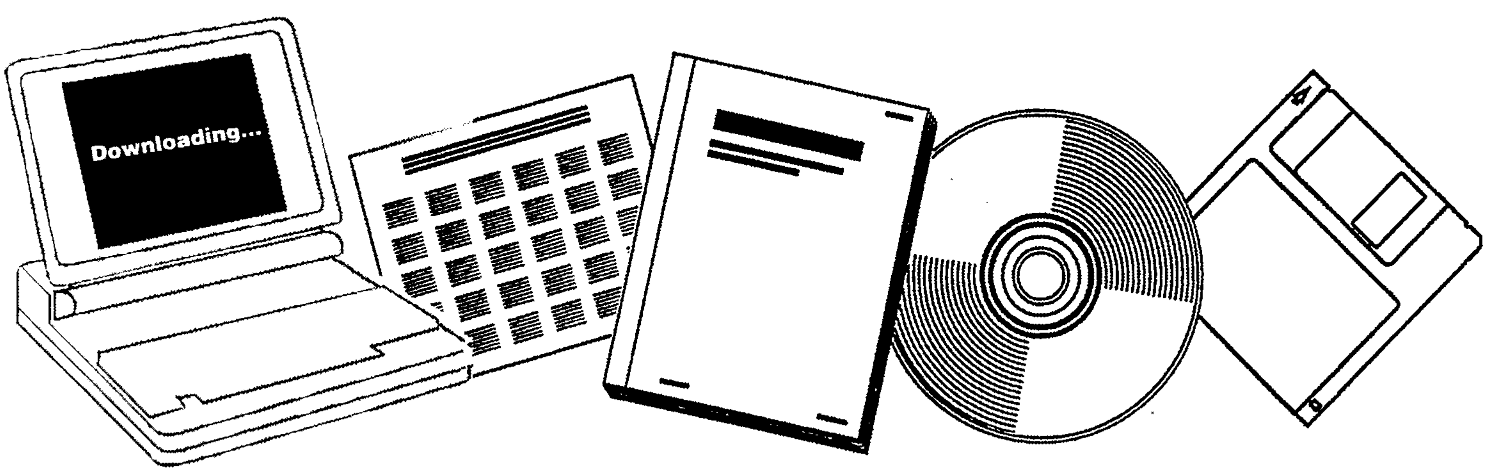
DE93016854

BASELINE DESIGN/ECONOMICS FOR ADVANCED FISCHER-TROPSCH TECHNOLOGY. QUARTERLY REPORT, OCTOBER--DECEMBER 1992

BECHTEL CORP.
SAN FRANCISCO, CA

1992

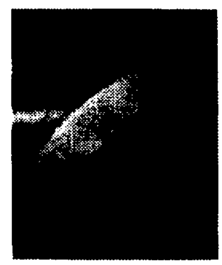


One Source. One Search. One Solution.

NTIS

Providing Permanent, Easy Access to U.S. Government Information

National Technical Information Service is the nation's largest repository and disseminator of government-initiated scientific, technical, engineering, and related business information. The NTIS collection includes almost 3,000,000 information products in a variety of formats: electronic download, online access, CD-ROM, magnetic tape, diskette, multimedia, microfiche and paper.



Search the NTIS Database from 1990 forward

NTIS has upgraded its bibliographic database system and has made all entries since 1990 searchable on **www.ntis.gov.** You now have access to information on more than 600,000 government research information products from this web site.

Link to Full Text Documents at Government Web Sites

Because many Government agencies have their most recent reports available on their own web site, we have added links directly to these reports. When available, you will see a link on the right side of the bibliographic screen.

Download Publications (1997 - Present)

NTIS can now provides the full text of reports as downloadable PDF files. This means that when an agency stops maintaining a report on the web, NTIS will offer a downloadable version. There is a nominal fee for each download for most publications.

For more information visit our website:

www.ntis.gov

U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Technical Information Service
Springfield, VA 22161

U.S. Department of Energy
Pittsburgh Energy Technology Center

Baseline Design/Economics for Advanced Fischer-Tropsch Technology

Contract No. DE-AC22-91PC90027

DOE/PC/90027-T4

Quarterly Report

October – December 1992

DISCLAIMER

DE93016854

U.S. Department of Energy
Pittsburgh Energy Technology Center

Baseline Design/Economics for Advanced Fischer-Tropsch Technology

Contract No. DE-AC22-91PC90027

Quarterly Report

October – December 1992

AMOCO

BECHTEL

Content

Tables

Figures

Drawing

Drawing		Page
PFD W106-B-01	PROCESS FLOW DIAGRAM PLANT 106 - ACID GAS REMOVAL POWDER RIVER BASIN COAL	2-30
PFD W109-B-01	PROCESS FLOW DIAGRAM PLANT 109 - SYNGAS WET SCRUBBING	2-31

Section 1

Introduction and Summary

This report is Bechtel's fifth quarterly technical progress report and covers the period of October through December, 1992.

1.1 INTRODUCTION

Bechtel, with Amoco as the main subcontractor, initiated a study on September 26, 1991, for the U.S. Department of Energy's (DOE's) Pittsburgh Energy Technology Center (PETC) to develop a computer model and baseline design for advanced Fischer-Tropsch (F-T) technology. This 24-month study, with an approved budget of $2.3 million, is being performed under DOE Contract Number DE-AC22-91PC90027.

The objectives of the study are to:

- o Develop a baseline design and two alternative designs for indirect liquefaction using advanced F-T technology. The baseline design uses Illinois No. 6 Eastern Coal and conventional refining. There is an alternative refining case using ZSM-5 treatment of the vapor stream from the slurry F-T reactor and an alternative coal case using Western coal from the Powder River Basin.
- o Prepare the capital and operating costs for the baseline design and the alternatives. Individual plant costs for the alternative cases will be prorated on capacity, wherever possible, from the baseline case.
- o Develop a process flowsheet simulation (PFS) model.

The baseline design, the economic analysis and computer model will be major research planning tools that PETC will use to plan, guide and evaluate its ongoing and future research and commercialization programs relating to indirect coal liquefaction for the manufacture of synthetic liquid fuels from coal.

The study has been divided into seven major tasks:

- o Task 1: Establish the baseline design and alternatives.
- o Task 2: Evaluate baseline and alternative economics.
- o Task 3: Develop engineering design criteria.
- o Task 4: Develop a process flowsheet simulation (PFS) model.
- o Task 5: Perform sensitivity studies using the PFS model.

- o Task 6: Document the PFS model and develop a DOE training session on its use.
- o Task 7: Perform project management, technical coordination and other miscellaneous support functions.

1.2 SUMMARY

During the reporting period work progressed on Tasks 1, 4 and 7. This report covers work done during the period and consists of four sections:

- o Introduction and Summary.
- o Task 1 - Baseline Design and Alternatives.
- o Task 4 - Process Flowsheet Simulation (PFS) Model.
- o Project Management and Staffing Report.

Completed work on Task 1, during the period of this report, consisted primarily of the revision of the design of the Syngas Preparation Section for the Western Coal Case, and this is now reported. The design of this section for the alternative upgrading case is identical to that for the baseline case, described previously.

Preliminary process design information was reported for the baseline case in the Third and Fourth Quarterly. Work is proceeding on the finalization of the baseline design, and this will be discussed at the next Process Design Review Meeting on March 4th. It is intended that the final baseline design will be reported in the next Quarterly Report.

Task 1 also consists of two alternative cases: baseline case with an alternative FT product refining scheme (ZSM-5 reactor) and baseline case with a Western coal. No design work has yet been done on the ZSM-5 Alternative Case, but Amoco has been asked to shuffle their original schedule so that they can modify the Baseline case ASPEN/SP code for the ZSM-5 Alternative Case synthesis-loop process simulations using the algorithm developed in the Third Quarterly Report. The revised model for the synthesis-loop will be used to develop the design of process plants in the loop.

The design for the syngas preparation section of the Western Coal Alternative Case has been completed. It is intended that, except for certain key plants, the individual process plants will not be redesigned for the alternative cases. Costs of other plants will be prorated on capacity from the overall block flow diagrams.

Under Task 4, preliminary block simulation models have been developed and are discussed for all plants in Area 100 except for the sulfur plant (Plant 107). An overall Area 100 simulation in ASPEN/SP also has been developed, and a block diagram is provided showing how the different blocks interact.

Under Task 7, cost and schedule control was the primary activity. During the quarter, work was interrupted for about 6 weeks, with DOE permission, for other work of a related nature of interest to the DOE. An invitation was accepted to present a paper at the 18th Coal and Slurry Technology Meeting in April, 1993.

Section 2

Task 1 - Baseline Design and Alternatives

Work progressed in the Syngas Preparation Section for the Western Coal Alternative Case. The primary differences from the baseline Eastern Coal case are as follows:

1. Properties of the Western coal affect the design of the coal receiving and drying plants and, as a result, the western coal is dried to 8% moisture as compared to 2% moisture for the eastern coal. This and the ash components affect gasifier capacity. In order to achieve approximately the same production of syngas, nine gasifiers are required in the Western Coal Case as compared to eight in the Eastern Coal Case. These nine gasifiers process 21507 stpd of dried western coal (18065 stpd MAF); whereas in the Baseline Case, eight gasifiers process 18954 stpd of dried eastern coal (16441 stpd MAF). Total production of H_2 + CO is 2,596,950 lb/hr (126651 Lbmol/hr) as compared to 2,652,023 lb/hr (125610 Lbmol/hr) in the Eastern Coal Case.

2. The western coal has a sufficiently low sulfur content that a selective amine system cannot be used for acid gas removal, otherwise the acid gas would contain too high a CO_2 content to feed the sulfur plant. The Rectisol Process is used instead. The sulfur plant is of similar design to the baseline case but is reduced in capacity.

3. Because the Rectisol Process is used, the hydrolysis step is no longer required to convert COS and HCN to constituents removable by amine solution. In addition, sulfur removal is more complete, and the duty on the sulfur polishers is reduced.

4. The lower carbon content of the western coal makes for a significantly higher H_2/CO ratio in the syngas (0.407 versus 0.361). The potential effects on the F-T Synthesis Loop will be evaluated as the design for the Loop is being developed.

2.1 BASELINE DESIGN CASE

Preliminary process design information was reported for the baseline case in the Third and Fourth Quarterly Reports, including the following plants in the Syngas Preparation Section (the number of on-stream trains is shown for each plant):

Plant 101	Coal Receiving and Storage (1 train).
Plant 102	Coal Drying and Grinding (5 trains).
Plant 103	Shell Coal Gasification (8 trains).
Plant 104	COS/HCN Hydrolysis (8 trains).

Plant 105	Sour Water Stripping (1 train).
Plant 106	Acid Gas Removal (4 trains).
Plant 107	Sulfur Plant (Claus/TGT) (2 trains).
Plant 108	Sulfur Polishing (8 trains).
Plant 109	Syngas Wet Scrubbing (8 trains).
Plant 110	Air Separation (8 trains).

as well as two plants in the F-T Synthesis Loop:

Plant 202	CO_2 Removal (8 trains).
Plant 206	Autothermal Reforming (4 trains).

While much work has been done on the remaining plants in the F-T Synthesis Loop, and work has commenced on downstream upgrading, the material balances have yet to be finalized for these sections of the facility. Final designs will be available in the next quarterly report.

2.2 ALTERNATIVE REFINING CASE

The design basis for the alternative refining case was discussed in Quarterly Report Number 3 (April-June 1992), Section 6.2. Work will commence on this case in the next quarter, starting with the modification of the ASPEN/SP code to include the ZSM-5 reactor. Amoco has agreed to help with this effort by moving up their schedule for the ZSM-5 reactor modeling effort.

The design of the plants in the Syngas Preparation Section remain identical in the Alternative Refining Case to those in the baseline case. Only the plants in the F-T synthesis loop and downstream processing areas are impacted, and many of these plants will be capable of proration.

2.3 WESTERN COAL ALTERNATIVE CASE

The analysis of the Powder River Basin coal used for the Western Coal Alternative Case is given in Table 2-1. The plant is located at a mine mouth site near Gillette, Wyoming.

The primary impact of using western, rather than eastern, coal is in the synthesis gas preparation section. The process units within the syngas production plant are grouped in Area W100. (The prefix "W" designates western coal.) They are:

Plant Number	Plant Description
W101	Coal Receiving and Storage (1 train)
W102	Coal Drying and Grinding (5 trains)
W103	Shell Coal Gasification (9 trains)
	COS/HCN Hydrolysis is not required
W105	Sour Water Stripping (1 train)
W106	Acid Gas Removal (Rectisol) (4 trains)
W107	Sulfur Plant (Claus/TGT) (2 trains)
W108	Sulfur Polishing (8 trains)
W109	Syngas Wet Scrubbing (9 trains)
W110	Air Separation (9 trains)

The block flow diagram for these process plants is shown in Figure 2-1. The overall material balances are found in Tables 2-2, 2-3, 2-4, 2-5, 2-6, 2-7 and 2-8. Process designs for Plants W101, W102, W103, W106, W108 and W109 are significantly impacted, and these have been redone. Plants W105, W107 and W110 have essentially the same design as in the baseline case and are capable of proration.

2.3.1 Plant W101- Coal Receiving and Storage

2.3.1.1 Design Basis

This plant receives, stores, and reclaims coal from storage, and delivers coal to the Pulverizer Feed Silos in Plant W102. The plant receives washed Powder River Basin coal from a mine-mouth coal washing plant. The storage and reclaiming facilities are designed to ensure a reliable and steady flow of coal to the gasifiers.

Long term coal storage and a conveyor for transporting washed coal to the F-T plant will be provided by the coal mine owner. The analysis of the washed coal is shown in Table 2-1. The design bases for the different sections of Plant W101 and their operating schedules are given in Table 2-2.

The design capacity of this plant (28,683 stpd of as-received coal) is based on the requirement of the coal gasification plant (Plant W103). Coal from this plant is ground and dried in Plant W102 before being sent to the gasifier feeding system.

2.3.1.2 *Process Description*

The mechanical flow diagram for Plant W101 is shown in Figure 2-3. A belt conveyor from a coal washing plant located at the coal mine delivers washed and crushed coal, 2" x 0" in size, to the Receiving Conveyor, W101T-1, which in turn feeds one of two Stacking Conveyors, W101T-3 or W101T-5, via a Motorized Gate, W101 T-2. The Stacking Conveyors run along the entire length of the coal storage yard. Coal from each Stacking Conveyor is stacked into two longitudinal piles by its corresponding travelling Stacker-Reclaimer, W101T-4 or W101 T-7, which also serves to reclaim coal from those corresponding piles. The boom conveyor of the Stacker-Reclaimer has swinging capabilities which enable it to make two piles, one on each side of the stacking conveyor. Coal can then be reclaimed from one pile or added to the other pile intermittently. The boom conveyor of the Stacker-Reclaimer can also be raised or lowered, as required, so coal is dropped on the pile from a minimum height. This method of operation minimizes airborne fugitive dust. The coal piles are designed to hold a total of 115,000 tons of coal which is adequate to meet consumption at the gasifiers for approximately four days.

The Stacker-Reclaimers reclaim the coal from the entire cross section of a pile using an adjustable scraper. Coal scraped from the pile slides over to a conveyor which is an integral part of the Stacker-Reclaimer. These conveyors each feed one of the two Silo Feed Conveyors, W101T-14A and B.

An emergency stockpile is not required since the two coal storage facilities, each with its own Stacker-Reclaimer, provide adequate redundancy. A motorized two-way gate W101T-2, located at the delivery end of the Receiving Conveyor, W101T-1, is used to divert the incoming coal to one or the other of the two coal storage areas.

The Silo Feed Conveyors and the downstream Tripper Conveyors are arranged in two equal capacity trains; normally, one will be operated and the other will serve as a spare.

The Tripper Feed Conveyors, W101T-16A and B, which are fed by the Silo Feed Conveyors, deliver the coal to the Pulverizer Feed Silos in Plant W102. Motorized trippers are used to transfer the coal to the silos. Belt weigh scales are provided at the Silo Feed Conveyors to monitor the coal feed rate to the silos.

To control the fugitive dust, all coal transfer points are fitted with dust extraction systems which consist of dust collectors (baghouses) and exhausters. The collected dust is delivered back to the coal stream. Sumps to collect coal pile runoffs and pumps to deliver the water to a water treatment plant also have been provided.

2.3.1.3 *Major Equipment List & Utility Summary*

A preliminary major equipment list for Plant W101 (not shown) has been prepared and will be finalized for cost estimating purposes. The total power requirement for this plant when all equipment is running, excluding spares and intermittent power users is estimated at 1679 KW. Total annual power requirement is 8383 Mwh.

2.3.2 Plant 102 - Coal Drying and Grinding

2.3.2.1 *Design Basis*

Plant 102 simultaneously dries and grinds the coal for use in the gasifiers. The plant consists of seven identical trains. Of these, six are operating trains, and the seventh is a spare. Each train has a design capacity of 205 short tons per hour (stph) of washed coal and produces roughly 154 stpd of dried coal. Normal capacities are 97% of these figures. Coal is dried from an initial (as received) total moisture level of 31 percent to 8 percent (by weight). The ground or pulverized coal has a size consist of 90 percent passing 88 microns or 170 mesh. The operating schedule for this plant and the coal characteristics are shown in Table 2-3.

In the development of the Western Coal Case plant design, the key parameter investigated was the final moisture content of gasifier feed coal. The vendor of the Pulverizer-Dryer (W102Y-1) recommended a moisture content of 8 wt% as a reasonable target for design. This is a compromise between advantages to the gasifier, temperature limitations and fuel requirements at the dryer. This moisture level was presented to Shell, who then provided a gasifier design based on 8 wt% moisture.

2.3.2.2 *Process Description*

The mechanical flow diagram for Plant W102 is given in Figure 2-4. There are seven trains in the plant. The following description addresses one train.

Coal from the Pulverizer Feed Silo, W102D-1, is fed to the pulverizer by a Weigh Feeder, W102T-1. A closed gas loop consisting of a mixture of air, make-up nitrogen from the air separation plant, and recycle combustion gases is used to dry the coal simultaneously as it is ground in the pulverizer. The maximum recommended temperature of the drying gases is 760 °F is used for design.

The gas mixture at 760° F enters the gas inlet connection at the lower portion of the Pulverizer, W102Y-1, and flows upward through the unit. The gases and coal particles entrained by the gases pass through a classifier which is integral with the pulverizer and is located at the upper end of the unit. During this transport, coal particles get dried. At the classifier, coarse particles of coal are separated and dropped back into the grinding zone for further grinding. The dried and ground coal is separated from the gases in a bag filter Dust Collector, W102T-2. The fine coal is collected in an integral hopper in the dust collector. From the hopper, the pulverized coal is delivered to a Pulverized Coal Silo, W102D-2, using a screw conveyor and an air lock.

The Pulverized Coal Silo, W102D-2, is sized to hold 600 tons, equivalent to approximately 4 hours of production from a grinding and drying train. The six silos in the operating trains together can hold 3,600 tons of dried coal which is adequate to supply the nine gasifiers for 4 hours at the design throughput.

The Main Fan, W102K-2, is used to recycle a large bulk of gases from the Dust Collector, W102T-2, outlet. A connection upstream of the Main Fan is provided to vent part of the gases, including moisture evaporated from the coal, to the atmosphere. Downstream of the Main Fan, the recycle gases are mixed with make-up nitrogen and air which provide the carrier for the vented moisture and ensure that the oxygen content in the system is below 7 percent (by volume). It is essential to maintain a low oxygen content of the gases in the circuit to reduce risks of fire and explosion. The mixture of recycle gases, make-up nitrogen, and air is heated to 400 °F in steam heater W102E-1 and then to the required mill inlet temperature of 760°F in Fired Heater, W102F-1, which is fueled with purge gas from the F-T reactor loop.

The drying and grinding plant designs were completed in consultation with Losche in Germany. Large capacity (199 stph) pulverizers as offered by Losche are used. Losche has several decades of experience in coal and mineral grinding systems. They have supplied coal pulverizers for the Shell gasification plant at Buggenum, Netherlands.

2.3.2.3 *Equipment List and Utility Summary*

The major equipment list and utility summary for Plant 102 have not yet been completed.

2.3.3 Plant W103 - Shell Gasification - Western Coal

Plant W103 is designed to gasify washed, dried Powder River Basin coal (a typical western coal) for the production of a medium Btu syngas. The process design, material and heat balance, utility requirements, and installed plant cost were prepared by the Shell Oil Company. Bechtel developed the design basis and assisted in the integration of the Shell gasification plant with the rest of the F-T plant. Below is a summary of the non-proprietary description of Plant W103 for this alternate case of the baseline study.

2.3.3.1 *Design Basis*

An integral number of single Shell gasifiers of maximum size is selected for the baseline design. Based on the most recent experience with their gasifier, Shell has determined that the maximum size single gasifier will handle an equivalent of 3,187 short tons per day of Powder River Basin coal on an "as received" basis or 2,390 stpd on a dried coal basis (8 wt% moisture). The design basis for Plant W103 is:

Category	Design Basis
Number of operating gasifiers	9
Coal feed rate to each gasifier	2,390 stpd (at 8% moisture)
Moisture content of as received coal	31 wt. %
Moisture content in gasifier feed coal	8 wt. %
Feed coal size	90% below 88 microns
Inert gas for coal feeding	carbon dioxide
Oxygen purity	99.5 mol %
Slag disposal	Return to mine for on-site disposal

Carbon dioxide is used as carrier gas in order to reduce the inerts buildup in the F-T loop. Analysis and composition of the dried feed coal to the gasifier are shown in Table 2-1.

The sensible heat from the syngas is recovered for the production of 900 psig, 1000°F superheated steam. Most of this steam is used to drive the air compressors in the Air Separation Plant (Plant W110).

2.3.3.2 *Process Description*

There are nine parallel operating gasifier trains. Figure 2-2 is the block flow diagram showing one Shell gasification train which consists of the following sections: milled coal pressurization and feeding, gasification and gas quench, high temperature gas cooling and flyslag removal, slag handling, flyslag handling, and solid waste handling.

Milled Coal Pressurization and Feeding

The milled and dried coal from Plant W102 is pneumatically transported to the coal pressurization and feeding system. This system consists of a receiving vessel, two lock hoppers, and a feed hopper. The receiving vessel separates the coal from its carbon dioxide transport medium, and then transfers the coal to one of the two lock hoppers. These two lock hoppers are operated on a time cycle such that one is filled and pressurized while the other is emptied and depressurized. Once a lock hopper has been charged with coal from the receiving vessel, it is then pressurized with carbon dioxide, and its contents are discharged into the feed hopper. Pressurized coal is continuously withdrawn from the feed hopper and pneumatically conveyed with carbon dioxide to the gasifier's coal burners.

Gasification and Gas Quench

Pressurized coal, oxygen and steam enter the gasifier through opposed burners. The gasifier consists of an outer pressure vessel and an inner, water-cooled membrane wall. The gasifier wall temperature is controlled by circulating water through the membrane wall to generate saturated steam for subsequent superheating in the syngas cooler. The membrane wall encloses the gasification zone from which two outlets are provided: one opening at the bottom of the gasifier is used for the removal of slag; the other opening allows hot raw gas to exit from the top of the gasifier.

Most of the mineral content of the feed coal leaves the gasification zone as molten slag. The high gasifier temperature (up to 3000°F) ensures that the molten slag flows freely down the membrane wall into a water-filled compartment at the bottom of the gasifier.

As the molten slag contacts the water bath, the slag solidifies into dense, glassy granules. These slag granules fall into a collecting vessel located beneath the slag bath and are transferred to a pair of lock hoppers which operate on a timed cycle to receive the slag. After a lock hopper is filled, the slag is washed with clean makeup water to remove entrained gas and any surface impurities. After washing, the lock hopper is depressurized, and the slag is fed to a dewatering bin. This bin is equipped with an inclined screw to lift the settled solids off the bottom of the vessel and deposit them on a conveyor belt for delivery to the off-site storage and disposal facilities.

The hot raw product gas leaving the gasification zone is quenched with cooled, recycled product gas to convert any entrained molten slag to a hardened solid material, called flyslag, prior to entering the syngas cooler.

High Temperature Gas Cooling and Flyslag Removal

The syngas cooler recovers high-level heat from the quenched raw gas by generating superheated high-pressure steam (900 psig, 1000°F). The syngas cooler includes superheat, evaporative, and economizer sections.

The bulk of the flyslag contained in the raw gas leaving the syngas cooler is removed from the gas using ceramic filters. The recovered flyslag is then recycled back to the gasifier via the coal feeding system or leaves the process as a coproduct similar to the slag. If not recycled, the flyslag leaving the process is pneumatically conveyed to one of two flyslag lock hoppers. After a lock hopper is filled, the flyslag is purged with high pressure nitrogen to remove any entrained raw gas. After purging, the lock hopper is depressurized, and the flyslag is pneumatically conveyed to an ash silo for intermediate storage. All vent gases from the flyslag lock hoppers and the storage silo are filtered during discharge to remove particulates. Then, they are flared at the incinerator located in the Claus plant tail gas treatment section.

2.3.3.3 *Material Balance*

The overall detailed material balance for Plant W103 is shown in Table 2-4.

2.3.4 Plant W105 Sour Water Stripping

The water produced in Plant W109 is stripped in Plant W105. The wastewater is sent to the waste water treatment area, and the stripped gas is fed to the sulfur plant.

2.3.4.1 *Design Basis and Considerations*

The process flow diagram is the same as for the baseline case, but the design capacity has been increased to 360 gpm. This plant employs one operating train and no spare train is provided. The sour water feed tank capacity is designed for 5 days of storage.

2.3.4.2 *Material Balance and Utilities*

Material balance around Plant W105, Sour Water Treating, is shown in Table 2-5. The plant will consume 22,000 lbs./hr. of 50 psig steam.

2.3.5 Plant W106 Acid Gas Removal

The purpose of this plant is to selectively remove H_2S and COS from the syngas to less than 1 ppmv total sulfur and, at the same time, produce an acid gas with a minimum of 30 Vol % of H_2S for feed to a Claus sulfur plant.

2.3.5.1 *Design Basis and Considerations*

Because of the high CO_2/H_2S ratio in the syngas (40 compared to 4 for the syngas derived from Illinois No. 6 coal), a physical absorption process is better suited for the selective removal of H_2S than a chemical absorption process. A Rectisol wash system, licensed by Linde AG or Lurgi Corporation is selected for this study. The Rectisol process has seen a wide range of commercial applications in the last decade, It can remove both H_2S and COS down to 0.1 ppmv, while minimizing the removal of CO_2.

The design specifications call for the following removals:

1. Less than 1.0 ppmv of total S (H_2S + COS) in the pure (treated) gas
2. A minimum of 30% by volume of H_2S in the acid gas
3. Less than 3 ppmv H_2S in the tail gas (can be vented to the atmosphere).

Because of the near complete removal of H_2S and COS, the downstream sulfur polishing step could theoretically be eliminated, and the treated gas fed directly to the F-T reactors. However, a sulfur polishing unit is retained to protect the downstream F-T catalyst in case of a Rectisol unit malfunction.

A total of 4 parallel trains is selected to handle the flow from 9 gasifiers to take advantage of the economy of scale while keeping the outside vessel diameter below 17 feet.

2.3.5.2 *Process Description (PFD-W106-B-01)*

The process flow diagram for the AGR plant (Plant W106) is shown in Drawing PFD W106-B-01. The Rectisol unit consists of four major columns: the Rectisol wash column (or absorber), the enrichment column, the hot regeneration column, and the methanol/water distillation column.

After injection of methanol, the feed gas is cooled against cold product gases in W106E-1. The condensed methanol/water mixture is separated in a drum, W106C-5, and the feed gas is routed to the Rectisol wash column, W106C-1.

In the wash column, H_2S and COS are almost completely removed from the syngas by the cold lean methanol. The heat of absorption warms the solvent. To maintain a low operating temperature, the methanol is cooled upstream of the wash column by refrigeration in W106E-2. Part of the CO_2 is co-absorbed.

The methanol is expanded to an intermediate pressure in a flash drum W106C-6, to recover the dissolved H_2 and CO. The flashed gas is compressed, cooled and recycled to the Rectisol wash column.

In the lower section of the enrichment column W106C-2, CO_2 is stripped off from the methanol by nitrogen in order to increase the H_2S concentration in the acid gas. The overhead gas (CO_2 + N_2) is desulfurized in the upper section of this column by contacting with lean methanol, so that the off gas can be vented to the atmosphere.

The cold H_2S-rich methanol is warmed against the hot regenerated solvent in W106 E-3 and fed into the hot regeneration column, W106C-3.

In the hot regeneration column, the dissolved acid gases are stripped off by means of methanol vapor generated in the reboiler, W106E-5. The lean solvent from the bottom of the hot regeneration column is returned to the wash column and the enrichment column.The methanol vapor is condensed from the acid gas fraction leaving the top by condenser W106E-4, separated in W106C-7, and refluxed back to the regeneration column. The acid gas is sent to the sulfur recovery plant.

The methanol/water mixture from W106C-5 is sent to distillation column W106C-4 wherein the mixture is separated into methanol (top-fraction) and waste water (bottom-fraction). The column bottom is heated by steam in a reboiler. The lean methanol from the hot regeneration column is used as reflux. The methanol from the top enters the hot regeneration column, thus enhancing the hot regeneration process. The waste water is sent to the water treatment plant.

2.3.5.3 *Material Balance*

The overall material balance of the Acid Gas Removal unit (Plant W106) is shown in Table 2-6.

2.3.6 Plant W107 -Sulfur recovery and tailgas treating

This plant receives the sour gas streams generated in the Coal Gasification/Syngas Cleanup section (Process Area W100), converts the H_2S to elemental sulfur, and converts the NH_3 to nitrogen. The treated offgas is vented to atmosphere via a stack after incineration. The product sulfur is stored and shipped as pellets.

2.3.6.1 *Design Basis and Considerations*

Except for a reduced capacity, this plant has the same design as the baseline case. It is designed with spare capacity so that continuous operation of the facility is allowed without violating the sulfur emission requirements during an unscheduled shutdown. Total design capacity is 150% of normal operating capacity in order to achieve high on-stream reliability with minimum capital investment cost. Thus the plant is configured with three (3) parallel trains each having 50% of the normal total plant capacity. Two trains will be in operating mode and the third on stand-by during normal operations.

The plant is designed to recover 94.5% of the sulfur in the feed coal. (5.45% is lost in the slag.) Unrecovered sulfur from the Claus unit is sent to the SCOT tail gas treating unit where the sulfur is recovered as H2S and recycled back to the Claus unit. The overall sulfur recovery from the acid gas stream in the Claus/SCOT system is 99.8%. Sulfur production is 108 tpd corresponding to 12.0 pounds of sulfur per ton of coal gasified (MAF) or 94.3% of the sulfur in the coal. The stack gas has an SO2 concentration of 0.025 vol% on a dry basis to meet the emission requirement at the Wyoming site.

2.3.6.2 *Material Balance*

The overall material balance is shown in Table 2-7.

The sulfur recovery plant has excess 600 psig steam, 15,000 lbs/hr. for export. It also has a net 50 psig steam consumption of 27,200 lbs/hr.

2.3.7 Plant W108 - Sulfur Polishing

The purpose of the sulfur polishing plant is to remove trace amounts of sulfur compounds from the syngas before it enters the F-T reactors. The F-T catalyst can be poisoned by sulfur containing compounds, such as H_2S, COS and CS_2.

2.3.7.1 *Design Basis*

The sweet gas from the Rectisol unit contains approximately 0.03 ppmv of total sulfur (COS plus H_2S). The design level is 1 ppmv, and higher levels could occur in case of a malfunction of the Rectisol plant (Plant W106). These small amounts of sulfur finally are removed in fixed bed reactors loaded with a zinc oxide (ZnO) . The ZnO chemically reacts with H_2S to form solid zinc sulfide (ZnS). The ZnO is permanently consumed and eventually replaced.

In order to provide a continuous H_2S pickup even when H_2S breakthrough occurs, a reactor configuration of two beds in series is used in the process design. The necessary piping is provided so that these two beds can be switched without any interruption of the normal operation. When H_2S breakthrough occurs in the lead bed, it is taken off-line for catalyst change-over and the lag bed is in service alone. After changeout, the lead bed, with freshly loaded catalyst, is put back in line as the lag bed. The two-bed-in-series operation continues until the other bed has breakthrough and is taken off line for a catalyst change-over. The operating cycle repeats. Desired cycle length is about 2 years before replacement of one bed.

The G-72D ZnO from United Catalysts has been selected because it can hydrolyze the light sulfur compounds, such as CS_2, to H_2S at 650 to 700 °F, and subsequently absorb the H_2S in the same reactor.

For the reactor configuration of two-bed in series, the ZnO usage rate is typically set at approximately 21 pounds of sulfur loading per cubic foot of catalyst volume. The sizing of the ZnO fixed-bed reactors is principally dictated by reactor pressure drop considerations. The ZnO catalyst bed will normally be operated at 650 °F at a space velocity of 3,000 SCF/hr/CF.

2.3.7.2 *Process Description*

The feed gas from the Rectisol unit will be heated to the reaction temperature of 650°F in successive heat exchangers and in a fired heater. Sweet gas at 83 °F from the Rectisol unit is preheated to 400 °F by the raw syngas in W109E-1. It is then heated to 600 °F in the ZnO Effluent/Feed Exchanger, W108E-1. The feed gas is further heated to its reaction temperature of 650 °F in the fired heater, W108F-1. The total absorbed duty per train for this normal operation is estimated to be 5.4 MMBtu/hr. The total design absorbed duty for each fired heater is 26.9 MMBtu/hr to account for the fact that during initial startup the ZnO Effluent/Feed Exchanger (W108E-1) will not be available.

Eight parallel trains, each with two reactor vessels, will be installed. The reactors are 11' 3" ID by 9' 0" T-T. The catalyst inventory for both beds is 2840 cubic feet per train. Expected replacement time at the design sulfur loading is over ten years.

2.3.7.3 *Material Balance*

The overall material balance for the sulfur polishing unit (Plant W108) is shown in Table 2-8.

2.3.8 Plant W109 - Syngas Wet Scrubbing

The primary function of this plant is to remove the HCN, NH_3 and HCl from the raw syngas. Its secondary function is to remove trace amounts of fine particulates and cool the syngas before the Rectisol acid gas removal unit.

2.3.8.1 *Design Basis and Considerations*

The residual ash particulate in the raw syngas is about 26 mg/Nm3. However, it is desirable to remove the HCN, NH_3 and HCl ahead of the Rectisol unit. The design basis is to:

1. Reduce HCN to < 4 ppmv
2. Reduce NH_3 to < 1 ppmv
3. Neutralize all the HCl with caustic addition

In order to achieve the above, the wet scrubber is operated at 100°F for better efficiency because the equilibrium vapor pressures of the compounds to be removed are lower at lower temperatures. The raw syngas is cooled to 100°F before entering the scrubber. The ash particulate is expected to be reduced to less than 2 mg/Nm^3.

There will be no COS hydrolysis unit following wet scrubbing. Therefore, the residual COS will not be hydrolysed to H_2S and the HCN will not be hydrolyzed to NH_3. Rather they will be absorbed in the Rectisol solvent.

The number of parallel trains for Plant W109 is set at nine based on consistency considerations with the number of upstream gasification trains to simplify interconnecting piping and enhance controllability.

2.3.8.2 *Process Description (PFD W109-B-01)*

The process flow diagram for Plant W109 is shown in Drawing PFD W109-B-01. The raw gas at 460°F from the Coal Gasification Plant H.T. Cooling Section is cooled against the cold treated gas from the Rectisol unit (Plant W106) in exchanger W109E-1. It is further cooled to 100°F by air in W109E-2, and by water in W109E-3 before entering the wet scrubber. The scrubber has four sieve-trays and a mist eliminator. The gas/condensate mixture enters the scrubber near the bottom to disengage the free water. The gas flows upward at a superficial velocity of 2.5 fps. The circulating liquid is sprayed near the top of the scrubber. The scrubber blowdown is sent to the sour water stripper (Plant W105). Part of the stripped water is returned as make-up.

The scrubbed gas at 100°F, is sent to the acid gas removal unit, Plant W106, for sulfur removal.

2.3.8.3 *Material Balance*

The overall material balance for the Syngas Wet Scrubbing Plant W109 is shown in Table 2-9.

2.3.9 Plant W110 - Air Separation

This plant provides the required oxygen for the gasification of coal. In addition, a small quantity of oxygen also is provided for the autothermal reforming operation in the F-T synthesis loop.

2.3.9.1 *Design Basis and Considerations*

The air separation plant design is the same as the baseline case design, except for capacity. Oxygen is used not only in the coal gasifiers but also in the F-T synthesis loop autothermal reformers. While the synthesis-loop requirement has yet to be firmed up, it is expected that a total of nine operating trains, each 1780 STPD, will be used. No spare train will be provided. The design, however, incorporates a back-up system including liquid oxygen storage of 16,020 tons, equivalent to one day of full-capacity production, and gaseous oxygen storage of 50 tons, equivalent to 40-minutes of production from one train.

2.3.9.2 *Material Balance*

The detailed material balance is shown in Table 2-10. The basis is nine 1780 stpd plants.

Table 2-1
Gasifier Feed Coal Analysis
(Powder River Basin Coal, Wyoming)

Item	ROM Coal	Gasifier Feed Coal (8% moisture)	Feed Coal (Dry Basis)
Higher Heating Value, Btu/lb	8,035	10,713	11,645
Proximate Analysis, wt %			
Moisture	31.00	7.99	
Ash	6.01	8.01	8.71
Volatile Matter	30.05	40.07	43.55
Fixed Carbon	32.94	43.93	47.74
Ultimate Analysis, wt %			
Moisture	31.00	7.99	
Ash	6.01	8.01	8.71
Carbon	46.81	62.42	67.84
Hydrogen	3.25	4.33	4.71
Nitrogen	0.65	0.87	0.95
Sulfur	0.40	0.53	0.58
Chlorine	0.01	0.01	0.01
Oxygen (by difference)	11.87	15.83	17.20

Table 2-2
Plant W101 - Coal Receiving and Storage
Design Basis and Operating Schedule
Powder River Basin Coal, Wyoming

A	<u>Coal Receiving and Storage Section</u>		
	Coal consumption for all gasifiers	US tons/day	28,683
	Gasification plant operating schedule:		
		hrs/day	24
		days/week	7
	Coal receiving and storage section operating schedule:		
		hrs/day	16
		days/week	5
	Minimum coal receiving and storage section capacity	US tons/hour	2,510
	Design coal receiving storage plant capacity	US tons/hour	3,000
B	<u>Coal Storage Section</u>		
	Storage capacity- equivalent days of consumption	days	4
	Storage capacity	tons	114,732
	Type of Storage		Open pile
C	<u>Coal Reclaiming and Silo Feeding Section</u>		
	Coal Drying and Grinding Plant (Plant 102) - operating schedule:		
		hrs/day	24
		days/week	7
	Coal reclaiming and drying/grinding plant feeding- operating schedule		
		hrs/day	16
		days/week	7
	Minimum reclaiming capacity required	US tons/hour	1,793
	Design reclaiming capacity	US tons/hour	2,000
D	<u>Coal Characteristics</u>		
	Size	inch	2 x 0
	'As Received' Total Moisture	%	31
	Bulk Density	lb/cft	50
	Coal Type		Subbituminous

Table 2-3
Plant W102 - Coal Drying and Grinding Plant
Design Basis and Operating Schedule
Powder River Basin Coal

Coal consumption for all gasifiers (as received from coal washing plant)	short tons/day	28,683
No. of drying and grinding trains	operating	6
	spare	1
Minimum capacity required/train	short tons/hr	199
Design capacity/train	short tons/hr	205
Operating schedule	hrs/day	24
	days/week	7

Table 2-4
Total Plant Material Balance
Plant W103 - Shell Coal Gasification Plant
(Western Coal)

Stream No.	103.1 Feed Coal	103.2 Carbon Dioxide	103.3 Oxygen Feed	103.4 Syngas to Scrubbing	103.5 Slag
Phase	Solid	Vap	Vap	Vap	Liq/Solid
Flow Rate, lb/hr					
H2				73,721	
N2			5,847	20,830	
O2			1,275,751		
H2S				8,901	
CO				2,523,229	
CO2		335,798		462,638	
H2O (or Moisture)	143,164			172,020	
COS				1,245	
NH3				464	
HCl				197	
HCN				327	
CH4				374	
Coal MAF	1,505,435				
Ash	143,637			92	143,548
C				5	1,471
Cl					48
Sulfur				0.2	521
NaOH					
NaCl					
H2SO4					
Total Lb/hr	1,792,235	335,798	1,281,598	3,264,044	145,587

Table 2-5
Total Plant Material Balance
Plant W105 - Sour Water Stripping Plant
(Western Coal)

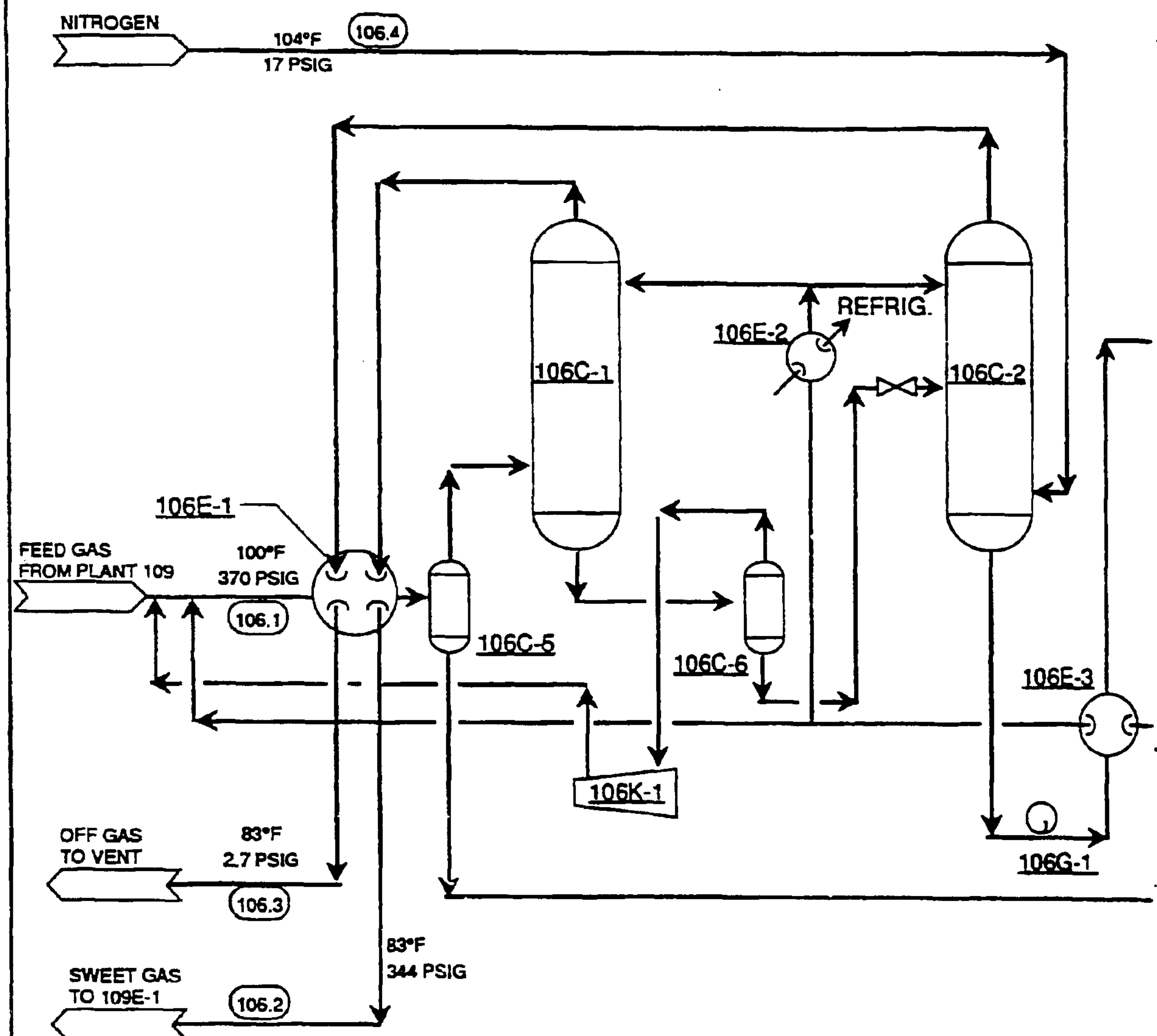
Stream No.	105.1 Scrubber B/D to SWS	105.2 Sour Gas to SRU	105.3 Water to Treating	105.4 Water to Scrubber	105.5 Acid to SWS
Phase	Liq.	Vap	Liq.	Liq.	Liq.
Flow Rate, Lbmol/hr					
H2	4.50	4.50			
N2					
H2S	2.70	2.70			
CO	12.60	12.60			
CO2	45.90	45.90			
H2O (or Moisture)	9997.68	59.64	9596.83	741.00	399.79
NH3	27.20	27.13	0.06	0.01	
HCN	11.60	11.60			
Ash	(92 lb./hr.)		(85 lb./hr.)	(7 lb/hr)	
C	(5 lb./hr.)		(4.7 lb./hr.)	(0.3 lb/hr)	
S	(0.2 lb./hr.)		(0.18 lb./hr.)	(0.02 lb./hr.)	
NaCl	5.40		5.01	0.39	
H2SO4			22.72	1.75	24.48
Total, MPH	10107.99	164.07	9625.01	743.18	424.27
GPM @T,P	360.00		345.00	27.00	16.00
Mol. wt.	18.18	26.35	18.23	18.23	22.63
MMSFCFD		1.49			

( ) = solids

Table 2-6
Total Plant Material Balance
Plant W106 - Acid Gas Removal (Rectisol) Plant
(Western Coal)

Stream No.	106.1 Syngas to AGR Absorber	106.2 Sweet Gas to 109E-1	106.3 Off Gas	106.4 Stripping Nitrogen	106.5 Acid Gas to Sulfur Recovery	106.6 Waste Water
Phase	Vap	Vap	Vap	Vap	Vap	Liq
Flow Rate, Lbmol/hr						
H2	36567.17	36552.96	14.21		0.00	
N2	743.58	742.68	2395.80	2478.60	83.70	
O2					0.00	
H2S	258.51	0.01	0.00		258.50	
CO	90069.28	89801.10	268.18		0.00	
CO2	10466.25	6195.78	3787.00		483.47	
H2O (or Moisture)	333.27	0.00	0.00		0.00	333.27
COS	20.73	0.02	0.01		20.70	
NH3	0.14		0.00		0.14	
HCl		0.00				
HCN	0.50	0.00	0.03		0.47	
CH4	23.29	23.29	0.00		0.00	
Coal MAF						
Ash						
C						
Cl						
Sulfur						
NaOH						
NaCl						
H2SO4						
Total	138482.73	133315.84	6465.23	2478.60	846.99	333.27
GPM @T,P						12.00
Mol. wt.	22.35	21.62	37.33	28.01	39.78	18.02
MMSFCFD	1,261.27	·1214.4	58.99	22.58	31.14	

106E-1	106C-5	106C-1	106E-2	106C-2	106E-3
Feed Projects/ Heat Exchanger	Feed K.O. Drum	Rectisol Wash Column	Lean Methanol Cooler	H2S Enrich. Column	Lean/Rich Methanol He Exchan.
		106K-1	106C-6		
		Flashed Gas Compressor	Flash Drum		



93 09796.001

106C-3
Hot Regeneration Column

106E-4
Methanol Condenser

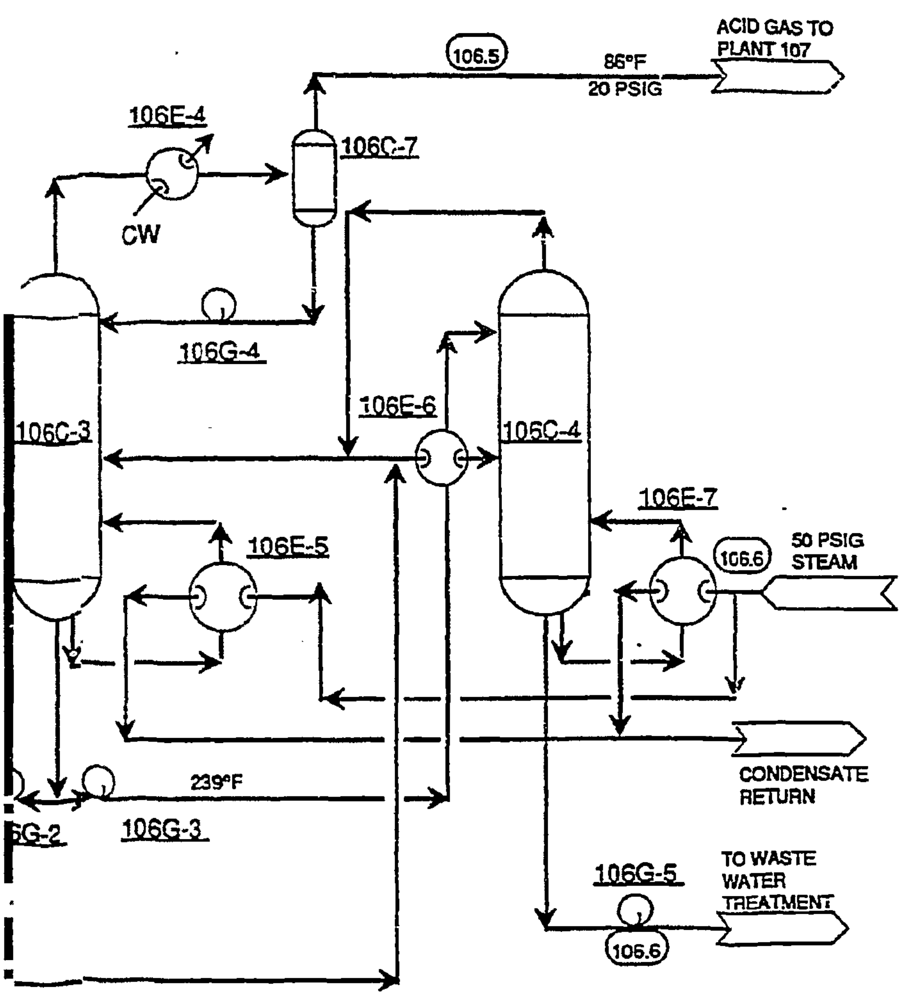
106C-7
Acid Gas K.O. Drum

106C-4
Methanol Water Distillation Column

106E-7
Distillation Reboiler

106E-5
Regeneration Reboiler

106E-6
Mechanical/ H2O Heat Exchanger



Notes

THE PROCESS CONDITIONS OF FLOW QUANTITIES, TEMPERATURES, PRESSURES, COMPOSITIONS AND INSPECTIONS, AND EQUIPMENT DUTIES SHOWN ON THIS FLOW DIAGRAM ARE FOR DESIGN PURPOSES ONLY, AND WHILE USEFUL AS GUIDES IN OPERATION, DO NOT REPRESENT EXACT OR GUARANTEED OPERATING CONDITIONS.

GUARANTEES ARE SPELLED OUT ONLY IN THE CONTRACT.

REV	DATE	ISSUE DATE	BY	PROJ ENG	ENG SUPV	PROC	PROJ	APPR
△								
△								
△								
△								
△								
△	3/93	5th Qtrly						

SCALE | DRAWN

Bechtel Corporation
San Francisco

U.S. Department of Energy
Pittsburgh Energy Technology Center

Process Flow Diagram
Plant 106 – Acid Gas Removal (Rectisol)
Western Coal

JOB No.	DRAWING No.	REV
21655	106-B-01	A

Table 2-7
Total Plant Material Balance
Plant W107 - Sulfur Recovery/Tail Gas Treating Plant
(Western Coal)

Stream No.	107.1 Acid Gas	107.2 Sour Gas	107.4 Treated Tail Gas	107.5 Sulfur Product	107.6 Air	107.7 Waste Water	107.8 Red. Gas
Phase	Vap	Vap	Vap.	Liq.	Vap	Liq	Vap
Flow Rate, Lbmol/hr							
H2	0.00	4.50	0.00				41.82
N2	83.70		876.88		773.51		
O2					205.68		
H2S	258.50	2.70	0.53				
CO	0.00	12.60					
CO2	483.47	45.90	574.75				
H2O	0.00	59.64	82.23		31.36	362.70	
COS	20.70	0.00					
NH3	0.14	27.13					
HCN	0.47	11.60					
S				281.37			
Total	846.99	164.07	1534.39	281.37	1010.55	362.70	41.82
GPM @T,P						12.00	
Mol. wt.	39.78	26.35	33.47	32.06	28.51	18.02	2.02
MMSFCFD	7.71	1.49	13.97		9.20		

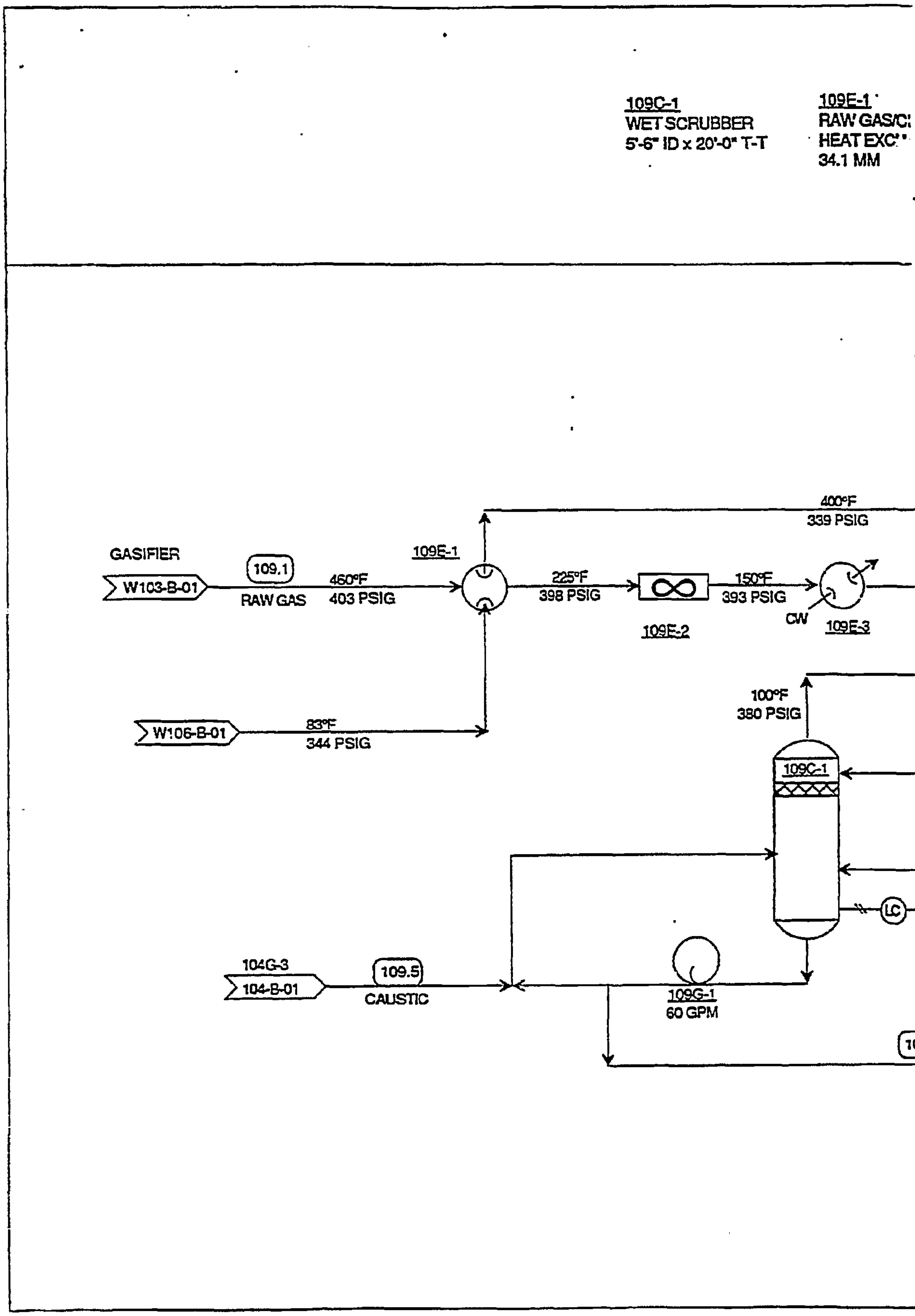
Table 2-8
Total Plant Material Balance
Plant W108 - Sulfur Polishing Plant
(Western Coal)

Stream No.	108.1 Syngas to ZnO Bed	108.2 Syngas to F-T Reactors
Phase	Vap	Vap
Flow Rate, Lbmol/hr		
H2	36552.96	36552.96
N2	742.68	742.68
O2		
H2S	0.01	
CO	89801.10	89801.10
CO2	6195.78	6195.78
H2O (or Moisture)		
COS	0.02	
NH3		
HCl		
HCN		
CH4	23.29	23.29
Coal MAF		
Ash		
C		
Cl		
Sulfur		
NaOH		
NaCl		
H2SO4		
Total	133315.84	133315.81
GPM @T,P		
Mol. wt.	21.62	21.62
MMSFCFD	1214.24	1214.24

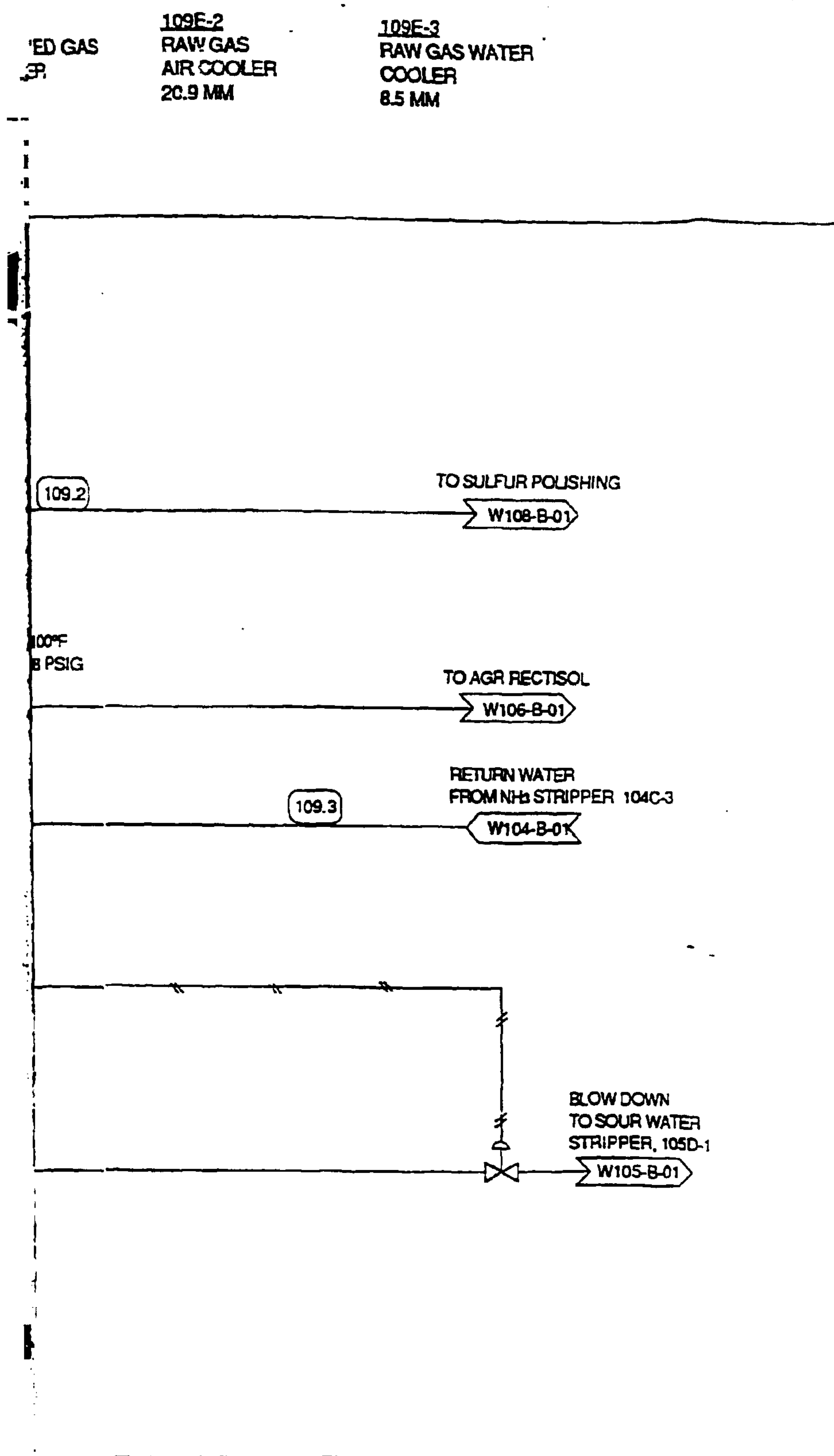
Table 2-9
Total Plant Material Balance
Plant W109 - Syngas Wet Scrubbing Plant
(Western Coal)

Stream No.	109.1 Syngas to Scrubbing	109.2 Syngas to Rectisol	109.3 Make-up Water to Scrubbing	109.4 B/D to SWS	109.5 Make-up NaOH to Scrubbing
Phase	Vap	Vap	Liq	Liq	Liq
Flow Rate, Lbmol/hr					
H2	36571.67	36567.17		4.50	
N2	743.58	743.58			
O2					
H2S	261.21	258.51		2.70	
CO	90081.88	90069.28		12.58	
CO2	10512.15	10466.25		45.90	
H2O (or Moisture)	9548.62	333.27	741.00	9997.68	35.94
COS	20.73	20.73			
NH3	27.27	0.14	0.07	27.20	
HCl	5.40				
HCN	12.10	0.50		11.60	
CH4	23.29	23.29			
Coal MAF					
Ash	(92 lb/hr)			(92 lb/hr)	
C	(5 lb/hr)			(5 lb/hr)	
Cl					
Sulfur	(0.2 lb/hr)			(0.2 lb/hr)	
NaOH					5.40
NaCl				5.40	
H2SO4					
Total	147808.31	138482.73	741.07	10107.99	41.34
GPM @T,P			27	360	1.40
Mol. wt.	22.08	22.35	18.02	18.18	20.88
MMSFCFD	1346.2	1261.27			

( ) = Solids



109C-1
WET SCRUBBER
5'-6" ID x 20'-0" T-T
109E-1
RAW GAS/C
HEAT EXC
34.1 MM
400°F
339 PSIG
GASIFIER
W103-B-01
109.1
RAW GAS
460°F
403 PSIG
109E-1
225°F
398 PSIG
109E-2
150°F
393 PSIG
CW
109E-3
W106-B-01
83°F
344 PSIG
100°F
380 PSIG
109C-1
LC
104G-3
104-B-01
109.5
CAUSTIC
109G-1
60 GPM



NOTES

1. Process flows and heat exchanger duties are for one train only.
2. Total of eight (8) trains are required for the whole plant.
3. MM = 1,000,000 BTU/HR
4. GPM shown are at flow conditions.
5. Air and cooling water design temperatures:

   Air = 95°F in
   CW = 87°F in
   = 115°F out

6. CW = Cooling Water

THE PROCESS CONDITIONS OF FLOW QUANTITIES, TEMPERATURES, PRESSURES, COMPOSITIONS AND INSPECTIONS, AND EQUIPMENT DUTIES SHOWN ON THIS FLOW DIAGRAM ARE FOR DESIGN PURPOSES ONLY, AND WHILE USEFUL AS GUIDES IN OPERATION, DO NOT REPRESENT EXACT OR GUARANTEED OPERATING CONDITIONS.

GUARANTEES ARE SPELLED OUT ONLY IN THE CONTRACT.

REV	DATE	ISSUED FOR	BY					
	2/25/93	Stn Cnty						

SCALE NONE | SH

Bechtel Corporation
San Francisco

U.S. Department of Energy
Pittsburgh Energy Technology Center

Process Flow Diagram
Plant W109 - Syngas Wet Scrubbing

JOB NO.	DRAWING NO.	REV
21655	W109-B-01	A

Table 2-10
Total Plant Material Balance
Plant W110 - Air Separation Plant
(Western Coal)

Stream No.	110.1 Air	110.2 Oxygen Product	110.3 Waste Nitrogen	Loss
Phase	Vap	Vap	Vap	Vap
Flow Rate, Lbmol.hr				
N_2	159019.64	0.00	158869.69	149.95
O_2	42661.90	41719.65	902.89	39.36
Ar	1898.05	209.54	1686.58	1.93
H_2O	5210.98	0.00	5210.98	0.00
Total	208790.57	41929.19	166670.14	191.24
GPM @ T.P.	208190.57			
Mol. Wt.	28.69	32.04	28.16	28.97
MMSCFD	1901.66	381.89	1518.03	1.74

NOTE: FLOW RATES ARE BASED ON NINE 1780 SHORT TPD (100%) OXYGEN TRAINS

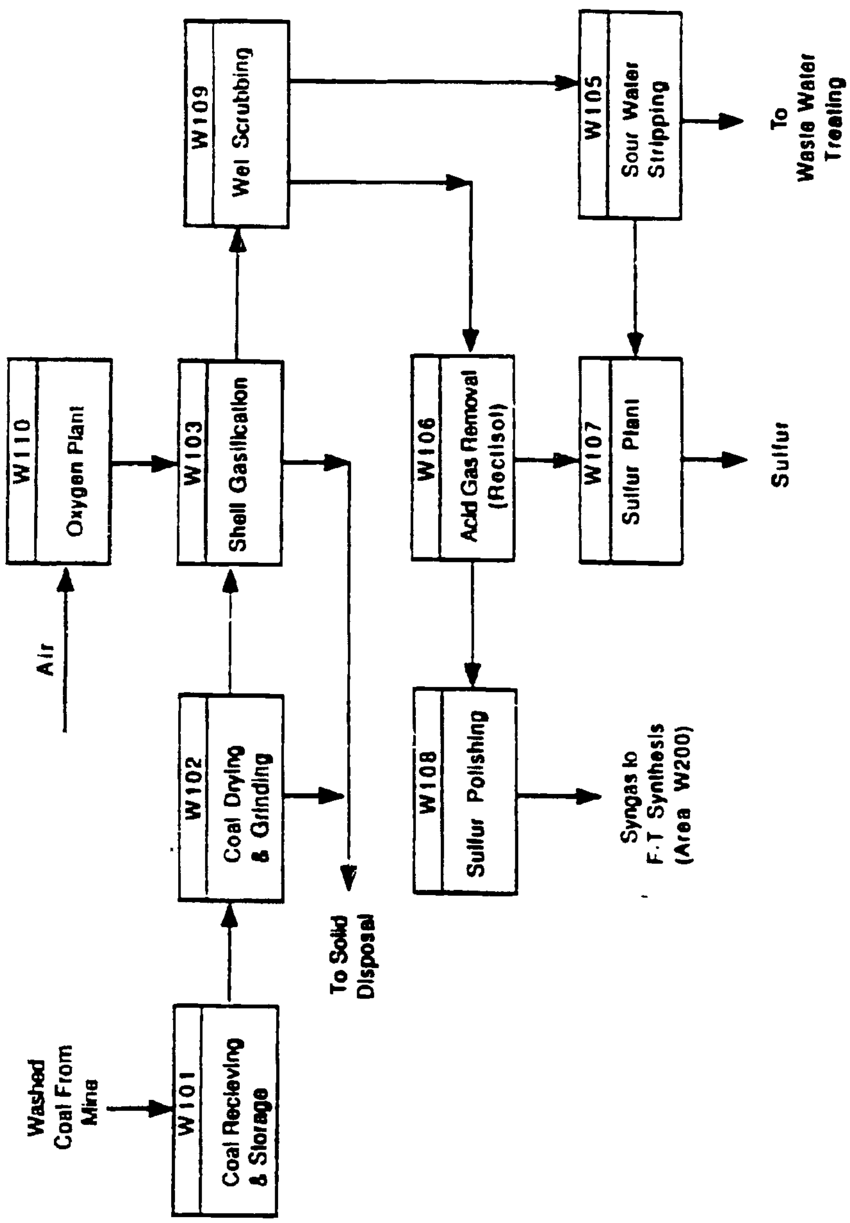


Figure 2-1 Block Flow Diagram for Area W100 - Syngas Production (Western Coal Case)

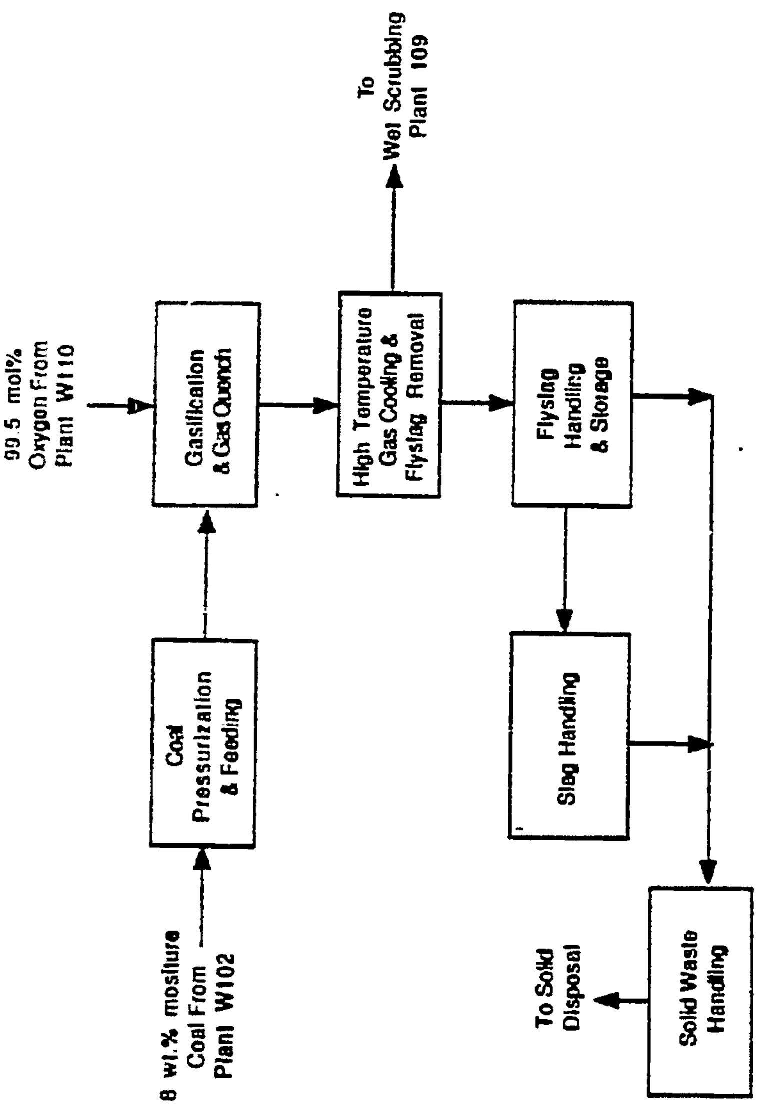


Figure 2-2 Block Flow Diagram Showing A Single Shell Gasification Train (Plant W103) (Western Coal Case)

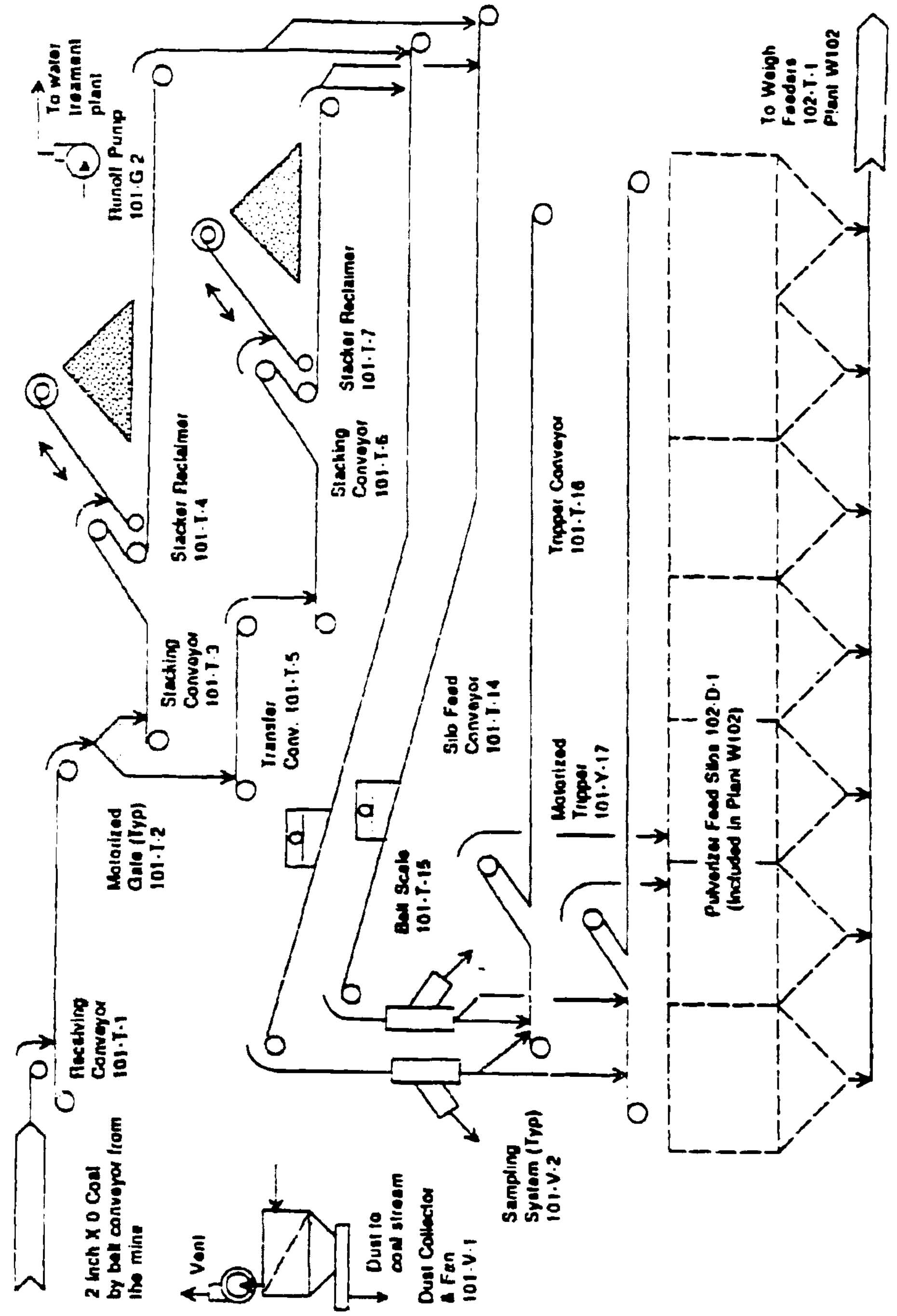


Figure 2-3 Mechanical Flow Diagram Showing the Coal Receiving and Storage (Western Coal Case - Plant W101)

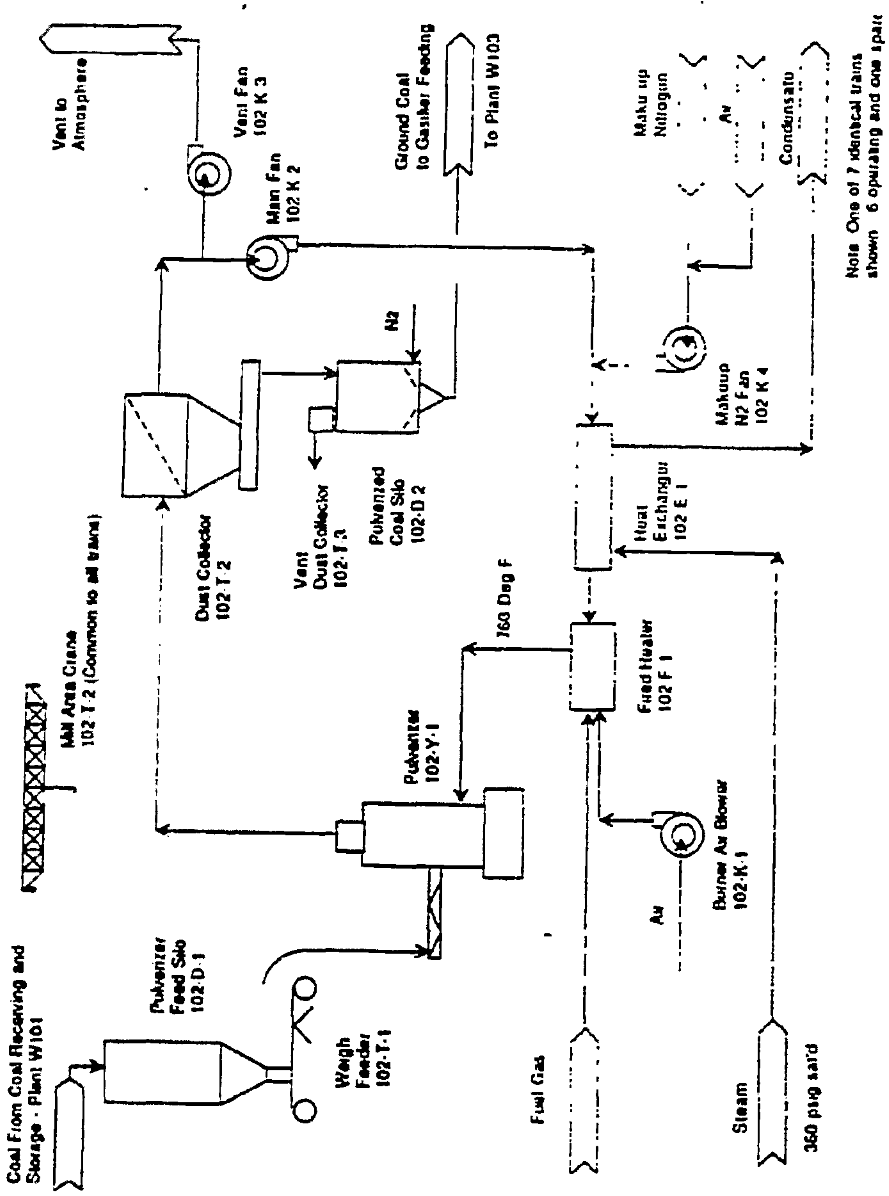


Figure 2-4 Mechanical Flow Diagram for Coal Drying and Grinding (Western Coal Case - Plant W102)

Section 3

Task 4 - Process Flowsheet Simulation (PFS) Model

The previous quarterly progress report described the development of a preliminary process simulation model for the Area 100 syngas production section of the plant. During this quarter, an improved equilibrium based gasifier model was developed and modeling was started on the Area 200 Fischer-Tropsch loop section of the plant.

3.1 EQUILIBRIUM GASIFIER MODEL

An ASPEN/SP equilibrium based model of the Shell coal gasification plant has been developed primarily for mass balance purposes. This model has been tuned to match the design yields for the baseline Illinois no. 6 coal case by adjusting the temperature approaches to equilibrium for the primary gasification reactions.

This equilibrium based model of the Shell coal gasification plant consists of a Fortran user block model, four ASPEN/SP unit operation block models and an in-line Fortran block. Figure 3-1 shows the block flow diagram of this ASPEN/SP model

Block P103D is the Fortran user block model which decomposes the ground and dried coal leaving Plant 102, the coal drying and grinding plant, into ASPEN/SP conventional components and pseudocomponents which can react in the ASPEN/SP reactor models. This Fortran block model converts the Ultimate analysis coal components not remaining in the slag product into ASPEN/SP conventional components C (a pseudocomponent), H_2, N_2, HCl, H_2S, O_2 and ash. Component C is an intermediate conventional pseudocomponent that is used only to allow the transfer of the carbon in the coal in an ASPEN/SP stream to subsequent processing blocks without requiring the use of an ASPEN/SP conventional solids substream. All carbon entering the gasification plant that does not leave in the slag is converted to the C pseudocomponent. All chlorine entering in the coal that does not leave in the slag is converted to HCl. All sulfur entering the gasification plant that does not leave in the slag is converted to H_2S. In a subsequent reactor block, some of this H_2S is converted to COS. All hydrogen entering in the coal that is not converted to HCl or H_2S is converted to H_2. All oxygen in the entering coal is converted to O_2.

In addition, for modeling simplicity, block P103D assumes the same slag composition for that entrained in the vapor and the solid product, and it sets the product slag composition and flow rate based on the user supplied REAL input parameters. These REAL input parameters are the percents of carbon, chlorine and sulfur remaining in the slag and the percent of slag entrained in the syngas vapor stream. The decomposed coal products that have been converted to conventional components, pseudocomponents and any entrained slag leave user block P103D in an intermediate vapor stream, the first outlet stream. The slag product stream is the second outlet stream.

This P103D Fortran user block model also calculates the utilities consumptions (or productions) for the entire Shell coal gasification plant (Plant 103) as a linear function of the dry coal feed rate based on user supplied input parameters. Also based on user supplied input parameters, this model also calculates the number of duplicate plant trains, the number of dedicated plant operators, and the ISBL plant cost.

In-line Fortran block SETUP103 (not shown in Figure 3.1) sets the flow rates of the CO_2 and oxygen-rich streams going to the Shell gasification plant as a function of the dry coal flow rate to block P103D.

Block P103M1 mixes the intermediate vapor stream from Block P103D with a CO_2 stream (that is used to pressurize and feed the coal to the gasification reactor) and an oxygen-rich stream from Plant 109 (the air separation plant) to produce a pseudo total gasifier inlet stream.

The coal gasification reactor is modeled by two ASPEN/SP reactor unit operation block models in series. The first reactor block model, block P103R1 is the ASPEN/SP stoichiometric reactor model (RSTOICH) which reacts all the entering pseudocomponent C with oxygen to produce CO. Since the reactions that produce NH_3 and HCN do not appear to be near equilibrium, these components are produced in this reactor rather than in the subsequent equilibrium reactor. The NH_3 and HCN productions are specified as fractions of the amount of nitrogen that is converted to these components.

The second reactor block model, block P103R2 is the ASPEN/SP equilibrium reactor (RGIBBS) which does the chemical equilibrium reaction calculations for the carbon, hydrogen, oxygen and sulfur containing compounds. The design yields for the Illinois No. 6 coal case were matched by specifying the temperature approach deltas for the key reactions. These temperature deltas were determined by trial and error to match the design yields. Since the yields of the nitrogen containing compounds were calculated in the first reactor block, the extents (molar production rates) of the NH_3 and HCN producing reactions are set to zero to prevent further reaction.

The above RGIBBS equilibrium based model assumed the following four reactions involving carbon.

		Temperature Approach, °F
1.	$2CO + O_2 = CO_2$	0
2.	$CO + H_2O = CO_2 + H_2$	-590.3

3.	$CO + 3\,H_2 = CH_4 + H_2$	107
4.	$CO + H_2S = COS + H_2$	360

With an assumed reactor outlet temperature of 2500 °F and pressure of 450 psia, the design yields were matched with the above temperature approach deltas that were determined by trial and error.

Block P103H1 is an ASPEN/SP heater block which cools the syngas product stream to the exit temperature of the high temperature gas cooler. This block has one inlet stream, and two outlet streams. The first outlet stream is the cooled syngas stream, and the second is a heat stream showing how much heat is removed in cooling the syngas.

This model has not yet been integrated into the previously developed Area 100 syngas preparation section model.

3.2 FISCHER-TROPSCH REACTOR LOOP

The preliminary version of the ASPEN/SP Fischer-Tropsch reaction loop model that was developed by Bechtel was simplified by removing two convergence loops to reduce the execution time since the as-received model took over five hours to run on a Compaq 386/33 machine. The major simplifications involved removing two loops that balanced heat exchanger duties and replacing them with fixed temperature specifications. Although these loops are important in developing an economic engineering design, they are not critical for predicting overall loop and plant performance.

Figure 3-2 shows the block flow diagram for the simplified ASPEN/SP model of the Area 200 section of the plant, the Fischer-Tropsch loop. The stream and processing blocks will be renamed later to conform to the model naming conventions. This simplified model now has only one convergence loop and executes in about 15 minutes on the Compaq 386/33 machine.

In addition, the coding of the Fortran user block model for the Fischer-Tropsch reactor (shown as block FT in Figure 3-2) was cleaned up, revised to speed up execution, and generate more meaningful intermediate results to the history file.

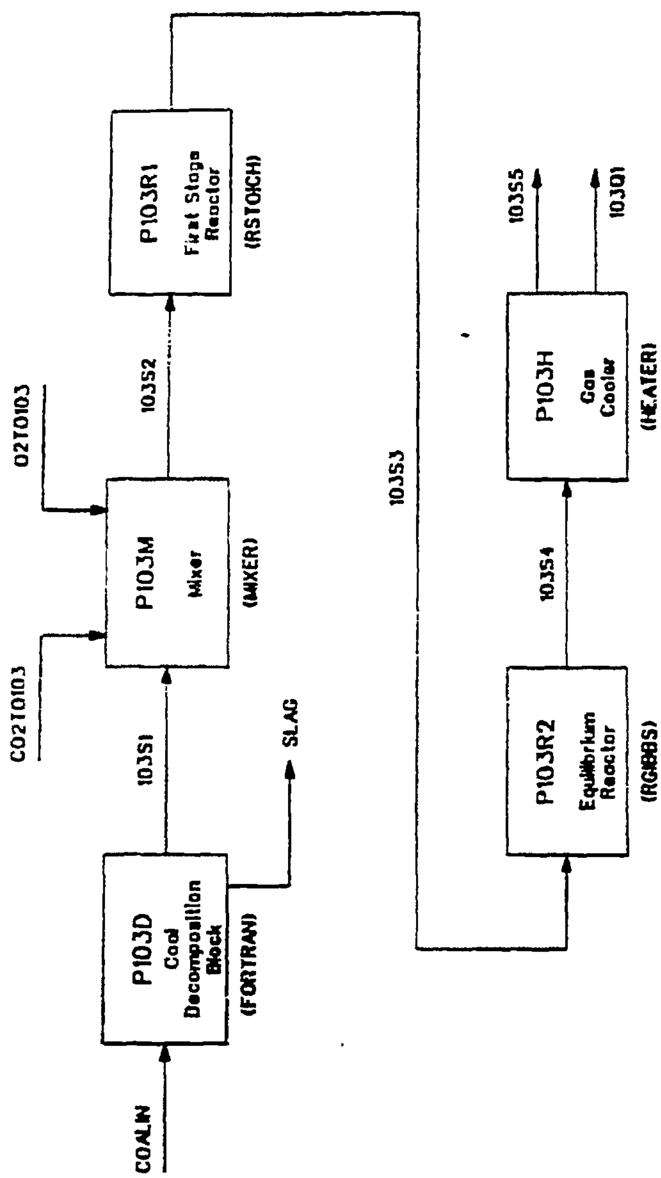


FIGURE 3-1
ASPEN/SP FLOW DIAGRAM FOR THE EQUILIBRIUM
BASED SHELL GASIFIER MODEL.

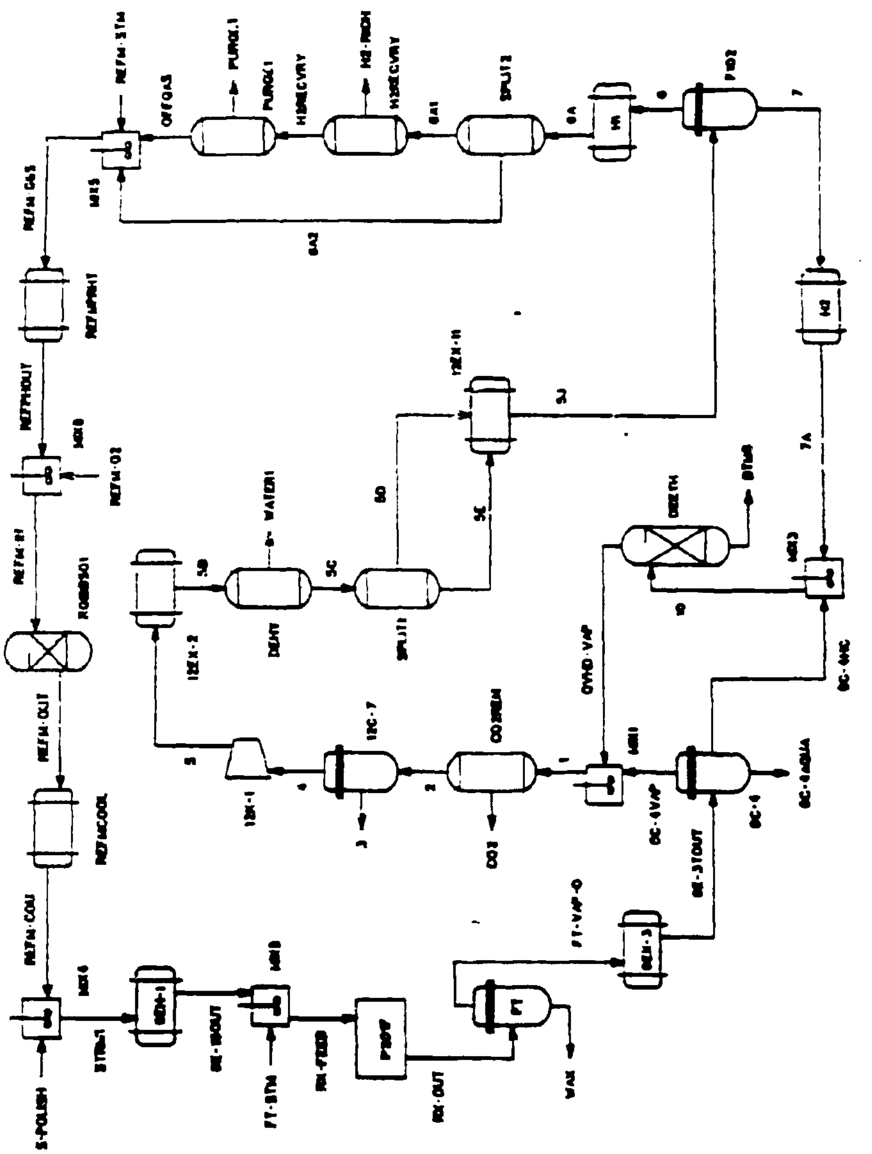


FIGURE 3-2
ASPEN/SP MODEL FLOW DIAGRAM FOR AREA 200 -
FISCHER-TROPSCH LOOP

Section 4

Project Management & Staffing Report

4.1 TASK 7 - PROJECT MANAGEMENT

An invitation to present a paper at the 1993 Coal Slurry conference at Clearwater, FL, was accepted.

4.2 KEY PERSONNEL STAFFING REPORT

With prior approval from PETC/DOE, some of the key personnel in the Baseline study were loaned to another FT-related project for about six weeks during this reporting period. Dr. Gerald Choi joined the project team. His initial assignment is to develop the Baseline design for the FT product upgrading plant.

The key personnel staffing report for this reporting period (September 28, 1992 through December 20, 1992) as required by DOE/PETC is shown below:

Name	Function	% Time Spent[(a)]
Bechtel		
Bruce D. Degen	Process Manager	20
Charles R. Brown	Offsite Facilities	0[(b)]
Gary Lucido	Cost Estimating	0[(c)]
Samuel S. Tam	Project Manager	31
Yang L. Cheng	Process Supervisor	50
Amoco		
A. Schachtschneider	Subcontract Manager	3
S. S. Kramer	Process Model/Simulation	15

(a) Number of hours spent divided by the total available working hours in the period and expressed as a percentage.

(b) C. Brown of Bechtel did not spend any time in this reporting quarter because no offsite facilities work was required.

(c) G. Lucido of Bechtel did not spend any time in this reporting quarter because no cost estimating work was required.

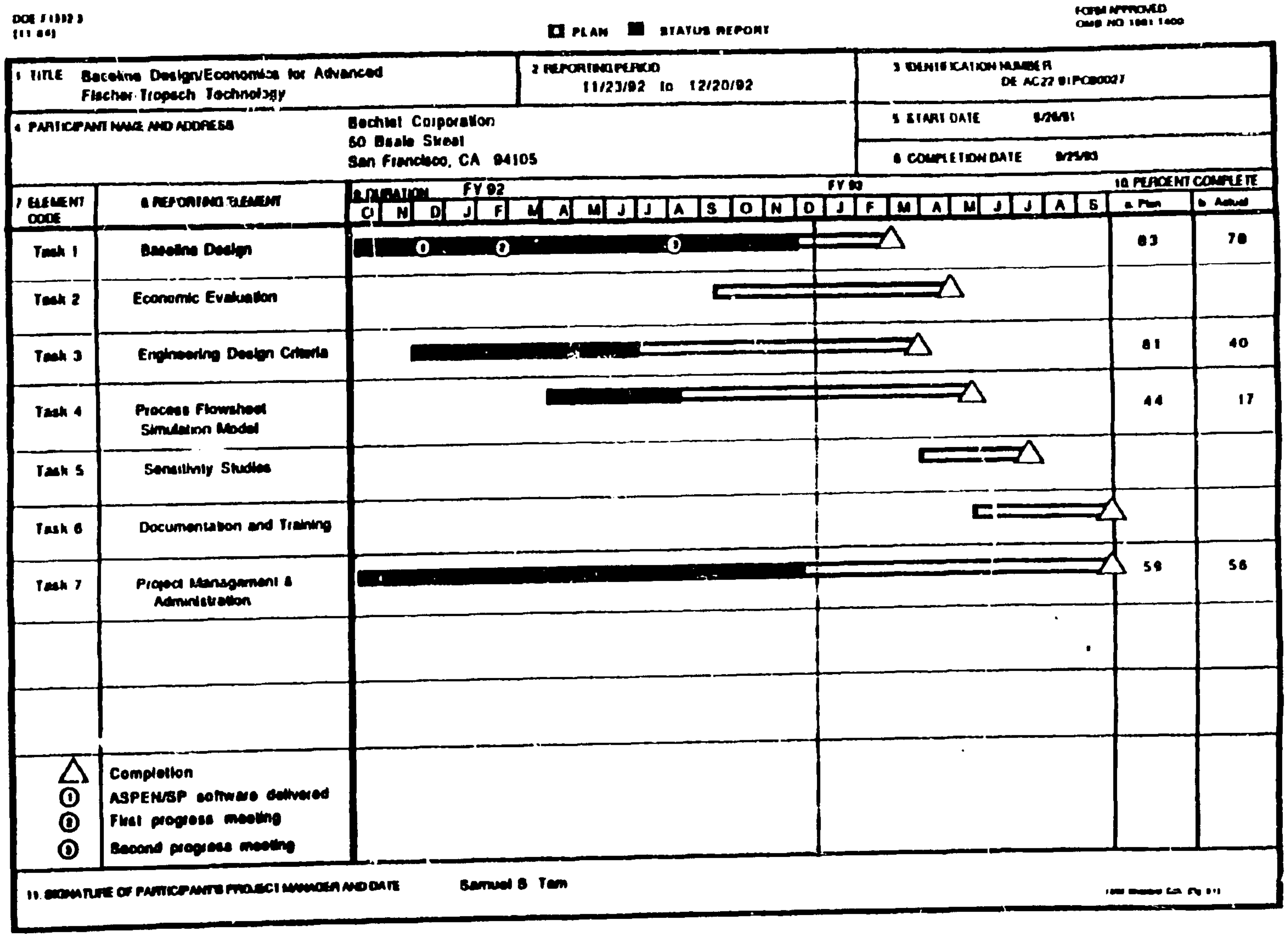
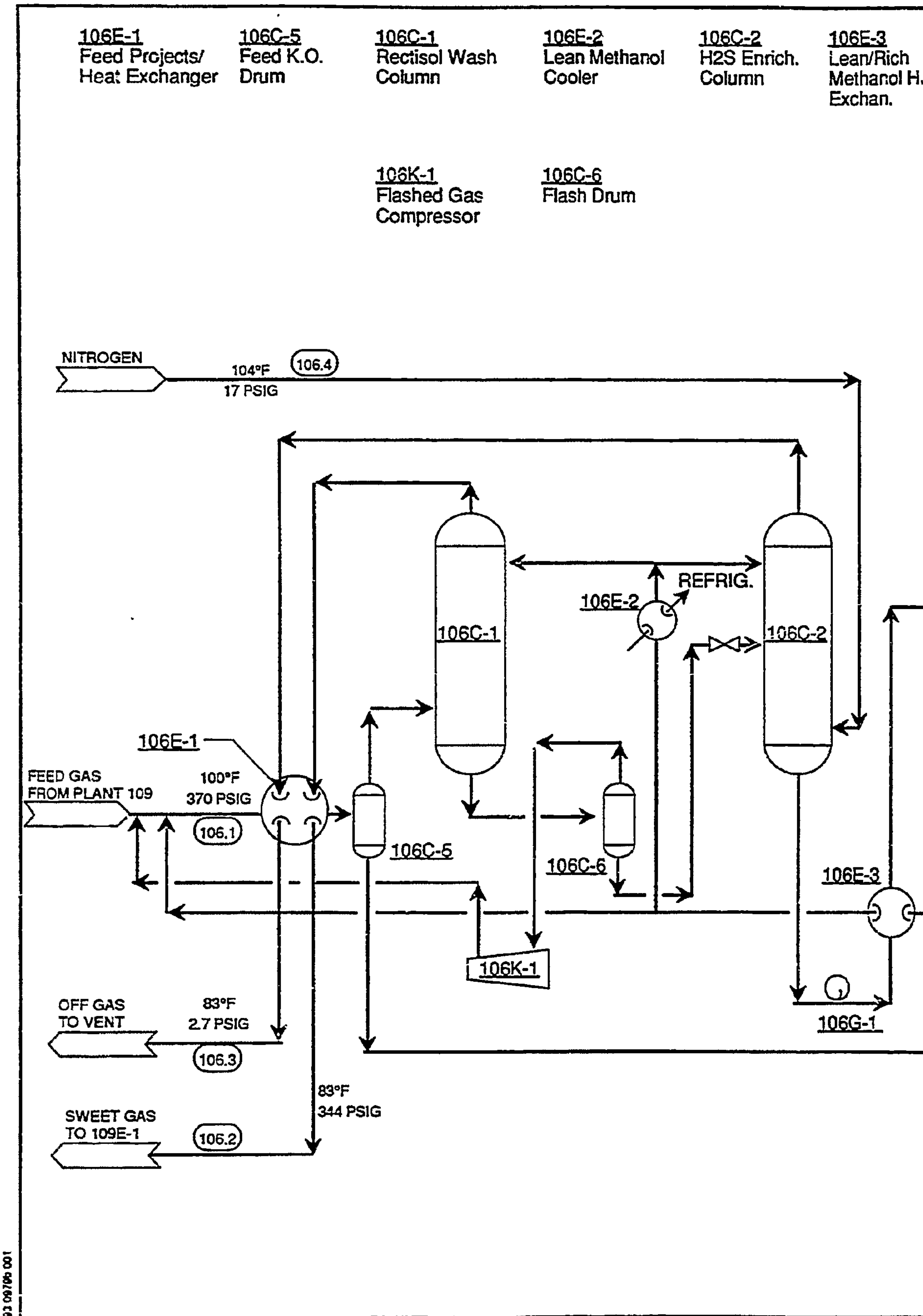


Figure 4-1 Overall Milestone Schedule (as of December 20, 1992)


106E-1
Feed Projects/
Heat Exchanger
106C-5
Feed K.O.
Drum
106C-1
Rectisol Wash
Column
106E-2
Lean Methanol
Cooler
106C-2
H2S Enrich.
Column
106E-3
Lean/Rich
Methanol H.
Exchan.
106K-1
Flashed Gas
Compressor
106C-6
Flash Drum
NITROGEN
104°F
17 PSIG
106.4
REFRIG.
106E-2
106C-1
106C-2
106E-1
FEED GAS
FROM PLANT 109
100°F
370 PSIG
106.1
106C-5
106C-6
106E-3
106K-1
106G-1
OFF GAS
TO VENT
83°F
2.7 PSIG
106.3
83°F
344 PSIG
SWEET GAS
TO 109E-1
106.2
93 09706 001

106C-3
Hot
Regeneration
Column

106E-4
Methanol
Condenser

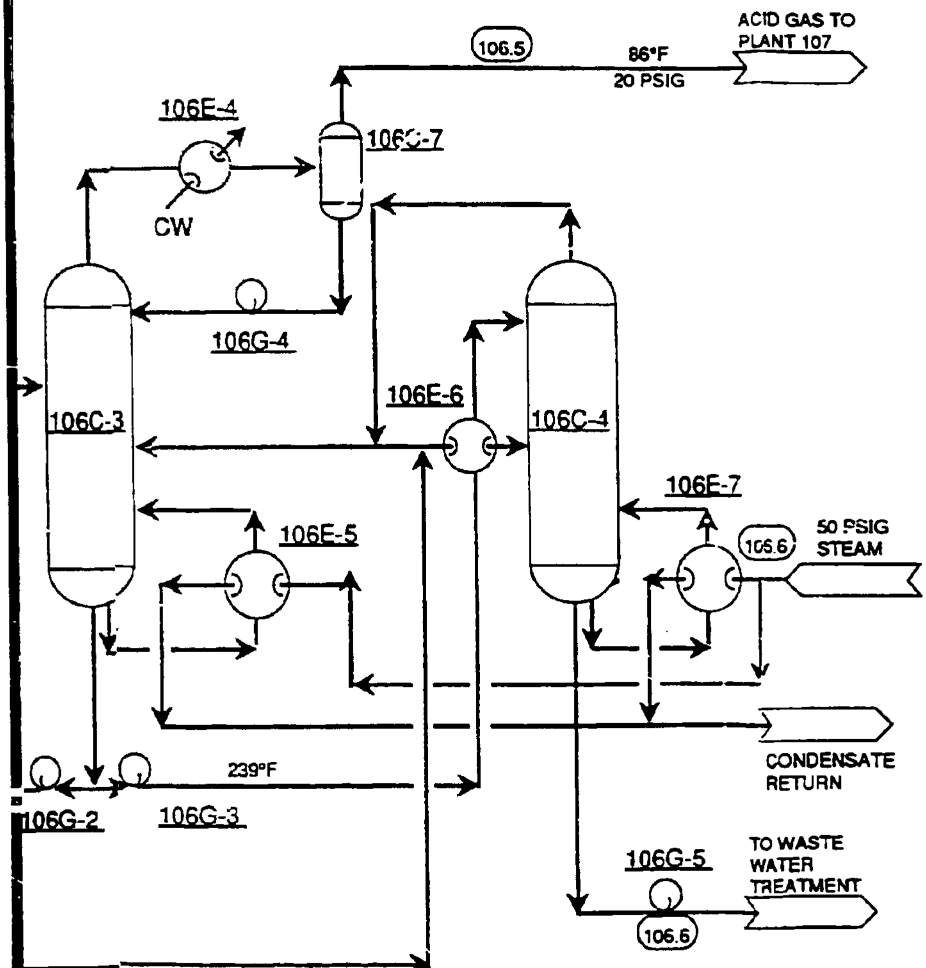
106C-7
Acid Gas
K.O. Drum

106C-4
Methanol
Water
Distillation
Column

106E-7
Distillation
Reboiler

106E-5
Regeneration
Reboiler

106E-6
Mechanical/
H2O Heat
Exchanger



Notes

THE PROCESS CONDITIONS OF FLOW QUANTITIES, TEMPERATURES, PRESSURES, COMPOSITIONS AND INSPECTIONS, AND EQUIPMENT DUTIES SHOWN ON THIS FLOW DIAGRAM ARE FOR DESIGN PURPOSES ONLY, AND WHILE USEFUL AS GUIDES IN OPERATION, DO NOT REPRESENT EXACT OR GUARANTEED OPERATING CONDITIONS.

GUARANTEES ARE SPELLED OUT ONLY IN THE CONTRACT.

REV	DATE	ISSUE DATE	BY	PROJ ENG	ENG SUPV	PROC	PROJ	APPR
	3/93	5th Qtrly						

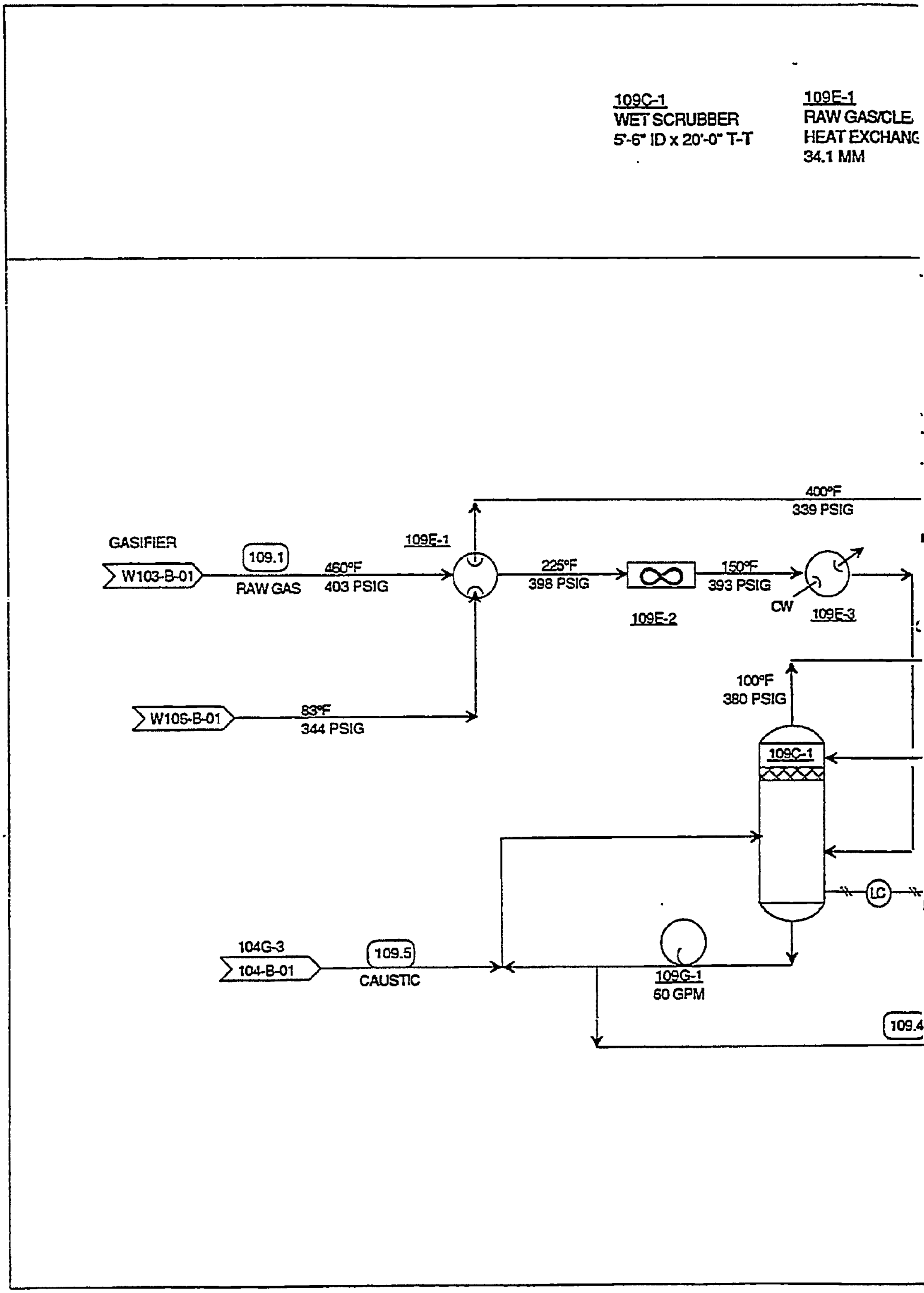
SCALE | DRAWN

Bechtel Corporation
San Francisco

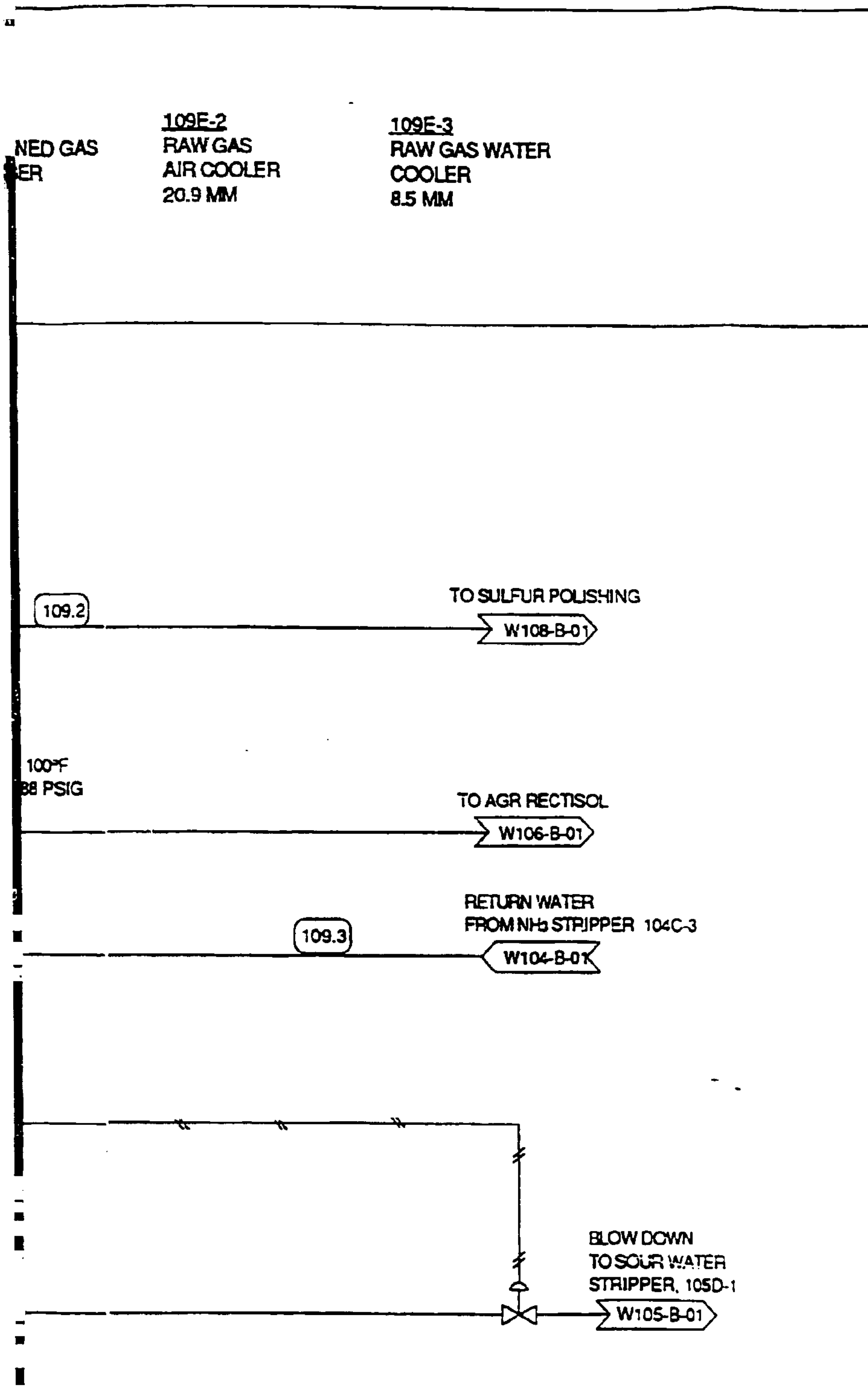
U.S. Department of Energy
Pittsburgh Energy Technology Center

Process Flow Diagram
Plant 106 – Acid Gas Removal (Rectisol)
Western Coal

JOB No.	DRAWING No.	REV
21655	106-B-01	A



109C-1
WET SCRUBBER
5'-6" ID x 20'-0" T-T
109E-1
RAW GAS/CLE
HEAT EXCHANG
34.1 MM
400°F
339 PSIG
GASIFIER
109E-1
109.1
W103-B-01
460°F
403 PSIG
RAW GAS
225°F
398 PSIG
150°F
393 PSIG
109E-2
CW
109E-3
100°F
380 PSIG
W105-B-01
83°F
344 PSIG
109C-1
LC
104G-3
104-B-01
109.5
CAUSTIC
109G-1
60 GPM
109.4



NOTES

1. Process flows and heat exchanger duties are for one train only.
2. Total of eight (8) trains are required for the whole plant.
3. MM = 1,000,000 BTU/HR
4. GPM shown are at flow conditions.
5. Air and cooling water design temperatures:

   Air = 95°F in
   CW = 87°F in
   =115°F out

6. CW = Cooling Water

THE PROCESS CONDITIONS OF FLOW QUANTITIES, TEMPERATURES, PRESSURES, COMPOSITIONS AND INSPECTIONS, AND EQUIPMENT DUTIES SHOWN ON THIS FLOW DIAGRAM ARE FOR DESIGN PURPOSES ONLY, AND WHILE USEFUL AS GUIDES IN OPERATION, DO NOT REPRESENT EXACT OR GUARANTEED OPERATING CONDITIONS.

GUARANTEES ARE SPELLED OUT ONLY IN THE CONTRACT.

REV	DATE	ISSUED FOR	BY					
△								
△								
△								
△								
△								
△	2/25/93	5th Qtrly						

SCALE NONE DRAWN SH

Bechtel Corporation
San Francisco

U.S. Department of Energy
Pittsburgh Energy Technology Center

Process Flow Diagram
Plant W109 - Syngas Wet Scrubbing

JOB No.	DRAWING No.	REV
21655	W109-B-01	A

U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Technical Information Service
Springfield, VA 22161 (703) 605-6000