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BI-GAS PILOT PLANT OPERATION

Quarterly Technical Progress Report for the Period July 1—September 30, 1980

Work Performed Under Contract No. AC01-80ET14705

Stearns-Roger Incorporated
Denver, Colorado

U. S. DEPARTMENT OF ENERGY

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BI-GAS PILOT PLANT
OPERATION

QUARTERLY
TECHNICAL PROGRESS REPORT
FOR THE PERIOD
1 JULY 1980 - 30 SEPTEMBER 1980

STEARNS-ROGER INCORPORATED
4500 CHERRY CREEK DRIVE
DENVER, CO 80217

TABLE OF CONTENTS

Executive Summary	Page 1
I. Introduction	5
II. Previously Reported Work	9
III. Plant Operations	15
A. Test G-13	15
B. August Activities	46
C. September Activities	51
IV. Support Activities	54
A. Instrumentation	54
B. Technical Engineering	56
C. Data Acquisition	57
D. Bituminous Coal Research, Inc.	59
E. Conoco Coal Development Co.	60
F. JAYCOR	61
Appendix A Raw Materials Received and Utilities Usage	65
Appendix B Investigation of Piping Failure	68

EXECUTIVE SUMMARY

During the final quarter of the 1980 fiscal year (July through September), Test G-13 was conducted. In addition, the stainless steel process gas line from the gasifier to the gas washer was replaced with chrome molybdenum steel. Test G-13 was the longest to date and was characterized by smooth start-up and operation, long Stage I thermocouple life, and collection of much material balance data. Stress corrosion cracking in several areas of the process gas line delayed start-up of Test G-14 and a large part of the quarter was spent in replacing this piping.

A. Test G-13

1. Test G-13 was conducted from July 1 - 6, 1980 with:
 - a. 119.6 hours of coal feed,
 - b. 118.7 hours of char feed, and
 - c. 112.3 hours of char burner firing.
2. Observations during the test included:
 - a. There were four operating periods during the test that were stable and from which material balance calculations could be made.
 - b. Coal feed to the spray drying section of the plant was higher than previous tests; however, the oxygen consumption and the product gas flow were essentially the same.
 - c. The solids concentration in the bottoms from the water degassing tank was considerably higher than previous tests. This coal loss accounts for the discrepancy in Item "b" above. The loss was attributed to the closed trickle valve in the coal cyclone dip leg.
 - d. A carbonate build-up occurred in the inlet venturi and aerial cooler for the gas washer.
 - e. The slag collected during the test was granular in nature with a minimum of needles. It was observed that a significant quantity of carbon (20 percent average) was present in the slag.
 - f. The two lower Stage I thermocouples read higher than and fluctuated more than the upper Stage I thermocouple.
 - g. Char feed through the 'C' leg was influenced by the cooling effect of the char sample station which was located directly above the 'C' char leg.

- h. The 'C' char leg ball valve used to control char feed only controlled in the range of 60 to 70 percent opening.
- i. The new one inch diameter 'B' char leg performed similarly to the 'A' and 'C' legs.

3. Conclusions

- a. From the condition of all the burner faces at the end of the test, it is evident that a new burner design is needed if longer tests are to be conducted.
- b. A method of preventing calcium carbonate deposits in the gas washer venturi must be found.
- c. The ball valve used in the 'C' char leg to control solids flow did not perform as well as the Vee-ball valve.

4. Recommendations

- a. Make 'B' coal leg identical to the 'A' coal leg. This entails replacing the four inch diameter line with a one and one-half inch diameter line containing a one inch Vee-ball control valve. Replace 'B' coal eductor with a tee. Add instrumentation so it is identical to that of the 'A' coal leg instrumentation.
 - b. In order to prevent the solids from entering the cooling water surge drum via the equalization line, the line should be re-located with a rupture disc separating the systems. The gasifier cooling water system should be kept at a slightly higher pressure than the gasifier so that if a hole develops in the cooling water system, the water will flow into the gasifier rather than gas from the gasifier into the cooling water system.
 - c. Install one of the new design char burners.
 - d. Extend the char sample probe into the center of the char vessel so the purge flow through the probe will not cause lower temperatures in the 'C' char leg.
- B. Two product gas line failures, one on the eight inch section between the gasifier and char vessel and the other on the four inch line on the outlet of the east cyclone on the char vessel, prevented Test G-14 from being conducted during the month of August. The first failure occurred in the eight inch section on July 31 when the gasifier pressure reached 40 psig, during the pressuring phase of the test. The second failure occurred on August 22 at 750 psig, but before burner firing or solids feed was established. Both failures were in sections of 304 stainless steel pipe, at or near the weld with a chrome molybdenum forged steel tee. 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 chrome molybdenum steel. After the second failure was found in the four inch pipe, the decision was made to replace

the 304 stainless steel material between the char vessel and gas washer with chrome molybdenum steel. The existing fittings were chrome molybdenum steel so they were reused. Metallographic tests conducted on the affected process piping determined that intergranular stress corrosion cracking was the cause of the failures. This was initiated by an internal defect in the piping and due to the high stress situation of this pipe, the failure mechanism progressed along intergranular lines due to intergranular stress corrosion until failure resulted.

Pluggage of the gas washer reflux cooler, with a calcium carbonate build-up, prompted cleaning of this equipment and the rest of the gas washing system through the gas washer bottoms cooler and the ammonia stripper. Initially the reflux cooler was flushed with a five percent nitric acid solution, but did not become sufficiently clean. The gas washing system was then closed and water circulated when pluggage 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 due to its compatibility with Monel, the metal used as a liner in the gas washer vessel, and 304 stainless steel. An additive for the gas washing system is being investigated to prevent this carbonate build-up from recurring.

Modifications were initiated in the coal grinding area to reduce the amount of fines going to the pond. This will be accomplished by sending the underflow from the rotex screen, containing the fines, to the centrifuge which will concentrate the solid material. This solid material will then be disposed of in solid form.

For Stage I temperature indication, recommendations have been made to test the Capintec "Ratio Probe III" dual pyrometer system. If problems are encountered with this unit then the Williamson Corporation "True Temp 8100" will be tried. This proposal has been made in order to replace the Barnes Engineering Radiometer, which did not give satisfactory performance.

The data acquisition area encountered problems with almost every major component including the printer, card reader, computer, card punch, and gas chromatographs. Attempts were made to refurbish components, continue diligent preventive maintenance and, where possible, to develop software programs to use alternate units.

- C. Test G-14 was not conducted during the month of September due to the repairs being made on the product gas line between the char vessel and gas washer. Work continued on welding, x-raying, and stress relieving the new chrome molybdenum steel pipe, which is replacing the 304 stainless steel pipe previously used in this area.

In the coal handling area, the rotex screen was moved from the second to the third floor. Piping revisions were made so the underflow from the screen, containing the minus 100 mesh coal, will go to the centrifuge feed tank. This modification, along with future revisions, should reduce the quantity of fines going to the pond.

Tests conducted on the gas washer level control instrumentation indicated mechanical and installation problems with this equipment. Repairs were made to a bent internal stem assembly for the Magnetrol indicator which had caused discrepancies between the indicated level and actual level as viewed on the vessel sight glass. A vent was installed from the top of the Magnetrol level column to eliminate the vapor space restriction which had prevented full scale indication from this device.

In the utilities area, problems were encountered with the demineralizer system due to loss of chemical capacity by the mixed bed resin. Analyses of the resin showed the material had lost chemical capacity and would have to be replaced. Enough resin to replace one demineralizer bed was ordered; it was installed before Test G-14.

Tests were conducted on the Jet Propulsion Laboratory solids flow meter which was developed for evaluation in the char feed system. Four 15 pound samples run at different time intervals indicated that the instrument responded to char flow. Recommendations have been made to install the JPL flow meter on one of the char feed legs for evaluation during Test G-14.

In the data acquisition area, problems were encountered with the computer hardware, particularly the card reader and card punch. Since the computer system is card oriented, a software subsystem is being developed which will allow modifications via keyboard to drum. This can be used when the card to drum path has malfunctioned, but will only be a temporary type action to give the system flexibility. Also under development are modifications to the tape writing programs which will speed acquisition of data from the cassette system.

Section I

INTRODUCTION

The BI-GAS pilot plant, located in Homer City, Pennsylvania is currently funded by the U.S. Department of Energy. Past funding has been by the precursors of DOE, as well as the American Gas Association.

The plant was designed and built by Stearns-Roger, Incorporated, under contract to Bituminous Coal Research, Incorporated. Stearns-Roger, which has operated the plant since its start-up, became prime contractor and program manager in November 1979. Previous to this, the project was managed by Phillips Petroleum Company, under subcontract to Bituminous Coal Research.

The 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 bed, 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.

As shown in Figure 1-1, 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 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. Refer to Figure 1-2 for details of the gasifier. Once the powdered 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, fuel gas and reaction steam through a surrounding annulus and oxygen through a separate passage. Cooling water is circulated through the burners to protect the assemblies and tip. A high temperature reaction takes place in Stage I (2500°F to 3000°F) which produces slag and a reducing gas of approximately 35 percent hydrogen. The slag exits through a tap hole, is quenched in water, and is removed from the gasifier by lockhoppers.

FIGURE 1-1, GENERAL SCHEMATIC
OF BI-GAS PLANT

FIGURE 1-2 - BI-GAS GASIFIER

Section 1

Page Two

The BI-GAS staged concept of gasification was developed by Bituminous Coal Research primarily to maximize the yield of methane as the coal is devolatilized by the hot, hydrogen rich gas in Stage II.

At present, the major developmental effort of this project is concentrated on gasification. Current goals are to assess the viability of the process from an operating and cost standpoint, determine possible improvements, and obtain design data for a full scale plant.

II. PREVIOUSLY REPORTED WORK

Testing of the gasifier was started in December 1976. Several problems, including explosions in the gasifier burners and associated piping, were encountered prior to successful operation. 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 T/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. The data indicated that the total heat loss from the system was about 7.3×10^6 Btu/hr under those conditions. With no slag coating on the cooling tubes of Stage I, the heat loss represented about 47% of the total heat generated in Stage I. Loss from Stage I alone was about 5.1×10^6 Btu/hr representing about 32% of the total heat generated. It was expected that, when char recycle was introduced to Stage I and a layer of slag was formed on the tubes, the heat loss would be reduced. It was also determined that the Stage I thermocouples were reading approximately 500°F low because the tips were inserted only one-inch beyond the cooled wall.

After the base condition test was completed, test G-1 was conducted. The objective was to feed coal to Stage II while continuing to fire Stage I only with natural gas. Coal was fed for a period of 51 hours, but was discontinued because of several plant problems, including high water level in the settling pond, a badly leaking rod mill in the coal grinding area, and a high concentration of hydrogen sulfide in the recycle purge gas. A spot material balance indicated that about 80% of the carbon in the coal feed was gasified in Stage II. This high conversion would not leave enough carbon in the char for generation of heat and hydrogen in Stage I.

The overall objectives of the next series of gasifier tests (G-2 through G-2L) were to operate Stage I with char feed, while still using natural gas as a supplemental fuel, and to reduce Stage II carbon conversion from the 80% to 50-60%. The specific goal was 24 hours of lined-out conditions with 2000 lbs/hr of coal feed and observable slagging. Although these objectives were not met, the major operating problems of the BI-GAS gasifiers were identified and included:

1. the inability to maintain continuous slag tapping,
2. inadequate solids flow measurement instrumentation,
3. inadequate solids flow control, and
4. the inability to maintain thermocouples in Stage I over extended periods.

An effort was made to address the slag tapping problem in the next series of tests (G-2M and G-2P), by drawing hot Stage I gases down through the tap hole while operating. Along with being ineffective in keeping the tap hole open, this procedure created a fog below the tap hole, which prevented visual verification of tapping.

The next series of tests (G-3 through G-3G), addressed the slag tapping problem with (1) the addition of a fluxing agent (limestone), (2) the extension of the slag tap burner, and (3) the reduction of the cooling of the tap stone. The combination of these three effectively kept the tap hole clear and resulted in much longer runs. Several new problems surfaced during these tests, including:

1. the formation of deposits in Stage II,
2. extensive damage to the char burners, and
3. the inability to establish a level in the char vessel because of leaking control valves in the char line.

In the fifth series of tests (G-4 and G-4A), the main objectives were (1) to establish levels in the char vessel (2) to maintain slagging without limestone flux, and (3) to test various solid flow indicators. In both tests, hot spots developed on the exterior of the char burners, probably caused by the backflow of hot (2700°F) Stage I gases. On February 16, 1978, while attempting Test G-4B, the line between the 'C' char burner and eductor ruptured. The gasifier depressured through the rupture, and a fire ensued. The resulting fire caused about \$60,000 in damage and delayed further testing approximately five months.

After repairs were completed and instrumentation revised to prevent backflow of gases, the sixth series of tests (G-5 through G-5C) were conducted. Two major objectives were (1) to build a level in the char feed vessel, and (2) to control and measure the flow of this char into Stage I. The ability to build a char level and to feed steadily from a settled bed in the char vessel, was demonstrated. Some of the solid flow indicators located in the char feed line responded satisfactorily to the flow of char, in particular the Argonne high temperature microphone and the burner and eductor pressure differentials. A new problem surfaced during this test series - the formation of calcium-rich deposits in Stage II. This build-up of material was thought to be related to the use of limestone as a slag flux.

The next series of tests (G-6 through G-6F), were conducted without limestone flux, and the Stage II deposits formed in the previous series were eliminated. The coal feed was also operated in an "as-designed" mode, i.e. with a level in the feed vessel. Real progress was also made in improving the television picture of slag tapping and the factors which influence reception. An unsatisfactory condition which developed during this series was the inability to remove slag from the quench section, potentially limiting operation to 36 to 40 hours. Obtaining a good material balance was also found to be more difficult than anticipated.

Section II
Page Three

During the next tests (G-7 and G-7A), an effort was made to quantify the amount of coal and char loss from the system and to meter total purge gas and nitrogen to the gasifier. This improved the quality of gasifier material balances. A new nitrogen/oxygen purge system (to eliminate a constant N_2 bleed) on the Stage I burners worked very well without any apparent damage to the burners. Differential pressure measuring instrumentation, was installed on the coal eductors and injection nozzles, and gave a good indication of coal flow. It was apparent that a new char burner design was needed to eliminate the plugging tendencies, damaged burner faces, and premixing of fuel and oxygen, all of which had been experienced several times. The test was terminated when 'A' char burner ruptured. The gasifier rapidly depressured through the rupture creating a fire. Extensive damage was sustained by the electrical wiring, controls, and insulation in the gasifier structure. Total damage was approximately \$42,350 with repairs taking about five months. It is believed that the rupture was caused by the failure of an internal bellows on the char burner. This failure allowed natural gas, char, and steam to mix with the oxygen and burn in the burner assembly rather than at the tip. Stress corrosion cracking appeared to be the probable cause for failure at the bellows.

A study was made by Phillips as to the operability and safety of the BI-GAS pilot plant. As a result of the study, a large number of safety corrections were made to the plant after which the plant was judged safe and operable.

The next test (G-8) was conducted after 5 months taken up by repairs and installation of safety corrections. Slag tapping proceeded well through the two-inch tap hole. Nitrogen purge to the oxygen annulus after shutdown was found to adequately reduce the bellows temperature increase. Test G-8A produced slag with good consistency and a reasonable calibration point was obtained on the level indicators for the coal and char feed vessels. By eliminating fines in the slurry feed, the gas washing systems ran smoothly without plugging. All the char feed indicators worked properly and gave reasonable flow/no-flow indications. The new coal grinding screen system and ammonia stripper seemed to operate properly. The test was terminated because of unstable coal feed.

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 pluggage occurs in the char burners. Fuel gas flow is not interrupted since it now has a separate annulus shared with bypass steam.

An operating change was made in an attempt to prolong the life of the tap stone. The oxygen flow rate to the slag tip burner was reduced by 15% and to the slag heating burner by 25%. Slag tapping was maintained at these firing rates.

The major equipment change in preparation for test G-10 was to replace one of the four-inch char feed lines with a one-inch line and the four-inch control valve with a one-inch control valve. It was determined that the four-inch line valve is a more controllable system at the required flow

rate. Because expansion bellows are not required in a one-inch line, the cool purge gas required to purge the bellows in a four-inch line is not required so there is less cooling of the flowing char. 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 one-inch char feed system measurement of differential pressure was provided across the upper leg, control valve, lower leg, eductor, and burner. This configuration is shown in Figure 2-1. Data from these measurements were obtained to develop a correlation between differential pressure and char feed rate as indicated by control valve opening.

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

In test G-10A, char was successfully fed through two one-inch char legs. The plant operated quite well during 49 hours of char feed. The coal feed rate of 2200 lb/hr was lower than desired and this is an area of continued work for improvement.

A cold gas efficiency of 48.6% was calculated for test G-10A. This low efficiency is mainly attributed to the high addition rate of natural gas to Stage I to maintain a reducing atmosphere for safety reasons in the event that char flow is inadvertently reduced or stopped.

The Selexol H₂S removal system effectively removed H₂S to a level of 1 ppm in the total synthesis gas stream.

Successful char feeding through one-inch diameter systems led to the decision to change one coal feed system from four-inch diameter with a four-inch control valve to 1½ inch diameter with a one-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.

The coal feed vessel is maintained at a pressure higher than the gasifier. Therefore, there is no requirement for an eductor to provide a pressure boost. For the 1½ inch feed system in test G-11A the eductor was converted to a simple tee by eliminating the nozzle and diffuser section. Coal feeding through the system was very effective up to 6000 lb/hr. A program was started to correlate coal and char flow rates with differential pressure readings on segments of the feed system.

Natural gas was withdrawn from one char burner in order to determine any deleterious effects. Char flow was less stable through the burner in the absence of heated fuel gas. Visual inspection showed no damage to the burner face in six hours of operation.

Tests 11-B through 11-F provided operating experience but did not attain the extended operating time planned for because of char burner failure,

FIGURE 2-1, ONE INCH CHAR FEED SYSTEM

coal slurry line pluggage, pressure fluctuations in the gasifier, as well as tap hole plugging. The tests pointed out that overcoming mechanical difficulties must still remain a high priority concern.

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. A redesign of the burner was made to overcome this problem and the burners were refabricated for use in tests subsequent to G-13.

III. PLANT OPERATIONS

A. Test G-13

1. Test G-13 - Summary

a. Test G-13 was conducted on July 1 - 6, 1980 with:

- 1) 119.6 hours of coal feed,
- 2) 118.7 hours of char feed, and
- 3) 122.3 hours of char burner firing.

b. This test was the longest to data and characterized by:

- 1) smooth plant start-up and operation,
- 2) long Stage I thermocouple life (the three thermocouple/thermowell assemblies remained intact and gave good readings the entire test), and
- 3) collection of much material balance data.

Test G-13 was terminated when a cooling water leak developed in Stage I as shown by a Stage I temperature drop and a cooling water system level loss. Upon inspection, the leak was found to be in 'C' char burner.

c. The gasifier was pressurized to 750 psig by 1900 hours on June 29. Minor mechanical problems delayed burner ignition until 1035 hours on July 1.

The burners were successfully lit on the first try. Slurry feed was initiated to the spray drying section of the plant at 1332 hours and coal and char feed to the gasifier shortly thereafter. The 'A' coal leg and the three char leg control valves were kept open prior to solids feed, as in previous tests, to keep these legs warm.

At 1837 hours, the char vessel level instrument started rising, indicating the accumulation of a detectable char level. At 1930 hours, a similar level rise in the coal vessel was noted. By 1400 hours on July 2, the plant operation had stabilized to the point that the first set of material balance samples were taken. Coal and char feed then continued uninterrupted for three and one-half days with material balance samples being taken every four hours. Notable observations taken during this period of operation are presented below:

- 1) There were four operating periods during this three and one-half

day period that were stable and from which material balance calculations could be made.

- 2) It was observed that the coal feed to the spray drying section of the plant was higher than in previous tests; however, the oxygen consumption and the product gas flow rates were essentially the same as previous tests. The average net coal feed to spray drying during the four material balance periods was approximately 8300 lbs/hr. The product gas rate during the same periods was approximately 940 moles/hr.
- 3) The solids concentration in the bottoms from the water degassing tank was observed to be considerably higher (10 to 15 percent) than during previous tests (typically one to two percent). This high coal loss from the coal cyclone accounts for the discrepancy, noted in Item "2" above, between the coal feed and the net product gas make. Post-test analysis showed that approximately thirty-two percent of the coal was not separated by the coal cyclone.
- 4) The television picture of the tap hole became obscured shortly after char feed, and the tap hole image completely disappeared soon thereafter.
- 5) The slag collected at the slag collector was granular in nature with a minimum of needles. However, it was observed that a significant quantity of carbon (20 percent average) was also present in the slag. Typically, two to four 55 gallon barrels of this slag material were collected following each lockhopper dump.
- 6) The two lower Stage I thermocouples read higher than and fluctuated more than the upper Stage I thermocouple. The slag heating burner oxygen rate was adjusted accordingly to stabilize these lower Stage I thermocouples.
- 7) Char feed through the 'C' leg was influenced by the cooling effect of the char sample station purge which was located directly above the 'C' char leg. It was observed that during collection of a char sample, several instruments on 'C' char leg indicated that flow was disrupted.
- 8) Several plugs occurred in the 'B' coal leg which required purging up and down the leg.
- 9) On July 5 at 0127 hours, a gasifier emergency shutdown (ESD) occurred due to high Stage II temperature. Attempts to lower the Stage II temperature before the emergency shutdown through the addition of steam were unsuccessful. During the shutdown, coal and char feed were removed from the gasifier while slurry feed to spray drying continued. Review of the Stage II temperature trends just preceding the emergency shutdown show that the lower thermocouple on which the ESD is located had increased and fluctuated, whereas the higher Stage II thermocouples had remained at approximately 1700°F. The Stage II shutdown was subsequently changed to the higher Stage II thermocouple. All burners were then relit by 0220 hours with solids feed resumed shortly there-

after. During the time period 0240-0425 hours, some difficulty in solids feed was experienced in 'B' coal leg and 'A' char leg, necessitating purging up and down each leg to clear plugs and restrictions.

Although material balances continued to be taken after solids feed was resumed, steady conditions were not achieved prior to another shutdown which occurred at 1307 hours on July 5. This was a char burner shutdown only, caused when an Instrument Technician inadvertently bumped the fuel gas header pressure transmitter causing a low fuel gas flow reading. The technician was working on a transmitter at the time in an attempt to eliminate external vibration caused by the high pressure service water pumps. Also at this time the slurry feed pump shut down automatically, which, in turn, shut down the recycle gas heater on high spray dryer outlet temperature.

At 1315 hours, the char burners were relit and at 1320 hours coal feed to the gasifier was started. Char feed was initiated as soon as Stage I reached its normal operating temperature. Solids feed was then maintained to both coal and char systems until test termination on July 6.

Material balance samples were again taken during this operating period. Notable observations are summarized below:

- 1) The flow from the recycle gas compressor was observed to be somewhat erratic. The flow through this unit fluctuated in steps indicating that the valves in the compressor were malfunctioning. Attempts to remedy this problem were not successful though the flow fluctuations experienced were not serious enough to hamper operation of the plant.
- 2) The 'B' coal leg system plugged on several occasions and required purging to unplug the line.
- 3) The slag agitator began slowing down and required maintenance work to improve its operation.
- 4) The gasifier pressure fluctuated somewhat during this test period (approximately 20 psi) most likely due to variations in solids feed and difficulties with the gas washer level control (see gas treating section for explanation of this operation).
- 5) The lower Stage II thermocouple continued to cycle upward and downward.

At 0320 hours on July 6, a high differential pressure was observed between the gasifier and the outlet of the gas washer. Solids feed to the gasifier was decreased to reduce gas flow through the gas washer and thus reduce the pressure drop through this vessel. The coal feed rate to spray drying was reduced from approximately 9000 lb/hr to 7800 lb/hr.

At 1245 hours on July 6, a leak was observed in the steam valve feeding the overhead section of the gasifier. It was determined at this point that the leak was not serious enough to necessitate shutting the unit down. However, the leak was monitored closely.

At 1442 hours, the Stage I thermocouples suddenly dropped from their normal reading of 2700-2900°F to 1800-2000°F. At the same time, the gasifier cooling water surge drum level began to drop abruptly and the water letdown rate from the gasifier quench section began to increase. These three signs were indicative of a cooling water leak in Stage I. Coal and char feed were shut off, and the char burners were subsequently shut down. At 1525 hours, the slag tap and slag heating burners were shut down, terminating the test.

2. Background

- a. As part of the continuing program for developing a good data base and operating efficiency, a test of three to five days with collection of material balance data is desired.
- b. In working toward the goal of eliminating supplemental fuel gas usage in the gasifier, it is necessary to observe operation at various stages in the oxygen to fuel gas ratio. Reduction of methane to stoichiometric ratio with oxygen to determine the effects on Stage I and Stage II temperatures is a step in reaching this goal.
- c. To increase operating experience and add to the plant data base determination of the highest coal flow at which the char vessel level will remain constant while feeding char at the maximum rate is required.

3. Objectives of Test G-13

- a. Operate for three to five days at stable conditions to collect material balance data.
- b. Determine the highest coal flow at which the char vessel level will remain constant while feeding char at the maximum rate.
- c. Reduce the fuel gas and oxygen flows to the stoichiometric ratio to determine the effects on Stage I and Stage II temperatures.

Objectives "a" and "b" were met. Objective "c" was not met because the test had to be terminated due to a cooling water leak into Stage I.

4. Modifications and repairs Prior to Test G-13

- a. The four-inch diameter 'B' char leg was removed and replaced with a one-inch diameter char leg. The configuration of the new one-inch 'B' char leg is identical to those used in the 'A' and 'C' char systems.
- b. The one-inch diameter block valve on the 'A' coal leg was moved to the 'B' char leg for use as a block valve. A one and one-half inch Kamyr valve was used as a replacement block valve in the 'A' coal system. The thermal flow meter was removed from the 'A' coal leg.
- c. In Stage I, the radiometer probe was removed and a thermocouple was installed in its place. The location of this thermocouple is in the middle position of the three Stage I thermocouples. All three thermowells were molybdenum, flame-sprayed with Cr₂O₃.

- d. A knock-out drum was installed in the main fuel gas line.
- e. Accumulated solids were removed from the settling pond.
- f. The number one slag lockhopper inlet valve for the 'B' lock-hopper was replaced and the actuator was repaired.
- g. Repairs were made on the demineralizer unit; the resin was treated with ten percent NaCl solution for organic fouling.
- h. A new heat exchanger was installed in the cooling water system for the recycle gas compressor, the purge gas compressor, and the fuel gas compressor.
- i. A new picture tube was installed on the north TV monitor.

5. Test Results

a. Coal Grinding

Before the test, the pulp storage tank was filled with coal slurry. During the test, a coal feed rate of 10 tons/hr. and 64 gpm water feed rate was maintained to the rod mill. The rod mill contained a charge of 25 four-inch rods. The water degassing tank bottoms were sent to the surge water tank for a greater part of the test.

While the test was in progress, coal was ground for approximately 90 hours with no major operating problems.

Table I shows the particle size distribution in the coal as it passes through the system and compares this test with previous tests.

b. Spray Drying

The solids concentration in the water degassing tank bottoms was very high (11 percent average compared to a normal value of about 1 percent) through most of G-13, indicating poor efficiency in the coal cyclone.

Post test inspection showed the trickle valve was closed on the coal cyclone dip leg; apparently the wire holding it open has broken early in the test. This may account for the poor efficiency of the cyclone. The spray drying system operation data are summarized in Table II. Feed to spray drying was very good and even reached the design rate of 10,000 lb/hr. for a short period. High feed rates predominated through most of the run and the stated feed objectives were accomplished.

c. Gasifier Area

1) Coal Feed

Coal was fed to the gasifier during Test G-13 for 119.6 hours, the longest period to date. The average coal feed to spray drying for the five material balance periods was 8335 lb/hr. The main objectives concerning coal feed were:

TABLE I

Coal Particle Size Distribution

Test Number	G-10	G-10A	G-11	G-11A	G-11B	G-11C	G-11D	G-11F	G-12	G-12A	G-13
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SIZE, Wt. %, U.S. SIEVE	Slurry Blend Tank				Slurry Circulating Pump						
	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.			Avg.
8	1.2	1.1	2.8	3.4	7.0	5.0	0.9	1.5	3.1	7.0	2.1
12	3.5	3.0	6.5	6.7	10.7	7.2	2.0	4.4	5.4	7.0	3.9
20	19.0	16.3	20.9	24.5	24.2	23.9	15.1	19.3	22.5	21.0	16.4
50	44.8	43.1	37.5	38.4	33.1	33.6	43.5	41.0	40.1	35.7	36.7
100	18.4	19.8	16.0	13.8	10.8	13.0	20.2	18.0	13.2	13.6	18.1
200	7.1	8.4	7.9	6.3	5.5	6.9	9.9	8.8	6.3	7.8	11.6
325	1.4	1.9	1.9	1.5	1.5	2.0	2.4	2.2	1.5	1.6	3.2
PAN	4.6	6.5	6.3	5.5	7.1	8.5	6.1	4.9	8.0	6.3	8.0
SOLIDS, Wt. %				33.2%	31.4%		32.4%		39.1%	31.1%	35.9%

Coal Vessel

SIZE, Wt. %, U.S. SIEVE											
8	<0.1					0.4		<0.1			<0.1
12	0.1	TR	0.1	0.2	0.2	0.5	0.1	3.6		0.2	0.2
20	4.5	2.8	4.9	3.6	4.1	3.3	3.3	33.9		5.6	3.5
50	42.2	32.2	39.9	33.6	37.3	14.2	27.2	33.4		45.2	33.4
100	33.1	34.8	36.1	50.3	34.8	18.7	45.3	19.6		33.5	38.6
200	14.4	20.8	17.1	11.7	16.4	22.5	21.8	5.1		13.7	20.0
325	3.0	5.0	1.4	0.4	4.2	19.7	1.9	4.4		1.5	3.0
PAN	2.6	4.0	0.5	0.2	3.0	20.7	0.4			0.4	1.1
SOLIDS, Wt. %											

Char Vessel

SIZE, Wt. %, U.S. SIEVE											
8					Avg.	0.1					
12			0.1	0.4	0.2	0.1	0.1	0.3	0.1		0.3
20	0.2	0.4	6.4	10.5	3.4	0.9	2.8	6.0	0.7	0.5	8.3
50	19.0	17.2	36.4	46.2	36.7	13.5	25.8	30.2	12.8	32.4	36.3
100	40.5	38.2	27.2	26.2	32.0	25.0	27.3	28.9	54.9	35.2	28.5
200	27.0	28.8	17.5	11.6	16.2	19.9	20.8	20.0	16.3	20.9	16.1
325	7.4	8.1	5.1	2.5	4.8	8.8	7.7	7.2	6.3	5.7	4.2
PAN	5.9	7.4	7.4	2.5	6.7	31.7	15.6	7.4	8.9	5.2	6.0
SOLIDS, Wt. %											

TABLE I (continued)

Coal Particle Size Distribution

Test Number	G-10	G-10A	G-11	G-11A	G-11B	G-11C	G-11D	G-11F	G-12	G-12A	G-13
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Water Degassing Tank

SIZE, Wt. %, U.S. SIEVE	Avg.	Avg.	Avg.								Avg.
8											
12											0.1
20			0.5	0.1	0.1	0.2	0.1	0.1			2.3
50	8.6	2.9	9.0	4.4	5.8	3.4	2.3	0.7	1.0		22.4
100	23.1	27.0	16.2	13.7	12.9	8.8	9.1	3.1	2.9		25.6
200	27.8	20.5	19.4	16.2	13.6	11.3	14.4	7.7	5.1		18.8
325	6.2	7.3	8.4	8.0	1.8	6.0	7.6	6.1	4.3		7.6
PAN	34.3	42.2	46.5	57.4	65.8	70.3	66.5	82.3	86.6		23.6
SOLIDS, Wt. %	1.0		1.6%	1.3%	1.2%	0.5%	1.6%	1.5%	1.8%	2.2%	10.9%

Ammonia Stripper

SIZE, Wt. %, U.S. SIEVE	Avg.	Avg.	Avg.	Avg.	Avg.			Avg.			Avg.
8											
12											
20			0.3	0.5	0.4		0.8	0.2	0.8		
50			12.2	7.5	10.5	0.1	6.0	12.8	12.5		
100	0.8	0.7	16.8	10.1	14.0	5.6	6.4	17.4	17.4		1.9
200	2.0	1.5	14.5	9.5	13.7	5.6	9.3	13.7	12.3		2.0
325	2.5	1.8	6.7	10.2	11.7	3.9	22.6	5.9	5.2		3.1
PAN	94.7	95.9	49.5	62.2	49.6	81.3	54.9	50.1	51.8		93.8
SOLIDS, Wt. %	0.17%	0.3%	1.3%	0.7%	0.9%	0.6%	0.8%		1.3%	0.5	0.3 Avg.

Rod Mill R-103

20 Four - inch rods in rod mill

25 Four inch rods in rod mill

SIZE, Wt. %, U.S. SIEVE								Avg.			Avg.
8	1.0	1.2	3.4		3.4			0.6		0.5	1.8
12	3.4	3.9	6.1		5.1			2.4		2.4	5.1
20	13.9	18.9	20.6		14.4			11.9		14.4	16.4
50	33.8	33.2	32.6		30.4			33.9		34.8	30.7
100	15.7	13.4	11.3		14.4			16.2		16.5	15.3
200	10.9	10.1	9.0		9.9			11.3		11.4	10.9
325	5.0	4.9	3.9		4.7			5.2		4.5	4.6
PAN	16.3	14.4	13.4		17.7			18.6		15.5	15.2
SOLIDS, Wt. %	18.4%	18.2%	25.2%					23.5% Avg.			27.8%

TABLE II
TEST G-13
SPRAY DRYING OPERATION

Material Balance Period: 1600-1829 Hours - 7/3/80

Slurry Feed to Dryer	8615 lb/hr.
Solid Waste From Water Degassing Tank	2494 lb/hr.
Coal Feed to Gasifier	6120 lb/hr.
Coal Cyclone Efficiency	71 percent
Condensate Waste	5000 lb. cond./ton coal
Recycle Gas Rate	2,100,000 SCFH
Spray Dryer Outlet Temperature	554 F
Spray Dryer Outlet Pressure	772 psig

TABLE III
TEST G-13
GASIFIER OPERATION

Material Balance Period: Average of five material balance periods.

Coal Type: Montana Rosebud

*Average GHV of Coal	11,370 BTU/lb.
Coal Feed	5,918 lb/hr.
O ₂ Total	4,710 lb/hr.
Char Burners (3)	3,776 lb/hr.
Slag Heating Burner	531 lb/hr.
Slag Tap Burner	698 lb/hr.
Fuel Gas Total	1,753 lb/hr.
Char Burners (3)	1,130 lb/hr.
Slag Heating Burner	251 lb/hr.
Slag Tap Burner	277 lb/hr.
Steam Total	3,435 lb/hr.
Stage I	1,627 lb/hr.
Stage II	1,808 lb/hr.
**Nitrogen	1,032 lb/hr.
Gasifier Pressure	750 psig
***Average Stage I Temperature	2,695 F
****Average Stage II Temperature	1,660 F
Synthetic Gas Rate	18,451 lb/hr.

* Moisture free basis but includes ash.

** Includes assumed flow of 60 lb/hr. to RTA systems.

*** Stage I temperature from upper thermocouple.

**** Stage II temperature of four vertically spaced thermocouples.

NOTE: Computer was not functioning at this time. Data were obtained from strip charts and local indicators.

- a) to consistently feed at a reasonable rate (>5000 lb/hr.) while maintaining stable coal and char feed vessel levels, and
- b) to determine the highest coal flow at which the char vessel level would remain constant while feeding char at a maximum rate.

Operation was generally stable for the test and both of these objectives were met. The 'A' and 'B' coal legs were both used, averaging approximately 40% and 20% valve settings respectively, through the test. Some pluggage was encountered, mostly in the 'B' eductor; but all problems were able to be cleared and feed was never seriously limited.

'A' Coal Leg System

Coal feed to spray drying started at 1332 hours on July 1 with the 'A' flow control valve open at 45 percent and the 'B' valve closed. Soon after spray drying started, feed through the 'A' leg was indicated by changes in the system differential pressures (dP's). This type of solids flow situation lasted for about 1.5 hours when it appeared that the leg lost its seal. The dP's went back to a condition similar to that for gas only, but the ranges were wider and more erratic, indicating solids were present. This non-sealed condition lasted for 3.5 hours before stable flow was established. From this point until 0750 hours on July 2, coal was fed through the 'A' leg with the valve kicker on. During this 14 hour period, there were four plugs of short duration in the lower leg as indicated by:

- a) an increase in the upper leg dP,
- b) a decrease in the valve dP,
- c) an increase in the lower leg dP,
- d) an increase in the eductor dP, and
- e) a decrease in the nozzle dP.

From 0750 hours to 0930 hours on July 2, the 'A' valve kicker was turned off. Initially little effect was noted, though the dP's did become smoother. Shortly after the kicker was turned off, a leg plug occurred that was cleared by fully opening the feed valve. After this, the valve position was varied, ranging from 33 to 40 percent. During this period:

- a) the upper leg dP dropped from 270" to 125" WC,
- b) the valve dP rose from 180" to 300"WC,
- c) the lower leg dP dropped from -70" to -100"WC,
- d) the eductor dP dropped, and
- e) the nozzle dP went up slightly.

When the valve position was lowered to 34 percent and the kicker turned back on, the dP's stabilized at:

- a) an upper leg dP of 240"WC,
- b) a valve dP of 180"WC,
- c) a lower leg dP of -70"WC,

- d) an eductor dP of -15"WC, and
- e) a nozzle dP of 65"WC.

After a short stable period at 34 percent valve setting, a lower leg plug occurred that was cleared by stroking the feed valve. For approximately six hours after the plug was cleared, the valve position was increased to as high as 44 percent. During this time, it was again noted that at 40 percent valve setting or above, the flow indications were more erratic, and

- a) the upper leg dP dropped,
- b) the valve dP rose,
- c) the eductor dP dropped and the nozzle dP rose slightly.

When the valve position was lowered to below 40 percent at 1800 hours on July 2, the dP's stabilized notably. For the following 19 hours, the valve setting was at 38 percent except for two short periods of 40 percent flow. These two periods of 40 percent flow. These two periods experienced similar results, as outlined above for 40 percent opening, in an otherwise extremely stable period. At 1300 hours on July 3, the valve was opened to 40 percent for a five hour period. Again, the dP's reacted as follows:

- a) the upper leg dP dropped,
- b) the valve dP increased,
- c) the eductor dP dropped, and
- d) the nozzle dP rose slightly.

During some of the periods when the valve was at 40 percent or greater opening and the dP's were more erratic, there was evidence of higher flow rates by drops in the feed vessel level and small increases in the leg temperature. At 1800 hours on July 3, the valve was returned to 38 percent and the dP's again stabilized. After this point the trends were less distinct; but there were still some indications that approximately 40 percent valve opening on the 'A' system was a critical set point for flow.

Two stoppages of coal feed occurred on July 5; one from 0127-0232 hours due to an emergency shutdown and another from 1307-1320 hours caused by a low fuel gas indication. Coal feed was reestablished after both of these shutdowns. After the second shutdown, particularly, the valve position was changed several times between 38 percent and 42 percent. The upper leg, valve, eductor, and nozzle dP's changed noticeably for these small increments as did the feed vessel level. This again illustrated the narrow control range in this range of valve settings.

At approximately 0700 hours on July 6, the nozzle dP started to rise and eventually pegged high. This condition lasted for four hours before feed was stopped due to a recycle gas heater (H-201) shutdown. When feed was restored, the nozzle came back onto chart range, but it was still high. This condition lasted until test termination. Of interest is the fact that the 'B' coal nozzle dP increased identically to 'A' during the same time period. This could possibly have been

an indication of the buildup in Stage II that was found after the test.

'B' Coal Leg System

Coal feed to spray drying was started with the 'B' control valve closed and the 'A' open due to the imbalances experienced in the past from the 'B' eductor. The 'B' coal leg was first put in service at 1745 hours on July 1 at 18 percent valve opening but was shut off after 2.5 hours to help build a level in the feed vessel. The 'B' leg was reopened at 0515 on July 2 with the valve kicker on, and the following dP indications were noted:

- a) the nozzle dP was pegged high with some spikes back on scale from the kicker;
- b) the eductor read 0"WC,
- c) the leg dP was 275"WC, and
- d) the leg temperature was 460°F.

Between 0750 and 0930 hours on July 2, the valve kicker was turned off. The only noticeable effect was that the nozzle dP pegged high with no downward spikes, while the other measurements were not affected. The 'B' system ran fairly steadily until 1930 hours on July 3 when a plug occurred on the downstream side of the eductor. When this plug was cleared, the nozzle dP came on range at approximately 64"WC. This dP then stayed in range for most of the remainder of the test, before it started to rise at 0700 hours on July 6 and eventually pegged high. Again, the interesting aspect of this occurrence was that the nozzle reading compared identically to that in the 'A' coal system at the same time, possibly indicating buildup problems in Stage II.

Though the 'B' coal feed system ran fairly well throughout the test, a total of nine plugs occurred, all of which appeared to be in the downstream side of the eductor. All of these plugs were able to be cleared by:

- a) closing the remote operated valve (ROV), below the control valve,
- b) closing the ROV between the eductor and gasifier,
- c) venting down then closing off the isolated section of line,
- d) opening the ROV between the eductor and gasifier and clearing the plug with gasifier pressure,
- e) reopening the ROV below the control valve, and
- f) opening the control valve to reestablish flow.

Flow through the 'B' coal system was interrupted three other times during the test; once due to an emergency shutdown, a low fuel gas shutdown, and a recycle gas heater shutdown. Flow was successfully restored after each of these instances.

Coal flow through both 'A' and 'B' legs was quite stable throughout Test G-13 and did not limit plant operation. Feed to spray drying was very good and even reached the design rate of 10,000 lb/hr. for a short period. High feed rates predominated through

most of the run and the stated feed objectives were accomplished.

2) Char Feed

- a) Characteristically char feed through the three systems was stable throughout the test. Minor plugs that formed were eliminated by purging up and down the leg.
- b) Instrumentation on the 'B' char feed system indicated that the new leg performed in a similar manner to 'A' and 'C' legs.
- c) There were times during char feed in each of the three systems where the lower leg differential pressure (dP) indicated a positive reading. As noted in previous reports, a negative value for the lower leg differential pressure is more expected responses during char flow. It is not known why this reading was positive at various times on all three legs. It should be noted that there were other times during stable char flow conditions where the lower leg dP read the expected negative value. Two possible explanations are as follows: 1) a plug occurred in the purge to the high pressure tap on the instrument, driving the instrument to read high, and 2) a restriction in the lower leg developed, causing a high differential pressure to be present in this pipe section.
- d) The lower leg temperatures on the three char lines read typically 600-650°F, while the upper leg temperatures varied from system to system. 'A' char upper leg temperature read approximately 750°F during stable char feed while 'B' char read approximately 500°F. The relatively low temperature on 'B' is thought to be due to the presence of a purge on a differential pressure tap located immediately above the char leg. 'C' char upper leg temperatures fluctuated considerably around the 400°F temperature level until the purge gas flow to the char sampling station was shut off. At that point, the 'C' char leg temperature increased to 700-750°F.
- e) The greatest amount of char feed most likely occurred between 1420 hours July 4 when 'B' char control valve was open from 78 to 86 percent and when the gasifier shut down due to high Stage II temperature, 0129 hours, July 5. Even though the valve differential pressure did not change with the valve opening, the lower leg temperatures all reached their maximum values during this period. 'A' lower leg temperature reached 665°F, 'B' leg reached 694°F, and 'C' leg reached 656°F. During this time, 'A' char control valve was 100 percent open and 'C' char control valve was 87 percent open.
- f) The sensitivity of controlling char feed with the ball valve can be shown by looking at the behavior of 'C' char leg from 1700 hours to 1830 hours on July 2. During this period of time, the ball valve was opened to 70 percent from 65 percent and then closed back to 65 percent.

Control Valve Position	65%	70%	65%
Control Valve dP	320"WC	50"WC	300"WC
Eductor dP	500"WC	250"WC	500"WC
Nozzle dP	13"WC	11"WC	16"WC
Lower Leg dP	-95"WC	-95"WC	-95"WC
Lower Leg Temperature	615°F	625°F	610°F
Argonne Flow Monitor	50%	37%	49%

Also notice from these data that the Argonne flow meter response decreased with higher flows. The initial Argonne response is an increase in signal when char feed is started. It is recommended that control of char feed on 'C' char leg be moved back to the Fisher Vee-ball valve (4102°C) while the operating pressure of the gasifier remains at 750 psig.

3) Behavior of Stage II Thermocouples

- a) A loose wire was found on the Stage II temperature multi-point recorder number six at 0245 hours July 2. Before this time, the recorder was indicating a reading approximately 100°F higher than the value obtained in the computer van. This problem was corrected by the Instrument Technician.
- b) After this problem was corrected, all Stage II thermocouples were reading within 20°F of each other until 2250 hours July 2 (33.2 hours after starting coal feed). At this time, number two thermocouple increased approximately 50°F above the other Stage II thermocouples for one hour. No problem could be found at this time and no corrective action was taken.
- c) The next temperature deviation started at 0715 hours July 3, when over the next three hours number two thermocouple indicated a temperature that was as much as 140°F lower than the other Stage II thermocouples. Again, the thermocouple returned to agreement with the other thermocouples.
- d) A minor upward drift in the number two thermocouple continued until 0100 hours July 5. At this time, number two was at 1760°F (60°F above the other thermocouples). Twenty-seven minutes later, the thermocouple had increased to 1900°F. At this point, operators started to take corrective action, but the thermocouple exceeded 2000°F at 0129 hours, and the gasifier had an emergency shutdown (ESD) on high Stage II temperature. The thermocouple responded to the gasifier shutdown so all burners were relit without taking any corrective action.
- e) At 0215 hours on July 5, with thermocouple numbers three and six at 1540°F, number two was again up to 1900°F. At this time, the alarm and shutdown was moved from number two to number three

and number two increased up to 2090°F before it started to drift down toward the other Stage II thermocouples.

- f) The number two thermocouple continued to drift both higher and lower than the other Stage II thermocouples for the rest of the test. The reason for this drift was the large deposit in Stage II. The higher readings would be caused by Stage I gases being channeled over number two thermocouple and the lower readings would be caused by the thermocouple being buried in the Stage II deposit.

4) Stage II Deposits

The two types of deposits found in Stage II were analyzed by the laboratory after the test. One sample was a hard material taken from the lower section of Stage II, and the other, a slag, char-like loose material found above the hard deposit in Stage II.

The hard deposit was a sintered (not glassy) mass and was found to be not unlike deposits found in Stage II in previous tests. Analysis showed the iron and calcium to be higher and the silicon content to be lower than that found in the usual glassy slag removed from the quench section of the gasifier.

The deposit taken from the upper section of Stage II was found to be a loose slag, char-like mixture. The larger material above four mesh appeared to be mostly sintered slag, while the material smaller than four mesh appeared to be a mixture of slag and char. The particles varied in appearance from smooth, black, shiny to uneven black and grey. The carbon content of this material indicates that about one-third of the material was char. Investigations are continuing to determine whether this deposit is due to slag being entrained upward from Stage I into Stage II or due to the accumulation of "oversized char" that is too large to be entrained and too small to be dropped into Stage I after being fed into Stage II of the gasifier.

5) Slag

A significant amount of carbon containing material was found with the slag during the earlier periods of the test. The first three material balance periods showed a carbon content of 30-40 percent in the slag. During the fourth material balance period, only 11 percent of the material collected in the slag collector was carbon. During the final material balance period on July 8, an insignificant amount of carbon was found in the slag dump. During the test a total of 37,410 lbs. of slag were collected.

6) Char Sampling

During Test G-13, the char sampling station had a very noticeable effect on the 'C' char leg, particularly the leg temperatures and to a minor extent, the dP's. From the onset of char feed until approximately 1000 hours on July 2, the sampling station purge was left on, after which it was turned off and reopened only during sample periods. Before

the purge was turned off the notable effect was on the 'C' char upper leg temperature, which was very erratic, ranging from 260°F to 580°F. When the purge was turned off the temperature rose to 700°F, where it ran fairly consistently except for char sampling periods.

Five char samples were taken during the test after the purge was turned off. The purge was turned on while the sample was being taken. The effects on the 'C' char leg during these samples are listed as follows:

Date/Time	July 2 1345 Hours	July 4 2030 Hours	July 5 0020 Hours	July 5 1820 Hours	July 6 1315 Hours
Upper Leg Temp.	decrease 250°F	decrease 80°F	decrease 1050°F	decrease 150°F	decrease 70°F
Lower Leg Temp.	decrease 60°F	decrease 180°F	decrease 360°F	decrease 230°F	-----
Valve dP	stable	no change	no change	increase	no change
Upper Leg dP	stable	no change	no change	increase	no change
Lower Leg dP	stable	increase	increase	increase	no change
Eductor dP	stable	erratic	erratic	increase	increase
Burner dP	increase	increase	increase	increase	increase
Char Vessel dP	decrease	decrease	decrease		

7) TV Picture

During most of the test, nothing was visible on the TV picture of the slag quench section. The only times when slag tapping or the tap burner flame were visible were:

- the first 12 hours after coal and char feed were started,
- after the oxygen rate to the slag heating burner was increased, July 2, 1100 hours (TV picture improved slightly for a brief time),
- when the tap burner shut down (flame was visible for a short time after the tap burner was relit),
- after the ESD due to Stage II high temperature measurement (details on TV picture barely visible for about 30 minutes), and
- after the char burner shut down due to low fuel gas flow (details on TV picture seen until char feed restarted, about 10 minutes later).

Since large amounts of material were collected in the lock-hopper dumps, the loss of the TV picture was not considered serious.

One attempt was made to improve the TV picture. The water level in the quench section was dropped from 50 percent to 40 percent. However, the picture did not improve.

A sample was taken of the gases in the quench section to determine if water vapor or char was responsible for the poor TV pictures. Very little water and no char was found in the sample, however. The dry gas consisted of 41.9 percent H_2 , 7.7 percent N_2 , 10.7 percent CH_4 , 34.4 percent CO , and 5.6 percent CO_2 .

d. Naphthalene Removal

The combined effluent trim coolers were switched six times during Test G-13.

Since the only portion of product gas required for purge gas was sent to the gas treating area, there was never a high pressure drop across the coolers. When naphthalene began to foul the tubes, the outlet temperature increased above 100-110°F. At this point, the coolers were switched.

When the coolers were opened, little naphthalene was found. The combined effluent knock-out drum downstream of the coolers was also opened; a moderate amount of naphthalene was observed.

e. Gas Washing and Gas Treating

1) Gas Washing

The gas washing system operation during Test G-13 was erratic, particularly the gas washer level and flow control. Until approximately 2100 hours on July 3, the level in the gas washer was fairly stable; but then started to fluctuate. The bottoms flow began to swing from 0-100 percent which, in turn, seemed to have a detrimental effect on the system pressure control. Operations personnel had to devote a good deal of attention to the control of this system and occasionally ran it manually in an attempt to stabilize the level. Adjustments were made on the instrumentation and the level column was purged on occasion, but erratic conditions prevailed until run termination. Due to the erratic flow from the gas washer, the level in the ammonia stripper consistently varied from the low alarm to the high alarm condition. This had an unfavorable effect on the operation of this vessel by preventing stable operation and was probably a factor in some of the high ammonia readings that were found in the ammonia stripper bottoms. On one occasion, water was found at the thermal oxidizer, which is believed to have come from entrainment out of ammonia stripper. Table IV summarizes gas washing area performance data.

After the test, a heavy scale buildup was found at the venturi on the gas inlet line to the gas washer and also in the reflux inlet to the column and on the trays near the top of the column.

A significant pressure drop occurred across the column which was most likely caused by the restriction in the gas inlet.

Below is an analysis of the gas washer venturi deposit:

Ash Wt.%	79.3
Carbon Wt.%	11.1
Hydrogen Wt.%	0.7
Sulfur Wt.%	3.2
Ash Composition Wt.%	
SiO ₂	34.0
Al ₂ O ₃	12.4
Fe ₂ O ₃	6.2
CaO	30.7
MgO	5.8
TiO ₂	1.0
MnO ₂	0.27
Na ₂ O	0.75
K ₂ O	0.19
SO ₃	9.4

2) Gas Treating

Absorption of H₂S by the Selexol system was adequate during Test G-13. Gas flows to the system averaged approximately 375 mol/hr.; enough to satisfy purge gas needs. This amounted to approximately one third of the total gas produced. The main problem encountered during the test was Selexol carryover from the flash tanks to the thermal oxidizer header.

On July 2 significant Selexol carryover was noted on several occasions, so process changes were made to alleviate the problem. The pressure in the high and low pressure flash tanks were raised from 150-158 psig and 30-50 psig respectively. This was done to decrease the amount of gas flashed in these two vessels and reduce liquid entrainment. A pint of defoamer was added and the level in the high pressure flash tank was lowered. These changes reduced liquid carryover until July 4 when problems arose again. Selexol losses were noted several times on July 4 but no further process changes were made. After this problem period, minimal trouble was noted with Selexol loss for the remainder of the test. Table V is a summary of gas treating area operation for Test G-13. Table VI summarizes gas analyses for the test.

3) High Pressure Drop Between Gasifier and Gas Washer

During Test G-13, there was a gradual increase in the pressure drop between the gasifier and the gas washer overhead. This pressure drop was about 20 psi for the first two days then increased to over 70 psi by the end of the test. (Figure II shows the trend of this pressure drop during the test.) Pressure checks made at several points between the gasifier and gas washer indicated that most of the pressure drop was occurring between the outlet of the char vessel and the bottom section of the gas washer. The pressure drop across this section was 44 psi out of a total pressure drop of 67 psi at the time of the checks.

TABLE IV
TEST G-13
GAS WASHER AND AMMONIA STRIPPER
PERFORMANCE DATA

Material Balance Period: Average of five material balance periods.

Gas Washer

Gas Washer Overhead Rate	373,808 SCFH
Pressure	710 psig
Inlet Temperature	768 F
Outlet Temperature	346 F
Fresh Water Make-Up	650 gph
Reflux Flow	6,813 gph
Solids Waste	89 lb/hr. char
Char Removed	14.8 lb/ton of coal to gasifier

Ammonia Stripper

Pressure	3 psig
Overhead Temperature	221 F
Inlet Ammonia	14.2 lb/hr.
Outlet Ammonia	2.6 lb/hr.
Stripper Efficiency	81.7 %
Condensate Rate	4,469 gph
Steam Rate (50# steam)	3,504 lb/hr.
Condensate Usage	1,090 gal/ton of coal

TABLE V

TEST G-13
GAS TREATING AREA PERFORMANCE DATA

Operating Period: Average of five material balance periods.

Synthesis Gas to Selexol	377 mol/hr.
Gas Temperature to Selexol	97 F
Gas Pressure to Selexol	689 psig
Selexol Circulation Rate	44 gpm
Percent Water in Selexol	4.8 %
Cold Selexol Temperature	64 F
H ₂ S in Synthesis Gas	1760 ppm
H ₂ S in Purge Gas	0.28 ppm

TABLE VI

TEST G-13GAS ANALYSES (Dry Basis)

Material Balance Period: Average of five material balance periods.

	<u>Gasifier Overhead</u> <u>Mole %</u>	<u>Purge Gas</u> <u>Mole %</u>	<u>Recycle Gas</u> <u>Mole %</u>
CH ₄	9.2	10.0	10.0
H ₂	39.0	43.9	43.4
CO	31.0	33.6	33.7
CO ₂	14.3	5.6	5.4
N ₂	6.8	7.3	7.5
H ₂ S	1760 ppm	0 ppm	23 ppm
COS	46 ppm	0.2 ppm	1.8 ppm

FIGURE II

TEST G-13

PRESSURE DROP FROM GASIFIER TO GAS WASHER OVERHEAD

(DATA DERIVED FROM AAI LOG)

TABLE VII

BI-GAS Plant Material Balance

Test G-13, 7/2/80, 1400-1900 Hrs.

All Units LB/HR

	C	H	ASH	H	O	TOTAL
INPUT						
(1) A. Coal to Spray Drying	5286	74	839	362	1620	8180
B. Purge Gas to Gasifier	574	197		123	718	1612
C. Fuel Gas to Gasifier	1312			437		1750
D. H ₂ to Gasifier and V-302		1034				1034
E. O ₂ to Gasifier					4911	4911
F. Steam to Coal Nozzles				269	2151	2420
G. Steam to Char Burner				179	1436	1615
H. Quench Water and Steam				869	6957	7825
I. Slag Quench Water Make-Up				1867	14953	16820
J. Gas Washer Water Make-Up				650	5203	5852
K. Steam to NH ₃ Stripper				383	3067	3450
L. Estimated Water Purges				1386	11097	12483
TOTAL INPUT	7172	1304	839	6525	52113	67952
OUTPUT						
M. Gas to Gas Treating	1226	298		212	1755	3491
N. Gas to Thermal Oxidizer	4076	990		979	8018	14062
(2) O. Ammonia Stripper Overhead		16		227	1786	2029
(3) P. Ammonia Stripper Bottoms	59		47	4108	32833	37046
(4) Q. V-203 Bottoms (Solids Only)	1410	20	274	96	278	2080
(5) R. Slag Collector	130		194			324
TOTAL OUTPUT	6901	1324	515	5622	44670	59032
CLOSURE, OUTPUT/INPUT	0.96	1.02	0.61	0.86	0.86	0.87

Remarks:

	<u>1400 Hours</u>	<u>1900 Hours</u>
LR-2100 (Coal)	55	52
LR-4102 (Char)	37	35

(1) Includes 500 lb/hr. recycle gas through coal legs.

(2) Assumed one volume percent ammonia.

(3) Estimated flow from: Gas washer bottoms and saturation water in process gas and reflux pump purge and ammonia stripper make-up.

(4) Assumed slurry flow 45 gpm.

(5) Averaged slag collection over 24 hour period. Part of the carbon and ash may have come from the water degassing tank bottoms since this was occasionally sent to the slag bin.

TABLE VII (continued)

BI-GAS Plant Material Balance

Test G-13, 7/3/80, 0300-0430 Hrs.

All Units LB/HR

	C	N	ASH	H	O	TOTAL
INPUT						
(1) A. Coal to Spray Drying	6028	91	934	399	1568	9019
B. Purge Gas to Gasifier	588	206		124	723	1641
C. Fuel Gas to Gasifier	1331			444		1775
D. H ₂ to Gasifier and V-302		1044				1044
E. O ₂ to Gasifier					4599	4599
F. Steam to Coal Nozzles				112	901	1013
G. Steam to Char Burner				182	1460	1643
H. Quench Water and Steam				736	5898	6635
I. Slag Quench Water Make-Up				1716	13740	15456
J. Gas Washer Water Make-Up				622	4985	5607
K. Steam to NH ₃ Stripper				383	3067	3450
L. Estimated Water Purges				1481	11870	13351
TOTAL INPUT	7946	1341	934	6199	48811	65233
OUTPUT						
M. Gas to Gas Treating	1206	326		210	1692	3434
N. Gas to Thermal Oxidizer	3597	971		803	6463	11834
(2) O. Ammonia Stripper Overhead		16		224	1764	2003
(3) P. Ammonia Stripper Bottoms	39		26	3862	30865	34793
(4) Q. V-203 Bottoms (Solids Only)	1922	28	298	127	500	2874
(5) R. Slag Collector	160		240			400
TOTAL OUTPUT	6924	1341	564	5226	41284	55338
CLOSURE, OUTPUT/INPUT	0.87	1.00	0.60	0.84	0.83	0.85

Remarks:

LR-2100 (coal)

0300 Hrs.
490430 Hrs.
49

LR-4102 (char)

35

36

(1)-(5) - See Material Balance No. 1

TABLE VII (continued)

BI-GAS Plant Material Balance

Test G- 13, 7/3/80, 1600-1830 hrs.

All Units LB/HR

	C	H	ASH	H	O	TOTAL
INPUT						
(1) A. Coal to Spray Drying	5750	84	887	396	1491	8608
B. Purge Gas to Gasifier	593	187		134	767	1681
C. Fuel Gas to Gasifier	1324			441		1765
D. H ₂ to Gasifier and V-302		986				986
E. O ₂ to Gasifier					4837	4837
F. Steam to Coal Nozzles				185	1485	1670
G. Steam to Char Burner				181	1449	1630
H. Quench Water and Steam				821	6569	7390
I. Slag Quench Water Make-Up				2056	16451	18507
J. Gas Washer Water Make-Up				566	4526	5092
K. Steam to NH ₃ Stripper				383	3067	3450
L. Estimated Water Purges				1207	9656	10863
TOTAL INPUT	7667	1257	887	6370	50298	66479
OUTPUT						
M. Gas to Gas Treating	1192	300		207	1676	3375
N. Gas to Thermal Oxidizer	4021	1011		1023	8276	14331
(2) O. Ammonia Stripper Overhead		14		197	1552	1763
(3) P. Ammonia Stripper Bottoms	72		52	4251	33960	38335
(4) Q. V-203 Bottoms (Solids Only)	2129	31	287	153	522	3122
(5) R. Slag Collector	110		246			356
TOTAL OUTPUT	7524	1356	585	5831	45986	61282
CLOSURE, OUTPUT/INPUT	0.98	1.08	0.66	0.92	0.91	0.92

Remarks:

	1600 Hrs.	1830 Hrs.
LR-2100 (Coal)	51	58
LR-4102 (Char)	61	70

(1)-(5) See Material balance no. 1.

TABLE VII (continued)

BI-GAS Plant Material Balance

Test G-13, 7/6/80, 0630 - 0930 hrs.

All Units LB/HR

	C	N	ASH	H	O	TOTAL
INPUT						
A. Coal to Spray Drying	5132	71	752	361	1356	7672
(1) B. Purge Gas to Gasifier	661	261		149	918	1989
C. Fuel Gas to Gasifier	1318			440		1758
(6) D. H ₂ to Gasifier and V-302		1256				1256
E. O ₂ to Gasifier					4368	4368
F. Steam to Coal Nozzles				179	1430	1609
G. Steam to Char Burner				187	1495	1682
H. Quench Water and Steam				693	5542	6235
I. Slag Quench Water Make-Up				2127	17013	19140
J. Gas Washer Water Make-Up				492	3938	4430
K. Steam to NH ₃ Stripper				383	3067	3450
L. Estimated Water Purges				1344	10756	12100
TOTAL INPUT	7111	1588	752	6355	49883	65689
OUTPUT						
M. Gas to Gas Treating	1184	402		213	1707	3506
N. Gas to Thermal Oxidizer	2399	813		605	4859	8676
(2) O. Ammonia Stripper Overhead		28		431	3408	3867
(3) P. Ammonia Stripper Bottoms	70		37	4492	35907	40506
(4) Q. V-203 Bottoms (Solids Only)	1781	26	263	121	444	2635
(5) R. Slag Collector	1		278			279
TOTAL OUTPUT	5435	1269	578	5862	46325	59464
CLOSURE, OUTPUT/INPUT	0.76	0.80	0.77	0.92	0.93	0.91

Remarks:

	0630 Hrs.	0930 Hrs.
LR-2100 (coal)	47	62
LR-4102 (char)	34	39

(1)-(5) See Material Balance no. 1

(6) Nitrogen flow about 5% high.

V-306 Coal Cyclone Vessel
 V-301 Gasifier
 V-402 Char Cyclone Vessel
 V-305 Slag Lockhopper
 V-501 Gas Washer

V-601, V-604 Knock-Out Drums
 E-602 Cooler
 V-502 Ammonia Stripper

Letter Stream Identification Keyed to Material Balance Table

FIGURE BI-GAS PLANT MATERIAL BALANCE SCHEMATIC

During the latter part of the test, the high pressure drop between the gasifier and the gas washer caused an alarm on two occasions for high pressure differential (>50 psi) between the gasifier and the cooling water surge drum. Since the cooling water surge drum vents into the gas washer bottom section and pressure equalizes with it, the gasifier/drum dP was increased due to the pressure drop problem. On the first occurrence, the problem was corrected by draining the gas washer which had become flooded due to a false level indication. After the second occurrence, it was necessary to cut coal and char feed and reduce the gas flow through the system to bring the pressure drop down.

Inspection of the gas washer after the test showed that the venturi through which the product gas enters the gas washer was partially blocked with solids. The deposition of solids in the throat of the venturi could explain the gradual increase in pressure drop during the test. The venturi had been inspected after Test G-11B, and no significant deposit was seen, although the gasifier/gas washer differential ranged from 40 to 65 psi during that test. During the remainder of the G-11 series and the G-12 series, the pressure differentials averaged 10 to 20 psi indicating that the venturi was open. The reason the venturi deposit occurred during G-13 is not known.

f. Material Balance

Process conditions were held relatively constant after stable conditions were reached on July 2 at approximately 1300 hours. Sets of material balance samples were taken at 1400, 1700 and 2000 hours on July 2 and then at four hour intervals through the remainder of the test. After the test the most stable periods of operation were identified as:

1. 7/2, 1400 - 1900 hours
2. 7/3, 0300 - 0430 hours
3. 7/3, 1600 - 1830 hours
4. 7/3, 4, 2200 - 0200 hours
5. 7/6, 0630 - 0930 hours

Material balance calculations were performed for these periods based on the average flow data and samples taken during these intervals; the results are shown in Table VII and Figure 3. Carbon and nitrogen closure was good for three of the five periods. The probable causes of the inaccuracy in material balance period number five were:

- 1) the coal vessel level increased 15 percent during the three hour, and
- 2) the thermocouple measuring the temperature of the total nitrogen flow to the gasifier malfunctioned.

It is not known why the carbon accountability in period number two is only 87 percent.

Ash accountability (60-70 percent) and hydrogen and oxygen accountabilities (83-92 percent) are typical. These have been discussed in past gasifier test reports.

During the test, it was not understood why the product gas flow was no higher than in previous tests; typically 7500-9000 lb/hr. of coal were fed to the spray dryer in Test G-13, while in recent tests only 5000-6500 lb/hr. of coal were fed. According to material balance calculations, 25-26 percent of the coal fed to spray dryer was not fed to the gasifier; this coal was detected in the water degassing tank bottoms stream. The calculated coal feed rates to the gasifier itself were only 5000-6200 lb/hr. during the five material balance periods. The cause of this relatively high coal loss was found during the post-run inspection. The "trickle" valve on the coal cyclone dip leg was found closed. Normally, this valve is wired to stay open.

g. Equipment Inspection

1) Gasifier

a) Slag Quench Section

The number one slag agitator quadrant was empty. The number two and three quadrants were half full of frit-like slag, and number four quadrant was full of slag.

The stalactite breaker had a one-eighth inch hole and a one inch long vertical crack on opposite sides of the breaker arm.

The north TV window was intact but very dirty. The bottom half of the mica lens was dirty while the top half was clean.

The west TV window was intact but very dirty. The bottom half of the mica lens was dirty while the top half was clean.

b) Stage I

The tap hole was open and six inches in diameter. 'B' and 'C' char burner sleeves were undamaged. The top half of 'A' sleeve was missing.

From the bottom of Stage I to the top of the burners, the tubes and studs were visible but covered with slag. From the top of the burners to the throat, the tubes and studs were visible but covered with a heavy coating of slag so that their shape was indistinct. Near 'A' char burner, there was a visible gap between two tubes.

'B' char burner port had a "curtain" with a two inch diameter hole in the center.

c) Stage II

The throat was open into a one foot high cavern formed by the hard deposit. The coal nozzles were covered with slag. The hard deposit extended approximately three feet above the cavern with some "rat-holing" present on the sides. The Stage II soft granular deposit extended three feet above the hard deposit. The weight of deposit in Stage II was 1410 lbs.

d) The coal feed vessel contained 3090 lbs. of coal. The trickle

valve was closed. Contents of the char vessel were not weighed since the char had to be washed out to clear the vessel. There was a layer of a hard crust that prevented the char from flowing freely from the char vessel.

e) Burners

- (1) The slag tap and slag heating burners were in good condition.
- (2) There was extensive surface cracking on the 'A' char burner face.
- (3) There was a large mass of slag on the face of 'B' char burner at the 9 o'clock position underneath the slag.
There was also a small hole in the burner tip into the O₂ annulus.
- (4) There was a large hole in the right side of the 'C' char burner's face, traversing water and O₂ sections of the burner face. The water flow separator also had extensive damage in the area of the hole.
- (5) Industrial Testing Laboratory's evaluation of materials submitted for metallurgical examination indicated that a very high temperature excursion existed during, and for a brief period, subsequent to failure of the burner.

The mechanism responsible for initiating the burner melt through has not yet been defined. It is possible that a slag deposit forming over the oxygen ports caused deflection of the oxygen stream and subsequent melting of the adjacent metal.

Thermal fatigue was cited by the laboratory as the cause of the fire-cracking on the Inconel 600 'A' char burner face. Although there was no evidence of fire-cracking on the Incoloy 800 tip as on the Inconel, there may exist a higher susceptibility to thermal fatigue with the former, resulting in melt-through.

f) Thermocouple Conditions

Stage I Thermocouples: The upper and middle thermocouples were in good condition with a light coating of slag and the Cr₂O₃ coating missing. The bottom thermocouple had the final three inches significantly eroded with the remaining thermowell heavily coated with slag and the Cr₂O₃ coating missing.

Stage II Thermocouples: TE-3401-3, 5, and 6 were in good condition. Thermocouple TE-3401-2, the lower thermocouple, had its sheath fused to the protector tube. The sheath appeared to be slightly collapsed.

2) Gas Washer

Trays eight through twelve (below the recycle inlet) were coated with a black deposit about 3/4" thick. Trays one through eight were relatively clean. The inlet venturi contained a hard deposit restricting the internal area approximately 75 percent.

h. Utilities

Compressor Room Cooling Water System:

Prior to this test, a new 54 square feet heat exchanger was installed to provide additional cooling in the closed loop water system in the compressor building. The cooling coil in the circulating tank had not been adequate to cool this loop and temperatures sometimes went as high as 100°F. The new heat exchanger, using cooling tower as a coolant, kept temperatures in the 65 to 75°F range during this test. The exit temperatures of the heat exchangers were consistently within 2°F of the cooling tower water temperatures indicating that it was cooling effectively.

It was believed that lower cooling loop temperatures would eliminate problems with the compressors overheating. During this test, however, the first stage of the fuel gas compressor ran hot and occasionally alarmed on high outlet gas temperature. Since there was a sufficient supply of cooling water to this compressor, it is believed that the overheating might be due to an internal problem.

6. Conclusions

- a. From the condition of all the burner faces, it is evident that a new burner design is needed if longer tests are to be conducted.
- b. A method of preventing calcium carbonate deposits in the gas washer venturi must be found.
- c. The ball valve does not control solids flow as well as the Vee-ball valve.

7. Recommendations

- a. Make 'B' coal leg identical to 'A' coal leg. This entails replacing the four inch diameter line with a one and one-half inch diameter line containing a one inch Vee-ball control valve. Replace 'B' coal eductor with a tee. Add the instrumentation so that it is identical to that of the 'A' coal leg instrumentation.
- b. In order to prevent the solids from entering the cooling water surge drum via the equalizing line, the line should be relocated with a rupture disc separating the systems. The gasifier cooling water system should be kept at a slightly higher pressure than the gasifier so that if a hole develops in the cooling water system, the water will flow into the gasifier rather than gas from the gasifier into the cooling water system.
- c. Install one of the newly designed char burners.
- d. Extend the char sample probe into the center of the char vessel so that purge flow through the probe will not cause lower temperatures in 'C' char leg.

B. August Activities

1. Summary

No tests were conducted during the month of August due to intergranular stress corrosion cracking problems in the product gas line between the gasifier and the gas washer. The first failure was found on July 31 in an eight-inch section between the gasifier and the char vessel and a second failure occurred August 22 in a four-inch line just downstream of the char vessel. Replacement of the 304 stainless steel portions of this line with chrome molybdenum steel prevented the scheduled Test G-14 from being conducted.

Acid cleaning of the gas washing system process vessels and lines was conducted to remove the calcium carbonate deposit that was beginning to restrict flows.

2. Modifications and Repairs

- a. The 304 stainless steel eight-inch diameter gas line between the gasifier and the char vessel was replaced with chrome molybdenum steel pipe. The existing chrome molybdenum tees were reused. Work was also started on replacing the 304 stainless steel pipe with chrome molybdenum steel in the four-inch and additional eight-inch diameter sections of the raw product gas line between the gasifier and the gas washer.
- b. A coal vessel sample station was installed. To decrease the influence of coal sampling on the coal leg temperatures:
 - 1) The sample probe was extended into the center of the coal vessel.
 - 2) A 1/32-inch diameter restriction orifice was placed in the purge gas line to the sample probe to reduce the flow rate of purge gas and thus its influence on coal leg temperature.
- c. The gas washing system including the gas washer, the gas washer recycle cooler, the gas washer bottoms cooler, and associated liquid transfer and reflux lines was acid cleaned to remove the calcium carbonate buildup.
- d. Steam at 150 psig was piped to the naphthalene coolers to be used for steam-cleaning the tubes. Steam at 50 psig was formerly used for this purpose. Steam at 150 psig was also tied into the process side of the combined effluent cooler.
- e. Rotameters were installed on the cooling water outlets from each stage of the recycle gas compressor, purge gas compressor, and fuel gas compressor.

- f. A new caustic line was installed from the 16,000 gallon caustic storage tank to the 250 gallon caustic day tank.
- g. The nitrogen make-up tie-in to the spray dryer system was switched from the discharge side of the recycle gas compressor to the suction side.
- h. The repulp tank was moved slightly so that in the future, the centrifuge can be used for separating coal solids from the plant waste streams.
- i. A bearing on the recycle gas compressor was replaced and the shaft was realigned.
- j. The thermocouples which were tied-in to the low temperature alarm on the gasifier overhead line were removed.
- k. Repairs on Argonne flow monitors for 'A' and 'B' char legs were completed and the monitors returned to service. The Argonne flow monitor on 'C' char leg has remained in service.
- l. A test stand for establishing a zero reference point on the Auburn flow meter was installed for use when the meter is put in service.
- m. Epoxy resin was installed over the recessed bolts holding the liner plates inside the rod mill.
- n. Relief valves in the gasifier, gas treating, and steam generation areas were removed for testing and repairs.

3. Area Operations

a. Coal Handling

Revisions are being made in the coal grinding area to reduce the amount of fines now going to the pond. Provisions will be made so that the underflow from the rotex screen, containing the fines, will go to the centrifuge feed tank. This fines slurry will be fed to the centrifuge, which will then concentrate the solid material. The repulp tank was moved so the solids from the centrifuge can feed a screw conveyor, which will transport the material to a truck for disposal.

b. Gasifier

Because of the intergranular stress corrosion cracking problems encountered with the raw product gas line between the gasifier and the gas washer, Test G-14 was not conducted during the month of August. On two occasions the plant was readied for operation and pressurization started, but the discovery of cracks in the line dictated the need for shutdown.

On July 29 all scheduled maintenance was completed in preparation for Test G-14. Pressurization of the gasifier was delayed due to pluggage in the gas washer reflux cooler.

On July 30 after acid cleaning the gas washer reflux cooler, gasifier pressurization was started. At 40 psig pressure a leak was discovered on the eight-inch product gas line between the gasifier and the char vessel and the system was depressured for repairs.

On August 21, after replacing the stainless steel sections of pipe between the gasifier and char vessel with chrome molybdenum steel, the gasifier was pressured to 750 psig. At 0715 hours on August 22 a leak was discovered on the four-inch outlet line from the east char cyclone and the system was again depressured for repairs.

C. Gas Washing

The gas washing system required major cleaning with acid solution due to a calcium carbonate deposit that had been accumulating in the equipment.

On July 29 pressurization of the gasifier was delayed due to pluggage in the gas washer reflux cooler. The cooler was backwashed with fire water and sufficient flow was established to permit start-up. Once circulation was started the cooler plugged again so a five percent nitric acid solution was circulated through the tubes. On the evening of July 30 this cleaning was finished and the system was readied for operation. After the shutdown on July 31, because of the crack in the product gas line, the decision was made to further clean the recycle gas washer with acid and to flush the gas washer bottoms cooler with water. Nitric acid was again used and a stainless steel pump and tubing were set up to circulate the solution through the reflux cooler. The acid solution was circulated through the west bank of the cooler until consistently low pH readings of the liquid indicated that section was clean. The east bank of the reflux cooler was then cleaned and the system was ready for closing on August 12.

The gas washing system was filled with water and circulated started on August 14. Flow through the reflux line and cooler were good, but on August 15 pluggage problems occurred in the gas washer bottoms cooler from carbonate deposits that had come loose from the process lines. This led to the decision to clean the entire gas washing system and reduce potential plugging problems to a minimum. A five percent sulfamic acid solution, with a wetting agent, was then circulated through the entire gas washing system.

This included the gas washer, gas washer reflux cooler, the gas washer reflux pumps and reflux lines, the gas washer letdown line, gas washer bottoms cooler, ammonia stripper, and ammonia stripper reflux pumps. 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 304 stainless steel. This cleaning operation was completed on August 21 and the system was flushed and closed. No circulation problems were encountered with the gas washing system after the cleaning with sulfamic acid.

Betz Chemical Co. was consulted on procedures for eliminating the calcium carbonate deposit in the gas washing system. A tentative recommendation was made for an additive, but further studies of the process liquid under test conditions will have to be conducted before a final recommendation can be made.

d. Equipment Inspection

On July 31, at system conditions of 40 psig and 100°F, a vertical section of eight-inch 304 stainless steel pipe in the raw process gas line between the gasifier and gas washer ruptured. The break, which covered two thirds of the pipe circumference, occurred 1½ inches above the weld which joined the stainless pipe to the chrome molybdenum forged steel tee near the ceiling of the ninth floor in the gasifier structure. This condition prompted a full ultrasonic inspection of the process gas piping weld joints, between the gasifier and gas washer, for additional cracking. Spot checks of pipewall cross section for indications of erosion were also made. The examination revealed three other locations in the line, between the gasifier and char vessel, that were cracked. The four-inch and eight-inch piping from the char vessel to the gas washer showed no indication of problems. Metallographic analysis of the ruptured section indicated that the 304 stainless steel was sensitized and had cracked due to intergranular stress corrosion. From these analyses the decision was made to replace the stainless steel pipe between the gasifier and char vessel with chrome molybdenum SA 335-P11. Since the existing fittings were chrome molybdenum steel (F-11) which showed no significant general corrosion and are not subject to stress corrosion cracking, they were reused.

After all the welds in the repaired piping between the gasifier and char vessel were stress relieved for service, the system was pressurized for Test G-14. On the morning of August 22 at a system pressure of 750 psig, before burner firing, a leak was found in the four-inch outlet line from the east cyclone on the char vessel. The crack was located at a weld on the horizontal section next to the first tee out of the vessel. This section had been ultrasonically tested during the earlier inspection, and had not indicated any cracking. A decision was then made to replace all stainless steel

pipng in the process gas line up to the inlet of the gas washer with chrome molybdenum SA 335-P11 steel. In addition to changing material to chrome molybdenum steel the wall thickness of the four-inch pipe was specified to be reduced from schedule 160 to schedule 80 to eliminate the necessity for heat treating the welds. A thinner wall is possible due to the higher allowable stress of P11 and also to the lower thermal expansion stresses resulting from a lower coefficient of expansion.

Metallographic lab testing was conducted on the process gas line to determine the source of failure. This indicated that the cracking had progressed along intergranular lines to failure; no transgranular cracking was evident.

All these stainless steel lines had been heated many times to sensitization (about 750°F). Once, inadvertently in an accidental thermal excursion in 1976; and repeatedly by normal operating temperature of about 800°F.

In this sensitized state 304 stainless steel is subject to stress corrosion by chlorides, polythionic acid and hydroxyl ion. Any of these could have had an effect in our case. The absence of significant general corrosion of the F-11 fittings tends to indicate there was no polythionic acid. And, past analysis indicate low chlorides in the gas evidently ruling out chlorides.

Although an initiating point is not necessary it appears the failure in the four-inch line started at an internal defect; a welding flaw or a flaw in the parent metal.

In summary it appears that both the eight and four-inch lines were in a sensitized state and in a high stress situation. Failure was due to stress corrosion cracking, and likely not caused by chlorides or polythionic acid.

C. September Activities

1. Summary

The plant did not operate during the month of September due to the repairs being made on the product gas line between the char vessel and gas washer. Work continued on welding and x-raying the new chrome molybdenum piping being installed in place of the 304 stainless steel in this area.

Revisions continued in the coal grinding area to reduce the amount of fines going to the pond.

In the gas washing area, tests were conducted and appropriate revisions made to improve the level control instrumentation on the gas washer.

The high pressure and low pressure boilers were shut down for inspection and relief valve preventive maintenance. Tests conducted on the demineralizer resin indicated that this material had lost chemical capacity and needed to be replaced.

2. Modifications and Repairs

The August monthly report outlined the major modifications and repairs for Test G-14. Additional work performed in September is covered in this report in the appropriate Area Operations section.

3. Area Operations

a. Coal Handling

Revisions continued in the coal grinding area to reduce the amount of coal fines going to the pond. The Rotex screen was moved from the second to the third level and piping revisions made so that the underflow containing the minus 100 mesh fines would go to the centrifuge feed tank. The coal cyclone vessel was removed to make room for installation of the scalping screen, which should arrive in November. This screen will be used to remove the plus 12 mesh particles from the feed slurry and recycle them to the rod mill.

Five drums of coal were sent to the Grundlach Machine Company for grinding and size tests in a new type of cage mill. Results of the testing were not available for this report period.

b. Gasifier

Work continued on replacing the 304 stainless steel piping between the gasifier and gas washer with SA335-P11 chrome molybdenum steel. X-ray testing was conducted on all completed welds in the four and eight-inch sections, while only the eight-inch pipe welds required stress relieving. Intergranular stress corrosion cracking of the stainless steel brought about the need for a change in material. Details of the product gas line failures and metallurgic testing were outlined in the August monthly report, and in a topical report.

Revisions were made to the slag agitator to improve indication of its movement during operation. Previous instrumentation provided only for display of direction of travel, according to hydraulic cylinder pressure, while the new equipment will actually indicate the position of the agitator in its cycle.

c. Gas Washing and Gas Treating

Tests were conducted on the gas washer level control system and modifications made to improve the performance of the existing equipment. It was found that the inner stem assembly of the Magnetrol level column was bent, causing part of magnetic level indication device to stick during operation. This created discrepancies between the indicated level and the actual level as viewed on the vessel sight glass. Repairs were made to the stem assembly and subsequent testing showed close agreement between the sight glass reading and the instrument indication.

Installation of the gas washer level control device was checked against similar Magnetrol equipment in the plant and was found to be incorrect. The float column for the Magnetrol equipment was connected to the sight glass column, which in turn had taps to the vessel. As installed, the upper connection of the Magnetrol was above the sight glass high level tap to the vessel. This created a vapor space between the upper taps of the sight glass indicator and Magnetrol device, restricting the Magnetrol float device from full scale indication. To correct this problem, a vent line from the top of the Magnetrol level column was connected to a higher tap on the gas washer, effectively eliminating the vapor space restriction for the float.

Magnetic flowmeters were installed on the bottoms flow for the water degassing tank and the ammonia stripper. This was done to improve measurement of these flows for material balance purposes. The sonic flowmeters, used previously, were removed from service.

The Selexol area was shutdown during September for testing and repairs of the relief valves in this system.

d. Utilities

Problems were encountered with the demineralizer system due to loss of chemical capacity by the mixed bed resin. Since operation of the demineralizer was not improved by various mechanical and procedural changes, samples of the resin were sent to Rohm and Haas for evaluation. Analyses concluded that the material had lost its chemical capacity and would have to be replaced. Enough resin was purchased to replace one demineralizer bed; this will be installed before Test G-14. The second bed will be replaced after Test G-14.

The high pressure and low pressure boilers were shut down during September to accomplish the following tasks:

1. Inspect and repair relief valves for the boilers and distribution systems.
2. The high pressure boiler was inspected and approved by the state of Pennsylvania.
3. A flowmeter was installed on the fuel gas line for the high pressure and low pressure boilers.

Section IV

SUPPORT ACTIVITIES

A. Instrumentation

1. Radiometer

An experimental instrument for monitoring temperature and gas composition in Stage I of the BI-GAS gasifier was developed by Barnes Engineering Company under the direction of C.F. Braun and funded by DOE. The instrument was tested at the BI-GAS Pilot Plant from January 1978 through June 1980. Results from the testing showed that the instrument, in its present form, could not reliably measure Stage I temperature under operating conditions. The major problem with the equipment was the two separate radiometers (model 12-880's) did not have the same fields of view. Barnes submitted a proposal to correct the problem with no promise of success.

A literature search was conducted to see if there were any commercially available two-color pyrometers which might be able to measure Stage I temperature. Results are shown in Table 4-1.

One criterion for a good instrument for the BI-GAS application is the absence of any water absorption areas. The Williamson Corp. Model 8100 instrument meets this requirement using wavelengths of 0.71 and 0.81 microns, the Capintec instrument (0.77 and 0.91 microns) is on the edge of minor H_2O peaks and the Ircon and Land instruments use wider bands which take in the stronger H_2O absorption band at 0.95 microns. Figure 4-1 shows atmospheric transmission at sea level over a 0.3 km path at wavelengths of 0.5 to 1.6 microns.

Figure 4-1

Another criteria is the availability of a housing for the sensing heads. Williamson has a NEMA 4 housing which could be purged to meet the requirements. Capintec and Land have a combination of water jackets, air purges and metal housings which would enclose the sensing heads. Ircon has no assembly, therefore, one would have to be fabricated.

For any of the instruments, a quartz window would be needed to replace the current silicon window because of the transmission response of silicon. A system to connect the instruments to the sight tube would also have to be designed.

TABLE 4-1
COMPARISON OF TWO-COLOR PYROMETERS

<u>Vendor</u>	<u>Williamson Corp.</u>	<u>Capintec Instruments</u>	<u>Ircon Inc.</u>	<u>Land Instruments</u>
Instrument	True Temp 8100	Ratio Probe III	Modline 'R' Series	NQN
Wavelengths (μ)	0.71/0.81	0.77/0.91	0.7→1.05/1.05	0.50→0.70/0.50→1.10
Temperature Range	2000→3000F or 2500→3500F	1400→3400F	1800→3200F or 2000→4000F	2200→3300F and 2900→9500F
Response Time	2 sec.	0.3 to 5 sec. adj.	0.1 sec.	4 sec.
Cable Std. Length	10 ft.	15 ft.	12 ft.	
Std. Output	0-10 mv 0-100mv 0-1Vdc	500 mv	0-100 mvdc	0-10 v or 4-20ma
Optional Output	4-20 ma	4-20 ma	4-20 ma	

A final criteria is the location of the electronics. The Capintec electronics would have to be housed in the gasifier structure since the maximum distance from the sensing head to the electronics is 150 feet. An additional cable would have to go from the electronics to a recorder in the control room. The cost of cable between the sensing head and the electronics could be reduced by using the standard 15 foot cable or a run shorter than 150 feet since the electronics must remain in the gasifier structure.

Recommendations are to initially test the Capintec "Radio Prove III" dual pyrometer system and if this is unsuitable then the Williamson Corporation "True Temp 8100". The selection was made because of the good technical backup offered by Capintec and their favorable rental agreement at a price significantly lower than the Barnes Engineering proposal.

2. Jet Propulsion Laboratory (JPL) Flowmeter

The solids flow meter developed by the Jet Propulsion Laboratory (JPL) was received in September and a test apparatus was set up to check whether this instrument would respond to char flow before installation on the gasifier. For testing, the meter and an 8.6 foot vertical section of one-inch I.D. pipe were supported by a 55 gallon receiving drum resting on a scale. The signal from the flowmeter sensors was fed to the instrument electronics and the output electronics recorded on a strip chart recorder. Tests were conducted by measuring 15 pounds of char into a bucket and pouring this material through a funnel into the feed pipe. Four samples were run at pouring times of 30, 48, 60 and 120 seconds for 15 pounds of char. Response, as registered on the strip chart, showed that the instrument responded very distinctly to char flow down the pipe. The recorder indicated that the output voltage increased with increasing char flow rate as expected. The response to char flow, however, did not appear to be linear as had been indicated by earlier tests performed at Jet Propulsion Laboratories using silica sand. The JPL flowmeter was installed on a char feed leg for evaluation during Test G-14.

B. Technical Engineering

1. The new char burners were returned to the Stearns-Roger pipe shop in Denver for modification of the oxygen tubing. Please refer to the May and June monthly reports for a description of the oxygen tubing failure that occurred in the new No. 1 char burner prior to Test G-12 and G-12A. The oxygen tubing was replaced with heavier gauge tubing, and reinforcement was added in the weld areas. The No. 1 char burner was modified on a priority basis, and expected to be returned to Homer City for installation in time for Test G-14. The other two burners will be returned later in August.

Work was performed on the following projects during this monthly report period:

- a. Modification of the gasifier cooling water piping and instrumentation to improve the accuracy of the heat balance data collection from Stage I.
- b. Piping modifications to permit steam and boiler feedwater to be injected through the coal injectors in Stage II. The purpose of this modification is to provide cooling without coal feed to Stage II during the experiment of withdrawing methane from Stage I.

- c. Specification of a pump to replace the existing coal pad sump pump which is out of service.
 - d. Specification of valves to replace the 600 psi steam letdown valve and the boiler feedwater control valve.
 - e. Redesign of the infra-red dual pyrometer radiometer sight tube to accomodate a new instrument.
 - f. Replacement of the slag heating burner sleeve with a high temperature alloy.
 - g. Design of a feed system to meter soda ash into the cooling tower water.
 - h. Redesign of the level control system on the gas washer slurry letdown system.
 - i. Preparations for installation of the Auburn solids fraction meter and the Braun flowmeter on one of the char legs.
 - j. Preparation of a procedure for replacement of the Stage I tube bundle.
2. Technical Engineering continued to provide support to maintenance for replacement of the raw gas lines from the gasifier to the gas washer vessel during September.

A two-week series of training lectures was conducted for the plant operators. The lectures were on engineering fundamentals and were intended to increase the operators' understanding of the technology behind the plant equipment.

The prototype of the momentum mass flowmeter was received from JPL. The meter was tested with char at ambient conditions and will be installed in the 'A' char leg.

The solids fraction meter was rebuilt by Auburn Instruments and returned to the site. A test stand has been built to zero the instrument with dry steam. Preparations have been made to install the meter downstream of the char eductor in 'A' leg.

C. Data Acquisition

1. Ways to improve the performance and efficiency of the data acquisition system via any software changes are under investigation. Programs are being developed to shorten the time required to handle the data. Recovery of data from cassette tapes is tedious because of its slow speed. Trending, which can list only a few points at a time, requires several passes through the tape to print the desired data. Therefore, to increase through-put, a program has been written which copies the tape to the drum. Once on the drum, data can be recovered as fast as the printer can type.

To insure readiness and operability, the computer based data acquisition system is kept running at all times. However, during this report period,

problems have occurred on almost every major component within the system. The printer, card reader, computer, card punch, and gas chromatographs have all encountered down time.

The architecture of the G.E. computer system is nearly 20 years old, and keeping it operational has become a significant problem. The only unit which has had no major problems is the cassette system, which is the newest and least used during non-testing and data recovery periods. Replacement parts for the card reader and punch are not readily available, and G.E. no longer services the card punch. Those items which can be spared have backup units; however, they are as likely to fail as the primary units.

During gasifier test periods, the data acquisition system could function without some of these units, however, the computer system; central processing unit, memory and drum are critical. Intermittent problems have been occurring on the computer. Some clear themselves without operator intervention, some indicate failures when none have actually occurred, while others indicate major problems and then do not reoccur. If these computer problems occur during testing periods, they can, in effect, eliminate process data acquisition until the solution is found.

An attempt is being made to refurbish components, maintain diligent preventive maintenance and, where possible, develop software programs which can use alternate units. It is hoped that this approach will eliminate some of the problems. However, as a permanent solution to the current problem, replacement of the major components within the data acquisition system will be necessary. To accomplish this with minimal inconvenience, data on state-of-the-art equipment are being obtained from vendors, talking with other DOE contractors in the data acquisition field and reviewing the salvageable components within the HERCO data logger on site. Upon completion of these tasks, appropriate recommendations will be developed which will insure a more reliable alternative to the present data acquisition system.

2. During September, problems continued to occur with the computer hardware, especially the card reader and card punch. These two affected the overall computer system since it is card-oriented. Any alteration to software must be made with the cards; hence time available for modification is a problem. During normal test periods, where minimal card handling is required, the data acquisition system can function adequately provided the system does not go down. However, even minor modifications, e.g. the addition or deletion of a point from the data base, require cards.

Under development is a software subsystem which would allow modification via keyboard to drum. This can be used during periods when the card to drum path has malfunctioned. However, the card system remains the primary means to make permanent changes and the new software will only be a temporary type action to give the system greater flexibility.

Also under development are program modifications to the tape writing programs. The cassette tapes are non-directory devices. To locate individual time blocks requires a sequential search through the tape. The programs will now count blocks and indicate time markers which will allow searches via skips. It will also aid in the recovery of tape data in the event of a system crash.

An effort was made to keep the gas chromatographs active during the September period. Carrier gas was purged through the system and weekly checks were made on the detectors.

D. Bituminous Coal Research, Inc.

1. The following is a report of BCR activities in support of the BI-GAS pilot plant during August:

- a. Mathematical Modeling: Work continued on revising GASIFY 4. Of the eleven proposed improvements to GASIFY, the eight deemed to be of the utmost importance were investigated and were, or are being, incorporated into GASIFY. These included a provision for allowing the Stage II steam temperature to be different from the Stage I steam temperature; the addition of analyses of input of Stage I char and Stage II coal leg gas; the generation and inclusion of a formula to calculate the enthalpy of liquid H₂O utilizing H₂O saturation-temperature data; and other input/output modifications. Formulas for the estimation of methane yield from hydrogen partial pressure continued to be investigated for future incorporation into GASIFY.

BCR assembled and sent to Stearns-Roger a package of information concerning the current status of GASIFY. Included were program listings, documentation, and completed and proposed modifications to GASIFY. In addition, BCR generated documentation for the KSEN system. As noted in the description, KSEN can be used for a wide range of applications requiring multilinear regression equations. Specifically, KSEN was used to develop equations for GASIFY 5 of the form $Y = AT^3 + BT^2 + CT + D + E/T$, where Y and T represent enthalpy and temperature values.

- b. Scientific Computing: An investigation into the effects of char loss on Stage I oxygen (REQ152) and Stage I natural gas (REQ153) requirements was performed to simulate the effects of a char-burner failure. Data from this were subsequently used to generate graphs of oxygen requirement versus char loss and natural gas requirement versus char loss. Further simulations of gasifier tests G-11C, G-11D, G-11F, and G-13 are anticipated during the forthcoming month.

2. The following is a report of BCR activities in support of the BI-GAS pilot plant during September 1980:

a. Computer-oriented Functions

- 1) Data Acquisition: During the September report period, three data-handling programs were revised and tested by BCR personnel; namely, Programs No. 47-Analyses to Tape, No. 48-Analogs to Tape, and No. 57-End of Tape Marker. The first two programs were changed to help in the recovery of data in the event of system crashes, while the last was altered to inform the operator that the end of a cassette tape was approaching.
- 2) Mathematical Modeling: Work continued on major revisions to GASIFY 4. Code changes and algorithm improvements, as detailed in the August monthly report, were incorporated into the program; and, as of the end of the month, the new version of GASIFY was

in its final debugging stage. Final testing will be completed in the forthcoming month.

Pursuant to Stearns-Roger computer service request No. 12, BCR assembled and sent to Sandia Laboratories, Albuquerque, New Mexico, a package of information concerning the current status of GASIFY. Included were an RL01 disk containing the current (August 1, 1980) running version of Gasify and five requested simulations, program listings, documentation, and completed and proposed modifications to GASIFY.

Work continued toward the establishment of the data-communications link between the Homer City pilot plant and BCR. (For details, see the August monthly report.)

3. Scientific Computing: Efforts during September concentrated on revising GASIFY 4 and the generation of the materials described above. Simulations of gasifier tests G-11C, G-11D, G-11F, G-13, and possibly G-14 are anticipated for the forthcoming month using the new version of GASIFY.

b. Special Operating Problems and Functions

- 1) Methanation: There was no activity in support of methanation process development at the BI-GAS pilot plant during September.
- 2) Slag Viscosity: No viscosity tests were made during September.

E. Conoco Coal Development Company

1. Conoco Coal Development Company performed tests and made recommendations as follows during August:

Calibration data on the gasifier cooling water ΔT measuring systems was obtained during the shutdown after G-13. The data indicates that the accuracy of both the control room and the AAI instruments are a function of the average water cooling temperature. The data collected at two nominal temperature levels, (304 and 370°F) were correlated as a linear function of the average cooling water temperature. The mean deviation between the calculated ΔT and that measured by the mercury thermometers was three percent for both the control room and AAI instruments. However, since the normal operating temperature of the cooling water is higher than that which can be obtained with the calibration equipment, another set of data at a higher temperature level of about 390°F will have to be obtained in order to determine if the correction factor is a linear function of the average cooling water temperature.

Work on the G-13 samples of slag and Stage II deposits is continuing. Results obtained thus far show that the carbonaceous material which was separated from the slag more closely resembles the Stage II granular material than the char feed. This work should be completed during the next month.

Recommendations

- a. Investigate the possibility of converting the bottom Stage II thermocouple into a sample probe. A daily sample of this material may produce some valuable information about the formation of deposits.

- b. Replace the existing gas washer level control valves with two standard Fisher angle pattern control valves. The new valves should be installed in parallel and such that either can be isolated to replace the trim while operating.
 - c. Obtain another set of calibration data on the gasifier cooling water water resistance temperature devices.
 - d. The procedure for obtaining the gasifier heat loss data in Test G-14 should stress the importance of insuring that the gas compositions have stabilized before the data are collected. Also, a material balance should be made during the test so that any gross inconsistencies in the data can be resolved before proceeding with the next test objective.
2. During September, CONOCO Coal Development Company performed tests and made recommendations as follows:

A sample of type "Alpha" silicon carbide which was obtained from Land Instrument Company was tested in the Library slag viscometer. The sample was rotated at 16 rpm in a bath of molten slag at a temperature of 2550°F for two hours. This exposure caused the sample to become very brittle and severely pitted. A sample of "KT" silicon carbide, which is the material that was recommended by Land Instrument Company, will also be exposed to the same conditions. If the material survives this short test without any appreciable deterioration, a longer test will be made.

Recommendations

The appearance of large amounts of char in the slag dumps of recent tests indicates that char may be escaping Stage I through the gap between the char burners and the tube wall. The char can then fall through the annular space between the bird cage and the gasifier shell into the quench section. To block this path of escape, the annular space between the bird cage and the gasifier shell should be filled with a low density castable refractory.

F. JAYCOR

1. This section is divided into eight sub-sections corresponding to the eight tasks of JAYCOR subcontract. During the month of August, major events included the completion of the first draft documentation of the BI-GAS computer model (FLAME) and a project status summary presentation at the Morgantown Energy Technology Center (METC).

Task 1. 2-D Development (Code Integration)

This task has been completed. Small modifications are continually being made to improve the overall logic of the integrated package.

Task 2. 2-D Development (Code Improvement)

As a first step toward the preparation of a User's Manual, the BI-GAS code is being reviewed with regard to its structure and clarity of logic.

Many additional comment cards will be added to help users locate the various components and understand their functions. This review may also lead to improved efficiency in those subprograms that deal with radiation heat transfer and particle temperature calculations, as these modules are newly added and have not yet been thoroughly examined.

Task 3. Documentation

A draft report on JAYCOR's computer model for BI-GAS was completed during the first week of this month. Copies of this report were distributed to the staff of METC before the presentation on August 12. This documentation is presently being reviewed internally at JAYCOR to improve its completeness and clarity. A separate write-up on turbulence modeling, mentioned in the last monthly report, has also been completed.

Task 4. Applications

Parameter initialization and program setup for simulating the pilot plant Run G-11A have been completed. Considerable effort was spent in checking the accuracy of the various input parameters through conversations with CCDC and Stearns-Roger personnel. The first test run has been carried out to 2000 time steps. The calculation will be continued as soon as the evaluation of this first cut result is finished. When a steady state is reached, it will be used to study the changes which occur when methane is withdrawn.

Task 5. Graphics

The contour plotting package is now capable of using different colors to distinguish different physical and chemical variables. In addition, a subroutine has been written to express gas species concentration in terms of mole percentage, which is then plotted as contours. The mole percentages of all gas species can now also be shown on a single plot, as a function of axial position (vertical height) within the reactor.

Task 6. Validation

Since expectations are to finish the G-11A calculation soon, this will provide a basis for initial comparisons during September. The plan is to use the steady-state results from the calculation to perform analyses for comparison with pilot plant mass and energy balances. Computed results will be expressed in the formats provided by Stearns to facilitate the use of JAYCOR model predictions.

Task 7. 3-D Development

No work was scheduled during the prior phase of the project. If an extension is approved, we would plan to continue 3-D development, beginning in October of 1980.

Task 8. Process Evaluation and Liaison

A project review presentation was given by JAYCOR at Morgantown Energy Technology Center on August 12, 1980. The meeting was attended by over 20 METC, Stearns-Roger, West Virginia University, and Sandia technical personnel. Copies of the draft BI-GAS documentation had been distributed to some of the METC staff before the presentation to familiarize them with major elements of the model. Recent results in the form of movies and contour plots were shown at the meeting following sections of the talk

describing the technical approach. Near-term plans for code validation, application, and documentation were presented.

2. This section is divided into eight sub-sections corresponding to the eight tasks of the JAYCOR subcontract. During the month of September, major emphasis was on simulation of Pilot Plant Run G-11A and on improvements in documentation.

Task 1. 2-D Development (Code Integration)

This task has been completed. Small modifications are continually being made.

Task 2. 2-D Development (Code Improvement)

All improvements planned for this period of the contract have essentially been completed, except for: (1) user-oriented modifications to the input procedures, planned for October, and (2) small changes to correct some minor errors found during the G-11A simulations.

Task 3. Documentation

The complete package of the documentation will consist of two parts: Volume I describes the mathematical formulation of the various physical and chemical processes, while Volume II gives detailed instructions on the use of the computer code. A revision of the draft copy of Volume I has been completed and is being typed. Work on Volume II has begun, and a draft copy is expected to be available by the end of October. Complete listings, card decks, and magnetic tapes will also be provided.

Task 4. Application

A number of calculations have been made to simulate Run G-11A and some difficulty has been experienced after a few thousand time steps. The difficulty may have been due to the use of inappropriate values for reaction rate coefficients in the upper stage heterogeneous chemistry. The problem is being traced and a resolution of the difficulty is expected soon.

Task 5. Graphics

No additional work was performed under this task in September. The graphic routines now available will be documented for the User's Manual during October.

Task 6. Validation

No work was performed under this task in September beyond that related to running G-11A. This task will be completed as soon as the G-11A simulation is completed.

Task 7. 3-D Development

No work is scheduled for this task.

Task 8. Process Evaluation and Liaison

Effort has been initiated to accelerate activities under this task. In October, one of JAYCOR's staff members will visit the BI-GAS pilot plant to provide a stronger liaison, and to put JAYCOR's modeling capabilities in synchronization with the needs of BI-GAS process engineers.

This activity is intended to result in further streamlining of JAYCOR's computer code into a user-oriented tool, readily useable by process and development engineers.

Advanced diagnostic techniques for evaluation of entrained-flow gasification will be discussed, including tracer methods using adaptations of probes developed at Brigham Young University, for which purpose a consultant from BYU will be present.

APPENDIX A

RAW MATERIALS RECEIVED AND UTILITIES USAGE

Coal	1,000 tons
Flux	0 tons
Oxygen	7,286,753 SCF
Nitrogen	6,007,190 SCF
Electricity	756,000 KWH
Water	6,801,000 gal.
Waste Water to City	3,164,500 gal.
Fuel Oil	Minimum usage
Fuel Gas Usage	36,802,000 SCF

The above are usages for the period from June 26, 1980 to July 25, 1980.

RAW MATERIALS RECEIVED AND UTILITIES USAGE

Coal	475 tons
Flux	0 tons
Oxygen	151,454 SCF
Nitrogen	3,061,931 SCF
Electricity	699,000 KWH
Water	5,752,500 gal.
Waste Water to City	3,965,400 gal.
Fuel Oil	Minimum Usage
Fuel Gas Usage	22,732,000 SCF

The above are usages for the period from July 25, 1980 to August 26, 1980.

RAW MATERIALS RECEIVED AND UTILITIES USAGE

Coal	0 tons
Flux	0 tons
Oxygen	195,772 SCF
Nitrogen	385,800 SCF
Electricity	461,000 KWH
Water	2,494,800 gal.
Waste Water to City	2,181,300 gal.
Fuel Oil	Minimum Usage
Fuel Gas Usage	1,528,000 SCF

The above are usages for the period from August 25, 1980
to September 25, 1980.

APPENDIX B
INVESTIGATION OF PIPING FAILURE

1.0 Introduction

This section covers an investigation by Stearns-Roger into several incidents of piping failure in the BI-GAS pilot plant. It includes decisions that have been made with regard to piping replacements and operating procedures that will be effected to avoid future failures. To that objective all piping systems have been reviewed. Because stress corrosion cracking has been found to be the culprit, only stainless steel systems are discussed in this report.

2.0 Background Information

2.1 Recent Failures

Two recent incidents of pipe failure were of concern:

- 2.1.1 A large circumferential crack was found in the gasifier outlet 8" pipe on July 31, 1980. This was near a weld and in an area of high stress.

Other areas of cracking in the same 8" gasifier outlet piping were found by checking the other points of calculated high stress. These cracks were also found near welds. The welds were at joints of Type 304 stainless steel pipe to chrom-moly (F-11) tees, wherein the weld was stress relieved as a code requirement. The cracks were in the 304 stainless in zones which were sensitized by stress relieving procedures.

- 2.1.2 A crack near a weld in the 4" char cyclone outlet piping was found three weeks later on August 22, 1980. This also was in an area of high stress which was earlier inspected by ultrasonics testing (UT). The crack was not detected but likely was present.

2.2 General Problem of Stress Corrosion Cracking

2.2.1 Stress Corrosion Cracking (SCC)

When certain alloys are subjected to a combination of:

- a. stress of some critical level,
- and b. an environment of a critical concentration of certain ions dissolved in water. Then the material can fail by cracking.

The threshold of stress required to produce such a failure can be well below the yield or design stress of the alloy. The coexistence of the above two conditions is all that is necessary for SCC to take place.

The time for SCC to become evident will depend on:

- a. stress level
- b. degree of sensitization
- c. temperature
- d. stress cracking ion concentration
- e. presence of condensate
- f. extent of temperature and stress cycling.

Conditions may exist which allow SCC to develop in a few hours or it may take years.

2.2.2 Sensitization

Stainless steel contains about 0.08% carbon. When it is heated, the carbon becomes mobile and migrates to the grain boundaries. Chromium will react with the carbon concentrated near the grain boundaries to form chromium carbide. This leaves a thin chromium depleted zone adjacent to the grain boundaries. This loss of chromium is called "sensitization". It weakens both the grain and the boundaries and makes the metal more susceptible to corrosion. SCC is greatly enhanced by sensitization.

The rate of sensitization depends on temperature. The extent of sensitization can thus be the same for metal heated to only slightly above 800°F as for the same metal heated to 1500°F provided it remains above 800°F for a much longer time. When a chrome moly steel such as P-11 (1¼% Cr, ½% Mo) is welded to type 304 stainless steel, and the weld is more than ½ inch thick, code requires stress relieving the weld. The pipes which failed by SCC were in this category. In stress relieving the weld the the 304 stainless steel will become sensitized in the vicinity of the weld.

2.2.3 SCC Susceptible Environments

When stress corrosion cracking was indicated in the present failures chlorides were immediately suspected. Chlorides, however, create only one of a number of possible types of ionic environments which can cause SCC.

Also, many metals are susceptible, to varying degrees, to SCC. The first to be so defined was brass cracked by ammonia. The OH^- ions of caustic, or solutions containing Cl^- ions can provide a critical environment for stainless steel.

General Electric has encountered similar problems with SCC in nuclear reactor systems made of highly sensitized 304 stainless steel. Their case was definitely not related to chlorides. Their findings, through the work of a task force, indicated their SCC to be caused by OH^- ions.

Three recent papers* indicate that cracking (similar to the BI-GAS failure) can be produced without chloride or caustic, provided as little as 0.8 ppm of added oxygen is present. It has been postulated that oxygen produces hydroxyl ion which is the contributory environmental ingredient.

Yet another stress cracking mechanism has been reported as a possible cause of intergranular corrosion in sensitized type 304 stainless steel. In this type polythionic acid corrodes the chromium carbide at the grain boundaries to form an intergranular type of failure. Generally it produces a multiplicity of cracks to some degree having a polygonal shape similar to shrinkage cracks in dried clay.

2.2.4 Metallurgical Options

Alloys resistant to SCC are:

(1) Stainless steels

To minimize sensitization, low carbon grades of stainless steel are available ("L" grades as 304L and 316L) wherein carbon content is limited to 0.035%. However, the low carbon reduces the allowable stress of the material.

Another approach has been to add an element to the alloy which has higher affinity for carbon than chromium does, but will be more soluble in the matrix. These are the stabilized grades types 347 and 321 in which Columbium

* STRESS CORROSION CRACKING OF WELDED TYPE 304 STAINLESS STEEL UNDER CYCLIC LOADING by J.N. Kass & W.L. Walker, NACE, #49, Atlanta, March '79

SCC of SENSITIZED AND QUENCH ANNEALED TYPE 304 STAINLESS STEEL IN HIGH PURITY WATER by Agarawal et al, NACE, #187, Houston, March '78

STUDIES OF PROTECTION METHODS FOR INTERGRANULAR STRESS CORROSION CRACKING of TYPE 304 STAINLESS STEEL IN BOILING WATER REACTOR APPLICATION by A.J. Giannuzzi et al, NACE, #188, Houston, March '78

and Titanium are added. Columbium carbide is formed in type 347 and Titanium carbide in 321. These deplete carbide available to precipitate at the grain boundaries without reducing the alloy strength.

Type 347 and 321 stainless are resistant to polythionic acid or hydroxyl ion cracking but can be sensitized by exposure to high temperature for long periods. They would not be sensitized at 850°F which is near maximum for most BI-GAS piping. Type 347 can be acceptable at this temperature but is not immune to chloride stress corrosion cracking.

(2) P-11 piping (1½% Cr, ½% Mo steel) is good for erosion but susceptible to general corrosion, but this can be allowed for by using thicker pipe. In evaluating P-11, corrosion has been found negligible in the offgas to the cyclones and down to the gas washer in the BI-GAS pilot plant.

(3) 20 cb is not adequate for stress at temperature.

(4) Inconel 800 or 825 are good but require long delivery.

(5) Inconel 600 is inadequate for stress at temperature and also has sulfidation susceptibility.

2.3 Detailed Examination of Current Incidents

2.3.1 Conditions of Failures

The July 31st gas line failure occurred during start up pressuring at 40 psig. The previous run was a long five day run. This had been followed by a twenty day shutdown.

During the shutdown, the affected lines were not heated and were opened allowing atmospheric oxygen to enter.

The through-wall crack was in an eight inch vertical, type 304 stainless steel line. It was just above the weld to a blinded F-11 (1½% Cr, ½% Mo) tee which was used in place of a vertical to horizontal elbow. The bull of the tee was horizontal and the other run was pointed down and had a type 304SS Grayloc flange welded to it (the flange has a blind on it).

Three other cracks were discovered by UT (Ultrasonic testing). These were not yet cracked completely through the pipe wall. They were located at each end of the horizontal line near welds to F-11 tees.

On examining the line it contained a significant (unmeasured) amount of water. Although the exact origin of this water is uncertain, it was sampled and analyzed; results indicated it contained 4.45 ppm of Cl^- ion and had a pH of 8.1. It is not certain that this liquid represents conditions responsible for the crack. But if so it would rule out chlorides or polythionic acid (due to high pH) as the troublesome environment.

Failure took place where thermal expansion would exert a high cyclic stress. It was in the type 304 stainless steel pipe and continued around three quarters of the circumference parallel to and about one inch away from the weld joining the pipe to the F-11 tee.

In this case code required that the welding of the stainless pipe to the F-11 tee be stress relieved. This had been done during construction. Unfortunately this had highly sensitized the 304 stainless steel and made it especially susceptible to failure.

In addition to high stress due to process pressure and temperature, the different thermal expansions of the two dissimilar metals also produced localized cyclic stress at or near the cracks.

Locations in this gas piping system with expected lower stress were examined by UT but did not reveal any cracks. Since all the piping sees the same environment, this indicates that stress is a factor.

The gas piping involved was that from the gasifier to the char cyclones. After the first failure, as a precautionary measure the eight inch gas line from the char cyclone, including the four-inch branches at cyclone were also tested by UT. No cracks were indicated.

After this first gas piping failure the eight inch 304 stainless steel gas line from the gasifier to the char cyclone was replaced with P-11. This was based on the good apparent condition of the F-11 tees (which were retained) and also based on the fact that P-11 is not susceptible to SCC. The gas line after the char cyclone was not replaced since the UT examination revealed no defects.

After this first replacement was completed, a new startup was attempted. But on August 22nd, while in startup pressuring at 750 psig, another failure occurred. This was at a tee in a four-inch branch at the

char cyclone outlet, a point specifically tested by UT after the first failure. Post incident examination revealed a deeply corroded crack which must have been present but was missed in the UT examination.

2.3.2 Cause of Failures

Samples were submitted to Industrial Testing Laboratories and Argonne Laboratories. They reported intergranular type stress cracking. The 304 stainless steel was highly sensitized and the crack followed the grain boundaries without tendency to enter the grains. The cracks were typically branching type, initiating from the inside of the pipe.

The attached figure shows the location of the July 31st failure and photo-micrographs of the crack.

Although both laboratories concluded chloride stress cracking, when questioned, their diagnosis allowed the possibility of other types of environment.

More insight into the circumstances was gained by Patrick Dempsey, Stearns-Roger Chief Metallurgist who presented the case to about 200 participants at the Pittsburgh Gasification Conference. "THE PROPERTIES AND PERFORMANCE OF MATERIALS IN THE COAL GASIFICATION ENVIRONMENT" on September 9, 1980. Group response offered that General Electric had experienced similar cracking in their Boiling Water Reactors. In their case type 304 stainless steel cracked in a pure water environment (without chlorides or sulfides) containing as little as 0.8 ppm of oxygen.

Argonne Laboratories is continuing analysis of the failures. But, a tentative decision of failure of the above mentioned General Electric type was made - stress induced cracking enhanced by oxygenation of condensate during shutdown conditions.

The general cure for this condition is to prevent infiltration of oxygen during shutdown and avoid presence of liquid by keeping the temperature above condensation at all times.

Fortunately the corrective actions above will be a general fix for any of the mechanisms under suspect. Therefore, gasifier operation can proceed without waiting for the ultimate diagnosis.

SCHEMATIC OF GAS LINE

VIEW OF PIPE ARRANGEMENT

PHOTOMICROGRAPH:
OF THE FAILURE CRACK
SHOWING IT'S BRANCHING
TENDANCY

PHOTOMICROGRAPH:
OF THE FAILURE CRACK
SHOWING IT'S TRANSGRANULAR
NATURE.

2.4 Review of Other SCC History in the Pilot Plant

There have been several other instances of suspected SCC in the pilot plant.

2.4.1 The expansion bellows in "A" car burner failed on February 25, 1979. "A" burner bellows was destroyed in the incident. The identical bellows of "C" char burner was then tested and SCC was found. The char burner bellows are subject to very high stresses. It was thought that chloride was coming from trichloroethylene used as a cleaning solvent. This source of chloride is unlikely due to the volatility of trichloroethylene.

2.4.2 A three-inch pressure relief valve outlet line of 304 stainless steel failed. This is an emergency relief from the gas line from the gasifier to the char cyclones (first of our two recent failures). The outlet discharges into the gas washer.

It failed, as in our current incidents by intergranular stress cracking on April 22, 1977, at a weld near an elbow. It was replaced with a new elbow and pup piece both of 304 stainless. This failed again on May 31, 1977. The material was again replaced with 304 stainless steel but 50 psig steam tracing was added. No further failures occurred, but the line was later replaced with alloy 800 also steam traced.

Phillips Petroleum, then manager of the BI-GAS project diagnosed the failure to be caused by polythionic acid. (See Per 23R-77 and Per 32-77).

2.5 Process Conditions and Environments

The chloride content of a particular coal is quite variable but remains within limits. The Rosebud coal used exclusively in this project has analyzed 50 to 200 ppm chlorine; the Rosebud char 75 to 400 ppm. The water feed to the spray drier is approximately 20 ppm chlorine. The Pittsburgh and Illinois coals, planned for future use in the project, are much higher in chlorine, from 0.4 to 1.0%.

Because of the low amount of chlorine currently fed (water with as much as 100 ppm is generally acceptable for use in hydrotesting pipe) it was thought that unless a mechanism for concentrating chlorides was present, it is unlikely that the current SCC is due to chlorine. No chlorine concentrating mechanism is evident in the BI-GAS pilot plant but internal discussion concerning prevention of chlorine buildup was generated.

A suggestion to monitor pH and/or chloride in all available sampling points in the plant was made. Sampling is suggested at the gas washer, the slag quench, the coal feed, the char feed, the water to the spray drier, the boiler feed water and the slurry to the spray drier. These would be especially helpful in establishing a threshold of chlorides so that it can be compared with the level when coals of higher chloride content are used.

It was reasoned that gaseous chlorides, in this typically reducing atmosphere, would probably be in the form of HCl. It was then further deduced that due to the solution of HCl in water most would be removed in the Gas Washer. And further downstream the Selexol unit would remove the last traces of HCl.

It was also further noted that failures downstream of the gas washer are of a "benign" nature. If a failure occurred downstream, hot gases would be retained in the gasifier-gas washer system by the normal pressure control valve. The retained atmosphere could then be vented safely to the thermal oxidizer thus by-passing downstream processing.

3.0 Corrective Actions

3.1 General

Revisions as presented below are to be implemented. Note that they do not make the plant risk-free with respect to future failures. The changes should bring the chance of additional failures within acceptable limits particularly considering the experimental nature of the pilot plant.

Note that the incidents here would be more prone to happen in a pilot plant with extensive down time between periods of operation. But, they do have application to full scale plant installations and point out necessary precautions.

3.2 Description of Revisions

All the stainless steel in the plant was identified and considered. Most of this can be grouped into "piping areas". Each piping area was discussed in terms of the important variables of SCC as presented in 2.2 above. For this particular plant these variables can be boiled down to extra stress due to thermal cycling, sensitization due to welds or high temperatures, condensation, and a medium for chloride ion, polythionic acid, and/or hydroxyl ion.

Although from the above discussion no conclusive evidence can be pointed to any particular environment being the culprit, stress corrosion (or induced) cracking is evident.

Therefore, the changes to be made as discussed below consider that the recent incidents were stress corrosion cracking, possibly caused by dissolved oxygen. Chloride SCC was not apparent in the recent incidents but is still a possibility and must be guarded against. Since condensation is a factor in Cl^- , polythionic acid, and OH^- SCC, a significant portion of the recommendations guard against condensation.

Only stainless steel piping is considered prone to SCC and therefore consideration was restricted to stainless lines. Product gas lines beyond the Combined Effluent Trim Cooler (E-601 A&B) were not considered since these are primarily carbon steel. Also they operate at temperatures below stainless sensitization and the gas will be free of chlorides.

Recommendations for prevention of SCC in terms of these variables were formulated. (The attached chart provides a summary).

a. Gasifier Outlet

This is the piping from the gasifier overhead to the char cyclone and from the char cyclone to the gas washer. The recent discoveries of SCC were in this system at points of high stress near welds. Stresses due to thermal cycling will be present. The system has many welds, including stainless to P-11. Condensation will definitely occur if cool off after shutdown is allowed. Runs of horizontal pipe and potential areas of condensate collection are present. Because of the combination of all potential factors favoring SCC it was decided to replace all this stainless steel piping with P-11. The F-11 tees have not shown significant corrosion in five years. Chrom-moly steel is generally considered subject to corrosion and therefore, monitoring for corrosion and steam tracing with heating during shutdown is recommended. The heat will prevent condensation and reduce cyclic stress by limiting the lower temperature range.

The P-11 pipe also provides a reduction in thermal pipe stress (about 23% less than type 304 stainless steel). And since there are no dissimilar materials cyclic stress extremes will be lower.

b. Coal and Char Feed Lines

The original 4" lines have been recently replaced with 1½" and 1" 304SS pipe. These lines have relatively thin walls and have not sensitized with welding. Also no stress relieving has been done on them. The service temperature is low so that sensitization will not occur. The lines are nearly vertical so condensation will not collect. They are flexible and not prone to high stress. These lines will remain in service. To prevent condensation the lines are to be kept dry on shutdown via draining and steam heating.

c. Coal and Char Sampling Stations

These are made of small 304SS pipe. They operate under the same conditions as the coal and char feed lines. Sampling is done only three times daily and the lines are well purged when sampling is completed so that condensate may not collect. Sensitization and stress is minimal for the same reasons as it was for the char and coal feed lines. These lines will remain in service but will be drained and purged on shutdown.

d. Recycle Gas Heater and Heated Recycle Gas Line to Spray Drier

The tubes in the heater are of 304SS and the line is of more resistant 316SS. The gas is heated to 1150°F in the heater, therefore both the heater tubes and gas line have been sensitized. Recycle Gas contains negligible chloride (< 20ppm) and has been dried to a dewpoint well below operating temperature (about 220°F at 800 psig or higher). During shutdown the heater and line are purged and kept in the purged condition thus avoiding condensation and atmospheric oxygen. (Note-checks will be required to assure that the purged condition atmosphere has a dewpoint below ambient temperature). During the five year life of the pilot plant there has been no evidence of SCC in the heater tubes or the line. The tubes and line will remain in service.

e. Water System for Gas Washer

The material is 304SS, but low temperature prevents sensitization. These lines will remain in service but will be fully drained and flushed at each shutdown.

f. Condensate from Fluid Bed Reactor K.O. Drum

This line is 304SS but it is not sensitized and does not contain chlorides. Thermal stresses will be minimal due to low temperature operation (less than 500°F). This line will remain in service.

g. Product Lines from Gas Washer and Alumina Filters

The temperatures are low (440°F) and the lines are all 304SS so sensitization due to stress relieving of welds between dissimilar metals is not a factor. Chlorides will not be present. These lines will not be changed.

h. Product Lines from CO Shift Feed Heater

The temperature (580⁰F) are below sensitization and no dissimilar metals are present (all is 304SS). Chlorides are absent. These lines will not be changed.

i. Product from CO Shift Reactor

The temperature is 825⁰F which is below sensitization for this 347SS line. Chlorides are not present. This line will not be changed.

j. Product from Sulfur Conversion and from A-601

These 304SS lines operate at 460⁰F so they will remain insensitized. Chlorides are not present. These lines will not be changed.