DOE/ET/10159--T10

DE83 000830

FOSSIL FUEL PROCESSING TECHNICAL/PROFESSIONAL SERVICES

FUTURE USE OF BI-GAS FACILITY FINAL REPORT

PREPARED FOR

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UNDER CONTRACT NO.
DE-AC01-78ET10159

SEPTEMBER 1981

A JOINT VENTURE OF
UOP INC. AND
SYSTEM DEVELOPMENT CORPORATION

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TR-81/008-02
FINAL

FUTURE USE OF BI-GAS FACILITY
FINAL REPORT
(PART II)

September 1981

PREPARED FOR THE
UNITED STATES DEPARTMENT OF ENERGY

UNDER CONTRACT NO. DE-AC01-78ET10159

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SECTION 1 - EXECUTIVE SUMMARY

Erection of the 120 tpd BI-GAS pilot plant, intended to produce SNG at high pressure, was completed in 1976. For the next three and a half years, the operator, Stearns-Roger Inc., was engaged in operating the plant while overcoming a series of mechanical problems that have prevented the plant from running at design capacity and pressure. Since July 1980, these problems have apparently been corrected and considerable progress was made.

In late 1979, the Yates Congressional Committee directed DOE to investigate the possibility of establishing an entrained-bed gasifier test facility at the site. In January 1981, the DOE established a study group composed of DOE and UOP/SDC personnel to determine how best to use the BI-GAS facility.

The group considered three possibilities:

- Continue operation of the facility in accordance with the technical program plan* developed by DOE and Stearns-Roger,
- Modify the plant into an entrained-bed facility for testing components and processes,
- Mothball the facility, or
- Dismantle the facility.

The group took the view that modifying the plant into a test facility would increase substantially the amount of engineering data available to the designers of commercial gasification plants. Since it appears that syngas plants will be of commercial interest sooner than SNG plants will, it was decided that the facility should test syngas production components and processes at high pressure.

* Reference: Stearns-Roger Inc., Technical Program Plan, August 1980.

At the beginning of the task, the study group selected ten areas pertaining to gasification in which the need for more engineering data is most apparent and important. The contributions that could be made to each of those areas by the two possible courses of action (continuation of present activities or modification of the existing plant into a test facility) were then assessed. The modifications required to change the BI-GAS plant into a high-pressure syngas producing entrained flow test facility were designed, and order-of-magnitude costs were estimated for making those modifications or, alternatively, for mothballing or dismantling the plant.

The study group concluded that worthwhile data could be obtained by continuing present operations, provided known and foreseeable problems could be overcome. However, more data could be obtained by modifying the plant to an entrained-bed test facility where various gasification concepts and associated equipment could be tested. The cost of the necessary modification would be far less than the cost of mothballing or demolishing the plant, in which case no engineering data of any kind could be generated and the experience gained thus far would become futile.

Consequently, it was recommended that:

- Operation of the plant be continued, both to collect data and to prove the BI-GAS process, as long as the schedule of the technical program plan is met;
- Begin at once to prepare a detailed design for modifying the BI-GAS plant to a high-pressure, entrained flow syngas test facility; and
- Implement the modification plan as soon as the BI-GAS process is proven or it becomes apparent that progress is unsatisfactory.

SECTION 2 - BACKGROUND

The BI-GAS process uses a high pressure, two-stage gasifier in which coal is devolatilized and gasified in an upper (second) stage by a steam and synthesis gas mixture produced by a steam-oxygen reaction with char in a lower (first) stage. The first stage is a wet, slagging bottom gasifier.

Stage two of the process was demonstrated at PDU scale (100 lb/hr) in 1969 through 1971. A 120-tpd, 100-atm pilot plant was completed at Homer City, PA in 1976, but initial operations were plagued by a succession of problems and mechanical failures. For safety, natural gas was added to the first stage of the gasifier to ensure complete consumption of all oxygen fed to this stage. In May 1981, the gasifier was operated for the first time without addition of this supplemental fuel thereby proving the viability of the BI-GAS process at the pilot scale.

In November 1979, the Yates Congressional Committee directed DOE to investigate the possibility of establishing an entrained-bed test facility on the site of the BI-GAS plant. In early January 1981, the Division of Coal Gasification of DOE, the Morgantown Energy Technology Center, and UOP/SDC formed a team to study the feasibility of alternative uses for BI-GAS facility as a test and evaluation center for entrained bed components and process developments. The results of the study are presented in this report.

SECTION 3 - STUDY APPROACH

3.1 RATIONALE FOR CONVERSION

The purpose of establishing a technological test facility by modifying the BI-GAS pilot plant facility is to provide engineering data (not presently available) that would be useful in designing and operating gasification plants of demonstration/commercial scale. It will test new equipment to demonstrate its commercial applicability. A facility that would serve this purpose would be one of at least pilot scale that could operate without interruption for at least 30 days in a steady state operation. It would also be flexible enough to:

- Permit the operating variables to be varied over a wide range of conditions,
- Permit equipment or components to be changed at reasonable cost, and
- Operate with a variety of feedstocks, including highly caking eastern coals.

The BI-GAS plant may not be able to meet that operating time requirement without modification. As of April 1981, the longest run achieved was 172 hours.

However, Stearns-Roger Inc., which has operated the BI-GAS facility since 1976, is continuing its development as outlined in the technical program plan. That plan would have the facility be capable of long runs in early CY 83 if all objectives were met on schedule. Although the early history of the BI-GAS project is not reassuring, the possibility that long-term operability might be achieved as planned cannot be dismissed. However, there is of course no guarantee that the technical program plan for the development of the BI-GAS facility will meet its objectives on schedule. If success is not achieved, enhancement of the engineering data base may be indefinitely delayed. Thus, there are valid arguments for going ahead with conversion.

3.2 CONVERSION OPTIONS

The BI-GAS gasifier has a two-stage configuration, which promotes the production of methane. Since producing methane from coal gasification is currently of less interest to industry than syngas production, it appears that use of a single-stage gasifier (which favors syngas production) would be a more logical choice now for a test facility.

It may be possible to modify the BI-GAS gasifier to a single-stage syngas producer by injecting coal into the present lower-stage char burners. If such a modification were judged too inefficient, a major modification involving replacement of the upper stage might be made, using the present bottom stage only for ash removal. Other modifications of the plant to provide the required flexibility should not be difficult to make.

3.3 STUDY PLAN

Because it is not clearly evident whether it is better to convert the BI-GAS facility or to continue its planned operation, it was decided to consider both possibilities in this study. As a means of doing so, it was decided to make the first step a listing of the types of engineering data one would hope to gain from an engineering test facility, then to assess the contributions that both options could be expected to make to that data, and finally to determine the cost of making the conversion under the two modification possibilities. It was recognized that the depth of the study would be limited by the time available for performing it.

SECTION 4 - DESCRIPTION OF BI-GAS PLANT

The BI-GAS pilot plant is a "grass roots" facility designed to study coal conversion from gasification through methanation to high Btu pipeline quality gas. A two-stage, entrained flow high-pressure gasifier designed to process a maximum of five tons per hour of coal is the principal feature of this process. Facilities for sulfur recovery and environmental protection are incorporated into the design and operation of the plant.

A schematic of the BI-GAS plant is shown in Figure 4.1, and details of the gasifier in Figure 4.2. A pulverized coal-water slurry is pumped to gasifier pressure (1500 psig maximum), preheated with steam, and mixed with recycle gas just prior to entering the spray dryer. After the water is evaporated in the dryer, the steam, gas, and coal mixture is taken to a cyclone. In the cyclone, the solids are separated from the steam and gas, and the dry coal drops into a feed vessel. The gas and steam are returned to a washer to remove any small particulate solids and to condense and dispose of the steam. The remaining gas is then compressed, heated, and recycled to the spray dryer. From the coal vessel, dry coal is fed through two legs by means of differential pressure into Stage II of the gasifier. Once the pulverized coal enters Stage II, it is contacted with hot reducing gas from Stage I to form synthesis gas and char. The char produced is carried by the hot gases upward through the refractory lined Stage II into a cyclone. The char is separated from the raw product gas in the cyclone and drops into a char feed vessel. The raw product gas continues to the gas washer for ammonia and particulate removal and then to a Selexol unit for absorption of the hydrogen sulfide.

Char is fed from the char vessel through three legs and injected into Stage I of the gasifier with high pressure steam through the three char burners. In the burners, char and motive steam pass through a central tube, additional reaction steam and fuel gas when necessary through a surrounding annulus, and oxygen through two separate coils. Cooling water is circulated through the burners to protect the assemblies, oxygen coils, and tip. A high temperature reaction takes place in Stage I (2500°F to 3000°F) that produces slag and a

Figure 4.1 General Schematic of BI-GAS Plant.

Figure 4.2 BI-GAS Gasifier.

reducing gas of approximately 35% hydrogen. The slag exits through a taphole, is quenched in water, and is removed from the gasifier by dual lockhoppers.

Testing of the gasifier was started in December 1976. In a base condition test, Stage I was fired with natural gas, oxygen, and steam, and Stage II was fed only purge gas and steam (no coal). The conditions were designed to match, as nearly as possible, the gasifier conditions that would exist when operating at 750 psig with a 3.5 ton/hr coal feed to Stage II and char recycle to Stage I. The objectives of the test were to determine gasifier heat loss and to establish reliability of equipment, instrumentation, and the data acquisition system. After the base condition test was completed, test G-1 was started. The last test reported is G-17E, run during July 1981. A summary table describing tests G-5 through G-17D appears in Appendix A. For each test, the table shows the date, the hours of feed operating of coal and char, the reason(s) for shutdown, observations and remarks, and the major revisions and repairs after the test.

SECTION 5 - DESIRABLE DATA AREAS

5.1 INTRODUCTION

The study team selected ten areas in which more engineering data than now exist would be helpful to the designers of gasification plants. The selection was made on the basis of the team members' personal knowledge of what the principal data needs are. The areas are listed below - not in order of importance, because they are all important. Existing projects to which new data could be applied are identified.

5.2 HIGH-PRESSURE SYNGAS PRODUCTION

Hydrogen production through the low-pressure coal-syngas-hydrogen route is a commercially available technology. This low-pressure technology is often used to produce hydrogen for use in ammonia synthesis. The low-pressure operation of a syngas producer requires uneconomical compression of the dirty gas prior to ultimate production of hydrogen. Syngas production using coal and char gasification at high pressure is not commercially proven in the U.S. or elsewhere. The operating experience gained from a high-pressure syngas gasifier would be beneficial to the support of hydrogasification and hydroliquefaction programs, e.g., Rockwell, SRC-I, and H-Coal.

Since the present BI-GAS gasifier is not designed to produce syngas, data could be secured in this area only by modifying or replacing the gasifier.

5.3 FLUIDIZED CHAR MANAGEMENT

Char behaves differently from coal in a fluidized state at high temperature and pressure. The engineering data base on char fluidization could be enhanced by the operating experience obtainable from the BI-GAS plant. This work would support the COGAS gasification system and the Rockwell FHP (Flash Hydropyrolysis) process.

Specifically, the facility could be used to test:

- Fluidized char flow characteristics at high temperature and pressure,
- Reliable measurement of char flow at high temperature and pressure.

This area could not be explored in a single-stage/entrained-bed gasifier, since no significant amount of char would leave the gasifier.

5.4 HIGH PRESSURE COAL SLURRY PUMP EVALUATION

Reliability, availability, maintainability, and materials of construction information for high-pressure coal slurry pumps should be accumulated for use in commercial plant design, since the available technical data base on such pumps is almost non-existent. High-pressure slurry pump data would support Texaco gasification and might be transferable to other programs, such as SRC-I and H-Coal.

5.5 SLAG FLOW MANAGEMENT

Slag flow management is crucial to the steady and continuous operation of a slagging gasifier.

Specifically, the facility could be used to test:

- Effect of fluxing agents on slag tapping operation,
- Measurement of high temperature in slagging and corrosive environment,
- Refractory lining performance,
- Testing of rotary and seal valves for slag, and
- Quenching (heat recovery) and removal of slag from gasifiers.

This testing program would support all other slagging gasification programs, such as Texaco, Combustion Engineering, Shell, and BGC/Lurgi.

5.6 ACID GAS REMOVAL

A Selexol system for high-pressure producer gas treatment has not been available on a commercial scale. The Selexol facility now available at the site can be used to gain valuable operating experience and commercial design information.

Most commercial and demonstration designs (Texaco and Shell gasification processes, among others) have specified the Selexol System for selective removal of H_2S and CO_2 from syngas.

5.7 SHIFT AND METHANATION

Adequate data at the pilot plant scale are not available on combined shift/methanation and on the effect of syngas impurities on catalysts. Accordingly, it would be desirable to:

- Convert the existing fluid-bed methanator into a combined shift/methanation system. Overall economics of a combined system is favorable in comparison with a separate shift/methanation process;
- Conduct catalyst life/rejuvenation studies; related effect of impurities such as chlorides, NH_3 , benzene, phenol, etc.; and
- Test catalytic hydrolysis of Carbonyl Sulfide (COS) to H_2S .

Most coal conversion reactor effluents contain chloride, NH_3 , benzene, phenols, and COS. The above catalytic studies will support many other programs.

5.8 ENVIRONMENTAL DATA COLLECTION

Environmental data should be collected that contribute to a growing coal gasification environmental data base. Currently the facility collects data to

satisfy Federal, state, and local permit requirements. In addition, the facility should be used to collect:

- Additional performance data for the Selexol and other pollution control hardware;
- Performance data on a new, state-of-the-art, zero discharge wastewater treatment system;
- Data on the composition of leachate from fresh and suitably aged slag; and
- Other pollution control and ecological data needed to support future commercial coal gasification permit acquisitions and EIS development.

5.9 BLOCK AND CONTROL VALVES

A commercial plant (particularly a coal liquefaction plant) will use several thousand block and control valves in slurry service. Recent operating experience has shown these valves to be susceptible to seat leakage, to have poor maintainability because of solids accumulation in the seat spring cavity, and to have extremely high costs. Alternate valves must be evaluated for commercial application to improve onstream factor and reduce capital costs.

Specifically, the BI-GAS facility can be used to accumulate technical information on block and control valves when used for hot and dirty gas at high pressure in a corrosive and erosive environment - the conditions the gasifier provides.

5.10 INSTRUMENTATION

Major areas of concern are the measurement of temperature, pressure, and multiphase and solid phase flow rate in a hostile environment. Lack of adequate instrumentation has been a major problem in development of the BI-GAS process,

as it has been in the development of other high-pressure and high-temperature coal conversion processes.

It is highly important to have a facility available in which instruments under development can be tested and evaluated in the actual operating environment for which they are designed. No such facility is now available to that sector of the instrumentation industry interested in developing instruments for high-pressure and high-temperature gasifiers. In this respect, the BI-GAS facility could perform a significant service that would be beneficial to all coal gasification and liquefaction processes. At present the BI-GAS Pilot Plant has been testing on-line several types of commercially available instruments for char-gas flow measurement and temperature measurement in a slagging environment.

5.11 MATERIALS OF CONSTRUCTION

Corrosion and erosion are expected to be major problems associated with both gasification and liquefaction processes.

A technical data base on the corrosion and erosion rates of different metals in the actual operating environment would be of great assistance in selecting optimum material for a commercial plant. The BI-GAS facility would provide this operating environment (i.e., high pressure, high slagging conditions).

The facility would continue its role as a test vehicle for continuation and enhancement of current material research by the Metal Properties Council, Argonne National Labs, Oak Ridge National Labs, etc.

SECTION 6 - CONTRIBUTIONS TO THE DATA BASE

6.1 INTRODUCTION

The contributions to the ten engineering data areas that might be expected from each of the two options -

1. continue to operate the BI-GAS plant under the Stearns-Roger technical plan, or
2. modify the BI-GAS plant into a syngas test facility -

are discussed below. Contributions to these data that have already resulted from earlier Stearns-Roger plant operations are presented in Appendix A.

6.2 HIGH-PRESSURE SYNGAS PRODUCTION DATA

6.2.1 Contribution From Planned Stearns-Roger Operation

Recent gasification tests conducted by Stearns-Roger achieved steady-state operation of the BI-GAS plant without using fuel gas in Stage I; Fiscal Year 1982 operations will concentrate on the use of coals other than the Rosebud coal that has been used in all tests to date. Since no conversion of the gasifier is planned, no significant contribution to the high-pressure syngas production data base should be expected.

6.2.2 Contributions From Test Facility

Once the BI-GAS gasifier has been successfully modified to a single-stage entrained-bed configuration, it can be expected that a broad engineering data base can readily be developed.

6.3 FLUIDIZED CHAR MANAGEMENT DATA

6.3.1 Contribution From Planned Stearns-Roger Operation

The tests planned by Stearns-Roger are not specifically directed to accumulation of data on char handling. However, it can be expected that new char handling data (and perhaps new problems) will result from the test runs as operating conditions and coal feed are changed. Tests will continue on new devices for the measurement of high temperature char flow, a problem that must be solved if the technical program plan schedule is to be met. The substantial amount of work Stearns-Roger has already done on this problem is presented in some detail in Appendix A.

6.3.2 Contribution From Test Facility

No applicable data will be produced if the gasifier is modified, since no significant amount of char will leave the gasifier.

6.4 HIGH-PRESSURE COAL SLURRY PUMP EVALUATION DATA

6.4.1 Contribution From Planned Stearns-Roger Operation

The technical program plan does not call for tests or study of the slurry pumps, since these have not been the source of operational difficulties to date. Since long test runs are not planned - 7-day runs are the longest scheduled - the slurry pumps may not be tested severely enough to cause excessive wear or failure. In that case, the only data expected are that the pumps operated successfully for x hours.

6.4.2 Contribution From Test Facility

Stearns-Roger's experience with slurry pumps may be considered atypical: failures have been fairly common in other projects. The long continuous runs the test facility would provide should make it possible to develop reliability data on available pumps. It might be desirable to install a split-stream system that

would make it possible to test pumps of higher capacity than is needed for operation of the test facility.

6.5 SLAG FLOW MANAGEMENT DATA

6.5.1 Contribution From Planned Stearns-Roger Operation

At this time, Stearns-Roger is satisfied with the slag tapping method for non-caking Rosebud coal at the pressures that have been used so far. (Stearns-Roger's experience in this regard is described in Appendix A.) However, if problems occur in operation at higher pressure or with caking coals, modification of the method of slag withdrawal can be expected. The technical plan does not provide for optimizing the slag withdrawal system nor for the accumulation of general data on the matter. Any data gathered will be in response to specific operating problems. Solutions to the broad range of problem areas in slag flow management mentioned earlier in subsection 5.5 cannot be expected to be a result of the current program plan.

6.5.2 Contribution From Test Facility

Both of the two alternative modifications to the BI-GAS gasifier proposed in Section 7 of this report would use the existing slag removal system. However, because of the difference in objective between the current technical program plan and the modified test facility operation, it can be expected that considerably more data will result from the latter.

6.6 ACID GAS REMOVAL DATA

6.6.1 Contribution From Planned Stearns-Roger Operation

In many of its future tests, Stearns-Roger will prove out operation of the entire Selexol system. It can be expected that a substantial amount of useful data will be generated as the test program progresses to the use of caking coals and higher pressures.

6.6.2 Contribution From Test Facility

Data gathered from the modified test facility might be somewhat different from that collected in the present program because of probable differences in the acid gas concentrations in the product gas of each. It can be expected that more variations in operating conditions would be introduced in the modified test facility than in the facility as currently operated, with the result that the modified test facility would produce a broader, rather than process specific data base.

6.7 SHIFT AND METHANATION DATA

6.7.1 Contribution From Planned Stearns-Roger Operation

The BI-GAS plant is designed to use a conventional system of separate shift and methanation. Consequently, such operation will make no contribution toward the collection of data on combined shift/methanation data, which is the data area that was recommended for investigation earlier in subsection 5.7. The catalyst studies recommended in subsection 5.7 are also not part of the current program, so no data on the subject are expected.

6.7.2 Contribution From Test Facility

For the cost of converting the existing fluid-bed methanator into a combined shift/methanation system, the test facility should be able to produce the data desired. Shift/methanation would not normally be functions of a syngas plant but could be included in the test facility as a means of collecting data on the subject.

6.8 ENVIRONMENTAL DATA COLLECTION

6.8.1 Contribution From Planned Stearns-Roger Operation

Stearns-Roger collects emissions data during sustained, steady-state operation of the plant. It is recognized that any environmental data collected in sporadic,

possibly atypical operations over short runs are of limited value. There are plans to have the environmental assessment of the plant done by a subcontractor, Radian Corporation, through cooperative effort with DOE and EPRI when operations with Pittsburgh coal are initiated. However, this program will not be specifically directed toward any of the four specific points mentioned earlier in subsection 5.8.

6.8.2 Contribution From Test Facility

One of the four points mentioned in the preceding paragraph is the collection of performance data on a new, state-of-the-art, zero discharge wastewater treatment system. The present system, in which wastewater is discharged to a treatment pond, would require considerable upgrading to fit that description. Such upgrading, not a part of the technical program plan, could be incorporated into the test facility, as could whatever changes in emphasis and equipment will be required to produce the desired data.

6.9 BLOCK AND CONTROL VALVE DATA

6.9.1 Contributions From Planned Stearns-Roger Operation

As can be seen in Appendix A, Stearns-Roger has already accumulated data in this area. The program plan states, in reference to apparatus (which includes block and control valves), that:

"The objective of this activity is to provide the facilities and operational environment for the testing and evaluation of instrumentation and apparatus directed to solve the specific problems of the BI-GAS process and coal conversion processes in general. The majority of these efforts are program initiated but as opportunity is provided, the pilot plant will be made available for testing purposes."

No specific steps toward attainment of this objective are described in the program plan. The experience cited in Appendix A indicates that, as might be expected, a satisfactory solution to a problem ends work on the problem, whether or not the solution has general application.

6.9.2 Contribution from Test Facility

It is expected that, in the test facility, a valve that had demonstrated satisfactory performance would be replaced by another that had not yet been tested. This difference in emphasis in the test facility operation versus the current technical program plan should produce a much wider data base from the former.

6.10 INSTRUMENTATION DATA

6.10.1 Contribution from Planned Stearns-Roger Operation

Stearns-Roger has already done substantial work on instrumentation, particularly for temperature measurement and char flow measurement (Appendix A). The lack of suitable instruments for these purposes has played a significant role in delaying development of the BI-GAS process. The company's objective with respect to instrumentation was expressed in the preceding subsection 6.9.1, and the comments and caveat given apply equally here.

6.10.1 Contribution from Test Facility

In view of the difficulty Stearns-Roger has had in finding adequate instruments for temperature measurement in Stage I of the gasifier, the concept of testing several such in the test facility may not have practical application. However, when one is found, it would be desirable to test it in a syngas environment. Char flow measurements would not be feasible in the proposed syngas gasifier, however, high pressure, high temperature coal flow reassurement instrumentation is highly desirable and the principles would be similar.

6.11 MATERIALS OF CONSTRUCTION DATA

6.11.1 Contribution from Planned Stearns-Roger Operation

The technical program plan states that:

"An independent responsibility of the program is to conduct such testing and evaluation which will aid in the development of improved materials for commercial application of the process. An ongoing program is in effect by which test strips of a variety of materials are installed in the gasifier system. This program and opportunity will be continued."

The detailed program plan makes no specific mention of such testing and evaluation, which is the responsibility of the Metals Properties Council who have a separate contract with DOE.

6.11.2 Contribution from Test Facility

The chief advantages seen for continued testing of materials in the test facility are that the testing program is more organized and broader in scope than would occur in a syngas environment.

SECTION 7 - APPROACH TO GASIFIER MODIFICATION

The BI-GAS gasifier has not shown itself to be a consistently reliable source of product gas, primarily because of interruptions of recycle char flow to Stage I of the reactor. Accordingly, the study group concluded that the gasifier itself was the main element that required improvement if the plant were to become a test facility. Since it was not clear that the gasifier could be modified successfully, and since there was a time limitation on the study, it was decided to consider two cases simultaneously:

- Case I, in which the gasification section (Stages I and II) of the BI-GAS gasifier would be replaced, and
- Case II, in which the gasification section would be modified.

For both cases, order-of-magnitude cost estimates were to be made.

Four design criteria were established for both cases:

- To minimize modification costs, the reactor was to operate in the slagging mode now used in the BI-GAS reactor.
- It was to be an entrained flow reactor to enhance the data base for such reactors.
- It was to be a single-stage reactor for simplicity of design and operation.
- Only synthesis gas was to be produced, in recognition of the shift of emphasis away from SNG production.

In addition, ability to revert to the BI-GAS mode of operation was required for Case II.

The Texaco, Shell, and Koppers-Totzek (KT) single-stage gasifiers were examined to determine if there were generic requirements for an entrained flow gasifier that could be met by a modified BI-GAS reactor or a replacement for it. All the gasifiers investigated operate at a combustion temperature of $\sim 2700\text{--}3000^{\circ}\text{F}$

and a pressure of ~ 650 psig, except KT which operates at atmospheric pressure. In the Koppers-Totzek reactor, the high temperature was maintained through the entire reactor, while the others cooled the gases as they proceeded through, sometimes to as low as 1800°F . The velocities varied over a wide range, from 2 fps to almost 40 fps, with flows upward in two and downward in Texaco. The residence times varied greatly also (2-10 seconds). None of the gasifiers recycled and reinjected the char and ash carried overhead. It was found that there is not what might be considered to be a standard entrained flow gasifier.

The present BI-GAS gasifier, shown in Figure 4.2, is divided into stages, Stage I and Stage II. Present Stage I operational conditions are approximately 750 psig and 2700°F . Char, oxygen, and steam are injected in this stage to provide the H_2 and heat for the carbon gasification reactions occurring in Stage II. As an additional safety precaution to guard against oxygen-rich conditions, natural gas can be injected in Stage I; one of the development aims is to find means of measuring char flow that will provide more complete data on process operating conditions. In Stage II, coal and steam are injected into the rising stream of synthesis gas from Stage I.

Measurements in test runs in late 1980 and early 1981 showed that velocities in Stage II of the gasifier are approximately 2-3 fps, and residence time is approximately 8-11 seconds. These conditions were based upon coal feed rates of 4,000 to 6,000 lbs per hour. The outlet temperature is $\sim 1600^{\circ}\text{F}$, which is much cooler than that of other synthesis gas gasifiers; therefore, more methane is produced and the carbon in the coal is not completely gasified. The char carried overhead is reinjected in Stage I, as stated above.

The operating conditions in the BI-GAS gasifier are similar to those in a manufacturer's proposal submitted for the Coal Gasification Multi-Test Facility (GMTF). (This is probably not a coincidence; the same manufacturer designed the original BI-GAS process.)

The results of the technical evaluation of Case I are given in Section 8 and those of Case II in Section 9. Cost estimates for both cases are given in Section 10.

SECTION 8 - REPLACEMENT GASIFIER STUDY (CASE I)

8.1 BASIC DESIGN

After evaluation of the Texaco, Shell, and Koppers-Totzek reactor configurations, it was decided to adopt the concepts of the pressurized entrained flow gasifier proposed for the GMTF. This gasifier is described in a report entitled "Technical Data and Design of a Pressurized Entrained Coal Gasification Process," which is summarized in Appendix G to UOP/SDC Report DOE/ET/03117-T1R on the GMTF. The principal reasons for selecting it were that a scalable design existed and its operating conditions were similar to those of the BI-GAS gasifier. Only the reactor from the GMTF report and its auxiliaries were considered.

The proposed GMTF reactor had a design capacity of 1500 tons per day of Illinois No. 6 coal. For the Case I study, the design rate was scaled down to 5 tons per hour.

It was intended to use the existing BI-GAS pilot plant facilities as much as possible to minimize capital expenditures. The present coal feed system was deemed to be satisfactory. The water quench system used to reduce the temperature of the reactor effluent gases was also considered to be satisfactory. New product gas cleanup cyclones were added because of the increased gas flow through the system. The increased size of the new cyclones made a new cyclone vessel necessary. It was decided not to recycle any unreacted char to the reactor on the assumption that sufficient conversion of the feed coal would take place to make recycle of the unburned char impractical. Therefore, new fly ash/char handling facilities, namely lockhoppers and screw conveyors, were added to the system. These few items constitute the new equipment required for a reactor replacement mode of operation for the BI-GAS facility.

The GMTF design calls for the reactor zone to have an operating temperature of 2900°F to ensure a slagging operation with as complete coal conversion as is practical within the allowed reactor retention time. In the study team adaptation of that design, a primary water quench is added on top of the modified GMTF

reactor to bring the 2900°F gases down to 1850°F to freeze the entrained slag (which may be gaseous, liquid droplets, or molten), and the water quench system currently installed in the BI-GAS facility is used to further reduce the gas temperature from 1850°F to 500°F. This temperature was selected so that the additional downstream equipment could be of either carbon steel or relatively low alloy construction. The gas flow out of the cyclones was checked to determine its compatibility for use with the existing equipment as presently designed and built. It is believed that the present equipment would be adequate to handle the gas flows from the proposed reactor. Some small amounts of additional boiler feed water for use in the quench system and for ash and/or dust cooling would be required. It is considered that these amounts could be supplied by the existing surplus capacity from the present pilot plant facilities. Also, the bottom ash (slag) facilities were deemed to be adequate to handle both the molten slag and subsequent slag-water slurry as well as the dust slurry from the cyclones.

8.2 NEW REACTOR

Since the bottom ash quench section of the existing reactor appeared adequate, it was retained in the UOP/SDC design. Consequently, the bottom flange of the new reactor section was designed to match that of the existing ash quench section. The flange to flange distance from this ash quench flange to the inlet flange of the water quenched system was maintained in the design of the new reactor and the primary quench section. The residence time was increased from the design rate of approximately 6.6 seconds of the present BI-GAS reactor up to an arbitrary 10 seconds in the proposed design. This was done in an attempt to insure complete conversion of the coal in the 2900°F combustion zone. The primary quench section, designed to reduce the gas temperature from 2900°F to 1850°F, was conceptually altered from that of the GMTF design because of the small size (2 ft. I.D.) of the section in the pilot plant unit. The water quench spray system was retained, but instead of using internal jackets to remove some heat, an external jacket was provided. The reactor as scaled down from the GMTF design is shown in Figure 8.1. The overall processing scheme is shown on the Process Flow Diagram, Figure 8.2 (Drawing No. 3637-08.00-99-001-D).

The new elements of the system are darkened in this diagram. The material balance (Table 8.1) is a compilation of the existing design flows for the pilot plant as well as modified flows from the GMTF design. This is a preliminary balance and should be checked further before any commitment is made to a final design.

8.3 ALTERNATIVE QUENCH METHODS

Several alternative quench methods have been proposed in case the initial proposal of spray quenching plus external jackets failed to cool the effluent gases from the 2900°F operating temperature to the 1850°F level desired. The first is a quench using a fog nozzle to atomize the quench water with steam so as to maintain a cold curtain of water droplets on the wall. Doing so would prevent the slag particles from freezing on the wall and causing a buildup that would be detrimental to heat transfer and could eventually plug the system.

A second proposal is to use frozen slag droplets in a rising curtain mode of operation to protect the wall from the still molten slag droplets in the hot gas. This method has been successfully demonstrated at Leatherhead, England in work done on the COGAS Project. The slag particles would have to be collected in a cyclone system and recycled back to the bottom of this quench system, and a net draw would have to be removed to maintain the material balance of the system. This would introduce an additional fluidized system to the process and might prove to be too expensive.

Another suggestion is to use silicon carbide to line those areas in which it is felt that molten slag would impact on a cold wall and possibly stick. It has been found from experience that slag will not stick to silicon carbide.

A further suggestion is to have a porous metallic plate as the liner through which a cold quench material would be passed. This material could be recycle gas, steam, or even liquid water. This arrangement would have the advantage of maintaining the pressure wall at a low temperature and still providing a means of cooling and freezing the slag particles before they could stick onto cold surfaces to cause problems.

Figure 8.1 GMTF Design.

PRELIMINARY
FOR COST ESTIMATE ONLY

DESIGN DATA	CODE <u>ASME-VIII DIV. 1</u> STAMP <u>YES</u>		SHELL <u>SA-387 GR 22 CL. 2</u>		LADDER & PLATFORM CLIPS		YES	NO	NOZZLE SCHEDULE	N15	1	2"	R.F.	INST. CON'N					
	OTHER SPECS		HEADS <u>SA-387 GR 22 CL. 2</u>		INSULATION RINGS & CLIPS		YES	NO		N14	1	2"	R.F.	LEVEL CON'N					
	DESIGN INT. @ TEMP. <u>1000</u> PSIG @ <u>600</u> °F		SUPPORT (SKIRT)		DAVIT SUPPORTS		YES	NO		N13	2	2"	R.F.	WALL WASH INLET					
	PRESS. EXT. @ TEMP. PSIG @ °F		FORGINGS: <u>SA-336-F-22</u>		PIPE SUPPORT CLIPS		YES	NO		N12	1	6"	R.F.	STALACITE BREAKER					
	OPER. PRESS. @ TEMP. <u>650</u> PSIG @ <u>2900</u> °F				PIPE GUIDE CLIPS		YES	NO		N11	1	6"	R.F.	START-UP BURNER					
	POST WELD HEAT TREAT ☒ YES ☐ NO				FIREPROOFING ATTACHMENTS		YES	NO		N10	2	8"	R.F.	COAL FEED BURNER					
	RADIOGRAPHING <u>100 %</u>				TRAY SUPPORT RINGS		YES	NO		N9	2	2"	R.F.	BFW OUTLET					
	EQUIV. EFFICIENCY SHELL <u>100</u> % HEADS <u>100</u> %									N8	2	2"	R.F.	BFW INLET					
	CORROSION ALLOWANCE SHELL <u>1/8</u> HEADS <u>1/8</u>									N7	4	4"	R.F.	BFW INLET					
TRAYS	FURN. BY		WT. LBS.							N6	4	4"	R.F.	BFW OUTLET					
	INST. BY									N5	2	2"	R.F.	BFW INLET					
WEIGHTS	LADDER & PLATFORM WT.		LBS.		WIND		MW=	FT.-LBS.		N4	2	2"	R.F.	BFW OUTLET					
	NET FAB. WT. (LESS TRAYS)		LBS.		EARTHQUAKE		ME=	FT.-LBS.		N3	2	4"	R.F.	QUENCH WATER					
	EMPTY WT.		LBS.		FIREPROOFING		"I.S. & O.S. (BY OTHERS)"			N2	4	3"	R.F.	BFW INLET					
	OPERATING WT.		LBS.		INSULATION		"THK. (BY OTHERS)"			N1	4	3"	R.F.	BFW OUTLET					
	TEST WT.		LBS.		PAINT					MK.	NO.	SIZE	RTG.	FCG.					
													SERVICE						
										GENERAL NOTES					BY <u>D. JUTLA</u> DATE <u>4/30/81</u> CHKD <u>BY</u> APRVD <u>BY</u>				
										1. ALL DIMENSIONS FROM BOTT. TAN. LINE.					SPEC. NO. <u>W-3637</u> PAGE <u>OF</u> REV. <u>0</u>				
										2. ALL TRAY SPACE DIMENSIONS ARE TO TOP OF TRAY SUPPORT RINGS									
										3. MANWAYS TO BE (HINGED) (DAVITED).									
										4. IT IS VENDORS RESPONSIBILITY TO ASCERTAIN THAT ALL ACCESSORIES ARE ATTACHED BEFORE PWHT, IF PWHT IS REQUIRED.

None of the above mentioned schemes has been carried to the design stage; they are presented as possible alternatives in case the proposed water spray quench and jacket system fail to cool the effluent gases sufficiently. All of the ideas have an industrial or present use background. To make any of them work, it would probably be necessary to put a vortex breaker in the throat of the reactor exit pipe to stop the swirling motion of the reactor gases. (The swirling is started in the base of the reactor because the coal burners were offset 15 degrees tangentially in an effort to simulate present day cyclone combustion burners.)

8.4 PROCESS DESCRIPTION

8.4.1 Raw Gas Treatment Section

Raw gas from the new gasifier (VN-301) is quenched with water to 500°F. The cooled raw gas enters the two new cyclone separators (SN-401 A & B) arranged in parallel. The cyclone separators are contained in a new pressure vessel (VN-402) that also serves to collect the ash removed from the gas stream. The gas leaving the cyclone separators flows to the existing gas washer (V-501).

The solids removed in the cyclone separators are collected in a new ash feed vessel (VN-402). A rotary valve controls the flow of solids from the ash feed vessel (VN-402) to a pair of new ash lockhoppers (VN 1A & 1B). The lockhoppers allow the cyclones to operate continuously. For Case I, each lockhopper is sized to hold 3 hours ash make. A motor driven diverter valve directs the ash to one lockhopper. When that lockhopper is full, the diverter valve directs the ash to the other lockhopper of the pair, and the full lockhopper is valved off.

The full lockhopper is then depressurized, and the ash is removed through a nozzle in the bottom of the lockhopper via a rotary valve. A new dust cooling screw conveyor (ZN-1) conveys the ash from the lockhoppers; cooling water flowing through the hollow screw flights cools the ash to about 140°F. When the lockhopper has been emptied, it is valved off, then pressurized to operating

pressure with high-pressure purge gas. It is then ready for a new fill cycle. A wetting screw conveyor (ZN-2) mixes water with the cooled ash, preventing ash dust from escaping to the atmosphere. The wetted ash, in the form of a slurry, is then sent to the sluice water pond.

8.5 NEW EQUIPMENT LIST

SN-401 A & B (Ash Cyclones)

Two cyclone separators arranged in parallel and enclosed in pressure vessel VN-402 (Ash Feed Vessel) remove particulate content of the product gas from V-301A (Gasifier Quench Section).

VN-1A & 1B (Ash Lockhoppers)

Two lockhoppers receive ash from VN-402 (Ash Feed Vessel). These vessels are identical in size for Case I and Case II. Their storage time is estimated to be 3 hours for Case I and 6 hours for Case II.

ZN-1 (Dust Cooling Screw Conveyor)

One Holo-flite type conveyor is used to indirectly cool the collected dust from VN 1A & 1B (Ash Lockhoppers). The ash will be cooled from 450°F to 140°F with cooling water.

ZN-2 (Wetting Screw Conveyor)

One screw type conveyor with water injection is used for increasing the water content of the material received from ZN-1 (Dust Cooling Conveyor).

A JOINT VENTURE OF UOP INC. AND SYSTEM DEVELOPMENT CORP.

CASE I - REACTOR REPLACEMENT MODE

PROJECT W-3637 T.O.-008

SH. NO 1 OF 5

BY _____

DATE _____

FOR REFERENCE SEE DWGS:

DWG. NO. 3637-08.00-99-001-D

DEPARTMENT OF ENERGY

CONTRACT NO. DEAC01-78ET10159

FUTURE USE OF BI-GAS PILOT PLANT FACILITY

HOMER CITY, PENNSYLVANIA

[illegible]

Table 8.1 Material and Energy Balance for Case I

CASE 1 - REACTOR REPLACEMENT MODE

PROJECT W-3637 T.O. - 078

SH. NO. 2 OF 5

BY _____

DATE _____

FOR REFERENCE. SEE DWGS:

DWG. NO. 3637-08.00-99-001-D

DEPARTMENT OF ENERGY
CONTRACT NO. DEAC01-78ET10159
FUTURE USE OF BI-GAS PILOT PLANT FACILITY
HOMER CITY, PENNSYLVANIA

[illegible]

Table 8.1 Material and Energy Balance for Case I (continued)

CASE I - REACTOR REPLACEMENT MODE

PROJECT H-3637

SH. NO. 3 OF 5

BY_

DATE _____

FOR REFERENCE SEE DWGS:

DWG. NO. 3637-08.00-99-001-D

DEPARTMENT OF ENERGY
CONTRACT NO. DEAC01-78ET10159
FUTURE USE OF BI-GAS PILOT PLANT FACILITY
HOMER CITY, PENNSYLVANIA

[illegible]

Table 8.1 Material and Energy Balance for Case I (continued)

A JOINT VENTURE OF UOP INC. AND SYSTEM DEVELOPMENT CORP.

CASE 1 - REACTOR REPLACEMENT MODE

PROJECT W-3637

SH. NO. 4 OF 5

BY _____

DATE _____

FOR REFERENCE SEE DWGS:

DWG. NO. 3637-08,00-99-001-0

DEPARTMENT OF ENERGY

CONTRACT NO. DEAC01-78ET10159

FUTURE USE OF BI-GAS PILOT PLANT FACILITY

HOMER CITY, PENNSYLVANIA

STREAM NUMBER		421		422, 423		424		425		426	
STREAM NAME		RAW GAS FROM GASIFIER		ASH FROM CYCLONES (EACH)		WATER TO WETTING SCREW CONVEYOR		ASH FROM COOLING CONVEYOR		ASH SLURRY TO POND	
COMPONENT	MOL.WT.	Lb-moles/Hr	Lb./Hr	Lb-moles/Hr	Lb./Hr	Lb-moles/Hr	Lb./Hr	Lb-moles/Hr	Lb./Hr	Lb-moles/Hr	Lb./Hr
CO	28.010	524.03	14,678								
CO ₂	44.010	117.04	5,151								
CH ₄	16.032	6.74	108								
H ₂	2.016	349.70	705								
N ₂ and Ar	28.016	12.17	341								
H ₂ S	34.076	8.60	293								
COS	60.070	-	-								
SO ₂	64.060	0.03	2								
HCN	27.026	0.29	8								
NH ₃	17.032	0.49	8								
H ₂ O	18.016	976.35	17,590			101.476	1,828.20			101.476	1,828.20
COAL (DAF)											
CHAR (DAF)			308		146				292		292
ASH			161		76				152		152
O ₂	32.000										
TOTAL		1,995.44	39,353		222	101.476	1,828.20		444		2,272.2
MOLECULAR WEIGHT		19.49				18.016					
MM SCFD											
TONS/DAY											
OPER.CON. - T,°F/P, PSIG		500/645		500/640		105/15		140/0		105/0	

Table 8.1 Material and Energy Balance for Case I (continued)

A JOINT VENTURE OF UOP INC. AND SYSTEM DEVELOPMENT CORP.

CASE 1 - REACTOR REPLACEMENT MODE

PROJECT W-3637

SH. NO. 5 OF 5

BY

DATE

FOR REFERENCE SEE DWGS:

DWG. NO. 3637-08.00-99-001-D

DEPARTMENT OF ENERGY
CONTRACT NO. DEAC01-78ET10159
FUTURE USE OF BI-GAS PILOT PLANT FACILITY
HOMER CITY, PENNSYLVANIA

STREAM NUMBER		521		522		523					
STREAM NAME		RAW GAS FROM CYCLONES		RECYCLE PURGE GAS		FEED TO GAS WASHER					
COMPONENT	MOL. WT.	LB-moles/Hr	Lb./Hr	LB-moles/Hr	Lb./Hr	LB-moles/Hr	Lb./Hr	LB-moles/Hr	Lb./Hr	LB-moles/Hr	Lb./Hr
CO	28.010	524.03	14,673			524.03	14,678				
CO ₂	44.010	117.04	5,151			117.04	5,151				
CH ₄	16.032	6.74	108			6.74	108				
H ₂	2.016	349.70	705			349.70	705				
H ₂ and Ar	28.016	12.17	341			12.17	341				
H ₂ S	34.076	8.60	293			8.60	293				
COS	60.070	-	-			-	-				
SO ₂	64.060	0.03	2			0.03	2				
HCN	27.026	0.29	8			0.29	8				
NH ₃	17.032	0.49	8			0.49	8				
H ₂ O	18.016	976.35	17,590			976.35	17,590				
COAL (DAF)											
CHAR (DAF)			16				16				
ASH			9				9				
O ₂	32.000										
TOTAL		1,995.44	38,909			1,995.44	38,909				
MOLECULAR WEIGHT		19.49				19.49					
MM SCFD											
TONS/DAY											
OPER. CON. - T, °F/P, PSIG		500/640				500/640				190/630	

AS REQUIRED

Table 8.1 Material and Energy Balance for Case I (continued)

DESIGN BASIS

CASE I REACTOR MODIFICATION MODE

FEED Pittsburgh #8 Coal

FEED COMPOSITION

	<u>Wt. %</u>
C	77.04
H	5.23
N	1.40
O	4.69
S	2.61
Ash	8.03
H ₂ O	1.00

RAW GAS COMPOSITION (from gasifier)

	<u>Vol. %</u>
CO	42.12
CO ₂	9.41
H ₂	28.32
H ₂ O	17.94
CH ₄	0.54
N ₂	0.98
H ₂ S	0.69
NH ₃	500 PPM
HCN	300 PPM
SO ₂	30 PPM

OPERATING CONDITIONS ASSUMED

- (1) Coal feed rate 10,000 lbs./hour.
- (2) 96% gasification of carbon.
- (3) 2900°F at combustion conditions.
- (4) Water gas shift reaction in equilibrium at 2300°F outlet.
- (5) O₂ to coal ratio $(\frac{9,745}{10,000}) = 0.974$
- (6) Steam to coal ratio $(\frac{578}{10,000}) = 0.058$

SECTION 9 - MODIFIED GASIFIER STUDY (CASE II)

9.1 OPERATING CONDITIONS

The operating conditions for the modified BI-GAS gasifier were chosen as follows:

Temperature (bottom)	- 2900 - 3000°F
Pressure	- 650 psig
Residence Time	- 13 seconds
Coal Flow Rate	- 2.5 tph

The velocity, temperatures, and pressures are based on the GMTF proposal. Because the gas flowrate in the reactor is assumed to be proportional to the coal flowrate, the velocity sets the coal flowrate at 2.5 tph. The residence time, also a function of velocity and the height of the gasifier, was 13 seconds at the given conditions. A modified material and energy balance is attached in Table 9.1.

9.2 MAJOR AREAS OF CONCERN

To meet the requirement that the Case II modification must allow for reconversion of the gasifier to the BI-GAS mode of operation, it was decided to leave the basic gasifier untouched except for switching the point of coal injection from Stage II to Stage I.

The three major areas of concern in modifying the BI-GAS gasifier are how the coal is to be injected in the Stage I burners, whether the gasifier internals are adequate to provide complete gasification and withstand the higher operating temperatures, and how the ash is to be discharged from the gasifier. These three areas were the major focus of the Case II evaluations. The following discussion summarizes the results. Various facility elements mentioned in the discussion are shown on the Process Flow Diagram, Figure 9.1 (Drawing No. 3637-08.00-99-002-D).

9.2.1 Modifications of the Coal Feed System

The coal feed must be redirected from its present injection point in the second stage to the existing char injection nozzles in the first stage. The existing coal cyclone vessel, V-306, serves as the splitting device to the existing coal injectors in Stage II. In the proposed modifications, the coal must be split into three streams for injection into the three existing char nozzles in Stage I. To add flexibility to the proposed system, a five-way split was designed for the new vessel. This enables not only injection of coal into Stage I but also gives additional flexibility by providing supplementary injection into Stage II if needed. It is envisioned that the three Stage I injectors will be normally used, but supplemental firing can be made with the Stage II injectors if additional capacity is required. The five-way split is accomplished in a vessel to be placed between the existing coal cyclone vessel, V-306, and the gasifier, V-301. The new splitter vessel, VN-2, is shown in Figure 9.2. Details of the vessel are listed in the new equipment list (subsection 9.3).

9.2.2 Modification of Gasifier Internals

The three major considerations in the modification of the gasifier vessel are maintenance of adequate velocities and residence times to provide adequate conversion and entrainment, determination of the adequacy of the refractory and cooling system to protect the reactor metal shell from failure, and determination of the adequacy of burners to insure good flame propagation and velocity distribution. As mentioned earlier, the proposed GMTF gasifier was used as a basis because it is so closely aligned with the BI-GAS conditions. Proper velocities and adequate residence times are attained with the present dimensions of the BI-GAS gasifier by specifying the pressure and feed rates. The only discrepancy between the GMTF proposals and the BI-GAS gasifier is the venturi throat between Stage I and Stage II of the BI-GAS gasifier. This venturi could present problems because more gas will be processed in Stage I in the modified gasifier than was processed there in the original BI-GAS design, potentially creating adverse velocity distributions and excessive entrainment of slag from Stage I. If this problem arises, it could be solved by modification of the venturi, but doing so would involve a reconversion expense if it

PLAN VIEW OF
BOTTOM HEAD

NOTES

LOWER HEAD TO HAVE FIVE CONES 1/4" R 316L S.S.
SUPPORT CONES TO HEAD AND WELD CONES TO
NOZZLE NECKS

PRELIMINARY
FOR COST ESTIMATE ONLY

DESIGN DATA CODE <i>PSME-VIII DIV. I</i> STAMP <i>YES</i> OTHER SPECS DESIGN INT. TEMP. <i>1650</i> PSIG @ <i>650</i> °F DESIGN EXT. TEMP. — PSIG @ — °F OPER. PRESS. @ TEMP. PSIG @ °F POST WELD HEAT TREAT ☒ YES ☐ NO RADIOGRAPHING <i>FULL</i> JOINT EFFICIENCY SHELL <i>100</i> % HEADS <i>100</i> % CORROSION ALLOWANCE SHELL <i>1/8</i> " HEADS <i>1/8</i> "		MATERIAL SPECIFICATIONS SHELL <i>SA-516-70</i> HEADS <i>SA-516-70</i> SUPPORT (SKIRT) <i>SA-516-70</i> NOZZLE NECKS <i>FORGING SA-105</i> FLANGES <i>F</i> GASKETS BOLTING INT. EXT. NUTS INT. EXT. INTERNALS <i>S.S. 316L</i> COUPLINGS LINING		ACCESSORIES TO BE FURNISHED & INST. BY FABR. LADDER & PLATFORM CLIPS YES ☒ NO ☐ INSULATION RINGS & CLIPS YES ☒ NO ☐ DAVIT SUPPORTS YES ☒ NO ☐ PIPE SUPPORT CLIPS YES ☒ NO ☐ PIPE GUIDE CLIPS YES ☒ NO ☐ FIREPROOFING ATTACHMENTS YES ☒ NO ☐ TRAY SUPPORT RINGS YES ☒ NO ☐		GENERAL NOTES 1. ALL DIMENSIONS FROM BOTT. TAN. LINE. 2. ALL TRAY SPACE DIMENSIONS ARE TO TOP OF TRAY SUPPORT RINGS 3. MANWAYS TO BE (HINGED) (DAVITED). 4. IT IS VENDORS RESPONSIBILITY TO ASCERTAIN THAT ALL ACCESSORIES ARE ATTACHED BEFORE PWHT, IF PWHT IS REQUIRED.		NOZZLE SCHEDULE <table border="1"> <thead> <tr> <th>NO.</th> <th>SIZE</th> <th>RTG.</th> <th>FCG.</th> <th>SERVICE</th> </tr> </thead> <tbody> <tr> <td>N9</td> <td>4"</td> <td>1500</td> <td>R.F.</td> <td>DRAIN</td> </tr> <tr> <td>N8</td> <td>6"</td> <td>1500</td> <td>R.F.</td> <td>OUTLET</td> </tr> <tr> <td>N7</td> <td>6"</td> <td>1500</td> <td>R.F.</td> <td>OUTLET</td> </tr> <tr> <td>N6</td> <td>6"</td> <td>1500</td> <td>R.F.</td> <td>OUTLET</td> </tr> <tr> <td>N5</td> <td>6"</td> <td>1500</td> <td>R.F.</td> <td>OUTLET</td> </tr> <tr> <td>N4</td> <td>6"</td> <td>1500</td> <td>R.F.</td> <td>OUTLET</td> </tr> <tr> <td>N3</td> <td>6"</td> <td>1500</td> <td>R.F.</td> <td>INLET</td> </tr> <tr> <td>N2</td> <td>3"</td> <td>1500</td> <td>R.F.</td> <td>VENT</td> </tr> <tr> <td>N1</td> <td>6"</td> <td>1500</td> <td>R.F.</td> <td>INLET</td> </tr> <tr> <td>M1</td> <td>18"</td> <td>1500</td> <td>R.F.</td> <td>MANWAY</td> </tr> </tbody> </table>		NO.	SIZE	RTG.	FCG.	SERVICE	N9	4"	1500	R.F.	DRAIN	N8	6"	1500	R.F.	OUTLET	N7	6"	1500	R.F.	OUTLET	N6	6"	1500	R.F.	OUTLET	N5	6"	1500	R.F.	OUTLET	N4	6"	1500	R.F.	OUTLET	N3	6"	1500	R.F.	INLET	N2	3"	1500	R.F.	VENT	N1	6"	1500	R.F.	INLET	M1	18"	1500	R.F.	MANWAY	<div style="text-align: center;"> UOP/SDC COAL SPLITTER FEED VESSEL BI-GAS PILOT PLANT HOMER CITY, PENNSYLVANIA </div>	
NO.	SIZE	RTG.	FCG.	SERVICE																																																														
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Figure 9.2 Coal Splitter Vessel - VN-2.

became necessary to return the gasifier to operation in the BI-GAS mode. A more detailed analysis is necessary before the overall effect of the venturi can be determined. For this study, it will be assumed that the venturi does not affect the gasifier operation adversely.

The higher temperatures proposed for synthesis gas production could present a problem for the reactor shell because of an inadequate refractory and cooling system. A study of the refractory and cooling system was made to determine its adequacy. The evaluations are summarized in Appendix E. The calculations indicated that the existing refractory and cooling system will be adequate with relatively minor modification. The overall gasifier heat loss was estimated to be 7.85 MMBtu/hr, with over 50% of the loss occurring in the existing Stage I. The gasifier outlet temperature was estimated to be $\sim 2300^{\circ}\text{F}$. The only problem area with refractory was the use of Fiberfrax bulk fiber to act as an "expansion joint" in the top of the reactor and in the thermowells. The maximum documented recommended temperature for Fiberfrax is 2300°F . Therefore, another resilient refractory is needed to replace Fiberfrax. Several refractories have been found that can withstand a 3000°F temperature and still provide the resiliency required for thermal expansion protection. This is the only refractory change required for conversion of the BI-GAS gasifier.

It was estimated that the cooling water system in the gasifier would cool the reactor shell to acceptable limits. The only section considered marginal was the top head cooling coil. The estimated water flow rate needed in this top coil was 4-5 times greater than the original design of the BI-GAS gasifier. The increased pressure drop from this increased flow was estimated to be ~ 90 psi for the cooling coil alone. A pump with a greater head is proposed to handle this added pressure drop (head = 150 psi). All the cooling systems were estimated to be sized adequately to remove the necessary heat even in the areas of highest heat loss. The revision list summarizes the refractory and circulation pump requirements.

The existing arrangement of burners in Stage I is proposed to be used for coal, steam, and oxygen injection. The original burners are assumed to be sufficient to provide good combustion, flame propagation, and velocity distribution. It is believed that this is a good assumption in view of the excellent operation achieved with both the coal and char burners in the existing pilot plant operation.

Before the modifications are made, a detailed analysis of the burner system should be made to insure that the conversion to coal will not affect the gasification adversely. This analysis was not made in this evaluation because of time limitations.

9.2.3 Modification of Raw Gas and Char Handling Systems

Existing operation of the BI-GAS gasifier reinjects char into the gasifier after collection in two parallel cyclones. With the higher operating temperatures and longer residence times of the synthesis gas mode, it is assumed that almost complete combustion occurs; therefore, no char injection is necessary. To simplify the estimation of this raw gas and char handling, both studies, i.e., the partial replacement gasifier and the modified gasifier, used the same downstream systems. Consequently, Case II, or the modified gasifier study, will have equipment sized twice what is required. (Case I is 5 tph coal feed, Case II is only 2.5 tph.)

The existing direct quench of the raw gas cools the gas from $\sim 1600^{\circ}\text{F}$ to 850°F . The new proposed modified gasifier produces a gas at $\sim 2300^{\circ}\text{F}$ that will be quenched with water to 500°F . The cooled raw gas enters the two cyclone separators (SN-401 A & B) arranged in parallel. The cyclone separators are contained in a new pressure vessel (VN-402) that also serves to collect ash (See Figure 9.3). The gas leaving the cyclone separators flows to the existing gas washer (V-501). New cyclones and a pressure vessel are proposed instead of using the existing system so that the particulates will be collected at a high efficiency at the new modified gasifier operating conditions. After the solids are separated from the gas in the cyclones, they are collected in the new ash feed

INTERNAL CONES SHALL
BE $3/16"$ THK S.S. 316 L WITH
60° BOTTOM ANGLE

2:1 SE HEAD
TYPICAL BOTH ENDS
 $3/4"$ MIN THICK

ALT HEMI-SPHERICAL
HEADS
 $1 7/8"$ MIN THK

PRELIMINARY
FOR COST ESTIMATE ONLY

DESIGN DATA CODE <u>ASME-VIII-DIV.1</u> STAMP <u>YES</u> OTHER SPECS DESIGN @ TEMP <u>1650</u> PSIG <u>350</u> OPER @ TEMP <u>645</u> PSIG <u>450</u> POST WELD HEAT TREAT <u>YES</u> <u>NO</u> RADIOGRAPHING <u>FULL</u> CORROSION ALLOWANCE SHELL <u>1/8</u> HEADS <u>1/8</u>		MATERIAL SPECIFICATIONS SHELL <u>SA-387 GR11 CL2</u> HEADS <u>SA-387 GR11 CL2</u> SUPPORT (SHIRT) <u>SA-387 GR11 CL2</u> NOZZLE NECKS <u>FORGINGS SA-142-F11</u> FLANGES <u>FLEXITALLIC STYLE CG</u> GASKETS <u>EXT.</u> BOLTING INT. <u>EXT.</u> NUTS INT. <u>EXT.</u> INTERNALS <u>S.S. 316 L</u> COUPLINGS <u>—</u> LINING <u>—</u> WIND <u>—</u> MM <u>—</u> FT. <u>—</u> LBS EARTHQUAKE <u>—</u> ME <u>—</u> FT. <u>—</u> LBS FIREPROOFING <u>—</u> "I.S. & O.S. (BY OTHERS) INSULATION <u>4"</u> THK. (BY OTHERS) PAINT <u>None</u>		ACCESSORIES LADDER & PLATFORM CLIPS <u>YES</u> <u>NO</u> INSULATION RINGS & CLIPS <u>YES</u> <u>NO</u> DAVIT SUPPORTS <u>YES</u> <u>NO</u> PIPE SUPPORTS <u>YES</u> <u>NO</u> PIPE GUIDES <u>YES</u> <u>NO</u> FIREPROOFING ATTACHMENTS <u>YES</u> <u>NO</u> TRAY SUPPORT RINGS <u>YES</u> <u>NO</u>		NOZZLE SCHEDULE <table border="1"> <tr> <th>NO.</th> <th>SIZE</th> <th>TYPE</th> <th>SIZE</th> <th>DESCRIPTION</th> </tr> <tr> <td>N5</td> <td>4"</td> <td>RF</td> <td>4"</td> <td>INSTRUMENT CONN</td> </tr> <tr> <td>N6</td> <td>1"</td> <td>RF</td> <td>3"</td> <td>VENT</td> </tr> <tr> <td>N3</td> <td>2"</td> <td>RF</td> <td>6"</td> <td>ASH OUTLET</td> </tr> <tr> <td>N2</td> <td>2"</td> <td>RF</td> <td>8"</td> <td>GAS OUTLET</td> </tr> <tr> <td>N1</td> <td>2"</td> <td>RF</td> <td>8"</td> <td>GAS INLET</td> </tr> <tr> <td>M1</td> <td>1"</td> <td>RF</td> <td>24"</td> <td>MANWAY COVER</td> </tr> </table>		NO.	SIZE	TYPE	SIZE	DESCRIPTION	N5	4"	RF	4"	INSTRUMENT CONN	N6	1"	RF	3"	VENT	N3	2"	RF	6"	ASH OUTLET	N2	2"	RF	8"	GAS OUTLET	N1	2"	RF	8"	GAS INLET	M1	1"	RF	24"	MANWAY COVER
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Figure 9.3 New Pressure Vessel - VN-402.

pressure vessel (VN-402). A rotary valve controls the flow of solids from ash feed pressure vessel (VN-402) to a pair of new ash lockhoppers (VN-1A & 1B), each sized to have a 6 hour capacity of ash (see Figure 9.4). The two lockhoppers are operated in parallel. A motor driven diverter valve directs the ash, which is withdrawn continuously, to either lockhopper; when one lockhopper is full, the diverter valve directs the ash to the other lockhopper, and the full lockhopper is valved off. The full lockhopper is then depressurized and the ash removed through a nozzle in the bottom of the lockhopper. When the lockhopper has been emptied, it is valved off and then pressurized to operating pressure with high pressure purge gas.

A new dust cooling screw conveyor (ZN-1) conveys the ash from the lockhoppers via a rotary feeder to a new wetting screw conveyor (ZN-2). The dust cooling conveyor (ZN-1) uses a hollow screw to move ash while cooling water flows through the screw to cool the ash to about 140°F. A wetting screw conveyor (ZN-2) mixes water with the ash, preventing ash dust from escaping to the atmosphere. The wetted ash in the form of a slurry is then sent to a sluice water pond. This system discharges the ash from the system instead of reinjecting it back into the gasifier.

The evaluations that have been made suggest that the present BI-GAS gasifier can be modified to a single stage entrained flow gasifier producing a synthesis gas. The process flow diagram, (Figure 9.1) and the new equipment list (subsection 9.3) show the equipment required to make such a system workable. This information is sufficient to estimate an order-of-magnitude cost for the BI-GAS modification.

As is noted in the text of this report, several areas have not been studied because they are beyond the scope of this study. However, they are of great importance to the overall success of a BI-GAS modification. The major area of concern is the ramifications of injecting coal in the existing char burners and its effect on burner performance. Another potential problem is that the venturi throat in the BI-GAS reactor could contribute to incomplete coal gasification. These areas must be studied in greater detail before any modifications proceed. The cost estimate presented in Section 10 has not addressed in any detail the problem associated with considerations of those two areas.

HEMI-HEAD
2" THK.

**PRELIMINARY
FOR COST ESTIMATE ONLY**

TWO ITEMS REQ'D

UOP/SDC

ASHLOCK HOPPERS

BI-GAS PILOT PLANT

HOMER CITY, PENNSYLVANIA

SPEC. NO. W-3637	PAGE	OF	REV. 0
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Figure 9.4 New Ash Lockhopper.

9.3 NEW EQUIPMENT LIST

VN-2 (Coal Splitter Feed Vessel)

Design Pressure - 1650 psig
Design Temp. - 650°F
Diameter - 66" I.D.
Length - 6'-0" TT

SN-401 A & B (Ash Cyclones)

2 in parallel encased in VN-402

Design Pressure - 50 psig
Design Temp. - 500°F

VN-402 (Ash Feed Vessel)

Design Pressure - 1650 psig
Design Temp. - 500°F

VN-1A & 1B (Ash Lockhoppers)

2 lockhoppers in parallel

Design Pressure - 1650 psig
Design Temp. - 500°F
Diameter - 3'-0" I.D.
Length - 7'-6" (overall)

7N-1 (Dust Cooling Screw Conveyor)

One Holo-flite type conveyor
Purpose - to cool the ash indirectly
from 150°F to 140°F with cooling water.
Ash flow rate is 500 lb/hr.

ZJ-2 (Wetting Screw Conveyor)

One screw type conveyor with
water injection to wet the ash and
preventing dusting. Ash flow rate is
500 lb/hr.

V-301 Refractory

Replace Fiberfrax bulk fiber at top
of gasifier and in thermowells with
WRP-AS (Refractory Products Co.,
Elgin, IL)

Design Temp. - 3000°F

PN-301 (Cooling Water Circulation Pump)

Flowrate	- 2000 gpm
Head	- 150 psi
Temperature	- 530°F
Fluid	- Boiler Feedwater

CASE II REACTOR MODIFICATION MODE

PROJECT W-3637

SH. NO. 1 OF 4

BY

DATE _____

FOR REFERENCE SEE DWGS:

DWG. NO. 3637-08.00-99-072-3

DEPARTMENT OF ENERGY

CONTRACT NO. DEAC01-79ET10159

CONTRACT NO. DEAC-71-752110139
FUTURE USE OF BI-GAS PILOT PLANT FACILITY
HOMER CITY, PENNSYLVANIA

9-12

Table 9.1 Material and Energy Balance for Case II

CASE II REACTOR MODIFICATION MODE

PROJECT W-3637

SH. NO. 2 OF 4

loy.

DATE _____

FOR REFERENCE SEE DWGS:

PWG. NO. 3637-08.0C-99-002-D

DEPARTMENT OF ENERGY

CONTRACT NO. DEAC01-78ET10159

FUTURE USE OF BI-GAS PILOT PLANT FACILITY

HOMER CITY, PENNSYLVANIA

[illegible]

Table 9.1 Material and Energy Balance for Case II (continued)

CASE II REACTOR MODIFICATION MODE

PROJECT W-3637

IN NO. 3 OF 4

BY.

DATE _____

FOR REFERENCE SEE DWGS:

DWG. NO. 3637-08.00-99-002-D

DEPARTMENT OF ENERGY
CONTRACT NO. DEAC01-78ET10159
FUTURE USE OF BI-GAS PILOT PLANT FACILITY
HOMER CITY, PENNSYLVANIA

STREAM NUMBER		451		452,453		454		455		456	
STREAM NAME		RAW GAS FROM GASIFIER		ASH FROM CYCLONES (EACH)		WATER TO HETTING SCREW CONVEYOR		ASH FROM COOLING CONVEYOR		ASH SLURRY TO POND	
COMPONENT	MOL. WT.	LB-moles/Hr	Lb./Hr	LB-moles/Hr	Lb./Hr	LB-moles/Hr	Lb./Hr	LB-moles/Hr	Lb./Hr	LB-moles/Hr	Lb./Hr
C											
H											
N											
O											
S											
ASH			80.00		37.90				75.8		75.80
H ₂ O	18.016	469.31	8,455.00			61.83	1,114.00				1,114.00
O ₂	32.00										
CH ₄	16.032	3.39	54.40								
CO	28.010	308.90	8,652.22								
CO ₂	44.010	16.07	707.15								
H ₂	2.016	121.69	245.32								
N ₂	28.016	6.17	172.79								
H ₂ S	34.076	4.35	148.26								
A											
COS											
SO ₂											
HCN											
NH ₃											
CHAR			154.00		73.10				146.20		146.20
TOTAL LBS/HR.		929.88	18,669.14		111.00	61.83	1,114.00		222.00		1,336.00
MOLECULAR WEIGHT		19.83 (ash and char free)				18.02					
MM SCFD											
TONS/DAY											
OPER. CON. - T, PF/P, PSIG		500/645		500/640		105/15		140/0		105/0	

Table 9.1 Material and Energy Balance for Case II (continued)

CASE II REACTOR MODIFICATION MODE

PROJECT W-3637

SH. NO. 4 OF 4

BY _____

DATE _____

FOR REFERENCE SEE DWGS:

DWG, NO. 3637-08.00-99-002-D

DEPARTMENT OF ENERGY

CONTRACT NO. DEAC01-78ET10159

CONTRACT NO. DERCOT-78ET10199
FUTURE USE OF BI-GAS PILOT PLANT FACILITY

HOMER CITY, PENNSYLVANIA

AS REQUIRED

Table 9.1 Material and Energy Balance for Case II (continued)

DESIGN BASIS

CASE II REACTOR MODIFICATION MODE

FEED Pittsburgh #8 Coal

FEED COMPOSITION

	<u>Wt. %</u>
C	77.04
H	5.23
N	1.40
O	4.69
S	2.61
Ash	8.03
H ₂ O	1.00

RAW GAS COMPOSITION (from gasifier)

	<u>Vol. %</u>
CO	63.32
CO ₂	3.29
H ₂	25.13
H ₂ O	5.40
CH ₄	0.70
N ₂	1.26
H ₂ S	0.90
NH ₃	500 PPM
HCN	300 PPM
SO ₂	30 PPM

OPERATING CONDITIONS ASSUMED

- (1) Coal feed rate 5,000 lbs./hour.
- (2) 96% gasification of carbon.
- (3) 2900°F at combustion conditions.
- (4) Water gas shift reaction in equilibrium at 2300°F outlet.
- (5) O₂ to coal ratio $(\frac{5,069}{5,000}) = 1.01$
- (6) Steam to coal ratio $(\frac{289}{5,000}) = 0.058$

SECTION 10 - COSTS

Table 10.1 shows the estimated total costs for Case I and Case II.

Table 10.1 Total Costs

	<u>Case I</u>	<u>Case II</u>
Material and Labor	\$1,456,400	\$901,100
Construction	108,400	74,500
Corporate Charges, including Engineering, Services, etc.	437,300	373,400
Contingency	334,800	224,300
Total Cost	\$2,336,900	\$1,573,300

This is an order-of-magnitude estimate, meaning that it has an estimated accuracy of plus/minus 25 to 30 percent.

The accuracy stated is predicated on the amount and type of data from which the estimate is made. The bulk materials had to be factored from the Major Equipment Cost. One major element of the cost estimate that was not factored was the cost of work and manhours required to open the structure for the removal of equipment.

To increase the accuracy of the estimate, considerable detail engineering would be required. At the time of this estimate, new and revamped equipment has not been located. The piping, instrumentation, and electrical changes and relocations have not been designed.

The basis of the estimate is as follows:

- Process Flow Diagram was used.
- Design sketches of new vessels were used.
- Preliminary specifications for other major equipment were used.
- A site visit was made to gain a perspective on the present condition of the plant and the physical relationship of equipment.
- In-house factors for bulk material were taken from the major equipment cost for a similar new unit of the same type (gasifier).
- Engineering and field cost were factored with in-house numbers.

Only two actual quotes were used in the estimate, and their value is a very low percentage of the total material cost (about 5% for Case I, and 8.5% for Case II).

It is believed that the estimate, at the present state of the engineering, gives a good indication of the relative costs of the two cases studied. At such time as a selection is made of the process scheme to be followed and the basic engineering design is made, an estimate of far more accuracy can be made. The cost of all equipment and material can be quoted by vendors, and manhours can be more closely estimated.

To place these conversion costs in perspective, order-of-magnitude costs for dismantling or mothballing the BI-GAS plant were also calculated. To determine the shutdown, mothballing, and dismantling costs, a visual inspection of the plant was made, and the pilot plants, foundations, structural drawings, and the inventory of government-owned tagged property items were reviewed.

Basis for Plant Dismantling Cost

The estimate includes the cost of dismantling of all facilities on the site. A minimum allowance was taken for resale of equipment and materials. The items included in the estimate are:

- Building and Structures
- Major equipment
- Commodities such as concrete, pipe, and insulation
- Site finishing
- Special hauling and disposal

Each of the above was considered in enough detail to make sure all major costs were included. Improvement in the accuracy of the estimates would require a significant effort.

The costs of dismantling the administration building and parking lot and the costs of dismantling other steel buildings (all of which are included in the overall estimates) were also estimated separately. If it is decided to keep these buildings, their dismantling cost should be subtracted from the overall dismantling estimate.

Basis for Plant Mothballing Cost

The cost of mothballing the plant includes the cost of plant shutdown and equipment decontamination plus a series of preparation activities. All these are "one time costs."

In addition, there will be a yearly cost to maintain a skeleton crew at the plant site for routine maintenance chores and guarding the plant, plus the contingency sum to allow for cleanup in case of plant fluid spills.

These costs are shown below.

COST OF PLANT SHUTDOWN AND DISMANTLING

Shut-down by operator (by S-R)	\$4,750,000
Material, Labor and Subcontracts (after credit on scrap and used valves)	7,842,000
Demolition Field Costs	3,591,000
Engineering	594,000
Others: Insurance, Contingencies, Overhead and Profit	<u>3,068,000</u>
Total Estimated Cost (accuracy of estimate $\pm$ 30%)	\$19,845,000

ESTIMATE FOR MOTHBALLING

Shutdown by operator	\$4,750,000
Preparation and repairs	<u>2,318,000</u>
Total (one time cost)	\$7,068,000

YEARLY COST FOR MOTHBALLED PLANT

Manpower	\$947,000
Allowance	<u>500,000</u>
Total (yearly)	\$1,447,000

SECTION 11 - CONCLUSIONS AND RECOMMENDATIONS

11.1 CONCLUSIONS

1. Conversion of the BI-GAS plant to a test facility will provide desired data - except for data on char flow management.
2. Data on char flow management can be obtained only by continued operation of the BI-GAS facility, and then only if a suitable means of measurement of char flow can be found.
3. Data in some other areas can be obtained by continued operation of the BI-GAS facility in accordance with the technical program plan. These areas include acid gas removal, block and control valves, instrumentation, and materials of construction. The data collected will be subject to the limitation, in most cases, that they will consist only of the solutions found to specific BI-GAS problems. Also, they will not be derived from tests conducted in a syngas environment and may therefore not be completely applicable to the design of syngas plants.
4. Success in meeting the test schedule established in the current program plan is by no means certain. Among other factors, failure to find a reliable means of temperature measurement may prevent operations of longer than 7-days.
5. The designs presented in this report for modification or partial replacement of the BI-GAS gasifier are preliminary in nature. Substantial further study will be required to select an optimum gasifier design for the test facility.
6. The cost of establishing a test facility would be far less than the cost of dismantling or mothballing the existing plant.
7. A cadre of experienced technical personnel, including operators and craft-maintenance personnel, are on-site and totally familiar with existing equipment. These personnel have over four years experience performing major modifications, as well as routine maintenance, to the plant.

11.2 RECOMMENDATIONS

1. If it is considered desirable to collect engineering data needed for design and operation of future syngas plants, initiate a study to select and make a detailed design of the optimum gasifier for a test facility on the BI-GAS site and make other necessary changes in the existing facility, as required.
2. During the period required for the above study, continue operation of the BI-GAS facility in accordance with the technical program plan with the twin objectives of proving the BI-GAS process and of collecting engineering data.
3. Make the conversion when it appears that the BI-GAS facility has either reached its objectives or appears unlikely to do so in a reasonable time.

APPENDIX A - DATA COLLECTED BY STEARNS-ROGER

A.1 INTRODUCTION

Engineering data already collected by Stearns-Roger that are applicable to the ten areas considered earlier in the body of this report are presented in this appendix. These data are principally solutions or attempted solutions to problems encountered in development of the BI-GAS process. They are grouped under the data area to which they apply. Brief descriptions of the tests under which the data were accumulated are given at the end of the appendix.

A.2 HIGH-PRESSURE SYNGAS PRODUCTION

A.2.1 Coal Injector Nozzles

Two nozzles inject coal into Stage II of the gasifier. These nozzles, operating at 1800°F and 750 psig, have generally performed satisfactorily. Plugging sometimes occurred, probably because of inconsistent coal size. Screening equipment was installed to assure meeting the new specification of no more than 5 weight percent of +12 mesh coal size.

A.2.2 Coal Feed Continuity

A screw conveyor was used to feed the rod mill directly from the weight belt. This solved the problem of coal feed interruptions previously experienced when using a bucket elevator.

A.2.3 Gas Exit Line

Char and gas leave the gasifier through this line to the char separator. Two product gas line failures, one on the 8-inch section between the gasifier and char vessel and the other on the 4-inch line of the outlet for the east cyclone on the char vessel, prevented Test G-14 from being conducted during the month of August 1980. The first failure occurred in the 8-inch section on 31 July

when the gasifier pressure reached 40 psig during the pressuring phase of the test. The second failure occurred on 22 August at 750 psig before burner firing on solids feed was established. Both failures were in sections of 304 stainless steel pipe, at or near where the pipe was welded to a forged steel alloy tee (1.25% chromium, 0.5% molybdenum-Type F-11). After the first failure, the product gas line was ultrasonically tested from the gasifier to the gas washer, and several cracks were found in the pipe upstream of the char vessel. Since intergranular stress corrosion cracking was determined to be the cause of the problem, the piping section between the gasifier and char vessel was replaced with P-11 (about the same composition as F-11 fittings). After the second failure was found in the 4-inch pipe, the decision was made to replace the 304 stainless steel piping between the char vessel and gas washer with P-11. The existing fittings, which were F-11, exhibited no significant general corrosion, so they were reused.

A.2.4 Char Burners

The char burners are one of the most critical items in the gasifier. The original design provided for a mixture of steam and char to be fed through an inner tube of the burner. Around this, oxygen was fed in an annulus to oxygen ports at the burner face. Cooling water was provided along the body and face through an annulus.

Operational safety requirements necessitated a modification for adding supplementary fuel gas to insure using up oxygen if char flow stopped. At first, the fuel gas was added with the steam. Burner plugging problems then arose, evidently caused by cold oxygen's partially condensing steam in the steam-char mixture. To solve this problem, an inner tube was added to convey the char/steam mixture separately.

The supplementary fuel gas, conveyed in an annulus around the steam-char mixture, was heated to provide a warm blanket around the steam-char mixture and separate it from the cold oxygen. That eliminated, to a large extent, plugging in the char burner.

Two burner failures, possibly caused, at least in part, by rupturing of bellows in the burner, caused the discharge of high-pressure combustibles outside the gasifier. That caused a fire and damage to surrounding equipment.

Burner tip pitting and burnout had been frequent. A switch from Inconel 600 to Incoloy 800 in burner design was made.

Char burners have been in operation since October 1980 based on a new burner design developed to incorporate solutions to the problems encountered:

- The burner materials of construction have been carefully selected.
- Bellows (required for expansion on heatup) have been replaced by coiled tubes. At worst, rupture of these tubes will only leak oxygen to the cooling water.
- The burner tip has been redesigned to a more round (heat reflective) configuration, and cooling passages in it have been carefully designed for efficient cooling.
- Number of oxygen ports was reduced from eight to four.

A.2.5 Stage I Temperature Measurements

Temperature measurements are made at three points along the approximately 5 1/2-ft. height of Stage I: at the top, at the bottom, and in the middle.

The measurement of Stage I temperature is very important because an increase in temperature in Stage I above 2990°F will automatically start feeding supplementary fuel gas when operation without supplementary fuel (normally) becomes routine. Firing of the slag heating burner can be changed to assure good slag tapping.

Thermocouples have to date been the only reliable method of Stage I temperature measurement. However, thermocouple materials capable of giving reasonably long life in the hot, reducing atmosphere containing molten slag and hot char particles, especially at high pressures, have been an area of concern.

Many materials provided by the National Bureau of Standards have been tried. These include Type AE molybdenum thermowell with Cr_2O_3 coating (lasted 50 hours); Type AE alumina sheath with SiC deposited on thermowell; Cr_2O_3 sprayed thermowell; Cr_2O_3 applied with solid rod; and the tungsten-rhenium thermocouple. Best success to date has been with tungsten-rhenium thermocouples of .002" wire (.001" wire burned out in only a few hours) in molybdenum wells flame coated with Cr_2O_3 . In one of the tests, three thermocouples of this construction lasted for 120 hours on stream.

An infra-red device for use at the center temperature measurement location has been under development. A two-channel measurement is needed to offset effects of partial plugging of the viewport. Progress has been made in using periodic blasts of nitrogen to keep the viewport from being completely coated over with slag. A search is continuing to find a two-channel system in which the focus of both channels is coincident. Studies to date indicate that coincident focusing is needed to get satisfactory accuracy.

A.2.6 Effect of Fuel Gas Reduction

During the fuel gas reduction test G-16, it was observed that the plant pressures and temperatures were slightly less steady than during operation with excess fuel gas. The gasifier pressure oscillated plus or minus 5 psi compared to a normal fluctuation of plus or minus 2 psi, and the Stage I temperature varied plus or minus 50°F as against a normal fluctuation of plus or minus 20°F. Fuel gas was returned to normal flow during this test because of problems with gas washer control and instabilities in char feed. Reduction of fuel gas to the char burners was routinely accomplished during all tests since G-16. Elimination of fuel gas was accomplished during several tests of the G-17 series.

A.3 FLUIDIZED CHAR MANAGEMENT

In the BI-GAS plant as designed, the product gas and char residue of the gasified coal leave Stage II together. After an in-line water spray to reduce temperature, the char and gas are separated in a cyclone.

The char (along with some trapped gas) must be fed back to Stage I of the gasifier to be gasified with oxygen and steam to provide the necessary process heat and synthesis gas.

The problem that originally plagued the pilot plant was frequent plugging of the three char feed lines. As the result of a number of changes, this problem has been corrected to the point where plugs are greatly reduced in frequency and can be unplugged quickly on stream. These changes included:

- Alterations in the char burner construction.
 - In test G-9, the major equipment change tested was the separation of the char flow from the fuel gas flow in the char burners. Addition of a center tube in the char burners permitted smoother operation of the gasifier by avoiding char burner shutdowns when plugging occurs in the char burners. Fuel gas flow is not interrupted, since it now has a separate annulus shared with steam.
 - A char burner of a new design was installed for Test G-12. Thirteen hours of burner firing was attained, including 7.75 hours of char feeding. The burner performed well but a weakness was discovered in the method of sealing the oxygen tubing from the cooling water chamber. The burner was redesigned to overcome this problem, and the burners were refabricated for use in tests subsequent to G-13.
- Reduction in size of the char-gas conveying lines from 4-inch to 1-inch nominal pipe. Laboratory studies indicated that the smaller size would be adequate for all necessary flows. The smaller size causes higher velocities and less delay time on route; longer transport time apparently

had allowed water to condense from the saturated trapped gas and cause plugs in the larger lines.

- Reduction in the size of the control valve (vee ball valve) from 4-inches to 1-inch. The larger valve was opened such a small amount at normal flows that even a minor turndown adjustment left an extremely small (and easily plugged) opening.
- Provision of heated gas for purging at pressure drop measurement taps (thus also avoiding the condensation of water).

With plugs in the char lines now essentially controllable, efforts to find a device to measure the mass flow of the char and of the gas with it are being given increased emphasis. Determining the flow rate of the char and of the gas trapped with it are essential because:

- Making measurements of these flow rates is basic to determining material and energy balances around Stages I and II, since they are measures of part of the products of Stage I and part of the feeds to Stage II. Accurate balances are necessary for process evaluation and scale up.
- Char flow stoppages (and reductions indicating the onset of a stoppage) must be measurable for safety reasons when supplementary fuel gas is not fed to the char burners. Oxygen feed to Stage I must be consumed by char to leave a reducing atmosphere. An oxidizing atmosphere would cause potentially hazardous conditions in Stage I and Stage II of the gasifier; and, if extended that far, in downstream gas purification equipment. An interlock instrumentation system is in operation which automatically restarts supplementary fuel gas when char flow stoppage is indicated.

Numerous mass rate and density measuring devices have been tried to date:

- The original flow devices by Thermal Instrument Company of Trevose, Pennsylvania attempted to proportion flow to power required to hold the

flow at constant temperature. Efforts to calibrate were not fruitful and response was essentially nil. This effort was discontinued.

- Heat balance around the pressure boosting eductors, as suggested by Westinghouse Electric, was attempted. The temperature differential was insufficient to provide necessary response.
- A sonic probe device by Oceanography International Corporation of College Station, Texas gave no response.
- Thermocouples located along the conveying lines have been too slow in response to show sudden changes in rate. However, they do trend lower with lower flow and higher with increased flow rate. They have been of value in diagnosing plugging problems and locating where plugs may be starting.
- Nuclear density meters were provided initially with the pilot plant. In some instances, these will trend higher with higher flows and lower with lower flows. However, the response is not at all dependable, and there is never a return to the same zero when the lines are emptied.
- An impact grid flow meter was developed by the Braun Company. In this device, relative distortion of a screen grid in the solids flow path is measured on piezoelectric crystals. First testing was unsuccessful. Modifications were made, and the corrected version was tested and also failed.
- Acoustic Flow Meter. The Argonne National Laboratory has developed a char flow/no-flow device that uses a passive microphone to measure sound levels in the char flow channel (which vary as density and velocity change). Amplitudes and frequencies of the sounds are transmitted to an analyzer. The analyzer was expected to correlate these data to yield a measure of density of the flowing mixture of gas and char. To date, the apparatus has not been able to yield density measurements but is serving

as a flow/no flow device in all three char lines at the pilot plant. A program to develop this meter to a flow rate with additional microphones has not been funded.

- Auburn Density Meter. A device that measures dielectric constant and correlates it to a measure of the density of a solids-gas stream has worked well at the Synthane Pilot Plant at Bruceton, Pennsylvania. A version of this adapted for the higher temperature and pressure of the BI-GAS pilot plant is being tested. It was determined after Test G-15 that char accumulation behind the electrodes held moisture and grounded the plates. Auburn solved this problem by filling the void spaces behind each electrode with a ceramic compound and then applying a moisture sealing compound to moisture proof the ceramic. The results from Test G-16A on the Auburn monitor indicate that the equipment has a great deal of potential but that further refinements and testing are necessary. It appears that moisture is still the biggest problem with the instrument at the moment and that some circuit modifications may be necessary to account for the conductivity of the char.
- Differential Pressure. Pressure difference measured across parts of the flow channels for the char-gas mixture is fundamentally related to the flow rate of solids and gas. Pressure differential measurement has been provided across each increment of the solids-gas flow channels at the pilot plant. These measurements are encouraging in that they do tend to vary with the flow velocity and density. Efforts are continuing to establish good accuracy and correlate pressure drop to flow rate.

A.4 HIGH-PRESSURE COAL SLURRY PUMP EVALUATION

Very little information on the high-pressure pumping of coal-water slurry in the BI-GAS plant has been reported. Presumably this part of the process has worked well over the duration of various tests. As the test durations become longer, it will be possible to test the slurry pump over a longer time period.

A.5 SLAG FLOW MANAGEMENT

The char remnant of the coal reacted in Stage II is gasified in Stage I to provide process heat. Stage I is maintained at temperatures sufficient to keep slag molten (2700 to 2900°F for Rosebud).

A swirling action in Stage I moves the heavier molten slag droplets to the wall, and the gas and lighter unburned char particles are entrained upward into Stage II. The slag droplets collect at the walls and flow down and out a tap hole at the bottom center of Stage I. The molten slag then drops into a water quench below the tap hole.

A slag heat burner, located in Stage I, is pointed downward and at the tap hole. A slag tap burner is located below the tap hole in the quench section. It is directed upward at the tap hole to avoid solidification and plugging at the tap hole. At the bottom of Stage I, the tap stone is fabricated from Monofrax E (chrome spinel).

A number of problems have been met and resolved working with Montana Rosebud coal (other coals and their different slag properties may require solving different problems).

Problems found early in the development efforts included plugging at the tap hole; large stalactites building up at the tap hole, eventually falling off as large chunks and making removal from the quench section difficult to impossible; and bundles of hairlike quenched slag forming nests that were difficult to remove.

Early efforts at flux (limestone) addition proved unfruitful for Rosebud coal and have been discontinued.

Several changes that have been made during the course of the testing and have apparently allowed reasonably good tapping are:

- The tap stone has been raised closer to the char burners and slag heat burner. At first it was raised a full 4 to 5 inches by using two bottom stones, one on top of the other. This arrangement worked well for five 40-hour runs. Presently, a single tap stone (of the original dimensions) raised 2 inches above the cooling coils is used. For two runs (one of which was an extended 120-hour run) this configuration also worked well.
- The inner turn of the cooling-water coils (closest to the tap hole) was removed so that there would be less cooling at the tap hole.
- Tap hole size was changed. In the two-stone configuration, the top stone had a 2-inch hole and the bottom stone a 6-inch hole. The top hole washed and eroded away to 4 to 6 inches in diameter. The single stone now used, which is elevated 2 inches with castable, has a 6-inch tap hole and appears to be giving reasonably good service.
- A water cooled stalactite breaker was provided. It sweeps across the flow pattern of the slag below the tap hole at timed intervals and prevents stalactite formation.
- The firing temperature (oxygen rate) of the slag heat burner has been adjusted as required to keep the temperature (measured by the thermocouple located lowest in Stage I) high enough to avoid excessive slag viscosity.

Slag removal from the gasifier was much improved during Test G-16 (to 90 percent) because of use of the slag breaker and a slag agitator and installation of a grating over both lockhopper legs.

To improve slag removal from the gasifier further, it was decided to remove the grating on the tops of the lockhopper legs and to reroute the slag agitator hydraulic lines to better accommodate pipe stresses.

The slag heat burner not only keeps molten slag hot but is also the pilot burner. It is the first to be heated in Stage I startup; the char burners are lighted from it. It is also the burner monitored to insure flame in Stage I. Conventional methods, such as sparks and glow plugs, proved to be unworkable for igniting the slag heat (and slag tap) burner. A spark of at least one million volts would have been required, and materials of construction problems would have been severe. The method selected for igniting the slag heat and slag tap burners is currently working satisfactorily for the pilot plant. In this method, triethyl aluminum (a pyrophoric material) is mixed with oxygen in the burner flame zone to provide ignition.

A.6 ACID GAS REMOVAL

Early in the start-up of the pilot plant, problems developed with the H₂S Solvent Pumps (P-701 A & B) that circulate the Selexol through the H₂S Gas Treating System. Plant engineering and maintenance have enabled two pumps to perform to design specifications.

From time to time large Selexol carry-over losses to the thermal oxidizer have occurred. To eliminate this problem, pressure control valves were installed to vent the H.P. and L.P. Flash Tanks (V-702 & 703) to the thermal oxidizer. Operating these vessels at their proper pressure has solved the carry-over problem.

A.7 COMBINED SHIFT AND METHANATION

During the test period, shift and methanation units have not been operated with the gasifier; hence, data are not available.

A.8 ENVIRONMENTAL DATA COLLECTION

Ammonia content of the plant waste waters rejected to the Homer City sewer system during gasifier operations exceeded permissible limits in the past. The atmospheric vent gas washer (V-502) was converted to an ammonia stripper by

increasing the sizes of vessel steam sparger and steam supply line. A caustic feed system was added to increase the pH of the wastewater in the vessel. Maintenance of the pH of the water above 10.5 and the addition of 1 lb of steam per gallon of wastewater has effectively reduced the ammonia content of the wastewater to less than the allowable 25 ppm. The ammonia stripping efficiency was improved by repiping the gasifier slag quench letdown to enter the stripper bottom.

As the plant became capable of longer operating times, naphthalene pluggages developed in the trim cooler (E-602). A second exchanger was installed, and steam supply and condensate returns were piped to both exchangers. These exchangers are alternated in service. When the exchanger in use develops a pressure drop of about 60 psig, it is taken out of service and the alternate exchanger is placed on line. The plugged exchanger is then steamed out, and the process tubes are vented to the thermal oxidizer to burn the naphthalene.

The design specification for the particle size of the gasifier feed was 70% passing 200 mesh. However, the quantity of -325 mesh produced in the pilot plant coal preparation system was much greater than anticipated: it amounted to almost 80% of that passing 200 mesh. As a result, carryover of fines through the gasifier and into the gas washing units produced solid content of 10% in the gas washer bottoms, compared with a design projection of 1% or 2%. A variety of operating problems occurred, such as pluggage of process lines and instrument taps.

An extensive effort was made to revise and modify the rod mill operating procedures to reduce production of -325 mesh size and increase the amount of larger sizes in the gasifier feed. The various modifications included changing of water rate to the rod mill, changing coal feed rate to the rod mill, and changing the numbers of rods in the mill. This extensive testing on Rosebud coal established an optimum pulverization procedure. However, the quantity of -325 mesh material was still excessive.

During the month of July 1979, it was decided to add a screening unit to the system to remove the major portion of the -325 mesh size particles. A Rotex vibrating screen unit with 5 mesh scalping and 100 mesh product screens was installed during the last part of July 1979 to remove the major portion of -325 mesh size. The results indicated that, within reasonable limits, the top of screen product contained approximately 15-20 wt% -100 mesh material.

A larger size consist of coal feed was specified for tests G-8 and G-8A. The new specification was no more than 5 wt% of +12 mesh, and/or no more than 15 wt% of -100 mesh material.

The typical size analysis of the rod mill effluent revealed that removing approximately 30-40 wt% of the coal (that passing through a 100 mesh screen) has solved the operating problems caused by excessive fine material, and a smoother gas washer operation has resulted.

It was decided to investigate the feasibility of using the centrifuge in the coal handling area to remove solids from the pond. Appropriate pump and piping installations will be needed to transfer the slurry to the centrifuge, where the solids will be separated for disposal and the liquid returned to the pond. The results of this investigation are not available.

Plugging of the gas washer reflux cooler (A-501) by a calcium carbonate buildup prompted cleaning of this equipment by flushing it with a five percent nitric acid solution. The gas washing system was then closed and water circulated, but plugging problems were encountered with the gas washer bottoms cooler. These plugs were caused by carbonate deposits that had come loose from the process lines.

At this point, the decision was made to circulate a sulfamic acid solution through the entire gas washing system, including the gas washer column, the reflux lines, both aerial coolers, and the ammonia stripper. Sulfamic acid was used for this application because of its compatibility with Monel, the metal

used as a liner in the gas washer vessel, and with 304 stainless steel. An additive for the gas washing system is being investigated to prevent this carbonate buildup from recurring.

A.9 BLOCK AND CONTROL VALVES

Among all the valves in the plant, the char feed valves have been tested most because of the significance of char feed control. A Fisher vee ball was used in all tests to control char flow at 700°F and 750 psig. The performance was satisfactory, but the flow did not correlate well with the valve position. A Kamyr valve was installed in test G-16A as a substitute.

A Kamyr 1500-psig-rated ball valve with a modified ball (notched on the lower side) was installed in 'B' char leg in place of the EPG ball valve. The ball was notched on the lower side to prevent solids buildup in the valve when partially opened. This valve was installed to test flow controllability, since the Fisher Vee-ball has a rating of only 985 psi at 800°F. Both the Kamyr valve and the Fisher Vee-ball valve had controllers, and the valve pressure differential of the controlling valve was measured by blocking off sensing lines to the other valve.

Before base conditions were established with gas flow only, the Kamyr valve was closed and then slowly opened until the valve differential decreased, indicating that the valve had opened enough to permit gas flow. The reason for this test was to observe the operation of the valve, since it operates somewhat differently from the Fisher Vee-ball. When there is a three psi air signal on both valves, both are completely closed. The Kamyr valve is set up so that very little additional air signal makes it "jump" to the position where the valve is just starting to open. Only a five percent air signal is needed to open the Kamyr valve, whereas a 20 to 25 percent air signal is needed to open the Fisher Vee-ball. The results of Kamyr valve operation were found encouraging, and its further testing was recommended. The control appeared to be centered in the 20 to 55 percent range.

The initially installed 4-inch char feed lines experienced some problems. The major equipment change in preparation for test G-10 was to replace one of the 4-inch char feed lines with a 1-inch line and the 4-inch control valve with a 1-inch control valve. It was determined that the 1-inch line and valve are more controllable at the required flow rate. Because an expansion bellows and cool gas to purge it are not required in a 1-inch line (but are in a 4-inch line), there is less cooling of the flowing char when a 1-inch line is used. Also, char is fed uniformly through the smaller line, and the eductor can handle this steady flow without plugging. Char feeding was successful using this system.

In the 1-inch char feed system, measurement of differential pressure was provided across the upper leg, control valve, lower leg, eductor, and burner. Data from these measurements were obtained to develop a correlation between differential pressure and char feed rate as indicated by control valve opening.

Successful char feeding through 1-inch diameter systems led to the decision to change one coal feed system from 4-inch diameter with a 4-inch control valve to 1-1/2 inch diameter with a 1-inch Vee-ball control valve. In Test G-11, it was proven that the smaller system was more stable and controllable through 54.5 hours of slagging operation. Coal feed rates of up to 6000 lb/hr were attained.

It was found that the coal vessel/gasifier differential pressure should be lowered to decrease erosion across the coal feed valves. Also, to assure accurate measurement of this differential pressure, the trim in the spray drying system vent valve should be properly adjusted.

During test G-16, the bodies of the coal feed valve were coated with Cr_2O_3 to counteract erosion that was found in the previous tests.

Also, the gasifier heat loss test conducted at the end of the test was modified so the coal feed valves would be closed instead of open. Closing the valves prevents residual coal from falling into the coal legs and eroding the valve bodies as a result of the high gas flow rate that occurs when there is no level

in the coal vessel. Inspection after the test showed no additional wear in the bodies of these valves.

A.10 INSTRUMENTATION

Some of the critical instrumentation in the system, viz., thermocouples and char flow measurement devices, has been discussed earlier.

Model 880, Barnes Radiometer, was also used for Stage I temperature measurements in tests G-9 through G-13. Its performance was very poor and erratic. It had to be discarded because the lens and the silicon window were easily obscured, and alignment problems developed. For Stage I temperature indication, test of the Capintec "Ratio Probe III" dual pyrometer system has been recommended. If problems are encountered with this unit, then the Williamson Corporation "True Temp 8100" will be tried.

A thermal flowmeter was tried to measure coal feed flow rate during test G-9, but no reading was observed. It was then replaced by a Density Indicator during tests G-9, 11, 11A, 14 and 16A. In all cases, the observed response was very erratic. The response did not correlate with the data. Differential pressure measuring instrumentation was installed on the coal eductors and injection nozzles and gave a good indication of coal flow. Thermocouples with boron-coated molybdenum thermowells were used in test G-14 and performed well.

Some of the other lessons learned are as follows:

- The view of the flame detector is through the inlet of the slag heating (and also slag tap) burner. The original ultraviolet device did not work adequately, presumably being interrupted by the heterogeneous atmosphere of Stage I. Presently, however, a flickering infra-red detector (Fire-eye) has been installed and is working well.
- An independent, single-point, level detector should be installed above the present level column. This will insure that a high level will not occur.

- Different level measurement systems for the gas washer should be investigated. A single point detector that would alarm when a high level occurred should be installed as soon as possible.
- The water degassing tank bottoms magnetic flowmeter should be moved downstream of the control valve bypass. This bypass is frequently opened.

A.11 MATERIALS OF CONSTRUCTION

Materials of construction for the thermocouples in Stage I of the gasifier have been discussed in Section A.3. A tungsten-rhenium thermocouple with boron coated molybdenum worked well with temperature measurements in Stages I and II. The life of the instrument is lower in Stage I application because of very severe conditions.

The Fisher valves used for flow control of char and coal showed beneficial results when they were spray-coated with Cr_2O_3 .

Sleeves made from Hrmco 18 SR, high-temperature-resistant stainless steel, were installed on the slag heating burner to provide proper cooling. However, performance did not improve significantly.

A new tapstone of Monofrax E with a 4-inch taphole was installed during tests G-15, -15A, and -16 in place of the previous one, which had a 6-inch hole. A smaller diameter taphole allows less heat loss from Stage I, which can improve tapping, but must be tested to determine whether the restricted size is sufficient for the amount of slag produced. These tapstones have been used throughout test G-16 and G-17 series.

TABLE A.1

BI-GAS PILOT PLANT TEST SUMMARY
(G-5 thru G-17D)

TEST #	TEST DATE	HOURS OF FLED COAL	CHAR	ESTIMATED COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-5	July 28, 1978	9.3	4.75	5000 #/hr.	<ol style="list-style-type: none"> 1. Gasifier overhead quench water control problems. 2. Erroneous alarms. 3. Char feed problems in 'B' and 'C' legs. 4. O₂ control problems to 'A' char burner. 	<ol style="list-style-type: none"> 1. Level was accumulated in V-402 and seen through the nuclear indicator. 2. Char flow was indicated through dP instruments and Argonne sonic flowmeter. 3. New O₂/N₂ system performed well. 4. STB successfully lit with 50/50 TEA. 5. LIC's on char legs sealed properly. 6. 'A' char burner damaged. 7. Fuel gas was used as purge gas. 8. Tap hole plugged with thin slag plug. 	<ol style="list-style-type: none"> 1. New trim installed on utility area boiler feed water PCV. 2. New bypass ROV installed around gasifier quench water TCV. 3. Reduced purge gas flow to both TV ports.
G-5A	August 8-9, 1978	10.0	3.9	5000 #/hr.	<ol style="list-style-type: none"> 1. Loss of Stage I thermocouples. 2. No visible tapping seen on TV. 	<ol style="list-style-type: none"> 1. Level was controlled in V-402 by throttling LCV's in char legs. 2. Burners undamaged. 3. Selexol system operated with no problems. 4. 'B' coal eductor orifice and diffuser tube eroded. 5. T/C-3401-12 severely eroded. T/C-3401-10 sagged. 6. Tap hole plugged with thin slag plug with rat hole. 7. Stage II had 1 ft. deposit on south side. 	<ol style="list-style-type: none"> 1. Oceanographics sonic flowmeter on 'B' coal leg activated. 2. Radiometer put in service with: <ol style="list-style-type: none"> a. Increased purge gas rate to port. b. N₂ purge added to lens. c. Slag shield added to port. 3. Replaced Stage I & II T/C's. 4. 'B' coal eductor repaired. 5. Tightened clearance on 'A' & 'B' coal leg and 'A' char leg vee ball valves.
G-5B	August 22-23, 1978	15.0	9.5	6000 #/hr.	<ol style="list-style-type: none"> 1. Automatic shutdown of 'A' char burner on 2 occasions. 	<ol style="list-style-type: none"> 1. Controlled V-402 level with 'A' & 'B' char legs only. 2. 'A' char burner shutdown due to low fuel gas flow, caused by restricted or plugged burner. dP instruments, oceanographics meter, and line temperature indicators showed this. 3. Tap hole open. 4. T/C-3401-10 & 12 damaged. 5. Tapping could not be seen. 6. 500 gals. Selexol lost. 7. 'B' char burner outer surface damaged from tip back ~4-5" at 11 o'clock position. 8. 'A' coal eductor diffuser tube eroded. 9. Radiometer responded to temperature; however, port appeared to get covered with slag. 	<ol style="list-style-type: none"> 1. Installed "cement" bucket near pond to collect slag. 2. Installed new sleeves and filler plate for 'A', 'B', 'C' & SH burners. 3. Repaired 'A' coal eductor. 4. Replaced Stage I T/C's. 10. Gas treating successfully removed H₂S from purge gas. 11. Stage II had 2 ft. high deposit; crusted top layer with gray particles underneath; ~1 ft. diameter hole through center.

TEST #	TEST DATE	OPERATING DATA	ESTIMATED COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-5C	Sept. 9, 10, 1978	1. 24.8 hr. coal feed 2. 18.6 hrs. char feed 3. Char burners lit 39 hrs. 4. Pressured up 57 hours	~4500 #/hr.	1. 'C' char burner possibly plugged and damaged. 2. Slag tapping not visible on TV. 3. No evidence of slag accumulation in 'A' slag lockhopper. 4. Gasifier CW pump seal problems.	1. Stage I had ~1/2" slag layer above tap hole with mound of particles up to burners. 2. Stage II had deposit on wall up to #2 T/C. "Bar" of hard material across throat. 3. Quench section had fibers, particles of slag up to M/H. 4. Naphthalene in E-602. 5. 'C' burner damaged. Bellows badly damaged. 6. Were able to stop and restart char feed. 7. Slag breaker eliminated stalactites from forming. 8. Much less O ₂ required. 9. Plugs formed in 'A' and 'C' char burners during test. Able to clear them. 10. Added 450 gallons of Selexol. 11. V-502 operated as ammonia stripper with some success.	1. Repaired 'C' burner. Moved bellows back where O ₂ enters burner. 2. Put end plate on Johnson screen covering sample probe. 3. Replaced trim on TCV-4402B. 4. T/C #12 replaced. T/C #10 new protection tube only. T/C #2 new T/C element only. 5. Installed water wash for glass plate over TV ports.
6-6	Sept. 25, 26, 1978	1. 17.2 hrs. coal feed 2. 11.0 hrs. char feed 3. Char burners lit 25.8 hrs. 4. Pressured up 146.5 hrs.		1. Eroded hole in gasifier vent line downstream of PCV-5204.	1. Established coal level in V-306 and fed coal with level. 2. Established char level in V-402 and controlled level by feeding char. 3. Successfully tapped with no flux addition. Tap hole not plugged, w/2" diameter hole at test end. 4. No deposit in Stage II. 5. Stage I in good condition. 6. No burner damage. 7. Ammonia stripper somewhat successful. 8. Slag buildup in bottoms quench section. Total of 815# slag collected from L-II and quench section. 9. Selexol successfully removed H ₂ S. Some Selexol loss experienced before test start. 10. Appeared to flood V-501. 11. Slag L-II electrical problems experienced. 12. Lit and shutdown burners several times.	1. Eliminated purge gas from TV lens. Sealed glass plate and installed vent. 2. T/C-3401-10 & 12, new T/C element and sheath. 3. Repaired eroded hole in gasifier vent line. 4. Repaired Selexol system LCV's during test.

TEST #	TEST DATE	OPERATING DATA	ESTIMATED COAL FEED RATE	REASONS(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-6A	Oct. 5, 6 1978	1. 8.2 hr. coal feed 2. 4.1 hrs. char feed 3. Burners lit 17.9 hrs. 4. Pressured up 52.5 hrs.	5,000 - 5,500 #/hr.	1. Gasifier ESD- High Stage II temperature. 2. Plugged line between V-202 and V-203.	1. V-202 level control problems due to line pluggage. 2. 'B' & 'C' char burners appeared to plug. Closing LCV appeared to quickly eliminate problem. 3. Tips of 'B' & 'C' char burners damaged. a. 'B' (2" long) @ 9-10 o'clock position. b. 'C' (1" long) @ 1 o'clock position. 4. 'B' char burner sleeve almost completely missing. Much of filler plate missing. 5. Tap hole open but somewhat restricted. 6. 1160# slag collected. a. 744# in bottoms quench section b. 370# inslag bucket c. 46# in B L-H 7. 2700# coal in V-306. 8. 12.5 yds. ³ char in V-402. 9. Stage II excellent condition with no deposits. 10. Level established in V-306.	1. Spray drying system instrumented similarly to utilities in order to maintain pressure above gasifier. 2. Steam to Stage II directly controlled by temperature. 3. New tip on 'B' char burner. 4. Weld repaired 'C' char burner. 5. Electronic K.O. pot for CO/CO ₂ analyzer. 6. New centrifuge gear box installed. 7. New #10 and #12 T/C's. 8. New Argonne char flowmeter put in service. 9. 'B' char burner bellows moved to rear.
G-6B	Oct. 13, 1978	1. 11.2 hrs. coal feed 2. 9.7 hrs. char feed 3. Burners lit 21.2 hrs. 4. Pressured up 64.75 hrs.	7,000 - 10,000 #/hr.	1. No visible tapping. 2. Little slag collected in slag bucket at pond. 3. 'A' and 'B' char legs continued to plug.	1. a. 'A' char burner tip had 2 1/2" long crack in it at 11:00 position. b. 'C' char burner slightly damaged on inside edge 9-10:00 position. 2. Tap hole open with 4-6 inch hole. 3. Quench section full of slag needles. 1700# of total slag in L-H's and quench section. 4. CO/CO ₂ analyzer performed satisfactorily. 5. No deposit in Stage II. 6. Burner sleeves in very poor condition. 7. Stage I thermocouples in good condition. 8. Level established in V-306.	1. New sleeves installed around 4 burners. 2. N ₂ line tied into annulus between mica and glass plate with equalizing line. 3. New tip installed on 'A' char. 4. New, more sensitive weigh cell installed on 'A' L-H. 5. Modified radiometer port (larger with end uncooled) installed. 6. 'A' char burner bellows moved to rear. All char burners have this modification.

TEST #	TEST DATE	OPERATING DATA	ESTIMATED COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-6C	Nov. 2, 1978	<ol style="list-style-type: none"> 8.0 hrs. coal feed 2.3 hrs. char feed Burners lit 19.0 hrs. Pressured up 59.3 hrs. 	4,000 - 9,000 #/hr.	1. Slag tapping ceased.	<ol style="list-style-type: none"> Events before SD: <ol style="list-style-type: none"> Temp. excursion for unknown reason from 2550° to 2850°F with heavy tapping. Temp. drop to 2200°F when 'C' char leg feed started. Tapping stopped. Slight temp. excursion to 2700°F before being reduced to 2550°F. Increased temp. to 2750°F to clear tap hole with no success. Good TV picture on both cameras: <ol style="list-style-type: none"> RCA (West) slightly better picture. Once char feed started, picture got brighter. Tap hole not as well defined as before char feed. All burners undamaged. CO/CO₂ analyzer responded to coal and char feed. Plugged tap hole above "hole": <ol style="list-style-type: none"> ~ 17" striated deposit. Difficulty experienced in heating up gasifier. Coal leg pluggage problems. Small deposit over 'B' coal nozzle face. Selexol vessels looked OK. 	1. STB and SIB lens purge moved from TEA system to separate IIP N ₂ source.

TEST #	TEST DATE	OPERATING DATA	ESTIMATED COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-6D	Nov. 14-15, 1978	1. 32.5 hrs. coal feed 2. 32 hrs. char feed 3. Burners lit 40.6 hours 4. Pressured up 133.4 hours	~7500 #/HR.	1. Lack of slag collection. 2. Shutdown planned and orderly once it was determined that slag was not properly being collected.	1. Longest char and coal feed period to date with controlled level in feed vessels. 2. 3,350# slag recovered mostly from quench section. Slag level approximately to top of gasifier manway. 3. Slag breaker failed. 4. New RCA camera installed on north port during test. Picture improved. 5. "Fog" obstructed view of tap hole. TV image good. 6. Small naphthalene quantities in downstream vessels and exchanger. 7. Ammonia stripper lowering NH_3 to 600 ppm only. 8. Smooth deposit in Stage II covering coal nozzles. 9. 'B' coal nozzle steam annulus restricted. 10. 3-4" diameter tap hole. 11. A & B char burner sleeves damaged.	1. Bottoms slag quench section spray installed.
G-6E	Dec. 1-2, 1978	1. 9.6 hrs. coal feed ~8000#/HR 2. 0.4 hrs. char feed. 3. Burners lit 14.1 hrs. 4. Pressured up 46.1 hrs.		1. Loss of Stage I thermocouples. 2. Fluctuating flow to "B" char nozzle.	1. Slag quench ring and (or) spray nozzle caused fogging. 2. Confirmed that initiating char feed caused a fuzzy, foggy TV image. Stopping char feed resulted in a clearer TV image. 3. Stage II deposit left only a 2" diameter hole in throat. 4. 3" diameter tap hole. 5. Difficulty experienced in V-501 level control.	1. Replaced transmitter to steam feeding 'B' char eductor at test beginning. 2. Replaced transmitter on steam to 'C' char eductor after test. 3. PSV's on HP Boiler reworked in place. 4. New spray nozzle configuration installed in slag quench section.

TEST #	TEST DATE	OPERATING DATA	ESTIMATED COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-6	Dec. 13-14, 1978	1. 26.9 hrs. coal feed. 2. 26.2 hrs. char feed. 3. Burners lit 33.5 hours. 4. Pressured up 81.3 hours.	6000 #/HR.	1. Lack of visible tap hole. 2. STB shutdown for no apparent reason.	1. New spray nozzle configuration and (or) ring promoted fogging. 2. Reducing C-201 from Step 5 to 4 reduced spray dryer outlet temp. 30°F. 3. STB stoppage resulted in cessation of tapping. 4. Increasing steam to char burner made char feed unstable. 5. Bucket elevator shaft broke during test. 6. Fed char early, to coat Stage I. 7. 6" diameter tap hole with shroud. 8. Throat clear; coal nozzles covered. 9. No slag was collected at pond during test.	1. Slag agitator installed. 2. Higher Stage I floor with 2" diameter tap hole. 3. Water-cooled sleeves installed. 4. Many modifications to improve material balance made. 5. P-508 tied into bottom of V-502. 6. N ₂ surge bottles installed on purge line to each of 5 burners. Continuous N ₂ purge removed. 7. Coal leg dP's installed. 8. V-601 level controller installed. 9. Slag lockhopper sequence changed to prevent RED valve rupture. 10. Slag collector installed at pond.
G-7	Feb. 4-5, 1979	1. 8.3 hrs. coal feed 2. No char feed 3. Char burners lit 13.3 hrs. 4. Pressured up 145.6 hrs.	5800#/hr. (average)	1. Rapid drop in V-302 level indicating cooling water leak. 2. Water spray observed on TV monitor.	1. Depressuring was required several times due to leaks. 2. Both TV pictures were very clear. 3. Trouble feeding through both coal nozzles. 4. Newly installed 2" tap stone remained free and clear, appeared undamaged. 5. Stage I TC's gave good readings throughout test, but wells were slightly damaged. One of the Stage II TC's read 200° low; the others gave good readings. 6. 4" overhead line from S-703 plugged; 3/4" vent line used in its place was inadequate to prevent vessel from pressuring up. 7. Inability to hold SHB "tenor" sequence in firing mode experienced. 8. 'C' char burner tip had crack in 12-1:00 position. 9. Gasifier ESD caused by high cw/gasifier dP.	1. 3/4" vent line from S-703 replaced with 2" line. 2. Low FG flow, high O ₂ /FG ratio alarms added to SHB and STB. 3. Switched blinds on V-502 to rectify past error. 4. Rotated brackets on nuclear LI's on V-306 and V-402 to give better level indication. 5. Disconnected PdIS-3215. Added transmitter to surge drum, comparator in control room, and switch set to trip at 50 psi dP. 6. Changed zeros on coal nozzle PdR's. 7. Repaired IIP switches sensing lines on P-202A & B. 8. New P-202 discharge sample bomb installed. 9. TE-3401-5 NBS type installed.

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G-7A	Feb. 24-25, 1979	<ol style="list-style-type: none"> 8.5 hrs. coal feed. 7.5 hrs. char feed. Burners lit 36 hrs. Pressured up 345 hrs. 	6100 #/HR. (average)	<ol style="list-style-type: none"> Rupture in 'A' char burner resulting in rapid depressurization and fire. 	<ol style="list-style-type: none"> Several times lit burners without being able to achieve coal feed. Problems were due to extreme cold weather and repair work required on both P-302 pumps and on aerial coolers, A-201 and A-202. Change in level detection on char vessel proved successful. Corresponding change on coal cyclone vessel failed to solve level detection problems. T-106 and V-203 percentage fines increased over the course of the test. Resulted in V-202 level control problems. The Argonne acoustic flow monitor correlated well with the char dP's giving a good indication of any disturbances in char flow to the burners. Residue collecting on the burner sensor lens on both STB and SHB was effectively removed whenever necessary. 2" tap hole performed very well throughout run. G-7A was the first time the 2" hole had seen char feed. Tap hole was in good condition at inspection. Line from quench section to 'A' slag lockhopper plugged with slag plug. Withdrawal of continuous N₂ purge to burners did not result in any problems. Char feed was introduced (at a low rate) very early to build slag coating. This proved successful as an excellent coating developed in Stage I. Char level was detected in V-402 after 6 hrs. coal feed/ 5 hrs. char feed. 'A' char burner shut down - low FG flow apparently caused by plug in burner downstream of FG inlet. Char feed was resumed rapidly. Rupture of 'A' char burner resulted in rapid depressurization and fire. Rupture believed to have been caused by failure in expansion bellows. Coal nozzle and eductor dP's responded well. 'A' and 'C' water cooled sleeves developed leaks. It was decided to shut off water flow to sleeves and continue test. 	<ol style="list-style-type: none"> Fire damage repair. Gasifier structure modifications for personnel safety in event of a rupture including: <ol style="list-style-type: none"> Diamond plate installed on 6th and 7th floors to contain blast and/or fire to 6th floor. Shields installed to deflect blast from burner out of structure away from equipment. P-501 A & B and P-203 A & B moved to ground level. Ladders installed 1st through 8th floors. Char burners modified to prevent another rupture. Thermistor strips installed on char burners. Solids feed instrumentation changes: <ol style="list-style-type: none"> Argonne instrument board mounted. Coal and char feed valve position recorders. Coal and char leg thermocouples. Braun flowmeters installed. 15 Incoloy 825 bellows installed on coal and char legs, replacing existing stainless steel bellows. Coal vessel level recorder repaired. Rotex screens installed in coal system. Grids installed at entrance to lockhopper feed lines. V-502 modifications to increase steam flow. Coal vessel sampling system.

TEST #	TEST DATE	OPERATING DATA	ESTIMATED COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-8	Aug. 4-5, 1979 (1st try - Aug. 2-3, 1979)	1. 4.7 hrs. coal feed 2. 2.0 hrs. char feed 3. Char burners lit 19.4 hrs. 4. Pressured up 344.0 hrs.	5,700#/hr. (average)	1. Loss of Stage I thermocouples. 2. Erratic coal and char feed.	<p>1. Start-up was delayed two weeks due to:</p> <ul style="list-style-type: none"> a. discovery of many high pressure leaks. b. problems with C-921A & B. c. problems with P-701A & B. d. problems with P-302B. e. problems with C-201. f. problems with C-901A. g. problems with York chiller. <p>It is believed these problems all resulted in part from the extended shutdown preceding Test G-8.</p> <p>2. Failed to light STB. Had to depressure to clean sensor of oil, apparently from C-921 lubrication.</p> <p>3. After all five burners were lit, STB shut down due again to oil on sensor. When STB would not relight, gasifier was depressured again to clean STB sensor. Approximately 1/2 gallon of oil was drained from the fuel gas header. The lube oil flows to the C-921 compressors were decreased.</p> <p>4. Were unable to feed through 'A' coal or 'A' or 'B' char legs. Feed through 'B' coal and 'C' char legs was erratic.</p> <p>5. Were able to feed coal left in V-306, coal vessel, from 1st try.</p> <p>6. The coal and char level recorders, LR-2100 and LR-4102, failed to give meaningful readings. It is believed that the transmitters failed because of high temperature in the instrument cabinet.</p> <p>7. V-502, the ammonia stripper, pressured up, forcing curtailment of steam flow to the stripper.</p> <p>8. Both Stage I thermocouples failed - #10 failed before coal feed; #12 failed after 2 hours char feed.</p> <p>9. New thermistors on char burner bellows showed great temperature increase when burners were shut down after 1st try. When burners were shut down at test completion N₂ flow was increased so that bellows temperature did not increase as much.</p>	<p>1. York chiller was overhauled.</p> <p>2. Purge flow to Barnes radiometer sight tube was changed from purge gas to nitrogen. Purge gas absorbs some of the infrared light analyzed by the radiometer.</p> <p>3. Level transmitters, LT-2100 and LT-4102, were moved from the cabinet containing the AAI chromatograph to a new cabinet.</p>

TEST #	TEST DATE	OPERATING DATA	ESTIMATED COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-8A	August 14-15, 1979	<ol style="list-style-type: none"> 25 2/3 hrs. coal feed 26.5 hrs. char feed 55 hrs. gasifier pressure 	3,940#/hr. (average)	A steady and stable char feed rate could not be maintained because the char burners kept plugging up.	<ol style="list-style-type: none"> Rotex screen system worked; amount of fines in coal slurry reduced. Ammonia stripper performed excellently. Amount of ammonia in V-502 significantly reduced. Had excellent tapping. Produced good frit (slag). Most material balance instruments worked correctly. Stable coal feed. Slag collector worked. Using N₂ for purge in the Barnes radiometer produced the following results; <ol style="list-style-type: none"> 1st time there was a complete spector scan from 1.6 to 5.5 microns, very little buildup of carbon in sight tube, sight tube remained open for almost the whole test, 1st spector scan of char feed for an extended period of time, and correlation could be made between thermocouple #10 and radiometer unit #12-880. The Argonne flowmeter responded to char feed faster than the char dP. The Argonne flowmeter monitored char flow in a qualitative manner. Argonne, leg temperature, and char dP's correlated very well with each other. The MSA CO and CO₂ recorder responded with char feed. Char burner plugging occurred quite often downstream of fuel gas causing burner shutdown. Stage 1 thermocouples in good condition. 	<ol style="list-style-type: none"> Bellows in 'A' char burner had 2 convolutions expanded. The bellows in the other burners were undistorted. The bellows in all the burners were replaced. There had to be some grinding done on 'C' char burner annulus to get the bellows to fit. The inner tube of the char burner was shortened. Total O₂/total fuel gas ratio shutdown installed and tied to 3 char burners.

TEST #	TEST DATE	OPERATING DATA	ESTIMATED COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-8B	Sept. 4, 5, 6 & 7	<ol style="list-style-type: none"> 1. Gasifier pressurized up for 136.5 hrs. 2. Coal feed to Stage II 33.5 hrs. 3. Char feed approx. 51 hrs. 	2,212 #/hr (approx. average)	<ol style="list-style-type: none"> 1. 'A' & 'C' char burner legs plugged. 2. Slurry line upstream of P-202 plugged. 	<ol style="list-style-type: none"> 1. One of the best carbon and nitrogen material balances thus far. 2. Successfully varied Stage I temperature. At 2550°F the slag was noticeably more viscous. 3. No significant Selexol losses after reducing V-702 pressure from 180 to 150 psig. 4. Ammonia stripper performed excellently. Typical V-502 bottoms NH₄ concentration 10 ppm. 5. TV pictures on both cameras were good all through the test. 6. Good quality slag produced (frit). 7. Low solids in V-203 and V-502 bottoms. 8. Thermocouple 3401-12 failed during test (eaten away at test end). Thermocouple 3401-10 read throughout the test although thermowell was reduced in size. 9. Barnes radiometer did not work. Site port was blocked with slag/metal. 	<ol style="list-style-type: none"> 1. Put new burner tip on 'C' char burner. There was a large hole in the face of the burner tip at the oxygen annulus. 2. Installed a heat exchanger (formerly E-801) on the 6th floor to heat up the fuel gas going to the char burners. 3. New sleeves and tap stone were installed (one stone with 2" diameter hole). 4. Check valve installed on main steam header. 5. New center tube (1" sched 80) installed in char burner from point upstream of fuel gas/process steam tie-in to burner tip. This change results in separation of the eductor motive steam/char from the fuel gas/process steam.

TEST #	TEST DATE	OPERATING DATA	ESTIMATED COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-9	October 2-3, 1979	1. Gasifier press- sured up 109 hrs. 2. Coal feed 21 hrs. 3. Char fed 18 hrs. 4. Char burners 11t 26 hrs.	3,262#/hr. (average)	1. Recycle gas compressor (C-201) malfunctioned causing a plant-wide power failure. Emer- gency power systems functioned properly. When power was restored it was decided to in- vestigate reasons for this failure. 2. Aggravating conditions leading to this decision. a. Two char legs ('A' and 'C') were known to be plugged. b. Problems in the coal grinding area caused by wet coal.	1. Because of the limited operating time during the test and the continued occurrence of char burner plugs (although less frequent on 'B' char burner than during past tests), it was difficult to evaluate the effectiveness of the pretest G-9 modifications. 2. 'A' and 'C' char legs plugged during the test as a result of burner plugs and could not be cleared. 3. The fuel gas heater was used throughout the test to heat the fuel gas to 475- 500°F. 4. The char feed through 'B' char system was more stable than in Test G-8B. Char feed through 'A' and 'C' similar to previous tests with numerous burner plugs. 5. Barnes radiometer did not work. Site port was blocked with a large amount of coal and char-like material. 6. The following good results of the test G-8B were repeated. a. No significant Selexol losses. b. Ammonia stripper performed excellently. c. TV pictures on both cameras were good. d. Good quality slag produced (frit). e. Low solids in V-203 and V-502 bottoms. 7. Thermocouples in Stage I functioned throughout the test. Thermocouple (TR-3401-2) failed. It had a life of 1046 hours. 8. There were numerous problems in the coal handling area all of which were a direct result of wet coal. 9. It required only 8 rts. of O ₂ to reach operating temperature vs. 9.1 rts. before the installation of the new water-cooled sleeves and tap stone.	1. 'A' char leg (3") has been removed and replaced with a 1-inch char leg. New dP's added across new leg (upper leg, valve, and lower leg). 2. A new dP tap was installed in each char burner, putting the burner dP back in service. 3. New thermocouples were installed in the upper section of each char leg. 4. The Braun flowmeter was taken out of 'B' coal leg and replaced with a spool piece. 5. A bypass was installed around the N ₂ purge on the Barnes radiometer; operable from the control room. 6. A screw conveyer was installed to feed the rod mill directly from the weigh belt. 7. The discharge chute of the Rotex screen was modified to increase its capacity. 8. Smaller control valve installed on steam line to fuel gas heater. 10. Two material balances were conducted. 11. Char burners in good condition.

TEST #	TEST DATE	OPERATING DATA	ESTIMATED COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-10	October 23-25, 1979	<ol style="list-style-type: none"> 37.5 hrs. coal feed 35 hrs. char feed 42 hrs. char burner firing 108.5 hrs. gasifier pressure 	2,750#/hr. (average)	<ol style="list-style-type: none"> Packing leak on ROV-2413A in A Coal Leg. 	<ol style="list-style-type: none"> A number of tests were performed with the new 1" 'A' char feed system by varying the LICV-4102 'A' opening from 25% to 100% and back down to 0%, while noting changes in flow characteristics. Tests were also conducted by changing purge gas flow rates to the char leg and also by varying the temperature of the fuel gas. In general, operation of the new 1" system was very good. Some of the new dP's will have to be reranged for better observation. The new screw feeder in the coal handling area worked well. The Rotex screen system continued to reduce the fines in the coal slurry. High temperatures were noted in the thermistors when each burner was lit. No bellows damage was found on inspection. A coal vessel calibration test was run by comparing level vs. slurry feed rate. The slag tap burner O₂ flow was reduced for ~8 hrs. Tapping became erratic during this period. A packing leak on ROV-2413A resulted in 'A' coal leg being manually valved in for the majority of the test. One material balance was conducted. Tapping was generally consistent and good quality grainy slag produced. The Barnes radiometer responded throughout the test. The response would become more steady after purging with the new N₂ bypass. E-602A successfully cleaned with steam after becoming restricted with naphthalene. 	<ol style="list-style-type: none"> Install 1" char line on 'C' char leg. Relocate dP-4244 on the char vessel. Hook up density meters on 'A' and 'C' char legs. Relocated sonic flowmeter, FM-5013, on V-502 bottoms. Installed CM booster pump for C-201, C-901, and C-921. Reranged dP's on 'A' char leg as necessary.

		TEST SUMMARY				
TEST #	TEST DATE	OPERATING DATA	ESTIMATED COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-10A	December 11-14, 1979	1. 55.5 hrs. coal feed. 2. 49.2 hrs. char feed. 3. 63 hrs. char burner firing. 4. 722.2 hrs. gasifier pressure.	2210#/hr. (average)	1. Continuing difficulties with coal feed to gasifier. 2. Completion of most of the test objectives.	1. The coal screw feeder and Rotex screen both continued to perform well. 2. A coal vessel level calibration test was run as in Test G-10. 3. Both coal legs (especially 'A' leg) experienced problems throughout the test. Plugs occurred often; when there were no plugs, coal feed was well below design rate. 4. While 'A' coal leg was being cleared, flow of Stage II gases up the leg to atmosphere resulted in the leg twisting and moving visibly. 5. Purge gas flow to 'B' coal eductor fell suddenly from 7 to 5 roots. No explanation was found. 6. The fuel gas flow to 'B' char burner spiked low several times, twice causing burner shutdowns. No explanation found. 7. Char feed tests were conducted on 'A' and 'C' legs. Control valve position was varied; feed instrumentation responses were noted. Char feed proved consistent and controllable. Char capacity appears to be about 1 ton/hr. for each leg. 8. One material balance was conducted. 9. Tapping and slag collection were consistent. 10. The new timed purge on the Barnes radiometer sight tube worked well, keeping the radiometer signal strong except during two brief periods. Radiometer response was similar to that seen in G-10. 11. E-602A was successfully steamed out. A large amount of naphthalene was flushed out.	1. A 1-1/2" leg was installed in place of the existing 4" 'A' coal leg. The valves and instrumentation are analogous to the valves and instrumentation on the 1" char legs. 2. E-903 was installed to heat purge gas to coal and char legs and coal eductors. 3. PdR-3219 was installed between the char vessel and the gasifier. 4. The lower tap of PdR-4244 was moved to the top of LCV-4102A. 5. Supports were installed on the inlet and discharge piping of P-302A and B to reduce stress on the pumps. 6. A closed glycol/water cooling loop was installed to cool C-921A and B, C-901A and B, and C-201 (except for the jacket cooler.) 7. Loop 3217 was modified as follows: a. PdF-3217 now has direct sensing lines to pressure. Previously, it compared signals from transmitters. b. Valve trim was added to both PdCV-3217A and B to reduce maximum flow by a factor of about 4. 8. Coal and char leg density instruments were put on recorders, DR-2807A and B, and DR-4803A, B, and C. 9. Adjustments were made on the Barnes Infrared Radiometers. 10. P-912A and B, high pressure boiler feed water pumps, were repaired. 11. The coal vessel sampling station was moved to the char vessel.

TEST #	TEST DATE	OPERATING DATA	ESTIMATED COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR REVISIONS & REPAIRS	A TEST
G-11	January 28 to January 31, 1980	<ol style="list-style-type: none"> 57.5 hrs. coal feed 54.5 hrs. char feed 66.5 hrs. char burner firing 112 hrs. gasifier pressure 	41000/hr. (average)	<ol style="list-style-type: none"> Slurry feed line to the high pressure P-202 pumps became plugged and had to be dismantled to clear. 	<ol style="list-style-type: none"> Coal flow was more stable and a higher rate than it has been in previous tests; up to 60000/hr. coal feed rate to spray drying. <ol style="list-style-type: none"> Performed coal flow variation tests on 'A' and 'B' coal legs. Purge gas heater helped coal feed. Char flow was good. Performed char flow variation tests on 'A' and 'C' legs. Longer stable operating periods than in previous tests. Another point on char vessel calibration curve which falls in line with previous points. Selexol processed a higher rate of gas than ever before. Radiometer data collected. H-201 operated successfully on fuel gas throughout the test. All but one of the test objectives were completed. 	<ol style="list-style-type: none"> The expansion joint in E-201 was weld repaired. The bearing case on P-302A, gasifier cooling water pump, was remachined. Holes in impellers of P-302A & B were plugged to reduce the axial pressure exerted on the pump thrust bearing. An O₂ shutoff valve was installed on the O₂ line on the 3rd floor. This valve will be activated by an ESD. New char burner tips made of Incoloy 800 and expansion joints were placed in all char burners. The low pressure boiler, B-912, was retubed. A permanent steam line was installed to the shell side of E-602A & B coolers. A sensing line was installed on the overhead line from V-702 and V-703 and tied into PIC-7200 and PIC-7201. These signals read out in the control room. A PI, TI and sample station were installed on V-203 tank overhead line. An Elliott representative inspected the turbines on P-302B and P-912B. Some replacement parts were required, but the general condition was good. The purge gas line was modified for material balances purposes. A Cuno filter was installed in AI-5804 feed line to keep the pH analyzer operational. Operators were added to block valves on both coal systems between the coal eductor and nozzles. A new rupture disc, rated at 100 psig and 3000 l was installed on E-602A. The 1-1/2" slurry return line from the P-202 suction was routed such that it will return slurry back to V-201 or V-106. A new coal eductor shell was fabricated without orifice or venturi and installed in the 'A' coal system. Supports holding the pall rings in the H₂S stripper (V-704) had broken and collapsed. The pall rings were removed, the supports repaired, and the pall rings returned. The relief valve on each of the two slag lockhoppers was relocated (with larger piping, from the 1" dia. nitrogen inlet line to the 3" dia. depressuring line connected to the lockhopper. A new thermowell, with a tungsten-rhenium thermocouple and 5/8" O.D. moly tube coated with boron, was inserted in point #12 in Stage 1. 	

TEST SUMMARY

TEST #	TEST DATE	OPERATING DATA	ESTIMATED COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-11A	March 5-7, 1980	<ol style="list-style-type: none"> 37.5 hrs. coal feed 34.5 hrs. char feed 44 hrs. char burner firing 224.5 hrs. gasifier pressure 	5400#/hr. (average)	<ol style="list-style-type: none"> Completion of modified objectives. 	<ol style="list-style-type: none"> A redesigned coal eductor without orifice or venturi was installed on 'A' coal system. Flow tests conducted on this system achieved feed rates up to 6,000 lb./hr. Methane was removed from 'A' char burner for a period of 5 hours. No damage was seen on burner face. Pressure control in gasifier system was improved by controlling with PIC-5204A set at 750 psig and PIC-7206 set at 550 psig. Another point on char vessel calibration was obtained. 	<ol style="list-style-type: none"> An activator positioner and a position transmitter were installed on the EPG ball valve in 'C' char leg to enable this valve to be used to control char feed. FIC-2014 was set up to control the make-up to the spray drying section through FICV-2014 (formerly PdCV-3217B). Pressure differential between spray drying and gasifier (PdIC-3217) will be controlled by venting through PdCV-3217A. PdR-4244 was changed to measure pressure across the char vessel. PdR-4247A & C were installed to measure upper leg pressure differentials on 'A' and 'C' char legs. The seal flush to the boiler feedwater pumps (P-912) was changed to discharge outside of the building instead of going into the trench to the pond. The 600 psig steam letdown valve (PCV-9217) which had been badly eroded was repaired. The Selexol system H₂S solvent pump (P-701B) was removed from service and is being rebuilt. The tempered glass windows over the television ports were replaced with Pyrex windows.
G-11B	March 22-23, 1980	<ol style="list-style-type: none"> 22 hrs. coal feed 18 hrs. char feed 30.5 hrs. char burner firing 49 hrs. gasifier pressure 	5200#/hr. (average)	<ol style="list-style-type: none"> 'A' char burner developed cooling water leak in burner face. 	<ol style="list-style-type: none"> Objective of 5 to 7 days stable operation at 5000 lbs./hr. coal feed not realized due to 'A' char burner failure. Experiments run for BCR. Char legs closed while maintaining constant oxygen flow; Stage I temperature increased 250°F 1st attempt, greater than 500°F 2nd attempt. E-201 leak between shell/tubes repaired. Significant pressure fluctuations in plant noted; resulting in less stable solids feed. Ball valve on 'C' char leg used to control solids feed. Larger pg usage than previous test noted. Stage I coated with gray-black, grainy, clinker-like material. The clinker-like material also found in Stage II. Only 75 pounds of slag material in slag quench section after run. 	<ol style="list-style-type: none"> Tip of 'A' char burner replaced with Inconel 600 tip. Taps for PdR-4247C, 4245C, and 4246C relocated. Changed fiberfrax in coal vessel. Maytag pressure switches placed in upright and elevated positions to keep out dirt. Block valves placed in entrance and exit hydraulic lines to gasifier.

TEST #	TEST DATE	OPERATING DATA	ESTIMATED COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-11C	April 1, 1980	1. 10 hrs. coal feed 2. 11.5 hrs. char feed 3. 14 hrs. char burner firing 4. 35.5 hrs. gasifier pressure	5300 lb/hr (average)	1. Coal plug in high pressure slurry line to spray drying	1. Planned 5 to 7 days run at 5000 lb/hr terminated due to plug in H.P. slurry line. 2. High grinding rates (20 T/hr.) produced coarser than normal coal. May have contributed to slurry line plugging. 3. Ran test to determine minimum purge gas flow to coal eductors for stable feeding. 'A' coal leg was stable as low as 4.0 roots; 'B' coal leg was unstable at 4.5 roots. 4. Adjusting response on PIC-5204B and PdIC-9291 improved plant pressure control.	1. Five rods added to rod mill to reduce large coal particles. 2. T-106 was emptied and cleaned out. 3. T-106 mixer rotation direction changed.
G-11D	April 7 to April 8, 1980	1. 31 hrs. coal feed 2. 30.5 hrs. char feed 3. 33 hrs. char burner firing 4. 108 hrs. gasifier pressure	5300 lb/hr (average)	1. Line to 'A' lockhopper plugged; no slag dumped in 24 hrs. 2. Slag tap burner down; could not relight. 3. Char burner dP's pegged negative. 4. Stage I thermocouple (TI-3401-12) dropped to less than 500°F. 5. Quench section temperature (TI-3401-1) dropped from 500 to 150°F.	1. Planned 5 to 7 day run at 5000 lb/hr. terminated due to operational problems listed under REASONS FOR SHUTDOWN. 2. Reduced purge gas to 'A' coal eductor from 6.0 to 3.0 roots. Ran 16 hrs. at 3.0 roots. 3. Quench section full of water at end of run. 4. 8403 lbs. of slag in quench section. 5. Very erratic level control in gas washer (V-501).	1. Removed RED valve from 'B' lockhopper and replaced with metal sleeve. 2. Replaced 'A', 'B' and 'C' char burner sleeves. 3. Replaced gasifier tap stones with new ones made of monofrax E. Same stone configuration as past tests. 4. Replaced the P-302A & B seal water coolers with a single, large cooler. 5. Installed new high pressure service water purge to bottom of Magnetrol level controller (LIC-5100) on V-501. 6. A 90° angle nose cone lens and automatic iris installed on west TV camera. 7. Mica windows replaced on both TV cameras. New TV window sprays (from Rotex screen spray bars) installed and line size increased from 1/4" to 1/2" dia. Added metal frames for mounting windows. 8. Sleeve and filler plate installed on Barnes radiometer sight tube. 9. Water flush and drain lines on slurry feed pumps (P-202A & B) increased to 2" dia. 10. Pressure switch settings increased on slag agitator. Hydraulic cylinder replaced. Flexible hoses to cylinder replaced into metal tubing. 11. Leak in HICVD-5100B repaired. 12. Replaced screen in char vessel lower port and repaired with Fiberfrax. 13. Section below brick work in Stage II repacked with JADE PAK-88-P. Thermowell ports and seam filled with Fiberfrax and covered with AA-22. Upper Grayloc joint and quench nozzle port covered with AA-22. 14. 1/4" dia. tubing section with bypass added to

TEST #	TEST DATE	OPERATING DATA	ESTIMATED COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-11E	May 2-3, 1980	1. 3.5 hrs. coal feed 2. 3 hrs. char feed 3. 8 hrs. char burner firing 4. 60 hrs. gasifier pressure	6100 #/hr. (average)	1. Normal tapping not visible; no slag in lockhopper dumps. 2. TR-3401-12 running 200-300°F below TR-3401-10. 3. Char and slag tap burners shut down accompanied by 100 psi surge in gasifier pressure and flashing on TV.	1. Normal tapping stopped 10 min. after start of spray drying. 2. Test terminated before planned experiments could be run. 3. No slag was obtained from lockhopper dumps. 4. Slag filled 30" above taphole in Stage I (9" above char burners). Weight of slag in Stage I was 700 lbs. 5. New tap stone had been mounted approx. 1 1/2" higher than previous position. 6. Red material (iron oxide) found on char burners and surfaces in quench section. 7. High stage II temperature ESD occurred 2 1/4 hr. before final shut down. Accompanied by 35 psi surge in gasifier pressure and flashing on TV.	1. Tapstones replaced with single Monofrax E tapstone having 6 inch tap hole. Castable refractory used to elevate tapstone approx. 2 inches above cooling coil. 2. 'B' char eductor replaced due to misalignment of nozzle and throat. 3. Replaced both Stage I thermocouples and thermowells. TE-3401-10 thermowell is molytube coated with Cr ₂ O ₃ . TE-3401-12 thermowell is molytube coated with boron.

TEST #	TEST DATE	OPERATING DATA	ESTIMATED COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-11F	May 13-16, 1960	<ol style="list-style-type: none"> 135.3 hrs. gasifier pressure 57.7 hrs. char burner firing 48.1 hrs. coal feed to spray drying 49.6 hrs. coal feed to gasifier 54.4 hrs. char feed to gasifier 	4700 lb/hr (average)	<ol style="list-style-type: none"> Loss of visible tapping from Stage I. Loss of fuel gas flow while switching fuel gas compressors. All burners shutdown compounding loss of tapping problem. 	<ol style="list-style-type: none"> Conducted flow variation tests on 'C' char leg to test the ball valve characteristics. Collected four sets of material balance data over six hours at 2800°F Stage I temperature and 1700°F Stage II temperature. Lowered Stage I temperature to 2700°F with Stage II at 1700°F on two occasions to take material balance data. Both times tapping was lost after a period of time. During the first plug, burner firing was increased and the plug broke through. Burner firing was increased during the second plug, but fuel gas was lost and the burners shut down before the restriction could be cleared. 	<ol style="list-style-type: none"> 'A' char burner replaced with S-R designed burner. Cooling water, fuel gas and steam piping to the burner adapted to accept new burner. Auburn capacitance-type flowmeter installed upstream of 'A' char burner. Stage I cooling water tubes inspected for leaks and wall thickness. V-201 bypass piping installed.

TEST #	TEST DATE	OPERATING DATA	ESTIMATED COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-12 (Run 54)	May 30, 1980	<ol style="list-style-type: none"> 5 3/4 hrs. coal feed 7 3/4 hrs. char feed 13 hrs. char burner firing 43 1/2 hrs. gasifier pressure 	5,917 lbs/hr. (average)	<ol style="list-style-type: none"> To inspect the internal integrity of the oxygen lines inside the burner. 	<ol style="list-style-type: none"> This test was characterized by a very smooth start up and shut-down. 	<ol style="list-style-type: none"> No. 1 Char Burner The No. 1 char burner was repaired and inserted in the 'A' char burner slot. The two 1/2-inch oxygen tubes which had broken prior to Test G-12 were repaired and pressure tested. Cooling Water Flow Rate to 'A' Char Burner The flow measurement orifice on the cooling water line from 'A' char burner was put in service. This cooling water flow rate will read out on AAI as well as the spare pen on FR-3003. New Vidicon on West TV Camera A new Vidicon tube was installed on the west TV camera to improve sensitivity of the camera. Spool Piece for Auburn Flow Meter Since the Auburn flow meter will not be available this test, a spool piece will be installed in its place. P-502B, Ash Transport Pump The rpm on P-502B was reduced from 1200 rpm to 590 rpm.

TEST #	TEST DATE	OPERATING DATA	AVERAGE COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-12A (Run 55)	June 9-10, 1980	1. 2.8 hrs. coal feed 2. 1.3 hrs. char feed 3. 10.0 hrs. char burner firing 4. 22.3 hrs. gasifier pressure	4,750 lb/hr. average to gasifier	1. Failure of Stage I thermocouples.	1. Large stalactite formed at the tap hole. 2. No feed through 'A' coal system during test due to plug.	1. Four-inch diameter 'B' char leg replaced with one-inch diameter line. 2. Solids removed from settling pond. 3. Repairs made on demineralizer unit; resin treated for organic fouling. 4. P.O. drum installed in main fuel gas line. (not in service) 5. ROV-36000 repaired. 6. Radiometer probe removed and thermocouple (TR-3401-11) installed. 7. Heat exchanger (E-964) installed on close-in cooling system for compressors, C-201, C-90 and C-921. 8. Relocated ROV-2413A (1" valve) from 'A' coal leg to 'B' char leg. New number is ROV-4616B. Installed 1 1/2" Kamyr valve in 'A' coal leg. Thermal flowmeter (FM-2020A) removed from 'A' coal leg. 9. New picture tube installed in North TV monitor.
G-13 (Run 56)	July 1-6, 1980	1. 119.6 hrs. coal feed 2. 118.7 hrs. char feed 3. 122.3 hrs. char burner firing 4. 186.25 hrs. gasifier	8,000 lbs/hr average during material balance periods to gasifier	1. Cooling water leak into Stage I.	1. Longest run to date. 2. Smooth start-up and operation. 3. Equipment reliability was better than previous runs. 4. Thermocouples lasted 120+ hours. 5. A large amount of data was collected for material balance. 6. 'C' char leg control with ball valve was in a 10% range with 60% open for no flow and 70% open for full flow. 7. Good tapping throughout run. No TV picture for most of run. Six-inch tap hole present at shutdown. 8. Significant amount of carbon material found with slag. 9. High pressure drop across gas washer at end of run. Inlet venturi found to be restricted 10. Level control problems with gas washer throughout test. 11. High V-203 solids throughout test (5-10%). 12. Hole in 'C' char burner face, cooling water and O ₂ section, small hole in 'B' char burner face O ₂ section, pitting and surface cracking of 'A' char burner face.	1. Four-inch diameter 'B' coal leg was replaced with one and one-half-inch diameter line. 'B' coal leg eductor was replaced with a tee. 'A' and 'B' coal legs are now identical. 2. New char burner #1 installed in the "A" position. 3. Sample station installed at coal vessel. 4. Low pressure water cooled sample station installed in the bottoms line of the gas washer. 5. Gasifier cooling water system separated from the high pressure gas washer. 6. Ammeters installed on P-106 pumps. 7. Sample station penetration tube extended into center of coal and char vessel. Purge rate reduced to char sample station. 8. Coal to snarv totalizer out in. 9. Stage II hi temp ESD moved to TE-3401-3. Alarms on TE-3401-283. 10. Boron coated molyseath installed for TE-3401-2 11. Switched back to Vee ball control in 'C' char leg.

TEST #	TEST DATE	OPERATING DATA	COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-14 (Run 57)	Oct. 13-17, 1980	1. 48.5 hrs. coal feed. 2. 51.2 hrs. char feed. 3. 56.5 hrs. char burner firing. 4. 86 hrs. gasifier pressure.	3700 lbs/hr.	1. Rupture disc gasket leakage on gasifier cooling water surge drum/gas washer pressure equalizing line.	1. High V-203 solids throughout test (10-37%). 2. Trickle valve in coal vessel found closed. Coal vessel cyclone cracked and contained holes. 3. AAI computer problems interrupted data acquisition. 4. Stage II maximum steam flow 13,400 lb/hr. 5. P-202 pumps plugged during an ESD. Feed could not be restarted.	1. Coal cyclone trickle valve removed. 2. J.P.L. meters replaced with spool piece on 'A' char leg. 3. Rupture disc removed. New V-302 pressure control system deactivated. 4. Oxygen pumps modified to increase system capacity. 5. ROV-46168 repaired. 6. TW-3401-11 flame sprayed using solid chrome oxide rod and installed. 7. Slag heating burner tip replaced. 8. Coal cyclone repaired.

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TEST #	TEST DATE	OPERATING DATA	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-14A (Run 58)	Oct. 23-28, 1980	<ol style="list-style-type: none"> 100.5 hrs. coal feed 5400 lbs/hr 100.5 hrs. char feed 107.1 hrs. char burner firing 127.5 gasifier pressure 	<ol style="list-style-type: none"> No slag was being collected in the lockhopper dumps for more than one day. 	<ol style="list-style-type: none"> AAI data acquisition was out of service for the majority of the test. High char vessel level caused char solids to carry over into the gas washing system. Quench section contained 12,900 lbs. of slag on inspection. Controlled Stage I temperature on fuel gas for short period. Slight melting of center tube on #1 char burner. All other burners in good condition. Ran majority of test with 1350 psig H.P. steam pressure to char eductors. There was a relatively small deposit in Stage II. There was a large deposit on the gas washer inlet venturi. 	<ol style="list-style-type: none"> Piping modified and new #2 and #3 char burners installed. New char burner sleeves installed. New tap stone installed. New resin put in 'A' demineralizer bed. Lockhopper sequence revised so that slag is collected simultaneously in both lockhoppers.

TEST #	TEST DATE	OPERATING DATA	ESTIMATED COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-15 (Run 59)	Nov. 18-22, 1980	1. 83.1 hrs. coal feed 2. 82.4 hrs. char feed 3. 90.4 hrs. char burner firing 4. 149.5 hrs. gasifier pressure	4985 lbs/hr (average to gasifier)	1. Loss of level control in gasifier slag quench section. Water level was visible on T.V. monitors. Believed to be caused by slag accumulation in slag quench section	1. The fuel gas flows to the char burners were reduced so that the total mole ratio of fuel gas to oxygen was 0.58 (normally 0.67). Ratios to #1 and #2 char burners were 0.37 and 0.40 respectively (normally 0.56). 2. Argonne monitor tests were conducted using additional equipment from Argonne laboratory and personnel from Argonne. 3. V-501 level control and reflux problems caused gasifier pressure fluctuations. 4. Betz water treatment chemical was added. It was removed after about 20 hours in service since it was believed to have caused foaming. An anti-foaming agent was then added. 5. There was no char feed through "B" leg.	1. The original type rupture disk was reinstalled between the cooling water surge drum (V-302) and the gas washer (V-501). 2. The flow elements on the spray drying system make-up (FE-2014, 1 1/2" annubar) and vent (FE-2013, 1 1/2" annubar) were replaced with 3/4" annubars. Both installations are in flanged sections of pipe. 3. The slag agitator was repaired and the stainless steel hydraulic lines rerouted. The gratings covering the lockhopper legs were removed. The position indicator was reinstalled. 4. The water degassing tank bottoms flow meter (FM-2369, a magnet) was moved downstream of the control valve bypass. 5. The coal feed Vee-ball valves (FV-2020 A and B) were replaced with new valves due to erosion. 6. A new, closed impeller was installed in P-502A, replacing a cracked impeller. 7. A knock-out pot (V-709) was put in downstream of the H ₂ S Selexol low pressure flash tank (V-703). 8. A tank liner was installed in the repulp tank T-105).

TEST #	TEST DATE	OPERATING DATA	COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-15A (Run 6E)	Dec. 9-12, 1980	1. 82.3 hrs. coal feed 2. 81.3 hrs. char feed 3. 87.9 hrs. char burner firing 4. 198.7 hrs. gasifier pressure	4950 lb/hr.	1. No slag was collected from the gasifier for over 24 hrs.	1. Number one char burner was operated without fuel gas for a period of the test. 2. Coal and char solids feed were stable. 3. Stage I temperature was successfully controlled on automatic for the majority of the test. 4. Material balance data was collected at different operating conditions. 5. Loss of oxygen pressure due to problems with liquid oxygen pumps.	1. Slag removal changes: Two bar by two bar gratings were installed over the lockhopper legs. Satisfaction of the low recycle flow switch was eliminated from the lockhopper sequence and put on alarm only. The stalactite breaker stroke speed was increased. 2. Gas washer changes: A hole was put in the baffle above the reflux outlet. A vortex breaker was installed. 3. The piping was revised to allow addition of the slag slurry let down directly to the bottom of the ammonia stripper. 4. Knock-out pot (V-710) was installed on the Selexol high pressure flash tank overhead. Second filter installed in parallel - S-701A/B. 5. The FE-5002 orifice run was changed 2 to 3 inches. 6. A double pipe fuel gas heater (E-401) was installed to replace E-801 which was returned to the methanation area. 7. Epoxy coatings were put on the bottoms of T-106 and T-108. 8. Isolation valves were installed downstream of the rupture discs on E-602A/B. 9. Modifications for using the coal centrifuge to remove the solids from the rotex screen concentrate were completed. 10. A Kamyr 1500# ball valve with a modified ball was installed in 'B' char leg in place of the ROV. This valve was installed to test its flow controllability. 11. Body of the coal feed valves FCV-2020A/B was coated with Cr ₂ O ₃ to counter act erosion. 12. Acid washed gasifier gas wash system. 13. Repaired small holes in coal cyclone S-302. 14. The clarified water diversion valve actuator was repaired. 15. Trim in spray drying vent changed from a Cv of 1.5 to 2.5. 16. The Auburn meter was installed behind 'A' char burner.

TEST #	TEST DATE	OPERATING DATA	ESTIMATED COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-16 (Run 61)	Jan. 21-24, 1981	<ol style="list-style-type: none"> 58.5 hrs. coal feed 60.5 hrs. char feed 69.7 hrs. char burner firing 252.1 hrs. gasifier pressure 	6690 lb/hr	<p>The test was terminated voluntarily in cooperation with the Department of Environmental Resources due to their concern that the plant effluent had possibly caused problems in local communities. BI-GAS personnel did not believe this to be an issue, but terminated the test until plant and borrough discharge samples could be analyzed. It was determined that the plant was not the source of contamination and a water monitoring program has been established to insure that the BI-GAS facility continues to stay within effluent guidelines.</p>	<ol style="list-style-type: none"> Oxygen to fuel gas ratio reduced to two to one. During this period, Stage I temperature varied plus or minus 50F compared to plus or minus 20F during excess fuel gas operation. Slag removal much improved over previous test. (90 percent removed from gasifier.) Favorable results obtained during initial test using flocculant addition to the coal fines stream feeding the centrifuge, to aid in solids removal. Installation of the vortex breaker and the drilling of the holes in the lower baffle did not improve operation of the process gas washer. Results of the first test of the modified Kamyr valve were promising. 	<ol style="list-style-type: none"> Single point independent high level probe installed on process gas washer (V-501). Auburn monitor repaired at factory and relocated above eductor in 'A' char leg. Gaps between the cooling tubes near the slag heating and 'C' char burners packed with castable refractory. Portion of annulus below 'C' char burner filled with insulator's cement. Differential pressure switches in the lockhopper overflow lines replaced with conductivity sensors. Piping of the clear water effluent from the plant to the settling pond modified. Water can be sent to the pond, to the clarified water pump sump, or to the effluent water pump sump. Two damaged flexible hoses for cooling water to 'C' char burner sleeve disconnected from header and header capped.

TEST #	TEST DATE	OPERATING DATA	ESTIMATED COAL FEED RATE	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-16A (Run 62)	February 23 - March 1, 1981	1. 122.0 hrs. coal feed 2. 120.2 hrs. char feed 3. 133.2 hrs. char burner firing 4. 149.8 hrs. gasifier pressure	4800-6700 lb/hr.	1. High pond solids and high pond level. 2. Problems with recycle gas compressor.	1. Longest run to date. 2. Oxygen to fuel gas ratio reduced to two to one for a 24-hour material balance period. 3. Auburn monitor flow tests showed immediate, consistent responses to changes in char feed valve setting. 4. The results of the modified Kamyr ball valve tests showed good control occurred between the 20-60% valve positions. 5. Slag removal systems operated well throughout test. 6. Problems with slag tap burner shutdowns and the gas washer reflux flow occurred early in the test; both were resolved. 7. The coal slurry discharge from the rod mill was sent directly to the pulp storage tank, by- passing the Rotex screen unit, for a six-hour period.	1. Installation of the sieve bend screen was completed. 2. A new actuator, which is designed for a 1900 rotation, was installed on the slag agitator. 3. The char burner sleeves and the tap stone were replaced with items of similar design. 4. A larger motor was installed on the thick- ener underflow pump. This will permit pumping of the thickener bottoms to the centrifuge. 5. A pressure control valve was installed for the CO ₂ flash tank in the CO ₂ Selexol system. Pressure control for the H ₂ S flash tanks were accomplished in a similar manner.

TEST G-168 SUMMARY

TEST #	TEST DATE	OPERATING DATA	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-168 (Run 63)	March 25- April 2, 1981	1. 169.0 hrs. coal feed 2. 171.9 hrs. char feed 3. 182.5 hrs. char burner firing 4. 260.5 hrs. gasifier pressure	1. Main test objectives were completed. 2. The plant fuel gas supply was scheduled to be interrupted on April 2 for maintenance by the gas company.	1. Longest run to date. 2. Six heat and material balance periods were run with coal feed rates of 5000 to 7100 pph. Balance periods were run with excess, stoichiometric and 85% of stoichiometric fuel gas flow. 3. The fuel gas reinitiation interlock system was tested and performed as designed. 4. A relatively large Stage II deposit occurred. 5. The product gas washing system operated smoothly for the majority of the test. 6. The thickener was used to concentrate the Rotex screen centrate and the surge water tank overflow. For this reason, the solids concentration in the plant effluent was very low for the majority of the test. 7. Slag removal systems continued to operate well. 8. The tap stone was broken; only 40% of the circumference was in place upon inspection.	1. A Capintec dual-color optical pyrometer was installed in place of the middle Stage thermocouple. The existing radiometer adaptor was modified, the sight tube was extended, and a quartz window was installed. 2. The Bird centrifuge was returned to the manufacturer for repairs and placed back in service. 3. The Auburn flow monitor was installed in 'A' char leg above the eductor. 4. The tap stone was replaced with one of similar design. 5. The slag collector was relocated next to the auxiliary building. 6. A patch was welded over a thin spot on a cooling water tube located between the 'A' char burner sleeve and the heating burner sleeve inside Stage I. Repairs were made to the refractory in Stage I and II. 7. The trim size and the transmitter range were increased on FCV-4011A, B and C to permit the addition of a maximum of 6500 lb/hr steam to Stage I. 8. The gas washer system was acid cleaned. 9. A rubber boot was installed in the chute to the Z-105 screw conveyor to isolate it from the vibration of the centrifuge.

TEST G-17 SUMMARY

TEST #	TEST DATE	OPERATING DATA	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-17 (Run 64)	April 21-23, 1981	<ol style="list-style-type: none"> 43.7 hrs. coal feed 41.8 hrs. char feed 49.2 hrs. char burner firing 78.5 hrs. gasifier pressure 	<ol style="list-style-type: none"> Continued poor feed and plugging of all three char legs and one plugged coal leg. 	<ol style="list-style-type: none"> Initial coal and char feed was unusually smooth. The Auburn flow monitor responded to variation in 'A' char leg feed. The response of the Capintec pyrometer was normally much higher than the Stage I thermocouples although, at times, there was agreement. Small chunks of alumina found in coal and char legs. 	<ol style="list-style-type: none"> The 'A', 'B', and 'C' char burner faces were replaced. The gasifier overhead quench liner was replaced. The pressure relief system knock-out drum level column was replaced with ultrasonic high/low level switches. TE-3401-12 was installed with a moly well flame-sprayed with stabilized zirconia. A nicrome adhesion layer was used to bond the zirconia to the well.

TEST G-17A SUMMARY

TEST #	TEST DATE	OPERATING DATA	REASON(S) FOR SHUTDOWN	OBSERVATIONS & REMARKS	MAJOR PLANT REVISIONS & REPAIRS AFTER TEST
G-17A (Run 65)	May 5-8, 1981	1. 60.2 hrs. coal feed 2. 61.3 hrs. char feed 3. 70.9 hrs. char burner firing 4. 133.6 hrs. gasifier pressure	1. Erratic readings of the Stage I control thermocouple, TE-3401-10	1. Fuel gas flows to the char burners were reduced to the lowest point to date. 2. The H ₂ S Selexol system was operated with the full process gas flow after a leak developed downstream of the pressure control valve between the gas washer and the thermal oxidizer. 3. A substantial char vessel level could not be attained due to the high amount of char carryover. This caused high solids in the gas washing system, which created operating difficulties.	1. The solids were removed from the pond. A strainer filter was installed at the plant effluent pump sump entrance. 2. The char cyclone was inspected and found in good condition. 3. Modifications for burning process gas in the boiler were completed. CO and O ₂ analyzers were installed for the flue gas. 4. A low pressure water booster pump was installed in the compressor building. 5. An analyzer was installed to continuously measure methane in Stage II. 6. The Auburn meter and the V-502 bottoms mag meter were removed for repair. 7. The installation of the sieve bend screen was completed.

TEST G-17B SUMMARY

TEST #	TEST DATE	OPERATING DATA	REASON(S) FOR SHUTDOWN	OBSERVATIONS AND REMARKS	MAJOR PLANT REVISIONS AND REPAIRS AFTER TEST
G-17B (Run 66)	June 2-5, 1981	<ol style="list-style-type: none"> 44.5 hrs. coal feed 45.3 hrs. char feed 58.9 hrs. char burner firing 209 hrs. gasifier pressure 	<ol style="list-style-type: none"> Inability to feed through either coal leg. 	<ol style="list-style-type: none"> All fuel gas was removed from the char burners for a 15-hour period. Material balance data was collected. Slag samples were collected at the slag bin. The high pressure boiler excess air was reduced from 38% to 15% using the CO and O₂ analyzers. 	<ol style="list-style-type: none"> The Auburn meter was reinstalled in 'A' char lower leg. New capacitance plates were fabricated from carbon steel rather than stainless steel. The gearbox on the centrifuge was changed so that the ratio of the speed of the screw to the speed of the bowl is 82 to 81. The low fuel gas flow switches on the char burners were removed from the char burner shutdown, and placed on alarm only.

TEST G-17C SUMMARY

TEST #	TEST DATE	OPERATING DATA	REASON(S) FOR SHUTDOWN	OBSERVATIONS AND REMARKS	MAJOR PLANT REVISIONS AND REPAIRS AFTER TEST
G-17C (Run 67)	June 16-21, 1981	<ol style="list-style-type: none"> 92.6 hrs. coal feed 94.2 hrs. char feed 105.4 hrs. char burner firing 171.4 hrs. gasifier pressure 	<ol style="list-style-type: none"> High pond level and solids concentration. Stage I control thermocouple TE-3401-10 failed just prior to scheduled shutdown. 	<ol style="list-style-type: none"> 51.6 hrs. of operation with no fuel gas to char burners. Material balance data was collected. Auburn capacitance meter flow tests were conducted. High char carryover caused major problems in downstream equipment. <ol style="list-style-type: none"> The process gas vent line to the thermal oxidizer and PIC-52048 were severely eroded. All process gas was sent to gas treating for a total of 10 hrs. The E-602A/B product gas coolers became plugged with char. The coolers were alternately opened for cleaning on June 20 without interrupting plant operation. 	<ol style="list-style-type: none"> PCV-52048 (vent to thermal oxidizer) was repaired. The downstream piping was revised. The A-501 aerial cooler was acid cleaned. The purge gas flows to Stage I and II were separated so that they could be measured individually. The slag agitator hydraulic cylinder was replaced. The new unit rotates 1/2 turn vs. 1/4 turn for the old unit. The high pressure steam flow transmitt. to the char burner eductors IT-4037A,B,C were moved from the 6th to the 5th floor. The low flow shutdown switches were moved to the equipment room. The 'B' Argonne microphone was reconditioned by Argonne Laboratories and was reinstalled. The 'A' and 'C' microphones were removed. The magnetometer on the ammonia stripper bottoms line was reinstalled. The Kamyr valve on 'B' char leg will now close if a low steam flow alarm occurs.

TEST G-17D SUMMARY

TEST #	TEST DATE	OPERATING DATA	REASON(S) FOR SHUTDOWN	OBSERVATIONS AND REMARKS	MAJOR PLANT REVISIONS AND REPAIRS AFTER TEST
G-17D	July 22-24, 1981	<ol style="list-style-type: none"> 67.1 hrs. coal feed 67.7 hrs. char feed 70.7 hrs. char burner firing 175.0 hrs. gasifier pressure 21.7 hrs. zero fuel gas to char burners. 	<ol style="list-style-type: none"> Stage I control thermocouple TE-3401-10 failed. 	<ol style="list-style-type: none"> Cracking open the equalizing line on the char feed vessel which contains the char cyclone may have significantly reduced the amount of char carryover. Pond solids were low throughout the test. One material balance period of 15 hours was run with no fuel gas to the char burners. The tap hole was plugged for several hours before the end of the test. This occurred during reduced firing on the tap and heating burners. 	<ol style="list-style-type: none"> The new DAS was put in service. A leak near 'C' char burner and two thin spots between the heating and 'A' char burners were repaired in the Stage I cooling water tubes. The purge gas separation for Stages I & II was completed. A new Monofrax-E tap stone with a 6-inch tap hole was installed. The 'A' slag lockhopper weigh cells and Red valve were removed. A solid spool piece replaced the Red valve. ROV's-3609A/II were jumpered from the lockhoppers sequence. The aerial cooler in the gas washer system (A-501) was acid cleaned. The stalactite breaker arm was replaced. An additional level control system was installed on the H.P. boiler feed water to test the control of a one-inch Kamyr ball valve (LCV-9109). TE-5400-1 and TE-5410 were installed in the gas washer gas inlet line and the high level probe port. The gasifier cooling water flows to Stage I and II were separated so that the heat loss of each stage could be measured individually. T-105 was coated with Stoneliner polymeric lining compound. The density meter (DT-4803) was reinstalled on 'A' char leg. The Capintec pyrometer was removed from the middle Stage I thermowell (TW-3401-11). A thermocouple inserted 2 inches was installed in its place. All Stage I thermowells were only, flame-sprayed with Cr₂O₃. The 'A' and 'C' Argonne microphones were installed after regeneration and the addition of O₂ reservoirs. The 'B' Argonne microphone was previously installed after regeneration without the O₂ reservoir. The Auburn meter was removed from 'A' char leg.

APPENDIX B

REFERENCES

During the preparation of this report, reference was made to the following items:

1. Stearns-Roger - Data Books dated 1975, produced for ERDA, Volumes:
 - 1) Plot Plan etc.
 - 2) Boilers, Compressors & Blowers
 - 7) Pumps, P-103 through P-511
 - 8) Pumps, P-701 through P-1001
 - 9) Mills, Separation and Filter Equipment
 - 10) Separation and Filter Equipment
 - 13) Vessels, V-201 through V-301 (Part)
 - 14) Vessels, V-301 through V-810
 - 17) Water Treating Equipment, Miscellaneous
 - 18) Solids Transfer Z-102 through Z-103
2. Stearns-Roger - Operating Reports for the following test runs:
G9, G10, G11, G11A, G11D, G13, G14, G14A, G15, G15A, G16, G16A
3. Stearns-Roger - Technical Progress Reports for the following months:
August 1980, September 1980, October 1980, November 1980, December 1980
4. Stearns-Roger - interoffice memorandum regarding gasifier inspection following test G16A.
5. Stearns-Roger - Mechanical Flow Diagrams issued March 1, 1981
6. Stearns-Roger - Topical Report - "Investigation of Piping Failure at BI-GAS Pilot Plant"
7. Stearns-Roger - Technical Program Plan, August 1980
8. Conoco (Project Number 268.000) - Report on Investigation of Stage II Deposits and Material Recovered After Test Run G-13
9. Pullman Kellogg - Monthly Technical Status Reports from September 29, 1978 through April 25, 1980
10. Foster-Wheeler Development Corp. - "Cold Flow Model Studies of BI-GAS Entrained Flow Gasifier", May 1979
11. "Development of the BI-GAS Process" - paper by Robert J. Grace of BCR, Inc.
12. Handbook of Gasifiers - Pre-print copy obtained from UOP/SDC
13. Koppers Co. - Report on Evaluation of BI-GAS Pilot Plant operation at Homer City, Pennsylvania. Period covered January 13, 1979 - September 14, 1979

14. Frummerman Associates Inc. - Preliminary Screening of Additional Uses for Homer City Site of BI-GAS Pilot Plant - February 26, 1980
15. Frummerman Associates Inc. - IPDU Interim Report, November 1, 1979
16. Frummerman Associates Inc. - IPDU Interim Report II, January 2, 1980
17. DOE GPRT - BI-GAS Project Review Report, October 1978
18. DOE/ET-03117 - DOE Coal Gasification Multi-Test Facility, July 13, 1979
19. Babcock & Wilcox - ASME Design Calculations for BI-GAS Gasifier
20. DOE/MERC/RI-78/2 - "An Engineering Assessment of Entrainment Gasification" April 1978
21. DOE/FE-1207-T10 - "Gas Generator Research and Development at the BI-GAS Process" - October 1979
22. DOE/FE-1207-T9 - "Solids Feeding, Metering, and Control at the BI-GAS Pilot Plant" - October 1979
23. DOE/FE-1207-69 Vol. 1 & 2 - "Gas Generator Research & Development BI-GAS Process" Final Report for August 19, 1971 - October 31, 1979. Published June 1980.
24. Zenz & Othmer - "Fluidization and Fluid Particle Systems"
25. EPRI Report AP-1268 - "Refractories for Coal Gasification and Combustion Systems" - prepared by Westinghouse, July 1980
26. "Coal-Ash Slag Attack and Corrosion of Refractories" by J. A. Bonar, Carborundum Company; C. P. Kennedy and R. Swaroop, Argonne National Laboratory
27. "Refractories for Application in Slagging Gasifiers" by C. R. Kennedy, Argonne National Laboratory, August 1979
28. Battelle Columbus Laboratories - "Production of Aromatics, Fuel Gas and Methanol/Gasoline by the Direct Hydrogenation of Catalyzed Coal" - Draft Topical Report
29. Technical Memo - "Scale-Up of the Battelle Direct Hydrogasification Process Using the BI-GAS Pilot Plant" - April 1979
30. Battelle Columbus Laboratories: "Direct Hydrogasification of CaO Catalyzed Coal in a Fluid-Bed Reactor" AIChE National Meeting, November 1978
31. Report Summary: "Battelle's Catalytic Treatment Process Simplifies Pressurized Gasification of Eastern Coals"

APPENDIX C

MASTER ITEM INDEX FOR CASE I

MASTER ITEM INDEX

PRELIMINARY - FOR ESTIMATE ONLY

Department of Energy
Contract No. DEAC01-78ET10159
Future Use of Bi-Gas Pilot Plant Facility

CASE I

REACTOR REPLACEMENT MODE

PROJECT

T.O. 008

REVISION

DATE

5/26/81

ITEM NUMBER	ITEM COST NUMBER	DESCRIPTION	SIZE	TYPE	WT. #	REMARKS
SN-401 A & B		Ash Cyclones	1'-4" ID x 7'-0" long	Vertical		Installed in VN-402 C.S. w/refractory lining
VN-1 A & B		Ash Lockhoppers	3'-0" ID x 2'-6" TT (7'-6" OAL)	Vertical		1-1/4 CR - 1/2 MO
VN-301		Oxygen Blown Gasifier	5'-0" ID x 32'-6" F-F	Vertical		1-1/4 CR - 1/2 MO Shell w/ ss pipe internals and DUAA layer refractory
VN-301B		Gasifier Primary Quench Section	2'-0" ID x 9'-0" F-F	Vertical		1-1/4 CR - 1/2 MO - Installed on top of VN-301
VN-402		Ash Feed Vessel	6'-6" ID x 26'-0" T-T	Vertical		Contains SN-401 A & B 1-1/4 CR - 1/2 MO
ZN-1		Dust Cooling Screw Conveyor	7-7/8" ID trough x 10'-0" long	Horizontal		304 SS - Wetted Parts
ZN-2		Wetting Screw Conveyor	1'-0" ID trough x 12'-0" long	Horizontal		304 SS - Wetted Parts

APPENDIX D

MASTER ITEM INDEX FOR CASE II

MASTER ITEM INDEX

PRELIMINARY - FOR ESTIMATE ONLY

Department of Energy
Contract No. DEAC01-78ET10159
Future Use of Bi-Gas Pilot Plant Facility

CASE II

REACTOR MODIFICATION
MODE

PROJECT

T.O. 008

REVISION

DATE

5/26/81

ITEM NUMBER	ITEM COST NUMBER	DESCRIPTION	SIZE	TYPE	WT. #	REMARKS
PN-302 A & B		Cooling Water Circulation Pump	2000 GPM at 150 psi Δ P	Centrifugal		Boiler Feedwater C.S.
SN-401 A & B		Ash Cyclones	1'-4" ID x 7'-0" long	Vertical		Installation in VN-402 C.S. w/refractory lining
VN-1 A & B		Ash Lockhoppers	3'-0" ID x 2'-6" TT (7'- 6" OAL)	Vertical		1-1/4 CR - 1/2 MO
VN-2		Coal Splitter Feed Vessel	5'-6" ID x 6'-0" TT	Vertical - w/5 outlets		1-1/4 CR - 1/2 MO w/316 SS Internal Cones
VN-402		Ash Feed Vessel	6'-6" ID x 26'-0" TT	Vertical		Contains SN-401 A & B 1-1/4 CR - 1/2 MO
ZN-1		Dust Cooling Screw Conveyor	7-7/8" ID trough x 10'-0" Long	Horizontal		304 SS - Wetted Parts
ZN-2		Wetting Screw Conveyor	1'-0" ID trough x 12'-0" long	Horizontal		304 SS - Wetted Parts

APPENDIX E

HEAT TRANSFER CALCULATION

SECTIONS*	LENGTH FEET	NET BTU/HR ABSORBED BY WATER	AVERAGE TEM- PERATURE OF FLUEGASES OF	G.P.M. OF COOLING WATER	
				AVAILABLE	REQUIRED
OK	5.75	4,490,050	3000	1344	1545
AK	0.75	612,296	3000		
AB	1.25	1,225,113	2824		
BC	1.25	976,042	2525		
CD	1.5	24,620	2399		
DJ	18.67	13,665	2382	456	22
JE		100,915			
EF	1.583	9,984	2367	18	86
FG	1.333	14,207	2363		
GH	2.75	384,501	2305		
TOTAL		7,851,393		1818	1653

* Sections have been established according to vessel wall construction or cooling water circuit, and are shown on Stearns-Roger drawing number 76068.

PRELIMINARY
FOR COST ESTIMATE ONLY

DESIGN DATA CODE ASME-VIII DIV. 1 STAMP YES OTHER SPECS DESIGN INT. TEMP. 1000 PSIG @ 600 °F DESIGN EXT. TEMP. PSIG @ °F PRESS. TEMP. 850 PSIG @ 2900 °F POST WELD HEAT TREAT YES NO RADIOGRAPHING 100 % EFFICIENCY SHELL 100 % HEADS 100 % CORROSION SHELL 1/8" HEADS 1/8"		MATERIAL SPECIFICATIONS SHELL SA-387 GR. 22 CL. 2 HEADS SA-387 GR. 22 CL. 2 SUPPORT (SKIRT) FORGINGS SA-336-F-22 GASKETS BOLTING INT. EXT. NUTS INT. EXT. INTERNALS-PIPES SA-312-316H COUPLINGS LINING WIND MW- FT. LBS. EARTHQUAKE ME- FT. LBS. FIREPROOFING "I.S. & O.S. (BY OTHERS) INSULATION "THK. (BY OTHERS) PAINT		ACCESSORIES TO BE FURNISHED & INST. BY FABR. LADDER & PLATFORM CLIPS YES NO INSULATION RINGS & CLIPS YES NO DAVIT SUPPORTS YES NO PIPE SUPPORT CLIPS YES NO PIPE GUIDE CLIPS YES NO FIREPROOFING ATTACHMENTS YES NO TRAY SUPPORT RINGS YES NO		NOZZLE SCHEDULE N15 1 2" R.F. INST. CON'N N14 1 2" R.F. LEVEL CON'N N13 2 2" R.F. WALL WASH INLET N12 1 6" R.F. STALACITE BREAKER N11 1 6" R.F. START-UP BURNER N10 2 8" R.F. COAL FEED BURNER N9 2 2" R.F. BFW OUTLET N8 2 2" R.F. BFW INLET N7 4 4" R.F. BFW INLET N6 4 4" R.F. BFW OUTLET N5 2 2" R.F. BFW INLET N4 2 2" R.F. BFW OUTLET N3 2 4" R.F. QUENCH WATER N2 4 3" R.F. BFW INLET N1 4 3" R.F. BFW OUTLET		GENERAL NOTES 1. ALL DIMENSIONS FROM BOT. TAN. LINE. 2. ALL TRAY SPACE DIMENSIONS ARE TO TOP OF TRAY SUPPORT RINGS 3. MANWAYS TO BE (HINGED) (DAVITED). 4. IT IS VENDORS RESPONSIBILITY TO ASCERTAIN THAT ALL ACCESSORIES ARE ATTACHED BEFORE PWHT, IF PWHT IS REQUIRED.		WEIGHTS TRAYS LADDER & PLATFORM WT. LBS. NET FAB. WT. (LESS TRAYS) LBS. EMPTY WT. LBS. OPERATING WT. LBS. TEST WT. LBS.		UOP/SDC PROPOSED REACTOR BI-GAS PILOT PLANT HOMER CITY, PENNSYLVANIA BY D. JUTLA DATE 4/3/81 BY D. JUTLA SPEC. NO. W-3637 PAGE OF REV. 0	
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Figure 8.1 GMTF Design.