27337

APENDICE ESPECIAL

COAL GASIFICATION REPORT

SYNTHETIC FUELS COMPLEX

PRODUCTING

MEDIUM BTU GAS

OR

METHANOL

FROM

RIO TURBIO COAL

INDEX OF COAL GASIFICATION REPORT

1 - INTRODUCTION

It is widely agreed that the availability of oil and gas in international trade is likely to diminish over the next two decades. A massive effort to expand facilities for the production, transport, and development of new coal technologiès and the greater use of coal is urgently required to ensure world economic growth. Coal will act as both a bridge to the energy systems of the future and as the keystone of economic growth.

The present known Austral Basin natural gas reserves of 94.6 billion cubic meter provides a 20 year supply, at present the usage level (13 million cubic meters per day). Potential offshore gas adds 10 years to the life of the reserve. However, projected industrial expansion in the Santa Cruz region will have a major impact in the reserve life. The present proposed plants will result in the reduction of 10 years in the reserves supply life.

Santa Cruz, in addition to its abundant supply of natural gas, possesses 99% of the known bituminous coal reserves of Argentina. The Yacimiento Rio Turbio containing 450,000,000 metric tons of sub-bituminous A coal will have a vital role in augmenting the natural gas reserves and in the continued future growth of the region.

There are three wavs in which coal can be used in the industrial development of the area.

- o The direct firing of coal to produce power
- o Gasification of coal for production of Medium BTU Gas (MBG) for direct use in the combine cylcle-power plant systems or as a fuel
- o Gasification followed by the production of a chemical or fuel such as methanol, which then can be used internally or sold on the worl market thus generating income for Argentina.

Gasification is a front end capital intensive industry which will be increasingly practiced in the future as a result of rising fuel costs. The time an required to develop its industrial practice using the unknown and untested Ri Turbio coal requires the early planning for the eventual use of gasification in development of an energy based industrial complex.

The objective of this pre-feasibility project concept report is to:

- o Develop the technical and economic parameters for the future retro-fitting Punta Loyola equipment to burn MBG produced from the gasification of coal.
- o Establish preliminary project definition as to potential product slate, capital investment requirements and production costs.
- o Provide management with the early on information required to structure a definitive commercial feasibility study for the development of Rio Turbio coal.

2 - PROJECT CONCEPT

The present state of the art of coal gasification, the need to develop the infrastructure to produce the required coal, the time span to design, erect and start up a gasification unit and the near term availability of natural gas, suggest that the initial development of the Santa Crux (Punta Loyola) Industrial Park be based on the use of natural gas. At a future date, the coal gasification unit will be built to produce coal derived fuel (MBG), which can be used to replace the natural gas used in the gas turbine combined cycle (GTCC) system and the fuel natural gas used in the production of ammonia and urea. This modification can be made with a minimum of change to the nature gas based design. This concept is illustrated in Figure 2-1.

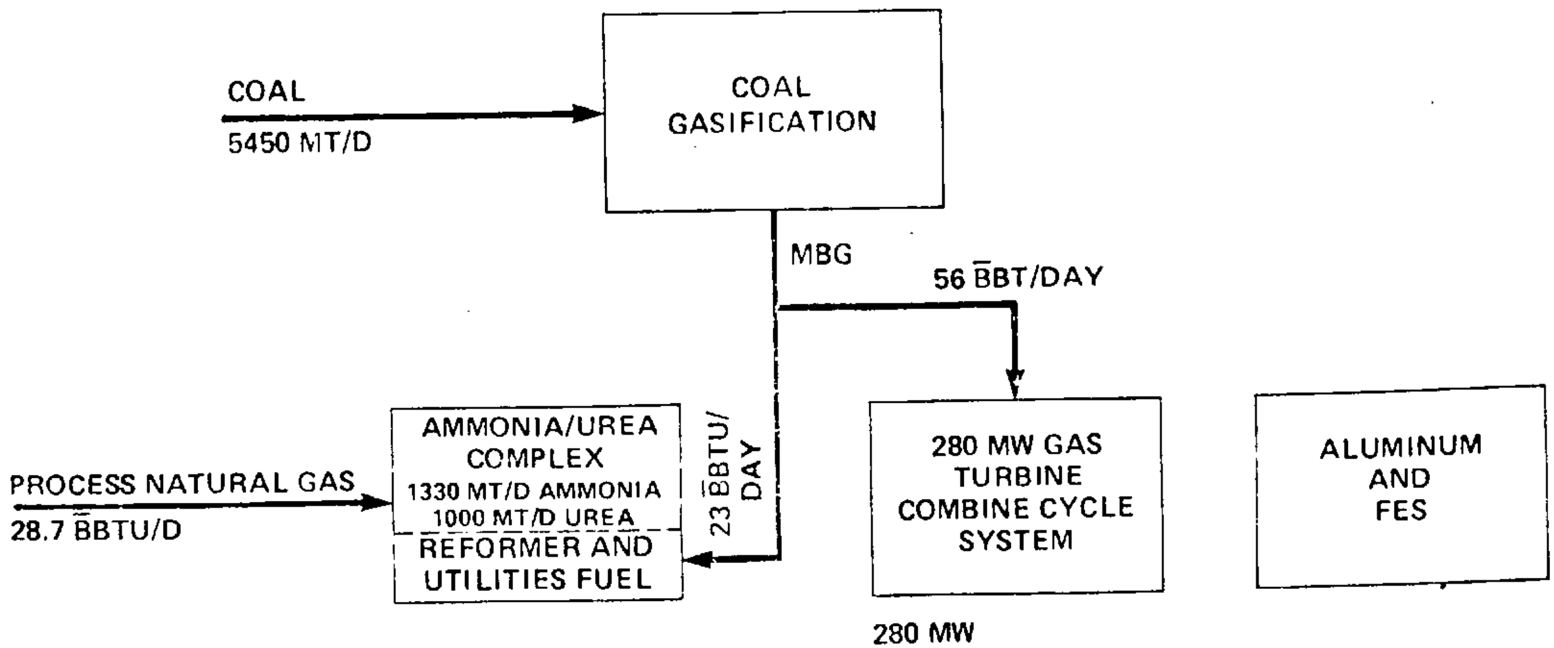
While coal derived MBG can be used to replace the process natural gas used in the ammonia plant, this change will in principle require extensive modifications. Figure 2-2 outlines the conceptual scheme for a coal gasification based ammonia plant. The salient differences between a natural gas based and a coal based ammonia plant are:

- o The methodology of introducing nitrogen into the synthesis gas
- o The higher quantity of carbon oxides introduced into the process system when a coal derived feed gas is used. This would require modification to the shift and the carbon dioxide removal system
- o Addition of a sulfur removal system
- o The process system used for final synthesis gas purification
- o Overall plant heat balance as a result of the deletion of the primary and the secondary reformers.

Product Slate

MBG is the lowest cost fuel which can be produced via coal gasification since its production requires a minimum number of processing steps. However, because MBG is a gas with limited economic storageability, its production must follow the electric power load when it is used as a fuel in a combined cycle plant. Its medium heat content also limits the distance over which it can be shipped. Figure 2-3 indicates the relative economic distances for shipping the products from a coal gasification complex.

ALTERNATE FUEL CONCEPT FOR SANTA CRUZ INDUSTRIAL PARK



CONCEPTUAL SCHEME FOR COAL GASIFICATION BASE AMMONIA PLANT

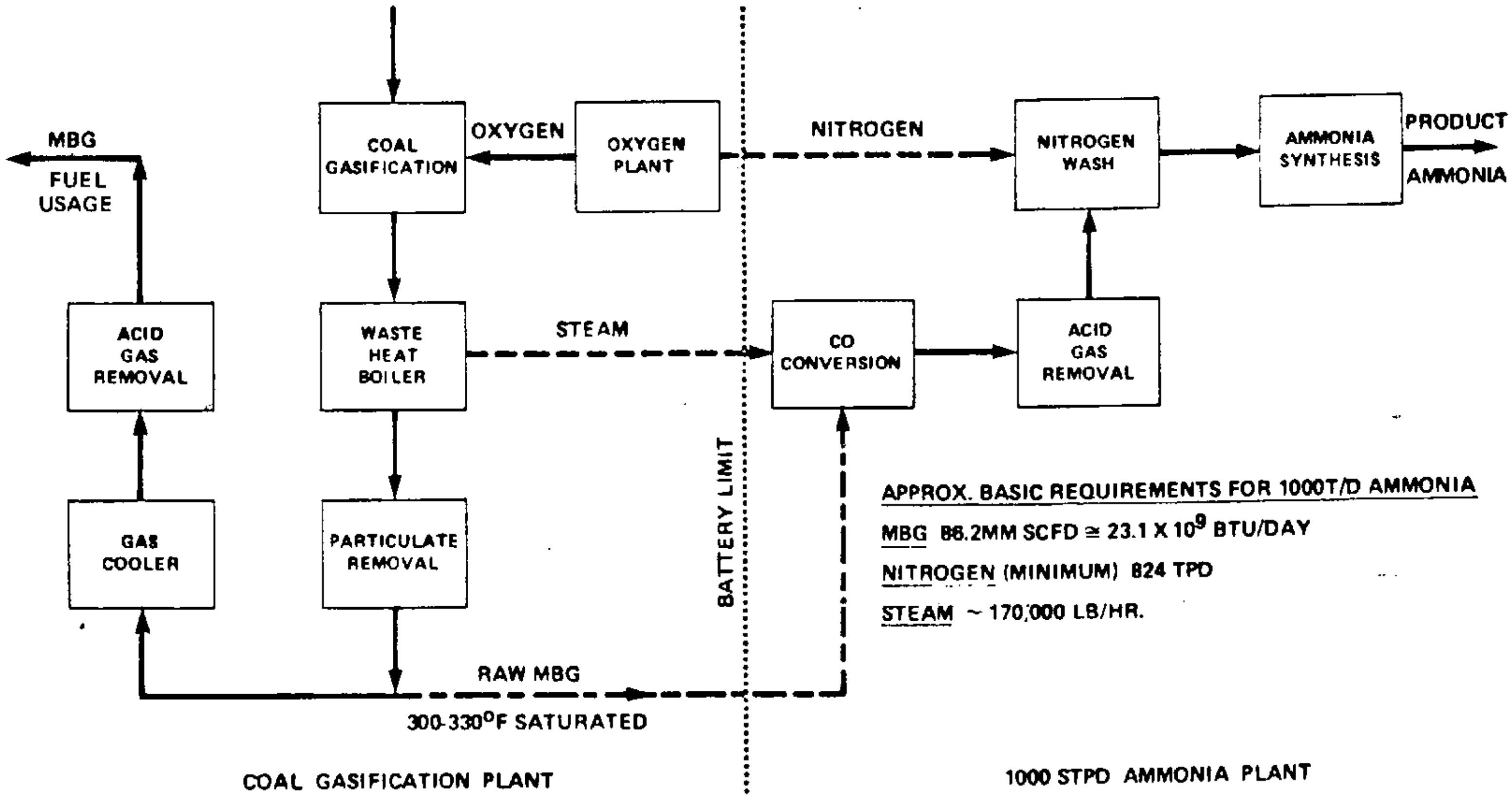
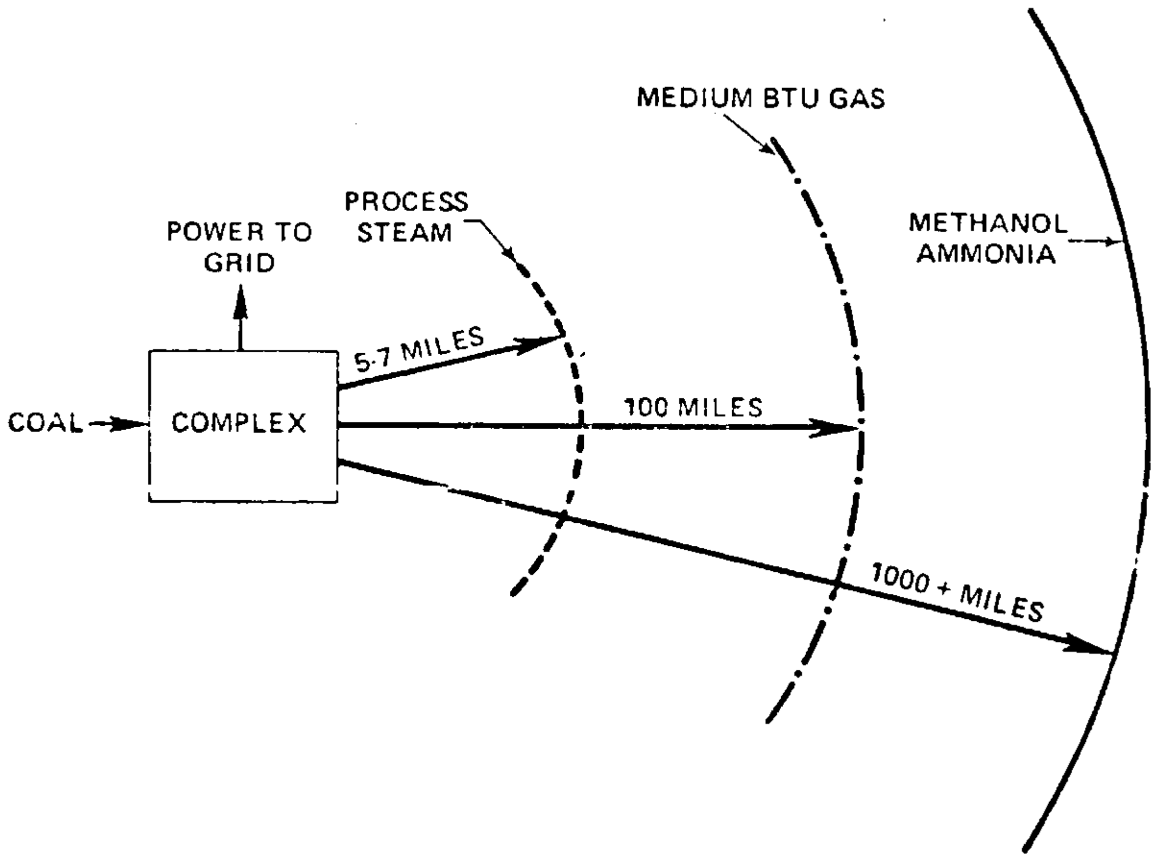


FIGURE 2-2

FIGURE 2-3

POWER/CHEMICALS COMPLEX PRODUCTS TRANSPORT LIMITATIONS



Methanol, an alternate fuel product of gasification, while requiring additional capital and operating costs to produce, has a great product flexibility. With domestic Argentine natural gas pegged at U.S. $1.20/Million BTU, results of studies carried out by Ebasco on other projects indicates that methanol, which can be sold in the International market at world prices, should prove to be a more attractive economic alternate.

Thus, two products will be considered, MBG as a fuel for the Santa Cruz Industrial Complex and the production of fuel or chemical grade methanol using a coal derived feedstock and fuel.

Plant Location

In the initial discussions held between CIF, Ebasco and Electrowatt, consideration was given to potentially locating the gasification plant at Rio Turbio. This location has the advantage of eliminating coal transportation costs to Punta Loyola (the proposed site of power/aluminum/Ferro Silicate/Ammonia/Urea plants). However, the disadvantages of this location include the need to develop a parallel infrastructure, negates the potential of cost minimization by intergration of operations, requires a dedicated pipeline to transport MBG to Punta Loyola and eliminates the potential for further expanding operations at Punta Loyola by using gasification products such as sulfur, nitrogen and oxygen in the industrial complex. Discussions with the operation staff of the Yacimento Carboniferous Fiscales at Rio Gallegos projects the lack of water at Rio Turbio. A coal gasification unit of the capacity as envisioned (5000 T/D) requires in the order of 20,000 cubic meters of fresh water per day. Present operations at Rio Turbio are targeted to conserve water which is in short supply. Studies which have been initiated over a period of years have failed to point to a viable solution to increase the water qantity availability at Rio Turbio.

This pre-feasibility study thus will be based on a Punta Loyola loc ion for the gasification complex.

Coal

For the purposes of this study the following coal analysis will be adopted:

Prominate Analysis	Weight %
Water	8.9
Ash	13.7
Carbon	38.1
Volatile Material	39.3

Ultimate Analysis	Weight %
Carbon	67.44
Hydrogen	5.19
Nitrogen	1.09
Oxygen	10.43
Sulfur	.77
Ash	15.08
Total	100.00

Higher Heating Valve 6,080 KCal/Kg (10,940 BTU/LB) Wet Basis

Rio Turbio coals have been classified as sub-butuminous A (International classification 800). The characteristics of the coal in this classification lie between the well known bituminous and the lignites coals.

While the selection of a gasifier for Rio Turbio coals is beyond the scope of this study this pre-feasibility analysis will be based on the use of a Westinghouse Gasification System. The Westinghouse gasifier is considered suitable for use with Rio coals as it has been tested successfully using lignites, sub-bituminous and bituminous coals. The type of coals and the range of the gasification properties of the coals tested is given in Tables 2-1 and 2-2 respectively.

Table 2-1

Coals Tested in Westinghouse Gasifier

Texas Lignite
Wyoming Sub-C - Subbituminous
Montana Rosebud - Subbituminous
Indiana No. 7 - Bituminous
Western Kentucky - Bituminous
Ohio No. 9 - Bituminous
Pittsburgh Upper Freeport - Bituminous
Pittsburgh No. 8 - Bituminous

Table 2-2

Range of Gasification Properties Tested

Free Swelling Index	0 to 9
Ash Content - %	2 to 22
Ash Deformation Temperature - °C	1080 to 1380
Ash Deformation Temperature - °F	1970 to 2520
Moisture - %	2 to 24
Volatile Matter - %	1 to 35
Reactivity*	1 to 50
Heating Value** - k.cal/kg	3890 to 7050
Heating Value** - Btu/lb	7300 to 12,700

* Kinetic ratio based on coke breeze as unity reference

** As received basis

Extensive testing and evaluation studies will be required, before a definite gasifier selection is made.

Capacity

Gasification For The Production of MBG

As presently envisioned the MBG Coal Gasification plant will be designed to provide the fuel for:

280 MW combined cycle system	56.0×10^9 BTU/D HHV
Fuel for ammonia plant	23×10^9 BTU/D HHV
Fuel for internal consumption of gasification plant	14×10^9 BTU/D HHV.
Total MBG produced	93×10^9 BTU/D HHV

In the planning of a multi-product industrial park, economies of capital and operations may be realized by integration of the common support utility systems and infrastrucutre requirements. For the purposes of this study, however, the gasification plant will be designed as a self-sufficient unit, requiring only coal and fresh water. This will allow for the development of all capital and operating charges which are incurred against the gasification complex, as a single cost center.

The production of net fuel product with a heating value of 79×10^9 BTU/Day (HHV) will require the gasification of 5,450 MTD of coal with a HHV of 10,940 BTU/lb. The product gas 273.8 million SCF/D (60°F and 14.7°F) will be delivered at a pressure of approximately 300 psig with the following composition on the dry basis.

Component	Mole %
CH_4	6.20
CO	41.30
CO_2	21.90
H_2	29.00
N_2	0 .8
Ar	0 .8
HHV	288.5 BTU/SCF

Methanol

When producing fuel grade methanol as an alternate product the gasification 5,450 MT/D of coal will produce 2,850 MT/D of methanol.

The methanol product will contain approximately 0.25% by weight water and 0.3% by weight higher alcohols.

2.1- MBG

2.1.1 Process Description

The proposed coal gasification plant to produce 79 billion BTU/Day (B BTU/D) of clean MBG fuel for combustion in the gas turbines of the combined cycle power plant and as fuel in the ammonia/urea complex will consist of a production train with the following subsections.

- Coal preparation
- Coal gasification, heat recovery and particulate removal
- Sulfur removal and recovery
- Ancillary and support systems

An overall process schematic and process flow schemes for the main line subsections of the gasification plant are given in section 2.1.2. The descriptions which follow will discuss salient features of each subsection.

Coal Preparation

The purpose of the coal preparation unit is to produce 1/4 inch coal feed without excessive fines or surface moisture for the Coal Gasification unit.

Coal for grinding is transported from the live coal pile via a conveyor into a holding bin from which it flows through a coal dryer and crusher unit. Oversized coal is recycled internal to the crusher. The coal product is weighed and transported by a gasification system bucket elevator.

Coal Gasification and Gas Cooling

The coal gasification system consists of a coal feed system, the gasifier proper, a fines separation system, and heat recovery system and a gasification waste water treatment system. The design of the Westinghouse coal gasification system is based on a modular concept, with 6 parallel gasifiers. With a rated capacity of approximately of 44 tons/hour coal each, or about 16.5 billion Btu/Day each. This provides several advantages:

- The building blocks form a pre-engineered, standardized plant that may be fully designed with all components identified and ready for procurement, thus reducing cost as well as the lead time required from commitment to installation.

- o Reliability and capability for turndown of the overall plant are enhanced, since the individual gasifier units may be operated in various modes, and the shutdown of any one gasifier does not interrupt the operation of the complete system.

Each module train consists of coal and recycled fines lockhoppers, gasifier cyclones, ash lockhoppers and conveyers, a recycled fines cooler, a raw gas quench scrubber, and recycled gas cooler and compressor. The crushed, dried coal is conveyed pneumatically from the lockhoppers and injected through a vertical feed pipe using recycled synthesis gas as a transport medium. Oxygen and steam are fed into the coaxial feed pipe to produce a vertical oxygen-steam-coal jet within the gasifier. Steam and recycled gas are also fed radially at other locations in the gasifier to ensure proper fluidization. Fines that are carried over from the reactor are collected in two cyclones and are recycled to the gasifier via the fines lockhopper.

The product gas which is free of tars and oils exits the cyclones at about 1800°F and is cooled by generating 600 psig steam. The remaining particulate in the hot gases exit the boiler and is then removed by quench cooling in a venturi quench scrubber feeding into a quench scrubbing column. The cooled gas is then split into two streams. The smaller stream, representing in the order of 12 percent of the total gas produced, is compressed and recycled to the gasification process, while the bulk of the produce gas is fed to the sulfur removal section. The water from the bottom of the gas scrubber contains ammonia, carbon dioxide, hydrogen sulfide, char fines, and ash fines, and is sent to the gasification waste water treatment system.

Gasification Waste Water Treatment System

The purpose of this process unit is to recover the ammonia produced from the nitrogen entering the gasification unit with the coal and oxygen, and to reprocess the water so it can be recycled back to gasification operations.

The water from the scrubber is decanted in a settling tank to remove most of the ash-fines and then filtered and pumped to a stripper column. The bottoms from the settling tank are removed via a slurry pump to a waste water settling area within the ash disposal area.

Sour water is stripped to remove CO_2, H_2S and NH_3. The reprocessed water is returned to the gasification unit. The overhead of the column is separated into ammonia and sour gases. The aqueous ammonia is further processed by using the Phosam-W-Process (licensed by U.S. Steel Corp.) for conversion to anhydrous ammonia. The sour gases are treated in the Claus unit for sulfur recovery.

The quantity of ammonia produced as by-product from the gasification corresponds to the nitrogen content of the coal.

Sulfur Removal

This unit consists of a hydrolysis unit for COS conversion and absorber section for hydrogen sulfide removal.

The hydrolysis sub-system is designed to convert carbon sulfide (COS) to hydrogen sulfide by hydrolysis in accordance with the following reaction:

$$COS + H_2O \rightleftharpoons H_2S + CO_2$$

The hydrolysis unit consists of a gas preheater, a catalytic COS converter and a gas cooler. Provisions will be made to adjust the steam to gas ratio in the process gas as the conversion of COS to H_2S over the catalyst is favored by low temperature and a high steam to gas ratio.

From the hydrolysis unit the gas passes to the absorber of the Selexol system. In the absorber the gas is counter-currently contacted by a stream of lean Selexol solvent. The purified gas MBG exiting the absorber may be used as fuel.

The Selexol scrubbing system (a proprietory Allied Chemical Process) uses dimethylether of polyethylene glycol to absorb hydrogen sulfide. Selexol can absorb approximately 9 times as much H_2S as CO_2 under like conditions of temperature, pressure, and solvent loading. This property makes it possible to remove H_2S to low levels, while retaining CO_2 in the gas.

(The CO_2 provides some advantages when MBG is used as fuel for gas turbines.) The absorption is favored by high pressure and low temperature. Pressure release and heating of the solution results in flashing of the absorbed H_2S and CO_2.

The absorber-bottom liquid is flashed in the flash drum to recover absorbed CH_4, H_2 and CO. The flashed gas is recycled by the recycle compressor to the abosorber feed. Solvent from the flash tank is heated by exchange with lean solvent and passes to the stripper, where the acid gas is stripped from the solvent by steam, generated in a steam heated reboiler. The lean regenerated solvent is then cooled and refrigerated before returning to the absorber to complete the cycle. The acid gases flow to the Sulfur Recovery for further processing.

Sulfur Recovery

To ensure that the sulfur recovery system is adequate to meet a wide range of sulfur in the coal, a baseline sulfur recovery unit consisting of a modified Claus-type system is proposed.

The conversion of hydrogen sulfide to sulfur is based on the reaction between hydrogen sulfide (H_2S) and sulfur dioxide (SO_2) in which H_2S reacts with SO_2 to form sulfur (S) and water (H_2O) according to the following reaction:

$$2H_2S + SO_2 \rightleftarrows 3S + 2H_2O + \text{Heat}$$

Part of the H_2S is burned with air to provide the SO_2 required. However, if due to the low sulfur content of the coal, the SO_2 produced by burning proves to be insufficient, thus sulfur is recycled for burning. Combustion air to the sulfur combustion unit is supplied by an air blower. The combustion gas containing SO_2 is cooled by generating medium pressure steam in a boiler. The SO_2 rich gas is combined with the H_2S rich acid gas at this point and is then reheated in the first reheater before entering the first converter where H_2S and SO_2 react over a catalyst to form free sulfur.

Most of the sulfur is produced in the first converter. The gas from this unit flows to a Sulfur Condenser where the sulfur is condensed and drained to the Sulfur Pit. In order to obtain the desired degree of conversion this process is repeated in the second and third reactor stages, which have similar reheaters, catalyst converters and condensers. The tail gas from the final condenser is incinerated before venting to the atmosphere.

2.1.2 MBG PROCESS FLOW SCHEMES

Drawing GP141 MBG PROCESS BLOCK FLOW DIAGRAM

Drawing GP142 COAL PREPARATION

Drawing GP143 COAL GASIFICATION AND PARTICULATE REMOVAL

Drawing GP144 AMMONIA RECOVERY

Drawing GP145 SULFUR REMOVAL

Drawing GP146 SULFUR RECOVERY

2.1.3 MBG Plot Plan

The preliminary land requirements for the MBG Plant have been estimated as 200 acres.

A general plot plan is shown on Drawing MP 152. The preliminary plot requirements for the process units may be estimated as 40 acres.

2.2 - METHANOL

2.2.1 Process Description

The envisioned process concept for the gasification of Rio Turbio coal for the production of methanol is illustrated in Drawing GP 147. Coal is gasified and converted to a raw synthesis gas which is then treated to remove particulate. After compression and adjustment of the synthesis gas hydrogen/carbon oxide ratio by shifting and acid gas removal, the gas is compressed and converted to crude methanol. Purification of the crude methanol can produce chemical or fuel grade methanol.

Specific major technologies to be used in conjunction with the gasification system include:

CO Shift - Sulfur Tolerant (CO MO) Catalyst
Acid Gas Removel - Rectisol
Methanol Synthesis - LURGI

Process flow diagrams illustrating these technologies are given in section 2.2.2.

As in the production of MBG, for this pre-feasibility study the Westinghouse Gasification System has been selected as the candidate technology for gasification. The description which follows will give the salient features of the additional sub-sections.

Coal Preparation and Gasification

Coal is prepared, gasified and rendered free of particulate in the same manner as described in the MBG Process Description. Product particulate free gas is compressed and passes to the CO Conversion section.

CO Conversion

The purpose of the CO Conversion section is to fix the proportion of hydrogen to monoxide at the proper ratio for methanol synthesis.

This is accomplished by reacting some of the monoxide with steam over a catalyst with controlled conditions of temperature and pressure to yield hydrogen and carbon dioxide.

$$CO + H_2O = H_2 + CO_2$$

In order for the shift reaction to occur, the water content of the raw gas must be raised. This is brought about by passing the gas through a series of Raw Gas/Shifted Gas Interchangers and Raw Gas Desuperheaters where water and steam are injected. The raw gas is heated to about 600^{o}F before entering the first shift converter.

A system consisting of three Shift Converters is required to obtain the desired CO conversion and to limit the temperature rise through each bed. Between the converters the gas is cooled in the Raw Gas/Shift Exchangers. After heating the raw gas feed in the First Raw Gas/Shift Exchanger, the gases leaving the final shift converters are combined and enter the heat recovery train.

The heat recovery train comprises a MP Steam Boiler and BFW Heater, a LP Boiler, a Regenerative Condensate Heater and a Deaerator Feedwater Heater. Condensate is removed in the Feedwater Heater Separator and the Shift Cooler separator.

This condensate, together with process condensate makeup, is reheated in the Condensate Heater prior to injection into the raw gas stream.

The composition of the shifted gas is temperature controlled in the shift converters by varying the steam injection rate and by bypassing some of the raw gas around the converters.

The shifted gas (make gas) exits this system at about 100^{o}F.

Acid Gas Removal

The make gas is further prepared for conversion to methanol in this processing step. Carbon dioxide is separated, the sulfur compounds are removed and the gas is dehydrated.

The system selected for this conceptual design report is the Rectisol System. This system has been selected, rather than the Selexol System used when producing MBG, due to the methanol synthesis gas requirements for (1) the strigent sulfur removal specifications and (2) the quantity of carbon dioxide to be removed.

The make gas is contacted with chilled methanol in an absorber where the carbon dioxide and sulfur compounds (predominently hydrogen sulfide) are removed. The make gas (synthesis gas) is sent to the methanol synthesis step. The carbon dioxide and hydrogen sulfide are stripped from the methanol and separated in a series of columns. The carbon dioxide after a final washing with water is sent to the atmosphere. The hydrogen sulfide is sent to the Claus sulfur removal system which is similar to the sulfur recovery system discussed in MBG plant.

Methanol Synthesis

The synthesis gas consisting of hydrogen, carbon monoxide, carbon dioxide and some inerts (mostly methane) from the Acid Gas Removal Section is compressed to the methanol synthesis pressure. It is then passed through the Sulfur Guard Vessel containing zinc oxide in order to remove any last traces of sulfur which may be present in order to assure a long catalyst life.

The gas is cooled and combined with recycle gas from the synthesis loop flowing to the Recycle Compressor. After the gas mixture is heated by the converter effluent in the Converter Heat Exchanger it enters the Converter. The methanol Converter is a multitube unit with catalyst filled tubes surrounded by pressurized water, which are maintained at reaction temperature by the generation of steam on the shell side. The overall reactions taking place over the catalyst can be represented by the following two equations:

(1) $CO + 2H_2 \rightleftharpoons CH_3OH + \text{Heat}$

(2) $CO_2 + 3H_2 \rightleftharpoons CH_3OH + H_2O + \text{Heat}$

2.2.2 METHANOL PROCESS FLOW SCHEMES

Drawing GP147 METHANOL PROCESS BLOCK FLOW SCHEME

*Drawing GP142 COAL PREPARATION

*Drawing GP143 COAL GASIFICATION AND PARTICULATE REMOVAL

*Drawing GP144 AMMONIA RECOVERY

Drawing GP148 CO CONVERSION AND HEAT RECOVERY

Drawing GP149 ACID GAS REMOVAL

Drawing GP150 METHANOL SYNTHESIS

Drawing GP151 METHANOL DISTILLATION

*Drawing GP146 SULFUR RECOVERY

*Drawings are given in Section 2.1.2 MBG Process Flow Schemes.

2.2.3 Methanc. Plot Plan

The preliminary land requirements for the Methanol Plan have been estimated as 225 acres.

A general plot plan is shown on Drawing MP 153. The preliminary plot requirements for the process units may be estimated as 58 acres.

2.3 ANCILLARY SYSTEMS AND UTILITIES

This section consists of the utility systems and other ancillary systems supporting the operation of the MBG or the Methanol Process Units. The prinicpal units are as follows:

Ancillary System

Air Separation plant

Coal storage, receiving and handling

Process water and boiler feed water

Cooling water systems

Steam system

*Product storage

Inert gas system

Flare header, flares, and safety equipment

Solids disposal system for sulfur and ash

Environmental protection system, waste water treatment, etc.

*Required for methanol only.

These units are briefly described in the following discussion.

Air Separation

The Air Separation plant design is conventional, compression based, air purification, and cryogenic separation of air into oxygen and nitrogen. The oxygen is used in the coal gasification process. A small amount of the nitrogen is used as inert gas in the process, for CO_2 Removal and for tank blanketing while the remainder is vented. The air separation plant technology is available from several vendors as standard plant units.

Coal Storage, Receiving and Handling

The coal will be transported to the site by train. Handling systems for the receiving and transport to the coal storage area are provided. The coal storage consists of a "dead coal pile" of about 45 days plant consumption and a "live pile" with appropriate automatic equipment for the depositing and retrieval of the coal.

Flare Headers, Flares, and Safety Equipment

This unit includes the distributed system of process unit relief valves, flare headers, process vent headers, the flare stacks and their ignition systems, and any liquid knock-out vessels and pumps associated with it. As part of this unit are the safety equipment and systems for firefighting, including firefighting tanks and pumps, monitors and interconnecting pipelines. The underground process and storm water drain system will also be part of this unit.

Solids Disposal Systems (Sulfur and Ash)

The areas designated for the disposal of sulfur and agglomerated ash will be diked and lined as necessary to prevent migration of these materials in case of flooding.

The sulfur is deposited as molten elemental matter or as a granulate inert material.

The ash is an inert, nonleachable granulate which may serve as a noncompactable, dustfree landfill material. It has been assumed that only a minimum of storage is required at the site. The solids disposal system includes provisions for the transport and distribution of the solids as fill in the mine area.

Environmental Protection System

This unit consists of the monitoring equipment and disposal systems required to assure that all liquid and gaseous emissions are disposed of in an environmentally acceptable manner.

Within the plant concept there are only a few point sources of emissions of either gas or liquids from the process and utility areas. The technology for their control exists and is used in commercial plants.

Process Water and Boiler Feed Water

The water for use as process water, cooling water makeup, and boiler feed water will be drawn from the plant battery limits through a water treatment unit consisting of appropriate filters, and water conditioning tanks. In addition to the water intake system and distribution system, this unit includes process water treatment, BFW treatment and storage.

Cooling Water Systems

The cooling water requirements for makeup are drawn from process water system. A cooling tower is included to reduce the temperature of the cooling water, before it is recycled. Blow-down is discharged into the wastewater treatment system.

Steam System and Power System

This system is designed to permit the MBG or the methanol plant to operate independently from the power plant for steam requirements and the grid for power. Three levels of steam pressure are visualized, i.e. at about 600 psig for the high temperature requirements, at about 350 psig and at about 50 psig. Steam is supplied by heat recovery from the process sections (the gasification, CO-shift, and methanol synthesis) and from an auxiliary steam boiler using process waste gases and liquids, and MBG as needed.

Product Storage

Storage is provided for the methanol production and for by-product ammonia solution, while the MBG is discharged directly to pipeline for consumption by the industrial complex. The methanol storage consists of day-check tanks and finished product storage. Thirty (30) days of storage are envisioned for the methanol plant. The methanol storage includes provisions for discharging the products to shipment by tanker.

Inert Gas System

The inert gas system includes provisions for tank safety blanketing, process purging operations, and safety uses. The nitrogen obtained from the air separation plant section is used as the source of inert gas. A storage volume is provided for surges and start-up of the plant.

2.4 - CAPITAL INVESTMENT AND OPERATING REQUIREMENTS

2.4.1 BASIS OF COSTS

The coal gasification plants to produce MBG or Methanol as discussed in Sections 1, 2, 3, and 4 are similar to a number of major feasibility studies presently being conducted by Ebasco. Because of this similarity, the information in Ebasco's Data Base is with minor modifications applicable to the proposed MBG and Methanol plants at the Santa Cruz (Punto Loyola) Industrial Park.

In addition to the data from the present on-going studies, Ebasco has compiled an extensive data base as a result of client initiated gasification studies, internal studies, and literature data.

The specific methodology used to develop the U.S. Gulf Coast capital and operating cost data was to modify "in-house" data base information as required to meet the project requirements. This cost estimate was then adjusted to reflect Argentine conditions and factored by 1.45 to develop local costs. While based on previous experience, costs are budgetary in nature.

As with capital costs, operating requirements are based on industrial practice and, as a result of previous studies. Only those factors which are considered as cost effective at this prefeasibility level have been reported.

The data presented here is based upon the application of the available "in-house" data base information to the study conditions. Additional engineering analysis and estimation work will be required at the next project stage to optimize specific project parameters and validate the extrapolations and engineering judgement used to develop this planning and budget level information.

2.4.2 MBG PLANT

The estimated capital requirement for the medium BTU coal gasification as discussed in Section 2.1 is outlined in Table 2-3. The "Total Instantaneous" costs are based on a first quarter 1982 equipment and construction costs.

The cost components in the estimate of the total installed costs include process ancillary systems and utilities equipment, material, erection, A/E services, fees and normal budget level contingencies. While U.S. Gulf Coast costs were factored to account for expected Argentine condition, further studies and investigation will be required to confirm these budget level costs.

TABLE 2-3

Total "Instantaneous" Capital Requirements

MBG PLANT

	Million Dollars US$
Total Installed Costs (TIC)	1,300
Owners Costs	40
Preproject and Commissioning Cost	90
Working capital	65
Total Cost First Quarter 1982	1,495

An allowance of U.S.$ 40 Million (approximately 3% of the TIC) has been made for feasibility studies, testing, engineering and consulting to define project parameters.

Preproject and commissioning cost include cost to owner such as staff, consultation, pre-startup training and startup costs. These have been estimated at 7% of TIC.

An allowance of 5% of TIC has been made for working capital.

Inflation

For the purpose of this study a startup date of January, 1990 has been assumed. The conceptual schedule for the design erection and construction of a synthetic fuel unit for Punta Loyola is shown in Figure 5-1 of paragraph 5.1. The draw down of the bulk of project funds would occur between the third and the eighth year. For a projected U.S. inflation rate of 10% the allowance for inflation may be estimated as follows:

$$(1300 + 40 + 90)\ (1.1)^{7.5} - 1430 = \text{US\$ } 1{,}493 \text{ Million Dollars}$$

Final plant cost must reflect added cost of interest during construction and financial charges.

2.4.3 Methanol Plant

The estimated capital costs requirements for a coal based methanol plant as discussed in Section 2.2 are outlined in Table 2-4. The "total instantaneous" costs presented are based on a first quarter 1982 equipment and construction cost.

The cost components for the total installed costs included in the estimate include equipment process, ancillary systems and utilities, and material, erection, A/E services, fees and normal budget level contingencies. While U.S. Gulf Coast costs were factored to account for expected Argentine conditions, further studies and investigation will be required to confirm these budget level costs.

TABLE 2-4

Total Instantaneous Capital Requirement

Methanol Plant

	Millions, US$
Total Installed Costs (TIC)	1,580.0
Owners' Costs	47.5
Preproject and Commissioning Costs	110.5
Working Capital	80.0
Total Cost, First Quarter 1982	1,818.0

An allowance of US$ 47.5 million (approximately 3% of the TIC) has been made for feasibility studies, testing and engineering consulting to define project parameters.

Preproject and commissioning cost include cost to owner, such ... staff, consultation, prestartup training and startup costs. These have been esimtated to be 7% of the TIC.

An allowance of 5% of TIC has been made for working capital.

Inflation

For the purpose of this study, a startup date of January, 1990 has been assumed. As previously discussed under MBG paragraph 2.4.2, the allowance for inflation may be evaluated as follows:

$$(1580 + 47.5 + 110.5)\ (1.1)^{7.5} - 1738 = \text{US\$ 1,814 Million Dollars}$$

Final plant cost must reflect added cost of interest during construction and financial changes.

2.4.4 OPERATING REQUIREMENTS

2.4.4.1 Products

MBG Plant

The MBG plant is planned for a maximum net output of 79 x 10^9 BTU/Day. This capacity can be achieved for 300 days per year. The modular construction of the plant allows the plant to achieve continuous operations for longer periods at reduced rates. It is anticipated that the plant can operate for 365 days per year at an output in the order of 40 x 10^9 BTU/Day.

MBG Product

300 Days @ 79 $\bar{B}$ BTU/Day =	23,700 $\bar{B}$ BTU[(1)]
65 Days @ 40 $\bar{B}$ BTU/Day =	2,600 $\bar{B}$ BTU[(1)]
Total $\bar{B}$ BTU/Year	26,300

(1) $\bar{B}$ BTU = 10^9 BTU

Methanol

Methanol plant is planned for production capacity of 2850 MT/D of Fuel Grade Methanol per 24 hr. day. The plant will be designed to operate 300 days per year.

Methanol Product

Annual Production Rate = 855,000 MT/Year

By Products

The gasification of 5450 MT/D of Rio Turbio coal will produce the following by products.

Elemental Sulfur	35.7 MT/D
Anhydrous Ammonia	60 MT/D

In additon to elemental sulfur and anhydrous ammonia which can be sold as by-products the plant produces 735 T/D of Ash Agglomerate which can be used as dry fill if there is a local need.

2.4.4.2 Raw Material Utilities and Chemicals

The MBG and the Methanol plants have been designed as self sufficient units requiring only coal and fresh water.

The estimated raw material requirements when the plants are operated at design capacity is as follows:

MBG

Coal	5450 MTD (HHV 10,940 BTU/LB)
Water[1]	5000 USGPM (27,240 CU. METERS/DAY
Chemicals[2]	4900 US$/Day

Methanol

Coal	5450 MTD (HHV 10,940 BTU/LB)
Water[3]	8400 USGPM (46,450 CU. METERS/DAY
Chemicals[4]	5000 US$/Day

(1) Based on a U.S. cost of U.S.$ 0.6/1000 GPM Daily cost is U.S. $4320.
(2) Cost based chemicals and consumables of U.S. $0.9/MT of coal consumed.
(3) Based on a U.S. cost of $0.6/1000 GPM daily cost is U.S. $7257.
(4) Based on chemicals and consumables of US $1.75/MT of Methanol.

2.4.4.3 Operating Costs

Lock Staff Requirements

The staffing requirement of the synthetic fuel complex when operated as a self sufficient autonomous unit for the production of MBG or Methanol is given in Table 2-5.

TABLE 2-5

Local Operating Staff

Function	Staff MBG	Staff Methanol
Plant Administration	45	45
Engineering and Laboratory	50	50
Operations		
Process, Utilities Solids handling	165	180
Maintenance	175	200
Stores	15	20
Total	450	495

The average individual annual cost for the staff may be assumed as US$ 30,000 for total annual operating local staff cost of US$ 13,500,000, and US$ 14,350,000 for MBG and Methanol, respectively.

Technical Assistance

Technical assistance will be required for startup and during the early years of plant operations. An allowance of US$ 3,000,000 should be added to the MBG and Methanol operating costs for this assistance. This will decrease in a straight line over the first five years of operations.

General Expenses

General expenses not included in local staff cost or technical assistance may be assumed on the order of 40% of the local staff costs.

Maintenance Costs

Maintenance costs, i.e. spare parts which are in addition to the cost of maintenance included in the local staff costs, may be estimated at 2% of the total installed cost (TIC) of the MBG and the methanol, respectively.

In addition, the following allowance for contracted maintenance labor costs should be added for assistance during shutdown, turnaround, and major maintenance operations which local staff cannot perform.

MBG	US$ 8,500,000
Methanol	US$ 10,500,000

Insurance Costs

An allowance of 0.5% of TIC of the Ammonia/Urea Complex should be included in the operating costs for plant insurance.

2.4.5 CONVERSION METHANOL-TO-GASOLINE

The conversion of methanol-to-gasoline can be accomplished using a process developed by Mobil Oil Corporation. Since 1975, the process has been tested on a four (4) bbl/day pilot unit at Mobil's Paulsboro, New Jersey facility.

Based on information from available literature the operating requirements and products produced for a facility utilizing a methanol feedstock of 2850 MT/D are illustrated in the following tables.

Typical Economics For Fixed-Bed System

Basis	
1982, U.S. Gulf Coast	
Methanol required	
100% pure	22170 bbl/day (2850 MT/D)
Gasoline product	8900 bbl/day
C_3/C_4 LPG product	1970 bbl/day
Capital Investment	U.S.$ 110 Million

Typical Properties of Finished Gasoline

Components, wt. %		Composition, Vol. %	
Butanes	3.0	Paraffins	53
Alkylate	3.0	Olefins	12
C_5+ gasoline	94.0	Naphthenes	7
	100.0	Aromatés	28
			100

An order of magnitude capital cost of U.S. $ 110 million would be required to produce 8900 bbl/day of gasoline from a methanol feedstock of 2850 MT/D for a Gulf Coast location. The process would achieve approximately a 90 percent energy recovery from the methanol feedstock including by-product C_3/C_4 LPG.

2.5 - PLANT LOCATION

The Rio Gallegos location was selected for the synthetic fuel complex because of the reported lack of adequate water resources at Rio Turbio.

The relative advantages of each location has been discussed previously.

Using available information from in-house studies, there appears to be an economic advantage for the Rio Gallegos location when producing MBG.

Economic Criteria for Evaluation

Cost of transport by rail for 200 miles	US$ 2.40/ST
	US$ 5.2 million/year
Annualized coal transport cost (1)	US$ 14.5 million
Capital cost of pipeline	US$ 100 million
Fixed charge rate	18%
Annual Capital Recovery Costs	US$ 18 billion

In addition fuel operating requirement for pipeline compression station consume 1.6 billion BTU/D of product MBG.

While annual capital recovery charges for methanol pipeline will require approximately 1/3 of the MBG pipeline cost a definitive study of water availability is required before Rio Turbio location is selected for methanol plant site.

(1) Inflation Factor 10%
Weighted cost of capital 12%

3 - REVIEW OF GASIFICATION TECHNOLOGY

3.1 Overview

The gasification of coal is essentially the reaction of coal, steam and oxygen at elevated temperatures to produce a coal gas. To achieve the required temperatures the coal is partially oxidized with either air or essentially pure oxygen. When the source of oxygen is air, the gas produced has a heating value of approximately 100-150 Btu/Scf and is called low Btu gas (LBG). When the oxidant is 98-99.5 percent oxygen the gas produced will have a heating value of 250-350 Btu/Scf and is called medium Btu gas (MBG). The primary constituents in the gas are carbon monoxide, carbon dioxide, hydrogen with varying quantities of methane, tars and oils depending on the gasification technology employed.

The principal commercially available technologies are:

- Fixed Bed

  Lurgi Dry Ash
  BGC/Lurgi Slagger

- Fluid Bed

  Westinghouse
  Winkler

- Entrained Bed

  Texaco
  Shell-Koppers
  KBW Gasification Systems

Worldwide research efforts in the gasification of coal have led to the development of approximately twenty gasifier technologies. The most significant development work being pursued today is high pressure gasification which can lead to the reduction in both overall gasification energy requirements and the capital investment of the gasification facility as whole.

3.2 Criteria for Selection of Gasification Systems

Current state-of-the-art of coal gasification technology can be grouped into three categories fixed, fluid and entrained bed systems. The associated characteristics for each group of gasifiers are illustrated in figure 3.2.2A entitled "Comparison of Gasifier Systems". The principle characteristics to be noted are the increase in product gas temperature, change in product slate and coal feedstock associated with each group of gasifiers.

Specifically, fixed bed gasifiers produce a product gas with considerable amounts of tars, oils and methane. Methane is the only hydrocarbon found in the product gas from fluid bed gasifiers, while the entrained bed product gases are free of all hydrocarbons. In general, the flexibility as to potential coal feed, the simplicity of raw gas treatment and the capacity (lbs coal/sq. ft. of gasifier cross section) the inertness of the solid product (ash/slag) increases moving from fixed, to fluid to entrained bed. These benefits are offset by an increase in requirements, the fraction of coal completely combusted and increase in potential corrosion and erosion problems.

The "Principle Criteria for Gasifier Evaluation", are illustrated in figures 3.2.2B. While from a process point in view, the main criteria in the selection of a gasifier technology is a fit between the coal type, product gas and thermal efficiency, the need for a reliable mechanical operation is of prime importance. A balance between process requirements and mechanical implementation is, therefore, necessary to provide overall efficient plant operation.

An initial screening of a gasifier technology for a specific project such as production of MBG or a synthesis gas for the production of methanol involves evaluation of each potentially applicable gasifier, and its suitability to the coal feedstock available and the product gas end uses. The thermal efficiencies, state of technical development, and mechanical reliability must also be evaluated and analyzed.

FIGURE 3.2.2 A

COMPARISON OF GASIFIER SYSTEMS

CRITERIA	FIXED BED	FLUIDIZED BED	ENTRAINED BED
GAS TEMPERATURE	900-1100° F	1600 - 1800° F	2500 - 2600° F
PRODUCT SLATE IN GAS	TARS, OIL, CH_4 CO, H_2	CH_4, CO, H_2, CHAR	CO, H_2, SLAG PARTICULATE
GAS VELOCITY	< 1 FPS	1 - 10 FPS	>10 FPS
COAL TYPE	NON-CAKING	CAKING	CAKING
BY-PRODUCTS	DRY ASH, TARS OIL SLUDGE, SULFUR	DRY AGGLOMERATES, SULFUR	SLAG-WATER SLURRY, SLUDGE, SULFUR
MATERIALS PROBLEMS	CORROSION	CORROSION	CORROSION, EROSION, HIGH TEMPERATURE
THROUGHPUT PER UNIT AREA	LOW	MEDIUM	HIGH
PROCESS RESPONSE	SLOW	MODERATE	FAST

FIGURE 3.2.2 B

PRINCIPLE CRITERIA FOR GASIFIER EVALUATION RELIABLE OPERATION

- ABILITY TO GASIFY PROJECTED RANGE OF COALS
- ADAPTABILITY TO PRESSURE GASIFICATION
- HIGH THERMAL EFFICIENCY AND INTEGRATION WITH DOWNSTREAM PROCESSES
- ANTICIPATED MECHANICAL RELIABILITY
  - COAL AND OXYGEN FEED SYSTEM
  - SLAG DISCHARGE SYSTEM
  - HEAT RECOVERY SYSTEM
  - REFRACTORY SYSTEM
- STATE OF TECHNICAL DEVELOPMENT
- ANTICIPATED ENVIRONMENT FACILITIES REQUIRED
- COMMERCIAL COMMITMENTS

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The selection of a gasifier technology is critical to the technical and economic success of the project. Reliable data from pilot plant runs and/or existing commercial plant operations for the specific coal feedstocks anticipated are necessary to confirm and validate the selection of a gasifier technology.

The data required and procedures used in generating the necessary information to be analyzed for gasifier selection are discussed in Section 4, Data Development and Testing Program.

3.3.1 - LURGI

3.3.1 History and Commercial Status

The Lurgi dry bottom is the best known commercially proven gasification process. The first work dates back to 1936. Since 1961, it has operated on a large scale at several locations to produce, town gas, synthesis gas and low Btu gas, using subbituminous, lignite and anthracite coals.

The most recent concept being test is the Lurgi Ruhr-100, which incorporates the following two improvements:

- o Operates at 100 atmospheres versus 35 atmosphers for the Lurgi/Mark IV, presumably inabiling it to increase gasifier through-put.
- o A second gas stream which does not contain any tars or oils is withdrawn from the middle of the bed, reducing the problem of tar and oil removal from the primary gas stream.

The project started up in September, 1979, with initial operation of 75-170 TPD of coal feed and a pressure of 25-40 atm, work is being done by Ruhr-Gas in Dorsten, West Germany.

The other projects in the demonstration state are a 1700 TPD unit, operated by KDV-Plant in Lumne, West Germany where chnages are being made to improve efficiency, and a 14,000 TPD plant using lignite coal is being planned by Great Plains Gasification Associates, Mercer County, North Dakota which has recently received a loan guarantee from the U.S. Synthetic Fuels Corporation.

3.3.1 Process Description

Lurgi pressure gasification of coal is an autothermic, counter-current, fixed bed, dry ash process which utilizes mixtures of steam and oxygen, steam and air, or steam and oxygen enriched air as the gasifying medium.

Coal Preparation and Gasifier Feeding

The crushed coal with fines eliminated through screening is conveyed to the coal bunker which is an atmospheric pressure vessel that normally contains approximately a 3 hour supply of coal. Coal then passes to the coal lock chamber through the coal distributor and into the gasifier. Under full load operation, coal supply in the lock is equivalent to about 15 minutes of operation. The lock operation, is therefore, cyclic at this interval. The coal lock is normally pressurized with downstream gases but can also be operated with an inert gas such as nitrogen or a low value by-product gas such as carbon dioxide. The coal distributor is a hydraulically or mechanically operated rotary device through which coal is introduced into the reactor to achieve an even distribution of coal across the reactor cross-section. To accomodate caking coal, blades are mounted on the distributor which rotates within the fuel bed. These blades not only agitate the bed, thereby preventing agglomeration or breaking up agglomerates, but also work to constantly move char from below upwards into the combustion zone. The mixing of this recycled char with a caking coal reduces its caking tendency through dilution or leaning.

Gasification and Heat Recovery

Referring to figure 3.3.1A and starting at the bottom of the reactor, the gasification process proceeds as follows. Oxygen required for combustion, and steam for gasification, enter the gasifier through slots in the rotary grate and flow upward through the ash bed. The ash bed helps to distribute the mixture evenly over the entire cross section of the gasifier. The oxygen is completely consumed in a narrow combustion zone above the ash bed where it reacts with the carbon contained in the downward moving char. Upon leaving the combustion zone, the gas is typically at a temperature of about 2200°F. As gasification progresses, sensible heat supplies the required reaction heat and gas temperature falls to the final reaction temperature where the gasification rates become negligible. This temperature depends on the reactivity of the coal and vaires between 1200°F for lignite and 1560°F for coke.

Gases leaving the gasification zone are still at relatively high temperatures (1350-1700°F). A significant portion of the sensible heat of the gas is recovered in carbonizing, drying, and preheating the coal as it moves downward in the gasification zone. The gas outlet temperature from the reactor is, therefore, relatively low. It varies between 570°F for a lignite with a high moisture content and 1200°F for coals with a low reactivity and low moisture content.

Starting at the bottom of the reactor, the coal is subjected to the following processing steps. Incoming ambient temperature coal is preheated and dried by effluent gases. As the coal gravitates downward and its temperature rises, most of the volatile components are stripped from it and eventually recovered as by-products. Then, beginning at a temperature of 1100 to 1380°F, devolatization is accomplished by gasification of the resulting char. The interaction between devolatization and gasification is a determining factor for the kinetics of the gasification process as a whole. The minimum residence time of a coal grain for good performance of the reactions at the desired temperature level of 1290 to 1650°F is about ½ to 1 hour. Unreacted carbon is finally burned from the ash in the combustion zone and a nearly carbon free dry ash is discharged by the rotary grate.

Referring to figures 3.3.1B and 3.3.1C, the raw gas leaving the reactor is then scrubbed to remove dust and the heavier liquid hydrocarbons produced in the gasifier. Hot gases exiting the gasifier are washed with a circulating steam of impure water referred to as gas liquor. This cools the gas and removes the dust and most of the tar. The temperature exiting the scrubber is such that the saturated gas and gas liquor leaving the scurbber transfers the heat from the raw gas to the waste heat boiler, water of saturation is condensed, resulting in a net production of liquor. This liquor, containing dust and condensed tar and oil, is continuously discharged to the gas liquor separation area for recovery of by-products.

FIGURE 3.3.1 A

THE LURGI DRY ASH GASIFIER

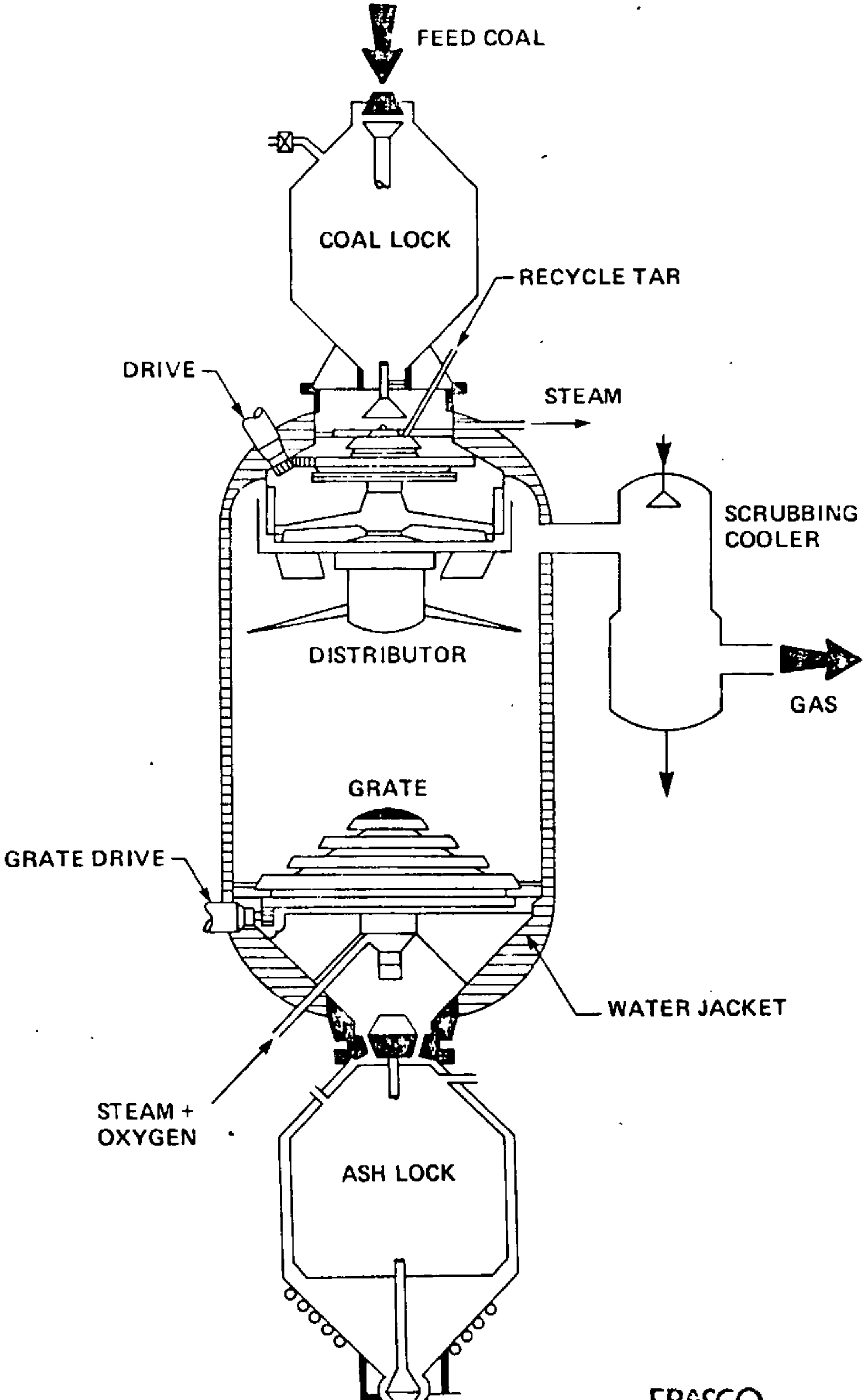

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FIGURE 3.3.1 B

LURGI COAL GASIFICATION AND RAW GAS SCRUBBING

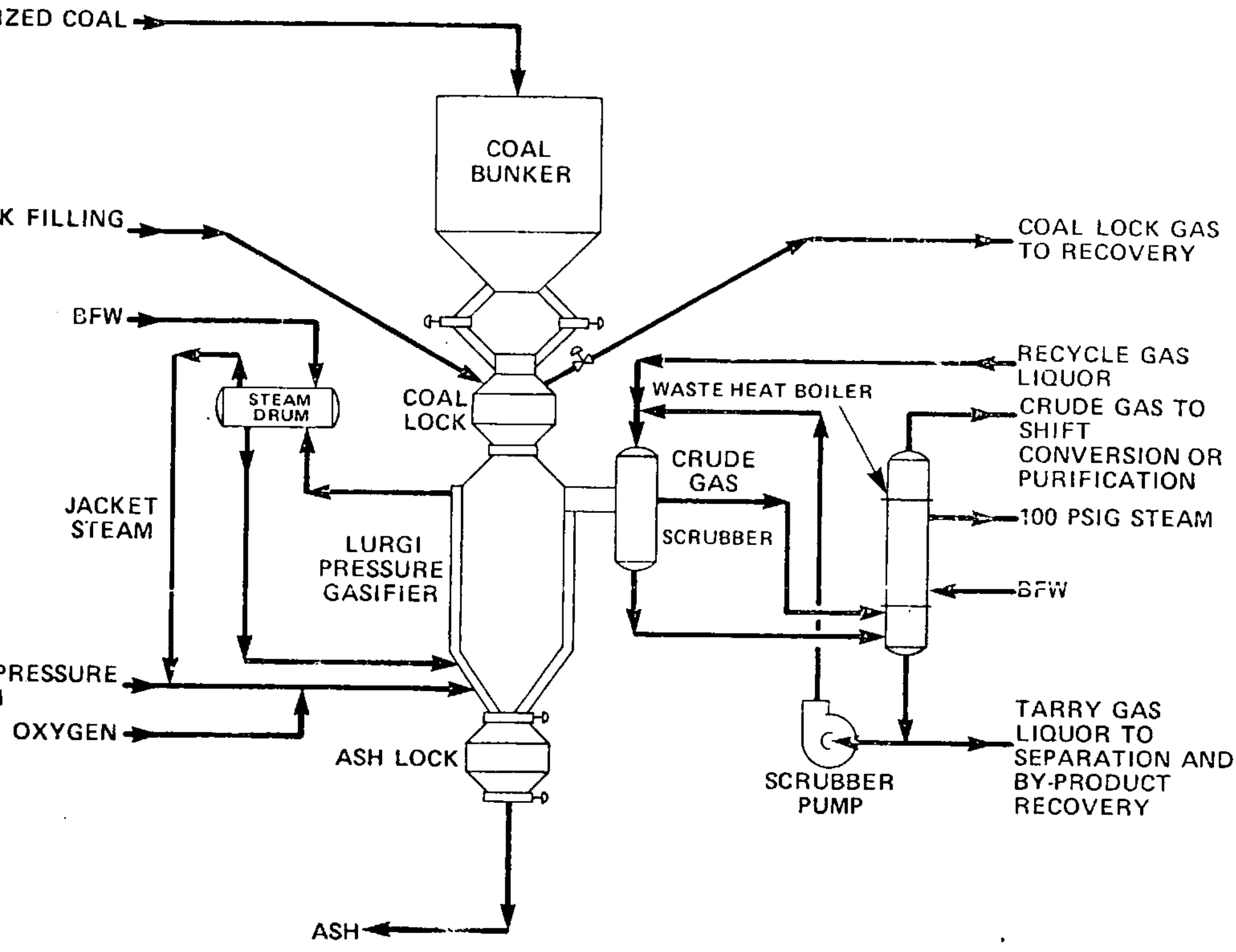
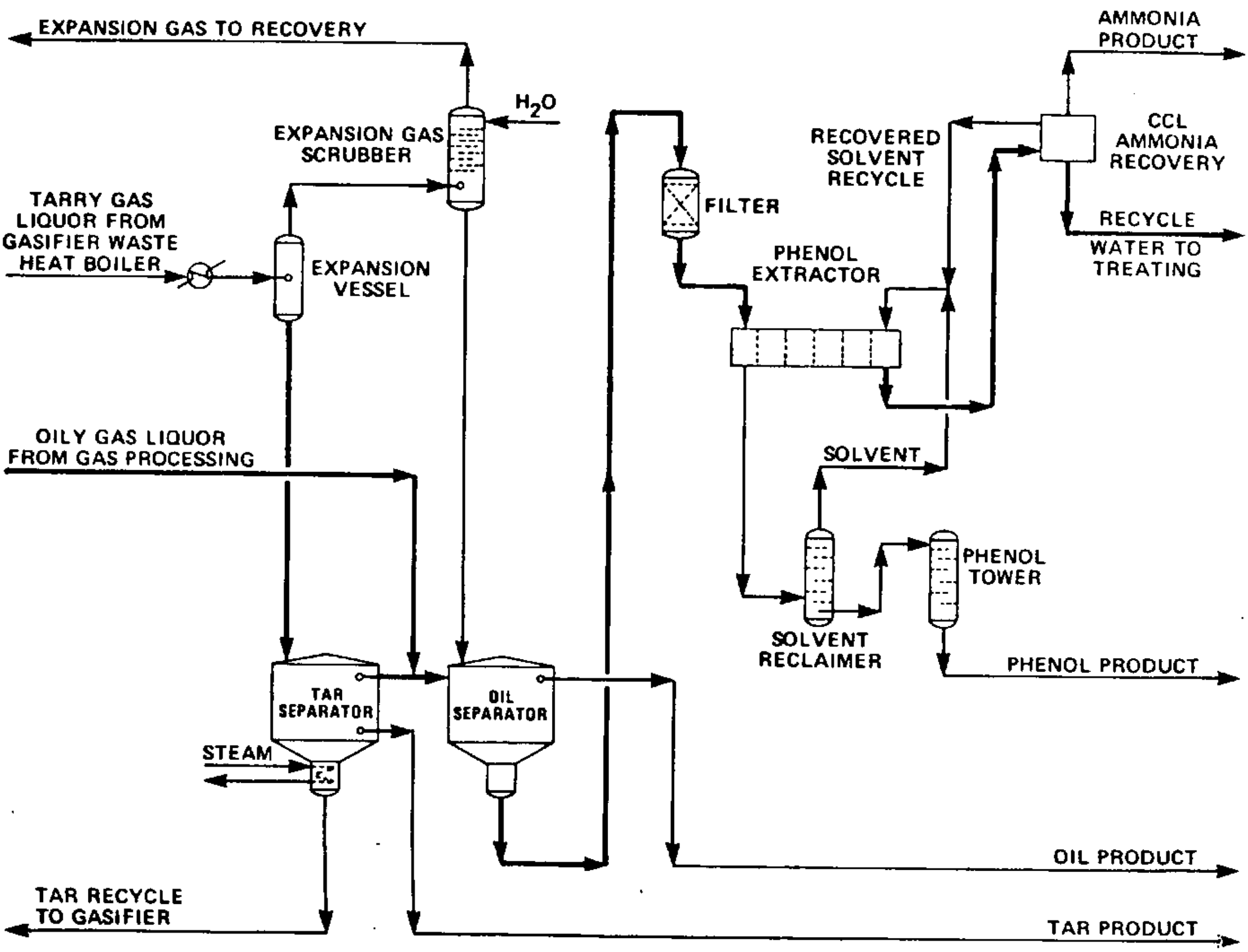


FIGURE 3.3.1 C

LURGI GAS LIQUOR PROCESSING AND BY-PRODUCT RECOVERY



3.3.2 BRITISH GAS/LURGI SLAGGER

3.3.2 History and Commercial Status

The Lurgi Slagger coal gasification process is the result of a joint effort of the British Gas Corporation and Lurgi Company technology. Since 1974, the British Gas Corporation, under the sponsorship of fifteen (15) U.S. companies, have been testing the process at Westfield, Scotland. The gasifier at Westfield is a 400 ton per day unit and to date has gasified over 50,000 tons of coal.

The U.S. coals tested include Pittsburgh 8 and Ohio 9 which are strongly caking and high swelling coals having moisture and ash contents in the range of 1.4-14.7 and 11.5-20.8 weight percent, respectively. These tests have shown no appreciable performance differences between weakly caking and highly caking high volatile bitminious coals.

There are two development stage projects utilizing the Lurgi Slagger technology. These include the Conoco, Coal Development project to be located in Noble County, Ohio utilizing 1250 ton per day of coal to produce 19 MMCFD of high Btu gas and the British Gas Corporation plans to begin operation of a 600-800 TPD unit by 1982.

BRITISH GAS/LURGI SLAGGER

3.3.2 Process Description

The British Gas Slagger is a high pressure, fixed bed, gravitional flow process which utilizes steam and oxygen as the gasification agents.

Coal Preparation and Gasifier Feeding

The crushed coal is fed from the bunkers to the coal lock chamber at the top of the gasifier similar to the Lurgi Dry Ash. The coal leaving the hopper enters a storage volume at the top of the gasifier from which it is delivered by a rotary distributor. This distributor ensures that the coal level in the gasification portion of the gasifier remains constant. Attached to the distributor and rotating with it is a stirrer which breaks up any agglomerates formed in the carbonization zone when using caking coals.

Gasification and Heat Recovery

Referring to figures 3.3.2A, high pressure steam and oxygen pass through flow controls and are blended together and fed to the base of the gasification section through tuyeres entering into the combustion area, where the oxygen is consumed. The gaseous products pass up through the bed with further endothermic gasification reactions occuring until the carbonization region is reached.

The gas leaves from the top of the carbonization zone and passes to the quench chamber where it is cooled by aqueous condensate. The recirculated condensate from the primary gas cooler with make-up from the liquor condensing in the quench cooler and primary gas cooler pass to the liquor spearation section. The tar and oils formed can either be recycled and injected through the tuyeres or can be sold as a by-product. The gas purification section is similar to that illustrated for the Lurgi Dry Ash, figures 3.3.1B and 3.3.1C.

Referring to figure 3.3.2B, the slag at the base of the gasification section collects in the hearth from which it is discharged through a slag tap hole into the slag quench chamber through which warm water is circulated.

FIGURE 3.3.2 A

THE SLAGGING GASIFIER

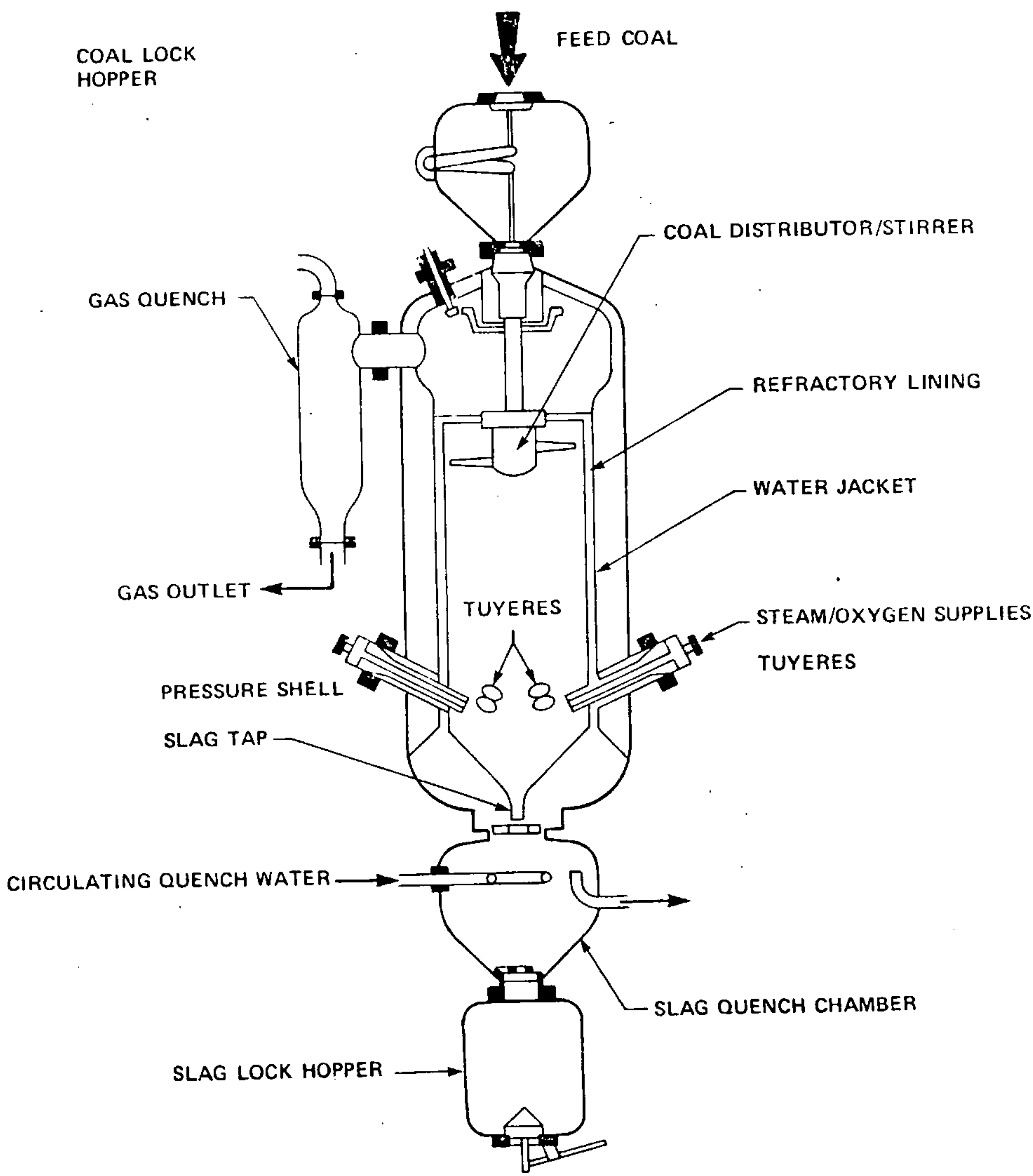


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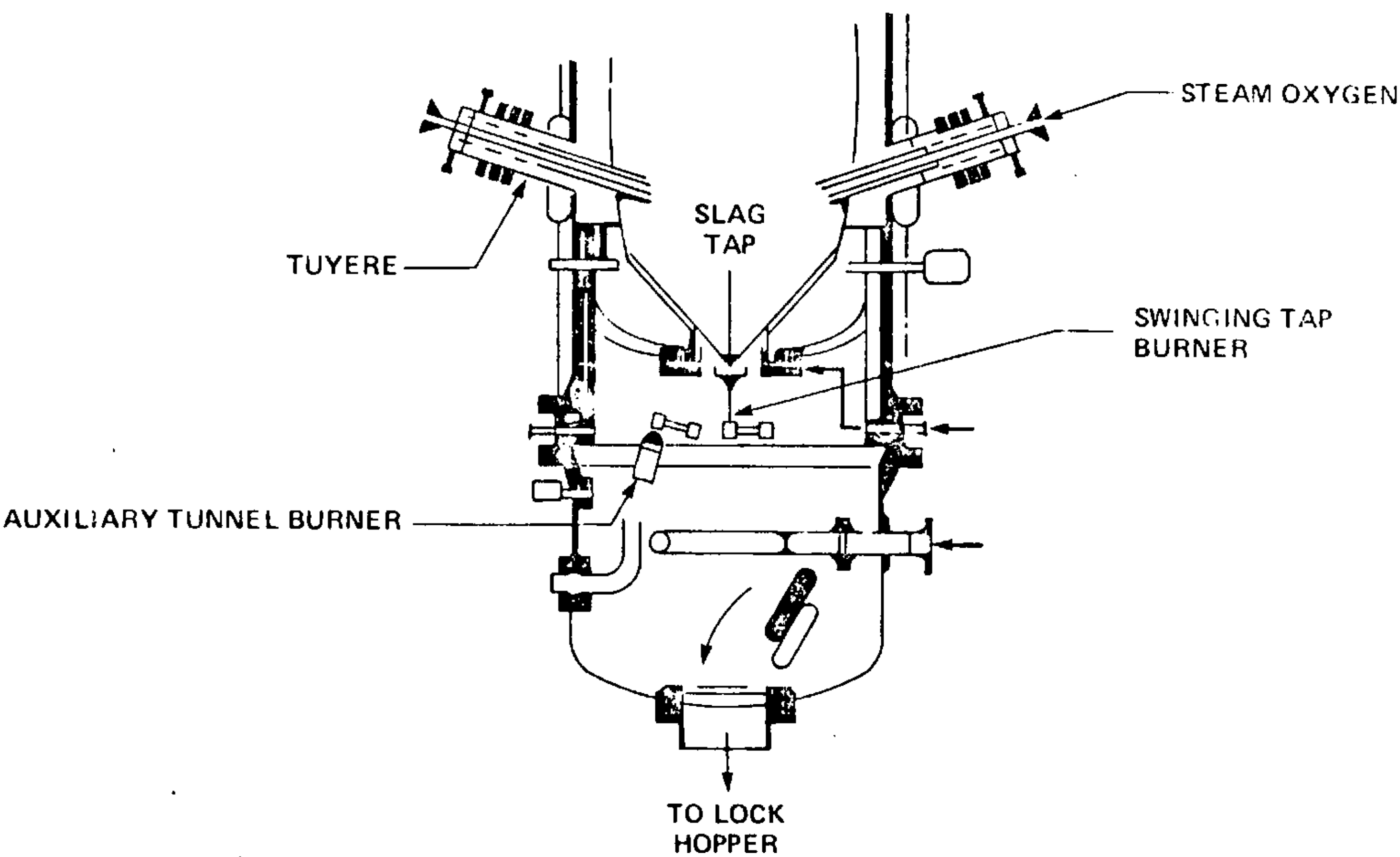
FIGURE 3.3.2 B

BG LURGI-SLAGGING GASIFIER SLAG REMOVAL



3.3.3 - WESTINGHOUSE

3.3.3 History and Commercial Status

Westinghouse has been engaged in the development of a pressurized fluidized bed coal gasification process since 1972, these efforts have resulted in a single-stage air or oxygen blown coal gasification technology.

Beginning in 1975, the Energy Research and Development Administration and the Coal Research Institute with the U.S. Department of Energy (DOE) have directed the program toward the development of a medium Btu, oxygen blown process.

Currently, research and development efforts are being carried out in a 15 ton per day process development unit (PDU) at Walts Mill, Pennsylvania, which has achieved over 7000 hours of operation. Based on the results obtained from the PDU, commercial plant designs have been considered by:

- NASA/LEWIS Research Center
- Gulf States Utilities
- Westinghouse Lamp Division Plant
- Gas Research Institute

A feasibility study has been granted by the U.S. DOE to Westinghouse for the Keystone Methanol Project. The Keystone Methanol Project would use Pennsylvania coal to produce methanol at a site in Cambria-Somerset County using the Westinghouse coal gasification pressurized, fluidized bed technology. Long range plans anticipate a 10,500 Bbl/day prototype plant on stream by 1985, with the potential to increase methanol production to 100,000 Bbl/day.

The most recent development for the use of the Westinghouse gasifier in a commercial application is in Secunda, South Africa.

The project involves a 1200 ton of coal per day gasifier at the South African Coal, Oil and Gas Corp (SASOL) complex. The gasifier is expected to come on-stream in 1983 producing a synthesis gas which will be used as a feedstock in existing downstream liquefaction processes.

3.3.3 Process Description

The Westinghouse gasification process is a high pressure, dry ash, fluidized bed reactor which utilizes steam and oxygen or air as the gasification media.

Coal Handling and Gasifier Feeding

The fresh, unpretreated coal is ground to a 3/16 by 0-inch size or smaller and conveyed by bucket elevator to the coal lockhoppers, which provides feed control through rotary feeders. Load cells monitor the feed rate by providing a continuous measure of lockhopper inventory. Recycled product gas is used to transport the coal as well as char-fines recycled from the collection cyclone downstream of the gasifier. The coal is then fed to the gasifier along its center line, where it is combusted in a stream of oxygen or air and steam through a central feed tube.

Gasification and Heat Recovery

Referring to Figures 3.3.3A and 3.3.3B, sized coal and recycled fines from the downstream cyclone are transported by recycled product gas and fed to the gasifier combustion chamber along with a stream of oxygen or air and steam. The oxidant and steam react with the coal and char to form hydrogen and carbon monoxide. As the bed of char circulates through the jet, the carbon in the char is consumed by combustion and gasification, leaving particles that are rich in ash. The ash-rich particles contain mineral compounds and eutectics that melt at temperatures of 1000 to 2000°F. These liquid phases within the char particles extrude through the pores to the surface of the char, where they stick to other liquid droplets on adjacent particles. Ash agglomerates form that are larger and denser then the particles of char in the bed. The agglomerates defluidize, migrate to the annulus around the feed tube and are continuously removed by a rotary feeder to the lockhoppers. Recycled product gas or steam is used to partially fluidize the ash and cool it as it is withdrawn.

The raw product gas, containing methane, hydrogen, carbon monoxide, carbon dioxide and gaseous impurities exit the reactor at approximately 1800^{o}F. A refractory-lined cyclone is used to remove char particles from the raw gas before it is quench-cooled in a quench scrubber that also removes most of the remaining particulate matter. The char fines collected in the cyclone are pneumatically transported to the lock-hoppers from which they are reinjected into the gasifier along with the fresh coal. All of the fines collected and recycled are consumed by the combustion, gasification and agglomeration processes within the reactor.

FIGURE 3.3.3 A

WESTINGHOUSE GASIFIER

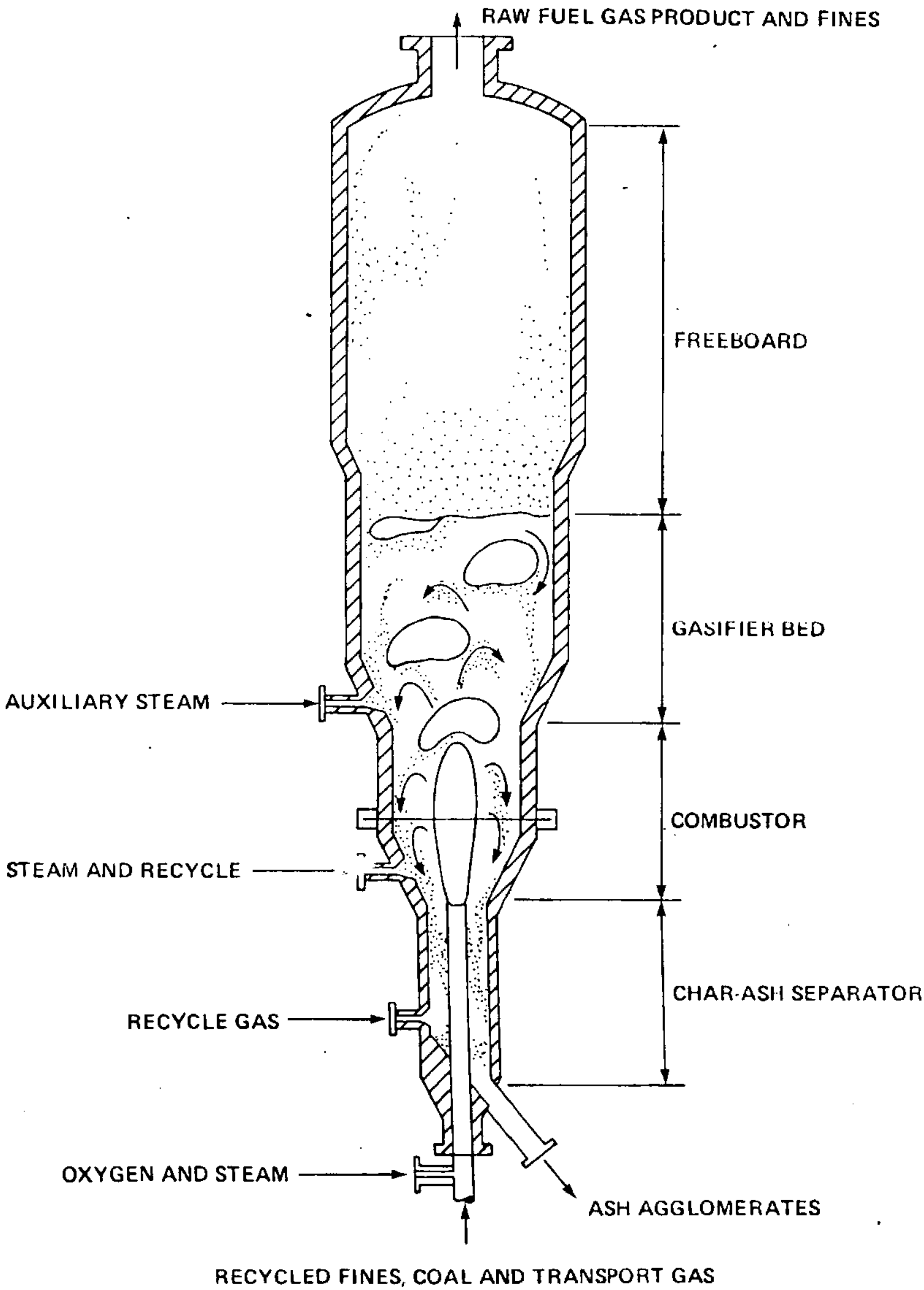
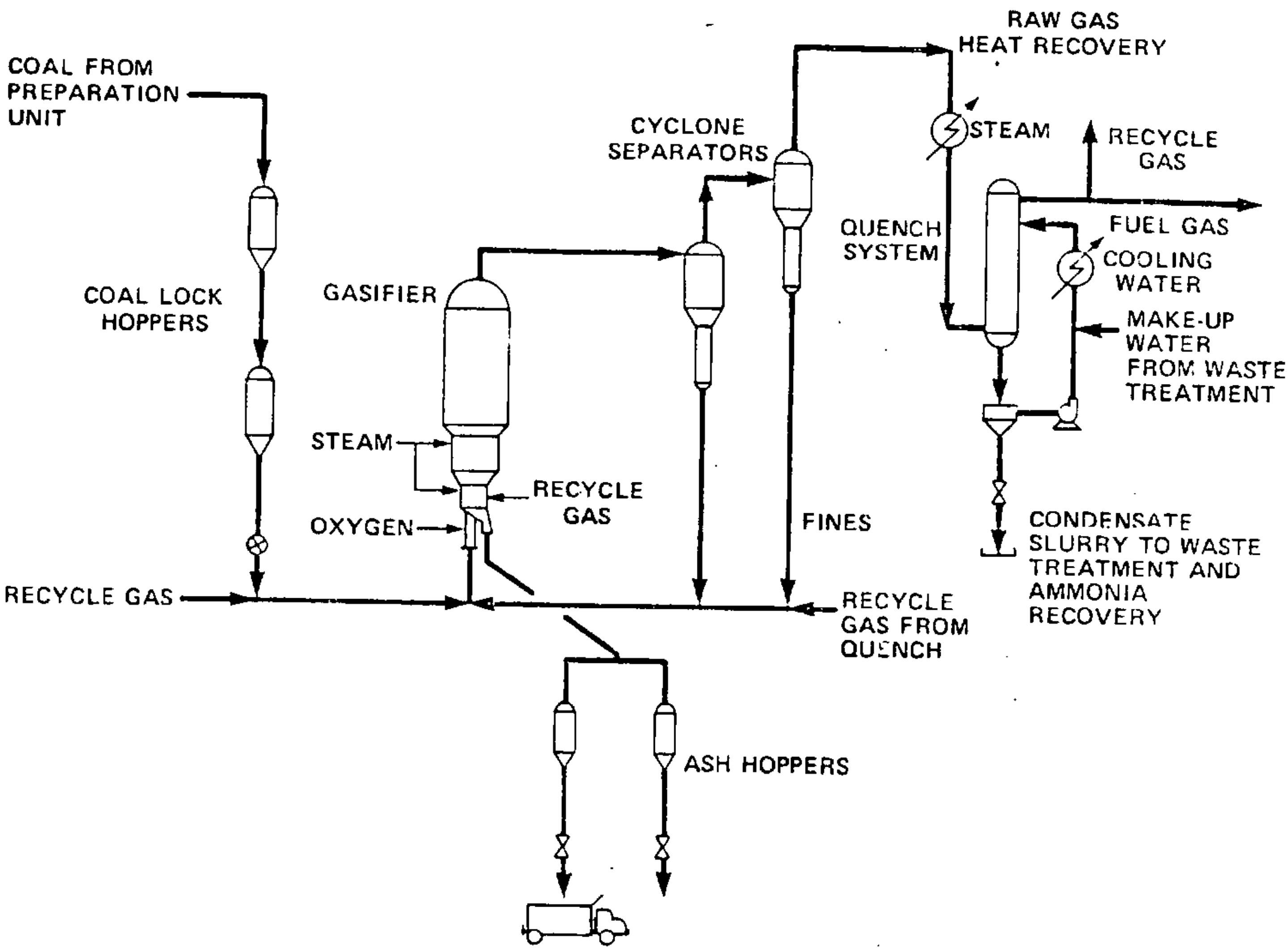


FIGURE 3.3.3 B

WESTINGHOUSE PROCESS SCHEMATIC



3.3.4 - TEXACO

3.3.4 History and Commercial Status

Texaco's process for the gasification of coal is an outgrowth of its partial oxidation of heavy petroleum fractions to produce hydrogen.

Texaco operates a process development unit in Montebello, California, which is rated at 15 TPD of coal fed, operating at forty (40) atmospheres and temperatures above the ash slagging point.

Two other Texaco units are also in operation, Ruhrkohle of West Germany started up a 150 TPD plant in 1978 which is now testing various coal feedstocks and slurry concentrations and Tennessee Vallety Authority is operating a unit rated at 200 TPD of coal which came on stream in October, 1980.

A number of additional projects at various levels of study, testing and design have been announced.

3.3.4 Process Description

The Texaco gasification process is a high pressure, entrained flow, slagging unit which utilizes oxygen and steam as the gasification agents.

Coal Preparation and Gasifier Feeding

The Texaco unit utilizes a coal slurry feed as the charge to the gasifier. The coal preparation system is comprised of coal silos, gravimetric feeders, grinding mills, mill slurry tanks and pumps, vibrating screening, first stage slurry tanks and pumps, and other auxillary facilities to assure the production of a coal slurry feed with the design concentration and particulate size distirbution. Slurry concentration is usually 55-65 percent solids.

Coal at 1-¼"x0" size is reclaimed from the slurry preparation silo to the gravimetric feeder. It is mixed with the slurry containing water and oversized particles separated by the vibrating screens. The slurry thus formed is discharged into the grinding mill. The grinding mill is a horizontal, cyclindrical, size reduction device that tumbles the material through grinding rods to effect the required size reduction.

When the coal slurry is up to specification it is transfereed to the run tank by circulation pumps. The slurry is then charged to the gasifier through a Texaco proprietary burner by charge pump.

To reduce oxygen consumption the coal slurry is preheated before it is charged to the refractory-lined reactor.

Gasification and Heat Recovery

Refer to Process Block Diagrams, figures 3.3.4A and 3.3.4B, for the inter-relationship between the plant subsystems, and for plant effluent streams.

The gasifier consists of a steel shell pressure vessel of cylindrical configuration and with a semi-hemispherical head and bottom. The top section of the gasifier is lined with a special refraction material designed to withstand the reducing atmosphere. The coal slurry is charged into the gasifier with oxygen and is atomized and entrained in the gas flow. The reaction is complete in approximately 10 seconds rising the temperature to about 2300-2600^{o}F to produce a gas consisting mainly of CO, H_2, CO_2. Most of the sulfur in the coal is converted to H_2S the balance being COS. Nitrogen and argon from the oxygen feed appear in the gas together with most of the nitrogen from the coal. The gas contains a small amount of methane and is essentially free of uncombined oxygen. The unconverted carbon and all of the ash exit the gasifier in the form of slag.

The gas products exit the reactor and can be cooled by either one of the following methods:

1. Gas-cooler/High Pressure-Boiler Mode (Figure 3.3.4C)

   In the gas cooler mode, the gas goes through the radiant heat boiler and the waste heat boiler to generate heat pressure steam. The gas is further cooled in the BFW heater before entering the scrubber for carbon soot particulates removal.

2. Water-Quench/Low Pressure Boiler Mode (Figure 3.3.4D)

   In the water quench mode, the raw gas and slag are quenched in the quench chamber below the gasifier. The raw gas then goes through a venturi scrubber and scrubber separator to remove any entrained slag particulates.

In both modes, the slag removal systems are identical. Solified slag is collected in a slag lockhopper which serves also as a pressure barrier. The slag is periodically discharged to a slag sump and removed by a scraper conveyed to the disposal area.

FIGURE 3.3.4 A

TEXACO COAL GASIFICATION PROCESS GAS COOLER MODE

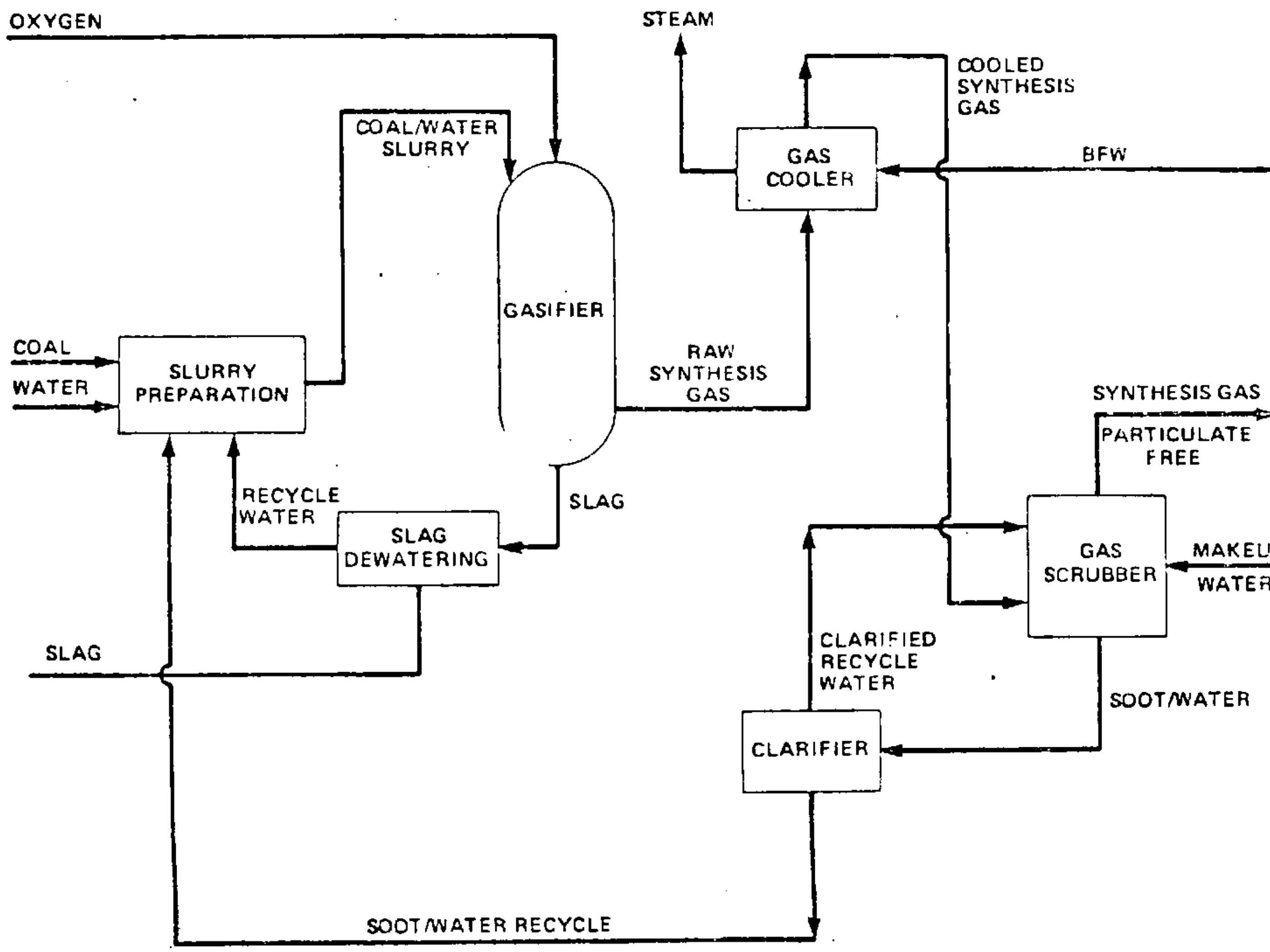


FIGURE 3.3.4 B

TEXACO COAL GASIFICATION PROCESS
Direct Quench Mode

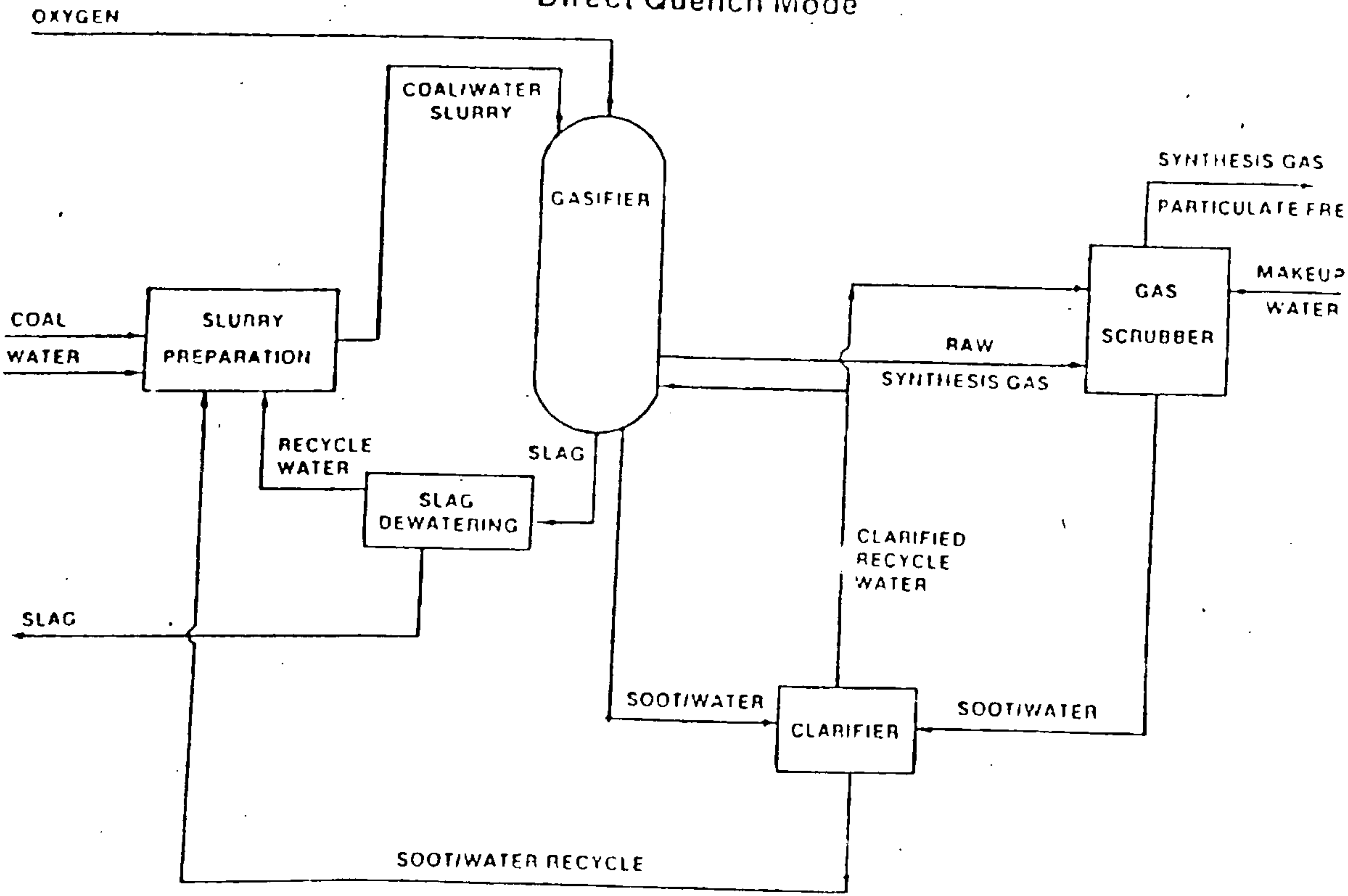


FIGURE 3.3.4 C

RADIANT SECTION OF TEXACO GASIFIER
(Gas Cooler Mode)

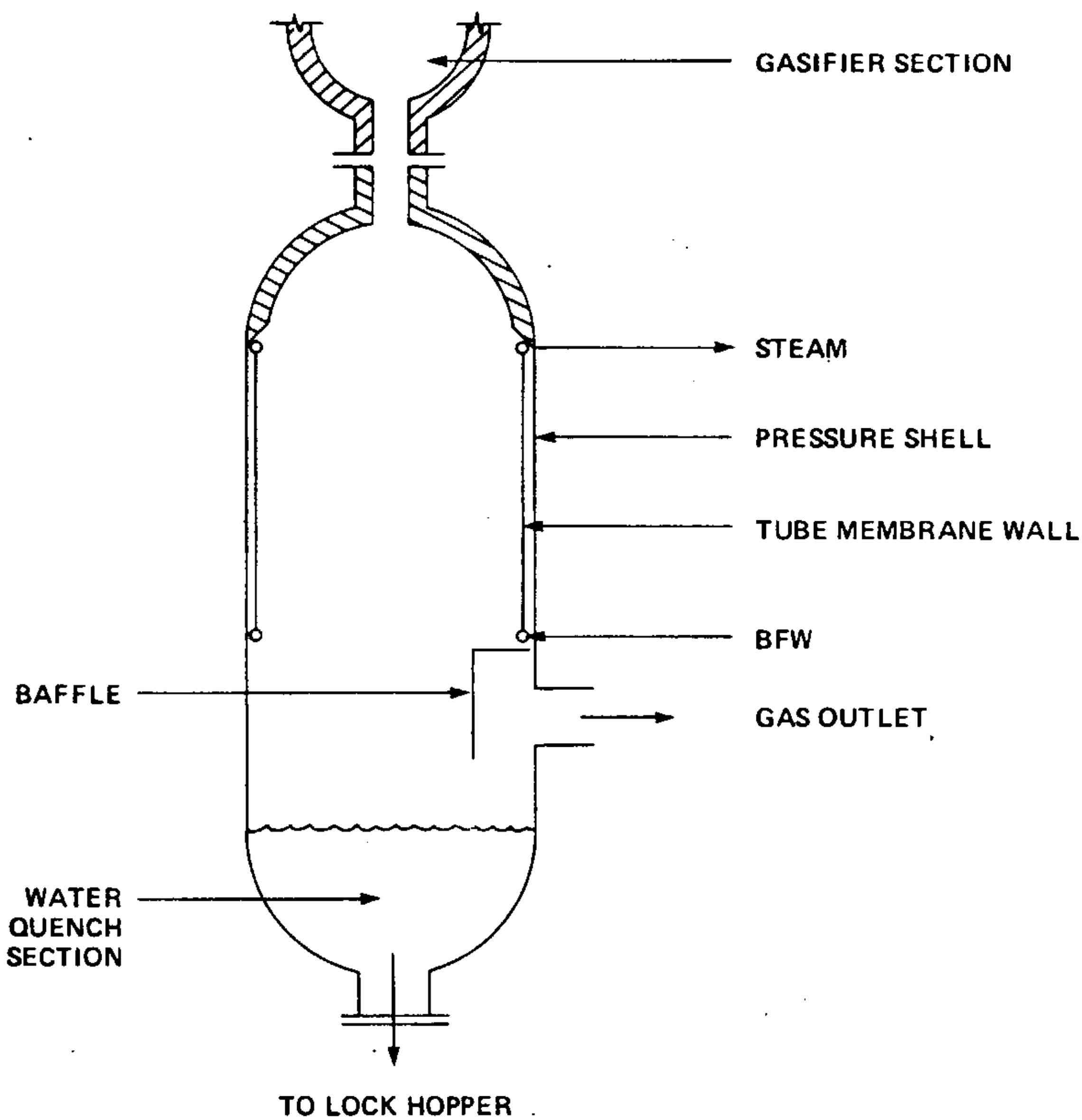
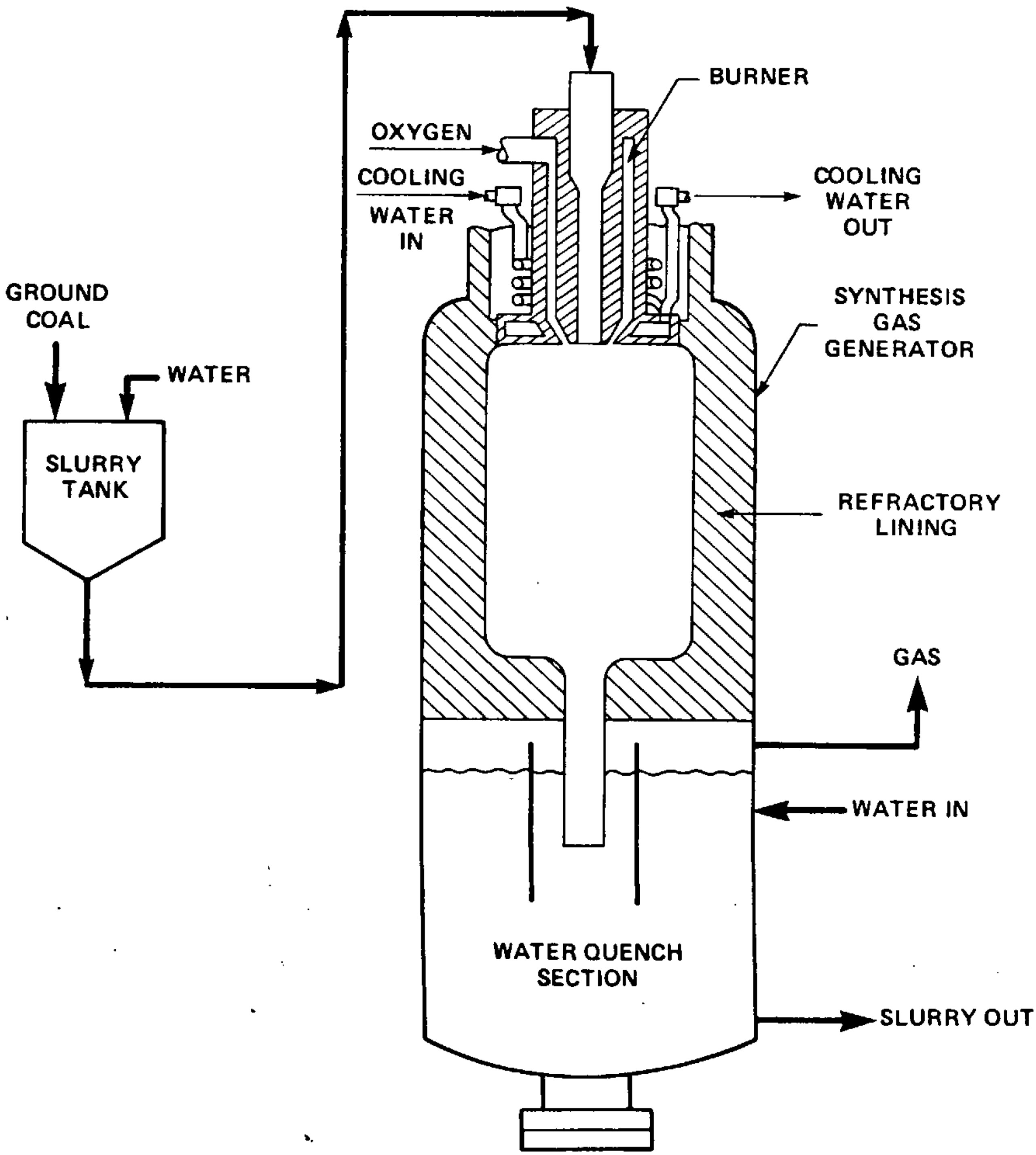


FIGURE 3.3.4 D

THE TEXACO COAL GASIFIER
QUENCH MODE



3.3.5 History and Commercial Status

The Shell-Koppers gasifier is an offshoot of the Koppers-Totzek unit which utilizes a high temperature and pressure operation. Shell has been using its experience with high pressure oil gasification to design and develop a system that combines the advantages of entrained-bed gasification with high pressure operations, enabling a wide variety of coals to be converted to a low methane content gas.

The Shell-Koppers unit began operation 1976 in Amsterdam feeding 6 ton per day of coal which in turn led to a 150 TPD unit developed by Krupp-Koppers at the Hamburg refinery of Deutsche Shell A.G. near Hamburg, the plant is fully owned by Shell A.G. The plant started producing a synthesis gas in November 1978 and achieved over 250 hours of operation by mid 1979.

Shell also plans to build a 2000 metric ton per day demonstration plant due for completion by 1985. It would produce synthesis gas only, although, there are plans to process this into methanol from 1986 onward. Plans also call for a second-phase expansion of 5000 MT/D capacity by 1992. rising to 17,000 MT/D by 1998.

3.3.5 The Shell-Koppers gasification process is an entrained bed, high pressure, slagging unit which utilizes steam and oxygen as the gasification media.

Coal Preparation and Gasifier Feeding

Coal is normally crushed and ground size, where 90 percent is less than 90 microns and dried to approximately 1 to 8 percent moisture content. The dried coal dust is pneumatically conveyed to a pressureless cyclone bin to the feed bin, which is under pressure, usually using nitrogen. From the feed bin, the dust is fed into the reactor chamber cocurrently with oxygen and a relatively small amount of steam.

Gasification and Heat Recovery

As schematically shown in figure 3.3.5A the dried coal is dust fed into the reaction chamber through diametrically opposed diffusion guns and reacts with the gasification media in a flame-like reaction. Flame temperatures can be as high as 1800-2000°C but reactor outlet temperatures will not normally exceed 1400-1500°C.

The reactor is an empty pressure vessel whose wall temperatures are controlled by water cooled tubes in which medium pressure steam is generated. The tubular wall is protected by a thin refractory lining.

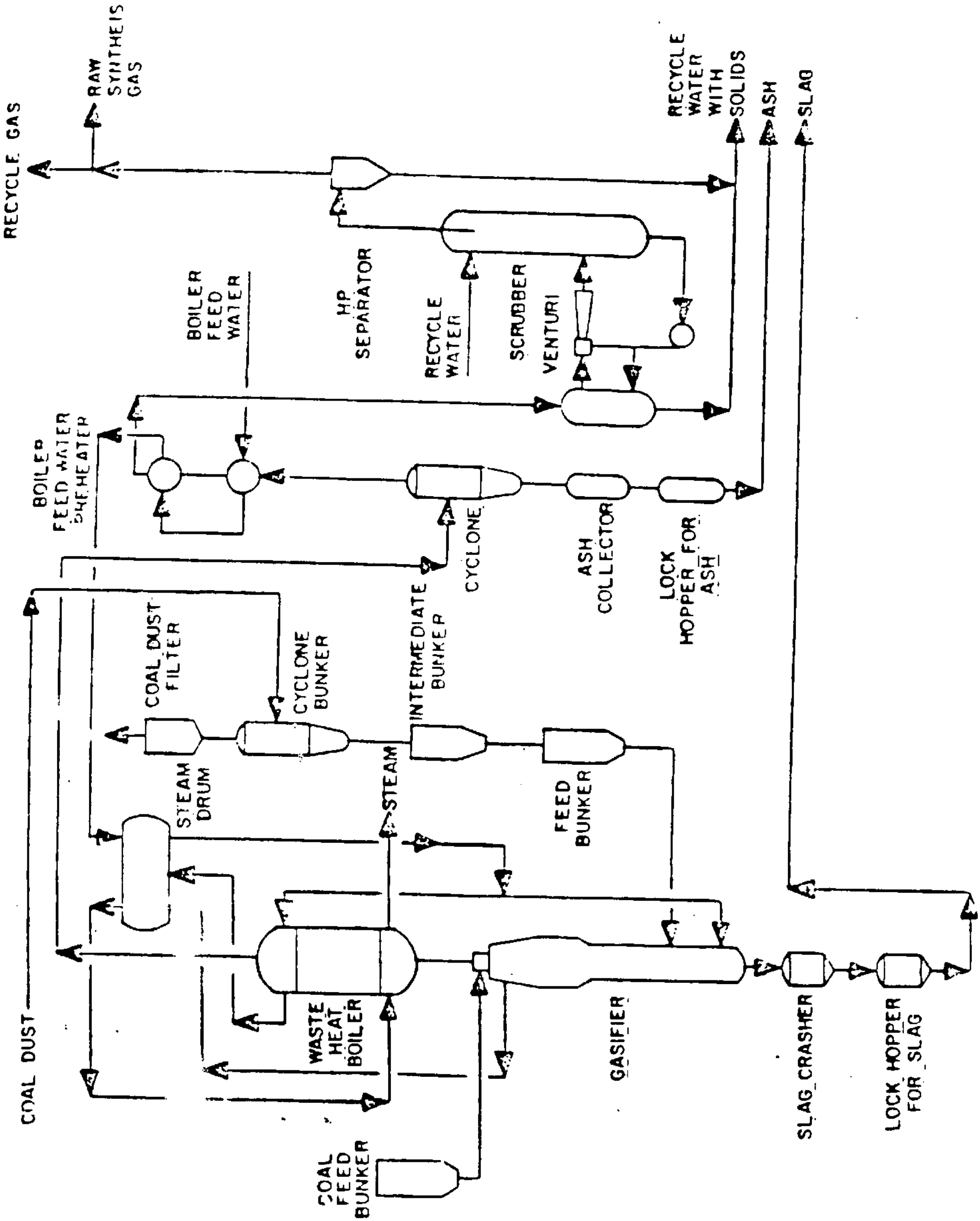
As the gasi..cation reactions proceed producing a crude synthesis gas, some of the ash is entrained in the product gas. As the product gas approaches the reactor outlet a quench zone is provided to solidify any of the ash ticles before entering the waste heat boilers.

The raw syn esis gas is quenched with either cold recycle gas or a water spra n a narrow zone immediately above the gasification zone. About 90 p nt of the particulate matter is precipitated out of the raw gas before ering the waste heat boiler. The gas leaving at about 320°F pas through to a proprietary system of cyclones and scrubbers designed to reduce the particulate content to less than 1 lb/Nm^3. The system also recovers a large proportion sensible heat of the gas as it is cooled to approximately 40^oC.

The molten ash formed in the reactor settles to the bottom of the bed and is collected in a cooling water bath equipped with a crusher to pulverize the quenched slag.

FIGURE 3.3.5 A

SHELL-KOPPERS GASIFICATION SYSTEM



3.3.6 - KBW GASIFICATION SYSTEMS

3.3.6 History and Commercial Status

The KBW Gasification Systems are a culimination of technologies developed separately by Babcox-Wilcox (BW) and Koppers-Totzek (KT). In early 1980 BW and KT formed KBW Gasification Systesm and are offering two distinct gasifier designs.

- o The KBW cooled gasifier is similar in design to the original Koppers-Totzed gasifier which operated in a slagging mode at atmospheric pressure.
- o A tubular cooler gasifier which operates at atmospheric pressure above the ash fusion temperature.

The principal difference between the two gasification systems is that by employing a tubular cooling system to remove reaction heat as the gasification reaction is taking place, a higher pressure steam can be generated. In addition, by removing the reaction heat in this manner, a greater coal through put per gasifier is realized.

KBW, offers and guarantees both systems for commercial scale operations, operated at atmospheric pressure, and will build, but not guarantee units operated at higher pressure.

3.3.6 Process Description

Coal Preparation and Gasifier Feeding

The coal is dried to between 2 and 8 percent moisture and pulverized in the order of 70 to 90 percent through 200 mesh. Roller-or-ball type wind swept pulverizing mills are used; and choice depends and capacity. Pulverizers are designed to use up to 600°F combustion gases for the drying medium so that the coal particle temperature never exceeds 180°F. At this temperature there is no devolatilization or chemical reaction of the coal particles. Thus, the evaporated coal moisture, after particle removal, can be discharged as vapor to the atmosphere. The pulverized coal is conveyed with nitrogen from storage to the gasifier service bins. In the pulverization system and thereafter, the finely divided coal particles are kept under an inter atmosphere to eliminate explosion hazards. Controls regulate the intermittent feeding of coal from the service bins to the feed bins, which are connected to two variable-speed coal screw feeders. The pulverized coal is continuously discharged from each screw into a mixing nozzle were it is entrained in a stream of oxygen and low pressure steam. The mixture is then delivered through a transfer pipe to the burner head of the gasifier. Moderate temperature and high burner velocity in the burner pipe prevent the reaction of the coal and the oxygen prior to entry into the gasification zone.

Gasification and Heat Recovery

A two heade asifier, capable of gasifying over 400 tons of coal per day is shown n figure 3.3.6A. The oxygen, steam, and coal react at a slight posit pressure in the refractory-lined-steel-shell gasifier. Coal, oxyger and steam are brought together in opposing burner heads spaced 180° art. Four headed gasifiers, capable of gasifying over 800 tons o al per day, employ burner heads 90° apart. These larger units resemb e intersecting ellipsoids having a major axis of 13 feet. The gasifier is lined with a monolithic refractory lining. The average life of th ning is normally 2 to 3 years.

Gasification of the coal is almost complete and instantaneous. Carbon conversion is a function of the reactivity is the coal. Exothermic reactions produce a flame temperature of approximately 3500°F. Endothermic reactions, occuring in the gasifier between carbon and steam and radiation to refractory walls, reduce the flame temperature from 3500°F to an equilibrium temperature of 2700°F. Low pressure process steam is produced in the gasifier jacket from the heat passing through the refractory lining.

Ash in the coal feed is liquified at the high reaction temperature. Approximately 50 to 70 percent of the molten slag drops out of the gasifier into a slag quench tank and is recovered for disposal as a granular solid. The remainder of the slag and most of the unreacted carbon are entrained in the gas exiting the gasifier. Water sprays located at the gasifier outlet quench the gas to drop the temperature below the ash fusion temperature to prevent slag particles from adhering to the tubes of the waste heat boiler mounted atop the gasifier.

Referring to Figures 3.3.6B and 3.3.6C raw gas from the gasifier passes through the waste heat where high pressure steam is produced. After leaving the waste heat boiler the gas at 350°F is cleaned and cooled in a water scrubber system. The system consists of a washer cooler for removing the largest particles followed by disintegrators where more than 99 percnet of the remaining particles are removed. The gas then passes into a separator and into a low-pressure fan. A precipitator is used only when gas is processed in catalytic units for chemical production.

The KBW tubular cooled system utilizes the equivalent coal preparation, gasifier feeding, waste heat recovery and slag removal units as presented for Koppers-Totzek and KBW jacket cooled systems.

The gasifier differs in physical shape and method of cooling as the gasification reactions are taking place. The gasifier is rectangular in shape and uses a water tube membrane wall, which generates 600 psig steam. A cross-section of the gasifier and a Heat Recovery Schematic are illustrated in figures 3.3.6D and 3.3.6E, respectively. The downstream product gas clean-up for the KBW tubular cooled gasifier is the equivalent of that for the KBW jacket cooled gasifier as illustrated in figure 3.3.6C.

FIGURE 3.3.6 A

KOPPERS-TOTZEK GASIFIER TYPICAL CROSS SECTION

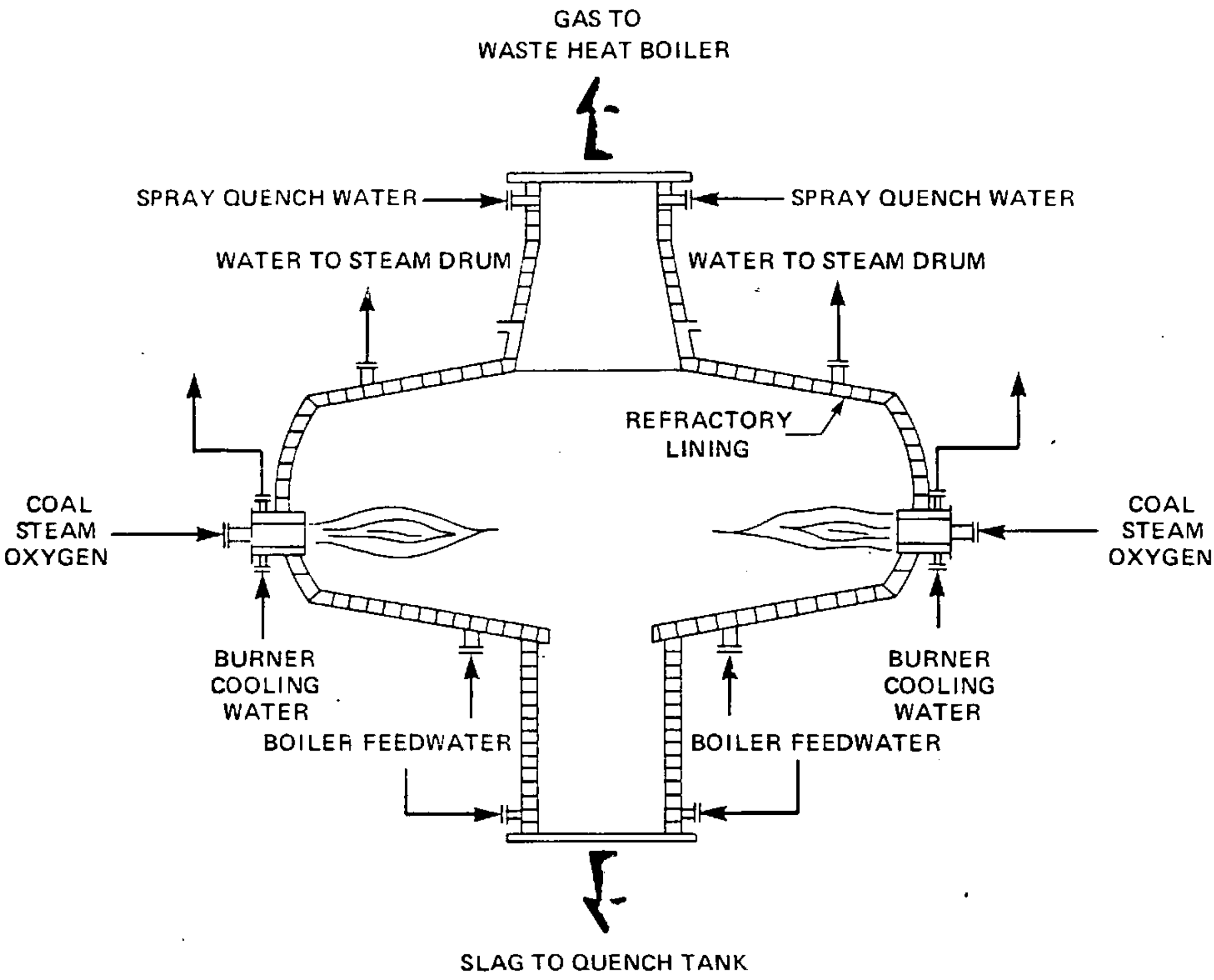


FIGURE 3.3.6 B

KT & KBW JACKET COOLED GASIFIER

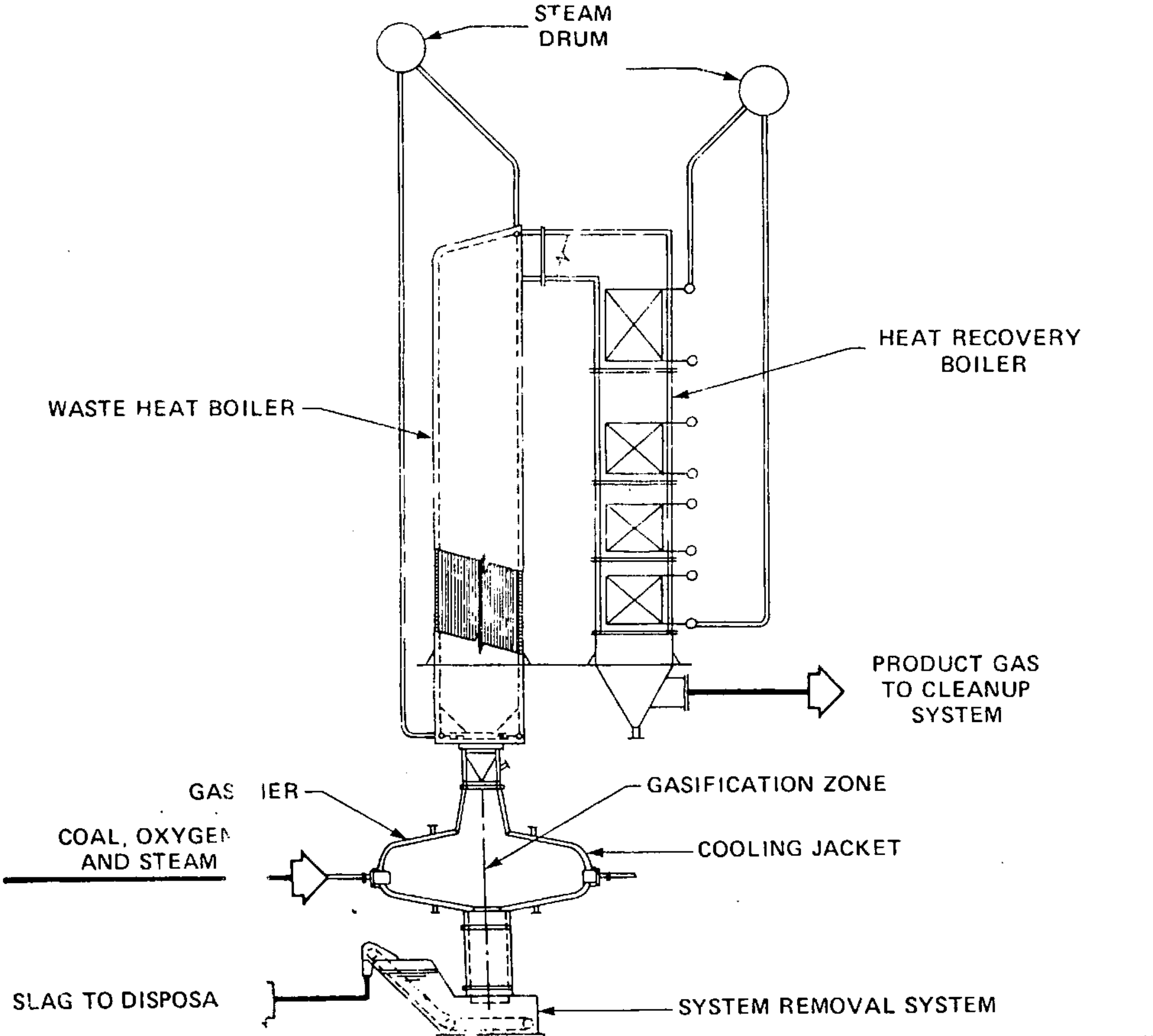


FIGURE 3.3.6 C

KOPPERS-TOTZEK GASIFICATION

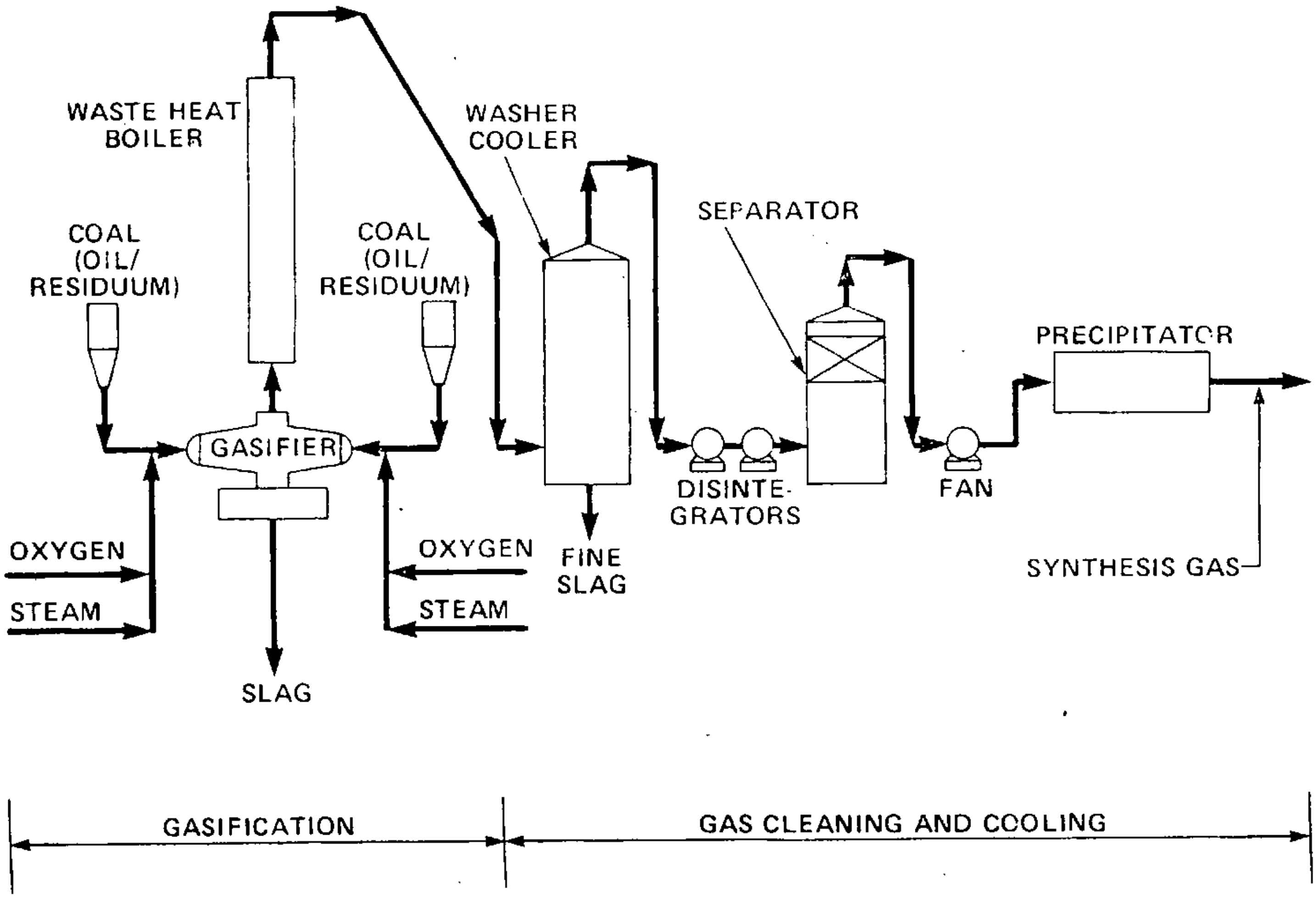


FIGURE 3.3.6 D

KBW TUBE COOLED GASIFIER

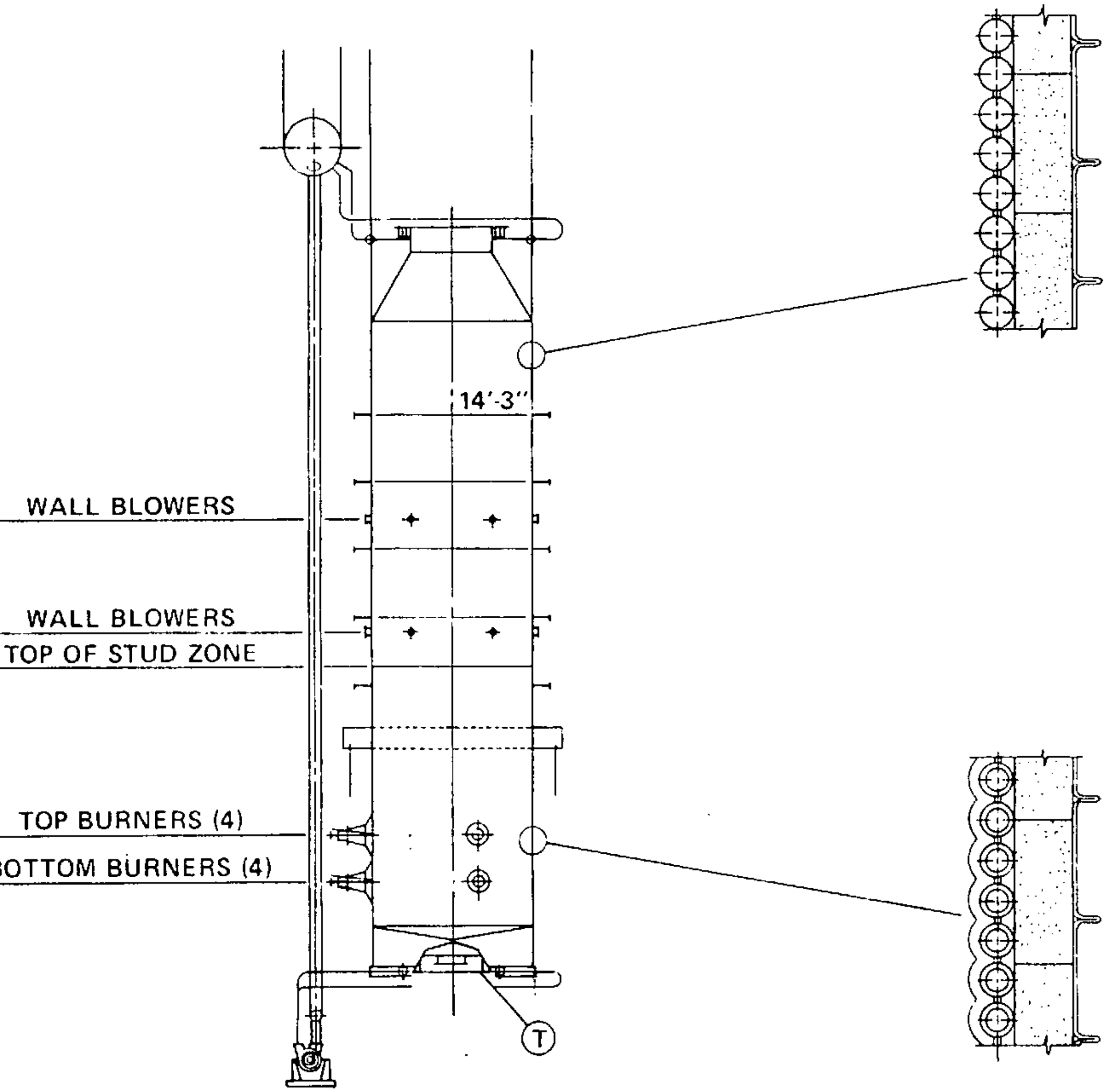
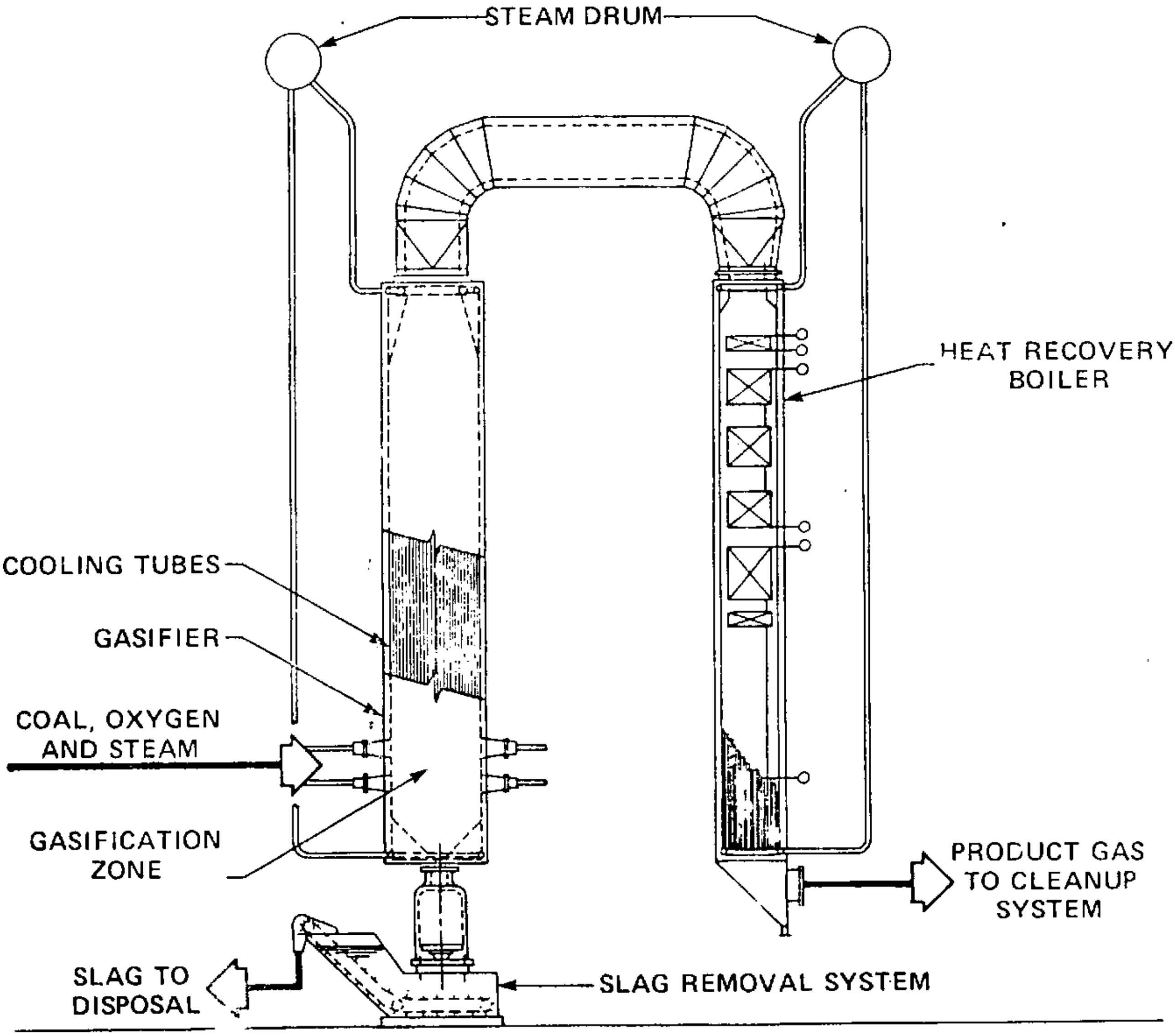


FIGURE 3.3.6 E

KBW TUBE COOLED GASIFIER



4 - DATA DEVELOPMENT AND TESTING PROGRAM

4.1 Coal

The complex hetrogenous nature of coal and the state-of-art- of coal gasification systems require that testing be undertaken to confirm that design considerations address the relevant coal and systems properties.

The following tests and/or data are recommended before initiation of the plant design and engineering. A critical review should be made to ensure that information used is applicable to the design requirements.

4.1.1 Survey of Coal Source

A survey of the potential coal sources should be undertaken to establish the project candidate coals. The results of the survey will provide comparative information on the coal characteristics, staged availability, quantity, and economics of each new coal source. An analysis of this data together with the data developed from Coal Characterization Tests should be used to establish the coal design parameters for the project.

Sampling of Coal

Although the coal consumed in a gasification plant may be measured in thousands of tons per day, the samples used for laboratory analysis are measured in grams. It is therefore, important and difficult to obtain representative samples of coal.

ASTM Standard D 492 now in used was developed, adopted in 1948, and reapproved in 1958. In this standard, which is less laborious than the original, lowances are made for the probable ash content of the coal, permittin the use of smaller gross samples for the coals of lower ash content.

Standard 492 also sets procedures for reducing gross samples and for obtaining samples for standard and special moisture determinations. Two additional pertinent publications by the ASTM are: Symposium on

Bulk Sampling (STP 242, 1958) and Symposium on Coal Sampling (STP 162, 1955). A new method has also been adopted in 1968 covering the mechanical sampling of coal, D 2234.

Careful coal sampling is of prime importance since any data resulting from subsequent analyses are only as representative as the sample provided.

2 Physical and Chemical Characteristics

A reliable source of data on the physical and chemical characteristics of the coal is essential to the project design. The results of the following analyses will characterize the gasification parameters for the selected coal.

.2.1 Coal Analysis

While a conceputal project study for the gasification of coal may be based on a composite of the range of coal in the region, it is best that specific coal analysis for the project be established early in the program.

For the design of the plant the proximate and ultimate analysis, of the design coal must be established. The scope of each analysis is indicated in the following exhibit.

COAL ANALYSIS ON AS-RECEIVED BASIS

Proximate Analysis	Weight %
Moisture	
Ash	
Volatile Matter	
Fixed Carbon	

Ultimate Analysis	Weight %
Carbon	
Hydrogen	
Nitrogen	
Chlorine	
Sulfur	
Oxygen (diff)	
Ash	

The standard Laboratory procedure for making these analyses where formerly listed under ASTM D-271. These methods were discounted in 1975 and were replaced by ASTM Method D3176 and ASTM D3172 for the proximate and ultimate analyses, respectively.

Also included in the coal analysis would be the gross calorific value or higher heating value. The gross calorific value is the heat produced by combustion of a unit quantity of a solid fuel, at constant volume, in an oxygen bomb caloricmeter under specific conditions. The preferred procedure for measuring the gross calorific value is ASTM Method D2015, which also covers methods for determining the net or lower calorific value.

The ultimate analysis and heating values determined in the coal analysis are important for calculating accurate material and thermal balances of the gasifier.

1.2.2 Free Swelling Index

This index (the FSI) is a measure of the volume increase that a coal undergoes when it is heated without physical restraines under standard conditions. The FSI provides a general indication of the plastic behavior of coal during combustion or gasification.

The standard emprical test method, ASTM D720 involves heating a 1 gram sample of coal in special equipment under specified conditions. A coke button is produced, the profile of which is then compared with a series of standard profiles. Readings are reported as the FSI, on a numerical scale of 1 through 9, in steps of one-half.

1.2.3 Grindability

Common indicators of this property relate the amount of work needed to pulverize a given coal to that needed to pulverize certain standard coals. Grindability is determined by a specific test procedure, ASTM D409, which employs a Hardgrove grindability machine.

The Hardgrove grindability index is derived by comparing the weight of a test sampler passing through a 200 mesh screen with that of the fines produced from standardized reference coals, using a standard calibration chart.

1.2.4 Ash Fusibility

The preferred procedure for measuring ash fusion temperatures is outlined in ASTM D1857. Earlier procedures used only a reducing atmosphere for such determinations, whereas the standard presently adopted employs both and oxidizing atmospheres.

Instead of measuring loosely defined softening and fluid - critical points, the new procedures specify the following types of data:

- o Initial Deformation Temperature
- o Softening Temperature
- o Hemispherical Temperature
- o Fluid Temperature

Along with the ash fusibility characteristics an analysis of the major components of the coal ash should be determined. The procedure used for a rapid and inexpensive analysis is ASTM Method D2795.

Knowing the major components of the ash and ash fusionability temperatures an analysis can be made to determine the T250 point. The T250 point is the temperature at which the viscosity of the slag is 250 poise. Analysis has shown, that it has been feasible to remove molten ash at or below the T250 point, reasonabily easily and reliably.

4.1.3 Specific Vendor Tests

Specific vendors of gasification technology may require special tests, for example, the Texaco Coal Gasification System requires tests on coal slurry characteristics to estimate maximum pumpable coal slurry which can be obtained.

Candidate gasification technology vendors should be contacted for specific test requirements.

.2 Gasification Tests

.2.1 Aim of Tests

It is recommended that for the gasifier system selected, tests be conducted on the candidate coal. Such tests will serve to confirm the parameters to be used in the design. The following items must be confirmed through testing.

- o Steam to carbon ratio
- o Oxygen to carbon ratio
- o Coal feed system
- o Gasifier capacity
- o Gasifier heat and material balances
- o Slag removing requirements
- o Trace component material balance

.2.1 Bench Scale Testing and Estimate of Operation

Based on data developed in the Coal Characterization Tests, an estimate of the operating conditions for the gasification section should be developed by the selected gasification vendor. This estimate, based on extrapolation of existing data, such as reaction kinetics, equilibrium data used in conjunction with computer simulations will serve to confirm the oxygen plant size, the steam system design and its associated equipment, the number of gasifiers required.

If the representative coal is outside the experience spectrum of the vendors gasification technology bench scale tests should be made to establish the relevant parameters as discussed above.

2.2.2 Short Gasification Runs

The objective of preliminary PDU test runs is to confirm the operability of the coal gasification process at the design pressure with the selected coals, to refine the estimate of preferred operating conditions, product gas yields and composition, to obtain and analyze samples of slag and fines and to establish the bases for a substained run with the selected coal. Maximum projected gasifier throughput will be determined and unexpected operating problems will be identified.

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A test will consist of several short pilot plant runs, each conducted at a different gasifier temperature, utilizing a single set of gasifier parameters.

?.2.3 Extended Gasification Run

The extended run shall be designed to simulate the plant operating and collect data which reflects the operating conditions of the plant. Approximately 200-300 tons of coal should be gasified during the extended run. The following tests should be included in the extended test run.

- Corrosion Test
  Test coupons should be inserted for corrosion at strategic points in the pilot plant to collect data. The results of the test will provide valuable insights for the selection of materials that are compatible with the type of coal used.

- Recycle Test
  This test using recycle solids should be designed to confirm the gasification parameters and the feasibility of operations with ash and carbon recycle.

- Blowdown Water
  Criteria used in the estimate of operations to determine blowdown rate based on total dissolved solids and/or chloride concentration level should be confirmed. This data will finalize the water management program within the gasification system. Blowdown water data including an analysis of trace components will provide the information necessary to determine and confirm the enviornmental impact of wastewater treatment requirements.

- Slag Discharge Simulation
  The slag discharge system of the pilot plant should simulate the operation of the proposed plant and/or provide data which can be used to design a slag discharge system. Slag discharge data will improve the operability and economics of the slag handling system.

- o Trace Components Analysis

  A trace component analysis is important from several points of view. If there are trace components present in the raw gas that are peculiar to the candidate coal, they could cause problems either in downstream processing units or the waste water treating system. Trace components which leave in the product gases may cause catalyst poisoning. Trace components which are removed during the washing step of particulate removal may lead to unforeseen problems in the waste water treatment system. Finally, trace components present in the slag or ash could lead to uncertainty in the solid waste disposal system.

- o Heat Recovery & Particulate Removal

  Every effort should be made to include a simulation of Heat Recovery and Particulate Removal in the PDU.

  Questions to be addressed in this area should include materials of construction, potential fouling and plugging of boilers and methods for extending waste heat boiler on stream time such as soot blowers.

  The potential for downstream equipment fouling due to the presence of particulate in the product gas must also be addressed.

  The scale and costs of PDU operations may limit the applicability of the data collected in this area. The specifics of the available equipment of the PDU may dictate that heat recovery and particulate removal tests be postponed to the Demonstration Scale Tests, as tests at this stage may not simulate final equipment design.

2.2.4 Semi-work or Commercial Testing

Process development and semi-commercial units have gasification capacities on the order of 15 to 250 MT/D. The gasifier for the proposed installation will gasify from 5000-5500 MT/D. Thus, the question of scale up remains.

Consideration should be given to obtaining data from large demonstration units. This data will be used to eliminate the unquantifiable scale up risk factor and provide data which cannot be obtained from PDU tests.

Slag Leachability Tests

The environemntal impact of the disposal of the slag/ash requires that tests be conducted to develop and assess design parameters to be used in solids waste disposal system.

Using slag/ash produced in the gasification tests, the slag leaching rates must be determined. This data will be used to desing the slag disposal system in an enviornmentally acceptable manner.

5 - PROJECT DEVELOPMENT PROGRAM

5.1 Overview

The proposed project schedule for the design procurement and construction of a synthetic fuel complex for the Santa Cruz Industrial Park (Punta Loyola) producing MBG or alternately methanol is graphically illustrated in Figure 5-1. The chart shows the work elements and their duration.

Production Rate

The production rate for the early years of operation is given in Table 5-1.

Table 5-1

Annual Production Rates

Percent of Design Capacity	MBG	Methanol
1st year of operation	70	70
2nd year of operation	85	85
3rd year of operation	95	95
4th year of operation	100	100

The projected operating rates have been based on typical operations of a chemical complex. The rates have been projected on the assumption that by 1990 there will be a number of coal gasification plants in operation.

Marketplace

MBG

MBG as a fuel must compete in the local marketplace with alternate forms of "clean" energy such as natural gas or oil. As the price of coal for this project has not been established, and as the price of natural gas is set by government regulation to encourage economic development, a number of alternate economic evaluations are possible, namely:

- Set price of MBG at fuel value equivalent of natural gas and calculate the government support required for the production of MBG at established government coal price
- Set price of MBG at 1990 world fuel value of natural gas and establish coal price and/or government support required for a viable industry

- As MBG will be used to fuel the complex, establish the price of coal to the synthetic fuel plant based on a fuel value of MBG which can be supported by the 1990 world prices of the complex products (aluminum, Ferro silicate ammonia and urea).

Methanol

Methanol can be used as an industrial chemical, as a fuel for dedicated motor fleets or combustion turbines. Chemical grade methanol is the only established price. At present, the price in the United States is in the order of US$ 12.6 MM/BTU.

As a fuel methanol will compete with motor and diesel fuels. The present price of these fuels in the United States is in the order of U.S.$ 6.90 MM/BTU.

The price of methanol in the marketplace will be subjected to a continued upward pressue due to inflationary forces and political pressures on hydrocarbon fuels. The suggested 1990 methanol price for economic analysis is:

Chemical Price - US$ 37.80 MM/BTU
Fuel Price - US$ 20.70 MM/BTU

These prices are based on a 13% annual price increase, 10% general inflation as assumed in establishing 1990 plant prices and 3% real price increase in fuel products.

5.2 PREPROJECT ACTIVITIES

The first milestone in the project schedule is the "conceptual design", the prime technical goal of preproject activities. This phase of the preproject activities encompasses the following main categories:

- Gasifier Selection
- Site Selection
- Conceptual Engineering
- Economic Analysis

The elements of each of these categories are shown in Figure 5-2.

FIGURE 5-1

PRELIMINARY PROJECT SCHEDULE SANTA CRUZ INDUSTRIAL PARK SYNTHETIC FUEL COMPLEX

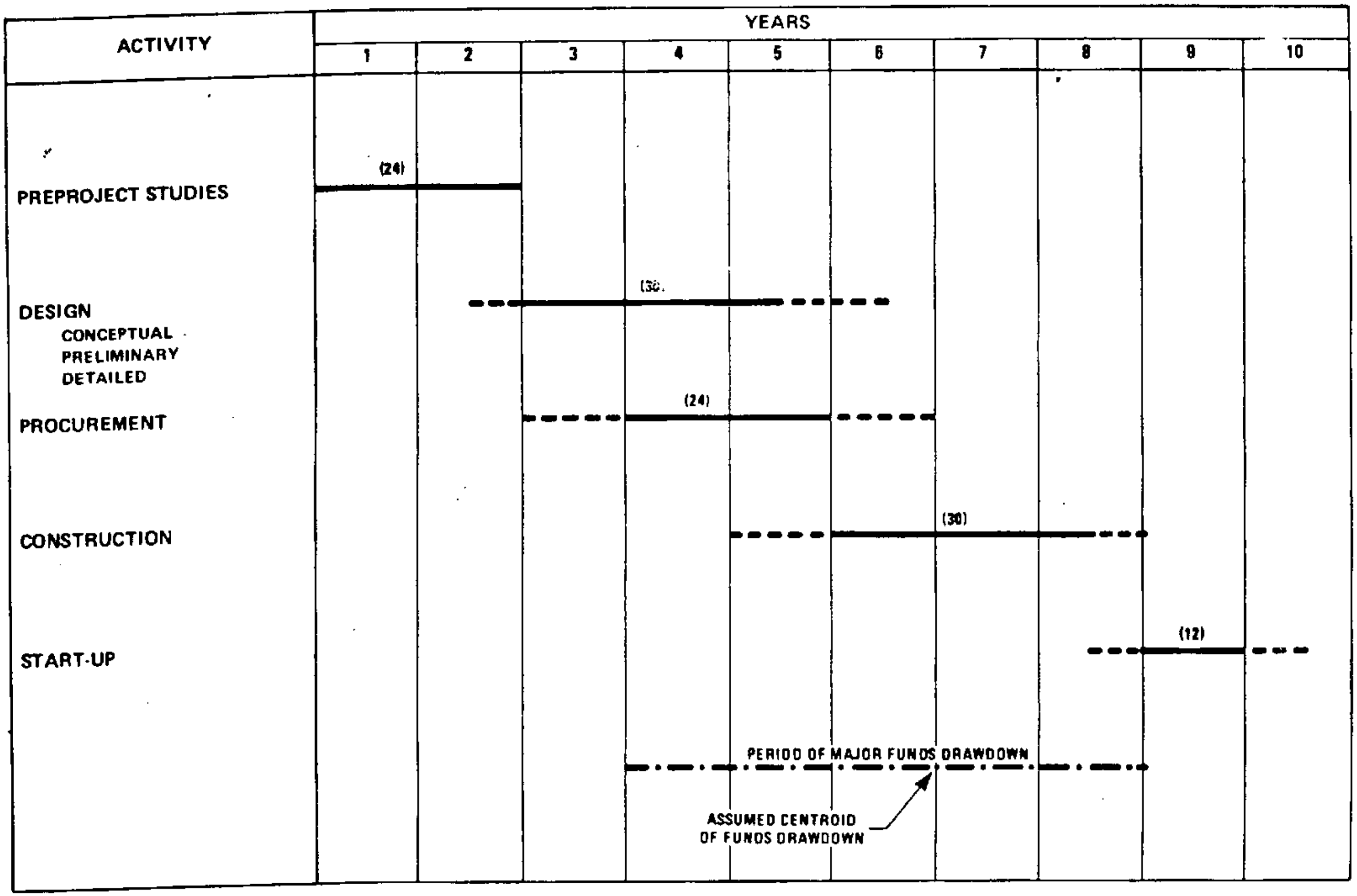


Figure 5-2
CONCEPTUAL DESIGN SCHEDULE

I. SELECT GASIFIER
- COAL TYPE
- PRODUCTS SLATE
- RISK FACTORS
- TRAIN SIZING
- SITE CONSIDERATIONS

II. SITE SELECTION (IN PARALLEL WITH I.)
- CANDIDATE SITES
- ENVIRONMENTAL
- TRANSPORTATION (COAL/PRODUCTS)
- STORAGE
- SOCIO-ECONOMIC

III. CONCEPTUAL ENGINEERING (BASED ON PREVIOUSLY SELECTED SITE)
- ENVIRONMENTAL ENGINEERING
- PLOT PLAN
- PROCESS FLOW DIAGRAMS
- OFFSITE DEF.NITION
- EQUIPMENT :T AND DESCRIPTIONS
- DRAWING LIST
- OPERATING REQUIREMENTS
- BAR CHART SCHEDULE
- BUDGET COST ESTIMATE (± 25%)

IV. EC IIC ANALYSIS
- :HNICAL INPUT
- MMERCIAL CONSIDERATIONS
- VERNMENT SUPPORT

The duration of the technical activities of this phase is projected as 12 to 18 months. The additional time which has been allowed (6 months) will be required for the financial organizational and marketing structuring necessary to establish a product outlet and operating entity to direct the project through its ensuing phases.

The range of geologically available coal from lignites to anthracites has gasified at various levels of operations. Major commercial gasification is practiced in Sasol and Montefontain. Several major gasification facilities are being projected in the USA. These are at various planning stages. Extensive facilities, at a laboratory level, pilot developmental units (PDU) with a capacity to gasify 0.5-1 tons/Hr and semi work scale with capacities of 150 T/D or higher, exist and must be used in the development of a gasification complex.

The development of gasification unit using the unknown and untested coal Rio Turbio will require careful planning to make maximum use of available information to minimize development costs.

The extensive data base which has been developed as a result of test data accumulated, internal studies and client commissioned studies, together with engineering judgment will expedite the conceptual phase of the project, reduce total study costs and focus on the essential information to be developed during the testing phase and the subsequent indepth studies.

The recommended technical development program steps consists of:

- Collect project specific coal information as outlined in paragraph 4.1.
- Develop preliminary gasification system assessment using available existing data base and specific vendor supplied information.
- Prepare a comparision venture analysis of the gasifiers which are considered suitable for application with Rio Turbio Coal. This venture analysis should make maximum use of available information to develop economic and technical assessments.
- Prepare a conceptual feasibility study using bench scale testing as required to develop an estimate of operations. Refer to Figure 5-2 for the elements of this study.

- Confirm the conceptual feasibility design parameters using short term gasification tests.
- Adjust conceptual feasibility design as required by the short-term gasification tests results.

The ultimate goal of the technical development program is to demonstrate to potential investors the technical and economic feasibility of the proposed project. While government sponsorship may be necessary to begin the program (as has been the case in the United States) early contact should be made with potential worldwide investors. Progress reports should be issued at technical development "milestones" to promote the early transfer of the development program to the world industrial community.

On completion of the financial, marketing and organizational structuring the project passes to the design phase.

5.3 Design

The design consists of two phases, the preliminary phase and the detailed phase. The preliminary design encompasses the following:

- Environmental Engineering
- Basic Engineering
- Economic Analysis
- Pilot Plant Testing

The elements involved in these categories are shown in Figure 5-3, Preliminary Design.

The second engineering phase encompasses "Detailed Engineering". Using the information developed during conceptual and preliminary design efforts, the detailed design for all mechanical, electrical, instrumentation and civil areas is completed in this phase. This detailed design results in a definition of the plant in sufficient detail to allow for procurement, construction and start-up to proceed.

Figure 5-3
PRELIMINARY DESIGN SCHEDULE

I. ENVIRONMENTAL ENGINEERING

II. BASIC ENGINEERING

- PROCESS FLOW DIAGRAMS
- SERVICE FLOW DIAGRAMS
- P & ID'S
- EQUIPMENT & MATERIAL SPECIFICATIONS
- STANDARD SPECIFICATIONS
- PLOT PLAN AND GENERAL ARRANGEMENTS
- DRAWING AND EQUIPMENT LISTS
- OPERATING REQUIREMENTS
- PRELIMINARY OPERATING INSTRUCTIONS
- MAJOR MILESTONE SCHEDULE
- COST ESTIMATE (± 15%)

III. ECONOMIC ANALYSIS

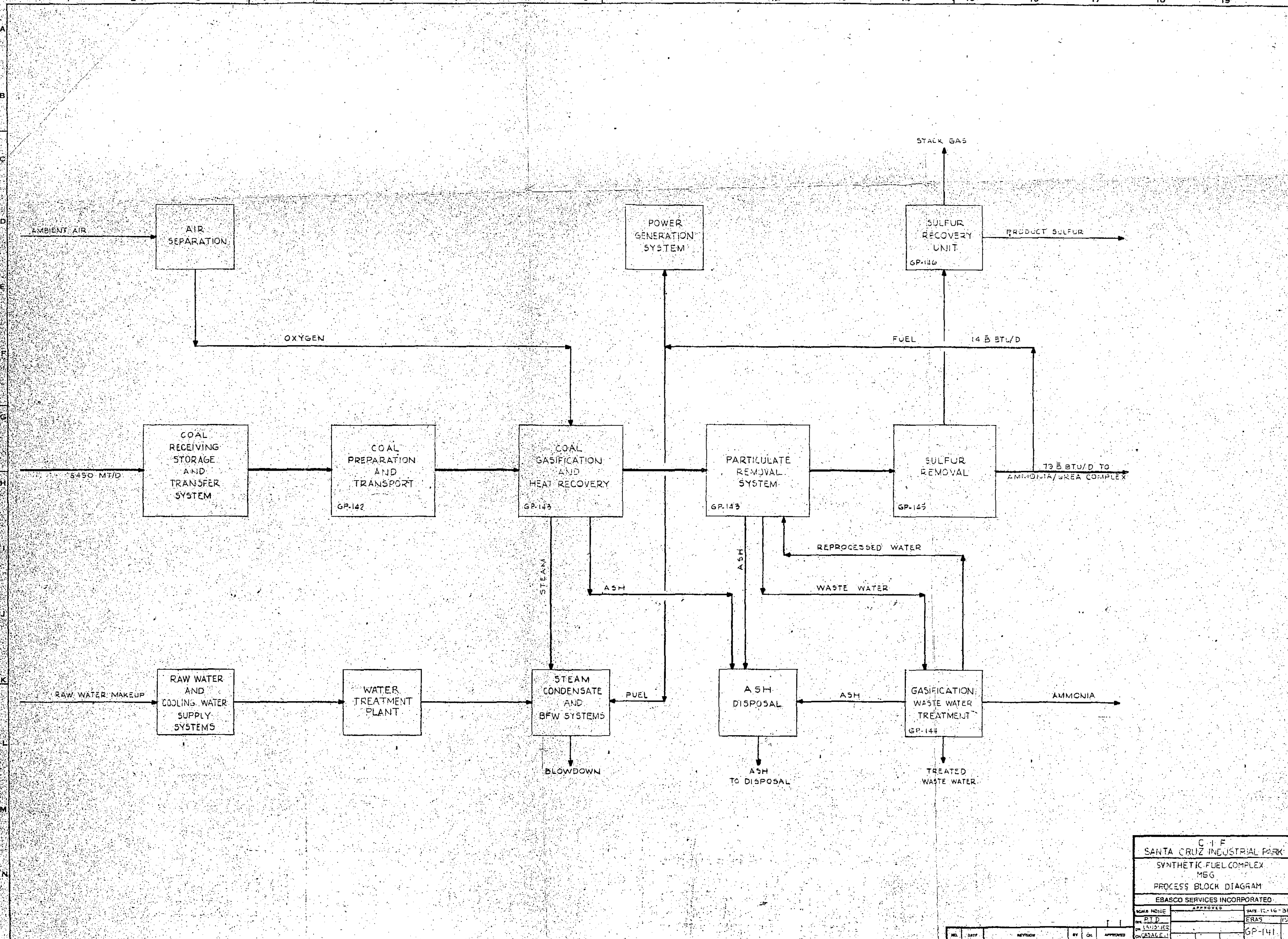
IV. PILOT PLANT TESTING

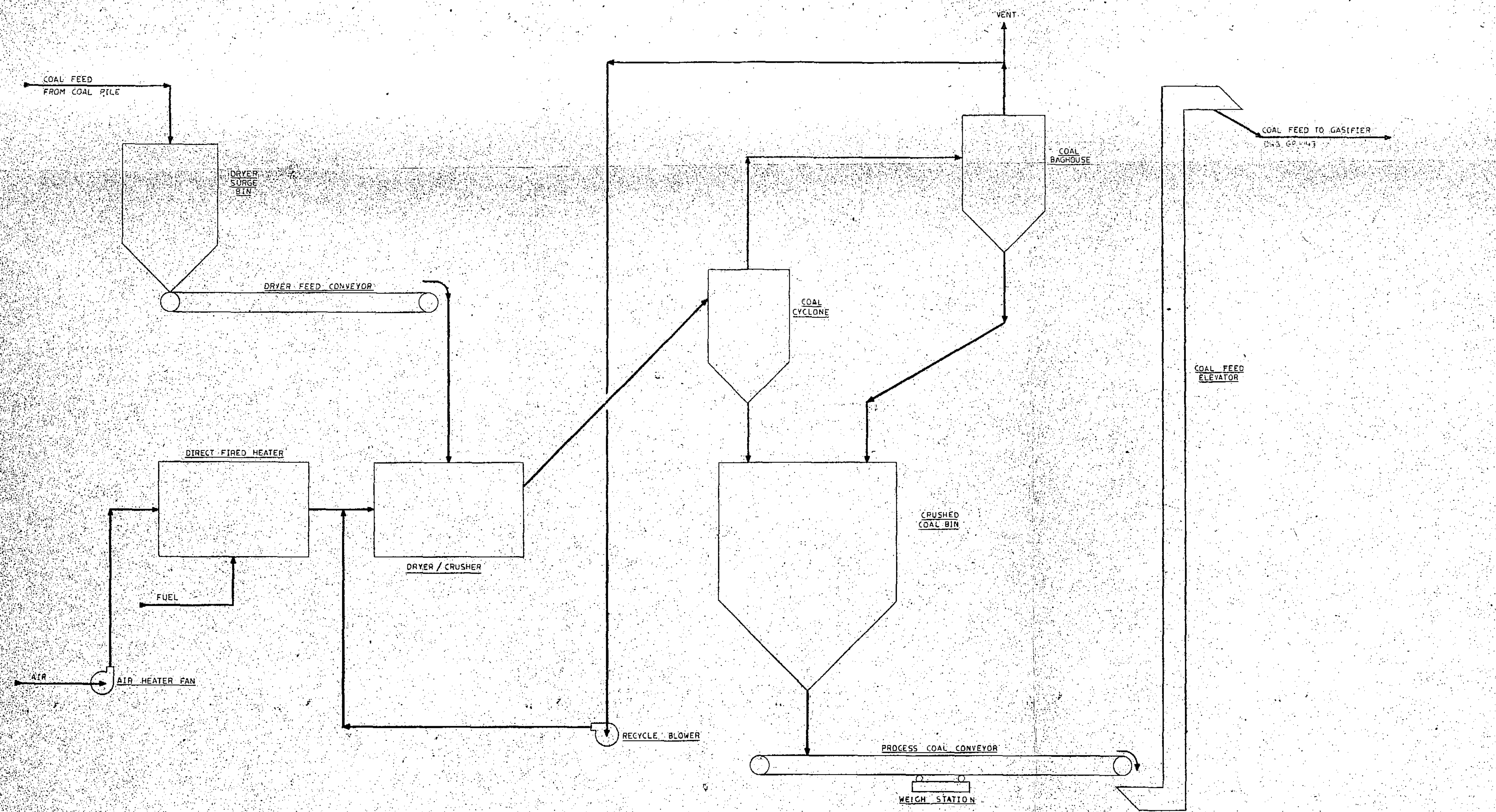
5.4 Procurement/Construction

There is an overlap of the Procurement/Construction Phase with the Detailed Design Phase. As procurement is vital to completion of detailed design phase the procurement function must be initiated as expeditiously as engineering information is available. While emphasis will be placed on the procurement of predetermined "long delivery" items because of their effect on the construction schedule, it is of utmost importance that procurement of all major items of equipment proceed with minimum delay as vendor prints are vital to the completion of design and subsequently construction.

5.5 Start-Up

A period of twelve (12) months is anticipated for the start-up and testing of the synthetic fuel complex. The production schedule envisioned for the early years of production is given in Table 5-1.


AMBIENT AIR
AIR SEPARATION
POWER GENERATION SYSTEM
STACK GAS
SULFUR RECOVERY UNIT
GP-146
PRODUCT SULFUR
OXYGEN
FUEL
14 B BTU/D
5450 MT/D
COAL RECEIVING STORAGE AND TRANSFER SYSTEM
COAL PREPARATION AND TRANSPORT
GP-142
COAL GASIFICATION AND HEAT RECOVERY
GP-143
PARTICULATE REMOVAL SYSTEM
GP-143
SULFUR REMOVAL
GP-145
73 B BTU/D TO AMMONIA/UREA COMPLEX
STEAM
ASH
ASH
REPROCESSED WATER
WASTE WATER
RAW WATER MAKEUP
RAW WATER AND COOLING WATER SUPPLY SYSTEMS
WATER TREATMENT PLANT
STEAM CONDENSATE AND BFW SYSTEMS
FUEL
ASH DISPOSAL
ASH
GASIFICATION WASTE WATER TREATMENT
GP-144
AMMONIA
BLOWDOWN
ASH TO DISPOSAL
TREATED WASTE WATER
C-I-F
SANTA CRUZ INDUSTRIAL PARK
SYNTHETIC FUEL COMPLEX
MSG
PROCESS BLOCK DIAGRAM
EBASCO SERVICES INCORPORATED
SCALE NONE
APPROVED
DATE 12-16-81
ERAS
ISS
GP-141

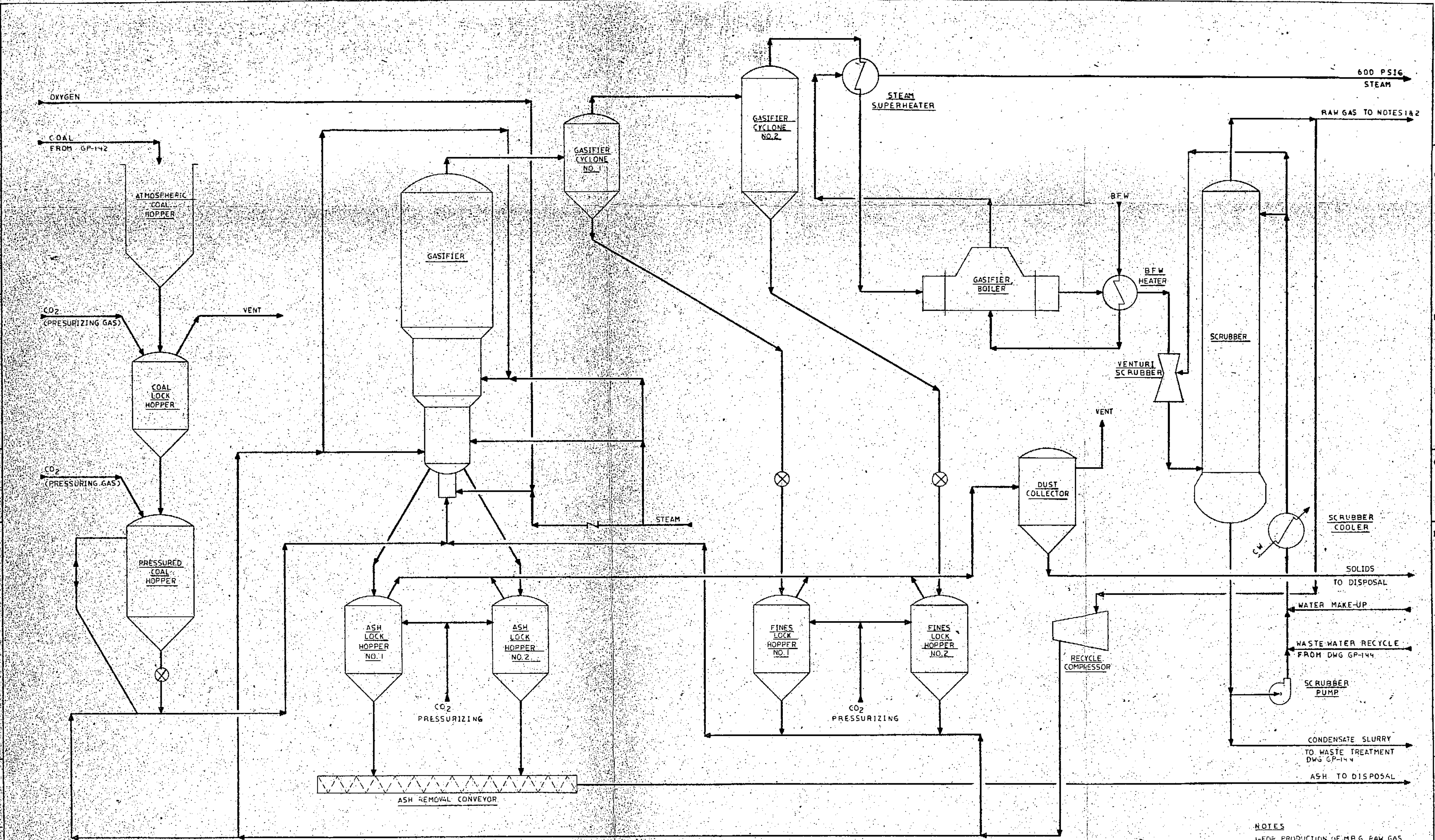


C I F
SANTA CRUZ INDUSTRIAL PARK

SYNTHETIC FUEL COMPLEX
MBG/METHANOL
COAL PREPARATION

EBASCO SERVICES INCORPORATED

SCALE NONE
APPROVED
DATE 12-16-81
EBAS
GP-1-2



NOTES

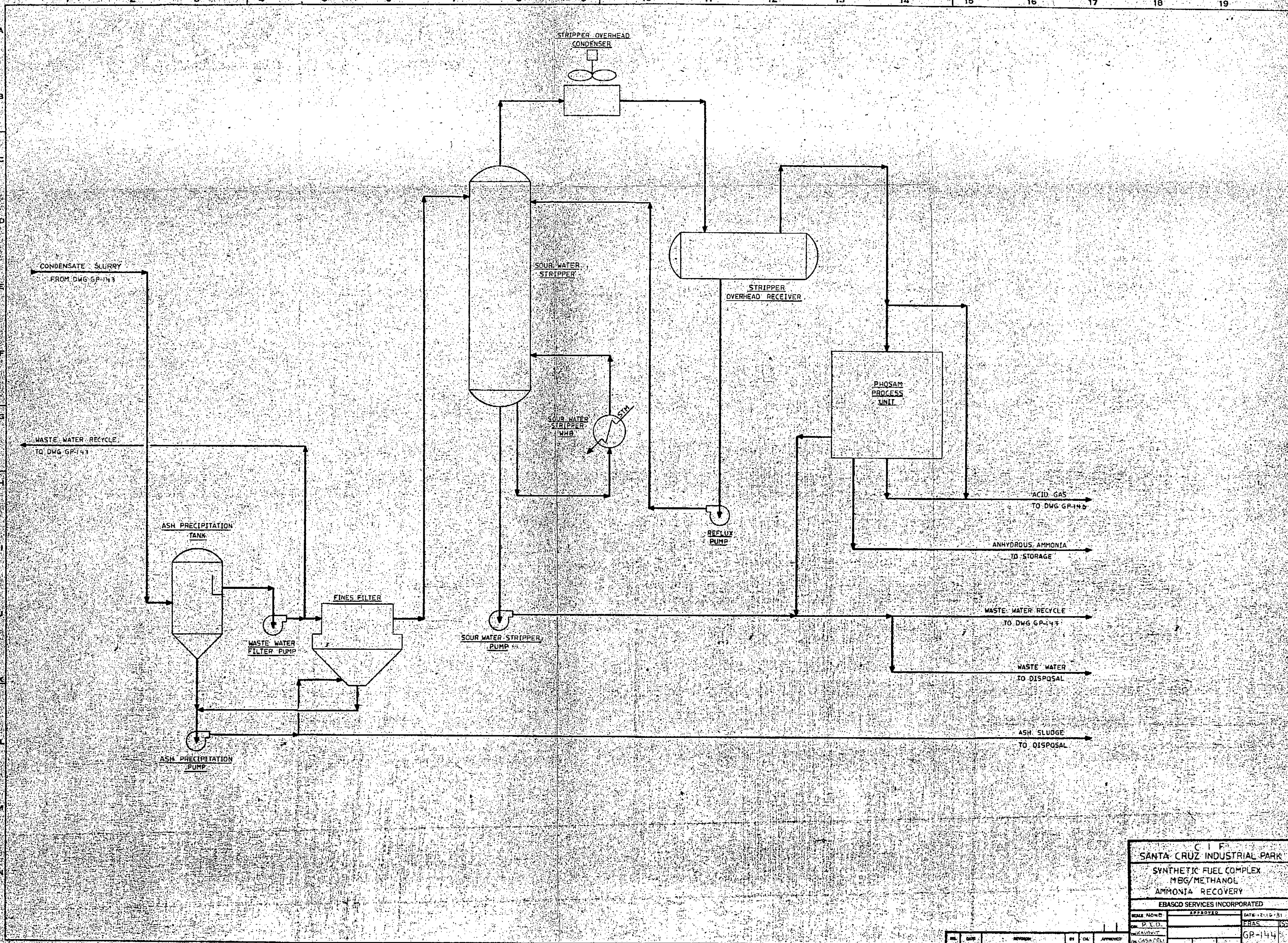
1-FOR PRODUCTION OF MBG RAW GAS FLOWS TO DWG GP-145 SULFUR REMOVAL
2 FOR PRODUCTION OF METHANOL RAW GAS FLOWS TO DWG GP-146

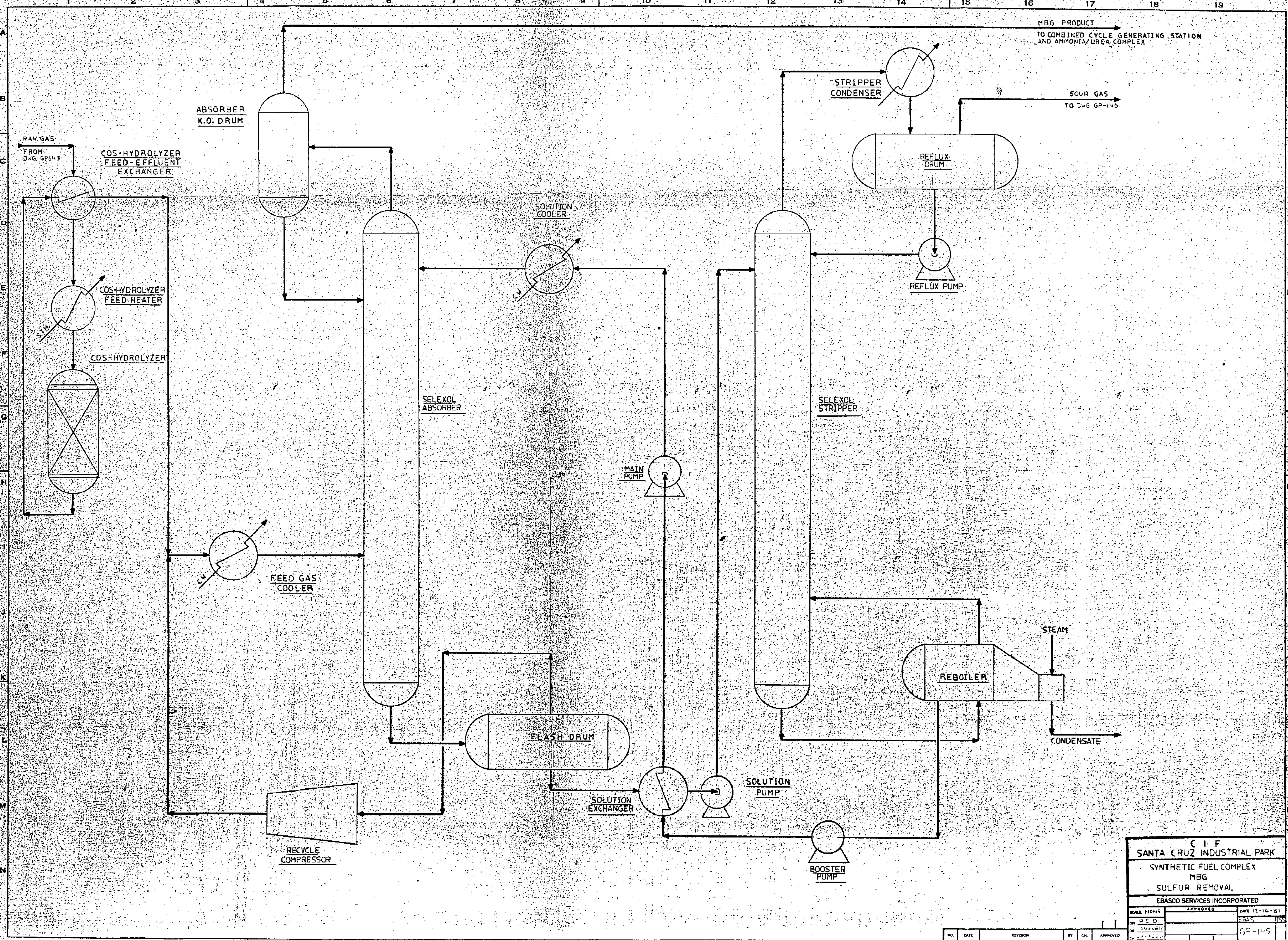
C. I. F.
SANTA CRUZ INDUSTRIAL PARK

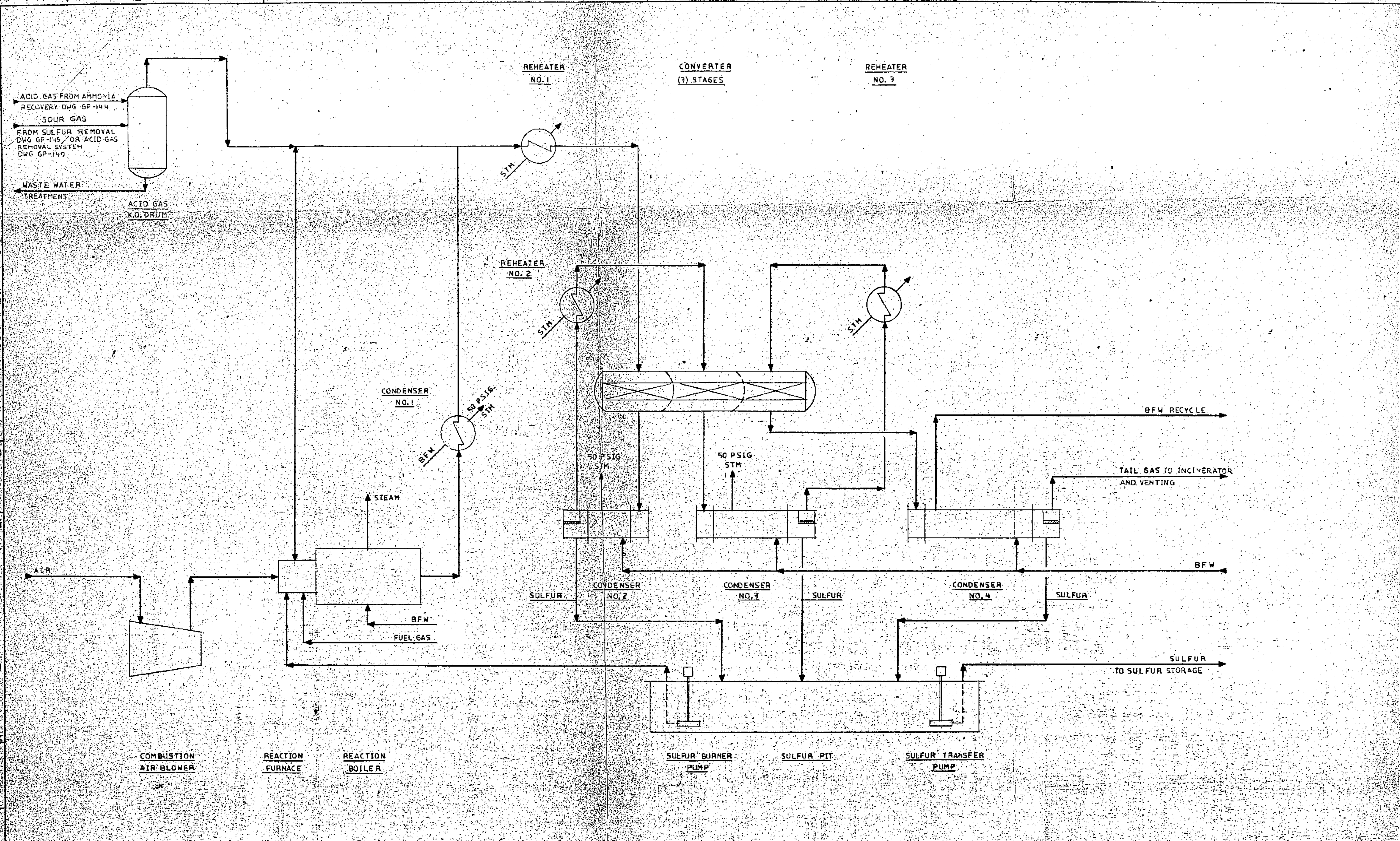
SYNTHETIC FUEL COMPLEX
MBG/METHANOL
COAL GASIFICATION & PARTICULATE REMOVAL

EBASCO SERVICES INCORPORATED

SCALE NONE | APPROVED | DATE 12-16-81
DIV. P.T.D. | EBAS- | ISS
GP-143


STRIPPER OVERHEAD CONDENSER
SOUR WATER STRIPPER
STRIPPER OVERHEAD RECEIVER
CONDENSATE SLURRY FROM DWG GP-143
PHOSAM PROCESS UNIT
SOUR WATER STRIPPER 'WHB'
STM
WASTE WATER RECYCLE TO DWG GP-143
ACID GAS TO DWG GP-146
REFLUX PUMP
ASH PRECIPITATION TANK
ANHYDROUS AMMONIA TO STORAGE
FINES FILTER
WASTE WATER FILTER PUMP
SOUR WATER STRIPPER PUMP
WASTE WATER RECYCLE TO DWG GP-143
WASTE WATER TO DISPOSAL
ASH SLUDGE TO DISPOSAL
ASH PRECIPITATION PUMP
C I F
SANTA CRUZ INDUSTRIAL PARK
SYNTHETIC FUEL COMPLEX
MBG/METHANOL
AMMONIA RECOVERY
EBASCO SERVICES INCORPORATED
SCALE NONE
APPROVED
DATE 12-16-81
P.T.O.
EBAS
SS
GP-144


MBG PRODUCT
TO COMBINED CYCLE GENERATING STATION AND AMMONIA/UREA COMPLEX
STRIPPER CONDENSER
SOUR GAS
TO DWG GP-146
ABSORBER K.O. DRUM
RAW GAS
FROM DWG GP143
COS-HYDROLYZER FEED-EFFLUENT EXCHANGER
REFLUX DRUM
SOLUTION COOLER
CW
REFLUX PUMP
COS-HYDROLYZER FEED HEATER
STM.
COS-HYDROLYZER
SELEXOL ABSORBER
SELEXOL STRIPPER
MAIN PUMP
FEED GAS COOLER
STEAM
REBOILER
FLASH DRUM
CONDENSATE
SOLUTION PUMP
SOLUTION EXCHANGER
RECYCLE COMPRESSOR
BOOSTER PUMP
C I F
SANTA CRUZ INDUSTRIAL PARK
SYNTHETIC FUEL COMPLEX
MBG
SULFUR REMOVAL
EBASCO SERVICES INCORPORATED
SCALE NONE
APPROVED
DATE 12-16-81
GP-145
NO.
DATE
REVISION
BY
CK.
APPROVED

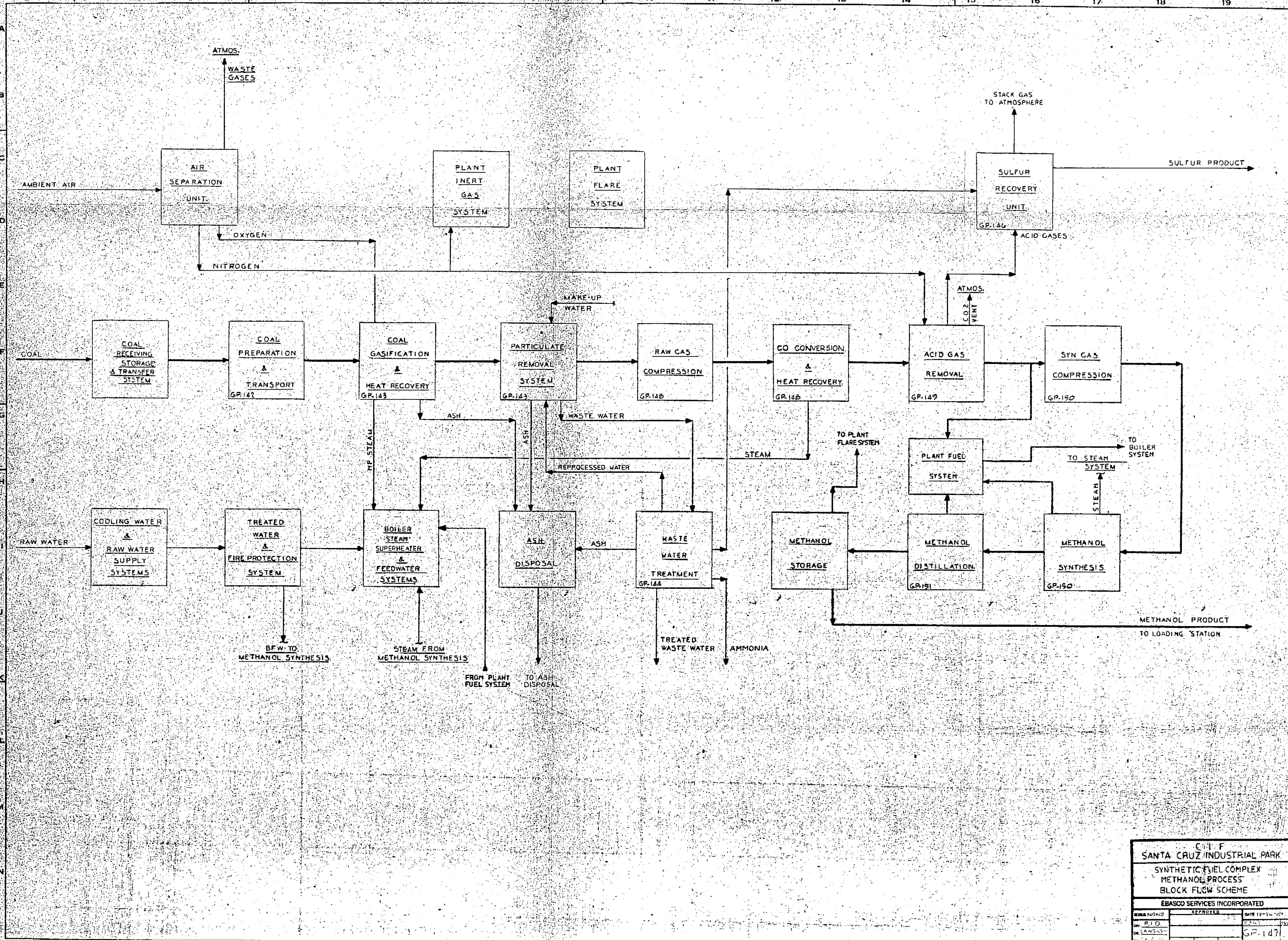


C I F
SANTA CRUZ INDUSTRIAL PARK

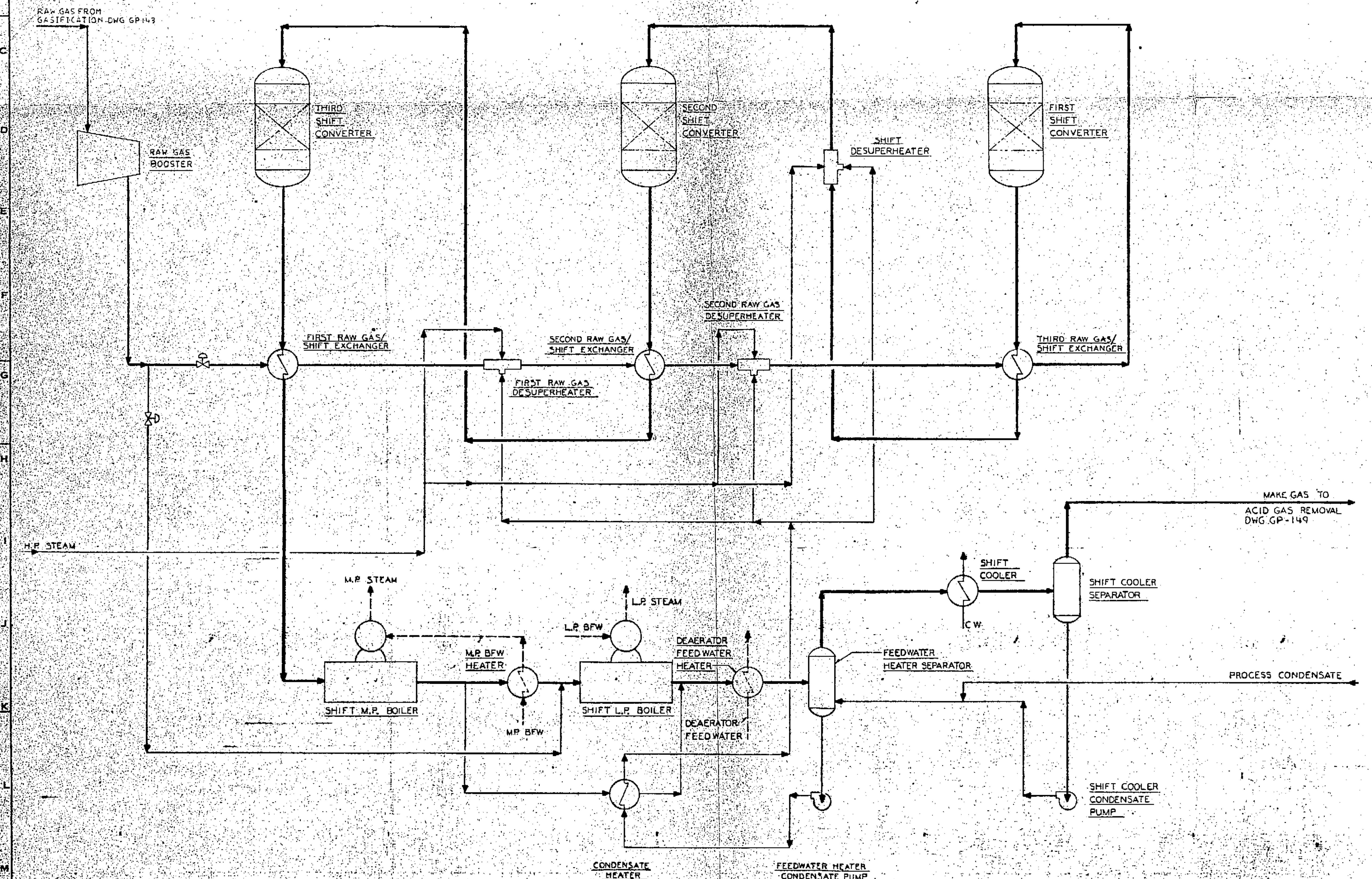
SYNTHETIC FUEL COMPLEX
MBG/METHANOL
SULFUR RECOVERY

EBASCO SERVICES INCORPORATED

SCALE NONE
DATE 12-14-81
EBAS
GP-146



ATMOS.
WASTE GASES
AMBIENT AIR
AIR SEPARATION UNIT
OXYGEN
NITROGEN
PLANT INERT GAS SYSTEM
PLANT FLARE SYSTEM
STACK GAS TO ATMOSPHERE
SULFUR RECOVERY UNIT
GP-146
SULFUR PRODUCT
ACID GASES
ATMOS.
CO2 VENT
MAKE-UP WATER
COAL
COAL RECEIVING STORAGE & TRANSFER SYSTEM
COAL PREPARATION & TRANSPORT
GP-142
COAL GASIFICATION & HEAT RECOVERY
GP-143
PARTICULATE REMOVAL SYSTEM
GP-143
RAW GAS COMPRESSION
GP-148
CO CONVERSION & HEAT RECOVERY
GP-148
ACID GAS REMOVAL
GP-149
SYN GAS COMPRESSION
GP-150
ASH
WASTE WATER
HP STEAM
STEAM
REPROCESSED WATER
TO PLANT FLARE SYSTEM
PLANT FUEL SYSTEM
TO BOILER SYSTEM
TO STEAM SYSTEM
STEAM
RAW WATER
COOLING WATER & RAW WATER SUPPLY SYSTEMS
TREATED WATER & FIRE PROTECTION SYSTEM
BOILER STEAM SUPERHEATER & FEEDWATER SYSTEMS
ASH DISPOSAL
ASH
WASTE WATER TREATMENT
GP-144
METHANOL STORAGE
METHANOL DISTILLATION
GP-151
METHANOL SYNTHESIS
GP-150
METHANOL PRODUCT
TO LOADING STATION
BFW TO METHANOL SYNTHESIS
STEAM FROM METHANOL SYNTHESIS
FROM PLANT FUEL SYSTEM
TO ASH DISPOSAL
TREATED WASTE WATER
AMMONIA
C I F
SANTA CRUZ INDUSTRIAL PARK
SYNTHETIC FUEL COMPLEX
METHANOL PROCESS
BLOCK FLOW SCHEME
EBASCO SERVICES INCORPORATED
GP-147

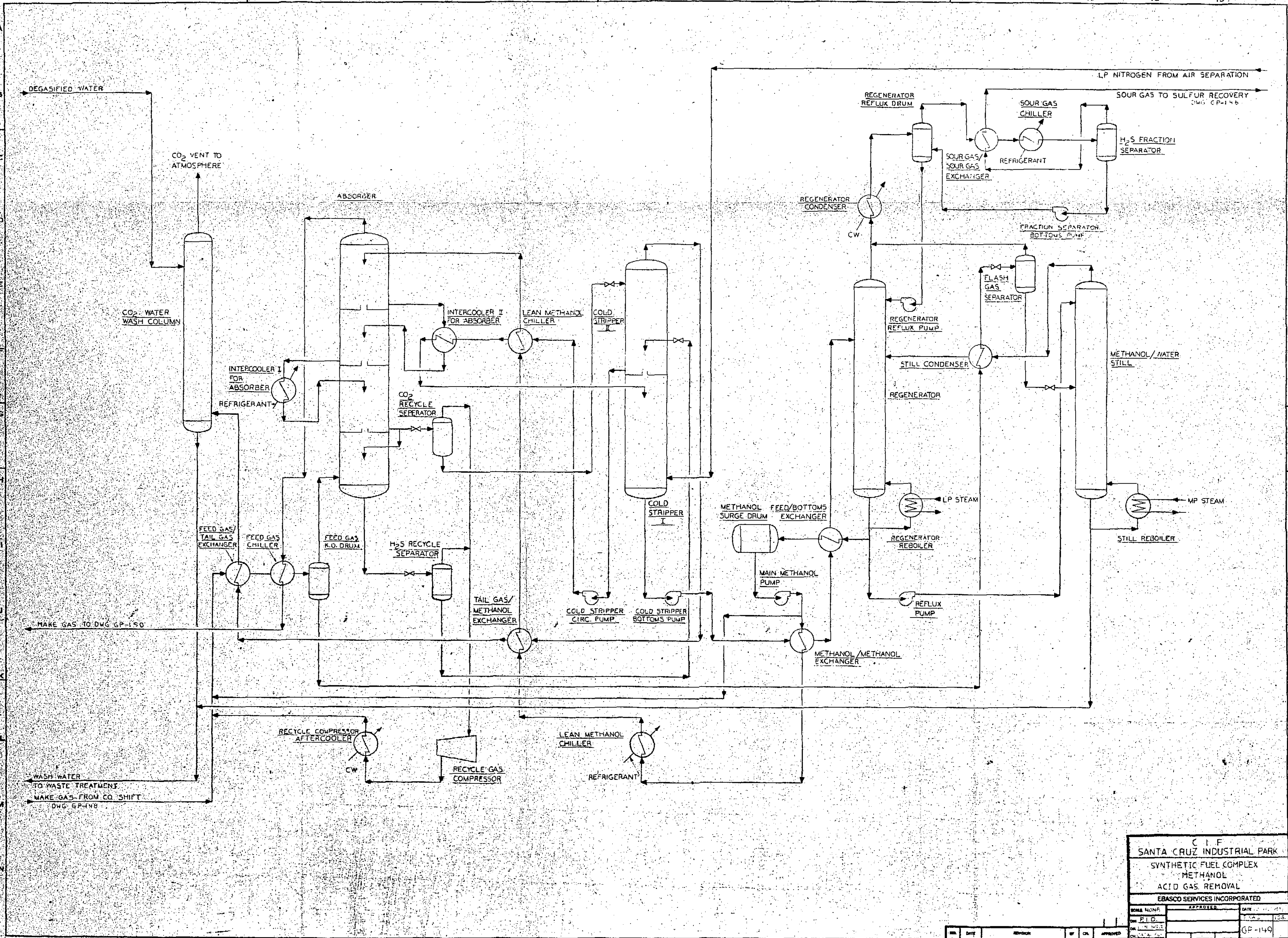


C F
SANTA CRUZ INDUSTRIAL PARK

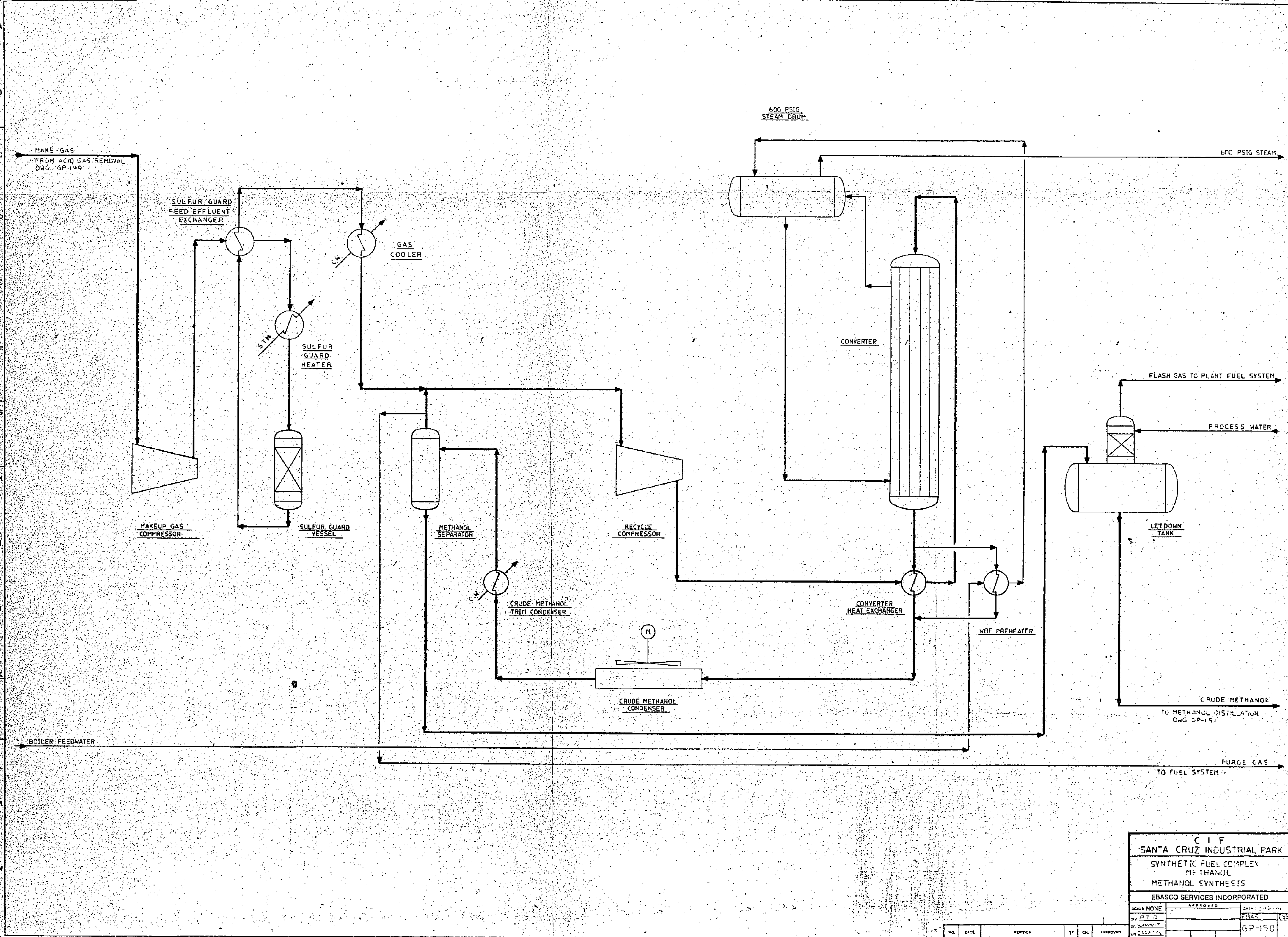
SYNTHETIC FUEL COMPLEX
METHANOL
CO CONVERSION & HEAT RECOVERY

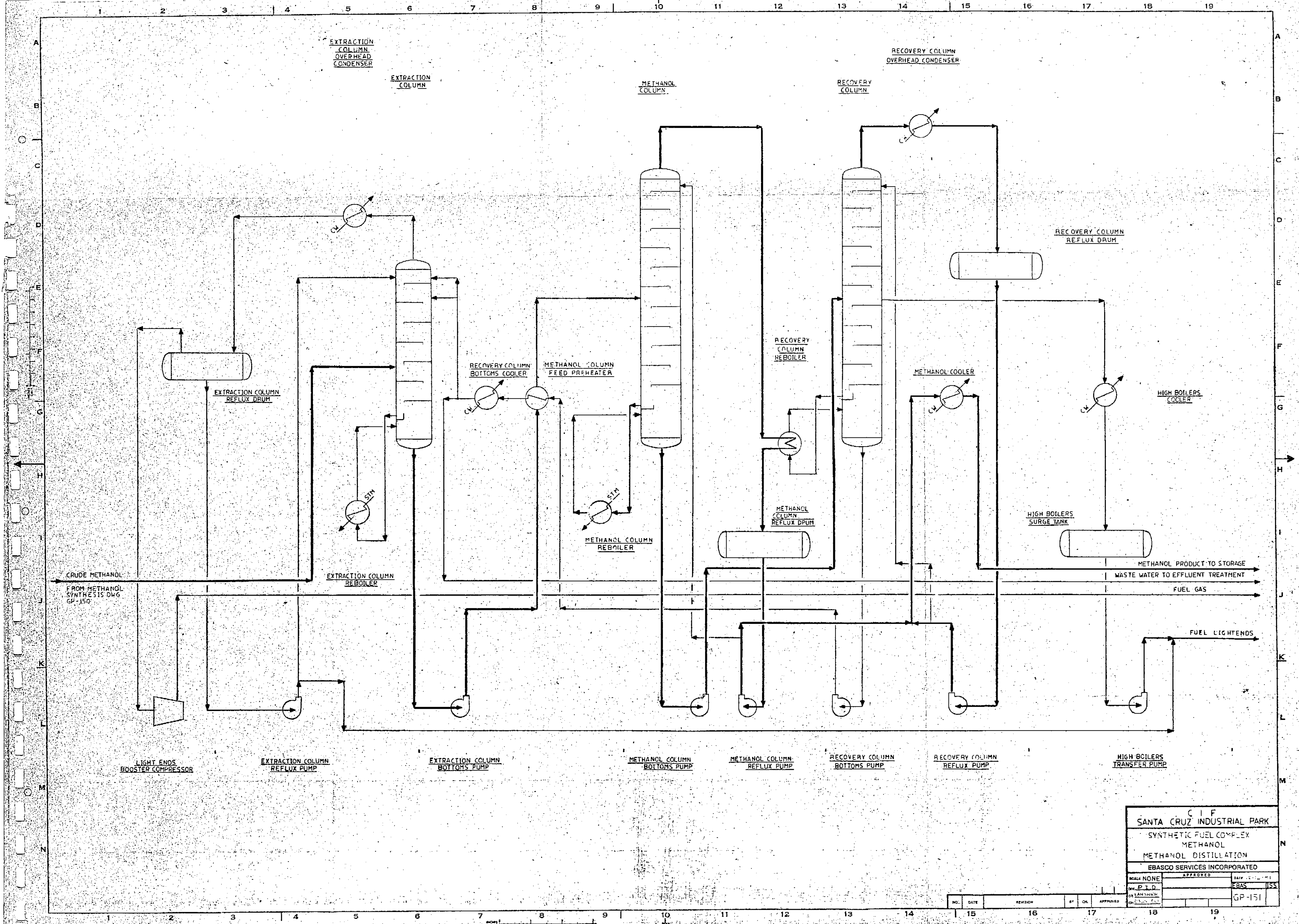
EBASCO SERVICES INCORPORATED

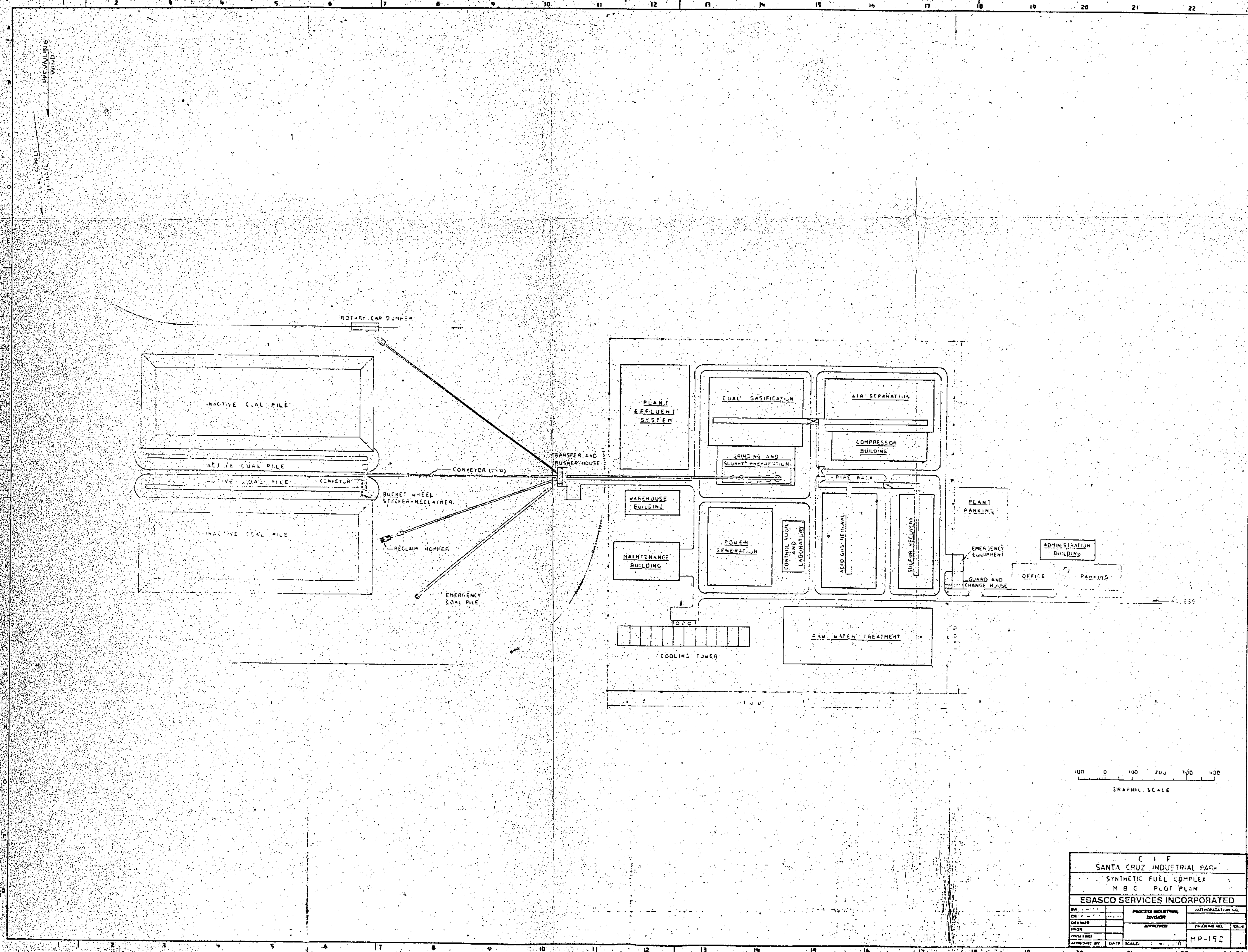
SCALE NONE | APPROVED | DATE 10-16-81
DW. P.I.D.
DR. EAVONT
CH. CA-ATELLI
GP-148

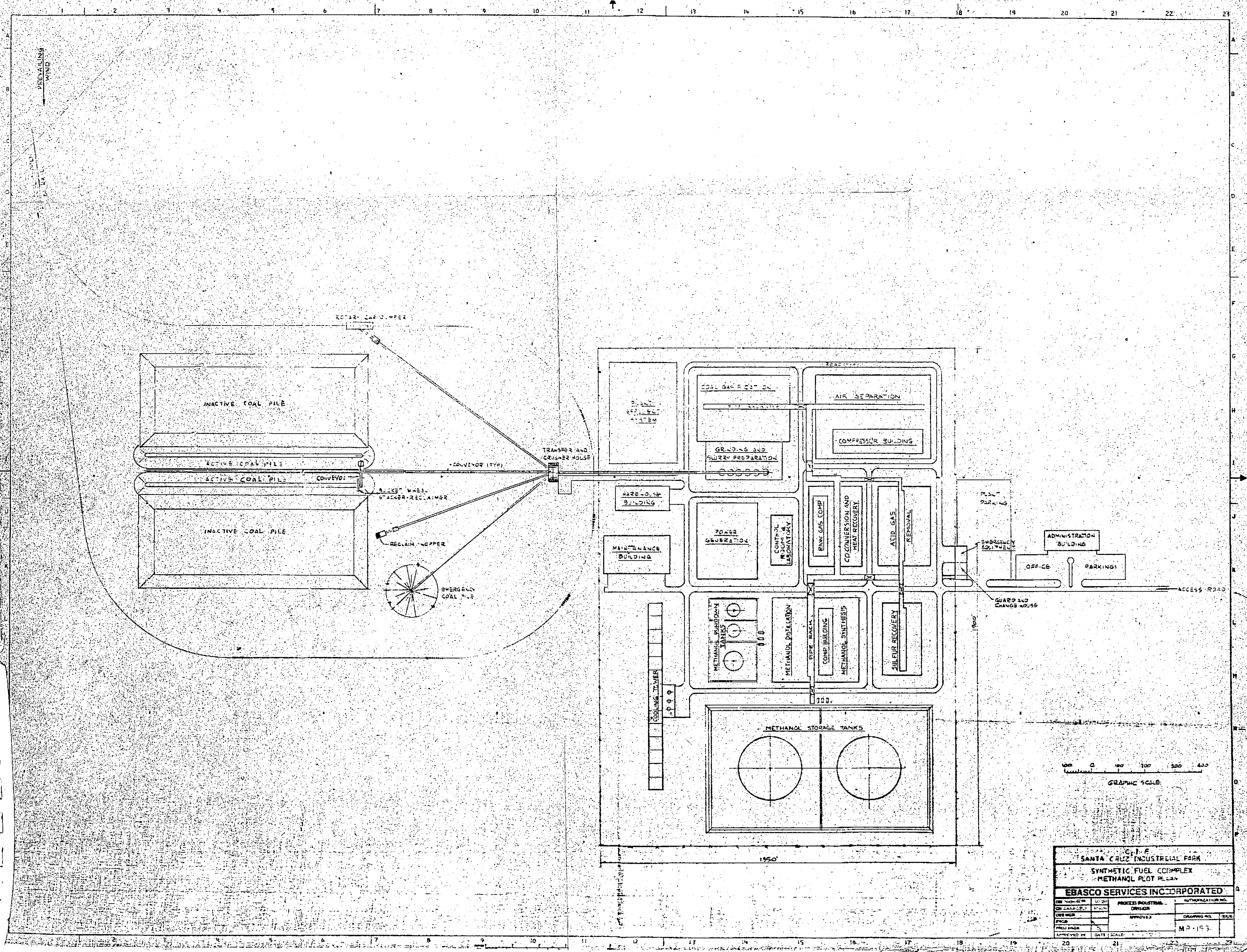


LP NITROGEN FROM AIR SEPARATION
SOUR GAS TO SULFUR RECOVERY
DWG GP-146
DEGASIFIED WATER
CO_2 VENT TO ATMOSPHERE
ABSORBER
REGENERATOR REFLUX DRUM
SOUR GAS CHILLER
H_2S FRACTION SEPARATOR
SOUR GAS/ SOUR GAS EXCHANGER
REFRIGERANT
REGENERATOR CONDENSER
CW
FRACTION SEPARATOR BOTTOMS PUMP
FLASH GAS SEPARATOR
CO_2 WATER WASH COLUMN
INTERCOOLER II FOR ABSORBER
LEAN METHANOL CHILLER
COLD STRIPPER II
REGENERATOR REFLUX PUMP
STILL CONDENSER
METHANOL/WATER STILL
INTERCOOLER I FOR ABSORBER
REFRIGERANT
CO_2 RECYCLE SEPERATOR
REGENERATOR
LP STEAM
MP STEAM
COLD STRIPPER I
METHANOL SURGE DRUM
FEED/BOTTOMS EXCHANGER
REGENERATOR REBOILER
STILL REBOILER
FEED GAS/ TAIL GAS EXCHANGER
FEED GAS CHILLER
FEED GAS K.O. DRUM
H_2S RECYCLE SEPARATOR
MAIN METHANOL PUMP
REFLUX PUMP
TAIL GAS/ METHANOL EXCHANGER
COLD STRIPPER CIRC. PUMP
COLD STRIPPER BOTTOMS PUMP
MAKE GAS TO DWG GP-150
METHANOL/METHANOL EXCHANGER
RECYCLE COMPRESSOR AFTERCOOLER
CW
RECYCLE GAS COMPRESSOR
LEAN METHANOL CHILLER
REFRIGERANT
WASH WATER TO WASTE TREATMENT
MAKE GAS FROM CO SHIFT DWG GP-148
C I F
SANTA CRUZ INDUSTRIAL PARK
SYNTHETIC FUEL COMPLEX
METHANOL
ACID GAS REMOVAL
EBASCO SERVICES INCORPORATED
SCALE NONE
APPROVED
DATE
DR. P.I.D.
GP-149
REV. DATE REVISION BY CH. APPROVED


MAKE GAS
FROM ACID GAS REMOVAL
DWG. GP-149
SULFUR GUARD
FEED EFFLUENT
EXCHANGER
GAS
COOLER
C.W.
STM
SULFUR
GUARD
HEATER
MAKEUP GAS
COMPRESSOR
SULFUR GUARD
VESSEL
METHANOL
SEPARATOR
RECYCLE
COMPRESSOR
600 PSIG
STEAM DRUM
600 PSIG STEAM
CONVERTER
FLASH GAS TO PLANT FUEL SYSTEM
PROCESS WATER
LETDOWN
TANK
CRUDE METHANOL
TRIM CONDENSER
M
CRUDE METHANOL
CONDENSER
CONVERTER
HEAT EXCHANGER
WBF PREHEATER
CRUDE METHANOL
TO METHANOL DISTILLATION
DWG GP-151
BOILER FEEDWATER
PURGE GAS
TO FUEL SYSTEM
C I F
SANTA CRUZ INDUSTRIAL PARK
SYNTHETIC FUEL COMPLEX
METHANOL
METHANOL SYNTHESIS
EBASCO SERVICES INCORPORATED
SCALE NONE
APPROVED
EBAS
GP-150
NO.
DATE
REVISION
BY
CH.
APPROVED


EXTRACTION COLUMN OVERHEAD CONDENSER
EXTRACTION COLUMN
METHANOL COLUMN
RECOVERY COLUMN
RECOVERY COLUMN OVERHEAD CONDENSER
RECOVERY COLUMN REFLUX DRUM
CW
RECOVERY COLUMN REBOILER
RECOVERY COLUMN BOTTOMS COOLER
METHANOL COLUMN FEED PREHEATER
METHANOL COOLER
HIGH BOILERS COOLER
EXTRACTION COLUMN REFLUX DRUM
STM
METHANOL COLUMN REFLUX DRUM
METHANOL COLUMN REBOILER
HIGH BOILERS SURGE TANK
CRUDE METHANOL
FROM METHANOL SYNTHESIS DWG GP-150
EXTRACTION COLUMN REBOILER
METHANOL PRODUCT TO STORAGE
WASTE WATER TO EFFLUENT TREATMENT
FUEL GAS
FUEL LIGHTENDS
LIGHT ENDS BOOSTER COMPRESSOR
EXTRACTION COLUMN REFLUX PUMP
EXTRACTION COLUMN BOTTOMS PUMP
METHANOL COLUMN BOTTOMS PUMP
METHANOL COLUMN REFLUX PUMP
RECOVERY COLUMN BOTTOMS PUMP
RECOVERY COLUMN REFLUX PUMP
HIGH BOILERS TRANSFER PUMP
C I F
SANTA CRUZ INDUSTRIAL PARK
SYNTHETIC FUEL COMPLEX
METHANOL
METHANOL DISTILLATION
EBASCO SERVICES INCORPORATED
SCALE NONE
APPROVED
DIV. P.I.D.
EBAS
ISS
GP-151


PREVAILING WIND
ROTARY CAR DUMPER
INACTIVE COAL PILE
ACTIVE COAL PILE
ACTIVE COAL PILE
CONVEYOR
CONVEYOR
BUCKET WHEEL STACKER-RECLAIMER
INACTIVE COAL PILE
RECLAIM HOPPER
EMERGENCY COAL PILE
TRANSFER AND CRUSHER HOUSE
PLANT EFFLUENT SYSTEM
COAL GASIFICATION
AIR SEPARATION
COMPRESSOR BUILDING
GRINDING AND SLURRY PREPARATION
PIPE RACK
WAREHOUSE BUILDING
MAINTENANCE BUILDING
POWER GENERATION
CONTROL ROOM AND LABORATORY
ACID GAS REMOVAL
SULFUR RECOVERY
PLANT PARKING
EMERGENCY EQUIPMENT
GUARD AND CHANGE HOUSE
ADMINISTRATION BUILDING
OFFICE
PARKING
ACCESS
RAW WATER TREATMENT
COOLING TOWER
100 0 100 200 300 400
GRAPHIC SCALE
C I F
SANTA CRUZ INDUSTRIAL PARK
SYNTHETIC FUEL COMPLEX
M B G PLOT PLAN
EBASCO SERVICES INCORPORATED
PROCESS INDUSTRIAL DIVISION
APPROVED
AUTHORIZATION NO.
DRAWING NO.
MP-152


PREVAILING WIND
ROTARY CAR DUMPER
INACTIVE COAL PILE
ACTIVE COAL PILE
ACTIVE COAL PILE
CONVEYOR
BUCKET WHEEL STACKER-RECLAIMER
INACTIVE COAL PILE
RECLAIM HOPPER
EMERGENCY COAL PILE
TRANSFER AND CRUSHER HOUSE
CONVEYOR (TYP)
COAL GASIFICATION
AIR SEPARATION
COMPRESSOR BUILDING
GRINDING AND SLURRY PREPARATION
WAREHOUSE BUILDING
POWER GENERATION
CONTROL ROOM & LABORATORY
RAW GAS COMP
CO CONVERSION AND HEAT RECOVERY
ACID GAS REMOVAL
MAINTENANCE BUILDING
METHANOL RUNDOWN TANKS
METHANOL DISTILLATION
PIPE RACK
COMP BUILDING
METHANOL SYNTHESIS
SULFUR RECOVERY
COOLING TOWER
METHANOL STORAGE TANKS
PLANT PARKING
EMERGENCY EQUIPMENT
ADMINISTRATION BUILDING
OFFICE
PARKING
ACCESS ROAD
GUARD AND CHANGE HOUSE
1900'
1550'
GRAPHIC SCALE
C.I.E.
SANTA CRUZ INDUSTRIAL PARK
SYNTHETIC FUEL COMPLEX
METHANOL PLOT PLAN
EBASCO SERVICES INCORPORATED
APPROVED
DRAWING NO.
ISSUE
AUTHORIZATION NO.
DATE
SCALE
MP-153