

Financial

Estimated expenditures for August are \$21,000 vs. a budget figure of \$18,300. Cumulative expenditures to date are \$218,887 vs. a budget figure of \$218,000.

OK	17.7K	17.7K	17.7K	5.6K
3	MAR.	APR.	MAY	JUNE
OK	210.0K	325.0K	375.0K	384.3K

B. Technical Results and Progress

Phase II - Bench Scale Program

1. Batch Kinetic Studies (Project No. 530.00)

Steam-Char Kinetics

The first series of carbon oxides addition runs at bottom-of-gasifier conditions was made. Preliminary calculations showed that the rates of CH₄ formation were unchanged, as was the case for the runs at top-of-gasifier conditions. Integral gasification rates for CO and CO₂ production were about 40-60% of those observed with no carbon oxide addition.

The immediate future program calls for completion of two series of runs at CO₂ partial pressures of nominally 0.5 and 1.0 atm at both of the above conditions. Depending upon the effect of CO₂ pressure which is found, a third series, at a much lower CO₂ pressure, will be made to ascertain if a threshold level exists which will stabilize the catalytic activity of sodium in the ash. In all cases, CO is added to bring the inlet gas to water gas shift equilibrium in order to ensure control of the CO₂ partial pressure which otherwise would be altered by the water gas shift reaction occurring on the stainless steel surfaces of the inlet gas preheater and reactor wall.

Spurious Methane Formation

Most of the month's experimental effort was devoted to finding a method to suppress spurious CH₄ which was formed from the inlet gas by a reaction such as



In the carbon oxides addition runs which were made immediately after the reactor, and internals, had been used in the studies of soot formation and of the effect of cycling on acceptor activity, spurious CH₄ began to appear in the product gas. In these studies, the reactor system had been exposed to oxidizing conditions in the temperature range of 1600°-1950°F. This history apparently activated the metal surfaces of the reactor system, since it had been shown earlier that the system when equilibrated to the steam-carbon kinetics conditions had essentially no catalytic activity toward CH₄ formation.

It was found that spurious CH₄ formation is totally inhibited by using an all-stainless steel (Type 310) system which has been passivated by treatment with a 0.5% H₂S - 99.5% H₂ mixture at 1500°F.

2. Mockup Studies (Project No. 531.02)

With completion of the correlation for the solids friction factor in pneumatic transport, this project was terminated on September 1. Publication of the Data Reports covering the work on this project was deferred while a paper on the status of the CO₂ Acceptor Gasification Process, to be presented at the December A.I.Ch.E. meeting was being written.

3. Construction of Continuous Gasification Unit (Project No. 531.03)

Construction again has been delayed by demands for shop time by the Gasoline projects. At present, all major equipment, vessels, and piping are in place. With completion of the instrumentation piping, the unit should be ready for cold pressure testing by September 15. Electrical and instrumentation wiring should be completed by the end of September, at which time hot testing and cold circulation of solids at 300 psia can begin.

4. Operation of the Continuous Gasification Unit (Project No. 532.00)

No direct work under this project has been done since the hot unit is still being constructed. Final sizing of the char feedstock is scheduled for completion by September 24.

During the week of September 20, training of the full operating crew will begin. The initial operations will involve calibrations and cold circulation of solids.

5. Supporting Process and Economic Analyses (Project No. 533.00)

No work was done on this project.

6. Supporting Patent and Legal Activities (Project No. 534.00)

The current laboratory reports and memoranda were reviewed for determination of Subject Inventions.

C. Subject Inventions

None

B. Financial Status

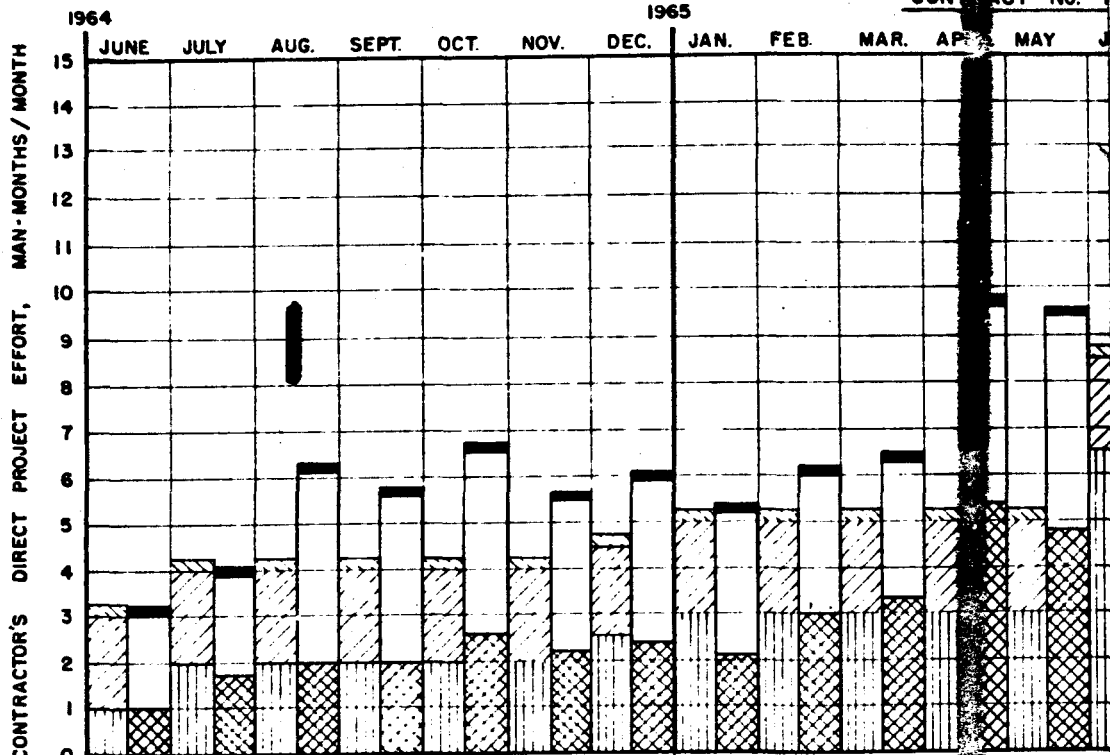
Expenses	Actual	Budget
Cumulative through July, 1965	\$ 197,887	\$ 199,700
Expended in Period	21,000	18,300
Cumulative through August, 1965	\$ 218,887	\$ 218,000

The indicated August expense is an estimate since accounting is not yet complete.

Att. Monthly Progress Chart

MONTHLY PROGRESS

CONTRACT No. 1



Start Test, Complete Prototype Unit Continuous Unit Complete Eng.

MONTHLY EXPENDITURES*

	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY
PREDICTED	2.9M	1.9M	9.3M	9.3M	19.4M	19.4M	20.1M	21.6M	10.5M	13.0M	13.0M	13.0M
ACTUAL	2.9M	1.9M	9.3M	9.3M	20.4M	10.7M	16.3M	15.0M	11.6M	11.7M	11.7M	19.0M

	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY
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PREDICTED	3.9M	12.7M	22.1M	31.4M	50.8M	70.2M	90.3M	111.9M	122.4M	135.4M	148.4M	161.4M
ACTUAL	2.9M	1.9M	17.1M	26.4M	46.8M	57.5M	73.8M	89.4M	101.0M	112.7M	124.4M	143.3M

CUMULATIVE EXPENDITURES*

* Expenditures Include All Costs & Fees.

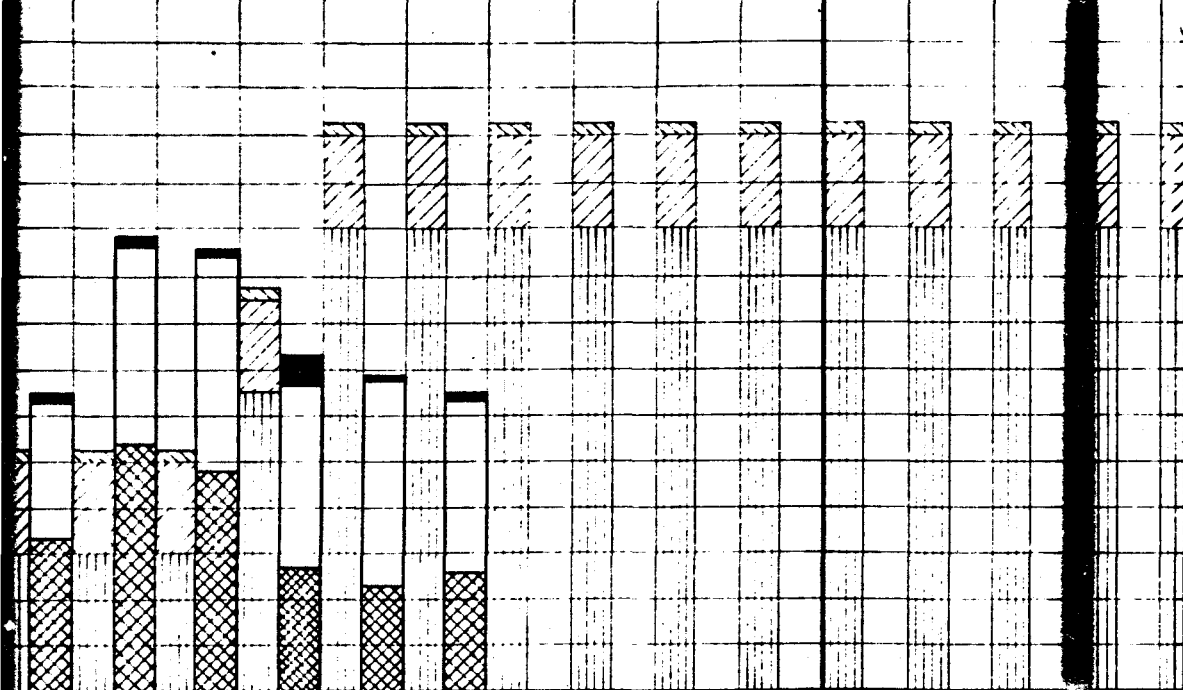
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MONTHLY PROGRESS CHART

CONTRACT No. 14-01-0001-415

1966

MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. M.



Complete Detailed Engineering Complete Construction Complete break-in Runs & Revisions

13.0M	13.0M	13.0M	18.9M	19.4M	18.3M	1.8M	17.5M	17.5M	17.5M	17.5M	17.5M	17.5M	17.5M
11.7M	14.6M	19.0M	25.3M	26.3M	21.0M								

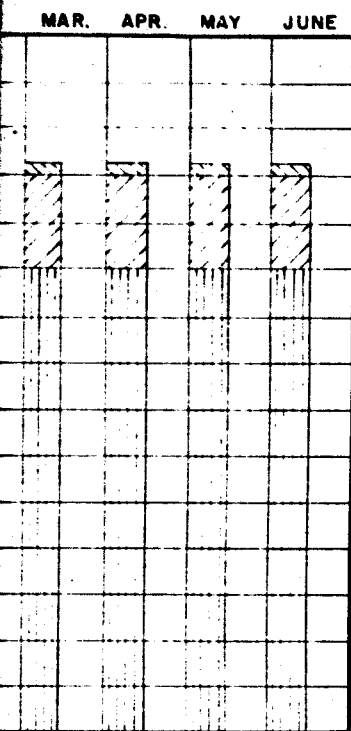
MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. M.

12.7M	127.3M	146.3M	171.6M	197.9M	218.9M								
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DATE: *August 1965*



PREDICTED **ACTUAL**

SUPERVISING

PROFESSIONAL

TECHNICIAN

3

MONTHLY PROGRESS CHART

OFFICE OF COAL RESEARCH
DEPARTMENT OF THE INTERIOR

CONSOLIDATION COAL CO.
RESEARCH DIVISION LIBRARY, PA.

CONTRACT No. 14-01-0001-415

PROGRESS REPORT NO. 18
OCR CONTRACT NO. 14-01-0001-415
CONSOL LIGNITE GASIFICATION PROCESS DEVELOPMENT

September 1 to 30, 1965

A. Summary

Phase I - Feasibility Study

Complete.

Phase II - Bench Scale Experiments

Construction of the hot continuous unit has been completed. Cold pressure testing of the unit has been carried out and faulty conditions corrected. It is planned to complete cold testing of the unit by the end of October, including circulation of solids at full system pressure and testing of instruments, alarms and probes.

Two pairs of gasification runs were made corresponding to top and bottom of the gasifier, respectively, but with varying CO₂ concentration in each pair. Variation of CO₂ concentration had no effect on rate.

Financial

Estimated expenditures for September are \$23,000 vs. a budget figure of \$17,500. Cumulative expenses to date are \$243,228 vs. a budget figure of \$235,500.

E. Technical Results and Programs

Phase II - Bench Scale Program

1. Batch Kinetic Studies (Project No. 530.00)

Four series of char-steam kinetic runs at top and bottom-of-gasifier conditions, with CO₂ partial pressures of 0.5 and 1.0 atmosphere, have been completed. Preliminary work-up of the data shows that the rates are virtually the same at either level of CO₂ partial pressure, and that the integral rates extrapolate in a straightforward manner to the desired differential rates at zero bed weight.

Considerable time was spent in resolving two problems which are specific to the runs in which carbon oxides are added to the inlet gas. As reported previously, spurious CH₄ formation can be prevented by sulfiding the reactor system. However, the suppression was found to be impermanent, especially during the runs with the higher H₂/H₂O ratio. The operating procedure now has been modified to include presulfiding prior to every run. The second problem involved circumspect control of the CO₂ which dissolves in the unconverted steam condensate. The amount of dissolved CO₂ is large compared with the net make CO₂ and distorts the composition of the product gas. Continuous addition of acid to the condensate, at system pressure, eliminated the problem.

2. Construction of Continuous Gasification Unit (Project No. 531.00)

Construction of the hot unit has been completed, and this project was terminated on October 1, 1965.

3. Operation of the Continuous Gasification Unit (Project No. 532.00)

Initial Operations

Cold leak testing was begun on September 15, and many minor leaks have been corrected. However, major leaks in the gasifier and regenerator pressure shells, caused by faulty machine work by the outside fabricator of the vessels, precluded reaching system pressures greater than 100 psi. The machining has been corrected by our own shop, and the unit is now completely reassembled and ready for further leak testing.

Two shift operation commenced on September 27, with three-shift operation being scheduled to begin in mid-October.

The immediate objectives are to achieve a leak-free system at 300 psi cold hydrogen pressure and to circulate the solids (cold) to test the probes, safety devices, and alarms. By the end of October, the electrical heaters will be installed and leak testing at process conditions will begin.

Feedstock Preparation

Sizing of the Husky lignite char to 35 x 150 mesh has been completed. Fines were removed by elutriation of the char in 130 lb. batches in the CC-2 coal preheater vessel. Three thousand pounds of feedstock were produced.

4. Supporting Process and Economic Analyses (Project No. 533.00)

No work was done on this project.

5. Supporting Patent and Legal Activities (Project No. 534.00)

The current laboratory reports and memoranda were reviewed for determination of Subject Inventions.

C. Subject Inventions

None.

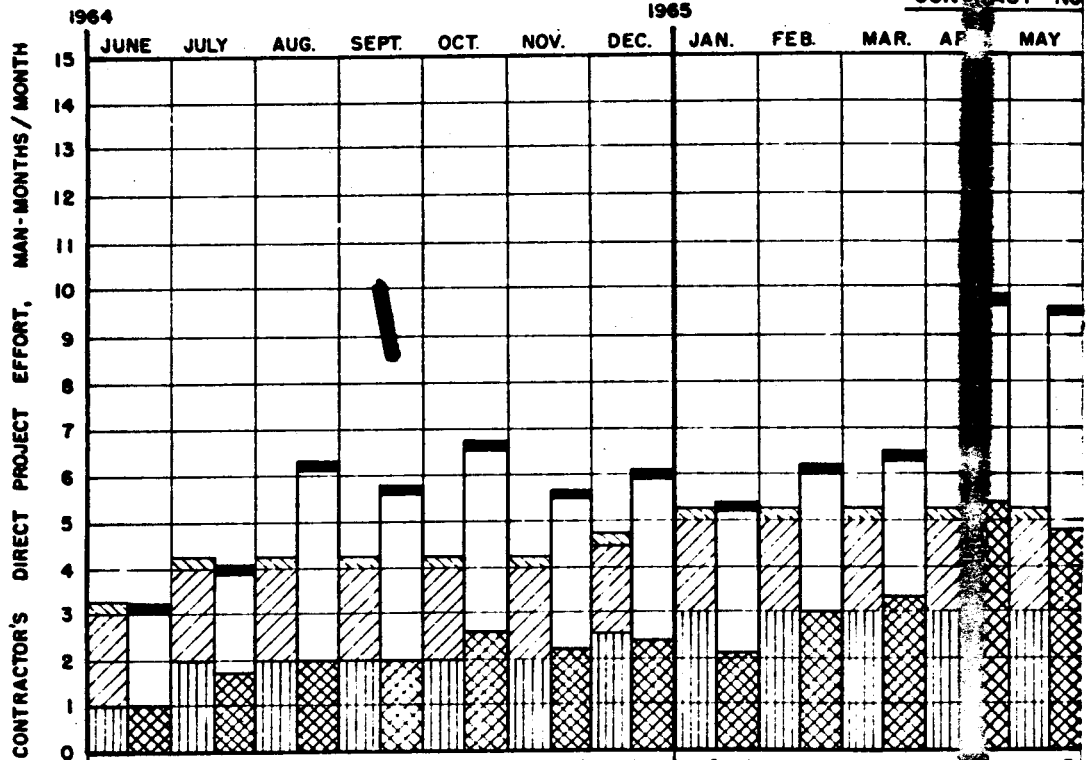
D. Financial Status

<u>Expenses</u>	<u>Actual</u>	<u>Budget</u>
Cumulative through August, 1965	\$ 221,228	\$ 218,000
Expended in Period	<u>22,000</u>	<u>17,500</u>
Cumulative through September, 1965	\$ 243,228	\$ 235,500

The indicated September expense is an estimate since accounting is not yet complete.

MONTHLY PROJECT EFFORT

CONTRACT No. _____



Start Prelim. Eng'g Continuous Unit Start Testing Complete On

FIGURES APPLY TO PHASE II PROGRAM ONLY

MONTHLY EXPENDITURES*

PREDICTED	3.9M	4.9M	9.3M	9.3M	19.4M	19.4M	20.1M	21.6M	10.3M	13.0M	13.0M	13.0M
ACTUAL	2.9M	5.6M	8.8M	9.3M	20.4M	10.7M	16.3M	15.6M	11.6M	11.7M	12.0M	19.9M

	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB	MAR.	APR.	MAY
PREDICTED	3.9M	12.6M	22.1M	31.4M	50.8M	70.2M	90.3M	111.9M	122.1M	135.4M	146.3M	161.4M
ACTUAL	2.9M	8.5M	17.1M	26.1M	46.8M	57.5M	73.8M	89.4M	101.0M	112.7M	124.7M	144.3M

CUMULATIVE EXPENDITURES*

* Expenditures Include All Costs & Fees.

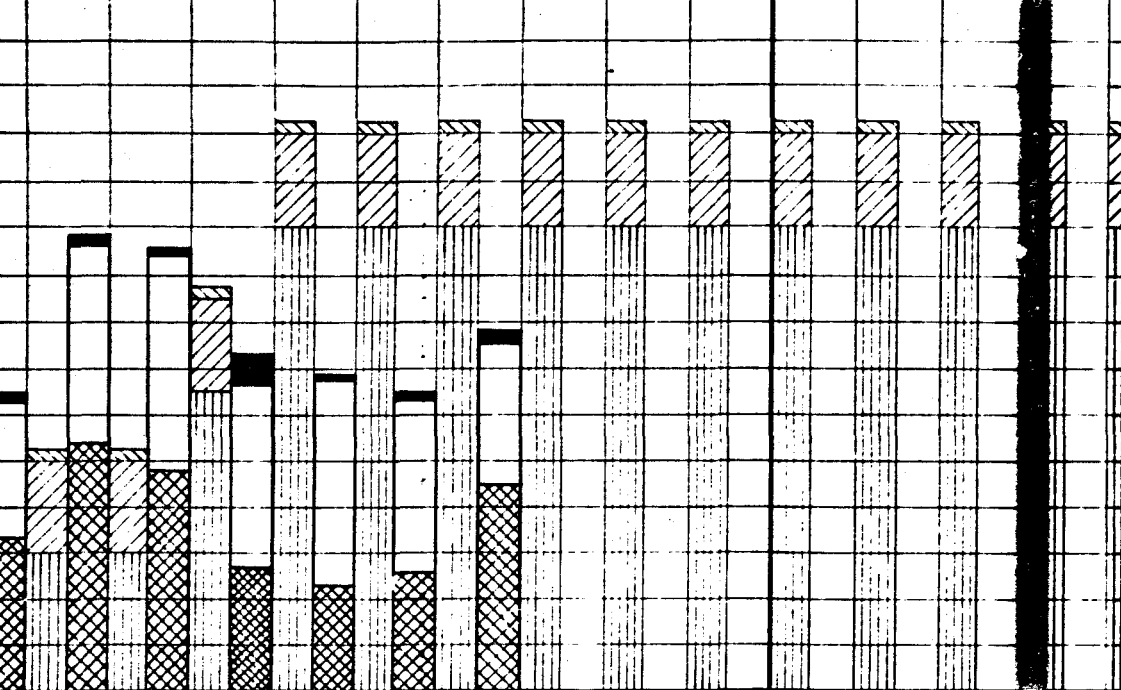
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MONTHLY PROGRESS CHART

CONTRACT No. 14-01-0001-415

1966

R. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR.



Complete Detailed Engineering Complete Construction Complete Break-in Runs & Revisions

1.0M	13.0M	13.0M	18.0M	19.0M	18.0M	17.5M	17.5M	17.5M	17.5M	17.5M	17.5M	17.5M	17.5M
1.7M	14.6M	19.0M	25.3M	26.3M	23.3M	21.0M							

MR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR.

4K	149.4K	151.4K	180.3M	198.7M	218.0M	237.5M	253.0M	270.5M	288.0M	300.5M	323.0M	340.5M	358.0M
7M	127.3M	148.3M	171.6M	197.9M	221.2M	243.2M							

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PROGRESS REPORT NO. 17
 OCR CONTRACT NO. 14-01-0001-415
CONSOLIDATION LIGNITE GASIFICATION PROCESS DEVELOPMENT

October 1 to 31, 1968

A. Summary

Phase I - Feasibility Study

Complete.

Phase II - Bench Scale Experiments

Cold pressure testing and calibration and testing of most instruments on the continuous unit has been completed. Electrical heaters and thermocouples have been installed. Solids circulation and testing of level control probes are now in progress.







An initial series of kinetic experiments have been completed to test the inhibiting effect of CO on gasification rate at conditions corresponding to the top and bottom of the gasifier, respectively. It is now found that CO inhibits both the methane and carbon oxide rates at the top of gasifier conditions. On the other hand, only the carbon oxide rate is inhibited at bottom of gasifier conditions.

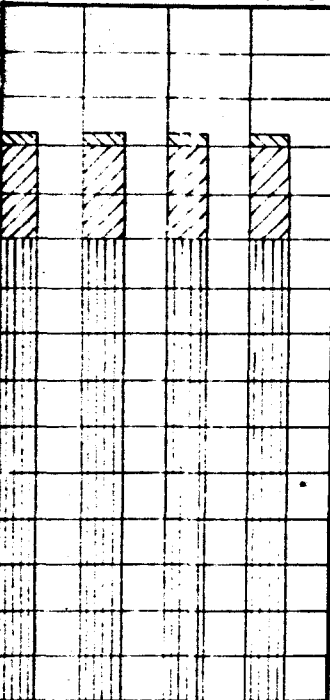
Financial

Estimated expenditures for October are \$23,000 vs. a budget figure of \$17,500. Cumulative expenses to date are \$258,715 vs. a budget figure of \$283,000.

DATE: September 1965

MAR. APR. MAY. JUNE

PREDICTED ACTUAL
 SUPERVISING  
 PROFESSIONAL  
 TECHNICIAN  



3

MAR.	APR.	MAY	JUNE
17.5M	17.5M	17.5M	8.6M
340.5M	338.0M	371.5M	364.3M

MONTHLY PROGRESS CHART

OFFICE OF COAL RESEARCH
 DEPARTMENT OF THE INTERIOR

CONSOLIDATION COAL CO.
 RESEARCH DIVISION LIBRARY, PA.

CONTRACT No. 14-01-0001-415

B. Technical Results and Program

Phase II - Bench Scale Program

1. Batch Kinetic Studies (Project No. 530.00)

Rate data from the recent runs in which CO₂ was added to the inlet gas at nominal partial pressures of 0.5 and 1 atm have been processed to yield differential rates. The inlet gas also contained sufficient CO to maintain water gas shift equilibrium. At bottom-of-gasifier conditions, the rates of carbon oxides production suffer a moderate, linear decrease with increasing CO partial pressure and the CH₄ rates are independent of the CO partial pressure. At the top-of-gasifier conditions, both rates decrease drastically on addition of carbon oxides. The CO partial pressure at these conditions is considerably greater than at the bottom-of-gasifier conditions. Inhibition by CO, rather than stabilization of the catalytic ash components by CO₂, may be responsible for the suppression of the rates. More data are needed to resolve the issue.

The results are tabulated below. The listed rates for the top-of-gasifier conditions at zero carbon oxides partial pressure are integral rates from the 5 gram initial bed weight run. In this series, reliable extrapolations to zero bed weight could not be made.

Differential CO + CO₂ Rates

Feedstock: Resmer Cove lignite char
Temperature: 1500°F
P_{H₂O} + P_{H₂} = 16.0 atm.
P_{CO}+P_{CO₂} = grams C gasified/g C in bed/min. x 10⁴

Partial Pressure, atm.		H ₂ /H ₂ O + H ₂ = .62					
CO ₂	CO	% Burnoff	0	20	40		
0	0		169	195	181		
.58	1.08		48	59	48		
.91	1.33		27	48	36		
		H ₂ /H ₂ O + H ₂ = .32					
CO ₂	CO	% Burnoff	0	20	40	60	80
0	0		440	578	615	674	710
.32	.26		484	800	811	823	831
.98	.48		438	450	442	423	396

Differential CH₄ Rates

		H ₂ /H ₂ O + H ₂ = .62					
		% Burnoff	0	20	40		
0	0		97	51	32		
.58)	1.08)		53	25	16		
.91)	1.33)						
		H ₂ /H ₂ O + H ₂ = .32					
		% Burnoff	0	20	40	60	80
			50	39	32	28	21

These rates are independent of carbon oxides partial pressures.

Since the carbon oxides production rates decrease by a factor of about 10 in going from bottom-to-top-of-gasifier conditions, the next series of runs will be made at a H₂/H₂O + H₂ ratio of about 0.5 in order to determine the behavior of the system at mid-gasifier conditions. Before starting the study of the 1400°F isotherm, one more series will be made at a CO partial pressure of 0.3 atm. at the top-of-gasifier conditions to determine if the rate suppression is caused by CO inhibition or by stabilization of catalyst activity.

2. Operation of Continuous Gasification Unit (Project No. 532.00)

The entire unit is now leak-free (cold) at 300 psig with hydrogen. Calibrations of the 18 rotameters have been completed. The rotameters which meter the recycle gases, which will have different compositions depending on the run conditions, were calibrated with two different gases so that the effect of molecular weight can be allowed for.

The two recycle gas systems and the pressure balance system for the regenerator and gasifier were tested at 300 psig at ambient temperature. Gas flow rates which were used covered the entire range of flows to be used at process conditions. After minor modifications, 18 hours of continuous trouble-free operation were demonstrated. Imposition of purposeful upsets showed that the control systems respond satisfactorily.

All electrical heaters and thermocouples have been installed, and cold circulation of solids has begun.

The immediate objectives are: (1) to obtain transfer line ΔP data at atmospheric pressure and 300 psig at both ambient temperature and 850°F, (2) to circulate the acceptor through the entire system at ambient pressure and temperature, and (3) to make the unit leak-free, hot, at 300 psig H₂ pressure with the goal, by the end of November, of feeding and circulating solids at process conditions of pressure and temperature, but in the absence of air or steam.

Feedstock Preparation

Greenfield dolomite was wet-screened into the following size fractions: 16 x 20, 20 x 28, and 28 x 35 mesh. About 25 lbs. of each fraction, sufficient for one month's operation, were prepared.

3. Supporting Process and Economic Analyses (Project No. 533.00)

No work was done on this project.

4. Supporting Patent and Legal Activities (Project No. 534.00)

The current laboratory reports and memoranda were reviewed for determination of Subject Inventions.

C. Subject Inventions

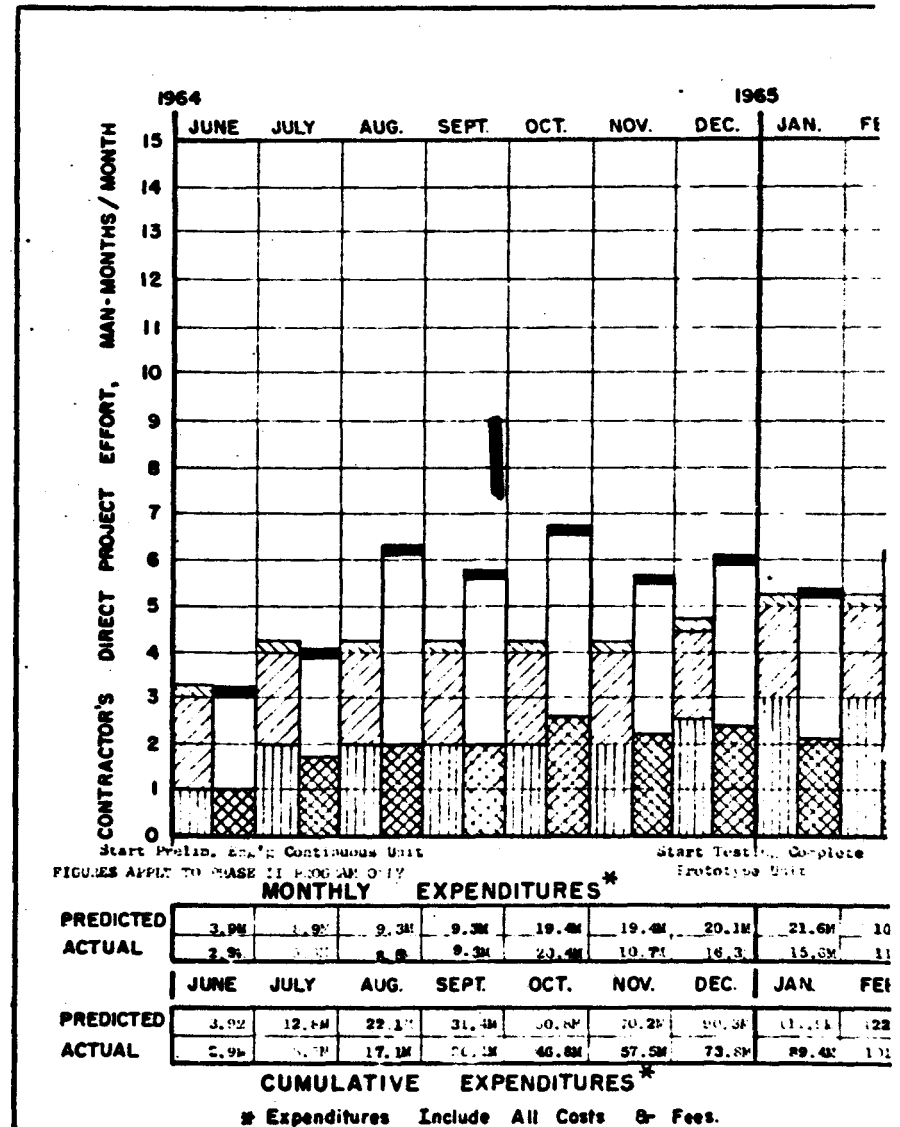
None.

D. Financial Status

<u>Expenses</u>	<u>Actual</u>	<u>Budget</u>
Cumulative through Sept., 1965	\$ 248,715	\$ 238,500
Expended in Period	<u>23,000</u>	<u>17,500</u>
Cumulative through October, 1965	\$ 268,715	\$ 253,000

The indicated October expense is an estimate since accounting is not yet complete.

Att. - Monthly Progress Chart

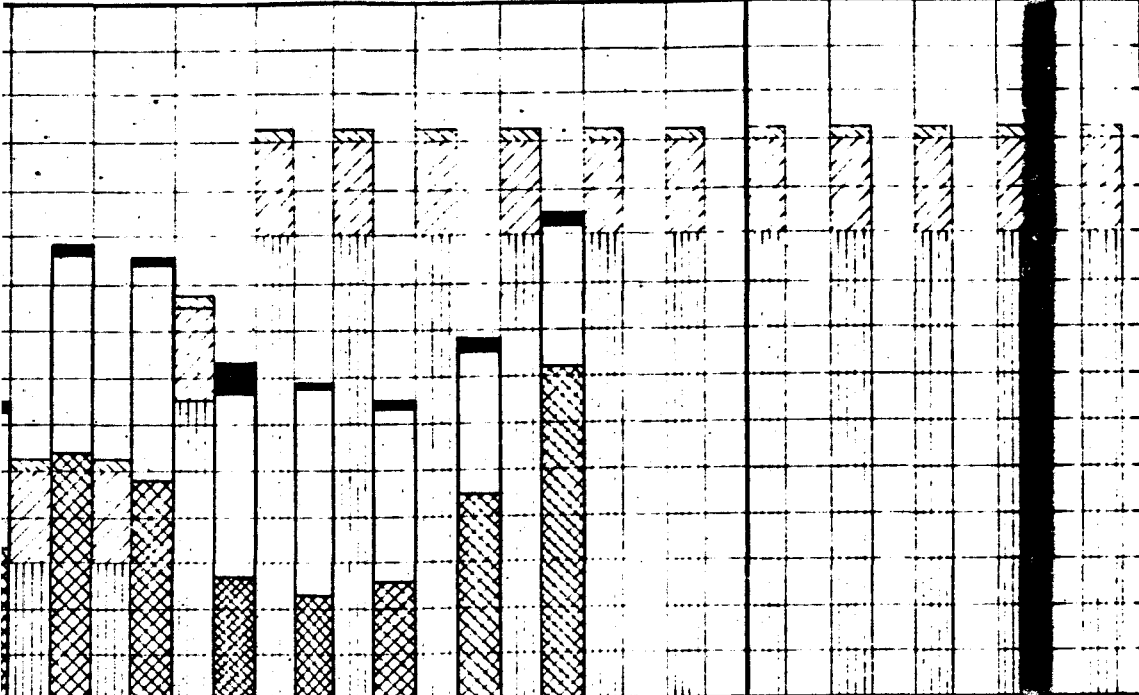


MONTHLY PROGRESS CHART

CONTRACT No. 14-CI-0001-415

1966

APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY



Complete Detailed
Engineering

Complete
Construction

Complete Installation
Rigs & Pipelines

13.0M	13.0M	18.9M	19.4M	18.2M	14.7M	17.4M	17.4M	17.2M	17.4M	17.0M	17.4M	15M	17.4M
14.6M	19.0M	25.3M	26.3M	23.3M	24.5M	23.0M							
APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY
141.4M	141.0M	171.3M	189.7M	218.0M	235.1M	253.0M	270.3M	288.0M	305.0M	323.0M	340.4M	357.0M	374.4M
127.3M	146.3M	171.6M	197.6M	221.3M	245.7M	268.7M							

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OFFICE OF COAL RESEARCH
RECEIVED

PROGRESS REPORT NO. 18
OCE CONTRACT NO. 14-01-0001-415
CONSOL. LIGNITE GASIFICATION PROCESS DEVELOPMENT

November 1 to 30, 1965

DEPT OF THE INTERIOR

A. Summary

Phase I - Feasibility Study

Complete.

Phase II - Bench Scale Equipment

Acceptor circulation has been satisfactorily demonstrated at 12 psig, ambient temperature and with transfer line temperatures up to 700°F. All instruments and controls were checked out and found to operate satisfactorily with two exceptions. The electrical conductivity probe used to detect the char-acceptor interface, although it operated satisfactorily at ambient temperature, was not usable at process temperatures. The difficulty was traced to development of an electrochemical EMF due to use of two dissimilar metals in the probe. A new probe is being constructed to obviate this difficulty. The equipment used to insure a sharp char-acceptor interface (restrictor) was also found to malfunction. The difficulty has been corrected.

Considerable difficulty has also been experienced due to faulty construction of electrical heaters by an outside contractor. The problems with the heaters and char-acceptor interface control have delayed the program about three weeks.

Kinetic data at 1500°F have been extended to cover a wider range of CO₂ concentrations, i.e., down to the equilibrium pressure over CaCO₃ and to H₂/H₂ + H₂O ratios representative of the middle of the gasifier conditions.







The data show that much higher rates may be expected at the top of the gasifier if equilibrium CO₂ pressure can be approached. The gasification rate also decreases much less than would be predicted by a linear interpolation in going from the bottom to the middle of the gasifier.

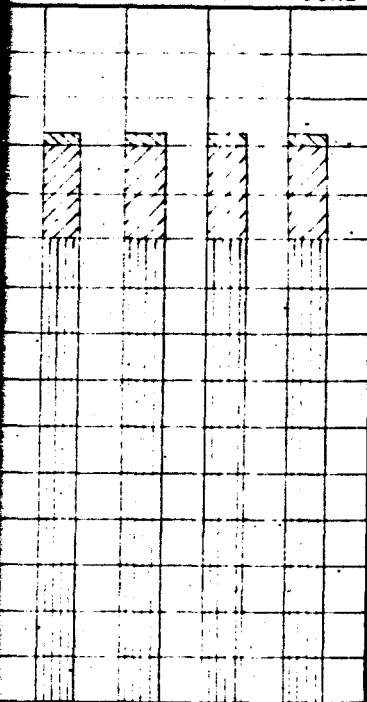
Financial

Estimated expenditures for November were \$20,900 vs. a budget figure of \$17,500. Cumulative expenses to date are \$287,855 vs. a budget figure of \$270,500. The December report will present a revised budget and schedule to reflect the contract amendment dated October 19, 1965.

DATE: Oct. 1965

MAR. APR. MAY JUNE

	PREDICTED	ACTUAL
SUPERVISING		
PROFESSIONAL		
TECHNICIAN		



3

MONTHLY PROGRESS CHART

OFFICE OF COAL RESEARCH
DEPARTMENT OF THE INTERIOR

CONSOLIDATION COAL CO.

RESEARCH DIVISION LIBRARY, PA.

CONTRACT No. 14-01-0001-415

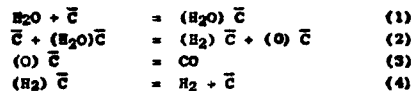
3M	17.0M	17.0M	17.0M	9.0M
B.	MAR.	APR.	MAY	JUNE
10M	310.0M	310.0M	317.0M	361.0M

B. Technical Results and ProgramPhase II - Bench Scale Program1. Batch Kinetic Studies (Project No. 530.00)

Differential rates from two new series of runs were obtained. The data from one series, corresponding to mid-gasifier conditions, show that the carbon oxides rates are higher than those predicted by linear interpolation between the top and bottom conditions. The methane rates are about the same as those for the bottom-of-gasifier conditions.

The other series, corresponding to top-of-gasifier conditions, was made in an effort to determine whether the rate suppression by addition of carbon oxides is caused by CO inhibition or by stabilization of catalyst activity by CO₂. In this series, low partial pressures of CO and CO₂ were used, which would be obtained if equilibrium were established in the dissociation of CaCO₃. If stabilization by CO₂ were responsible for the rate suppression, then the rates from this series would have been about the same as those from the previous series at considerably higher CO partial pressures. However, the rates were found to be more than twice as great.

A tentative correlation of all the differential rates shows that the observed values of R_{CO+CO₂} are compatible with the following mechanism adsorption and desorption from active sites on the carbon surface, where \bar{C} is an activated carbon atom.



If step (2) above is the rate controlling reaction, the rate expression given below for 20% burnoff is

$$R_{\text{CO}+\text{CO}_2} = \frac{983 \left(P_{\text{H}_2\text{O}} - \frac{P_{\text{H}_2} P_{\text{CO}}}{K} \right)}{(1 + .100 P_{\text{H}_2\text{O}} + .337 P_{\text{H}_2} + 3.27 P_{\text{CO}})^2}$$

where K is the equilibrium constant for the reaction



$$(K = 9.2 \text{ at } 1500^\circ\text{F})$$

The above equation represents the observed rates with a mean error of 18%. The correlation is highly speculative and more data, especially at system pressures of 11 atm., are needed to confirm it.

The new rate data are tabulated below:

Feedstock: Runner Cove Lignite Char
Temperature: 1500°F
P_{H₂O} + P_{H₂} = 16.0 atm.
R = grams C gasified/g C in bed/min. x 10⁴

Partial Pressure, atm.		H ₂ /H ₂ O + H ₂	% Burnoff	R _{CO+CO₂}			
CO ₂	CO			0	20	40	60
.27	.20	.62	139	158	131	-	
.47	.43	.45	345	327	303	258	
R _{CH₄}							
.27	.20	.62	67	37	26	19	
.47	.43	.45	51	48	43	32	

The study of the 1600°F isotherm will be started in December, after a single series at 1500°F and 11 atm. system pressure, needed to test the correlation, is completed.

2. Operation of the Continuous Gasification Unit (Project No. 532.00)Acceptor Circulation

In the absence of char, and at 12 psig system pressure using humidified H₂ at ambient temperature, fourteen hours of continuous, stable acceptor recirculation through the entire unit was demonstrated with rates ranging from 8 to 20 lb/hr. Routine operations such as filter changes and emptying of the regenerator dust collector were performed without upset. The two-stage regenerator bed was stable when subjected to extreme purposeful upsets.

Subsequently, the acceptor transfer line was heated to 700°F and the regenerator was heated to maintain the acceptor at 250°F. Successful acceptor recirculation was again achieved using the temperature-activated probe to control the level in the acceptor return line.

These operations were significant in that pressure balance across the entire unit was demonstrated and that the ΔP controllers satisfactorily compensated for normal variations in the acceptor transfer line ΔP.

Electrical Heaters

After installation of the main heaters for the gasifier and regenerator vessels, the lead wires were found to be defective. After considerable time was spent in repairing them, the heaters were again installed and the vessels were brought to 1500°F. At this temperature, the regenerator heater lead wires failed again.

It was found that the cement used to hold together the ceramic cone sections, and which contained aluminum silicates, had reacted with the potassium titanate insulation forming a flux which destroyed the lead wires. The cement had been carelessly applied by the outside fabricator of the heaters and should not have been in contact with either the lead wires or the insulation. The gasifier heater was constructed more meticulously and fusion of the cement and insulation is not expected to occur.

The regenerator heater was again repaired and installed. Both heaters now have been held at 1500°F for several days, with no signs of failure. Since the patched regenerator lead wires probably will not withstand the 2000°F plus temperature required for operation at full process conditions, material for a new heater, to be fabricated in the R&D shop, has been ordered. The existing heater should be adequate for the initial operations where operability can be forced at 1500-1700°F by use of lower CO₂ partial pressures.

Char-Acceptor Interface Control

Initial attempts to circulate the acceptor through a bed of char in the gasifier were unsuccessful. A stable char-acceptor could not be established. A hybrid model was constructed using the gasifier internals of the hot unit and a Lucite vessel. Visual observations on a batch char-acceptor system in the model showed that the fluidizing gas had been bypassing the acceptor portion of the bed due to faulty design of the restrictor.

After modification of the restrictor, a stable interface and proper operation of the interface detector probe were demonstrated in the hybrid model at ambient conditions. However, experiments in the laboratory have shown that the probe as now constructed will not perform properly at the process temperature of 1500°F. The electrical lead to the probe is a shorted chromel-alumel thermocouple insulated from its surroundings by MgO and encased in an Inconel sheath. At process temperatures, the lead and the sheath form a cell with impurities in the MgO insulation serving as the electrolyte. A large back EMF is generated which negates the desired EMF imposed by the circuitry. A new electrical lead has been ordered which uses Inconel as both lead and sheath and which is insulated by high purity alumina.

Program

The difficulties with the heaters and the char acceptor interface have delayed the program by about three weeks. The unit has been reassembled with the existing probe and December operations have the following goals:

1. To demonstrate acceptor recirculation through a bed of char in the gasifier operated at 12 psig system pressure and ambient temperature with the regenerator held at 1500°F.
2. To complete hot leak testing at 300 psig H₂ pressure with the entire unit at process temperatures. (Regenerator to be held at 1500-1700°F to protect the lead wires.)

3. Supporting Process and Economic Analysis (Project No. 533.00)

Some time was spent in systematizing gasification calculations in anticipation of joint pilot plant engineering work with an outside contractor. The calculation procedure has been "computerized" for greater efficiency in future work.

A methanation report by Aerojet-General was reviewed.

4. Supporting Patent and Legal Activities (Project No. 534.00)

The current laboratory reports and memoranda were reviewed for determination of Subject Inventions.

C. Subject Inventions

None

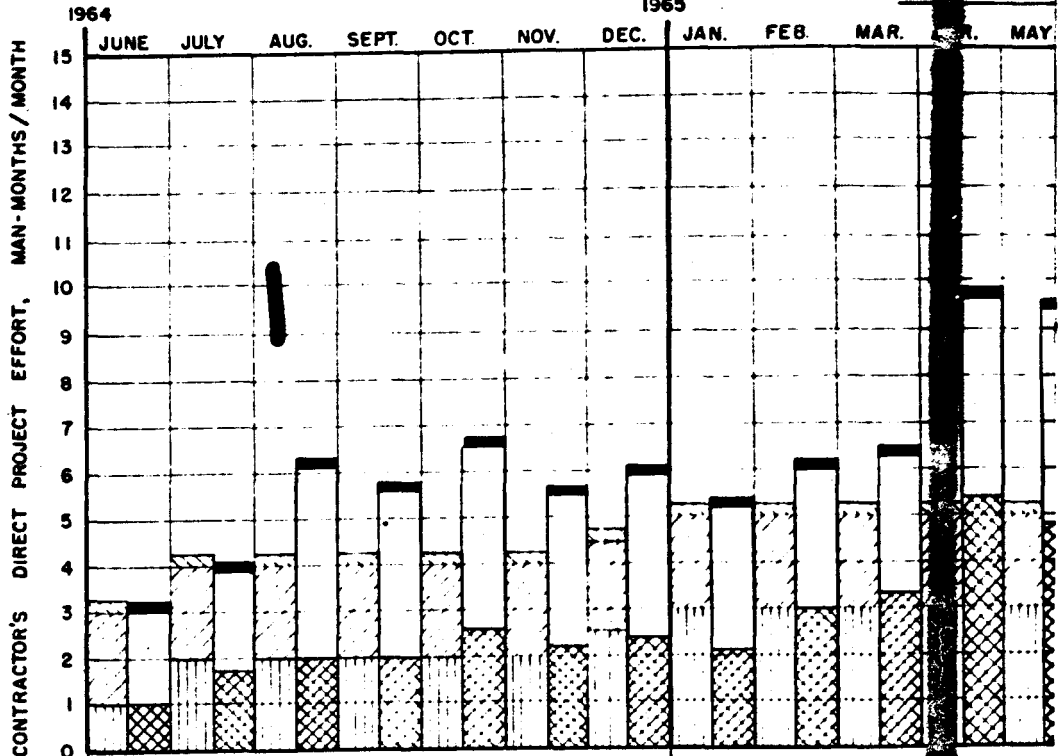
B. Financial Status

<u>Expenses</u>	<u>Actual</u>	<u>Budget</u>
Cumulative through October, 1965	\$ 286,958	\$ 283,000
Expended in Period	20,900	17,500
Cumulative through November, 1965	\$ 287,858	\$ 270,500

The indicated November expense is an estimate since accounting is not complete. Contract No. 14-01-0001-415 was amended on October 19, 1965 to extend to June 11, 1967 and include the design and engineering of a gasification pilot plant. A revised budget and progress chart will be issued in the December report to reflect this change.

MONTHLY P

CONTRACT N



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Source: Contracting Unit

MONTHLY EXPENDITURES*

	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY
PREDICTED	3.9M	4.9M	9.3M	9.3M	19.4M	19.4M	27.1M	21.6M	17.9M	13.0M	13.0M	13.0M
ACTUAL	2.9M	4.9M	8.8M	9.3M	20.4M	19.7M	18.3M	15.6M	11.6M	11.7M	14.6M	14.6M

CUMULATIVE EXPENDITURES*

	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY
PREDICTED	3.9M	7.8M	17.1M	26.4M	45.8M	65.2M	92.3M	113.9M	131.8M	144.8M	157.8M	170.8M
ACTUAL	2.9M	7.8M	16.6M	25.9M	46.3M	66.0M	84.3M	99.9M	111.5M	123.2M	137.8M	152.4M

* Expenditures Include All Costs & Fees.

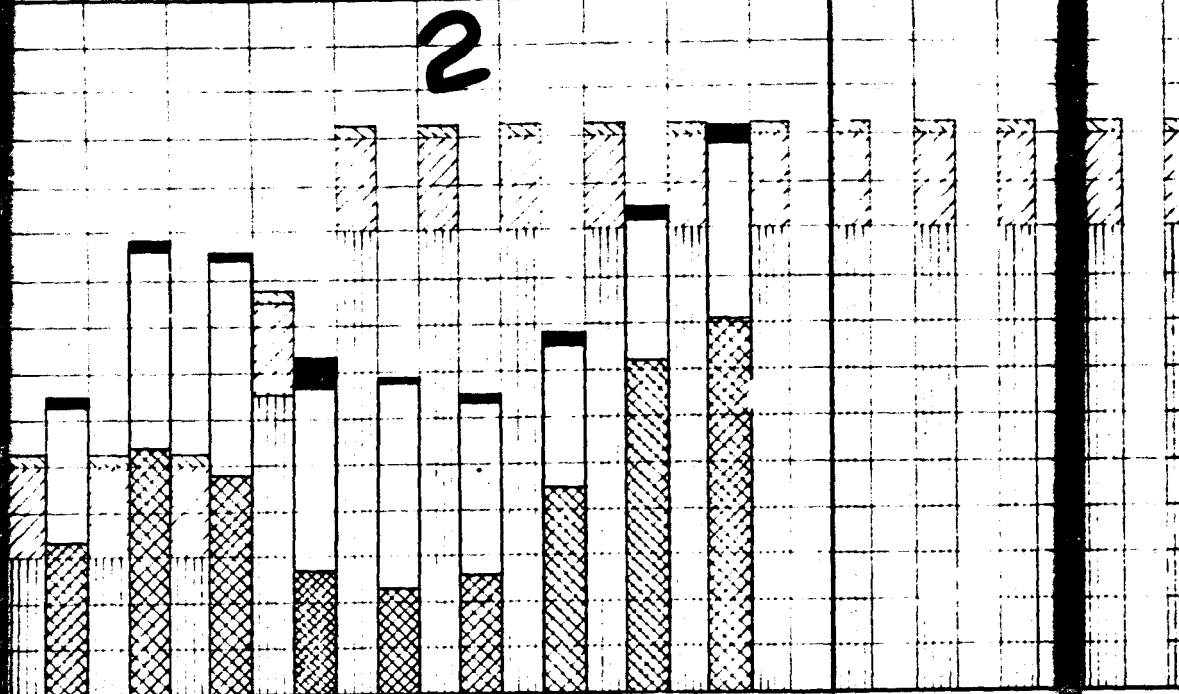
MONTHLY PROGRESS CHART

CONTRACT No. 14-01-0001-415

1966

MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. M

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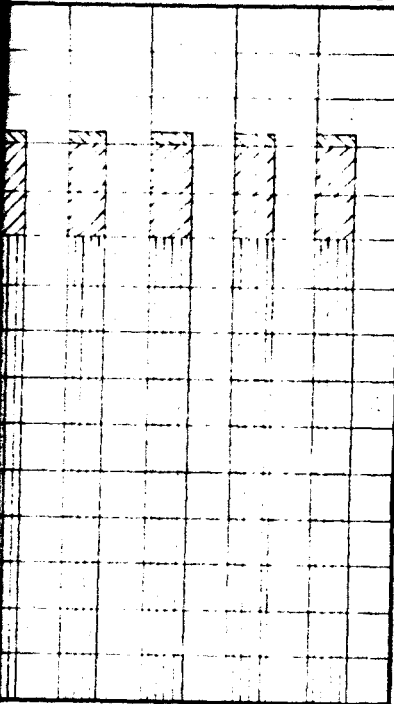
Complete Detailed
Complete Construction
Complete Breakdown

13.0M	13.0M	13.0M	18.9M	19.4M	18.3M	17.1M	17.1M	17.1M	17.1M	17.1M	17.1M	17.1M	17.1M
11.7M	14.6M	19.2M	25.3M	26.3M	23.3M	24.5M	21.2M	20.9M					
MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.
119.7M	127.3M	146.3M	171.6M	199.7M	211.0M	239.8M	259.0M	270.9M	285.0M	300.0M	323.0M	340.0M	355.0M

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FEB. MAR. APR. MAY JUNE



PREDICTED ACTUAL

SUPERVISING

PROFESSIONAL

TECHNICIAN

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MONTHLY PROGRESS CHART

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OFFICE OF COAL RESEARCH
601-753

PROGRESS REPORT NO. 19
OCR CONTRACT NO. 14-01-0001-415
CONSOL LIGNITE GASIFICATION PROCESS DEVELOPMENT

December 1 to 31, 1965

DEPT OF THE INTERIOR

A. Summary

Phase I - Feasibility Study

Complete.

Phase II - Bench Scale Equipment

The continuous unit has been rendered free of leaks at full operating temperatures and pressures. Continuing difficulties have been encountered with defective electrical heaters and with the probe used to detect the char interface acceptor. These have continued to delay progress.

The former difficulty has now been corrected. The electrical probe and measuring circuit have been redesigned to resolve the latter difficulty.

Kinetic data at 1500°F have been extended to a lower operating pressure of 11 atm. The correlation discussed in the last progress report predicts a rate increase under these conditions which has been confirmed experimentally.

Financial

Estimated expenditures for December were \$24,900. Cumulative expense to date is \$310,771. This is also the budget figure, revised as of December 31, 1965, to conform to the amended contract.

B. Technical Results and Program

Phase II - Bench Scale Program

1. Batch Kinetic Studies (Project No. 530.00)

The rate equation derived from the reaction model predicts that R_{CO+CO_2} will be greater at 11 atm $P_{H_2O} + P_{H_2}$ than at 16 atm, for a given steam/hydrogen ratio. Differential rates from two new series of runs at 11 atm confirm that this is indeed true, at both top and bottom-of-gasifier conditions.

These findings are of major significance since the process may now be operated at a total system pressure of 11 atm, with the gasifier recycle gas system eliminated. The lower pressure level also will allow the regenerator to be operated at temperatures as low as 1800°F rather than 1950°F, thereby easing the problems of acceptor activity loss and of ash fusion.

Economically, the ratio of the CH_4 production rate to the carbon oxides rate is of great importance. Use of the lower system pressure will tend to decrease the methane rate. The controlling factor is inhibition of the rate by approach to equilibrium. A reaction model for production of CH_4 also has been formulated, but it cannot be tested thoroughly until rate data from CH_4 addition runs are available.

In view of the importance of operation at 11 atm, the immediate future program will be to complete the study of the 1500°F isotherm, featuring CH_4 addition runs, and to evaluate the constants in the rate equations, as functions of burnoff level, for R_{CO+CO_2} and R_{CH_4} .

2. Operation of the Continuous Gasification Unit (Project No. 532.00)

Acceptor Circulation

Recent minor revisions to the unit, which included modifications of the feeder housings to eliminate unbalanced thrust on the rotors, range changes on several rotameters, and installation of an additional pressure tap in the regenerator required that cold leak testing be repeated. The unit was then heated to operating temperatures and was leak tested with H_2 at 300 psig. It is now leak free.

Stable operation of the unit including the recycle gas compressors, but in the absence of solids, was demonstrated at normal process gas flows at 300 psig and operating temperatures.

The specially designed mountings for the regenerator, gasifier, standlegs, and transfer lines properly compensated for thermal expansion and maintained alignment of all components when the unit was heated from ambient to operating temperatures.

Electrical Heaters

The defective electrical heaters continued to plague the operations. The gasifier heater burned out due to reaction of the Kanthal resistance wire with the cement used to hold together the ceramic core sections. A new heater, assembled without cement, was fabricated and installed. No further trouble with the gasifier heater is anticipated.

Char-Acceptor Interface Control

Laboratory studies have resolved the problem of electrical failure at high temperatures of the insulation for the leadwires to the probe plate used to detect the char-acceptor interface at the bottom of the gasifier. The problem has been resolved by improved design of the probe and by modification of the electrical measuring circuit to eliminate electrochemical generated EMF's.

A new probe has been designed and will be installed by January 14.

Program

Operations during January have the following goal: to demonstrate hot circulation of solids at normal process conditions of pressure and temperature, but in the absence of steam and air.

3. Supporting Process and Economic Analysis (Project No. 533.00)

Systemization of gasification calculations has continued, in satisfaction of joint pilot plant engineering work with an outside contractor.

4. Supporting Patent and Legal Activities (Project No. 534.00)

The current laboratory reports and memoranda were reviewed for determination of Subject Inventions.

C. Subject Inventions

None.

D. Financial Status

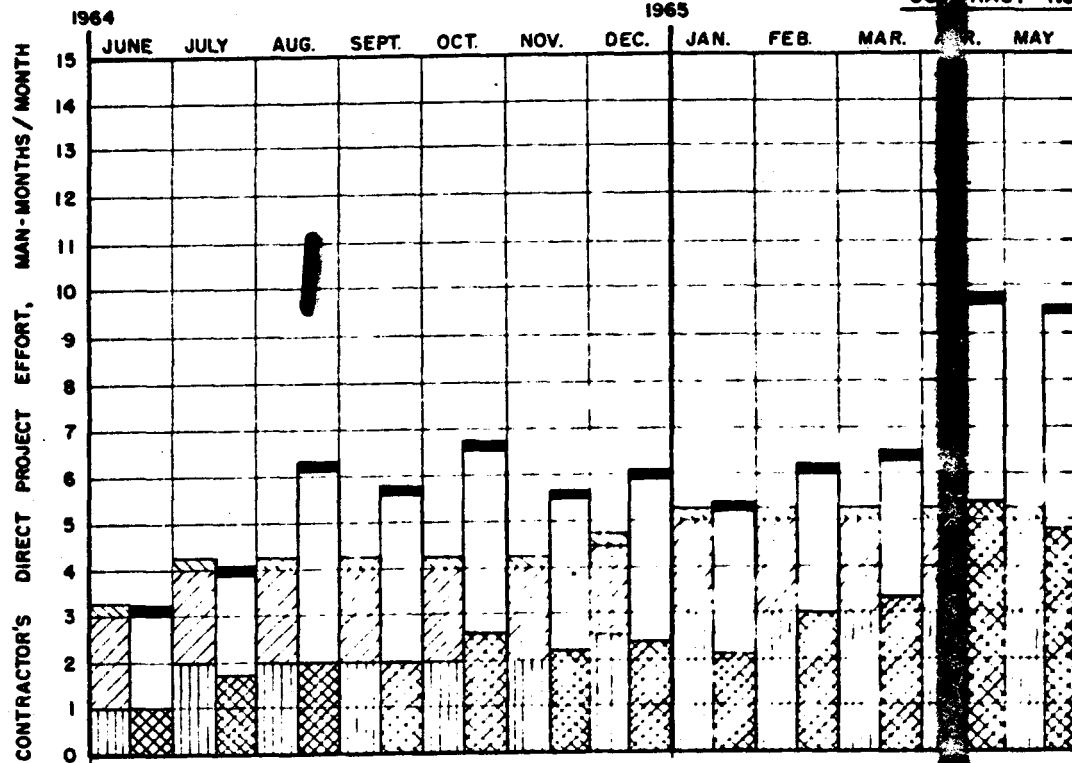
<u>Expenses</u>	<u>Actual</u>	<u>Budget</u>
Cumulative through November, 1965	\$ 285,871	
Expended in Period	24,900	
Cumulative through December, 1965	\$ 310,771	\$ 311,000

The indicated December expense is an estimate since accounting is not complete. The budget figure shown is a revised number, consistent with the contract amendment enacted on October 19, 1965.

Att. - Monthly Progress Chart
1/17/66

REVISED* MONTHLY PF

CONTRACT No



FIGURES APPLY TO PHASE II PROGRAM ONLY

MONTHLY EXPENDITURES*

	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY
PREDICTED	3.9M	4.9M	9.3M	9.3M	19.4M	19.4M	27.1M	21.6M	10.9M	13.0M	9.0M	13.6M
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CUMULATIVE EXPENDITURES*

* Expenditures Include All Costs & Fees

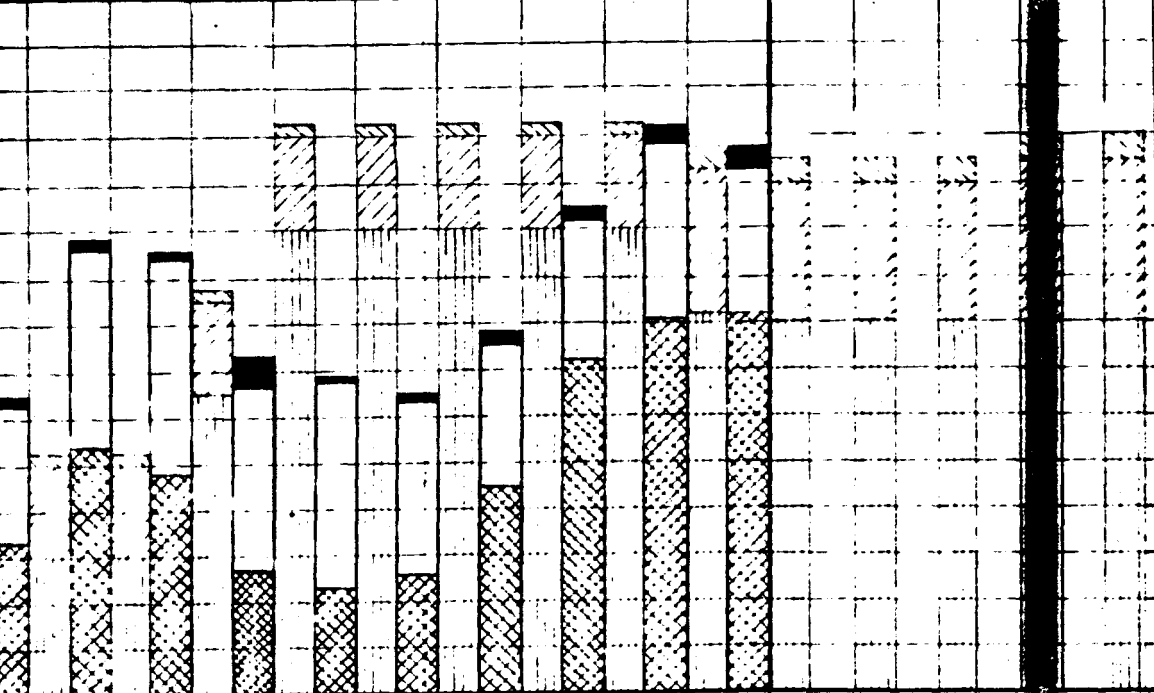
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MONTHLY PROGRESS CHART

CONTRACT No. 14-01-0001-415

1966

R. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY



Revised Budget

9.0M	13.0M	15.0M	18.0M	19.0M	18.0M	17.0M	17.0M	17.0M	24.0M	21.0M	21.0M	22.0M	25.0M
1.7M	14.6M	14.0M	25.0M	26.0M	23.0M	24.5M	21.2M	10.0M	24.0M				
APR.	APR	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR. MAY
			199.72	216.04	237.01	255.00	270.00	311.00	331.00	351.00	373.00		423.00
1.7M	127.3M	146.3M	171.8M	197.6M	231.3M	245.7M	266.9M	288.0M	310.0M				

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MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY
22.0M	25.7M	29.0M	27.0M	59.1M	51.1M	41.1M	42.1M	51.1M	52.1M	42.1M	42.1M	32.1M	32.1M	32.1M
373.1M	398.1M	423.1M	453.0M	473.1M	517.1M	539.1M	531.1M	553.1M	705.1M	717.1M	789.1M	821.1M	834.1M	867.1M

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DATE: *December 1965*

JUNE

	PREDICTED	ACTUAL
SUPERVISING		
PROFESSIONAL		
TECHNICIAN		

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*Revised 12/31/65

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