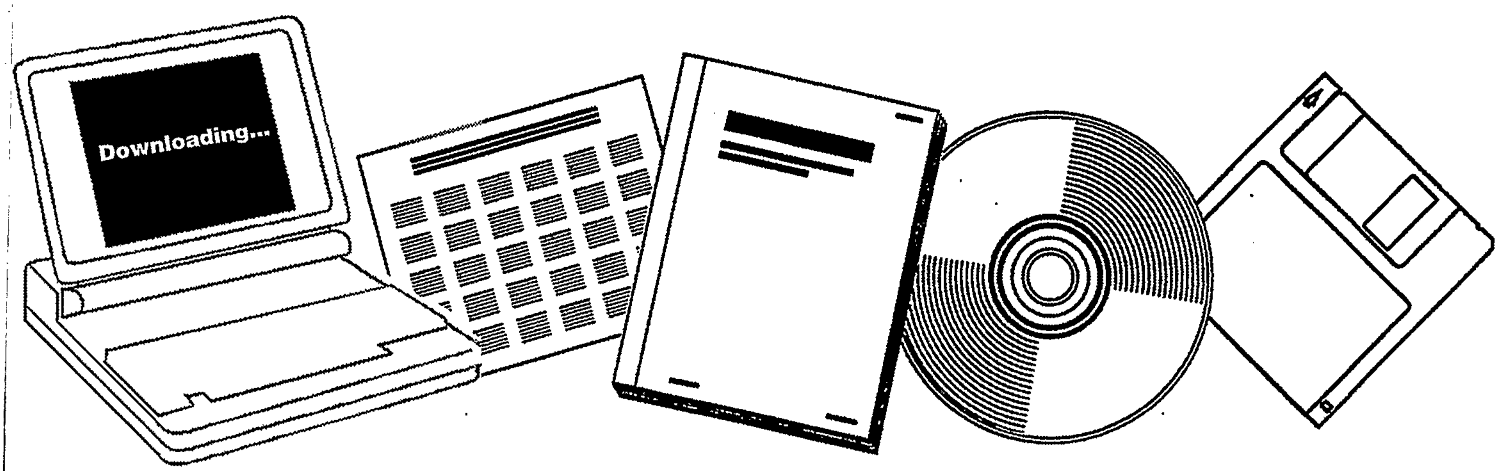
DEVELOPMENT OF IGT HYDROGASIFICATION PROCESS. PROGRESS REPORTS, JANUARY--DECEMBER 1969

INSTITUTE OF GAS TECHNOLOGY, CHICAGO, ILL

1969



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FE--381-T-6

DEVELOPMENT OF IGT HYDROGASIFICATION PROCESS

Progress Reports for the
Period January - December 1969

Institute of Gas Technology
IIT Center
Chicago, Illinois 60616

Prepared for

Office of Coal Research
U. S. Department of the Interior

OCR Contract No. 14-01-0001-381*

*This contract evolved into OCR Contract No. 14-32-0001-1221 in 1972

FE--381-T-6

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*This contract evolved into OCR Contract No. 14-32-0001-1221 in 1972

IGT-MPR--1/69

DEVELOPMENT OF IGT HYDROGASIFICATION PROCESS

Progress Report – January 1969
#52
to
Office of Coal Research
Contract No. 14-01-0001-381 (1)

Summary

1. The second successful hydrogasification test with Montana lignite was made.
2. Four hydrogasification runs were made to produce char for the electrothermal gasifier.
3. Three tests were made in the electrothermal test reactor at the 200-250 psig pressure level.
4. Long-delivery items for the pilot plant are being identified and successful bidders selected.
5. Work has started on process studies associated with the hydrogasification process.

Hydrogasification Test Program

This month we conducted our second successful hydrogasification test (Run HT-218) with Montana lignite in the balanced-pressure development unit. The dried lignite was gasified with a mixture of hydrogen and steam in a fluidized bed at a nominal temperature of 1700°F and a pressure of 1000 psig. This test is a portion of our study of the hydrogasification behavior of a Montana lignite designed to investigate operations with a hydrogen-to-lignite ratio of 25 percent of the stoichiometric ratio and a steam concentration of 30 percent in the feed gas. The test lasted about 5 hours with 3-1/2 hours of this time at steady-state conditions. Based on the weight of residue recovered, about 60 percent of the lignite was gasified.

We also conducted four other hydrogasification operations in the balanced-pressure development unit for the purpose of producing a residue feed for tests in the electrothermal gasifier. In these operations (Runs HT-EG-1, HT-EG-2, HT-EG-3, and HT-EG-4) we gasified a lightly pretreated Pittsburgh seam bituminous from the Ireland mine with a 50:50 hydrogen-steam feed gas at standard hydrogasification conditions. Only a limited amount of residue was produced in the first three runs because of mechanical difficulties. In the fourth test we produced 223 lb of residue, this quantity being limited only by the size of the feed hopper. Total residue production in the four runs was 300 lb.

Electrothermal Test Program

Following the heat-up tests to check the current-limit controller of the generator, the test unit was dismantled for cleaning in preparation for further testing. Inspection of the 6-in.-diameter, Type 316 stainless steel inner reactor liner revealed several breaks in the wall. Removal of the tube showed it to be severely eroded in the area of the char-bed interface to the depth of the electrode's immersion into the char bed. There were several large holes (3 to 5 in. diameter) in the wall and most of the thermocouples were severed.

Because of the initial thermocouples used were of the grounded type, stray current flow through the couples made it difficult to obtain an accurate temperature reading. A review of past power inputs when nitrogen, which gives no endothermic reaction heat sink, was used indicates temperatures were at times well in excess of 1700°-1900°F, the planned operating range.

The liner was replaced with a 6-in. Schedule 5, Type 410 stainless steel tube with nongrounded thermocouples attached to the outer wall for bed temperature measurement. The test unit was assembled, leak-tested, and three tests conducted with Ireland mine hydrogasified char as the feed. Nominal conditions for the runs are given below.

Run No.	Char Feed Rate, lb/hr	Steam Feed Rate, lb/hr	Reactor Temp., °F	Reactor Press., psig	Bed Ht., ft	Electrode Immersion, in.	Overall Resistance, ohm	Power Applied, kW	% Steam Converted	% Char Gasified
EG-10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	56.1	23.3
EG-11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	44.5	--
EG-12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]

During Run EG-10 the unit was successfully operated for 2-1/4 hours under steady-state operating conditions and continuous feeding and discharging of char. The power required to maintain an average bed temperature of 1835°F in the top 44 in. of the bed was 17-20 kilowatts while the overall resistance of the system averaged 0.55 ohm. The weight percent of the char fed that was gasified corresponded to 23.3%, and 56.1% of the steam fed was decomposed. The product gas hydrogen yield was 55.3 mole percent on a purge nitrogen-free basis.

Run EG-11 was conducted under similar conditions as Run EG-10 except for an increase in the steam feed rate from 27.5 lb/hr to 41.0 lb/hr. The fluidization and heat transfer in the lower section of the char bed was improved by the higher superficial velocity of the steam feed. Several minutes after beginning the continuous flow of char, the discharge screw jammed and could not be restarted due to the overheating of the pump motor in the hydraulic system. The run was continued as a batch test for 2-1/3 hours at steady-state conditions at power levels of 30-35 kilowatts and with indications of an average overall resistance of 0.63 ohm.

The average bed temperature in the top 44 in. of the bed was 1823°F and yielded 53.3 mole percent hydrogen on a purge nitrogen-free basis in the product gas. The weight percent of the steam that decomposed was 49.5 and the carbon gasification rate was 11.76 lb/hr.

Run EG-12, a repeat of the Run EG-11 conditions, was successfully conducted under continuous steady-state conditions for 2-3/4 hours at power levels of 30-35 kilowatts and an average overall resistance of 0.63 ohm. Bed temperatures averaged 1840°F in the top 44 in. of the bed with a hydrogen yield of 53.3 mole percent on a purge nitrogen-free basis in the product gas corresponding to 59.9% by weight of the steam fed being decomposed and approximately 50% of the char fed gasified.

Due to the shortage of Ireland mine hydrogasified char, the next series of tests will be run using FMC char residue from the COED process. If the results are similar to those of Ireland mine char tests, the use of the readily available FMC char will be incorporated in the project.

Fabrication of the replacement coil for the steam superheaters is in progress and installation is expected to be completed within a month.

Methanation Test Program

Investigations of the reaction order of methane in the methanation reaction have been completed for a temperature of 575°F at 300 and 600 psia. Initial results indicate the rate of methane formation at 575°F is lower by about [illegible]% due to the presence of 60-80 mole percent methane in the feed gas.

Pilot Plant

Details of the design and construction of the pilot plant are covered in Procon's Progress Report No. 6. Procon has submitted its guaranteed maximum price for the construction of the plant, which will be reviewed with OCR in the near future.

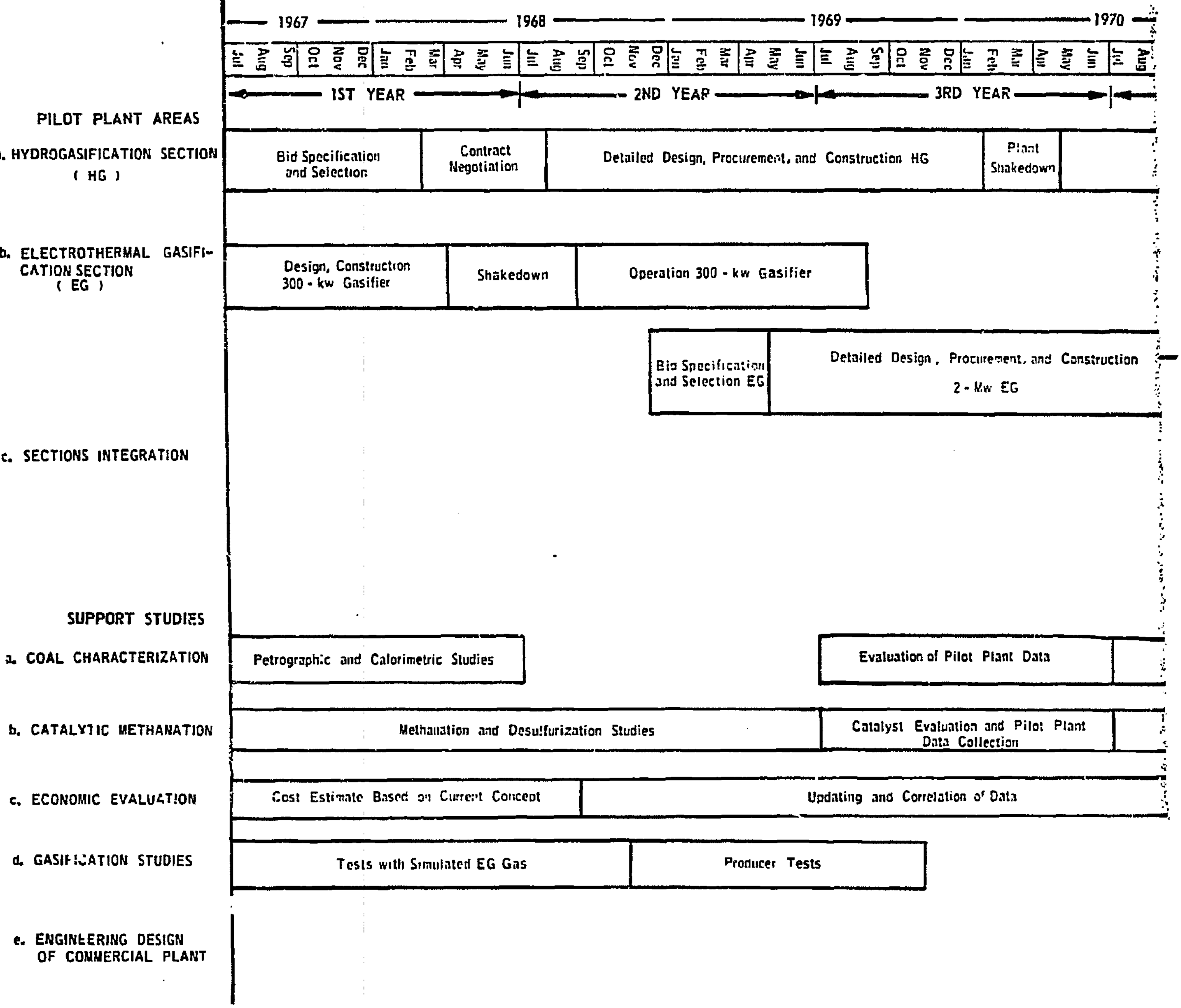
Items having long delivery times are being identified and successful bidders are being selected so that orders can be placed to prevent a delay in plant completion.

Process Studies

Preliminary flow sheets are being prepared for the pipeline gas-pure carbon combined product plant. We are also preparing a flow sheet for a low-pressure synthesis gas-catalytic methanation system for which we will prepare an economic analysis for comparison with the costs developed for the hydrogasification system. The flow sheet for the [illegible] product plant should be ready in a month and that for the low-pressure system in 2 months. During the month no new inventions were made in the course of the work.

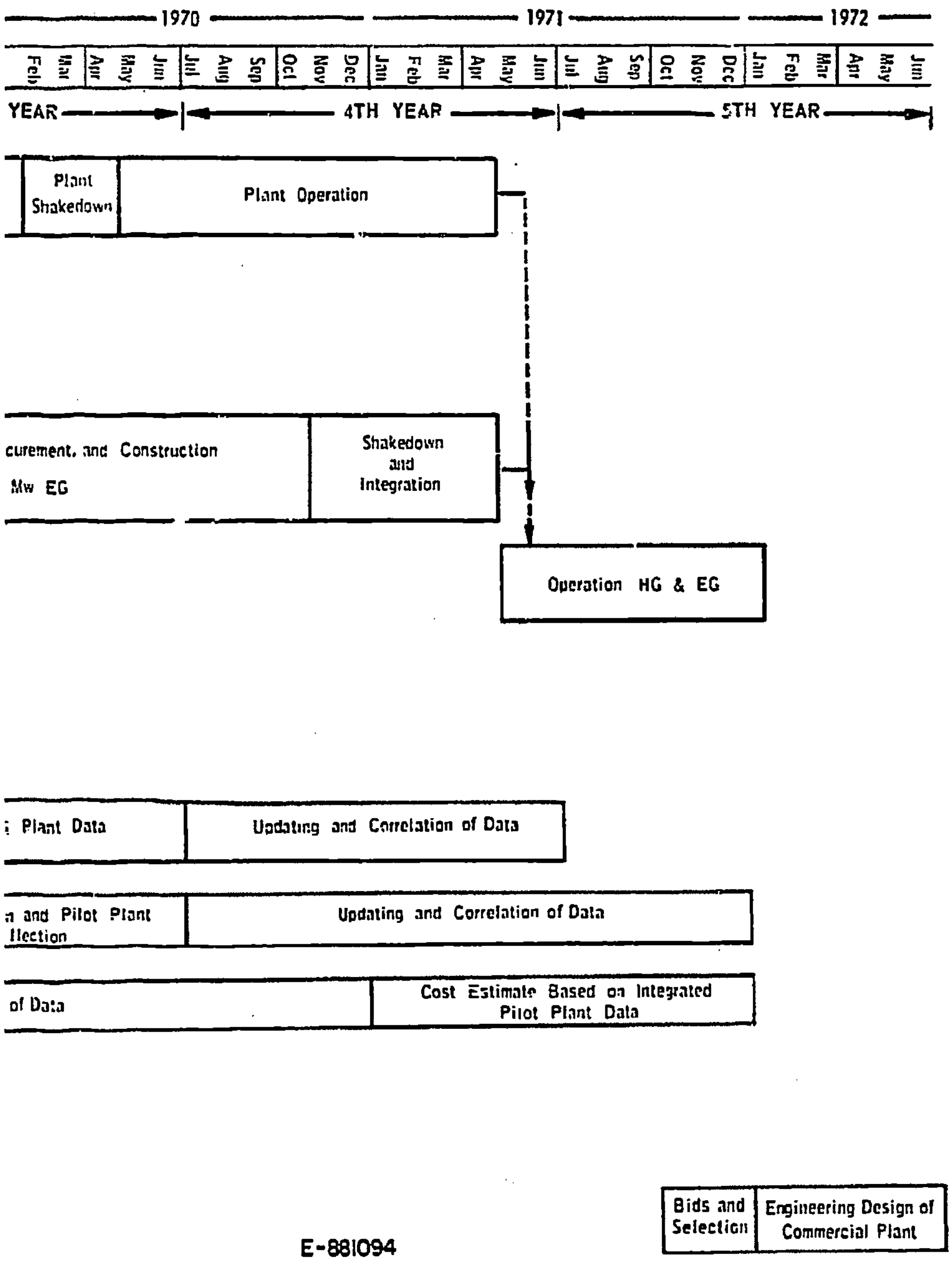
PILOT PLANT PROGRAM OF IGT HYDROGASIF

OCR CONTRACT No. 14-01-0001-381 (1) A



HYDROGASIFICATION PROCESS

1) AGA: IU-4-1



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2

PROGRESS REPORT NO. 6

COAL HYDROGASIFICATION PILOT PLANT

FOR

INSTITUTE OF GAS TECHNOLOGY

CHICAGO, ILLINOIS

W-1784

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DATE:	January 15, 1969
PROCON PROJECT MANAGER:	T.A. Taylor

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Progress Report No. 6

W-1784

Coal Hydrogasification Pilot Plant

I. SUMMARY

A. DEVELOPMENT OF THE GUARANTEED MAXIMUM PRICE W-1784 X-I

The estimate for the Guaranteed Maximum Price is complete and has been preliminarily reviewed with IGT. The Finalized Guaranteed Maximum Price will be submitted to IGT on January 20, 1969 for their review with OCR in Washington, D.C.

B. DESIGN ENGINEERING W-1784

Reactor design problems will be discussed with Struthers-Wells on January 20 in Des Plaines.

Supplementary refractory proposals have been submitted and are being evaluated.

Final evaluations of major equipment are proceeding with emphasis on the long delivery items. Construction of the warehouse is underway.

II. SCHEDULE

A complete project schedule will be finalized when the results of IGT's forthcoming meeting on the GMP with OCR are known.

III. CONTRACT FINANCIAL REPORT

Procon's portion of Form No. 80R0178 has been completed and reflects actual costs incurred through the last calendar month; estimated costs during this month; and the estimated total cumulative cost through this month. All costs have been rounded off to the nearest thousand dollars.

CONTRACT FINANCIAL REPORT
(Dollars in thousands)
(See instructions before preparation)

CONTRACT FINANCIAL REPORT (Dollars in thousands) (See instructions before preparation)	1 For Month Ended January 15, 1969	2 No. of Work Days	3 Contract No.	Form Approved Budget Bureau No. 80R0178 Sheet ____ of ____
4 To:	5 From:		6 Contract Value $	7 Contract Type
			8 Funded Contract Amount $	9 Amounts Billed $
10 Program/Scope of Work	11 Signature and Title of Authorized Representative		12 Preparation Date	13 Payments Received $

14 Appropriation (or Fund Citation) and/or Reporting Category	15 Cost Incurred/Contract Earnings			16 Planning Data (For Agency use only)			
	Cum. Actual End of Prior Mo. a	Actual/ Estimated Current Month b	Cumulative Actual/ Estimated To Date c	a	b	c	d
Procon Incorporated U-1784 less 10% Retention	$ 6 1 5	$ 32 3 29	$ 38 4 34				
Procon Incorporated U-1784 X-1 less 10% Retention	46 5 41	15 1 14	61 6 55				
17 Total							

"The undersigned certifies that the amount is due and payable to Procon, in accordance with the terms of the contract up to the date of this Certificate and that the Contractor has fully complied with the terms and conditions of the contract."

Progress Report No. 6, January 15, 1969

T. A. Taylor

T. A. Taylor

IGT-MPR--2/69

DEVELOPMENT OF IGT HYDROGASIFICATION PROCESS

Progress Report – February 1969
53
to
Office of Coal Research
Contract No. 14-01-0001-381 (1)

SUMMARY

1. Two hydrogasification tests were performed during the month, one on Montana lignite and the other on FMC char.

2. Four electrothermal tests were performed, one being our first test at 500 psi.

3. A computer program has been completed which will predict pressure drops in 2-phase flow (gas-solids). Initial results indicate pressure drops will be reasonable.

Hydrogasification Test Program

We conducted three hydrogasification tests this month in the balanced-pressure development unit. Two of these tests (Runs HT-219 and HT-220) were a continuation of our study of the hydrogasification behavior of Montana lignite at selected operating conditions. In one of the tests, the lignite was gasified with a hydrogen-steam mixture; in the other test, it was gasified with a synthesis gas-steam mixture. In the third test conducted this month (Run HT-221), we hydrogasified a bituminous coal char obtained from FMC Corporation, Project COED. This initial test with the FMC char was designed to test the reactivity of the char to hydrogasification with a hydrogen-steam feed gas.

In Run HT-219, the dried, but otherwise untreated, Montana lignite was gasified in a 3-1/2-ft fluidized bed at a nominal bed temperature of 1700°F with a mixture of hydrogen and steam. The hydrogen-to-lignite ratio was 25% of the stoichiometric ratio; the steam concentration in the feed gas mixture was 50 mole percent. Based on the weight of residue recovered, we converted nearly 55% of the lignite in this 4-hour run.

In Run HT-220, the Montana lignite was gasified at conditions similar to those of Run HT-219, but with a synthesis gas-steam feed gas. Lignite conversion in this test was about 50 weight percent, based on the weight of residue recovered. The test lasted 4-3/4 hours with 2-1/2 hours at steady state.

The objective of Run HT-221 was to determine the reactivity of the FMC char to hydrogasification. This low-volatile-content char (4.0%) is the residue char from the Project COED operation. It was produced from an Illinois No. 6 seam high-volatile C bituminous coal, Crown mine. In the initial hydrogasification test with this char we gasified it in a 3-1/2-ft fluidized bed with a hydrogen-steam feed gas containing 50 mole percent steam. Reactor bed temperature was a nominal 1700°F, and the unit pressure was 1000 psig. The hydrogen-to-char ratio was 30% of the stochiometric ratio. Unit operation was very smooth with this char for the entire 4-1/2-hour duration of the test. Based on the weight of hydrogasified residue recovered, we converted 15.5% of the char.

Electrothermal Gasification Test Program

Four runs were conducted during the month in the electrothermal gasification pilot unit. Char residue from the FMC Corporations Project COED pilot program was used in three of the tests for comparison with test results of Ireland mine char. The FMC char originates from a high-volatile bituminous coal (Illinois No. 6 seam, Crown mine) as does the Ireland mine char, and its chemical analysis approximates that of the Ireland char. The fourth test was conducted with Ireland mine char at 500 psig.

Nominal conditions for the runs are as follows:

Run No.	Char Feed Rate, lb/hr	Reactor Press., psig	Reactor Temp, °F	Power Input, kW	Overall Resistance, ohm	Steam Conversion, wt %	Char Gasified, wt %
EG-13	--	205	[illegible]	22.5	[illegible]	--	--
EG-14	[illegible]	201	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EG-15	[illegible]	[illegible]	1594	[illegible]	[illegible]	[illegible]	[illegible]
EG-16	[illegible]	543	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Run EG-13, the first test conducted with FMC char, was terminated before steady-state conditions were attained because of a plug in the gas offtake system. The electrical behavior of the char during reactor heat-up closely resembled that of Ireland mine char. The overall resistance at the start was 5-6 ohms, but it decreased to a nominal 1.0 ohm at 1600°F.

We had operated Run EG-14 for 1-1/2 hours at steady-state conditions when the overloading of char residue in the condenser collecting tank forced shutdown. The majority of the char residue had been carried from the reactor by the make gas into the cooling section, but at a relatively constant rate. Preliminary data indicate a char gasification of 50-60% and a steam decomposition of 50%. A power input of 41.6 kW was required to maintain an average bed temperature of 1806°F (top 2.75 ft), accompanied by an overall resistance of 0.57 ohm.

The steam feed rate was decreased during Run EG-15 to lower the steam superficial velocity through the reactor in an effort to prevent the solids entrainment in the make gas. After operating 30 minutes at steady-state conditions, a plug in the make-gas exit line caused the termination of the test. An average bed temperature of 1824°F (top 2.75 ft) was maintained by a power input of 37.2 kW. The overall resistance of the system was 0.57 ohm. Initial data indicate that 40% by weight of the char feed was gasified and that 80% of the steam was decomposed.

Because of the ease with which the FMC char particles break-down during handling and the subsequent plugging problems encountered in tests, we decided to resume testing with Ireland mine char at 500 psig. Modification of the present gas offtake and cooling section of the pilot unit will be required for operation at 1000 psig. The new quench system needed to handle the increase in quench duty will also be able to remove from the make gas the entrained solids that appear to be inherent in the process. Except for the problems in handling the FMC char, test results and operating characteristics are nearly identical to those of Ireland mine char. We plan to continue to use it in the program.

Run EG-16 was the first test conducted at 500 psig. Ireland char was used as the feed. During the run, carry-over of char fines into the condenser collecting pot was observed, but the test was continued for 1-1/3 hours at steady-state conditions. The average overall resistance during the test was a nominal 1.0 ohm, which approximates results of tests previously performed at IGT on the effect of pressure on the resistance of a fluidized bed of hydrogasified char.[1]

Preliminary data show 60% of the char feed gasified and 90% of the steam decomposed. The average bed temperature was 1817°F (top 2.75 ft) at a power input of 72.9 kW. The effect of the higher pressure (500 psig compared to 200 psig) on the steam-carbon reaction equilibrium was evident by the make-gas yield and undecomposed water during the test. In previous tests, at 300°F-400°F, approach to the steam-carbon equilibrium composition in the make gas was usually attained, while Run EG-16 showed indications of a less than 100°F approach.

The char residue collected following the test consisted of noticeable smaller sized particles than the feed char. A volume decrease of about one-half the original char fed was also observed. Residues from previous tests had little change in particle size or volume and resemble the feed char in appearance. The highest carbon gasification rate so far, was achieved in Run EG-16 and apparently caused the disintegration of the porous particles.

We will conduct several more tests at 500-psig pressure and at various reactant feed rates and bed temperatures using Ireland mine char. The unit will then be shut down for the modifications necessary for operation at 1000 psig. The replacement coil for the superheater will be scheduled for installation during that period.

Methanation Test Program

Investigations of the reaction order of methane in the methanation reaction have been completed at 575°F and 600 psig for a methane concentration of 50 mole percent in the product gas. The results indicate that the rate of methane formation becomes low when the H_2/CO ratio in the feed gas is less than 2 and that the activity of catalyst decreases after the low H_2/CO ratio runs. The rate of methane formation decreases with decreasing temperature, but does not decrease as much as when helium was used in the feed gas.

The lowest temperature run tested to date was at 525°F. The catalyst is still active after the low-temperature runs.

Engineering Economics

Work is proceeding on the economics section of the coal gasification bulletin which summarizes work done prior to 1964. This section consists of a discussion of the effect of processing changes on gas price for specific design cases. The discussions covered will include the effect of the use of a large excess of hydrogen in the hydrogasifier and the preliminary effect of steam.

Work is also proceeding on the correlation of data on heat transfer coefficients and CO_2 removal plants for our designs of pipeline gas plants.

Pilot Plant Design and Construction

The enclosed Procon report gives the information on pilot plant design and construction. A time schedule for the construction and completion of the plant will be presented next month.

Process Evaluation Studies

The computer program to calculate pressure drop losses in gas-solids pipelines is being debugged. Indications are that abnormally high pressure drops will not occur with reasonable solids loadings. We are awaiting confirmation of this program before using it to size the various systems that will make up our gas-solids process flow sheet.

We plan to obtain data for confirmation from work done at the Bureau of Mines.

Reference Cited

1. Lee, B.S., Pyrcioch, E.J. and Schora, F.C., Jr., "The Electrical Resistivity of a High-Pressure Fluidized Bed." Paper presented at the 61st Annual Meeting of A.I.Ch.E., Los Angeles, December 1-5, 1968.

During the month no new inventions were made in the course of the work.

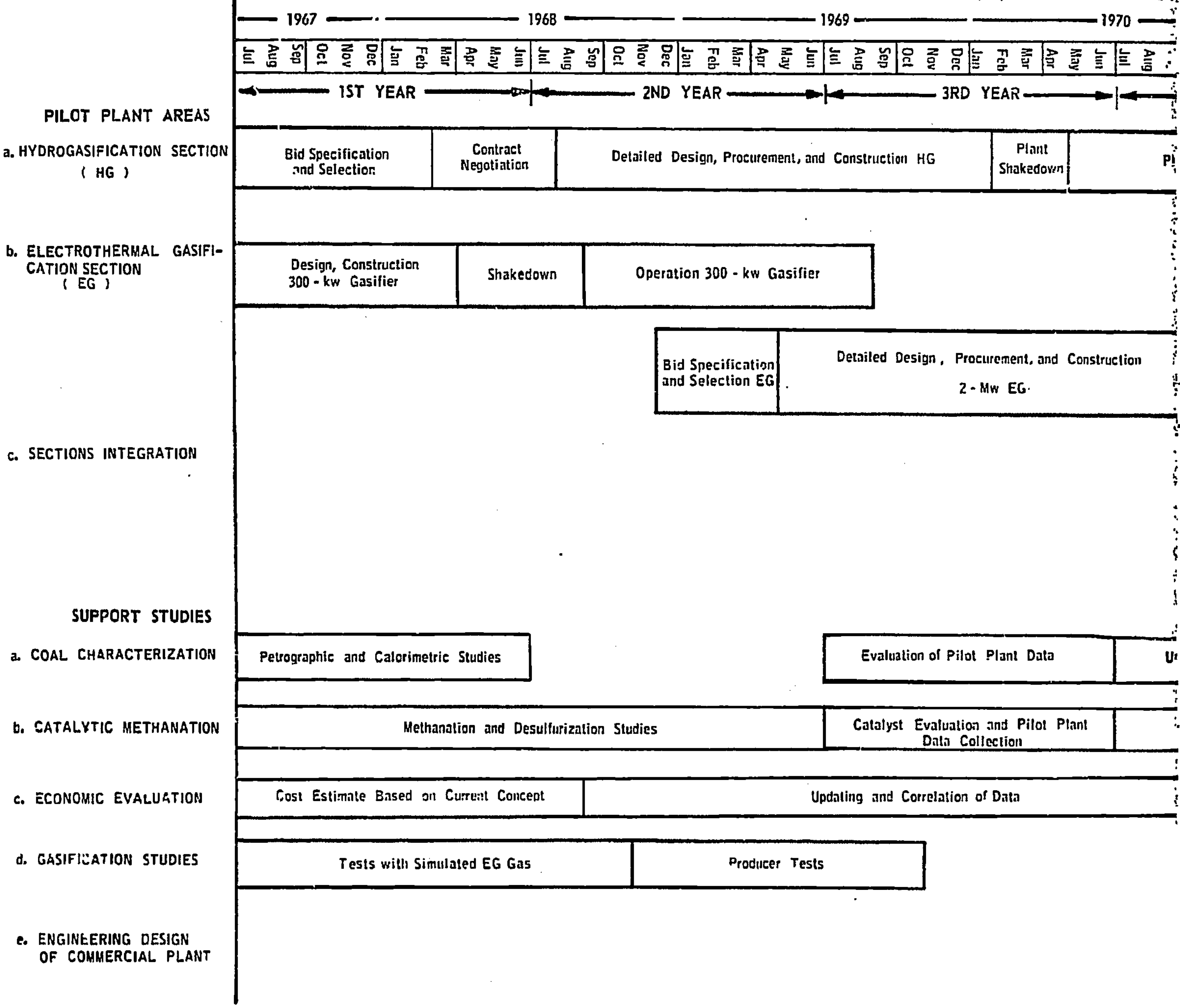
Jack Huebler, Research Director

Frank Schora, Associate Director

Bernard S. Lee, Manager

PILOT PLANT PROGRAM OF IGT HYDROGASIFIC

OCR CONTRACT No. 14-01-0001-381(1) AG



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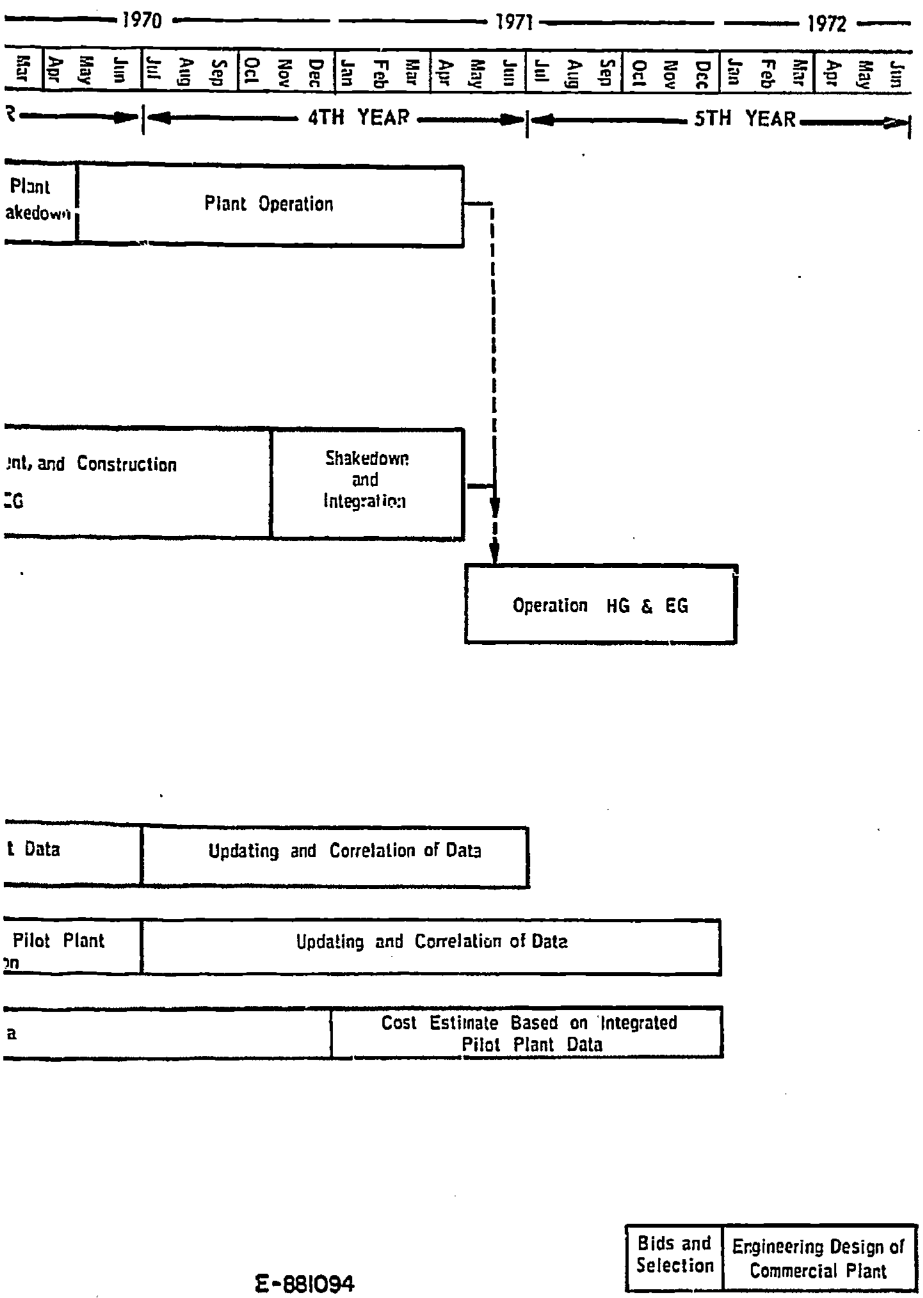

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2

PROGRESS REPORT NO. 7

COAL HYDROGASIFICATION PILOT PLANT

FOR

INSTITUTE OF GAS TECHNOLOGY

CHICAGO, ILLINOIS

W-1784

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DATE:	February, 15, 1969
PROCON PROJECT MANAGER:	T.A. Taylor

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Progress Report No. 7

W-1784

Coal Hydrogasification Pilot Plant

I. SUMMARY

A. DEVELOPMENT OF THE GUARANTEED MAXIMUM PRICE W-1784 X-I

IGT's review with OCR of the guaranteed maximum price was postponed from the week of January 20 to February 14.

B. DESIGN ENGINEERING W-1784

All major design problems have been finalized with Struthers Wells on the reactor, with the exception of the design of thermo-sleeves, which is under study. The following equipment has been evaluated and submitted to IGT for approval: (1) high pressure boiler (2) chlorination unit (3) sulfur plans (4) coal mill (5) demineralizer, and (6) service elevator. All other major equipment evaluations will be submitted to IGT during the week of February 17, with the exception of the pumps and compressors which will be submitted the following week.

Layout of a major portion of the material handling equipment has been finalized. Layout of the entire site has recently been revised with respect to electrical area classifications and revised drawings should be completed within this report.

The final building permit for the warehouse has been secured.

II. SCHEDULE

A preliminary schedule was made to indicate engineering procurement and construction dates. Detailed preliminary CPM schedule is underway. Procon will have an internal scheduling meeting during the week of February 17.

A scheduling meeting will be held with Struthers Wells within the next two weeks to determine exact delivery date of the reactor. When this date is applied to the project schedule, a project completion date can be determined.

III. CONTRACT FINANCIAL REPORT

Procon's portion of Form No. 80R0178 has been completed and reflects actual costs incurred through the last calendar month; estimated costs during this month; and the estimated total cumulative cost through this month. All costs have been rounded off th the nearest thousand dollars.

CONTRACT FINANCIAL REPORT (Dollars in thousands) (See instructions before preparation)	1 For Month Ended	2 No. of Work Days	3 Contract No.	Form Approved Budget Bureau No. 80R0178 Sheet ____ of ____
	February 15, 1969			

4 To:	5 From:	6 Contract Value $	7 Contract Type
		8 Funded Contract Amount $	9 Amounts Billed $

10 Program/Scope of Work	11 Signature and Title of Authorized Representative	12 Preparation Date	13 Payments Received $

14 Appropriation (or Fund Citation) and/or Reporting Category	15 Cost Incurred/Contract Earnings: Cum. Actual End of Prior Mo. (a)	Actual/ Estimated Current Month (b)	Cumulative Actual/ Estimated To Date (c)	16 Planning Data (For Agency use only) a	b	c	d
Procon Incorporated W-1784 Less 16% Retention	$ 6 1 5	$ 55 5 50	$ 61 6 55				
Procon Incorporated W-1784 X-1 Less 10% Retention	46 5 41	20 2 18	66 7 59				
17 Total							

"The undersigned certifies that the amount is due and payable to Procon, in accordance with the terms of the contract up to the date of this Certificate and that the contractor has fully complied with the terms and conditions of the contract."

Progress Report No. 7, February 15, 1969

T.A. Taylor

IGT-MPR--3/69

DEVELOPMENT OF IGT HYDROGASIFICATION PROCESS

Progress Report – March 1969

#54 to

Office of Coal Research

Contract No. 14-01-0001-381 (1)

SUMMARY

1. Two hydrogasification tests were conducted during the month using FMC COED char as feed.

2. Three electrothermal reactor tests were conducted at pressures of 500 psi.

3. A preliminary schedule has been submitted for construction of the plant. Testing and start-up operations are scheduled to begin in March 1970 with plant completion by May 1, 1970.

Hydrogasification Test Program

We conducted two hydrogasification tests this month in the balanced-pressure development unit. Both of these tests, Runs HT-222 and HT-223, are a continuation of the study initiated last month on the amenability of a bituminous coal char from the FMC Corporation's Project COED to hydrogasification. In these tests, we investigated the reactivity of this low-volatile-content char to gasification with a synthesis gas-steam feed gas to determine if it could be considered an acceptable feed for a hydrogasification system.

The char in both tests was hydrogasified in a 3.5-ft fluidized bed with a synthesis gas-steam feed gas. Synthesis gas composition was similar to that used in earlier tests with other feeds. Steam concentration in the feed gas was 50 mole percent. Flow rates were set so that the synthesis gas-to-char ratio was 20 SCF/lb, representing an H_2 + CO-to-char ratio of 43% of stoichiometric. Char bed temperature was held at 1700°F.

Run HT-222 was limited to 1 hour of steady-state operation because of erratic char feeding. Preliminary results show that about 10% of the char was gasified. Over 2 hours of steady-state operation was obtained in Run HT-223. Char gasification was similar to that in Run HT-222. These levels of char gasification are lower than the 15% char gasification obtained in an earlier test when the char was gasified with hydrogen and steam.

Maintenance work was done on the pilot plant coal pretreater so that the pretreatment of Pittsburgh seam bituminous coal could be conducted. This coal will be used as a hydrogasification feed to provide residue for the electrothermal gasifier studies.

Electrothermal Test Program

Three runs were conducted during the month at 500 psig and 1750-1810°F bed temperatures. Two tests were conducted using lightly gasified electrothermal reactor residues from initial tests at atmospheric pressure. One run was conducted using FMC char from the COED pilot program. Nominal conditions for the tests are as follows:

Run No.	Char Feed Rate, lb/hr	Steam Feed Rate, lb/hr	Reactor Press., psig	Reactor Temp., °F	Power Input, kW	Overall Resistance, ohms	Steam Conversion, wt %	Char Gasified, wt %
EG-17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.2	[illegible]	40
EG-1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EG-1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The steam feed rate during Run EG-17 was lowered below previous feed rates in an effort to reduce the solids carryover into the make-gas cooling section. The char feed rate was also lowered to maintain a 1:1 steam to char feed ratio. The test was conducted for 1-1/2 hours at steady-state conditions and was terminated when a leak developed in the water-collecting-pot drain valve. Electrically the system operated smoothly, maintaining an average overall resistance of 1.2 ohms at a power level of 54.0 kW. The average temperature of the top 2.75 ft of bed was 1809°F. Initial data indicate 40.0% gasfication of the char feed and 63.0% decomposition of the steam.

During run EG-18 the char bed level was held 1 ft lower to increase the freeboard space in the reactor and minimize the solids loading in the make gas. The electrode was extended 1 ft to maintain an immersion depth of 24 in., as in previous tests. The run was terminated after 1-1/2 hours of steady-state operation when the overall resistance increased from 1.0 to 5.5 ohms and were unable to maintain the bed temperature at 1800°F with an applied voltage of 450 V. The occurrence of this high-resistance condition in previous tests resulted in a melted electrode tip and slagging in the bed. Inspection of the electrode following the run showed it had been melted along one side extending 10 in. from the tip. Bed temperatures along the wall below the melted electrode section were less than 1000°F, indicating a settled bed in that area and channeling of the steam through one side of its lower section. Preliminary results obtained during Run EG-18 indicate char and steam conversion of 43.0 and 65.0%. A power input of 58.3 kW maintained an average temperature of 1806°F in the top 2.75 ft of the bed.

Run EG-19 was conducted using FMC char for comparison with results of Ireland mine char at 500 psig. The test was operated for 80 minutes at steady-state conditions and was terminated when conditions similar to those in Run EG-18 occurred. The overall resistance increased from 1 to 5 ohms, and we were unable to maintain the bed temperature.

Dismantling of the unit revealed the same damage to the electrode. Further inspection showed the steam inlet nozzle had been off-center at the reactor bottom and was leaning against the reactor wall. This prevented the even distribution of steam into the char bed and contributed to the channeling which was evident in Runs EG-18 and EG-19.

Preliminary data indicate a char gasification rate of 45% and steam decomposition of 50%. The average bed temperature was 1750°F maintained by 42.5 kW at an overall resistance of 1.8 ohms.

Testing in the pilot unit was completed at the lower pressures. Modifications necessary for operation at 1000 psig are in progress, as well as the installation of the superheater coil. Testing will resume upon their completion scheduled in 3-4 weeks.

Methanation Test Program

The methanation apparatus was modified so that steam can be injected into the reactor feed gas to study the reaction order of steam in the methanation reaction. The apparatus is also being modified so that traces of benzene can be carried into the reactor to study the activity of the catalyst used in the presence of benzene.

Pilot Plant Design and Construction

Details of the progress made during the month on the design and construction of the pilot plant are shown in the accompanying Procon Progress Report No. 8. In this area, IGT's activity has been to review the design and equipment specifications, and to study the feasibility of filtering the water-char slurry to obtain a dewatered char cake.

Process Evaluation Studies

We are now in the process of optimizing the solids-gas pipeline system. Our computer program to calculate pipeline pressure drops for 2-phase flow was checked against data obtained from the Morgantown Station of the Bureau of Mines. This data were for somewhat larger coal particles than we propose, in a nitrogen-CO_2 carrier gas. Our computer model predicts a somewhat higher pressure drop than reported by the Bureau. Use of this model to predict pipeline pressure drops indicates that the pressure drops will not be excessive. On this basis, we believe that our approach to 2-phase pipeline transmission is feasible. We are now establishing the gasifier configuration for the partial gasification of the lignite that will be necessary to produce the pipeline gas.

We are now investigating the possibility of upgrading the gas produced by our process by removal of the small amount of residual hydrogen by physical methods.

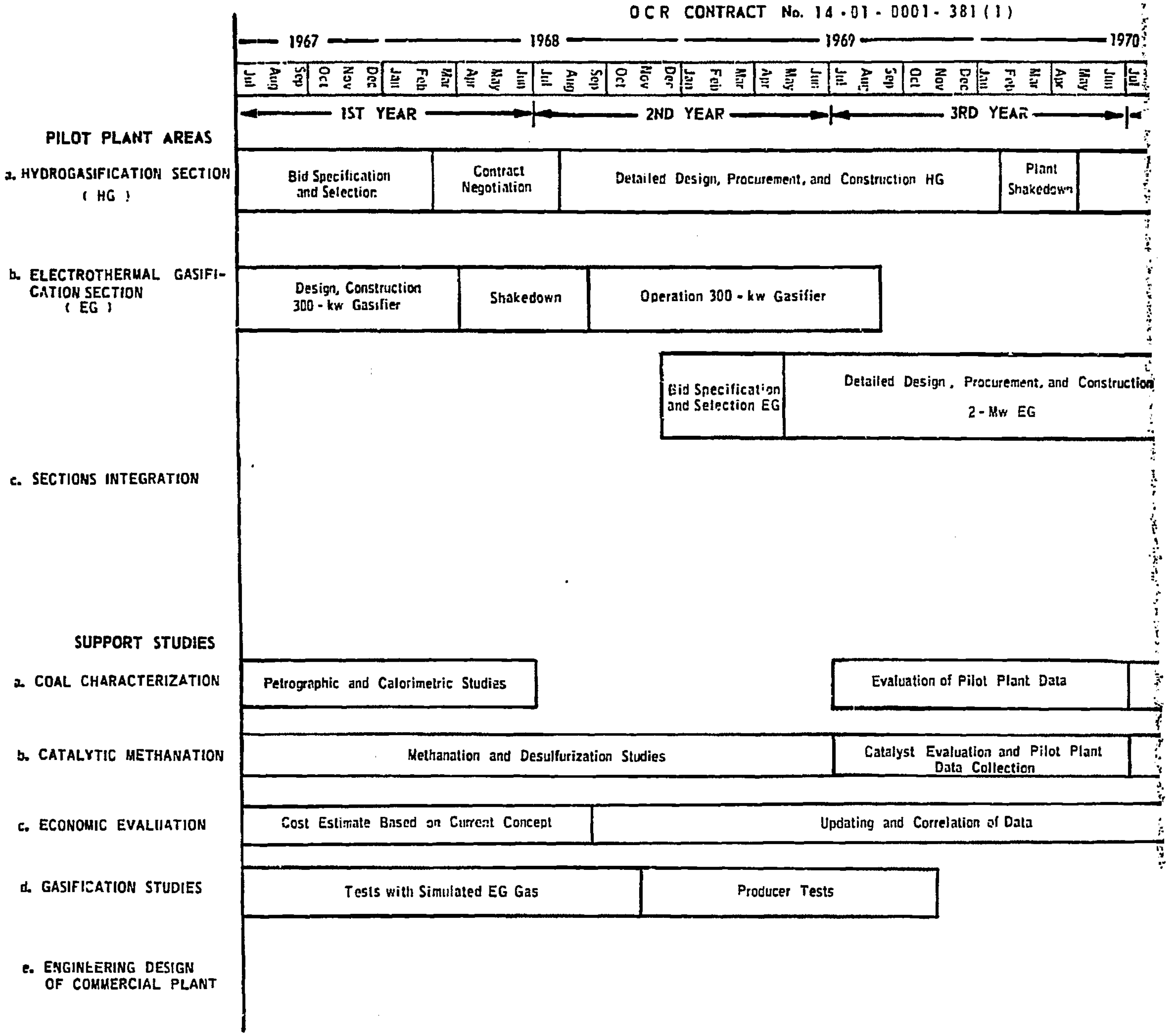
During the month, no new inventions were made in the course of the work.

Frank Schora, Associate Director

Bernard S. Lee, Manager

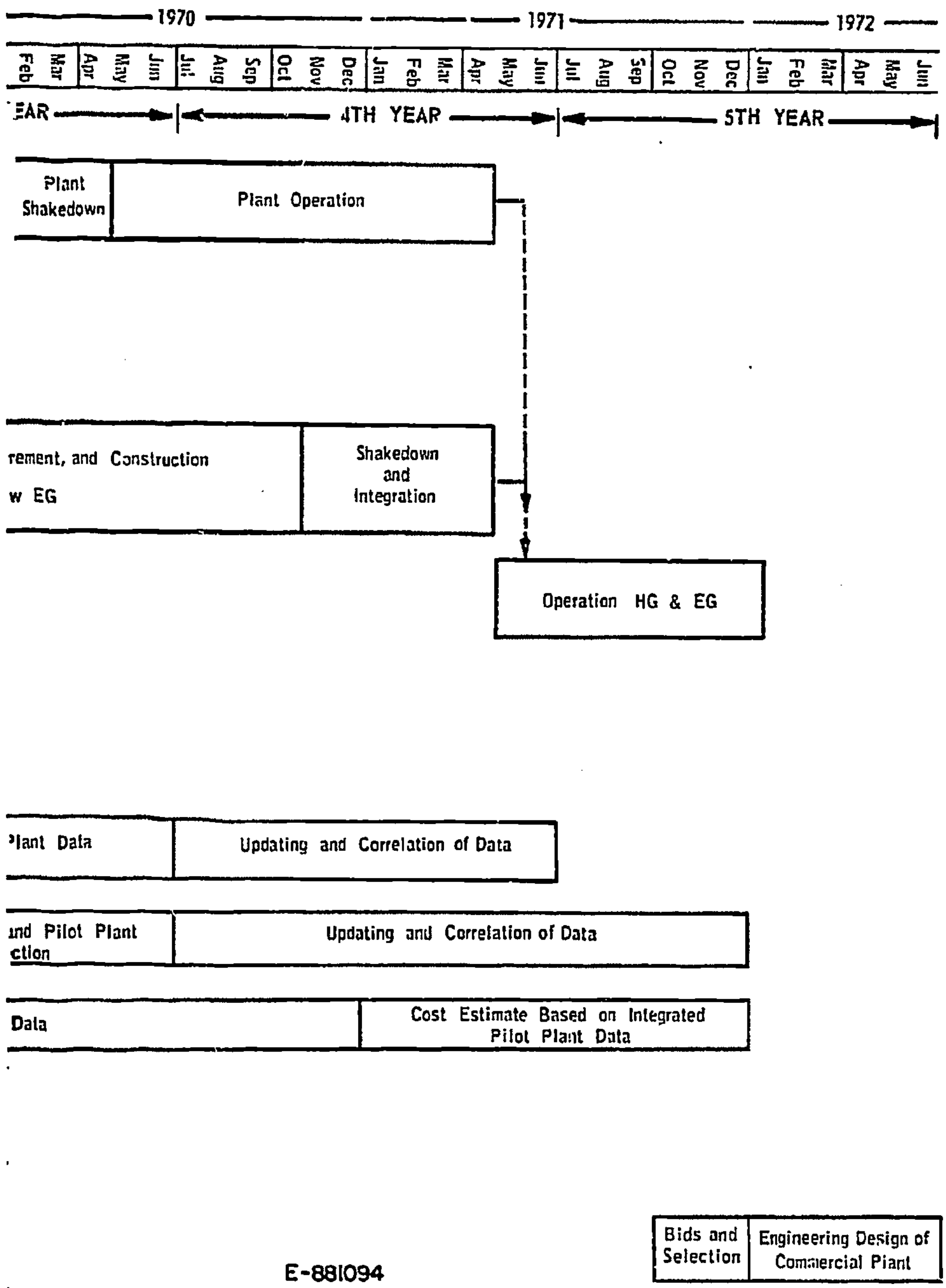
PILOT PLANT PROGRAM OF IGT HYDROGASI

OCR CONTRACT No. 14-01-0001-381(1)



HYDROGASIFICATION PROCESS

.) AGA: IU-4-1



E-881094

PROGRESS REPORT NO. 8

COAL HYDROGASIFICATION PILOT PLANT

FOR

INSTITUTE OF GAS TECHNOLOGY

CHICAGO, ILLINOIS

W-1784

TABLE OF CONTENTS

PROGRESS REPORT

PROJECT: Institute of Gas Technology
Chicago, Illinois
Coal Hydrogasification Pilot Plant
Procon Job No. W-1784

REPORT NO: 8

DATE: March 15, 1969

PROCON PROJECT MANAGER: T.A. Taylor

DISTRIBUTION:

Institute of Gas Technology

Mr. F.C. Schora - 10

Procon Incorporated

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Field	(1)

PROGRESS REPORT NO. 8

W-1784

Coal Hydrogasification Pilot Plant

I. SUMMARY

A. Development of the Guaranteed Maximum Price W-1784X-1

As a result of IGT's review with OCR, the project will continue on a reimbursible basis until October 1, 1969 at which time Procon will submit a guaranteed maximum price.

B. Design Engineering

Revised Piping and Instrument Diagrams for the process areas are being issued. Utility P&ID's are underway. Finalized site and plot plans are scheduled to be issued April 1st. Vessel orientations and piping plans have been started. Compressors/Pumps and Flare/Incinerator are the remaining major equipment evaluations to be submitted to IGT.

IGT and Procon met with the City of Chicago Air Pollution Control Department and established the basis for setting stack heights. Still pending with the APCD is permission to install a flare to be used to burn off excess product gas.

Procon is presently recommending finalization of the boiler feed water system based on total demineralization of make up water.

C. Procurement

Purchase orders or subcontracts for the following major equipment have been issued:

Reactor
High Pressure Boiler
Material Handling
Warehouse
Service Elevator

Approval has been received from IGT to issue orders for the following major equipment upon finalization of purchasing details, ie. terms and conditions:

Hydrogen Plant
Refractory Material
Refractory Installation
Reactor Valves
Reactor Expansion Joints
Sulfur Plant
Coal Mill

I. SUMMARY

C. Procurement (cont'd)

As of March 17th, the following other major equipment will have been evaluated and sent to IGT for approval:

Chlorination Unit	Exchangers	Deaerator
Demineralizer	Heaters	Vessel Internals
L.P. Boiler	Vessels	Process Filters
		Agitators
		Spent Slurry Filter

Approval of several of the above equipment items is being held pending reevaluation of some of the utility and process systems.

The present project schedule is based on all major equipment purchase orders being issued by the first week in April.

D. Construction

The warehouse is the only item presently under construction. The subcontractor has been working (on a fixed price contract) as weather permitted during the winter and is scheduled to complete the building structure and floor by April 1st.

The present project schedule indicates an August 18th date for opening the field office.

II. SCHEDULE

IGT and Procon attended a scheduling meeting with Struthers-Wells to establish a shipping date; it was not set at that meeting but should be finalized during the week of March 17th. The present schedule is based on a 12/15/69 shipping date.

A Precedence Diagram Method (PDM) schedule will be run on the computer by April 4th. It is anticipated that future Project Progress Reports will include the results of the latest computer run tabulated as a status of Mileston Events.

For this report, a listing of Milestone Events is included and is based on the attached preliminary bar chart schedule.

II. SCHEDULE (cont'd)

MILESTONE EVENTS

Based on preliminary bar chart schedule attached.

Award of Contract	7-15-68
Reactor Vessel Purchase Order	11-19-68
High Pressure Boiler Purchase Order	2-19-69
Compressors & Pumps Purchase Order	3-21-69
Hydrogen Plant Purchase Order	3-25-69
Major Equipment Purchase Order Complete	4-4--69
Finalization of Plot Plan	4-1--69
Process P&ID Complete	4-1--69
Utility P&ID Complete	4-15-69
Receipt of Vendors Drawings	4-15-69 to 5-15-69
Issue Drawings for Electrical Subcontract	6-1--69
Complete Piping Drawings	8-18-69
Open Field Office	8-18-69
Finish Foundations	10-15-69
Delivery of Piping	11-1-69
Delivery of Major Equipment	9-1--69 to 10-31-69
Delivery of Compressors & Pumps	9-1--69 to 11-31-69
Delivery of High Pressure Boiler	12-15-69
Delivery of Hydrogen Plant	1-1 -70
Delivery of Reactor	1-15-70
Erection of Reactor Complete	2-1 -70
Refractory Installation Complete	4-15-70
Testing and Start-Up	3-15-70 to 4-30-70
Completion	5-1 -70

III. CONTRACT FINANCIAL REPORT

Procon's portion of Form No. 80R0178 has been completed and reflects actual costs incurred through the last calendar month; estimated costs during this month; and the estimated total cumulative cost through this month. All costs have been rounded off to the nearest thousand dollars.

CONTRACT FINANCIAL REPORT (Dollars in thousands) (See instructions before preparation)	1 For Month Ended March 15, 1969	2 No. of Work Days	3 Contract No.	Form Approved Budget Bureau No. 80R0178 Sheet ____ of ____
4 To:	5 From:		6 Contract Value $	7 Contract Type
			8 Funded Contract Amount $	9 Amounts Billed $
10 Program/Scope of Work	11 Signature and Title of Authorized Representative		12 Preparation Date	13 Payments Received $

14 Appropriation (or Fund Citation) and/or Reporting Category	15 Cost Incurred/Contract Earnings			16 Planning Data (For Agency use only)			
	Cum. Actual End of Prior Mo.	Actual/ Estimated Current Month	Cumulative Actual/ Estimated To Date				
	a	b	c	a	b	c	d
	$	$	$				
Procon Incorporated W-1784 Less 10% Retention as applicable	45 * 1 44	22 2 20	67 3 64	* includes $31,389 for performance bond.			
Procon Incorporated W-1784 X-1 Less 10% Retention	66 7 59	- - -	66 7 59				
17 Total							

"The undersigned certifies that the amount is due and payable to Procon in accordance with the terms of the contract up to the date of this Certificate and that the contractor has fully complied with the terms and conditions of the contract."

Progress Report No. 8, March 15, 1969

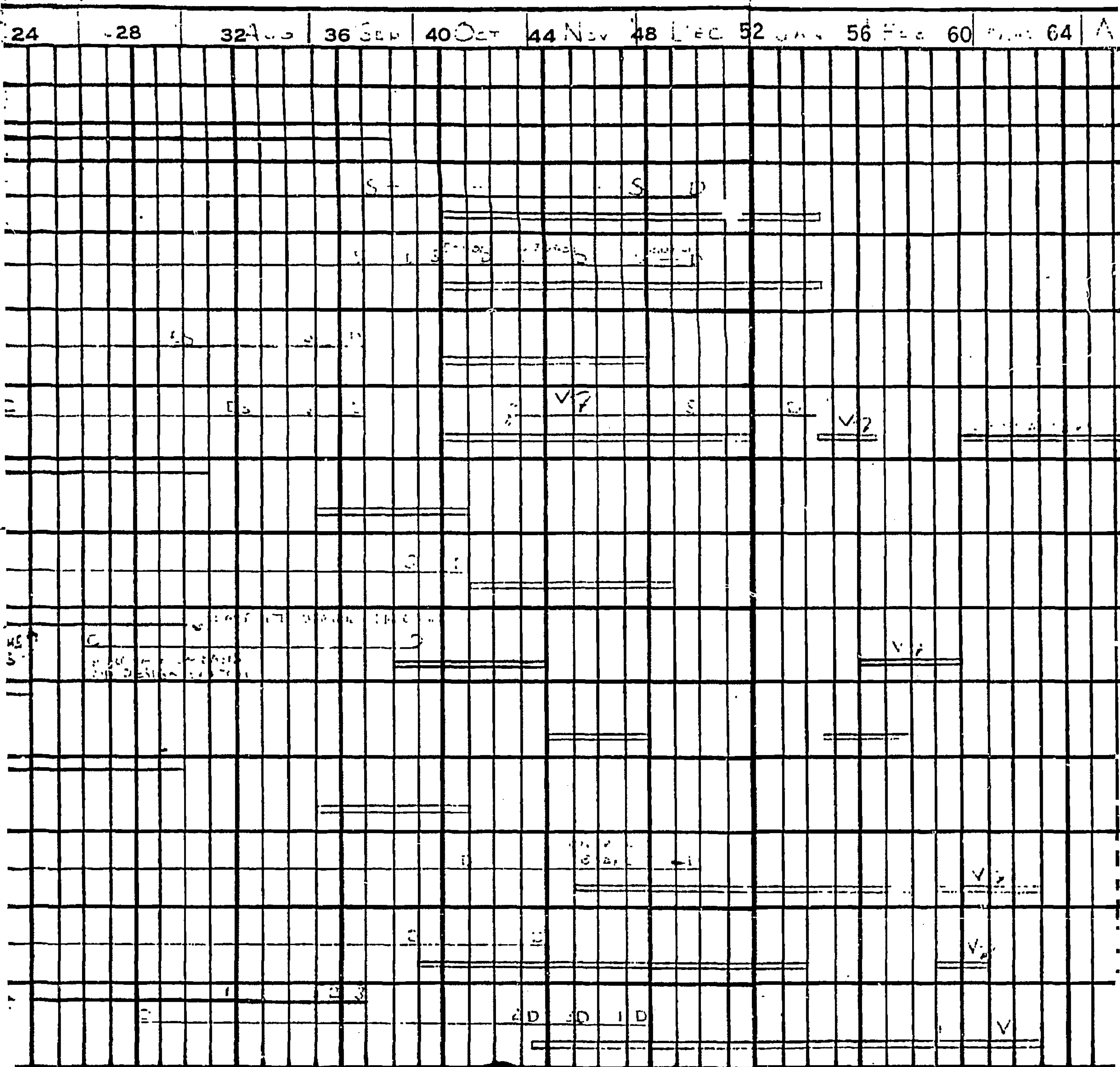
T.A. Taylor (signature)

T.A. Taylor

	% COMPLETE	DATE WEEKS	0	4	8	12	16	20
P&I DIAGRAMS								
PLOT PLAN		E						
PIPING PLAN		E						
PUMPS		E P C						
COMPRESSORS		E P C						
EXCHANGERS		E P C						
VESSELS		E P C						
FOUNDATIONS		E P C						
HEATERS		E P C						
STRUCTURAL STEEL		E P C						
BUILDINGS		E P C						
PIPE RACKS		E P C						
INSTRUMENTS		E P C						
ELECTRICAL		E P C						
PIPING [illegible]		E P C						

STITUTE OF GAS TECHNOLOGY — 1784

SCHEDULE AND STATUS OF ENGINEERING, PROCUREMENT AND CONSTRUCTION



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LEGEND

E—ENGINEERING & DRAFTING
P—PROCUREMENT
C—FIELD CONSTRUCTION
— SCHEDULE
— PERFORMANCE
R—REQ. ISSUED
O—ORDER PLACED
C—CERTIFIED PRINTS REC'D.
D—PROMISED DELIVERY

PROCON *Incorporated*

CHICAGO, U. S. A.

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LEGEND

E–ENGINEERING & DRAFTING

P–PROCUREMENT

C–FIELD CONSTRUCTION

— SCHEDULE

▬ PERFORMANCE

R–REQ. ISSUED

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PROCON *Incorporated*

CHICAGO, U. S. A.

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		C						
SPLIT SLURRY FILTER		E						
		P						
		C						
TESTING & START-UP		E						
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...ITUTE ... OF GAS TECHN... - 1784

SCHEDULE AND STATUS OF ENGINEERING, PROCUREMENT AND CONSTRUCTION

24	28	32 AUG	36 SEP	40 OCT	44 NOV	48 DEC	52 JAN	56 FEB	60 MAR	64

2

OPEN FIELD OFFICE

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LEGEND

E–ENGINEERING & DRAFTING
P–PROCUREMENT
C–FIELD CONSTRUCTION
— SCHEDULE
▬ PERFORMANCE
R–REQ. ISSUED
O–ORDER PLACED
C–CERTIFIED PRINTS REC
D–PROMISED DELIVERY

PROCON *Incorporated*

CHICAGO, U. S. A.

REV NO.	DATE	BY	REV NO.	DATE	BY	REV NO.	D

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LEGEND

E—ENGINEERING & DRAFTING
P—PROCUREMENT
C—FIELD CONSTRUCTION
— SCHEDULE
▬ PERFORMANCE
R—REQ. ISSUED
O—ORDER PLACED
C—CERTIFIED PRINTS REC'D.
D—PROMISED DELIVERY

PROCON *Incorporated*

CHICAGO, U. S. A.

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4

IGT-MPR--4/69

DEVELOPMENT OF IGT HYDROGASIFICATION PROCESS

Progress Report No. 55 — April 1969

to

Office of Coal Research

Contract No. 14-01-0001-381 (1)

SUMMARY

1. Five separate runs were made for pretreatment of Pittsburgh seam coal for use in subsequent test work. Mechanical trouble with the air-distributor disk or control system gave us problems in the operation of these tests.

2. Attempted operation at 1000 psig in the electrothermal reactor has resulted in repeated shorting of the high-pressure electrical insulating seal ring. The insulating closure is being changed to avoid this problem.

3. Procon reports engineering for the pilot plant is approximately 30% complete and purchasing approximately 50% complete.

Hydrogasification Test Program

During the month of April we conducted five separate operations in the pilot plant coal pretreatment unit to prepare a pretreated Pittsburgh seam bituminous coal for use in the balanced-pressure hydrogasification development unit. Only a limited quantity of nonagglomerating coal was produced in these operations. Each time we experienced either equipment component or instrument and control failures. These failures led to a loss of bed fluidization, partial caking of the coal, and curtailment of the operation. Maintenance and repair work, beyond the routine, was required for the following equipment components:

1. Gas distributor disk: Radial cracks in the disk were repaired by brazing. As this proved ineffective for sealing cracks, a new disk had to be machined and installed.
2. Pretreater bottom flange gasket: This 10-inch gasket in the heated zone of the pretreater had to be replaced.
3. Gas seal at distributor disk and standpipe: New packing was required to maintain a seal.
4. Product gas line: This 2-inch line required extensive cleaning of oil and tar deposits to reduce back pressure on the unit.

The following maintenance work on unit instruments and controls was performed:

1. Nine thermocouples sensing temperatures in the coal bed were replaced. They were either totally inoperative or of marginal reliability. Three of these thermocouples are sensors for the pretreater furnace temperature controllers.
2. A faulty relay in one of the pretreater furnace controllers was replaced.

Coal pretreatment will be resumed as soon as the operation of the unit is checked following the above changes.

Electrothermal Test Program

Since modifications of the electrothermal gasification pilot unit have been completed, two tests at 1000 psig have been attempted. Both tests were terminated because of the failure of the insulated seal ring in the pressure closure through which the electrode enters the reactor top. The failure resulted in a dead short in the system, overloading the current-limit controller as it decreased the voltage output of the generator. In both tests, the residual voltage in the armature coil arced to the generator casing before the circuit could be opened, causing minor damage to the SCR controller circuit and several contact brushes on the generator. The probable cause of the electrical breakdown of the insulated seal ring is the inability of the insulating material to resist cold flowing at the higher pressure.

The continued failure of the closure has necessitated the design of a more reliable closure for use at 1000-psig operation. Information obtained by IGT indicates a flanged closure with nonconducting gaskets and bolt sleeves should be satisfactory for our application. The flanged closure and special gasketing material have been ordered. Fabrication and installation will proceed as soon as they are received. Once that is completed, testing at 1000 psig will resume.

Methanation Test Program

Analysis of experimental data made for the determination of the reaction order of methane in the methanation reaction indicates that additional experimental work is needed to better establish the order. The apparatus was further modified so that the feed gas may be saturated with benzene at various saturation temperatures and the analysis of benzene in the product gas can be made more easily.

Pilot Plant Design and Construction

Details of the progress made during the month on the design and construction of the pilot plant are presented in the accompanying Procon Progress Report No. 9. Engineering is approximately 30% complete and purchasing is approximately 50% complete. The Procon completion date is May 1970, which does not agree with the attached progress chart. Our overall chart will be updated in the next progress report.

Process Evaluation Studies

During the month, studies were conducted to establish the optimum operating conditions for a typical pipeline to handle a pipeline gas-carbon mixture. A preliminary report on the results of this pipeline study will be presented next month.

A preliminary economic analysis was made of the approach of producing hydrogen with a high-temperature shorted-electrode fuel-cell-type system. This analysis, based on a system to produce hydrogen for 250 million CF of pipeline gas per day, indicates that such a system does not appear attractive, even when considering future potential improvements in electrode construction.

During the month no new inventions were made in the course of the work.

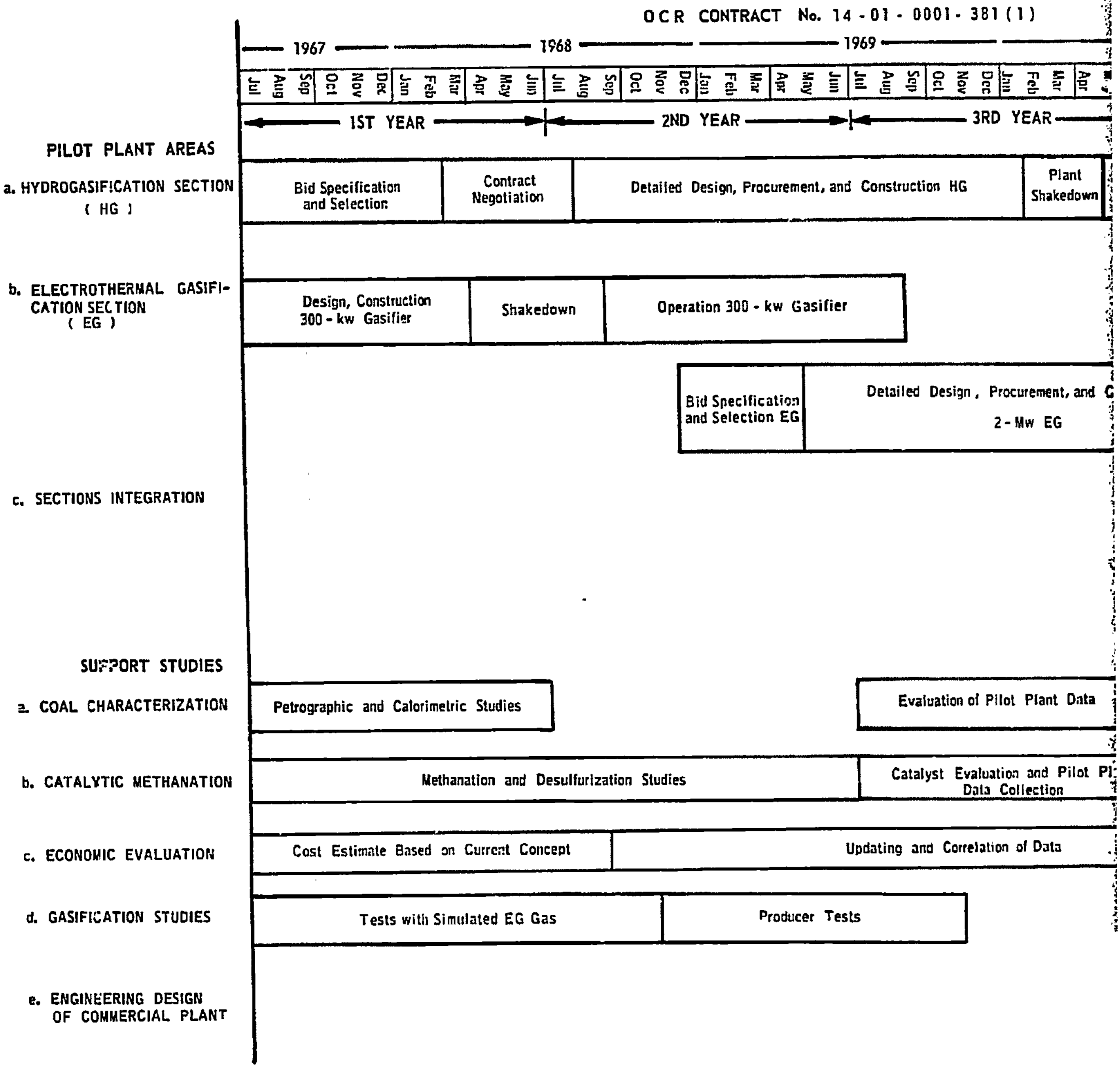
Approved ______________________
Frank C. Schora, Associate Director

Signed ______________________
Bernard S. Lee, Manager

____
Jack Huebler, Research Director

PILOT PLANT PROGRAM OF IGT HYDRO

OCR CONTRACT No. 14-01-0001-381 (1)



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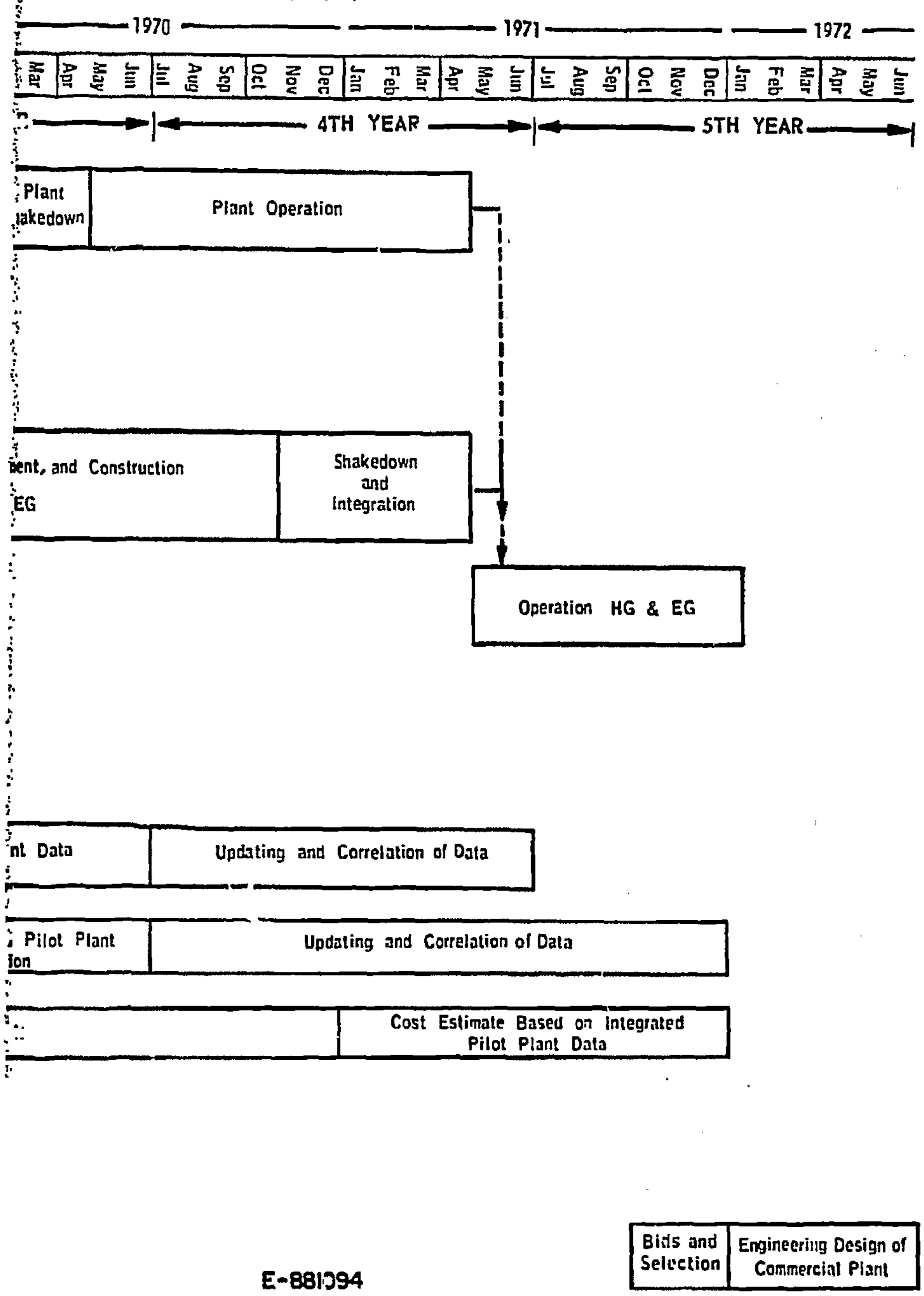
AGA: IU-4-1



E-881094

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IGT-MPR--5/69

Progress Report No. 56 -- May 1969
to
Office of Coal Research
Contract No. 14-01-0001-381 (1)

SUMMARY

1. Two tests to study the effect of system pressure on gasification were conducted in the hydrogasification test program during the month.

2. A partially successful first run at 1000 psi was made in the electrothermal gasifier test unit, having a 40-minute steady-state period.

3. Procon has started work at the pilot plant site. Engineering is 33% complete, and purchasing is 60% complete.

Hydrogasification Test Program

We conducted two hydrogasification tests this month in the balanced-pressure development unit. In these tests (Runs HT-224 and HT-225) we gasified a lightly pretreated Pittsburgh seam bituminous coal from the Ireland mine to study its reactivity at pressure levels other than the standard pressure of 1000 psig used in most other tests. At selected conditions for the study, the coal was reacted with a hydrogen-steam feed gas at a reactor pressure of 500 psig in one test, and with a synthesis gas-steam feed gas at 1500 psig in another test.

In Run HT-224, conducted at 500 psig, we evaluated the reactivity of the bituminous coal in a 3.5-ft fluidized bed controlled to a temperature of 1700°F. The coal was fed at a rate of 36 lb/hr for reaction with 345 SCF/hr of hydrogen and 8.8 lb/hr of steam. At these flow conditions, the hydrogen-to-coal ratio was 25% of the stoichiometric ratio, and the steam concentration in the feed gas was 35 mole percent. The test lasted 5-3/4 hr with 4-1/2 hr at steady state. Perliminary indications are that 26% of the carbon was gasified, and a product gas of 510 Btu/SCF (nitrogen-free basis) was produced.

Nominal flow rates in Run HT-225, conducted at 1500 psig, were 45 lb/hr of coal, 680 SCF/hr of synthesis gas, and 32 lb/hr of steam. The equivalent hydrogen (hydrogen plus carbon monoxide)-to-coal ratio was 35% of the stoichiometric ratio and the steam concentration in the feed gas was 50 mole percent. The coal was gasified in a 3.5-ft fluidized bed controlled to a temperature of 1700°F. Three hours of steady-state operation were obtained in this successful test of 4-hour duration. Based on the weight of residue recovered, over 30% of the coal appears to have been converted to gaseous and liquid products.

Electrothermal Gasification Test Program

Three tests were conducted during the month, one of which was partially successful. FMC char was used as feed in all three tests. The first run (EG-22) was conducted at 500 psig since the insulated seal ring and clamp-type pressure closure had functioned at that pressure in previous tests. Two tests (EG-23 and EG-24) were conducted at 1000 psig after the installation of the flange-type insulated pressure closure.

Nominal conditions for the partially successful test are as follows:

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Overall Resistance, ohms	[illegible] Conversion, [illegible]	Char Conversion, %
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

As steady-state conditions were being approached during Run EG-22, the steam superheater high-temperature safety interlock cycled the superheater off. While attempting to manually restart the superheater, the temperature in the lower section of the char bed decreased enough to defluidize that portion of the bed. A hot spot developed in the bed and the run was terminated. Examination of the reactor following the test showed that the electrode had melted about one-half through from 8 to 18 inches from the tip. The reactor wall had melted through in the area corresponding to the electrode burning, and most of the thermocouples along the outside of the reactor tube were severed. The damage necessitated the replacement of the inner reactor tube and thermocouples. A 6-in., 14-gauge, Type 316 SS tube and nongrounded thermocouples were installed.

During the reactor heat-up period of Run EG-23, a plug developed in the water drain line of the make-gas quench vessel. In clearing the heavy char slurry from the line, the drain valve could not be closed properly because char particles trapped in the valve seat prevented a satisfactory pressure seal. The run was terminated before steady-state conditions were attained.

Run EG-24 was the first partially successful test at 1000 psig, with steady-state conditions being maintained for 40 minutes. Problems in steam delivery to the reactor, inability to maintain temperatures in the lower section of the bed, and the flashing of the quench water and undecomposed steam when being drained led to the early shutdown. The steam nozzle has been rearranged for better flow control, and a larger water collecting tank with additional cooling capacity has been installed to correct these problems.

Preliminary data indicate nominal char gasification and steam decomposition of 50 percent by weight. The average power input was 103 kW, and the overall resistance of the system was 0.54 ohm.

Methanation Test Program

Additional experimental data were obtained at 575°F and 600 psig for the determination of the reaction order of methane in the methanation reaction. The results were satisfactory. Experimental runs with a feed gas consisting of H_2, CO, CO_2, and CH_4 saturated with benzene at 100°F have begun, and the sample collection method is being tested.

Pilot Plant Design and Construction

Details of the progress made by Procon during the month for the detailed design and construction of the pilot plant are covered in the accompanying Procon Report No. 10. Engineering is approximately 33% complete and purchasing is about 60% complete. Initial field work began during the last week in May.

We are now working with Procon to ensure that the electrothermal reactor can be installed with a minimum of upset to the remainder of the plant. The additional superheated steam line required for the electrothermal gasifier will be installed during the initial construction phase.

Process Evaluation Studies

Various approaches for the gasification of lignite for production of a pipeline gas-solid carbon mixture were studied during the month. Also considered was the operating pressure for the producer gas generator-carbon deposition system.

The accompanying time schedule was updated to reflect the schedule predicted by Procon and our revised schedule on the electrothermal reactor test program.

No new inventions were made during the month's work.

F. C. Schora, Jr., Associate Director

B. S. Lee, Manager

PILOT PLANT PROGRAM OF IGT HYDR

OCR CONTRACT No. 14-01-0 381(1)

1967 — 1968 — 1969

Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr

1ST YEAR — 2ND YEAR — 3RD YEAR

PILOT PLANT AREAS			
a. HYDROGASIFICATION SECTION (HG)	Bid Specification and Selection	Contract Negotiation	Detailed Design, Procurement, and Construction HG
b. ELECTROTHERMAL GASIFICATION SECTION (EG)	Design, Construction 300-kw Gasifier	Shakedown	Operation 300-kw Gasifier
	Detailed Design 2-MW EG	P	
c. SECTIONS INTEGRATION			

SUPPORT STUDIES		
a. COAL CHARACTERIZATION	Petrographic and Calorimetric Studies	Evaluation of Pilot Plant Data
b. CATALYTIC METHANATION	Methanation and Desulfurization Studies	Catalyst Evaluation and Pilot : Data Collection
c. ECONOMIC EVALUATION	Cost Estimate Based on Current Concept	Updating and Correlation of Data
d. GASIFICATION STUDIES	Tests with Simulated EG Gas	Producer Tests
e. ENGINEERING DESIGN OF COMMERCIAL PLANT		

* Reactor must be purchased during design period because of time required for fabrication.

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IGT HYDROGASIFICATION PROCESS

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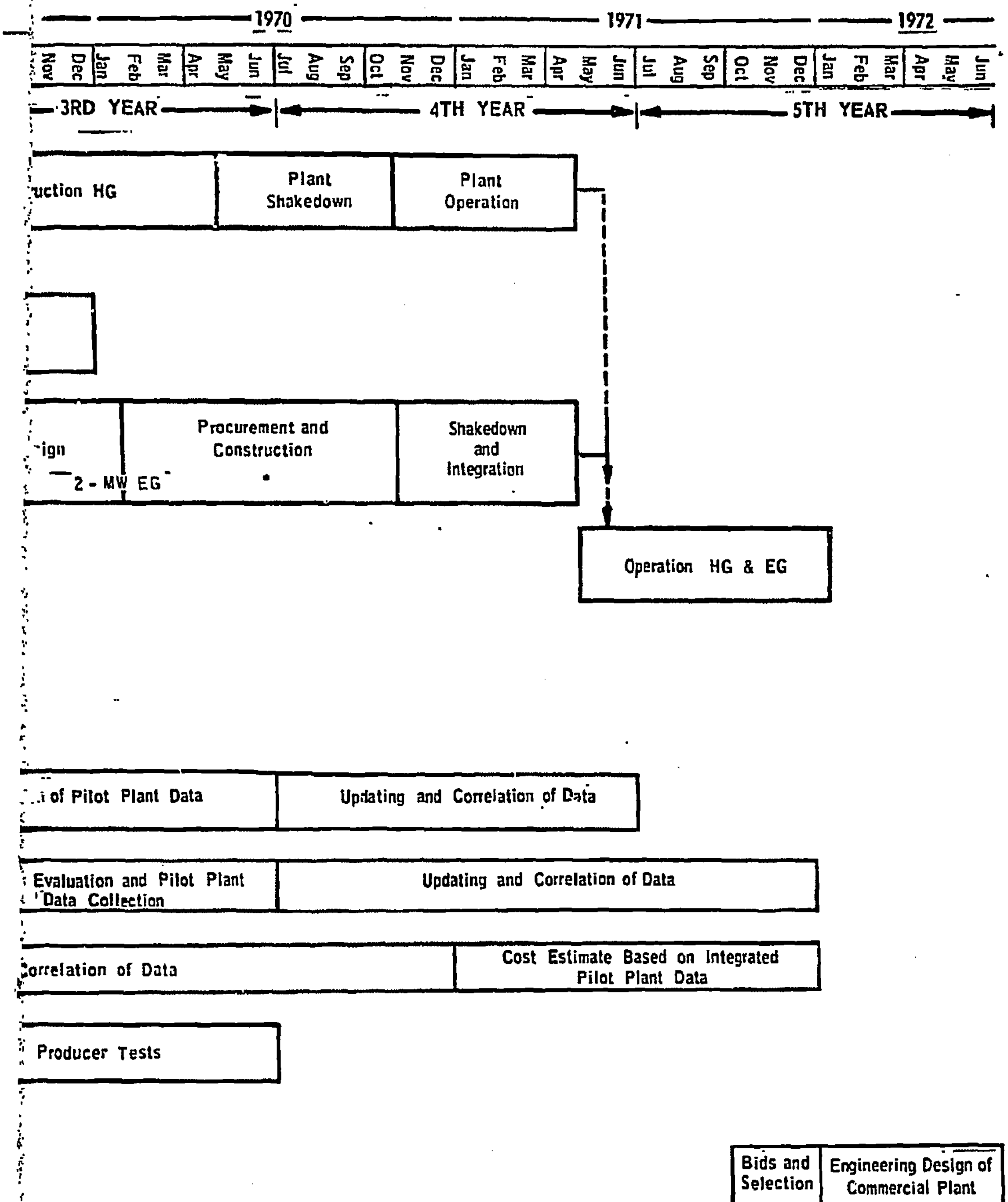

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IGT-MPR--6/69

DEVELOPMENT OF IGT HYDROGASIFICATION PROCESS
Progress Report No. 57 - June 1969

to

Office of Coal Research
Contract No. 14-01-0001-381 (1)

SUMMARY

1. Three 500-psi hydrogasification tests were attempted during the month. A steady-state period was not achieved in any of these runs because of mechanical problems with the feed system.

2. Three electrothermal gasification tests at 1000 psi were conducted during the month, one of which achieved steady-state conditions. Insulation problems occurred during two of the tests; also, we experienced problems with limit switches on the steam superheater. We believe these problems are now corrected.

3. Tests indicate that benzene in the feed gas at the concentrations expected in the process has little if any effect on the catalytic methanation rate.

4. Procon figures for the pilot plant indicate 40% of the engineering and 65% of the purchasing is now complete.

Hydrogasification Test Program

We conducted three hydrogasification test operations this month in the balanced-pressure development unit with a dried North Dakota lignite feed. The objective of these tests, Runs HT-226, HT-227, and HT-228, was to study the reactivity of the lignite to hydrogasification with a mixture of hydrogen and steam at a system pressure of 500 psig. All three of these tests had to be terminated before steady-state operation was reached when trouble was encountered with the feed system. The feed screw jammed in all three runs, which we believe resulted from a plug in the product gas condenser (Run HT-226), and a failure of the mechanical stirrer in the lignite feed tube (Runs HT-227 and HT-228).

In these tests, the lignite was fed at a nominal rate of 52 lb/hr to a 3-1/2-ft fluidized bed, with a hydrogen feed rate of 345 SCF/hr and a steam feed rate of 8.8 lb/hr. The lignite bed temperature was controlled to 1700°F. These tests were to have been compared with tests at similar conditions but at 1000 psig to evaluate the effect of pressure on lignite conversion.

An additional factor affecting operation in the three tests was a partial contamination of the lignite feed with untreated bituminous coal. Although not primarily responsible for shutdown of the tests, the bituminous coal was present in an amount sufficient to cause significant agglomeration of the lignite in the reactor. Petrographic examination of the lignite feed revealed that it was contaminated with bituminous coal. Contamination, estimated at about 5%, apparently occurred in the coal handling and conveying equipment where the lignite picked up isolated pockets of Ireland mine bituminous coal still left in the equipment. To prevent future contaminations of a similar nature, the coal conveying, crushing, and screening equipment will be cleaned more thoroughly between the handling of different coals.

North Dakota lignite feed for the three tests was prepared by fluid-bed air drying at 275°F in the pilot plant coal pretreatment unit. The lignite was dried from an as-received moisture level of 36% to 2% in a 2-stage operation.

Electrothermal Gasification Test Program

Three tests were conducted during the month, two of which were terminated before steady-state conditions were attained (EG-25 and EG-27), and one which was partially successful (EG-26). The tests were conducted at 1000 psig with FMC char from the COED process as feed.

Nominal conditions for the partially successful test are as follows:

Run No.	Char Feed Rate, lb/hr	Steam Feed Rate, lb/hr	Reactor Temp, °F	Reactor Press., psig	Power Input, kW	Overall Resistance, ohm	Steam Conversion, wt %	Char Conversion, wt %
EG-26	135	135	1600	1020	76	0.65	37	30

During the reactor heat-up period of Run EG-25, a short circuit occurred at the reactor top, creating a severe leak in the system. The test was then terminated. The failure, which occurred in the cooling section at the reactor top, was apparently caused by the collection of condensed steam and char in the annulus between the electrode and cooling-section inner wall. A new cooling section was fabricated and installed, but with the addition of a Teflon sheath to fill the annulus in the water-cooled section.

During Run EG-26, the steam superheater cycled off and could not be restarted. The test was continued until a current surge occurred in the system, followed by a decrease in the overall resistance from 1.0 to 0.4 ohm. While depressurizing the unit, a leak developed in the pressure closure at the bottom of the water-cooled section. Inspection of the closure showed the seal ring and closure surfaces had been melted but did not leak until the unit had cooled. Also, the electrode was melted at the point where the feed char enters the reactor; molten metal flowed down the electrode and into the char bed. It appeared as though the feed char had bridged between the electrode and the 6-in. inner reactor tube, creating a low resistance path at that point. A replacement closure was installed, and a high-temperature insulating sleeve (Mullite) was placed over the electrode and extended to below the point where the char enters the reactor. The manufacturer of the superheater attributed the malfunction of the unit to the overheating of a solenoid, which prevented it from cycling during the test. The superheater was repaired following the test.

Run EG-26 was continued for 45 minutes following the superheater failure. Results from data collected indicate a steam conversion of 37% and a char conversion of 30% by weight. The power input was 76 kW, accompanied by an average overall resistance of 0.65 ohm. A temperature gradient of 500°F through the bed was caused by the low steam inlet temperature. The average bed temperature of the top 2.5 ft was 1580°F.

While switching from fluidizing nitrogen to steam during Run EG-27, we again were unable to start the steam superheater. The run was terminated when the inlet steam temperature could not be maintained above the boiling point of water at that pressure. A check of the superheater control circuitry showed that dust particles on several relay contacts had prevented the unit from cycling. The relay contacts were cleaned, and the steam system, tested for several hours, operated satisfactorily. Measures have been taken to prevent the collection of dust in the control cabinet during downtime periods.

Methanation Test Program

Analysis of the experimental data indicates that methane in the feed gas has a negligible effect on the rate of methane formation. The test apparatus was modified so that feed gas could be saturated with benzene. Preliminary results at 575°F and 600 psig indicated that benzene present up to 7% in the feed had very little effect on the rate. More data are being taken to study the effect of benzene at higher concentrations and different operating conditions.

Pilot Plant Construction

The progress of pilot plant engineering and construction is covered in the attached Procon Progress Report No. 11. Based on current work schedules, a May 1, 1970, completion date still appears reasonable.

Progress Investigations

A preliminary process study on a dual carbon-pipeline gas plant is nearing completion. The basis for this study is a product ratio of 5 lb of carbon/lb of pipeline gas, a gas production rate of 500 billion Btu/day, and a plant location in the Dakotas with gas and carbon delivery to Chicago. Results of this preliminary study should be ready next month.

No new inventions were made in the course of this month's work.

Approved ______________________
Frank C. Schora, Associate Director

Signed ______________________
Bernard S. Lee, Manager

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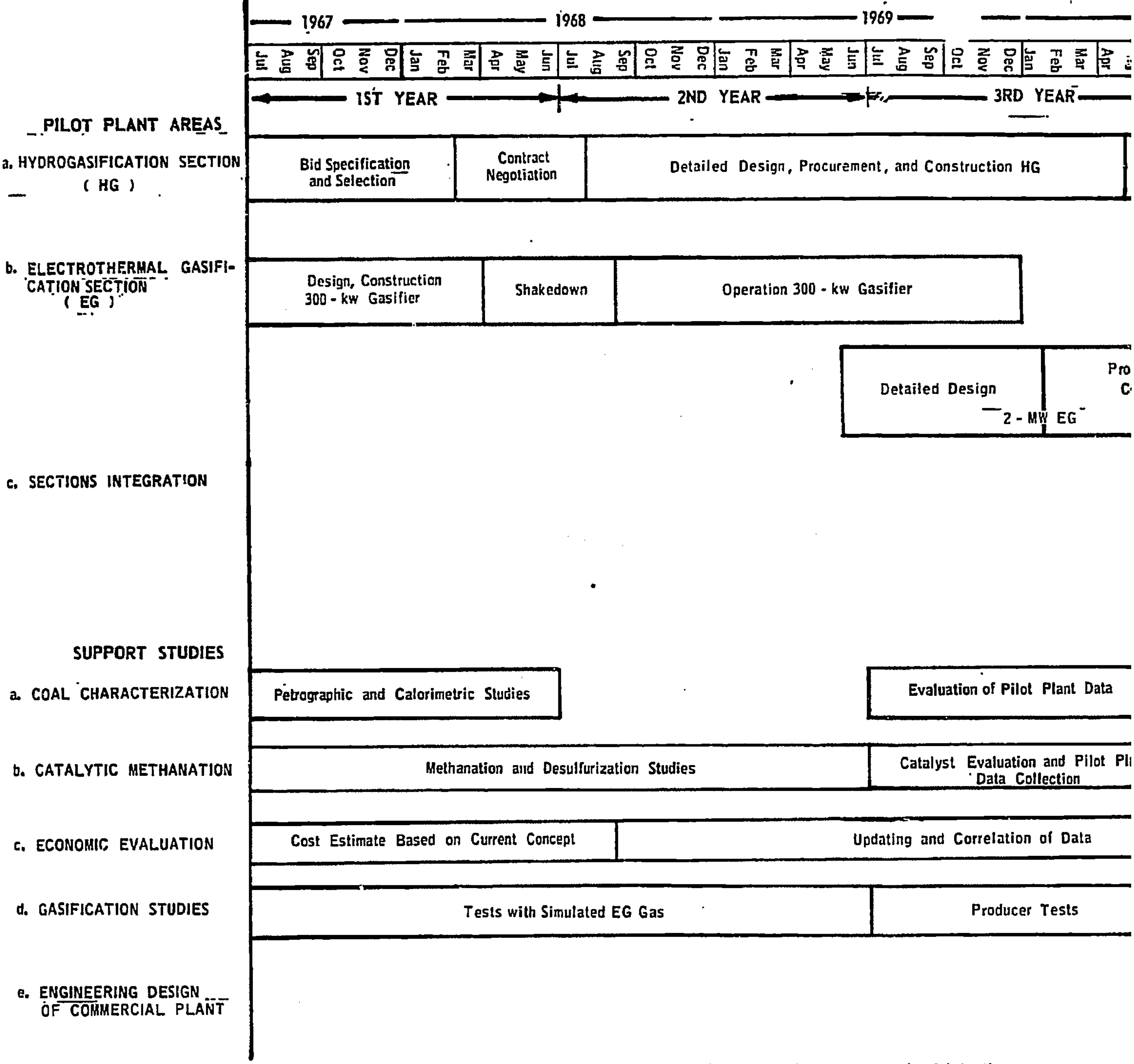
Jack Huebler, Research Director

PILOT PLANT PROGRAM OF IGT HYDRO

OCR CONTRACT No. 14-01-0 381 (1)



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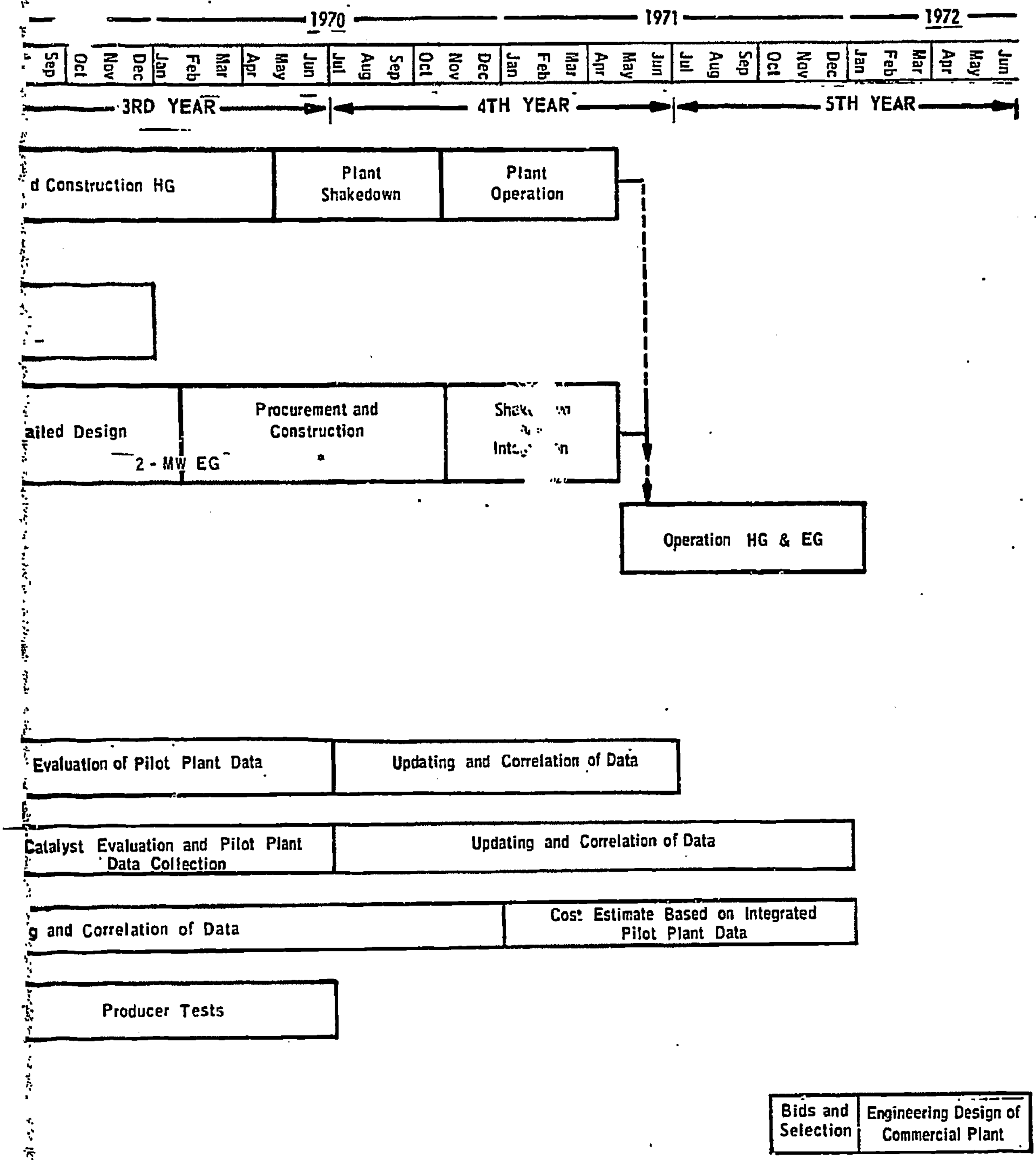

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IGT-MPR--7/69

DEVELOPMENT OF IGT HYDROGASIFICATION PROCESS

Progress Report No. 58 – July 1969

to

Office of Coal Research

Contract No. 14-01-0001-381 (1)

SUMMARY

1. One gasification test was performed during the month to establish the minimum degree of gasification of lignite that can be expected. Preliminary data indicate that 37% of the predried lignite was gasified or converted to liquid products.

2. Two successful steady-state tests were conducted in the electrothermal gasifier test reactor. These tests were conducted at 1000 psig.

3. Procon estimates that 49% of the engineering and 70% of the purchasing for the pilot plant are accomplished.

Hydrogasification Test Program

We conducted one test this month in the balanced-pressure hydrogasification development unit (Run HT-228). In this test, we thermally gasified a dried but otherwise untreated Montana lignite that was free-falling through the hydrogasification reactor. Lignite conversion was entirely due to thermal action as no reactant gas or steam was used. The objective of this test was to investigate the limited conversion of lignite by a mild carbonization at short residence time, and temperatures not exceeding 1500°F.

For this test, the upper half of the reactor tube was preheated to a temperature of 1300°F, and the lower half to 1500°F. The heated length of the reactor was 15.5 ft. These temperatures were also maintained during the test by the reactor furnace heaters. Lignite was fed at a nominal rate of 20 lb/hr to the top of the reactor maintained at a pressure of 1000 psig. A nitrogen sweep gas was fed to the bottom of the reactor at a nominal rate of 250 SCF/hr to keep product gases from diffusing into the residue receiver. Operationally, the run was successful, lasting nearly 5 hr with 4-1/2 hr of steady-state operation. Preliminary data indicate that 37% of the lignite was converted. It is estimated that 13% of the lignite was converted to liquid products, and 24% to gaseous products.

We conducted two separate coal pretreatment operations (Runs FP-139 and FP-140) in the pilot plant coal pretreatment unit. In these tests, we prepared 825 lb of nonagglomerating Sewell seam medium-volatile bituminous coal from Dante, Virginia, for use in hydrogasification tests. The coal was pretreated with air in a fluidized bed at temperatures of 850°-900°F in two stages. The partially treated coal of Run FP-139 was given final treatment in Run FP-140.

The pilot plant was shut down for vacation during the last 2 weeks of the month.

Electrothermal Gasification Test Program

Three tests were conducted in the electrothermal gasifier during the month. Two of the tests, in which FMC char was the feed, were successful; one test with hydrogasified Ireland mine char was terminated before steady-state conditions were attained.

Nominal conditions for the successful tests are as follows:

Run No.	Char Feed Rate, lb/hr	Steam Feed Rate, lb/hr	Reactor Temp, °F	Reactor Press., psig	Power Input, kW	Overall Resistance, ohm	Steam Conversion, wt %	Char Conversion, wt %
EG-28	[illegible]	155	[illegible]	1024	61	0.54	66	[illegible]
EG-29	[illegible]	145	[illegible]	1024	71	0.94	68	[illegible]

Steady-state operation was maintained for 1-1/2 hr during Run EG-28. The test was terminated when indications of plugging in the quench tower drain line were observed. Inoperation of the drain following the run showed that the liquid level sight gage had plugged rather than the drain line, causing erroneous level indications.

Data from Run EG-28 indicated nominal char gasification and steam decomposition of 47 and 66% by weight, respectively. The average power input during steady-state operation was 61 kW, accompanied by an overall resistance of 0.54 ohm.

At the start of the heat-up period of Run EG-29, the overall resistance of the system was 20 ohms, about 3 times that observed in previous tests. The bed height was increased to lower the resistance during this period. As the bed temperature approached 900°F, the resistance decreased to 3.0 ohms and continued to 0.94 ohm during the 1 hr 20 min of steady-state operation. Initial data from the run indicate a char gasification of 37% and steam decomposition of 68% by weight. The average power input was 71 kW, and the overall resistance was 0.94 ohm.

Run EG-30 was the first attempt to gasify hydrogasified Ireland mine char at 1000 psig. During the heat-up period we again experienced the high-resistance (20 ohms) condition as in the previous test. It was necessary to raise the bed height again to lower the resistance during heat-up. Forty minutes after the steam flow into the reactor was started, the resistance rapidly decreased to approximately 0.2 ohm, indicating a short circuit, and the run was terminated before steady-state conditions were attained.

Inspection of the reactor following the run revealed a plug of char in the top 2 ft of the 6-in. reactor tube, which created a low-resistance path from the electrode to the reactor wall. Several holes were burned in the reactor wall at a point just below the mullite insulating sleeve of the electrode, and a portion of the electrode melted. When the reactor tube was removed from the pressure shell for further inspection, the inner wall was found to be coated with a semiconductor material of either ash or metallic oxide. The coating accummulated during testing and resulted in the high-resistance conditions that occurred. Several sections of the tube will be sent to an outside laboratory for metallurgical analyses of the coating. A replacement 6-in. tube of 316 SS with a 3-ft expanded section of mullite (7-3/4-in. ID) at the reactor top is being fabricated. The increased cross-sectional area of the mullite section will decrease the superficial velocity of make gas through the reactor, minimize the carry-over of char into the make-gas system, and prevent the occurrence of short circuits at the reactor top by its electrical insulating characteristics.

Support Studies

We are investigating the loss of char from the electrogasification fluid bed by entrainment. Characterization of feed and residue by fractional air elutriation is planned.

A program of investigation of the hydrogasification reactivity of coal macerals is being developed. The IGT high-pressure thermobalance will be used in this work. Assistance of coal petrographers at Pennsylvania State University in obtaining appropriate samples has been solicited.

Methanation Test Program

The effect of traces of benzene present in the feed gas on the rate of methanation was studied at 300 psig and 575°F. Benzene was added to the feed at concentrations up to 6000 parts per million. For a set of data, a run was made without benzene, and the same run was repeated with benzene in the feed. Most of the benzene passed unreacted through the reactor. No noticeable change in the rate of methanation was observed due to the presence of benzene during a particular set. However, the subsequent set of runs with the same catalyst and at the same conditions indicated a slight decrease in the rate. The cause for the deactivation of the catalyst, possibly due to exposure to benzene, is being investigated further.

Process Evaluation Work

Because of the rather large air-compressor requirements and the large CO_2 rejection indicated in our study on the deposition of fine carbon for dual pipelining of a gas-carbon mixture, we are looking at alternative schemes for the conversion of char to ash-free fine carbon.

Pilot Plant Engineering and Construction

Procon's progress on the engineering and construction of the pilot plant is covered in its Progress Report No. 12.

Because of problems with the thickness of the hydrogasifier reactor shell and insulation on the second-stage hydrogasifier and the fluidized-bed heat exchanger, we have changed bed-level sensing from radiation-type systems to differential pressure measurement instruments. Provisions will be made to purge the pressure taps and to keep the system separate from other sensing systems to avoid erroneous level readings.

No new inventions were made in the course of the month's work.

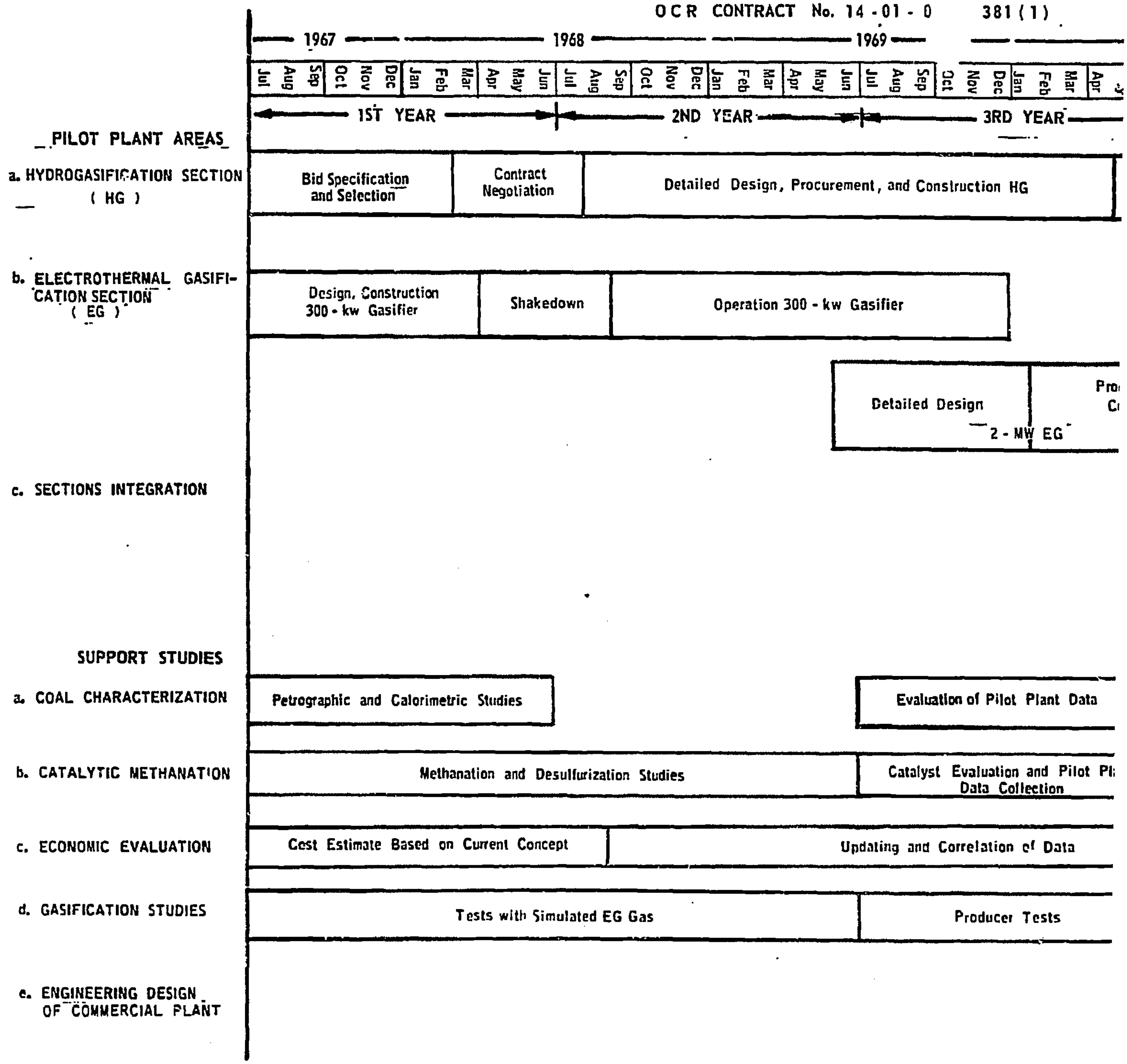
Approved

Approved: ______________________
F. C. Schora, Associate Director

Signed: ______________________
B. S. [illegible]

PILOT PLANT PROGRAM OF IGT HYDRO

OCR CONTRACT No. 14-01-0 381(1)



* Reactor must be purchased during design period because of time required for fabrication.

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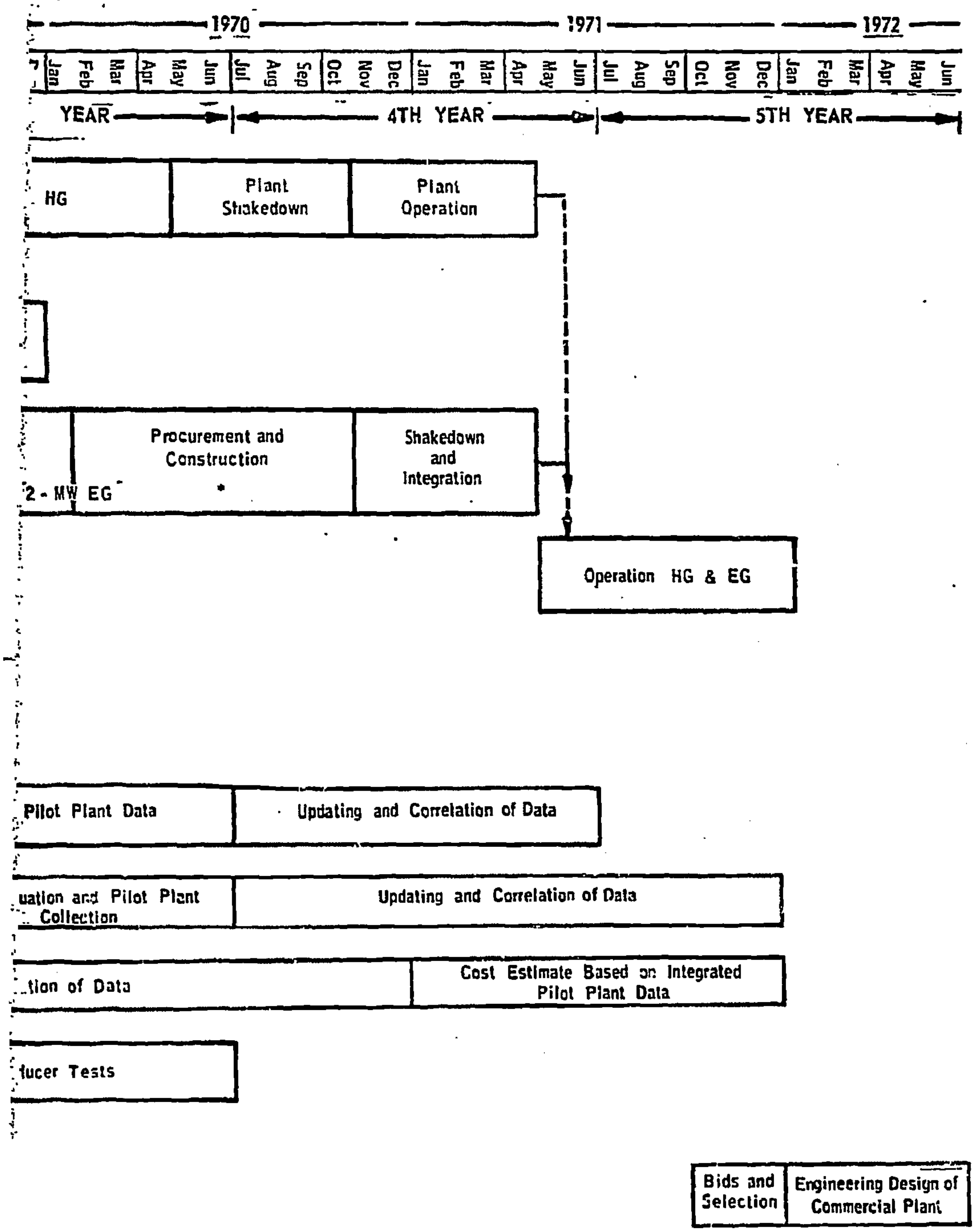

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IGT-MPR--8/69

DEVELOPMENT OF IGT HYDROGASIFICATION PROCESS
Progress Report No. 59 – August 1969

to

Office of Coal Research
Contract No. 14-01-0001-381 (1)

SUMMARY

1. Two hydrogasification tests were conducted during the month using Sewell seam medium-volatile-content bituminous coal. Both tests were successful.

2. Two tests were conducted in the electrothermal test unit. One run was partially successful with a 30-minute steady-state period.

3. Detailed engineering for the pilot plant is 55% complete. Purchase of all major equipment has been made, and total purchasing is estimated at 74% complete. The field work phase has been started.

Hydrogasification Test Program

We conducted two hydrogasification tests this month in the balanced-pressure development unit (Runs HT-230 and HT-231). In these tests we gasified a medium-volatile-content bituminous coal from the Sewell seam, Dante, Virginia, with a hydrogen-steam feed gas. The objective of these tests was to study the hydrogasification performance of a typical medium-volatile-content bituminous coal. In earlier tests in the development unit hydrogasification test program, we had studied the performance of a Sewell seam bituminous coal from the Lockgelly mine in West Virginia. However, petrographic studies of this coal showed it to be similar to a low-volatile-content bituminous coal and, therefore, not representative of a typical medium-volatile-content bituminous coal.

In the two tests conducted this month we hydrogasified the lightly pretreated medium-volatile-content bituminous coal in a 3.5-foot fluidized bed at a system pressure of 1000 psig. Temperatures in the reactor tube were controlled to 1300°F in the upper free-fall section and to 1700°F in the coal bed. In Run HT-230 the hydrogen-to-coal feed ratio was a nominal 30% of the stoichiometric ratio; the steam concentration in the feed gas was a nominal 35%. In Run HT-231, flow conditions were set so that the hydrogen-to-coal feed ratio was a nominal 20% of the stoichiometric ratio, and the steam concentration in the feed gas was a nominal 50%. Both tests were successful, each lasting from 4-1/4 to 4-1/2 hours. In Run HT-230, with 2 hours of steady-state operation, we converted 39% of the coal, based on the weight of the residue recovered. In Run HT-231, with 3 hours of steady-state operation, the coal conversion was about 36%.

A special heat input test was conducted in the hydrogasification development unit to measure the electrical heat input to the reactor heaters necessary to maintain the reactor tube at typical hydrogasification temperatures of 1300°-1700°F. The reactor was pressurized to 1000 psig for this test in which there was no coal or gas fed. Wattmeter readings measuring the electric power input to the reactor furnaces were taken over a 5-hour period as the reactor was controlled to a nearly constant temperature profile. Data from this test will establish the heat loss level from the reactor shell and will be useful for approximate heat balance calculations on hydrogasification runs.

Electrothermal Gasification Test Program

Two tests were conducted in the electrothermal gasifier during the month. Hydrogasified Ireland mine coal was the feed in both runs. One test, EG-31, was partially successful, having a 30-minute steady-state period, but Run EG-32 was terminated before steady-state conditions were attained.

During Run EG-31, erroneous bed height indications allowed an excessively high char bed to accumulate, causing abnormal solids carry-over into the quench system and subsequent plugging of the quench system drain line. The test was terminated when we were unable to discharge the cooling water and undecomposed steam from the system. Nominal conditions of the run are as follows:

Run No.	Char Feed Rate, lb/hr	Steam Feed Rate, lb/hr	Reactor Temp., °F	Reactor Press., psig	Power Input, kW	Overall Resistance, ohm	Steam Conversion, wt %	Char Conversion, wt %
EG-31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	55	40

During the preparation of the unit for the next test the quench water supply valve was accidentally left open over a weekend and flooded the unit vessels. Several days were spent attempting to dry the reactor insulation with a hot nitrogen purge.

As steady-state conditions were being approached during Run EG-32, the char feed screw would not deliver solids to the reactor. We believe residual water from the reactor insulation had condensed in the hopper bottom during the heat-up period and prevented the flow of solids to the screw. To overcome this problem we again purged the reactor with hot nitrogen and installed a nitrogen purge line at the hopper to prevent the condensing of water in that vessel during subsequent testing.

Pilot Plant Engineering and Construction

During the month we have placed major emphasis on specification and selection of control valves and controllers. Certified prints of the control valves are necessary to complete the isometric drawings for piping. It now appears that process piping is critical to plant completion. Engineering is estimated at 55% complete and purchasing at 74% complete. The material receipt and construction phase have just started.

Details of this work are covered in the accompanying Procon Progress Report No. 13.

Process Investigations

Work is continuing on the concept of producing a finely divided carbon to transport with synthetic pipeline gas. During the month investigations were centered on minimizing air compression requirements and on reducing the amount of carbon lost as carbon dioxide. We are attempting to reduce carbon lost as CO_2 by recycling the CO_2 to the gasification system. We are also investigating the recovery of fine carbon from a gas-solids mixture at the delivery end of a gas-solids pipeline.

Because of the need to hold plant water requirements to a minimum, next month we plan to start a study of maximizing the use of air cooling in the plant to reduce cooling water requirements.

During the month no new inventions were made in the course of the work.

Approved ______________ Signed ______________
F. C. Schora, Associate Director B. S. Lee, Manager

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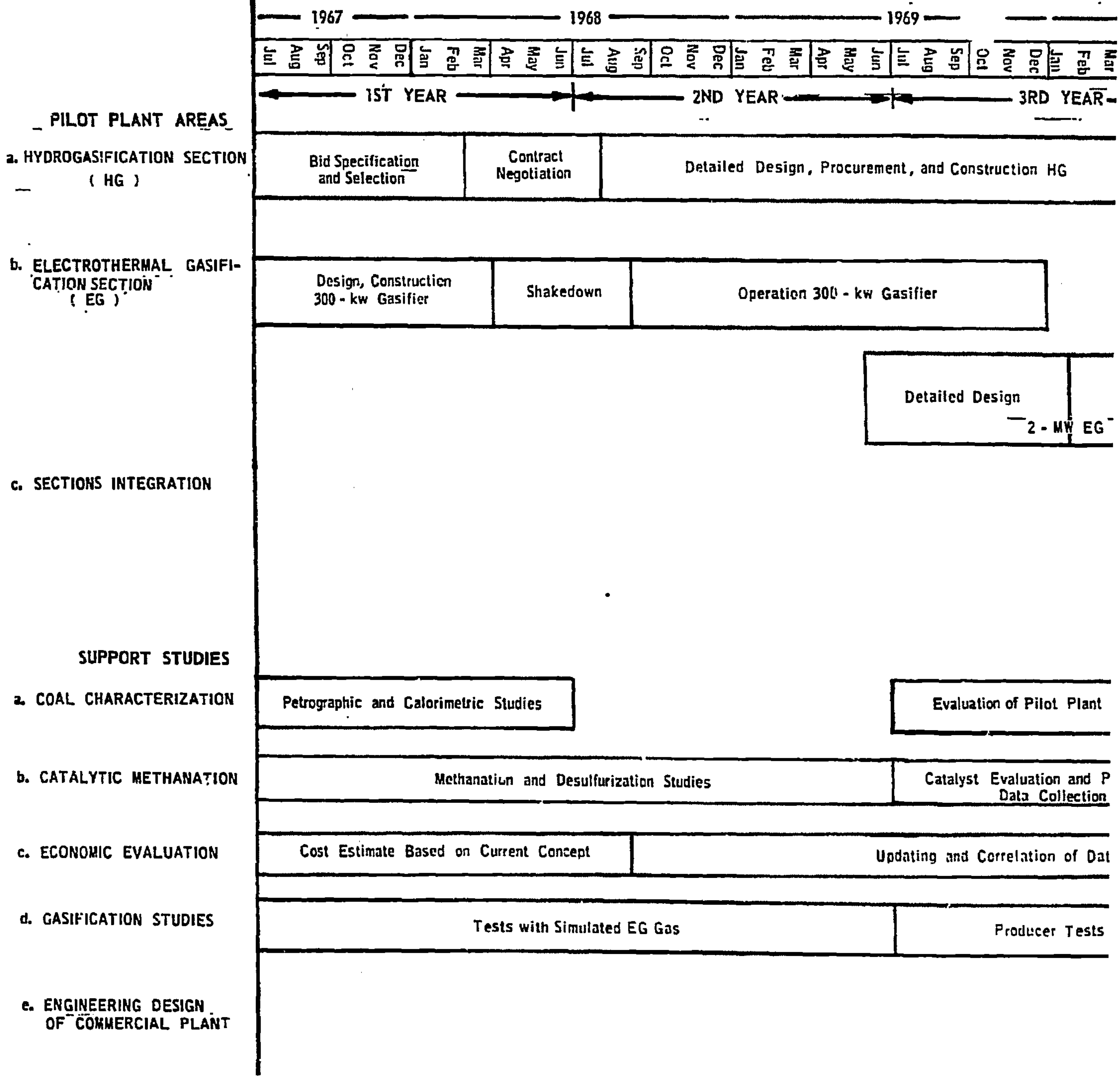
Jack Huebler, Research Director

PILOT PLANT PROGRAM OF IGT HY

OCR CONTRACT No. 14-01-0 381(1)



* Reactor must be purchased during design period because of time required for fabrication.

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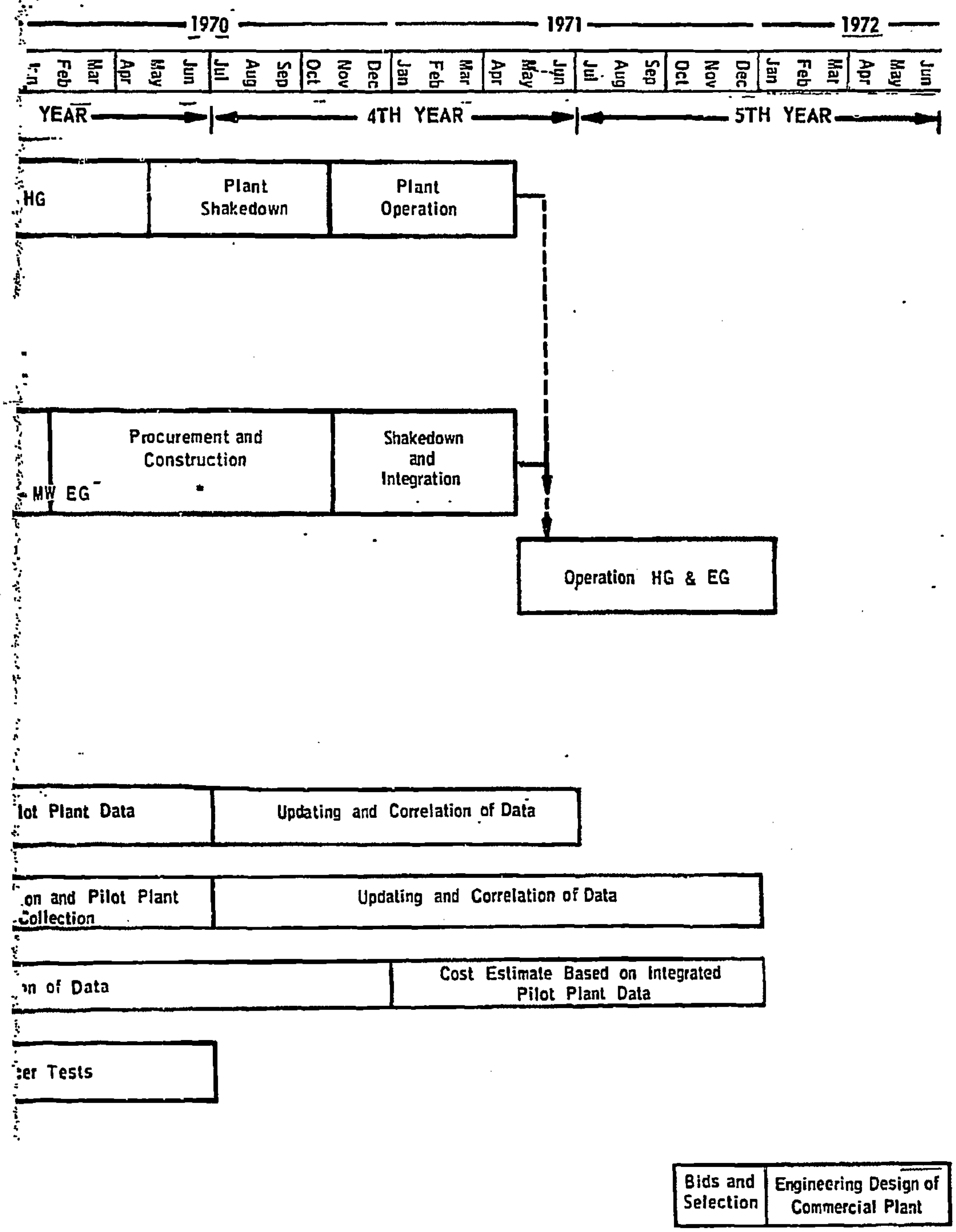

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I GT-MPR--9/69

DEVELOPMENT OF IGT HYDROGASIFICATION PROCESS

Progress Report No. 60 — September 1969

to

Office of Coal Research

Contract No. 14-01-0001-381 (1)

SUMMARY

1. Three hydrogasification tests were conducted.
2. Four runs were conducted in the electrothermal reactor test unit with one run having a steady-state period of over 2 hours.
3. A check on methanation catalyst deactivation indicates that the initial partial loss of activity levels off after several days to nearly constant activity.
4. Progress in the construction of the pilot plant continues satisfactorily, with the target date for mechanical completion being June 1, 1970.

Hydrogasification Test Program

We conducted three hydrogasification tests this month in the balanced-pressure development unit (Runs HT-232, HT-233, and HT-EG-5). In the first two of these tests we gasified a lightly pretreated medium-volatile-content bituminous coal from the Sewell seam with a hydrogen-steam feed gas. This Sewell seam coal has been properly identified as being from the Sewell No. 1 mine in Nicholas County, West Virginia. In the July and August 1969 Progress Reports we referred to this coal as being from Dante, Virginia, which is the location of the Clinchfield Coal Company, the supplier of this coal. In the third test, Run HT-EG-5, we gasified a lightly pretreated Pittsburgh seam high-volatile-content bituminous coal from the Ireland mine for the purpose of producing a residue feed for tests in the electrothermal gasifier.

The runs with the Sewell seam coal are a part of the series of tests conducted to study the hydrogasification performance of a typical medium-volatile-content bituminous coal. Run HT-232, the third test of the series, had to be terminated before steady-state operation was established when a plug developed in the product-gas reactor offtake line restricting the outflow of product gases. The plug was formed by the condensation of tars in the line following a failure of a segment of the product line heater.

Run HT-233 was conducted at conditions similar to those of Run HT-232. The coal was reacted in a 3.5-foot fluidized bed with hydrogen and steam. Feed rates were adjusted so that the hydrogen-to-coal ratio was 25% of stoichiometric, and the steam concentration in the feed gas was 50 mole percent. The run lasted 4-1/4 hours with 2-3/4 hours of this at steady-state conditions. Based on the weight of the residue recovered, 33% of the coal was converted.

The production of partially hydrogasified bituminous coal residue for use in the pilot plant electrothermal gasifier was the objective of Run HT-EG-5. This run was conducted at standard hydrogasification conditions to get a coal conversion of 35%. Over 150 pounds of Ireland mine coal residue was produced during this 5-1/2 hour run, which was terminated when the feed ran out.

Electrothermal Gasification Test Program

Four runs were conducted in the electrothermal gasifier during the month. We used hydrogasified char (high-volatile bituminous) as the feed in the four tests. One of the tests was successful, while two were partially successful but were terminated because of operational problems and one was terminated because of an equipment failure.

During the reactor heat-up period of Run EG-33, the steam superheater cycled off and could not be restarted, causing us to terminate the test. The probable cause of the failure was the overheating of the contacts of the control circuit. To reduce the ambient temperature behind the protective barricade, the fluidizing nitrogen preheat furnace was moved to an adjacent barricaded area and a vortex cooling tube was placed in the superheater control cabinet.

Run EG-34 was the first test at 1000 psig of a high-volatile-content bituminous hydrogasified char in which an extended steady-state operating period was maintained (over 2 hours). Preliminary data indicate a char conversion and steam decomposition of 30 and 51%. An average bed temperature of 1845°F was maintained by 83 kW of power input with an overall resistance of 1.57 ohms. The char feed rate was 118 lb/hr; the steam feed rate was 125 lb/hr.

As steady-state conditions were approached in Run EG-35, erratic bed-level control and excessive solids carry-over into the quench system could not be corrected. The run was terminated when the overall resistance increased to over 2 ohms and we were unable to maintain the bed temperature above 1800°F at a power input of 120 kW, the highest power level attained thus far.

Run EG-36 was conducted at the same conditions as EG-35 and was terminated due to the same problems as encountered previously: erratic bed height control, high resistance, and solids carry-over into the off-gas metering and vent system. Following the test, we found that the steam orifice pressure differential transmitter was malfunctioning. Thus, during the previous two tests the steam flow rate was probably much higher than indicated, the excess steam flow contributing to the problems of erratic bed height and solids carry-over due to the increased steam superficial velocity through the reactor and accounting for the water in the off-gas piping by exceeding the cooling capacity of the quench system. The steam orifice pressure differential transmitter has since been repaired and recalibrated, and a larger capacity water pump has been installed in the quench system for further testing.

Methanation Test Program

A continuous run was made to check the rate of deactivation of the catalyst being used in present catalyst studies (Harshaw Ni 0104-T). The feed gas was composed of 10 mole percent CO and 90 mole percent H_2. The reactor was at a temperature of 575°F and at a pressure of 598 psig.

At a calculated space velocity of 80,000-98,000 SCF/hr-sq ft catalyst, the activity of the catalyst decreased 12% after 16 hours. The activity remained essentially constant until the end of the experiment (5-1/2 days). Catalyst volume was based on catalyst weight divided by bulk density.

Pilot Plant Construction

Details of the engineering and construction of the pilot plant are covered in Procon's Progress Report No. 14 which is enclosed. Procon now estimates engineering to be 60% complete and purchasing 76% complete. We have been reviewing Procon's work and have had several meetings with vendors of packaged systems to ensure compatibility of control systems.

Procon has completed the reestimation of the guaranteed maximum price and has submitted its proposed figure for approval.

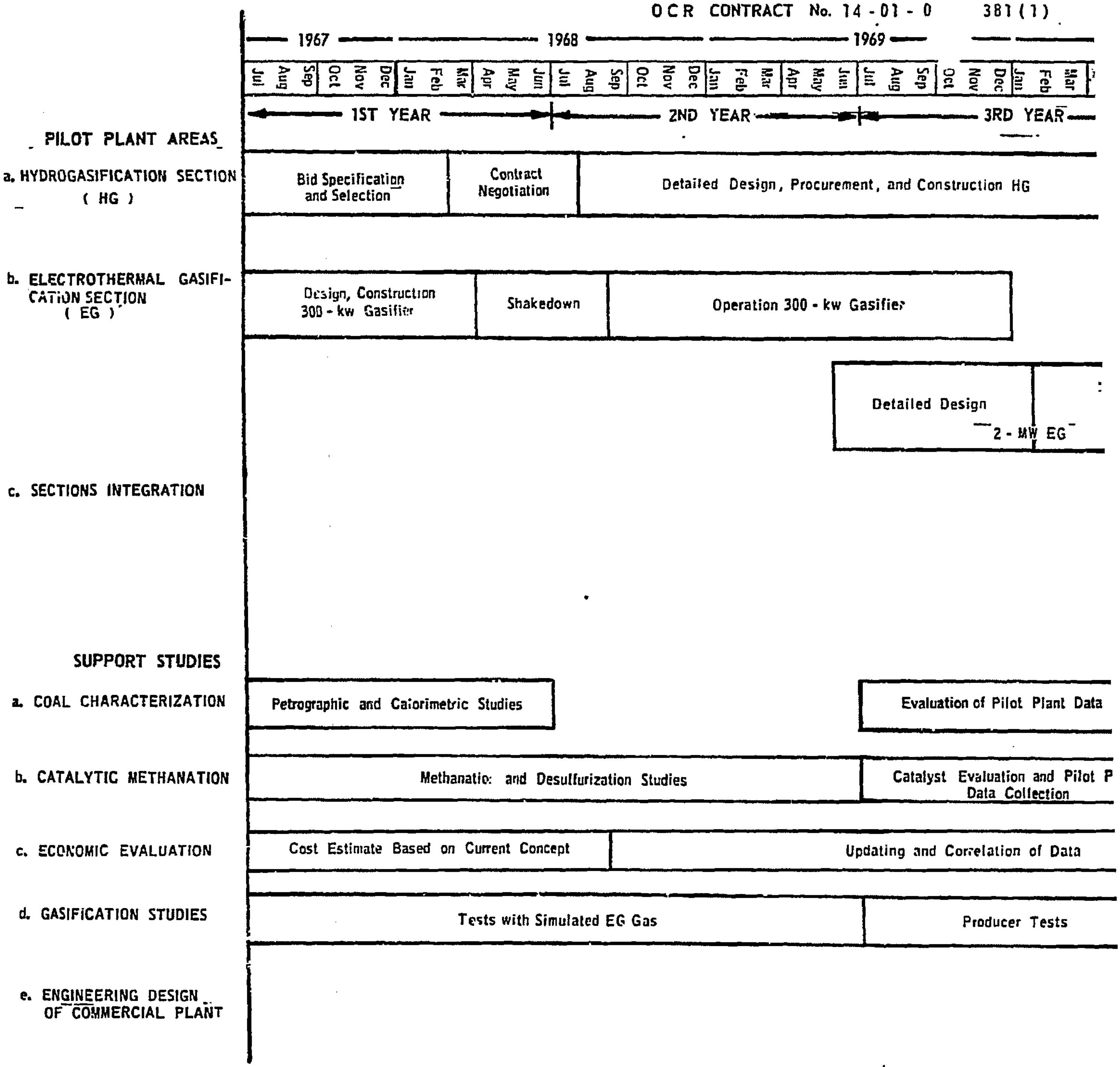
During the month no new inventions were made in the course of the work.

Approved ______________
F. C. Schora, Director

Signed ______________
B. S. Lee, Manager

PILOT PLANT PROGRAM OF IGT HYD

OCR CONTRACT No. 14-01-0 381(1)



* Reactor must be purchased during design period because of time required for fabrication.

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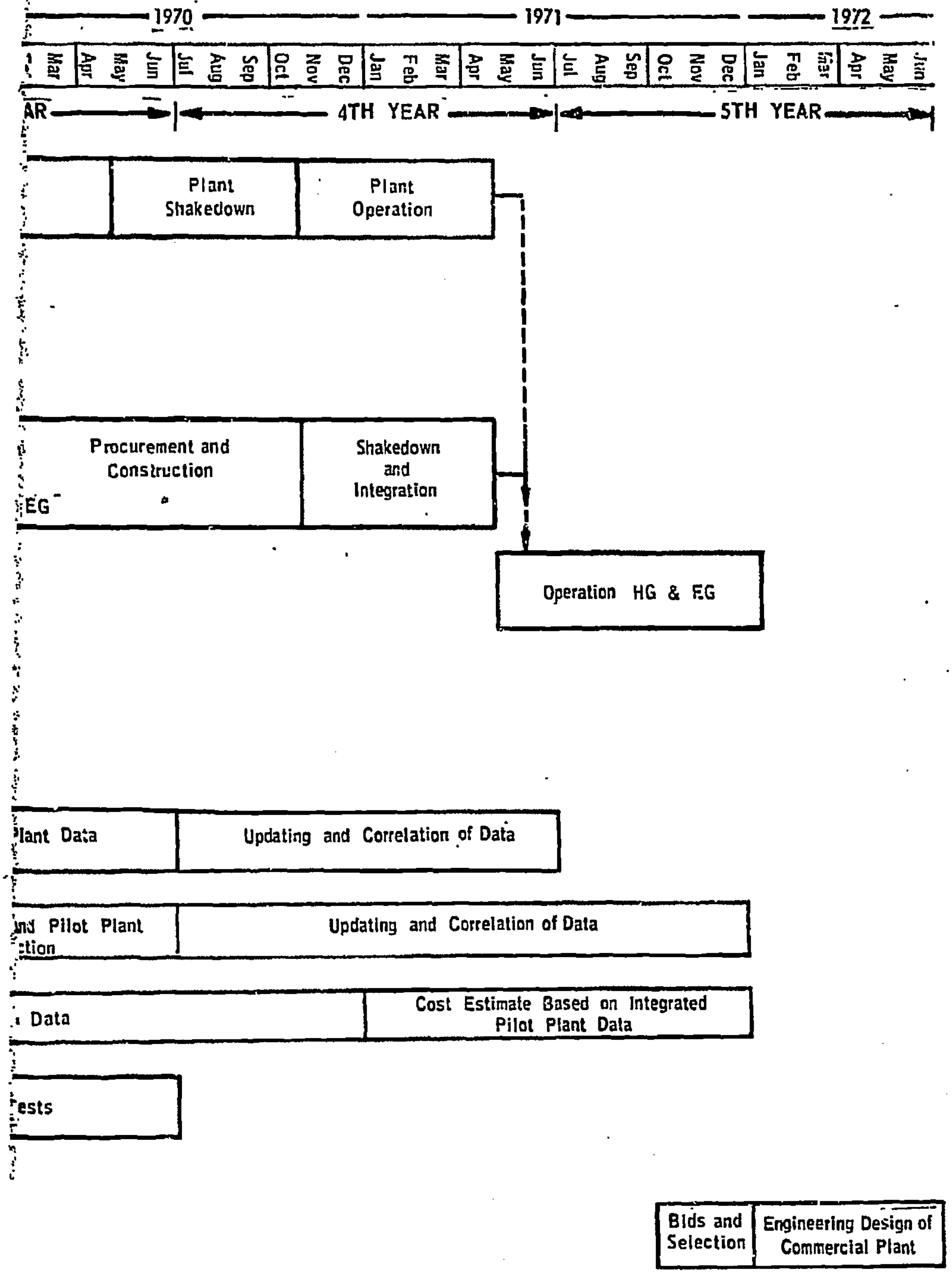

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PROGRESS REPORT NO. 14

COAL HYDROGASIFICATION PILOT PLANT

FOR

INSTITUTE OF GAS TECHNOLOGY

CHICAGO, ILLINOIS

W-1784

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DATE:	September 15, 1969
PROCON PROJECT MANAGER:	T. A. Taylor

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Mr. G. E. Davis	)	
Mr. W. J. Taylor	)	
Mr. G. A. Speir	)	
Mr. W. H. Grosse		1
Mr. J. Kozacky		1
Mr. R. P. Cousins		1
Mr. C. J. Towle		1
Mr. T. A. Taylor		1
Field		1

W-1784

Coal Hydrogasification Pilot Plant

I. SUMMARY

Engineering	60%
Purchasing	76%
Material Receipt	3%
Construction	3%

A. ESTABLISHMENT OF THE GUARANTEED MAXIMUM PRICE

The cost of the project has been re-estimated based on the latest specifications and current commitments. A Guaranteed Maximum Price has been given to IGT and is presently under review.

B. ENGINEERING

The Piping and Instrument Diagrams have been reviewed and revised again and can now be considered as finalized "for construction" and, therefore, will be used in checking the detailed construction drawings. Piping plans and details are 45 percent complete. The reactor structure detail drawings are 80 percent complete. All foundations are complete except for the building and some of the packaged plant foundations. Instrumentation and electrical specifications are complete and detailed instrument piping drawings will begin upon selection of field instrument supplier.

Total project detailed design and drafting is 55 percent complete.

C. PROCUREMENT

The Ingersol-Rand strike is over. It has delayed delivery of three compressors (as shown on the Bar Chart Schedule in Section II), but

C. PROCUREMENT (continued)

these delays will not affect the project completion date.

We have been notified by the manufacturer of the steam and hydrogen superheaters that they have obtained the required Incoloy 800 tubing and that the originally scheduled delivery date will be met. The nickel strike is affecting our purchasing of some Incoloy 800 pipe and valves. We are, therefore, buying stainless steel material to be used as a substitute in case the strike continues into 1970.

Instrumentation proposals are presently being evaluated with IGT and critical equipment is being purchased.

Receipt of material has begun and will increase through September and October.

D. CONSTRUCTION

Major field activity has begun and the underground piping and electrical work is underway. The erection of the control house will begin shortly.

II. SCHEDULE AND S-CURVE REPORT

The project PDM schedule was updated and run on the computer. The result confirms the project completion date of June 1, 1970. The details of this schedule are presently being discussed with IGT. This Progress Report includes an updated Bar Chart Schedule and S-Curve Report.

	% COMPLETE	DATE WEEKS	0	4	8	12	16	20
P & I DIAGRAMS								
PLOT PLAN		E						
PIPING PLAN		E						
PUMPS		E						
		P						
		C						
COMPRESSORS		E						
		P						
		C						
EXCHANGERS		E						
		P						
		C						
VESSELS		E						
		P						
		C						
FOUNDATIONS		E						
		P						
		C						
HEATERS		E						
		P						
		C						
STRUCTURAL STEEL		E						
		P						
		C						
BUILDINGS		E						
		P						
		C						
PIPE RACKS		E						
		P						
		C						
INSTRUMENTS		E						
		P						
		C						
ELECTRICAL		E						
		P						
		C						
PIPING		E						
		P						
		C						

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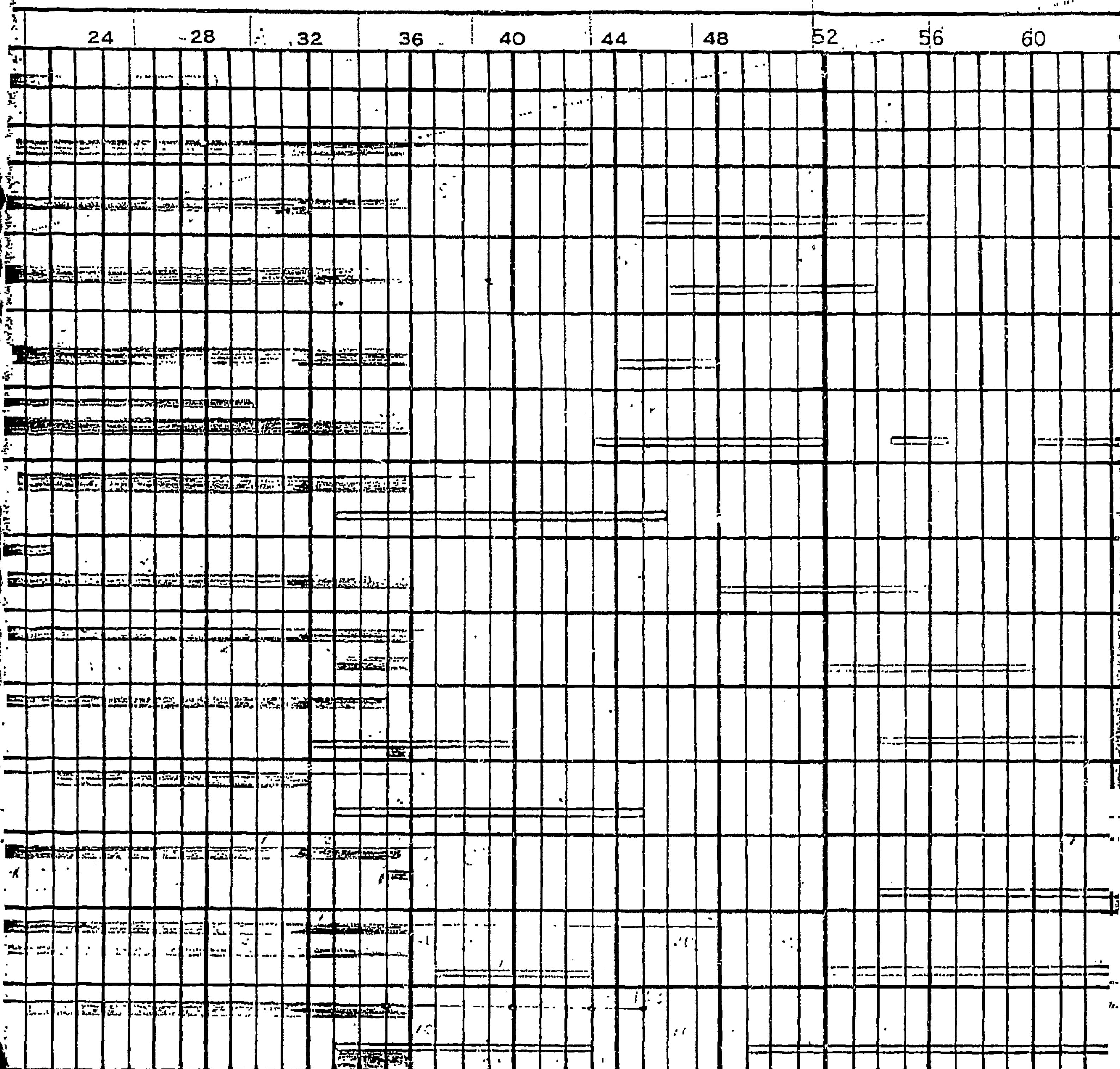
SCHEDULE AND STATUS OF ENGINEERING, PROCUREMENT AND CONSTRUCT



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LEGEND

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P–PROCUREMENT
C–FIELD CONSTRUCTIO
— SCHEDULE
▬ PERFORMANCE
R–REQ. ISSUED
O–ORDER PLACED
C–CERTIFIED PRINTS
D–PROMISED DELIVE

PROCON *Incor*

CHICAGO, U. S.

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LEGEND

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C–FIELD CONSTRUCTION
— SCHEDULE
▬ PERFORMANCE
R–REQ. ISSUED
O–ORDER PLACED
C–CERTIFIED PRINTS REC'D.
D–PROMISED DELIVERY

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PROCON *Incorporated*

CHICAGO, U. S. A.

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	% COMPLETE	DATE WEEKS	0	4	8	12	16
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TESTING & START UP		E					
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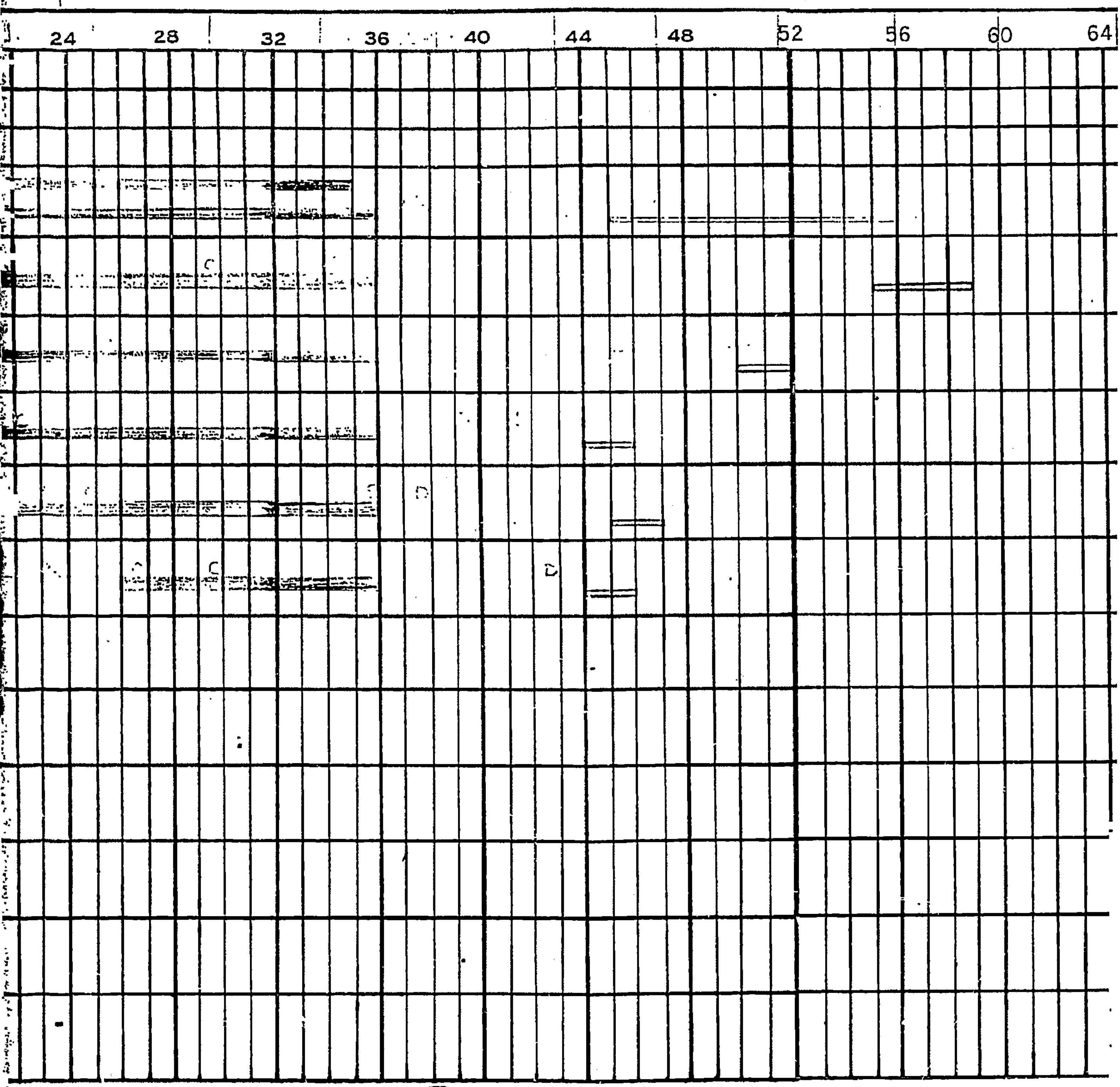
SCHEDULE AND STATUS OF ENGINEERING, PROCUREMENT AND CONSTRUCTIO



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R–REQ. ISSUED
O–ORDER PLACED
C–CERTIFIED PRINTS REC
D–PROMISED DELIVERY

PROCON Incorporated

CHICAGO. U. S. A.

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C–CERTIFIED PRINTS REC'D.
D–PROMISED DELIVERY

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PROCON *Incorporated*

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INSTITUTE OF GAS T

SCHEDULED ———

ACTUAL - - - - - -

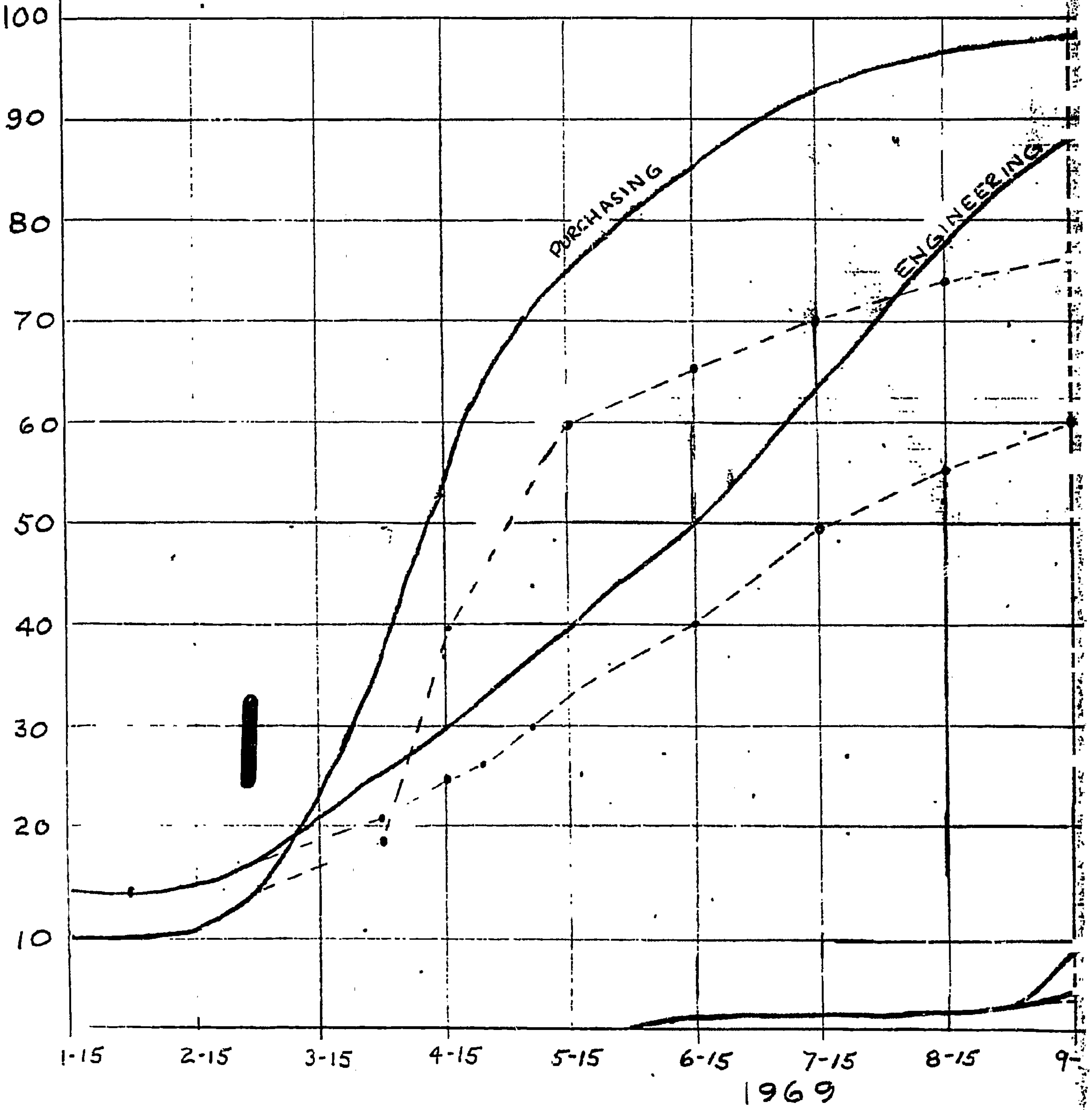
REPORT NO. — 14

DATE — 9-15-69

PERCENT COMPLETE:

ENGINEERING — 6C

PURCHASING — 76



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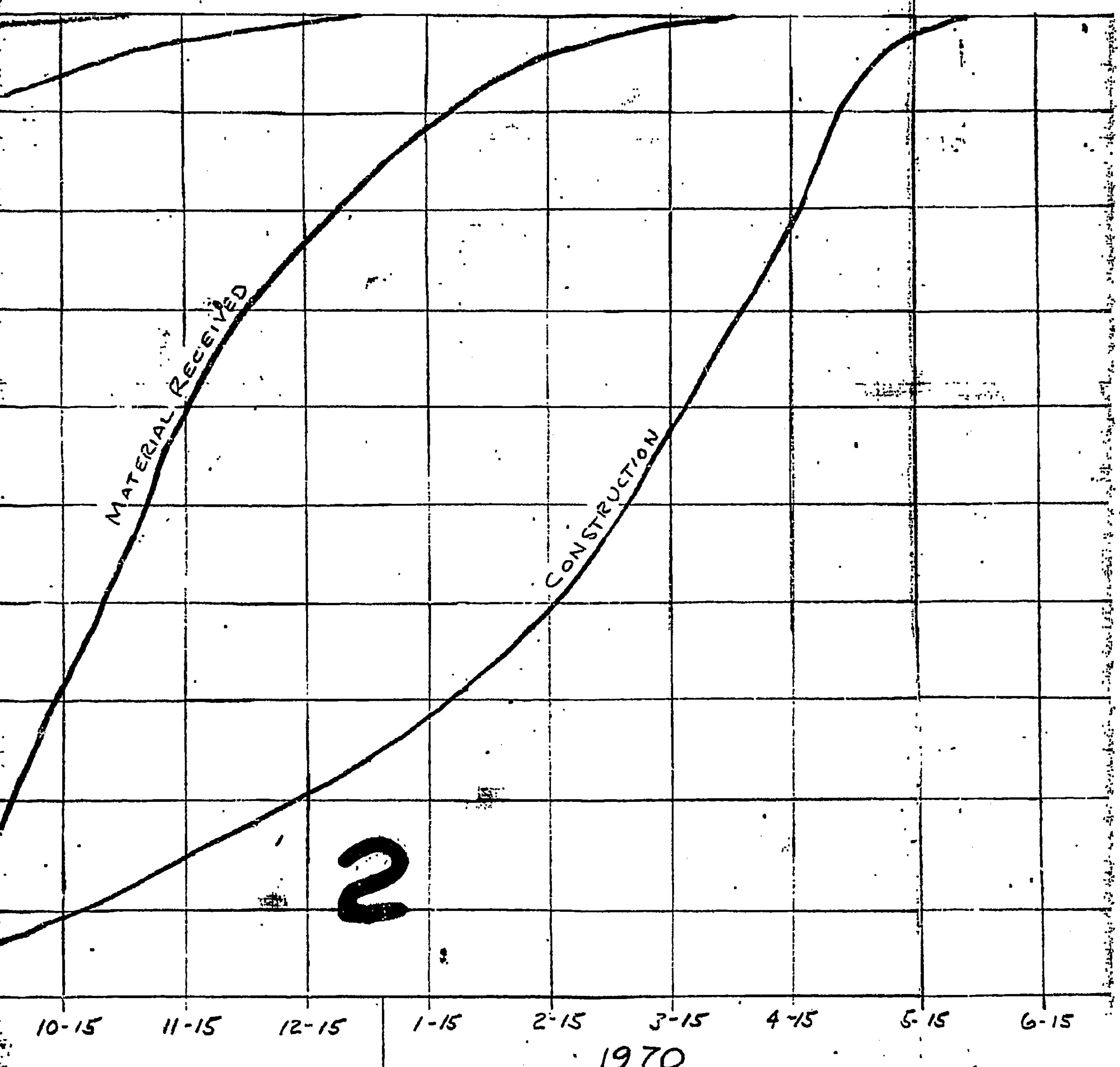
REV 0 - 3-15-69
REV. 1 - 4-15-69
REV. 2 - 7-15-69
REV. 3 - 8-15-69

MATERIAL RECEIVED — 3
CONSTRUCTION — 3



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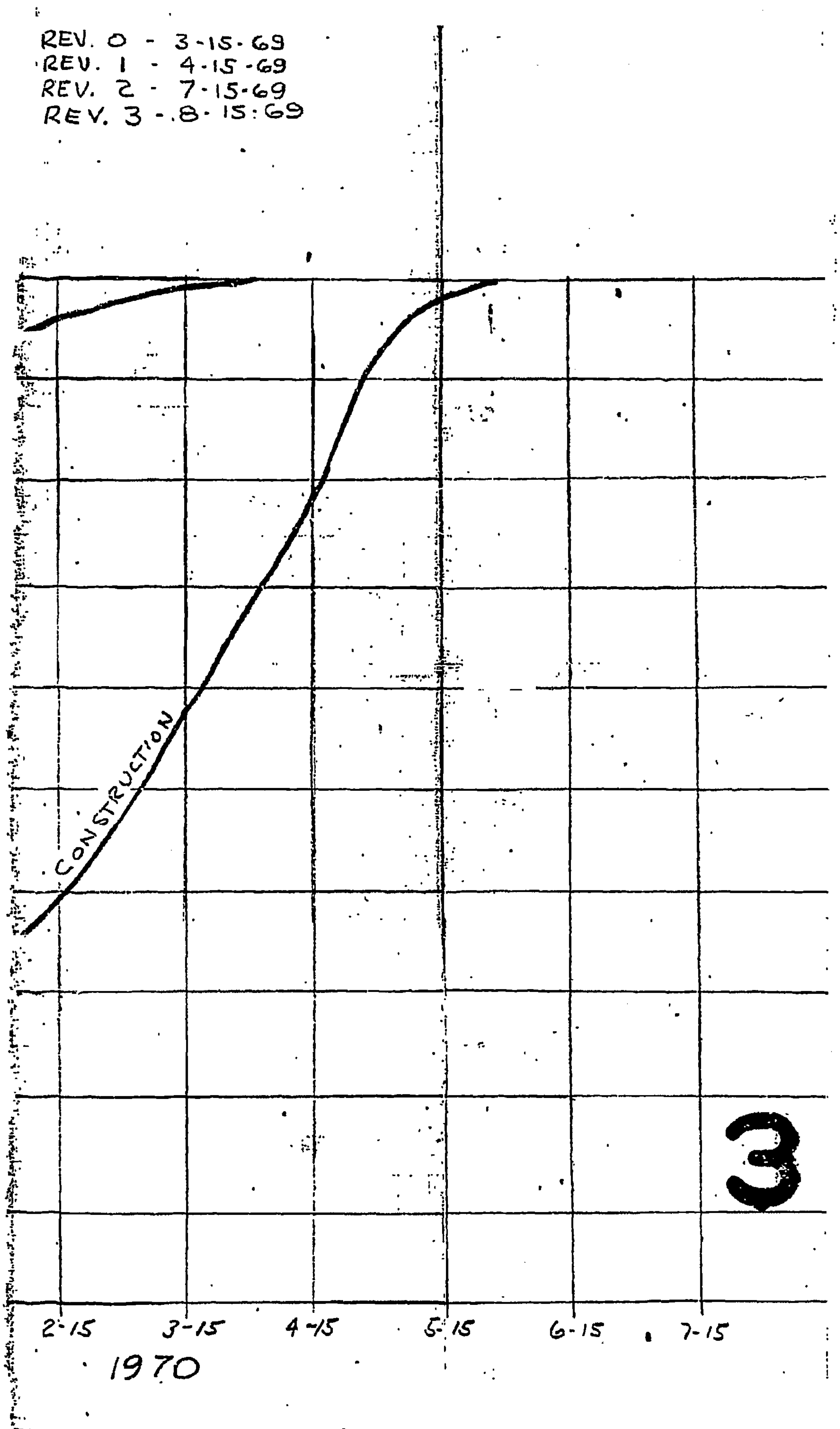

REV. 0 - 3-15-69
REV. 1 - 4-15-69
REV. 2 - 7-15-69
REV. 3 - 8-15-69
CONSTRUCTION
2-15
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4-15
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1970
3

CONTRACT FINANCIAL REPORT (Dollars in thousands) (See instructions before preparation)	1 For Month Ended September 15, 1969	2 No. of Work Days	3 Contract No.	Form Approved Budget Bureau No. 80R0178 Sheet ____ of ____

4 To:	5 From:	6 Contract Value $	7 Contract Type
		8 Funded Contract Amount $	9 Amounts Billed $
10 Program/Scope of Work	11 Signature and Title of Authorized Representative	12 Preparation Date	13 Payments Received $

14 Appropriation (or Fund Citation) and/or Reporting Category	15 Cost incurred/Contract Earnings			16 Planning Data (For Agency use only)			
	Cum. Actual End of Prior Mo. a	Actual/Estimated Current Month b	Cumulative Actual/Estimated To Date c	a	b	c	d
Procon Incorporated W-1784 Less: 10% Retention as Applicable	$ 676 72 604	$ 177 18 159	$ 853 90 763				
(Above includes 66 thousand dollars previously reported as (W-1784X1)).							
17 Total							

"The undersigned certifies that the amount is due and payable to Procon, in accordance with the terms of the contract up to the dat of this Certificate and that the contractor has fully complied with the terms and conditions of the contract."

Progress Report No. 14, September 15, 1969

T. A. Taylor

IGT-MPR--10/69

DEVELOPMENT OF IGT HYDROGASIFICATION PROCESS

Progress Report No. 61 – October 1969

to

Office of Coal Research

Contract No. 14-01-0001-381 (1)

SUMMARY

- Hydrogasification test work at low pressure is under way using North Dakota lignite.
- Five tests were performed in the electrothermal test unit. Investigations have started on end-to-end electrode configurations.
- Effects of sulfur and benzene on catalyst activity were investigated.
- Economic analysis comparing cost of lignite from operator-owned and utility-owned mines indicates an advantage for utility ownership.
- Detailed engineering of the pilot plant is 75% complete. Forty percent of the foundations and essentially all underground piping are complete.

III. CONTRACT FINANCIAL REPORT

Procon's portion of Form No. 80R0178 has been completed and reflects actual costs incurred through the last calendar month; estimated costs during this month; and the estimated total cumulative cost through this month. All costs have been rounded off to the nearest thousand dollars.

Hydrogasification Test Program

One thousand pounds of North Dakota lignite were prepared as a feed for the hydrogasifier. This preparation consisted of drying the lignite in the pretreater to a moisture content of less than 3.5%.

A free-fall run with the North Dakota lignite at 250 lb pressure was made with only nitrogen in the reactor. Results were not available for this report.

An attempt to run the North Dakota lignite at 500 lb pressure using hydrogen as the feed gas was unsuccessful. After about 45 minutes and before the bed was established, the lignite formed a cake about 1 ft below the top heating zone. This test will be rerun using an increased nitrogen down purge in the feed line.

Electrothermal Gasification Test Program

Five tests were conducted in the electrothermal pilot unit during the month. One of the tests, EG-37, was conducted at 1000 psig with a hydrogasified high-volatile bituminous char as the feed. Four tests were conducted with an end-to-end electrode configuration to obtain data on that mode of operation.

A steady-state period of 1-1/2 hours was maintained during Run EG-37. The steam flow rate was 142 lb/hr and the char feed rate was 131.5 lb/hr. Completed data indicate a char conversion and steam decomposition of 31.5 and 42.9%, respectively. A power input of 95.2 kW maintained the bed temperature at a nominal 1800°F, accompanied by an overall resistance of 0.87 ohm.

It was necessary to remove the inner reactor tube following the test to replace the thermocouples, so we decided to switch our mode of operation at that time from a concentric electrode configuration to an end-to-end configuration. With this configuration, the current flow is parallel to the reactor wall from an inner electrode in the upper portion of the bed to the reactor bottom.

A 6-in.-ID mullite refractory tube was installed in the pressure shell. The 1-1/2-in. stainless steel rod was extended to 12 in. above the metal cone at the reactor bottom. With the inlet gas nozzle extended to the top of the metal cone, the char below the nozzle is in a settled state and, with the metal cone, acts as one electrode in the system. The first heat-up test was conducted at atmospheric pressure using nitrogen as the fluidizing gas. With 12-in. spacing of electrodes, the overall resistance of the system was about 50 ohms. At the maximum voltage (550 V) from the M.G. set, we were unable to heat the reactor bed above 700°F. The 1-1/2-in. stainless steel electrode was extended to 6 in. above the metal cone at the reactor bottom for the second heat-up test to lower the resistance between electrodes. At the beginning of the heat-up period, the overall resistance of the system was a nominal 14 ohms at the maximum voltage of 550 V. With the current flow of 40 A, the power input was 22 kW, which should have been sufficient to heat the char bed and reactor to 1700°F. However, several thermocouples indicated a hot spot at the reactor bottom, and the test was terminated when the overall resistance decreased sharply, indicating a short circuit. Following the test, we found the inlet gas nozzle melted at the tip, as was about 1/2 in. of the 1-1/2-in. stainless steel rod. Also, several spots of either slagged char or melted electrode metal were on the refractory wall.

The inlet gas nozzle was shortened so it would not extend to the top of the metal cone at the reactor bottom to prevent the apparent high current density at its tip that previously caused it to melt. During both tests at atmospheric pressure, trouble was encountered in controlling the char bed height, and the fluidization of the char bed was erratic. The third test was conducted at the same electrode spacing (6 in.), but at 500 psig to take advantage of the pressure effect on fluidization behavior. At the beginning of the heat-up period, the overall resistance was a nominal 14 ohms. It decreased to less than 3 ohms in 1 hour. The bed thermocouples indicated that temperatures varied from 600° to 1700°F in 2 ft; this indicated short circuiting, so the test was terminated.

Dismantling the reactor bottom showed the 1-1/2-in. stainless steel rod to be unaffected by the short-circuit condition, but the mullite refractory was severely melted for a length of 12-15 in. from the bottom over one-fourth of the circumference. Also, the metal cone was melted 2 in. from its top at its junction with the burned section of mullite.

The bottom section of mullite was replaced by a 5-1/2 x 6-in.-OD section of mullite. A new metal cone was installed, with a stainless steel cross inserted at the top of the cone. The cross was two 316 stainless steel bars, 5 in. long, 1/2 in. wide, and 3/4 in. thick. It added 4-3/4 sq in. of contact area at the reactor bottom.

The next test, Run EG-38, was conducted at 500 psig with 6 in. between the 1-1/2-in. stainless steel rod and top of the cross section of the metal cone. After the heat-up of the reactor was accomplished, a steady-state period of 40 minutes was maintained during the run. Preliminary results of the test are similar to previously conducted runs under similar conditions. The voltage during steady-state operation was 344 V; the current was maintained at 138 A. The power input was 47.5 kW, with an overall resistance of 2.5 ohms.

The reactor temperature during the run was a nominal 1700°F. The test was terminated when the temperature along one side of the mullite tube indicated a hot spot. Inspection of the inner reactor following the run showed the mullite tube to be severely melted, as was the bulk ceramic insulation in the annulus of the pressure shell over one-third of the circumference and 2 ft along the wall.

The metal cone was also melted several inches from the top, but the cross section and the 1-1/2-in. stainless steel rod were unaffected. Apparently during Run EG-38 and the previous heat-up test, the mullite tube cracked and allowed char particles to accumulate along the inner wall. This condition created a low resistance path and a high current density area, which accounted for the melting of the wall. The actual mode of current flow was along the length of the 1-1/2-in. electrode to the outer wall.

Several designs for the reactor bottom configuration are being considered. A reactor tube of Vycor is being installed for further testing of the end-to-end electrode configuration.

Methanation Test Program

During the month the effect of sulfur and benzene on the rate of methane formation and catalyst activity was investigated. A mixture of 4.7% CO, 13.5% H_2, and 81.8% CH_4 containing [illegible] ppm propyl mercaptan was used. The experimental conditions were 575°F, 595 psig, and 575°F, 299 psig. We found that the rate of methane formation remained constant for 6 hours after an initial decrease of 6-10%. It should be recognized, however, that cumulative effects may damage the catalyst. In a second series, this feed gas was continuously saturated with about [illegible]% benzene while being passed to the reactor. The effect on the rate of methane formation was not detectable at the end of a 2-day run.

Engineering Economics Studies

Results of the study of production costs of North Dakota lignite made by Paul Weir Co. have been used to compute prices that might be charged to a pipeline-gas-from-lignite plant.

With a depletion allowance, the price of lignite for the gas plant averages $1.85/ton for a return typical of a mine operator. With utility financing, the average for two cases is $1.45/ton, indicating an advantage for utility ownership. It should be pointed out that the relative costs associated with typical mine operation and with utility ownership are important, and that absolute costs depend on the particular assumptions concerning the lignite to be mined.

Pilot Plant Construction

Detailed engineering is estimated to be 75% complete, and purchasing 77% complete. In the field, the underground piping is essentially complete. Foundations are about 40% complete.

Emphasis has been placed on the design of the dust removal system associated with the coal preparation section. Plans are to slurry the dust with water and filter it over the char filter cake. Also, details of the air distributor at the base of the pretreater were resolved. Schedules still indicate that the main reactor will be ready for shipment by mid-December.

Details are covered in Procon's Progress Report No. 15.

During the month there was a 2-week strike of the maintenance union at IGT. There was a slight slowdown in test runs because of the problem of getting nitrogen through the picket line.

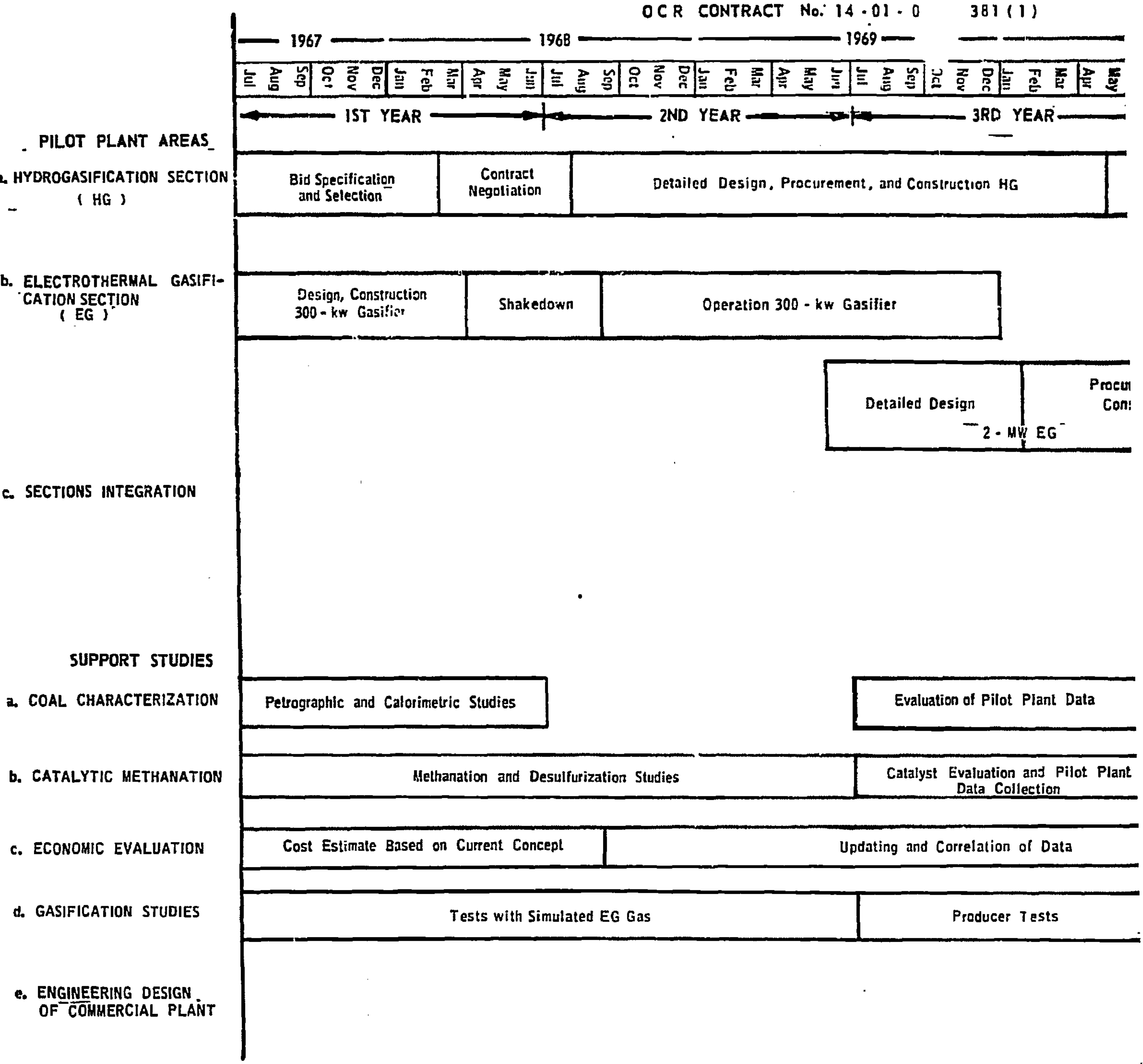
No new inventions were made in the course of the month's work.

Approved F. C. Schora, Jr.
F. C. Schora, Jr., Director,
Process Research

Signed B. S. Lee
B. S. Lee, Manager

PILOT PLANT PROGRAM OF IGT HYDRO

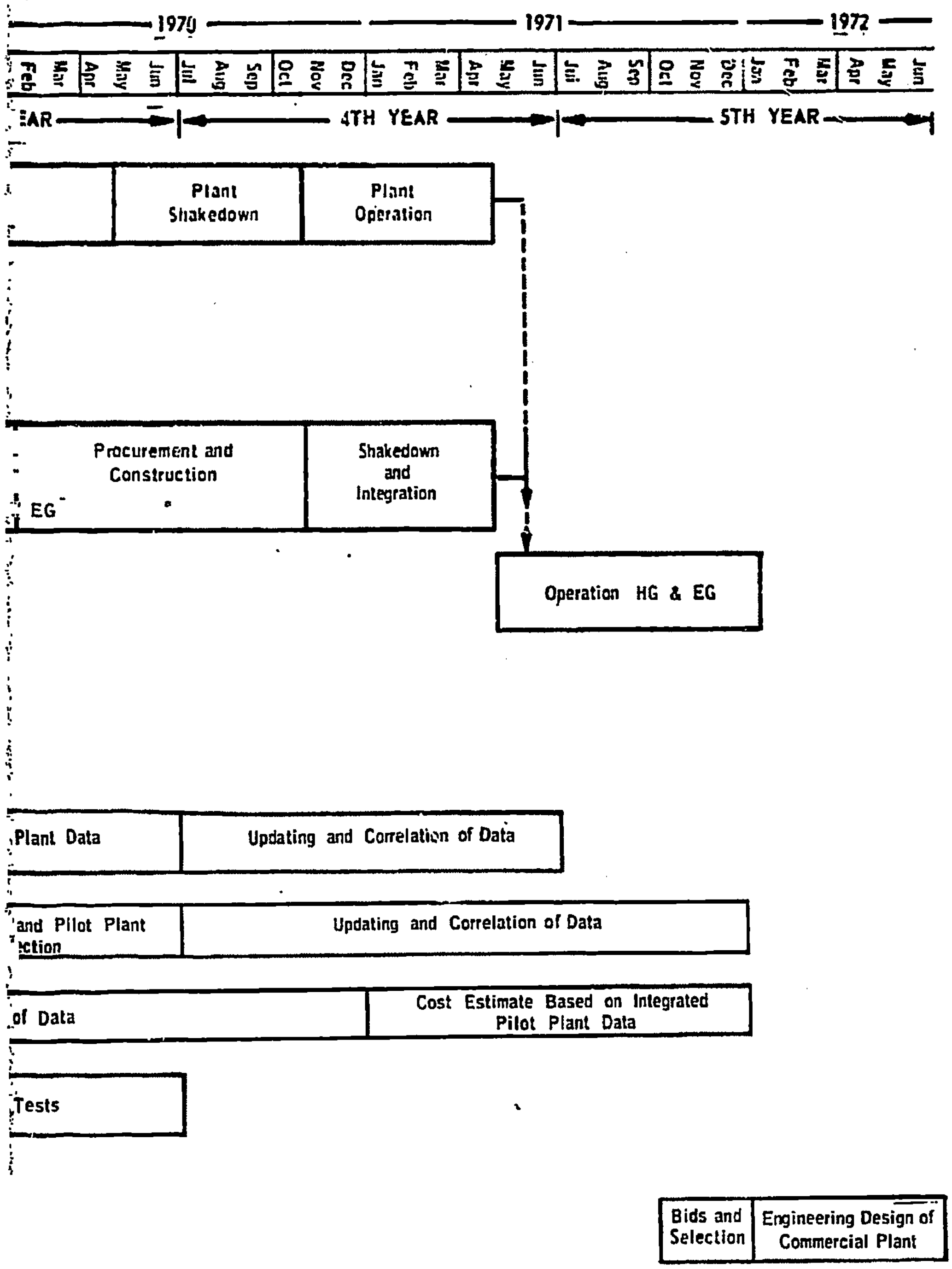
OCR CONTRACT No. 14 - 01 - 0 381 (1)



* Reactor must be purchased during design period because of time required for fabrication.

HYDROGASIFICATION PROCESS

AGA: IU-4-1



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IGT-MPR--11/69

DEVELOPMENT OF IGT HYDROGASIFICATION PROCESS

Progress Report No. 62 — November 1969

to

Office of Coal Research

Contract No. 14-01-0001-381 (1)

SUMMARY

- Four hydrogasification tests were performed using North Dakota lignite to investigate hydrogasification at 500 psi. Difficulties were encountered with feeding in the first three runs; however, in the fourth run a modified start-up procedure led to a successful 5-1/4 hour test.

- Five tests were conducted in the electrothermal gasifier during the month to investigate the use of end-to-end electrodes.

- Investigations of the effect of trace amounts of organic sulfur compounds on methanation catalyst activity are being undertaken.

- An investigation was made of various cost factors as they may apply to synthetic gas production costs.

- Engineering and purchasing for the pilot plant are 80% complete. All underground work and foundations are expected to be completed by the end of December.

Hydrogasification Test Program

We conducted four hydrogasification tests this month in the balanced-pressure development unit (Runs HT-236, HT-237, HT-238, and HT-239) with a dried, but otherwise untreated, North Dakota lignite from the Glenharold mine. The objective of these tests was to study the reactivity of the lignite to hydrogasification with hydrogen and steam at a system pressure of 500 psig. The first three tests had to be terminated after about 1 hour of feeding lignite, but before steady-state operation was attained, when the lignite was held up at the top of the reactor tube causing the feed screw to jam.

The exact cause of the lignite hold-up in these tests has not yet been established, but appears related to the composition of the feed gas and its linear velocity. Although the dried lignite was shown to be nonagglomerating in laboratory tests, further examination of the lignite feed used in the development hydrogasification unit showed a slight particle agglomeration when heated in a hydrogen atmosphere.

Run HT-239 was successfully conducted using the same lignite feed as in the three previous tests, but with a modified start-up procedure. Feed steam was not introduced to the reactor until after a lignite bed was established. The lignite was gasified in a 3.5-ft fluidized bed with a hydrogen-steam feed gas. Steam concentration in the feed gas was a nominal 35%. The hydrogen-to-lignite ratio was a nominal 20% of stoichiometric. The test lasted 5-1/4 hours, with 2-1/4 hours of this time at steady-state. Based on the weight of the lignite recovered, 51% was converted to liquid and gaseous products. Additional results for this test are not yet available.

Electrothermal Gasification Test Program

Five tests were conducted in the electrothermal gasifier during the month. The tests were a continuation of the study of operating characteristics of end-to-end electrodes in the pilot unit. All the tests were conducted at 500 psig using hydrogasified char from high-volatile bituminous coal.

The first two tests were conducted with a 3-ft long Vycor tube (6 x 5-3/16 in.) in the lower section of the reactor. The Vycor tube was sheathed in a

2-foot section of Schedule 80 stainless steel pipe to prevent burnout of the insulation in the annulus within the pressure shell sould a short circuit occur.

The top electrode was the 1-1/2-in. stainless steel rod and the bottom electrode consisted of an 8-in. long section of 1-1/2-in. stainless steel rod attached to the metal cone at the reactor bottom. A 4-in. long and 1/2-in. wide cross of stainless steel was attached to the bottom rod to increase the surface area of the electrode. The spacing between electrodes was initially 6 in. At 550 volts there was no measurable current flow and the test was terminated. The electrode spacing was decreased to 3-1/2 in. for the No. 4 reactor heat-up test. At 550 volts we were unable to obtain the power level required to heat the bed due to the high overall resistance of the system (175-275 ohms).

For the No. 5 heat-up test the bottom electrode was changed to the metal cone at the reactor bottom and the settled bed below the gas inlet nozzle with the distance from the top of the cone to the upper electrode at 3-1/2 in. Again, at 550 volts we were unable to heat the char bed due to the high overall resistance of the system.

The test was terminated when a sudden decrease in resistance occurred indicating a short circuit. A 1-in. hole had been burned through the Vycor tube and metal sheath and was probably caused by a break in the Vycor tube which created a high-current-density area.

For the No. 6 heat-up test the Vycor tube was replaced with a 3-ft long, 5-1/8-in. I.D., 5-1/2-in. O.D. mullite tube. The electrode configuration was similar to that in Test No. 4, except the cross section at the top of the bottom electrode was removed and the spacing between electrodes was set at 2 inches.

At 550 volts we were still unable to attain a power input level which would heat the char bed, and the test was terminated when indications of arcing occurred after a sudden drop in the resistance. The tops of both electrodes were slightly melted, probably caused by char lodging between the smaller space (2 in.) between the electrodes, or because the nitrogen velocity was near the minimum fluidizing velocity. A 1-in. hole was burned through the mullite tube near the top electrode tip.

The mullite tube was replaced with a 6-1/2-in. I.D. x 8-1/2-in. O.D. precast refractory (high alumina) and the No. 7 heat-up test was conducted at the same conditions as the previous test, but the nitrogen superficial velocity was maintained between 0.3 and 0.4 ft/s (compared to 0.1-0.2 ft/s in Run No. 6) to ensure a well-fluidized bed in the area of the electrode tips. At 550 volts the overall resistance (50-70 ohms) was high enough to prevent reactor heat-up and the run was terminated. However, no short circuiting occurred and the electrodes and reactor wall were unaffected.

Test No. 8 was run at the same conditions as No. 7, except we attempted to lower the overall resistance by varying the nitrogen flow rate below the minimum fluidizing velocity to enable heat-up of the bed. However, we were unable to maintain a stable operation and the run was terminated when an arcing condition occurred in the quiescent bed.

From the tests conducted with the end-to-end electrode configuration, we concluded that it will not be possible to conduct tests using this configuration in the pilot unit. An overall resistance of the system from 50 to 200 ohms has been observed at various electrode spacings, and without a maximum output voltage of 550 volts the power input has been insufficient to heat the char bed. The unit is being modified for the change-over to the concentric electrode configuration.

Methanation Test Program

To determine the life and activity of a catalyst (Harshaw Ni-0104T) in the presence of sulfur, a gas mixture (5% CO, 15% H_2, 80% CH_4) containing 0.3 ppm propyl mercaptan and 0.8 ppm thiophene was used in experimental runs. The activity was not changed at the end of a 67 hour run. Although it could not be accurately measured, there was appreciable breakthrough of sulfur.

A packed bed reactor which can be used to simulate either the linear velocity or the space velocity of the pilot plant methanator was designed and is being built to study the effect of sulfur (H_2S) on the activity of the catalyst. This unit will also be used to check out the operation of the sulfur chromatograph, which will eventually be installed at the pilot plant.

Coal Characterization

Plans are being made to study the reactivity of various macerals during hydrogasification. Maceral concentrates, which will be supplied by the coal research group at Pennsylvania State University, will be tested in a small thermal balance which has been used in the past for kinetic studies.

Engineering Economics Studies

An investigation was made to establish the effects of varying financial factors on the price of pipeline gas as compared to the A.G.A. accounting procedure used in all past economic studies. Debt fractions ranging from 0.5 to 1.0, interest rates of 5-7%, and return on rate bases of 7-9% were investigated. Variations of these factors caused changes of +2.1¢ to −1.7¢/million Btu of gas, compared to the cost of gas calculated from the standard procedure.

Pilot Plant Construction

Engineering and purchasing are both 80% complete. The bulk of engineering work remaining is detailed drawings for instrumentation and electricals. Foundations are 70% complete. All foundation and underground work should be completed by the end of December. Most of the vessels have been received on the site with the exception of the main hydrogasifier vessel. Schedules still indicate that this vessel should be in transit by the end of the year.

Procon is now undertaking a new estimate of schedules and any revisions in the present schedule should be known by the end of December.

Further details of the pilot plant construction are given in Procon's Progress Report No. 16.

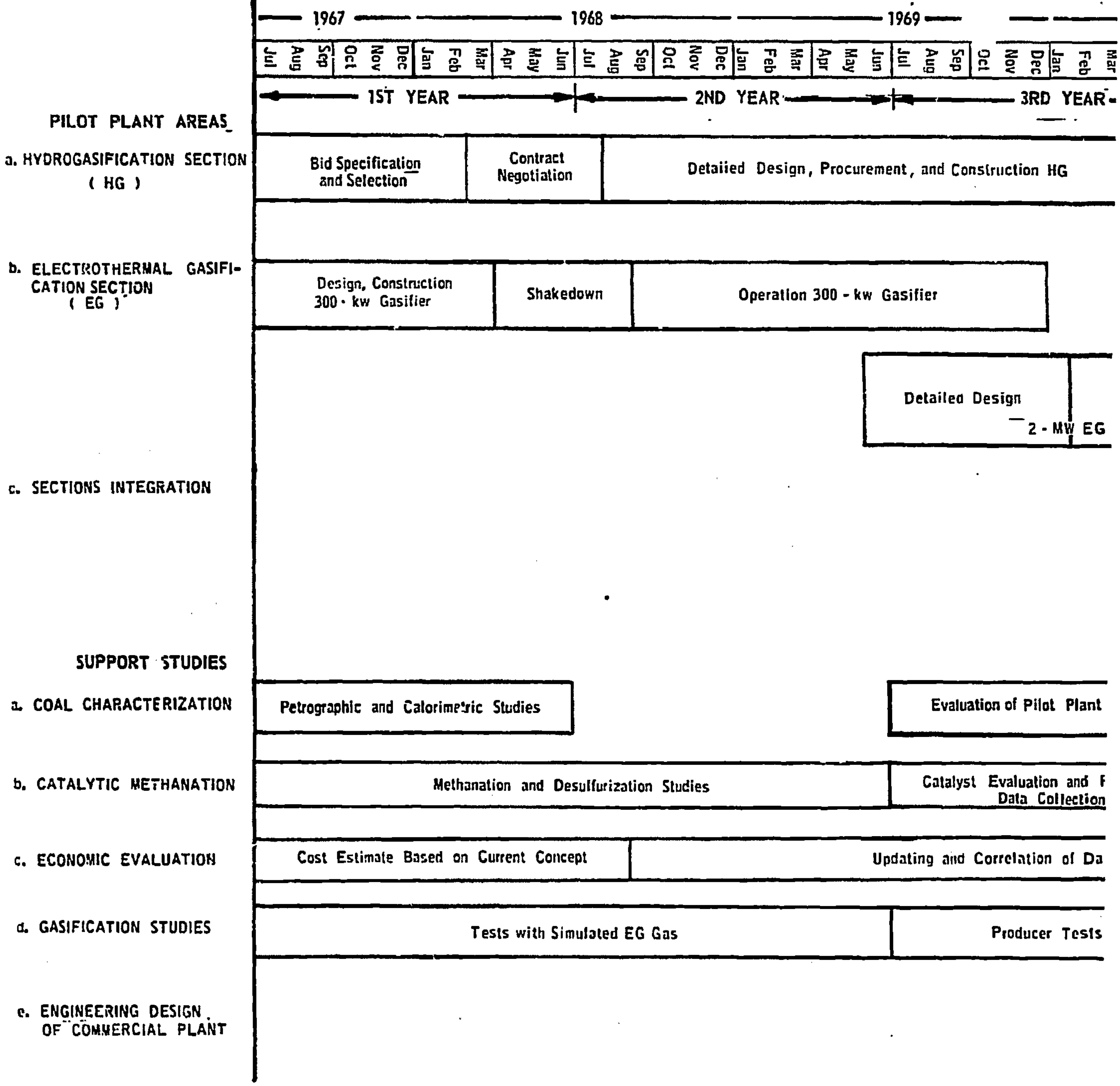
During the month no new inventions were made in the course of the work.

Approved _______________ F. C. Schora, Director

Signed _______________ B. S. Lee, Manager

PILOT PLANT PROGRAM OF IGT HY

CCR CONTRACT No. 14-01-0 -381(1)



° Reactor must be purchased during design period because of time required for fabrication.

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OF IGT HYDROGASIFICATION PROCESS

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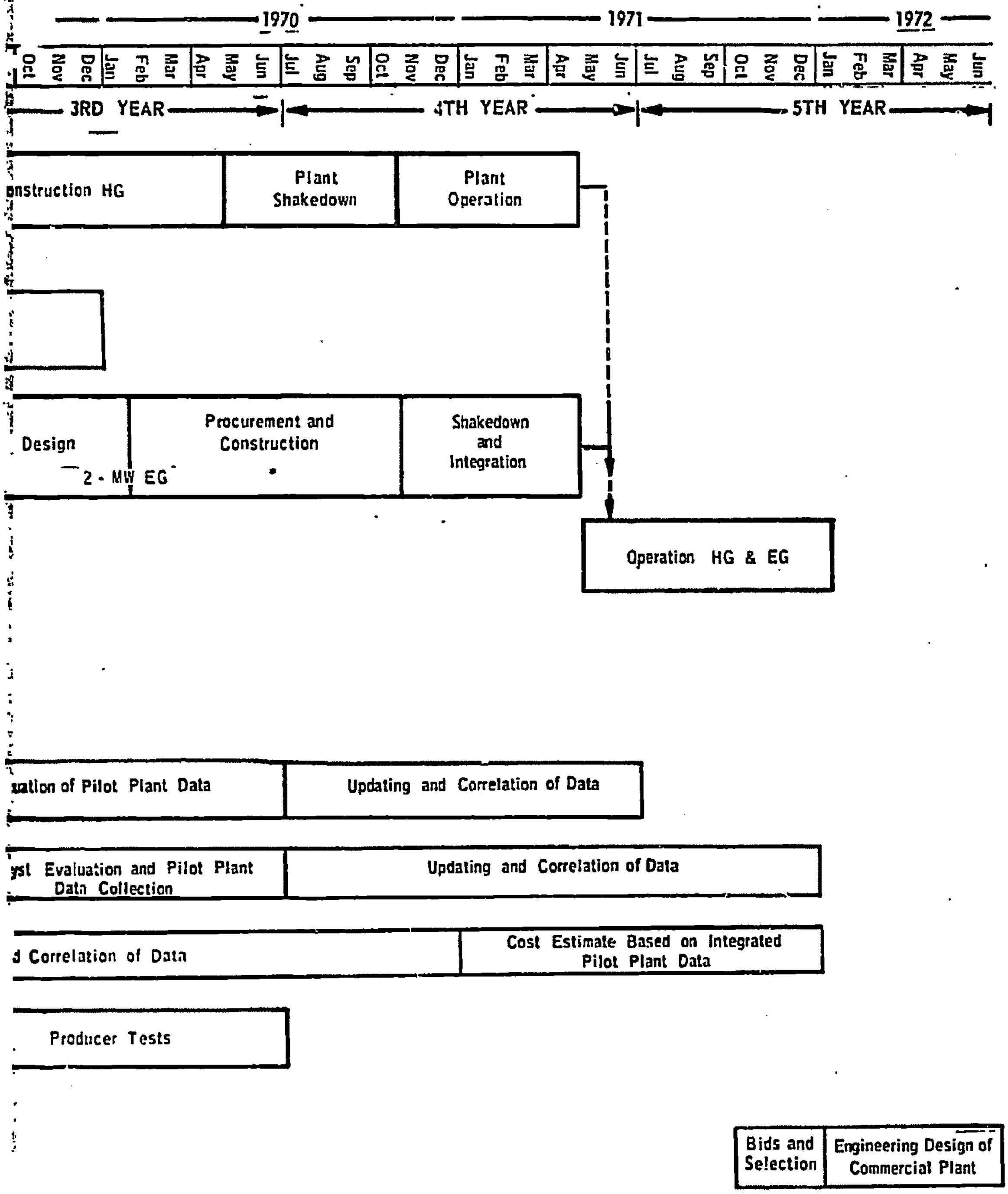

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IGT-QTPR--10-12/69

IGT EDUCATION · RESEARCH

INSTITUTE OF GAS TECHNOLOGY · IIT CENTER · CHICAGO 60616

Project Status Report
For
OFFICE OF COAL RESEARCH
and
AMERICAN GAS ASSOCIATION

Report For Fourth Quarter, 1969

OCR-AGA Progress Report No. 62

Project Title Pipeline Gas From Coal — Hydrogenation (IGT Hydrogasification Process)

OCR Contract No. 14-01-0001-381 (1) A.G.A. Project No. IU-4-1

I. Project Objective

The overall objective of this project is a process for production of pipeline gas from coal that is economically attractive for supplementing natural gas supplies. The present objective is the design, construction, and operation of a large integrated pilot plant to obtain scale-up data and operating experience. Developmental research, engineering studies, and economic evaluations are in progress to help attain this objective.

II. Achievements

COAL CHARACTERIZATION

Petrographic examination of the residue from electrothermal gasification indicates that the reaction occurred uniformly throughout the particle. The particle structure probably collapses when sufficient gasification has taken place. This mechanism is consistent with the observation of large fines production at high carbon gasification. Entrainment of particles can also be due to the low density of the particles. A fractional air elutriation technique is being used to investigate the causes of particle entrainment.

Project COED char before and after electrothermal gasification shows no anisotropy and less vesicle formation than IGT's hydrogasified char due to the stage-by-stage heating basic to the COED Process.

We have begun a program to study the reactivity of macerals in hydrogasification. Samples of macerals or maceral concentrates will be supplied by the coal research group at Pennsylvania State University. Four such samples have been prepared.

HIGH-PRESSURE METHANATION

Deactivation of catalyst occurs 1) after operation at temperatures below 525°F or 2) with feed gases of a H_2/CO ratio of <2.

Reaction rate studies in regions far from equilibrium show that methanation reaction rates at 600 psia and 575°F and in the presence of large concentrations of methane of up to 85% appear to be comparable to those using helium as the diluent. Methane, therefore, acts as an inert. At 300 psia, however, the presence of methane depresses the rate of methane formation somewhat more than helium does at the same concentration.

Tests of 4-5 days duration showed that after a few hours the fresh catalyst became stabilized in its activity. These long-term tests show no noticeable effect of benzene, up to 1% concentration, on the rate of methanation. Analysis of the catalyst after such tests showed no noticeable change in composition, particularly in carbon and sulfur content. These components will serve as indications of any carbon deposition or sulfur poisoning, respectively. Initial tests to measure sulfur poisoning showed that 0.3 ppm propyl mercaptan and 0.8 ppm thiophene in the feed gas did not reduce the rate of methanation.

Regression analysis of data based on all reproducible runs to date at 575°F and 600 psig strongly confirms the previously reported order of CO and H_2, namely, 1 and 0.5, in the methanation rate expression. The CO order is maintained in runs where a large excess of hydrogen is present.

ENGINEERING ECONOMICS STUDIES

A brief study of lignite mining cost was prepared by Paul Weir Co., consulting mining engineers. It estimated a cost of $1.42/ton without investment return, of which 20¢ is for United Mine Workers of America welfare fund and 18¢ for royalties. By capitalizing the mine based on utility financing, a 500 billion Btu/day lignite-based gas plant produces gas at 38¢/million Btu. The cost of lignite mining would be $1.55/ton.

A preliminary study of hydrogen production by oxygen transfer through shorted zirconia electrolyte cells indicates that the cost of hydrogen would be considerably higher than that from the steam-iron process. The main reason for the cost difference is the high investment cost of the cell system.

A brief study was made to correlate cost data of acid-gas removal systems with the concentration of acid gas in the feed stream. The recovery of sulfur from H_2S and SO_2 from the HYGAS plant was examined in a recent study. A paper based on this study was presented in September.

The effect of varying financial factors on the price of pipeline gas is calculated. The ranges of variation of these factors are —

Debt Fraction	0.5 to 1.0
Interest Rate	5, 6, and 7%
Return on Rate Base	7, 8, and 9%

For the base case of producing pipeline gas from bituminous coal using purchased electricity for the electrothermal gasifier, variations in the above factors caused a change of +2.1¢ to −1.7¢/million Btu from the base gas price.

DEVELOPMENT UNIT STUDIES

An evaluation of Montana lignite for hydrogasification was completed which showed it to be comparable in reactivity to North Dakota lignite. Hydrogasification of the char from FMC Corporation's Project COED was successful. This char, already gasified quite severely, showed a lower reactivity, as expected, than pretreated or partially gasified bituminous coal from the Ireland mine.

In a short-residence-time, free-fall test at 1000 psi and 1300°F, 37% of a dried Montana lignite was converted to gaseous and liquid products, of which 13% was liquid and the balance gas.

An evaluation of pretreated medium-volatile-content Sewell seam bituminous coal was completed that shows the coal to be comparable in reactivity to pretreated Ireland mine coal. We have just completed a study of the effect of pressure on the reactivity of lignite. Four tests were conducted this month.

The electrothermal gasifier has been successfully operated at 540 psig with Ireland mine hydrogasified char. Reaction rates appear to be much higher at the higher pressure; the desired carbon gasification can be readily achieved. A power level of 73 kW was attained. Bed resistance showed an increase over operation at 200 psig, which is highly desirable because, for the same power input, high-voltage operation is more efficient than high-current operation. Carbon gasification of over 50% and steam decomposition of over 80% were achieved in 1/2-hour char residence time.

Tests with the Project COED char showed that it behaved similarly to Ireland mine both in chemical and electrical characteristics. Continued testing of this char is planned.

Operation at 1000 psi, after considerable modifications, encountered a number of mechanical difficulties, particularly near the electrically insulating pressure closure. After modifying the closures, successful operation at 1000 psi with COED char was achieved, with carbon gasification of 40% and steam conversion of 60%. Operation was smooth.

After several unsuccessful attempts, operation at 1000 psi with IGT hydrogasified char was successfully achieved in September. At a char feed rate of 120 lb/hr and a steam rate of 125 lb/hr, 30% of the char and 45% of the steam were converted. The power input was 83 kW.

The pilot unit was converted to operate with end-to-end electrodes. A number of tests were conducted which showed that, with our present power supply, the high bed resistance made it impossible to achieve the power input required for the gasification reaction. Measurements were obtained of voltage gradients and bed resistivity with this type of electrode configuration. The reactor is being returned to the concentric electrode arrangement for further testing.

Pressure letdown tests of the char-water slurry from 1000 psi to ambient gave very encouraging results in that no noticeable wear was observed after 24 hours of operation on either a simple mild-steel nozzle or a flow-control valve. The flow rates through the valve can be readily controlled. The slurry, after letdown, can be easily filtered. These results were used to design the letdown and slurry disposal system of the large pilot plant.

Tests made with a Fisher butterfly valve, identical to the ones to be used in the HYGAS pilot plant for solids flow control, showed that the limiting torque of 600 in.-lb on the butterfly shaft will not be approached under all flow conditions. The valve, however, cannot be safely operated if it is immersed in unfluidized solids. Therefore, we have incorporated torque limiters on the valve operators and provided taps for introducing fluidizing gas to the pipe above and below the valve.

NEW PROCESS STUDIES

A preliminary study has been made to evaluate the feasibility of simultaneously producing synthetic pipeline gas and finely divided carbon from lignite and transporting both products as a mixture by pipeline. The study is based on a gas production rate of 500 billion Btu/day. In the range of variation studied so far, a 42-inch pipeline carrying 5 pounds of carbon/lb of gas shows an energy transportation cost of 0.48¢/million Btu-100 miles with capital charges assumed at 15%/year. The cost of gas and carbon production is being further investigated as a function of several parameters, such as by-products, degree of conversion, and operating pressure.

A brief exploratory experimental program was conducted to evaluate the possibility of separating methane-hydrogen mixtures in a vortex tube. With a feed gas of 82% methane and 18% hydrogen, no significant separation was noted under a wide range of operating conditions. As we concluded that the mass ratio of methane to hydrogen is apparently too small to permit separation by this technique, we terminated this study.

A preliminary engineering study is being conducted to examine the feasibility of using a molten carbonate fuel cell in a 400-megawatt power plant to supply power to the electrothermal gasifier. The power plant specifications were established at 5000 volts, using a producer gas generated from spent char. Single-cell specifications are 0.75 volt, 200 A/sq ft, and 10-sq-ft active area per cell. Based on this, the power plant will consist of 44 power units, a power unit will contain 67 batteries, each battery will contain 20 modules, and each module will consist of 5 cells. The optimum stacking arrangement of eight batteries in a package was selected. The preliminary cost estimate, based on conservative cost factors, shows $82/kW for the purchased equipment cost. The total plant investment and the power cost will be developed next.

PILOT PLANT CONSTRUCTION

Approval was received from OCR to establish the guaranteed maximum price of the pilot plant at $6,724,000. Included in this price is a labor contingency of $240,000 for "local conditions and premium pay." Procon will not share in any savings in field costs until such savings exceed $240,000.

Engineering is 88% complete and purchasing is 82% complete. Equipment has been arriving at the site; 27% has arrived. Construction of the underground and foundation is essentially complete; total construction is 17% complete.

A groundbreaking ceremony was held at the site on May 22, 1969.

The project schedule has been updated based on construction take-off of detailed piping spool sheets and the anticipated manpower availability. Indications are that the projected June 1, 1970, completion date will be delayed by about a month.

III. Problems

No major problems were encountered this quarter.

IV. Recommendations

We recommend that the project proceed into the areas defined in the contract amendment.

V. Status of Funding

1. A.G.A. Funding

A. 1969 Funds Allocated	$ 300,000
B. Funds Expended This Month (estimated)	$ 16,700
C. Funds Expended to Date (estimated)	$ 300,000

2. OCR Funding

A. Funds Expended This Month (estimated)	$ 580,000
B. Funds Expended Since Contract Amendment No. 1 (estimated)	$ 3,400,000

As a result of personally reviewing the pertinent data and information reasonably available, it is our opinion that the project's objective has been attained within the contract term and the funds allocated.

Approved ______________________
Frank C. Schora, Jr.
Director

Signed ______________________
Bernard S. Lee
Manager

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Jack Huebler, Vice-President

Appendix. Achievements in December

COAL CHARACTERIZATION

Pennsylvania State University has prepared four samples for determination of reactivity on the thermobalance and will send them to us after a portion has been acid-washed for removal of mineral matter. Three of the samples are vitrinite concentrates from a lignite, a subbituminous coal, and a high-volatile-content bituminous coal. The fourth is a fusinite concentrate from a subbituminous coal.

Methods of determining the elutriation and attrition characteristics of chars are being developed.

DEVELOPMENT UNIT STUDIES

Hydrogasification Tests

We conducted four hydrogasification tests this month in the balanced-pressure development unit (Runs HT-238, HT-239, HT-240, and HT-241). Feed in these four tests was a dried but otherwise untreated North Dakota lignite from the Glenharold mine. Two of the tests, Runs HT-239 and HT-241, were successful. The two other tests had to be terminated before steady-state operation was attained. In Run HT-238 the lignite plugged in the feed screw. In Run HT-240, the feed-gas preheat coil plugged. The feed lignite was prepared by crushing and screening to a −10+80 mesh size and air-drying in the fluidized-bed coal pretreatment unit at 220°-240°F.

Significant features of the four tests are given in Table 1.

Table 1. FEATURES OF HYDROGASIFICATION TEST RESULTS FOR RUNS HT-238 TO HT-241

Run No.	Temperature, °F	Purpose of Run	Results
Feed Solids: Dried North Dakota Lignite, Glenharold Mine Feed Gas: Steam-Hydrogen			
HT-238	1300-1700	To study the hydrogasification reactivity of a North Dakota lignite with hydrogen (20% of stoichiometric) and steam (35% concentration) at a system pressure of 500 psig	Plug in lignite feed screw
HT-239	1200-1700	Same as HT-238	Successful

Table 1, Cont. FEATURES OF HYDROGASIFICATION TEST RESULTS FOR RUNS HT-238 TO HT-241

Run No.	Temperature, °F	Purpose of Run	Results
Feed Gas: Steam-Hydrogen-Carbon Monoxide-Carbon Dioxide			
HT-240	1200-1700	To study the hydrogasification reactivity of a North Dakota lignite with a synthesis gas (35% of stoichiometric) and steam (50% concentration) at a system pressure of 500 psig	Plug in feed-gas preheat coil
HT-241	1200-1700	Same as HT-240	Successful

In Runs HT-238 and HT-239 we fed the lignite at a nominal rate of 50 lb/hr for gasification in a 3.5-foot fluidized bed controlled to 1700°F. Hydrogen was fed to the bottom of the reactor at a rate of 345 SCF/hr so that the hydrogen-to-coal ratio was 20% of the stoichiometric ratio. Steam was fed at a rate of 8.8 lb/hr, giving a steam concentration of 50 mole percent in the hydrogen-steam mixture. Lignite feeding stopped in Run HT-238 after 1 hour when the feed screw jammed as the lignite plugged in the feed tube. Partial cause of the plug was too rapid a heat-up of the lignite in the upper portion of the reactor. To improve temperature control at the top of the reactor, we installed three additional thermocouples inside the 4-inch-diameter reactor tube. These thermocouples were positioned as follows: 1) outlet of 1-inch-diameter coal feed tube, 2) product-gas bayonet filter, and 3) 30 inches below end of coal feed tube. Run HT-239 was conducted successfully with no lignite feed interruption over a period of 5 hours. Over a steady-state operating period of 2-1/4 hours, based on the weight of residue recovered, we converted over 50% of the lignite to gaseous and liquid products.

Nominal feed rates in Runs HT-240 and HT-241 were as follows: 21 lb/hr lignite, 265 SCF/hr of synthesis gas (54% hydrogen, 41% carbon monoxide, 5% carbon dioxide), and 12.6 lb/hr steam. The lignite was converted in a 3.5-foot fluidized bed controlled to a temperature of 1700°F. During the start-up of Run HT-240, we fed no steam to the reactor with the synthesis gas to maintain a high concentration of feed gases and thus reduce the chances of lignite plugging at the top of the reactor. However, preheating the synthesis gas with no steam resulted in carbon deposition in the furnace preheat tubes that eventually plugged the tubes and stopped the gas flow. After clearing the feed gas preheat tubes, Run HT-241 was made with the standard start-up procedure of a mixture of feed gas and steam. With proper control of temperatures at the top of the reactor (1150°-1200°F), the test was successfully conducted with no lignite plug. The test lasted over 5 hours with 2-3/4 hours at steady-state conditions. Based on the weight of residue recovered, over 50% of the lignite was converted.

Complete hydrogasification results of Runs HT-240 and HT-241 will be presented when analytical results are completed.

To complete the record, Table 2 gives significant features of four hydrogasification tests we conducted with North Dakota lignite during the month of November to study the effect of pressure on lignite conversion.

Table 2. FEATURES OF HYDROGASIFICATION TEST RESULTS FOR RUNS HT-234 TO HT-237

Run No.	Temperature, °F	Purpose of Run	Results
Feed Solids: Dried North Dakota Lignite, Glenharold Mine Feed Gas: None			
HT-234	1300	To study the limited conversion of North Dakota lignite at 250 psig in free-fall	Partially successful
HT-235	1300-1700	To study the hydrogasification reactivity of a North Dakota lignite with hydrogen (20% of stoichiometric) and steam (35% concentration) at a system pressure of 500 psig	Feed screw jammed.
HT-236	1300-1700	Same as HT-235	Feed screw jammed.
HT-237	1300-1700	Same as HT-235	Feed screw jammed.

Run HT-234 was designed to obtain a limited conversion of the lignite, 20% or less if possible, by thermal treatment of the lignite while in free-fall through the reactor tube with no feed gas. The lignite was fed at a nominal rate of 20 lb/hr and gasified in the 15-1/2-foot heated section of the reactor tube. To keep the lignite from hanging up on the walls of the reactor tube, we fed 185 SCF/hr of sweep nitrogen to the bottom of the reactor. The test lasted just over 3-1/4 hours. During this period, lignite feeding was interrupted 4 times by minor plugs at the top of the reactor. Because of these lignite feed stoppages and the relatively limited steady-state operating period of less than 1 hour, this test was only partially successful. Based on tentative results we estimate that 10% of the lignite was converted to liquids and 25% to gaseous products.

Test conditions for Runs HT-235, HT-236, and HT-237 were similar to those of Runs HT-238 and HT-239 already discussed. Each of these three tests was terminated after about 1 hour of lignite feeding when the feed screw jammed. Lignite holdup at the top of the lignite feed tube was responsible for the feed screw jamming. The lignite holdup appeared to be caused by a combination of too low of a nitrogen purge rate and physical compaction of the lignite. There was no evidence of any further holdup of lignite in the reactor tube when the unit was cleaned after each test.

Complete hydrogasification results of Run HT-234 will be presented when analytical results are completed.

We are presenting the complete test results of two hydrogasification tests conducted in September 1969 in the balanced-pressure, high-temperature development unit. One of these tests, Run HT-233, was conducted with a lightly pretreated medium-volatile-content bituminous coal from Sewell No. 1 mine in Nicholas, West Virginia. The other test, Run HT-EG-5, was conducted with a lightly pretreated high-volatile-content bituminous coal from the Ireland mine to produce residue for use in the pilot plant electrothermal gasifier. Operating conditions and results of these tests are presented in Table 3. Compositions and screen analyses of the feeds and residues are given in Table 4. Liquid products and compositions are shown in Table 5.

As shown in Table 3, 26.7% of the carbon in the Sewell No. 1 mine bituminous coal was gasified in Run HT-233. Methane (hydrocarbon) yield in this test was 4.39 SCF/lb coal. The results of Run HT-EG-5 — conducted at the standard hydrogasification conditions of 25% hydrogen-to-coal stoichiometric ratio and 50 mole percent steam concentration — comfirm the results of previous tests at these conditions.

For purposes of comparison Table 6 summarizes key hydrogasification results of Run HT-233 and those of two earlier tests, Runs HT-230 and HT-231, reported in the September 1969 Project Status Report, conducted with the same Sewell No. 1 mine bituminous coal.

The largest carbon gasification, 31.7%, was obtained in Run HT-230 when the Sewell No. 1 mine medium-volatile-content bituminous coal was hydrogasified with hydrogen at a hydrogen-to-coal ratio 33.5% of the stoichiometric

Table 3, Part 1. OPERATING CONDITIONS AND RESULTS OF THE HYDROGASIFICATION OF PRETREATED MEDIUM- AND HIGH-VOLATILE-CONTENT BITUMINOUS COAL IN HIGH-TEMPERATURE ADIABATIC REACTOR

Coal	Sewell No. 1 Mine Nicholas, W.Va. Bit. Coal	Ireland Mine Bituminous Coal
Source	IGT Pretreater FP-140	IGT Pretreater, FP-138
Sieve Size, USS	—10+80	—10+80
Run No.	HT-233	HT-EG-5
Duration of Test, hr	4-1/4	5-1/2
Steady-State Operating Period, min[a]	95-259	75-330
OPERATING CONDITIONS		
Bed Height, ft	3.5	3.5
Reactor Pressure, psig	1016	1022
Reactor Temp., °F[b] Inches From Bottom		
62-1/2	1000	1140
67-3/4	1380	1505
73	1480	1605
78-1/4	1480	1555
83-1/2	1605	1640
89	1555	1560
94-1/2	1510	1510
100	1705	1690
104	1720	1665
Average	1490	1540
Coal Rate, lb/hr[c]	46.21	52.19
Feed Gas Rate, SCF/hr	485.5	493.6
Steam Rate, lb/hr	25.36	25.75
Steam, mole % of hydrogen-steam mixture	52.3	52.3
Hydrogen/Coal Ratio, % of stoichiometric[d]	23.7	26.2
Hydrogen/Steam Ratio, mole/mole	0.911	0.912
Bed Pressure Differential, in. wc	64.0	--
Coal Space Velocity, lb/cu ft-hr	149.4	168.7
Feed Gas Residence Time, min[e]	0.340	0.328
Superficial Feed Gas Velocity, ft/s[f]	0.172	0.178

Table 3, Part 2. OPERATING CONDITIONS AND RESULTS OF THE HYDROGASIFICATION OF PRETREATED MEDIUM- AND HIGH-VOLATILE-CONTENT BITUMINOUS COAL IN HIGH-TEMPERATURE ADIABATIC REACTOR

Run No.	HT-233		HT-EG-5
OPERATING RESULTS			
Product Gas Rate, SCF/hr	939.6		907.6
Net Btu Recovery, 1000 Btu/lb	4.163		3.402
Product Gas Yield, SCF/lb	20.33		17.39
Hydrocarbon Yield, SCF/lb	4.39		4.07
Carbon Oxides Yield, SCF/lb	2.05		2.26
Net Reacted Hydrogen, SCF/lb	2.94		4.07
Residue, lb/lb coal[g]	0.667		0.678
Liquid Products, lb/lb coal[h]	0.500		0.478
Net MAF Coal Hydrogasified, wt %[i]	32.8		41.5
Carbon Gasified, wt %	26.7		31.7
Steam Decomposed, lb/hr[j]	2.65		1.32
Steam Decomposed, % of steam fed	10.47		5.12
Steam Decomposed, % of total equivalent fed[k]	26.0		26.2
Overall Material Balance, %	98.6		100.8
Carbon Balance, %	100.8		108.6
Hydrogen Balance, %	99.3		96.6
Oxygen Balance, %	95.5		98.4
PRODUCT GAS PROPERTIES			
Gas Composition, mole %		N_2-free	
Nitrogen	30.8		32.4
Carbon Monoxide	6.6	9.5	7.1
Carbon Dioxide	3.5	5.1	5.9
Hydrogen	37.2	53.9	31.0
Methane	21.2	30.6	23.0
Ethane	0.3	0.4	0.3
Propane	0.1	0.1	0.1
Butane	--	--	--
Benzene	0.2	0.3	0.2
Hydrogen Sulfide	0.1	0.1	--
Total	100.0	100.0	100.0
Heating Value, Btu/SCF[m]	366	529	366
Specific Gravity (Air = 1.00)	0.571		0.633
Nitrogen Purge Rate, SCF/hr	289		294

Table 3, Part 3. OPERATING CONDITIONS AND RESULTS OF THE HYDROGASIFICATION OF PRETREATED MEDIUM- AND HIGH-VOLATILE-CONTENT BITUMINOUS COAL IN HIGH-TEMPERATURE ADIABATIC REACTOR

a. From start of coal feed.

b. Tube wall temperatures. Bottom of coal bed at 62 in.

c. Operating conditions and results based on weight of dry feed.

d. Percent of the stoichiometric hydrogen/char ratio — the net feed hydrogen/char ratio required to convert all the carbon to methane.

e. Coal bed volume/(CF/min feed gas at reactor pressure and temperature).

f. (CF/s feed gas at reactor pressure and temperature)/cross-sectional area of reactor.

g. By ash balance.

h. Includes condensed, undecomposed steam.

i. 100 (wt of product gas-wt hydrogen in-wt decomposed steam-wt nitrogen in/wt of moisture-, ash-free coal).

j. Computed as difference between steam feed rate and the measured liquid water rate leaving the reactor.

k. Computed as difference between the total equivalent steam feed rate (includes moisture content of feed char and bound water corresponding to oxygen content of feed char) and the measured liquid water rate leaving the reactor.

m. Gross, gas saturated at 60°F, 30-in. Hg pressure. SCF: dry gas volume in SCF at 60°F, 30-in. Hg pressure.

Table 4. CHEMICAL AND SCREEN ANALYSES OF HYDROGASIFICATION FEEDS AND RESIDUES

Run No.	HT-233		HT-EG-5	
Sample	Feed	Residue	Feed	Residue
Proximate Analysis, wt %				
Moisture	1.8	0.9	2.2	0.7
Volatile Matter	19.4	3.4	21.7	2.1
Fixed Carbon	74.0	88.5	60.7	74.1
Ash	4.8	7.2	15.4	23.1
Total	100.0	100.0	100.0	100.0
Ultimate Analysis (dry), wt %				
Carbon	80.8	88.6	66.3	73.9
Hydrogen	3.54	1.52	3.05	1.15
Nitrogen	1.60	0.95	1.31	0.53
Oxygen	8.63	1.51	10.53	0.00
Sulfur	0.56	0.12	3.02	1.74
Ash	4.87	7.30	15.79	23.29
Total	100.00	100.00	100.00	100.61
Screen Analysis, USS, wt %				
+20	10.9	15.3	21.5	14.3
+30	15.4	20.0	19.8	19.7
+40	21.2	25.5	21.5	23.7
+60	31.3	26.8	22.7	25.1
+80	16.1	8.4	9.7	10.4
+100	4.0	2.2	2.7	3.3
+200	1.1	1.4	1.7	3.1
+325	0.0	0.2	0.2	0.2
−325	0.0	0.2	0.2	0.1
Total	100.0	100.0	100.0	100.0

Table 5. COMPOSITIONS OF HYDROGASIFICATION LIQUID PRODUCTS

Run No.	HT-233	HT-EG-5
Sample	Condenser	Condenser
Liquid Products,*		
lb/lb coal	0.500	0.478
Composition of Liquid Product, wt %		
Water	98.25	97.88
Oil	1.75	2.12
Total	100.00	100.00
Composition of Oil Fraction, wt %		
Carbon	89.00	85.60
Hydrogen	6.10	6.36
Total	95.10	91.96
Carbon in Oil Fraction,		
lb/lb coal	0.00779	0.00868
wt % of carbon in coal	0.96	1.31

* Includes condensed, undecomposed steam.

Table 6. COMPARISON OF SEWELL NO. 1 MINE BITUMINOUS COAL HYDROGASIFICATION RESULTS

Run No.	HT-230	HT-231	HT-233
Reactor Pressure, psig	996	1045	1016
Coal Bed Temp Average, °F	1345	1330	1490
Coal Bed Height, ft	3.5	3.5	3.5
Coal Feed Rate, lb/hr	40.97	56.58	46.21
Hydrogen Feed Rate, SCF/hr	596.3	506.0	485.5
Steam Feed Rate, lb/hr	15.94	27.33	25.36
Steam/Coal Ratio, lb/lb	0.389	0.483	0.549
Hydrogen/Coal Ratio, % of stoichiometric	33.5	20.5	23.7
Steam Concentration in Feed Gas, mole %	36.0	53.2	52.3
Steam Decomposed, % of total equivalent steam fed	35.4	28.6	26.0
Carbon Gasified, %	31.7	26.7	26.7
MAF Coal Gasified, %	41.9	35.2	32.8
Hydrocarbon Yield, SCF/lb	4.88	4.05	4.39
$CO + CO_2$ Yield, SCF/lb	2.68	2.27	2.05
Product-Gas Composition, nitrogen-free, mole %			
Carbon Monoxide	10.6	11.0	9.5
Carbon Dioxide	4.3	6.2	5.1
Hydrogen	57.7	51.7	53.9
Methane	26.6	30.1	30.6
Ethane	0.4	0.4	0.4
Propane	0.1	0.1	0.1
Benzene	0.3	0.4	0.3
Hydrogen Sulfide	--	0.1	0.1
Total	100.0	100.0	100.0
Product Gas Heating Value, nitrogen-free, Btu/SCF	503	525	529

ratio and with steam at a steam/coal ratio of 0.389 lb/lb. A somewhat lower carbon gasification, 26.7%, was obtained in Runs HT-231 and HT-233 when the hydrogen-to-coal ratio was in the range of 20.5-23.7% of the stoichiometric ratio. The heating value of Run HT-230 is lower than those of Runs HT-231 and HT-233 because of the greater dilution of the gas by unvented hydrogen from the higher feed hydrogen-to-coal ratio. The hydrogasification results obtained with this medium-volatile-content bituminous coal are not significantly different from those obtained with Ireland mine high-volatile-content bituminous coal at similar operating conditions.

ELECTROTHERMAL GASIFICATION

Five tests were conducted in the electrothermal gasifier during the month. All the tests were conducted with end-to-end electrodes at 500 psig and IGT hydrogasified char as the fluid-bed material.

The reactor configuration of Test No. 5 appears in Figure 1. The bottom section of the reactor was the 5-13/16-inch ID x 6-inch OD Vycor tube that was used in the previous test. The bottom electrode consisted of the metal cone at the reactor bottom and the static char bed below the gas inlet nozzle. The upper electrode, 3-1/2 inches from the bottom electrode, was a 1-1/2-inch stainless steel rod.

At the maximum voltage output of the d-c generator (550 volts), we were unable to heat the char bed above 600°F because of the high resistance of the system (50-100 ohms). The run was terminated after a sudden decrease in the resistance indicated arcing in the bed. Inspection of the reactor following the test showed that the Vycor tube had been severely cracked and melted through in several places. Again, we suspect the low-resistance condition occurred where the Vycor tube cracked and allowed char to collect along the wall.

The Vycor section was replaced with a 3-foot length of 5-inch-ID x 5-1/2-inch OD mullite tube before No. 6 heat-up test. The electrode configuration consisted of an 1-1/2-inch stainless steel rod as the upper electrode and an 8-inch length of 1-1/2-inch stainless steel rod mounted on the bottom cone as the lower electrode (Figure 2). The spacing between electrodes was decreased to 2 inches to lower the overall resistance of the system. At a voltage output of 350 volts the resistance was about 50 ohms and the corresponding power input did not increase the bed temperature. The voltage was

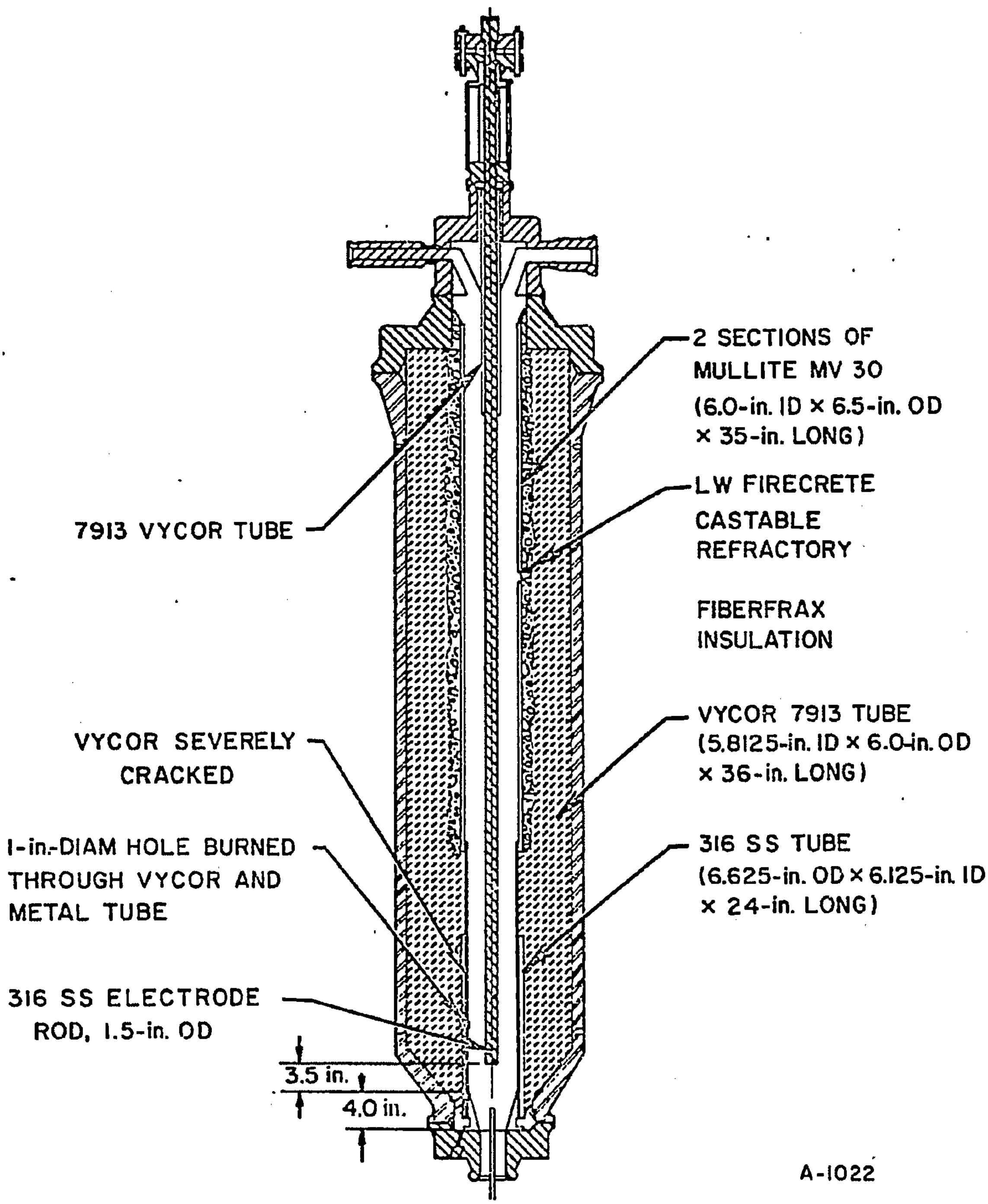

Figure 1. END-TO-END ELECTRODE CONFIGURATION FOR HEAT-UP TEST NO. 5

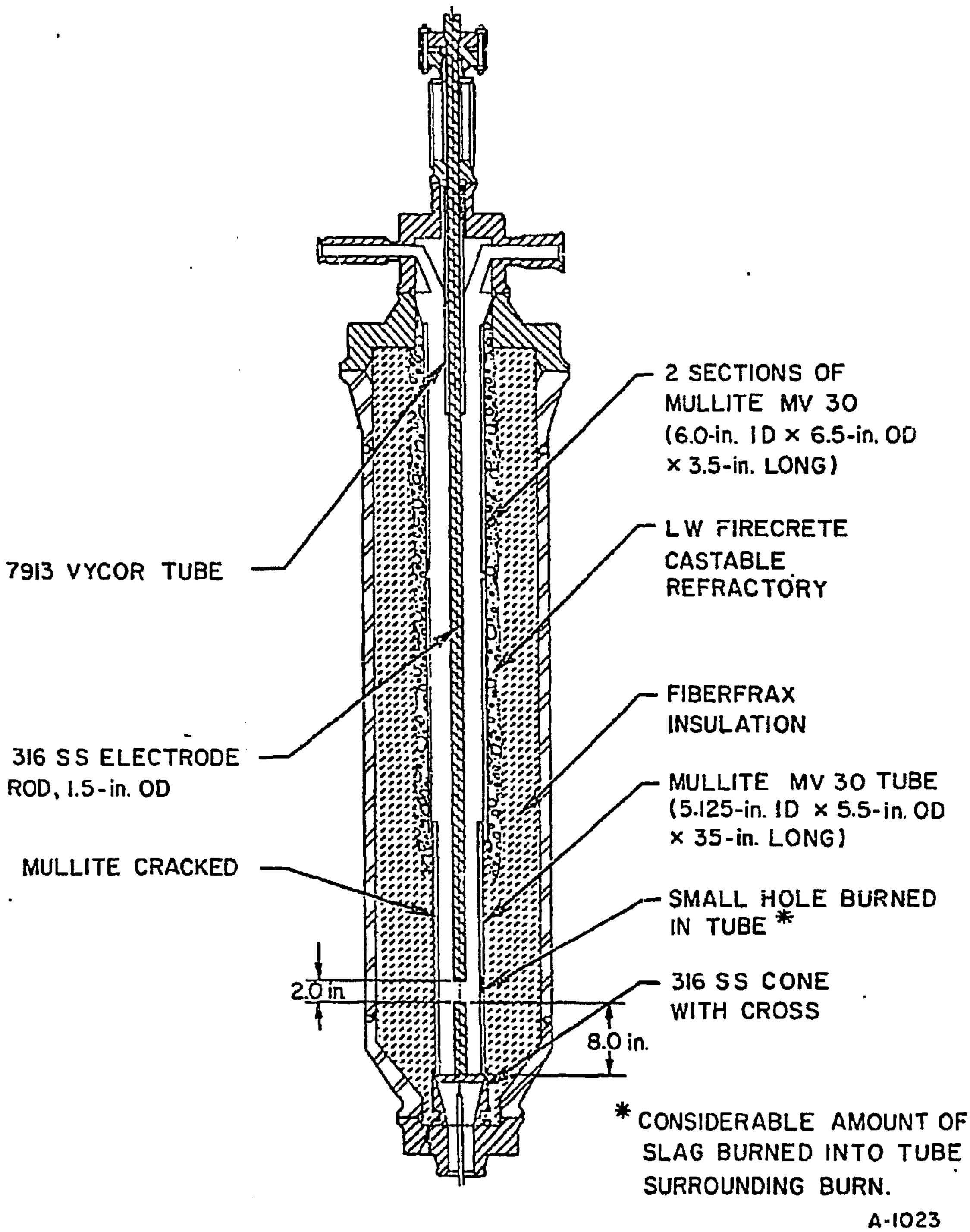

Figure 2. END-TO-END ELECTRODE CONFIGURATION FOR HEAT-UP TEST NO. 6

increased to 375 volts when the appearance of arcing occurred and the overall resistance decreased to 5 ohms in several minutes. The test was terminated when the arcing could not be arrested by decreasing the voltage. The arcing caused slight melting of the tips of both electrodes and burned a 1-inch-diameter hole through the mullite tube near the tip of the upper electrode.

The bottom section of mullite was replaced with a high alumina castable refractory (Johns Mansville H. T. Firecrete, 2808°F) for heat-up Test No. 7. Previous experience with castables of this type has shown them to be more durable than mullite or Vycor. A 3-foot length of 6-1/2-inch-ID x 8-1/2-inch-OD tube was installed as shown in Figure 3. The electrode configuration and spacing were the same as in Test No. 6 except the electrode assembly was raised 6 inches into the reactor. During the run, to observe the effect of the increased flow rate on the operation, the nitrogen superficial velocity was maintained between 0.3 and 0.4 ft/s as compared to 0.2-0.3 ft/s in previous tests. At 550 volts the overall resistance was 50-75 ohms and prevented us from obtaining the power input meeded to raise the bed temperature above 700°F. The test was terminated after several hours. No indications of arcing had occurred. Examination of the electrodes and reactor bottom following the run showed them to be in good condition.

In heat-up Test No. 8 the same electrode configuration and spacing were maintained. During the test we attempted to control the overall resistance of the system by varying the nitrogen flow at a rate below minimum fluidizing velocity that would enable the attainment of a power input sufficient to heat the reactor but would also prevent arcing from occurring. However, we were unable to maintain a stable operation and terminated the run when arcing occurred in the bed. Observation of the electrodes following the test showed that the tip of the upper electrode was slightly melted but that the bottom electrode was unaffected and the refractory wall was undamaged.

The fifth test, No. 9, was conducted with the same electrode configuration as the previous two tests except with a 1-inch spacing between electrodes. The purpose of the test was to determine if a voltage gradient could be reached in the bed if breakdown across the bed material had begun. We also hoped to obtain from the voltage-current relationship the overall resistance, before the occurrence of arcing, to compare with previous measurements at various electrode spacings. At 550 volts the resistance had been 50-100 ohms

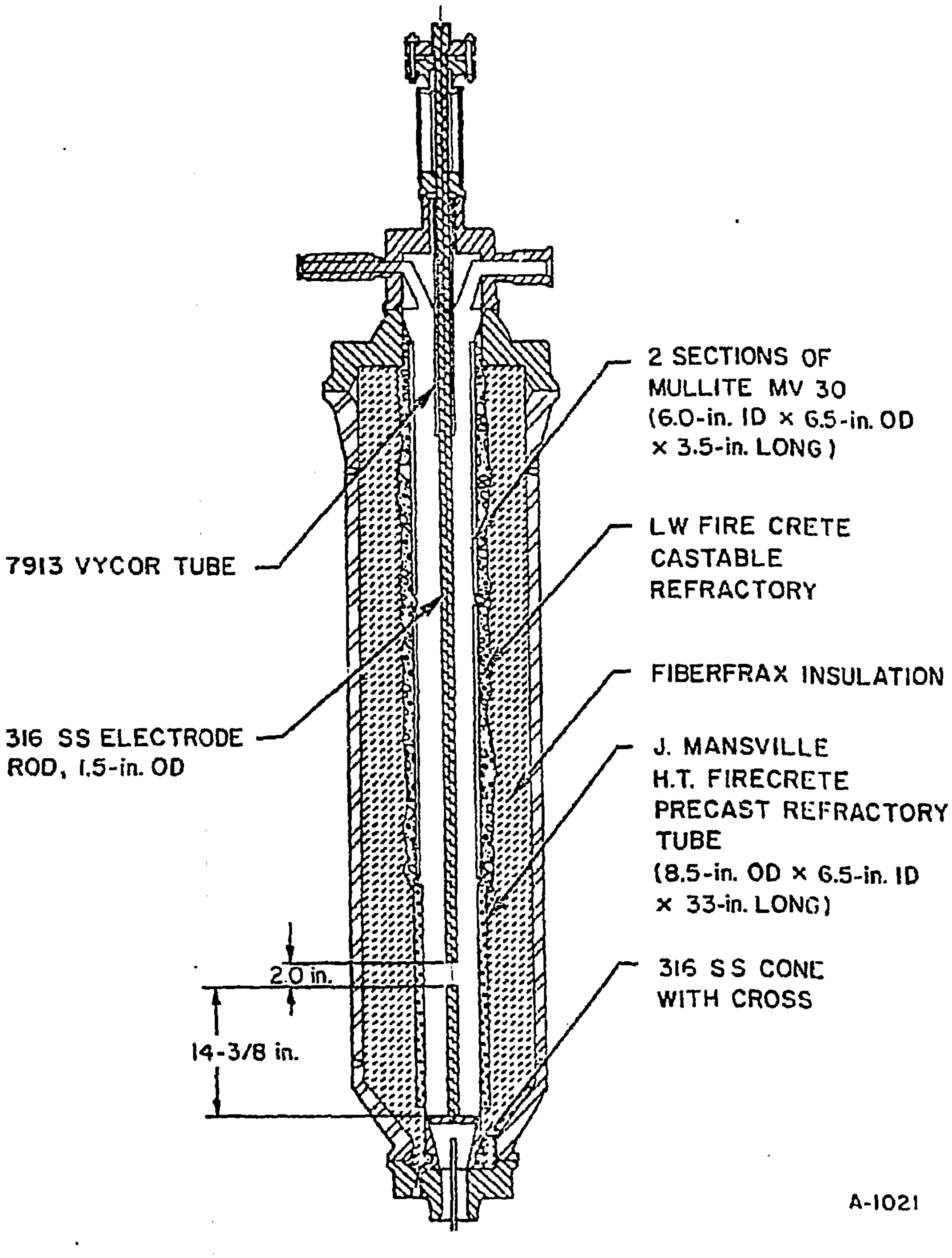

Figure 3. END-TO-END ELECTRODE CONFIGURATION FOR HEAT-UP TESTS NOS. 7, 8, AND 9

for 20 minutes when, soon after the first sign of arcing, a rapid short-circuit occurred and the run was terminated. The short circuit damaged a set of contact brushes in the generator and melted the metal at the ends of both electrode tips. Although we are not certain of the cause of the arcing, the voltage gradient between electrodes was 550 volts/in.

From results of the end-to-end electrode tests we concluded that with our present power supply it is not possible to achieve the required reaction heat input in the pilot unit because of the high overall resistance of the system.

The pilot unit has been dismantled to change over to a concentric electrode arrangement to emphasize obtaining additional operating data for design specifications of the 2-megawatt electrothermal reactor.

FUEL CELL ENGINEERING STUDY

Stacking Arrangement

The basic design of the components of a unit cell was reported in last month's report. Five such unit cells are placed one over the other to form a module. An extra heat transfer gap is provided to comply with heat transfer requirements. Twenty modules along with end plates and tie rods constitute a battery. A battery occupies about 50 cubic feet and produces 150 kW of power. Eight of these batteries are stacked in a package. Figure 4 is such an eight-battery power package. All the batteries are connected in series to produce a terminal voltage of about 600 volts. Selection of this design is based on trade-offs between the following considerations:

1. Minimum number of gas connections and, hence, minimum number of valves, etc.
2. Minimum possible pressure drop in the gas manifolds at a minimum cost
3. Ease of current collection and minimum allowable power losses
4. Compactness
5. Insulation cost
6. Accessibility for maintenance and control

Cathode gas from the mains enters the central manifold and goes to the individual cathodes of the eight batteries through entry ports. The gas follows a "W" flow pattern. Cathode exhaust gas is collected in the two manifolds that join together the downstream mains. Part of cathode gas also

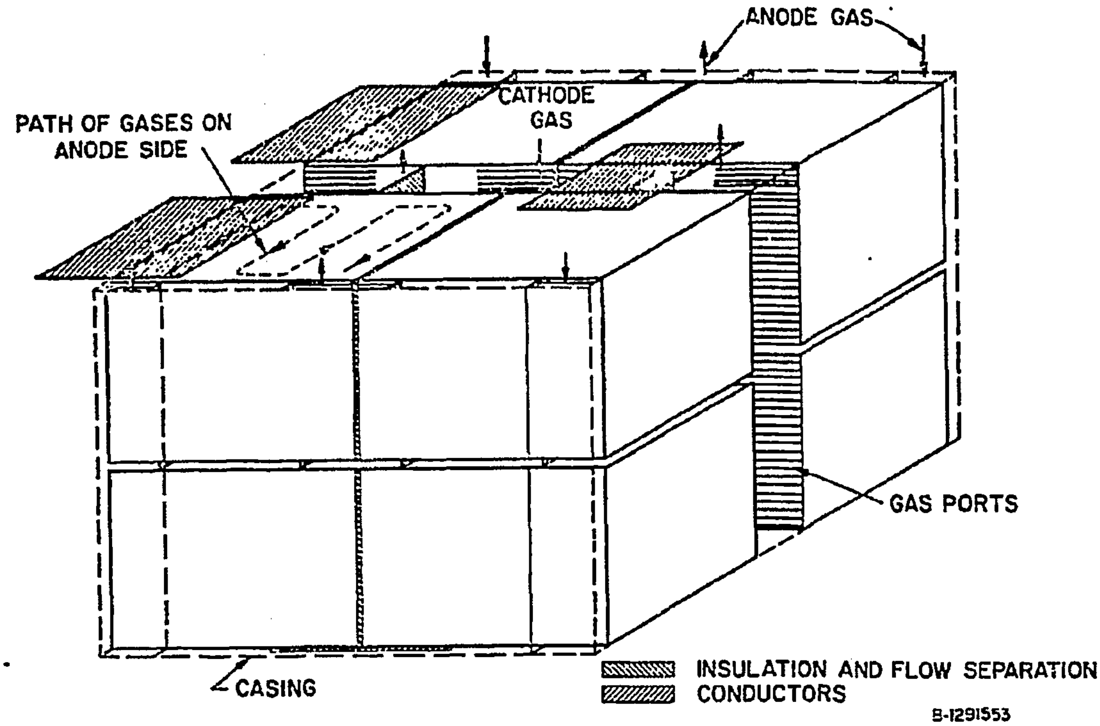

Figure 4. STACKING ARRANGEMENT FOR EIGHT BATTERIES IN A PACKAGE

passes through a heat transfer gap in a "U" flow pattern. Anode gases are mainfolded in a similar fashion, but they flow in the countercurrent direction within the cell.

Type-316 stainless steel is used for current collection. Gas streams are separated from one another by alumina spacers. The casing is made of mild steel sheets lined with a refractory and insulated externally. Refractory lining, insulation, and battery supports are not shown in Figure 4 for simplicity.

Parasitic Power Requirements

A good stacking arrangement should yield reasonable parasitic power requirements for handling various gas streams. It should also ensure a reasonably uniform gas distribution to each individual cell. Power requirements for the entire plant are estimated to be about 9% of the gross d-c power generated. Some parasitic power can be saved if high-pressure interface streams from the HYGAS plant are used to advantage.

Preliminary Cost Estimate of Power Package

The cost of a package of fuel cell batteries contributes significantly to the total capital investment cost of a power station. Costing is therefore made for the components of a package. A bill of materials is prepared for all major components of the package. Weight of each component is calculated from design specifications, and the material cost of each component is calculated. Purchased equipment cost (PEC) is then obtained by using cost multipliers based on knowledge of the cost of similar products and experience. Table 7 lists multipliers for various components and conventional multipliers. We have revised some of these conventional multipliers to obtain more realistic cost figures. The purchased equipment costs for various cost centers are summarized in Table 8. For a power density of 150 W/sq ft, which is presently achieved in our laboratory, the PEC for a package is estimated to be $82/kW (Estimate A). This estimate is somewhat higher than the estimate obtained by conventional multipliers (Estimate B). Estimate C gives a cost of $52/kW for a forecast power density of 300 W/sq ft. It should be emphasized here that further improvements in the present design are possible and that they will bring down the cost figures to a still lower level.

Estimates of PEC for other subsystems will be made with the help of rough designs. An estimate of the total capital investment will then be obtained by adding installation, utility, and civil engineering costs. We also plan to obtain operating cost per kW of energy generated.

PILOT PLANT CONSTRUCTION

Engineering

A major portion of the engineering effort during this report period has been on the piping plan and isometrics. Eighty percent of the piping plans and details have been issued. Electrical detail drawings are 90% complete, and instrument drawings are 25% complete. Total project detailed design and drafting are 90% complete.

Procurement

Repair of a minor crack in a reactor manway has caused a delay in the shipping date. The reactor is now scheduled to be shipped January 9, 1970. Major equipment is arriving as promised; no items have been delayed so as to affect the project schedule.

Table 7. COST MULTIPLIERS (M) FOR OBTAINING PURCHASED EQUIPMENT COST (PEC) OF INDIVIDUAL COMPONENTS

PEC = (Wt of component in lb X cost in $/lb) X Multiplier, M

Description	Material	IGT Cost Multiplier M_1	Conventional Cost Multiplier M_2
Cell Components			
Anode	Ni felt	8.0	4.0
Cathode	Ni felt	8.0	4.0
Electrolyte	Li-Na-K:CO_3 + Al_2O_3	5.0	1.7
Distributor Plate	SS 316 L	2.0	1.7
Module Components			
Spacer (Heat Tranfer Gap)	SS 316 L	2.0	
Battery Components			
End Plate	SS 316	1.5	1.7
Tie Rod	SS 316	1.5	1.7
Casing Components			
Anode Stream Separator	Alumina	5.0	1.7
Cathode Stream Separator	Alumina	5.0	1.7
Insulation Between Batteries	Alumina	5.0	1.7
Interbattery Current Collector	SS 316	1.5	1.7
Interbattery Current Bottom	SS 316	1.5	1.7
Interbattery Current Top	SS 316	1.5	1.7
Terminals	SS 316	1.5	1.7
Casing Inner Lining	Fireclay	5.0	1.7
Casing Shell	Mild Steel	5.0	1.7
Thermal Insulation	Kaolin Wool	5.0	1.7

Table 8. ESTIMATED PURCHASED EQUIPMENT COST (PEC) FOR PACKAGE

Estimate A: Present performance (150 W/sq ft), IGT cost multiplier (M_1)

Estimate B: Present performance (150 W/sq ft), conventional cost multiplier (M_2)

Estimate C: Forecast performance (300 W/sq ft), IGT cost multiplier (M_1)

		A			B	C
Cost Center	Description	Weight, lb/pkg	PEC, $/pkg	% of Total PEC	PEC, $/pkg	PEC, $/pkg
1.0	Unit Cell	31,496	64,540	65.6	39,610	76,400
2.0	Module Components	7,728	19,460	19.8	16,550	29,040
3.0	Battery Components	1,307	2,960	3.0	3,360	2,960
4.1	Gas Stream Separators	739	225	0.2		
4.2	Current Collectors	792	1,402	1.4		
4.3	Casing Shell, etc.	7,820	4,790	4.9		
4.0	Casing Components	(9,351)	(6,417)	(6.5)	3,290	9,700
5.0	Miscellaneous	--	5,000	5.1	5,000	5,000
	Total per Package	49,882	98,377	100	78,557	123,100
	Power Produced, kW/pkg		1,200		1,200	2,400
	Total per kW	41.5	82		56.5	51.4

Purchase orders have been issued for the carbon steel pipe, valves, and fittings. The alloy valve purchase order has been issued. The alloy pipe and fittings will be issued during the week of December 15th. The electrical subcontract bid package will be sent out during the week of December 15th.

Construction

The foundation work is approximately 82% complete, with some of the pipe rack footings and three building foundations remaining to be poured. The control house is approximately 70% complete, with the heating, lighting, and interior trim remaining. Field fabrication of piping has begun, as has the setting of equipment.

The procedure for erecting the reactor has been completed. The procedure is based on the use of two gin poles. The reactor platform structure will then be immediately erected.

Schedule

The project schedule has been updated on the following basis: revised reactor delivery, detailed labor hour take-off of piping work, and general review of all construction activity and sequence.

Construction activity durations have been based on expected availability of manpower in the various crafts. By February 15th Procon will know if these expectations are correct.

Indications are that the June 1, 1970, completion date will be delayed by about a month.

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