DOE/ET/13060-T3(Vol.1)
(DE81025507)

PHASE I: THE PIPELINE GAS DEMONSTRATION PLANT
DEMONSTRATION PLANT ENGINEERING AND DESIGN

Volume 1: Executive Summary

May 1981

Work Performed Under Contract No. AC01-77ET13060

Conoco Inc.
Stamford, Connecticut

and

Foster Wheeler Energy Corporation
Livingston, New Jersey

U. S. DEPARTMENT OF ENERGY

DISCLAIMER

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Volume 1
Executive Summary

Conoco Inc.
High Ridge Park
Stamford, Connecticut 06904

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Foster Wheeler Energy Corporation
110 South Orange Avenue
Livingston, New Jersey 07039

Prepared for the
United States Department of Energy
Division of Fossil Fuel Processing
Under Contract EF-77-C-01-2542

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ABSTRACT

The Phase I engineering and design of a demonstration plant under Contract No. EF-77-C-01-2542 between Conoco Inc. and the U.S. Department of Energy has been completed. The Demonstration Plant is designed to produce 19 million standard cubic feet per day of pipeline quality gas from 1,257 tons per day of Ohio No. 9 coal. The process to be demonstrated is based on the British Gas/Lurgi slagging gasifier which reacts coal with steam and oxygen at elevated temperatures and pressures to produce a crude synthesis gas. The crude gas is purified in a Rectisol unit and subsequently converted to high-Btu gas by a combination of shift/methanation, Benfield, and methanation processes.

Sulfur, ammonia, naphtha, oil, and crude phenols are produced as by-products. The Stretford, Beavon, PHOSAM-W, Rectisol, and Phenosolvan processes are used to recover the by-products.

Phase I of Contract No. EF-77-C-01-2542 has been completed except for the preparation of remaining reports. All reports are scheduled to be issued by June 30, 1981.

1.0 EXECUTIVE SUMMARY

Contract No. EF-77-C-01-2542 between Conoco Inc. and the U.S. Department of Energy provides for the design, construction, and operating of a demonstration plant capable of processing bituminous caking coals into clean pipeline quality gas.

Work under the contract is to proceed in three phases:

Phase I - Demonstration Plant Engineering and Design
Phase II - Demonstration Plant Construction
Phase III- Demonstration Plant Operation

One of the major efforts of Phase I is the completion of a process and engineering design of the Demonstration Plant. This design effort has been completed.

The Demonstration plant consists of the following plant sections:

Section		Name
100	-	Feedstock Preparation
200	-	Air Separation
300	-	Gasification
400	-	Rectisol
500	-	Shift/Methanation
600	-	CO_2 Removal
800	-	Product Gas Compression and Drying
900	-	Sulfur Recovery
1000	-	Slag Handling/Disposal
1100	-	Gas Liquor Separation
1200	-	Phenol Extraction
1300	-	Ammonia Recovery
2000	-	Water Treatment and Steam Plant
2400	-	Cooling Water
2500	-	Plant and Instrument Air
2700	-	Waste Water Treatment
3000	-	Flare
3200	-	Miscellaneous Offsites and Tank Farm
3300	-	County Road
4000	-	Electrical and Communications
4100	-	Buildings

A report covering the process and engineering design is being issued in 24 volumes. An index of the 24 volumes is given on the next page. This is Volume 1, the Executive Summary. It gives an overview of the design effort.

VOLUME INDEX
FOR DEMONSTRATION PLANT ENGINEERING & DESIGN REPORT

Volume	Title
1	Executive Summary
2	Overall Plant
3	Plant Section 100 - Feedstock Preparation
4	Plant Section 200 - Air Separation
5	Plant Section 300 - Gasification
6	Plant Section 400 - Rectisol
7	Plant Section 500 - Shift/Methanation
8	Plant Section 600 - CO_2 Removal
9	Plant Section 800 - Product Gas Compression and Drying
10	Plant Section 900 - Sulfur Recovery
11	Plant Section 1000 - Slag Handling/Disposal
12	Plant Section 1100 - Gas Liquor Separation
13	Plant Section 1200 - Phenol Extraction
14	Plant Section 1300 - Ammonia Recovery
15	Plant Section 2000 - Water Treatment And Steam Plant
16	Plant Section 2400 - Cooling Water
17	Plant Section 2500 - Plant And Instrument Air
18	Plant Section 2700 - Waste Water Treatment
19	Plant Section 3000 - Flare
20	Plant Section 3200 - Miscellaneous Offsites And Tank Farm
21	Plant Section 3300 - County Road
22	Plant Section 4000 - Electrical and Communications
23	Plant Section 4100 - Buildings
24	Job Specifications

1.1 Demonstration Plant Engineering And Design

The Phase I engineering and design of the Demonstration Plant consists of the following:

a. Job Specifications;
b. Process Flow Diagrams;
c. Piping and Instrument Diagrams (Engineering Flow Diagrams);
d. Equipment And Machinery Lists;
e. Instrument Lists;
f. Line Lists;
g. Equipment and Machinery Specifications (Data Sheets and Requisitions);
h. Instrument Requisitions;
i. Electrical One-Line Drawings;
j. Building Drawings and Specifications;
k. Site Preparation Drawings and Specifications;
l. Road Drawings and Specifications; and
m. Plot Plans.

The Demonstration Plant project is ready to proceed to Phase II - Demonstration Plant Construction if a decision is made to proceed with Phases II and III of the project. Additional engineering design work such as foundation designs, piping lay-outs, and piping isometric drawings will be necessary in Phase II after equipment drawings are received from vendors.

The following firms provided portions of the process and engineering design for the Demonstration Plant:

a. Foster Wheeler Energy Corporation
Livingston, New Jersey

b. Lurgi Kohle und Mineraloeltechnik, GmbH
Frankfurt (Main), Federal Republic of Germany

c. British Gas Corporation
London, United Kingdom

d. USS Engineers and Consultants, Inc.
Pittsburgh, Pennsylvania

e. Benfield Corporation
Pittsburgh, Pennsylvania

f. The Ralph M. Parsons Company
Pasadena, California

g. The Engineering Center
Conoco Inc.
Ponca City, Oklahoma

1.2 Process Description And Key Plot Plan

The overall plant configuration is shown on Drawing No. 1910-1-50-00151. This drawing shows the design mass rates into and from each section of the plant. A photograph of a Block Model of the plant follows the drawing.

The plant site consists of 1,265 acres, but only about 200 acres will be occupied by the Demonstration Plant. The Key Plot Plan of the area to be occupied by the plant is shown as Drawing No. 1910-1-01-00001.

The process to be demonstrated combines new technology and existing commercially proven technology. The new technology involves mainly the gasification and shift/methanation steps.

The feedstocks for the plant (coal, flux, and start-up fuel) are received and stored in Plant Section 100 - Feedstock Preparation and fed to Plant Section 300 - Gasification. Oxygen is produced by cryogenic separation in Plant Section 200 - Air Separation for use in the gasification process.

The coal is gasified with steam and oxygen in Plant Section 300 - Gasification using the British Gas/Lurgi slagging gasifier. The gasifier is a high pressure, moving bed, oxygen-blown slagging gasifier. Coal enters the gasifier through a lock hopper and is gasified by steam and oxygen fed through tuyeres near the bottom of the gasifier. Crude synthesis gas exits at the top of the gasifier, and the ash is removed as molten slag through a tap hole in the bottom of the gasifier. Flux is added to the coal to reduce the viscosity of the slag. The molten slag is quenched in a water-filled quench vessel where the slag solidifies into a granular material resembling frit. The solidified frit is removed through the slag lock hopper. The slag is disposed of in a landfill via Plant Section 1000 - Slag Handling/Disposal.

The hot crude synthesis gas exits the gasifier and is quenched and cooled for further processing. The cooling process produces an aqueous stream called gas liquor contaminated with tar, oil, phenol, and ammonia.

The cooled gas is treated in Plant Section 400 - Rectisol, where it is scrubbed with methanol at sub-zero temperatures to produce a clean synthesis gas. The acid gases in the crude gas are removed and sent to Plant Section 900 - Sulfur Recovery. Light hydrocarbon oils called naphtha are recovered and pumped to storage in Plant Section 3200.

The purified synthesis gas from Rectisol proceeds to Plant Section 500 - Shift/Methanation where the hydrogen and carbon monoxide are reacted to produce methane. Carbon dioxide is produced as a result of the reaction. Gas from the first reaction stages of Shift/Methanation is sent to Plant Section 600 - CO_2 Removal

where the excess carbon dioxide is removed by the Benfield process. The gas is then returned to the second reaction stage of Shift/ Methanation for further methanation.

The methanated gas is compressed and dried in Plant Section 800 - Product Gas Compression and Drying to produce a pipeline quality substitute natural gas.

By-product recovery from the gas liquor occurs in Plant Section 1100 - Gas Liquor Separation where the tar and oil are removed from the gas liquor. The gas liquor proceeds to Plant Section 1200 - Phenol Extraction where the phenolic material is removed by the Phenosolvan process. Tar is recycled to gasification. The oil and phenol are sent to product storage in Plant Section 3200.

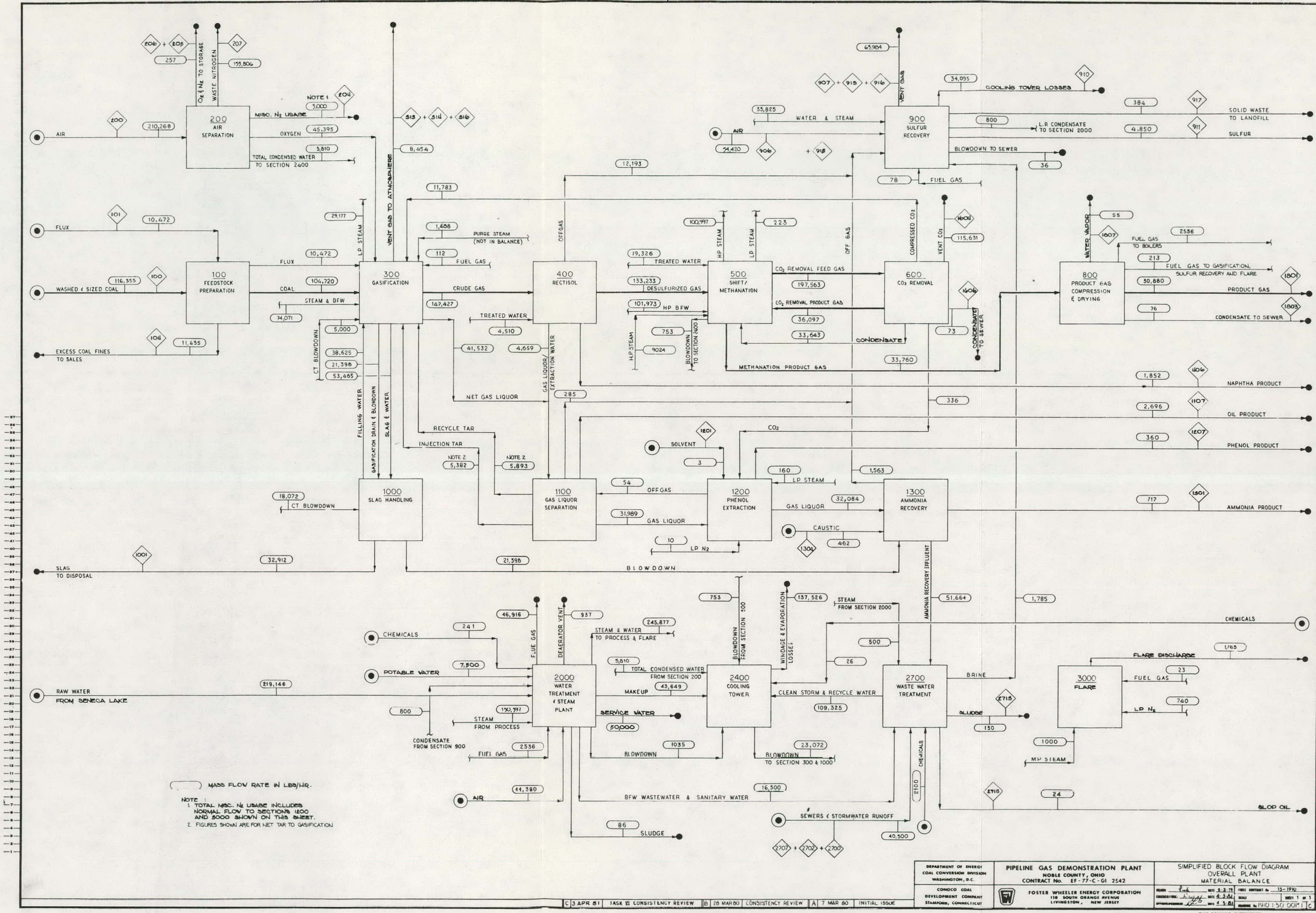
The dephenolated gas liquor is sent to Plant Section 1300 -Ammonia Recovery where the ammonia is stripped out of the water by the PHOSAM-W process and is recovered to produce commercial grade anhydrous ammonia. The waste water proceeds to Plant Section 2700 - Waste Water Treatment for final treatment.

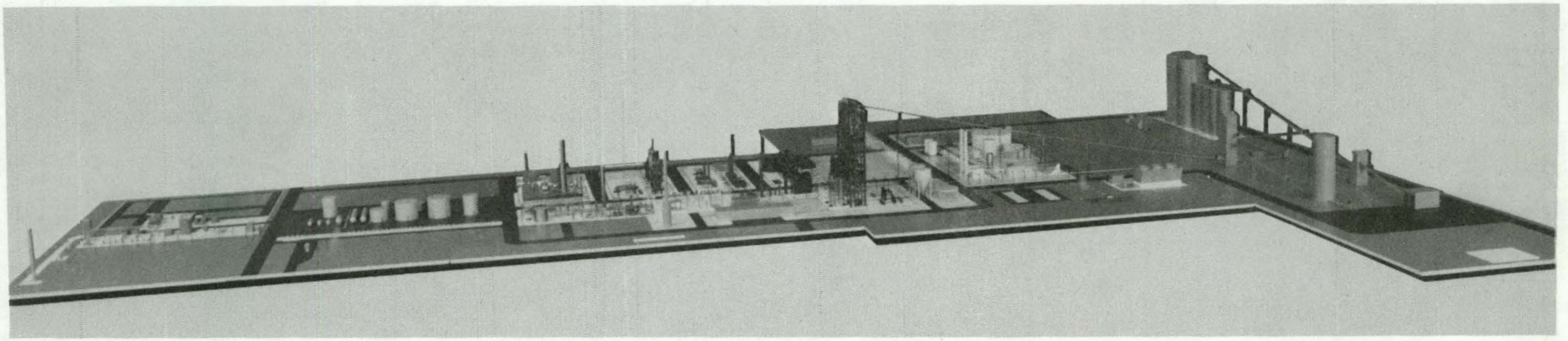
The sulfur bearing gases produced by Rectisol and other units are treated in Plant Section 900 - Sulfur Recovery. The sulfur components are removed and recovered as elemental sulfur using the Stretford and Beavon processes.

Raw water is received and treated in Plant Section 2000 - Water Treatment and Steam Plant to provide the plant water requirements. Demineralized water is produced to satisfy the boiler feed water requirements. Start-up and supplemental steam is produced in gas-fired boilers. A back-up fuel oil system is provided.

The plant is designed for zero discharge of liquid wastes. The plant waste water streams are processed in Plant Section 2700 - Waste Water Treatment to remove organic contaminants. The waste water is then evaporated to produce a clean condensate for reuse in the cooling tower and a brine containing the dissolved solids. This brine and a sulfur recovery section purge stream are combined and spray dried producing a dry solid for disposal in a secure landfill.

The remaining plant sections provide support utilities for plant operations.

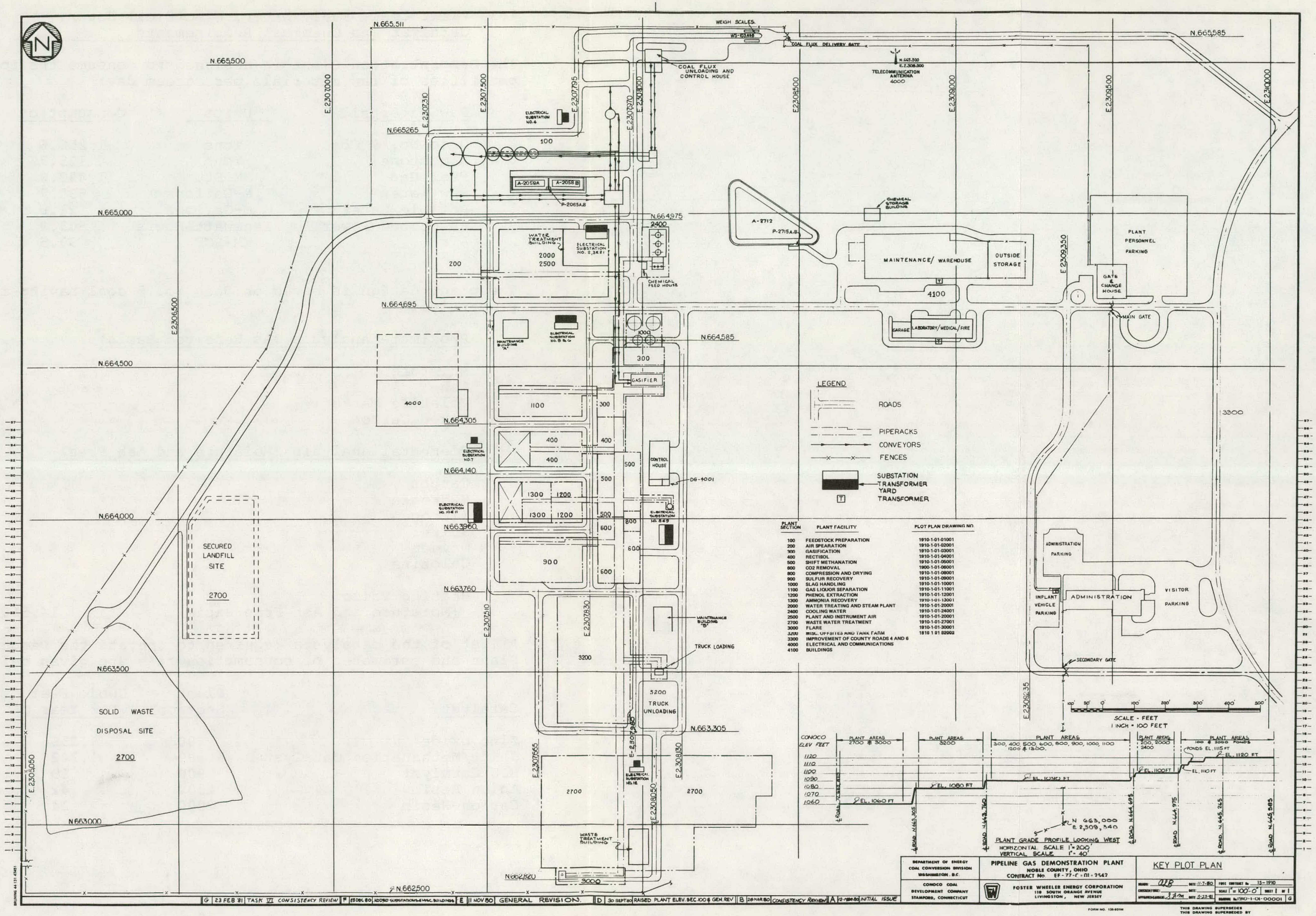

200 AIR SEPARATION
100 FEEDSTOCK PREPARATION
300 GASIFICATION
400 RECTISOL
500 SHIFT/METHANATION
600 CO2 REMOVAL
800 PRODUCT GAS COMPRESSION & DRYING
900 SULFUR RECOVERY
1000 SLAG HANDLING
1100 GAS LIQUOR SEPARATION
1200 PHENOL EXTRACTION
1300 AMMONIA RECOVERY
2000 WATER TREATMENT & STEAM PLANT
2400 COOLING TOWER
2700 WASTE WATER TREATMENT
3000 FLARE
AIR
FLUX
WASHED & SIZED COAL
EXCESS COAL FINES TO SALES
SLAG TO DISPOSAL
RAW WATER FROM SENECA LAKE
CHEMICALS
POTABLE WATER
CRUDE GAS
NET GAS LIQUOR
RECYCLE TAR
INJECTION TAR
BLOWDOWN
COOLING TOWER LOSSES
SOLID WASTE TO LANDFILL
SULFUR
PRODUCT GAS
CONDENSATE TO SEWER
NAPHTHA PRODUCT
OIL PRODUCT
PHENOL PRODUCT
AMMONIA PRODUCT
FLARE DISCHARGE
SLOP OIL
SERVICE WATER
SLUDGE
SEWERS & STORMWATER RUNOFF
MASS FLOW RATE IN LBS/HR.
NOTE:
1. TOTAL MISC. N2 USAGE INCLUDES NORMAL FLOW TO SECTIONS 1200 AND 3000 SHOWN ON THIS SHEET.
2. FIGURES SHOWN ARE FOR NET TAR TO GASIFICATION
DEPARTMENT OF ENERGY
COAL CONVERSION DIVISION
WASHINGTON, D.C.
CONOCO COAL DEVELOPMENT COMPANY
STAMFORD, CONNECTICUT
PIPELINE GAS DEMONSTRATION PLANT
NOBLE COUNTY, OHIO
CONTRACT No. EF-77-C-01 2542
FOSTER WHEELER ENERGY CORPORATION
110 SOUTH ORANGE AVENUE
LIVINGSTON, NEW JERSEY
SIMPLIFIED BLOCK FLOW DIAGRAM
OVERALL PLANT
MATERIAL BALANCE
C 3 APR 81 TASK III CONSISTENCY REVIEW
B 28 MAR 80 CONSISTENCY REVIEW
A 7 MAR 80 INITIAL ISSUE



PIPELINE GAS DEMONSTRATION PLANT

NOBLE COUNTY, OHIO

BLOCK MODEL


LEGEND
ROADS
PIPERACKS
CONVEYORS
FENCES
SUBSTATION
TRANSFORMER
YARD
TRANSFORMER
PLANT SECTION
PLANT FACILITY
PLOT PLAN DRAWING NO
100 FEEDSTOCK PREPARATION 1910-1-01-01001
200 AIR SPEARATION 1910-1-01-02001
300 GASIFICATION 1910-1-01-03001
400 RECTISOL 1910-1-01-04001
500 SHIFT METHANATION 1910-1-01-05001
600 CO2 REMOVAL 1900-1-01-06001
800 COMPRESSION AND DRYING 1910-1-01-08001
900 SULFUR RECOVERY 1910-1-01-09001
1000 SLAG HANDLING 1910-1-01-10001
1100 GAS LIQUOR SEPARATION 1910-1-01-11001
1200 PHENOL EXTRACTION 1910-1-01-12001
1300 AMMONIA RECOVERY 1910-1-01-13001
2000 WATER TREATING AND STEAM PLANT 1910-1-01-20001
2400 COOLING WATER 1910-1-01-24001
2500 PLANT AND INSTRUMENT AIR 1910-1-01-20001
2700 WASTE WATER TREATMENT 1910-1-01-27001
3000 FLARE 1910-1-01-30001
3200 MISC. OFFSITES AND TANK FARM
3300 IMPROVEMENT OF COUNTY ROADS 4 AND 6
4000 ELECTRICAL AND COMMUNICATIONS
4100 BUILDINGS
WEIGH SCALES
COAL FLUX DELIVERY GATE
COAL FLUX UNLOADING AND CONTROL HOUSE
TELECOMMUNICATION ANTENNA
MAINTENANCE/ WAREHOUSE
OUTSIDE STORAGE
PLANT PERSONNEL PARKING
GATE & CHANGE HOUSE
MAIN GATE
LABORATORY/MEDICAL/FIRE
GARAGE
SECURED LANDFILL SITE
SOLID WASTE DISPOSAL SITE
ADMINISTRATION
ADMINISTRATION PARKING
VISITOR PARKING
INPLANT VEHICLE PARKING
SECONDARY GATE
CONTROL HOUSE
GASIFIER
TRUCK LOADING
3200 TRUCK UNLOADING
WASTE TREATMENT BUILDING
SCALE - FEET
1 INCH = 100 FEET
PLANT GRADE PROFILE LOOKING WEST
HORIZONTAL SCALE 1" = 200'
VERTICAL SCALE 1" = 40'
DEPARTMENT OF ENERGY
COAL CONVERSION DIVISION
WASHINGTON, D.C.
CONOCO COAL
DEVELOPMENT COMPANY
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PIPELINE GAS DEMONSTRATION PLANT
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FOSTER WHEELER ENERGY CORPORATION
110 SOUTH ORANGE AVENUE
LIVINGSTON, NEW JERSEY
KEY PLOT PLAN
SCALE 1" = 100'-0"
SHEET 1 OF 1
1910-1-01-00001
G 23 FEB 81 TASK VI CONSISTENCY REVIEW
E 11 NOV 80 GENERAL REVISION
A INITIAL ISSUE
THIS DRAWING SUPERSEDES
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1.3 Plant Coal, Fuel, Water, Electrical Power, Catalyst and Chemical Requirements

The Demonstration Plant is designed to consume the following quantities of raw materials per stream day:

Raw Material	Units	Consumption
Ohio No. 9 Coal	Tons	1,256.6
Limestone	Tons	125.7
Fuel Gas	MM-Btu	1,493.8
Raw Water	M-Gallons	630.7
Potable Water	M-Gallons	21.6
Purchased Power	Megawatt-Hours	503.9
Air	MM-SCF	99.5

The plant design is based on Ohio No. 9 coal having the following properties:

Proximate Analysis (As Received Basis)	Wt.%
Moisture	2.5
Ash	22.5
Volatile Matter	35.0
Fixed Carbon	40.0

Elemental Analysis (Moisture and Ash Free)	Wt.%
Carbon	78.00
Hydrogen	5.65
Nitrogen	1.25
Sulfur	6.30
Oxygen	8.75
Chlorine	0.05

Heating Value (Moisture and Ash Free Basis) 14,560 Btu/lb

A list of the catalysts required to operate the Demonstration Plant and estimates of consumption rate are given below:

Catalyst	Plant Section	Cubic Feet Per Year
Zinc oxide	500	1,256
Shift/Methanation Catalyst	500	1,742
HDS Catalyst	900	30
Anion Resin	2000	42
Cation Resin	2000	24

A list of the chemicals required to operate the Demonstration Plant and estimates of consumption rates are given below:

Chemical	Pounds Per Hour
Antifoam	0.06
Anthraquinone Disulfonic Acid	7.5
Active Carbon-Granular	30
Active Carbon-Powdered	8.3
Caustic (50 wt.%)	900
Chlorine	0.32
Corrosion Inhibitor	9.0
Diethanolamine	0.91
Dispersant	4.5
Foam Agent	0.3
Hydrazine (35 wt.%)	0.004
Isopropyl Ether	3
Lime (93 Wt.%)	33.3
Lubricants	0.7
Methanol	88
Morphaline (40 Wt.%)	0.2
Phosphate	0.219
Phosphoric Acid (75 Wt.%)	15
Polymers	1.9
Potassium Carbonate	8.84
Potassium Nitrate	0.32
Sodium Ammonium Vanadate	7.7
Sodium Chlorite	0.82
Sulfuric Acid (96 Wt.%)	109.1
Triethylene Glycol	1
Vanadium Pentoxide	0.3
Sodium Chloride	2

1.4 Overall Plant Heat And Material Balance

An overall heat and material balance for the Demonstration Plant is given below:

Input Stream	Pounds per Hour	Heating Value, Million Btu per Hour
Ohio No. 9 coal	104,720	1,143.54
Air	309,068	-
Water	226,646	-
Limestone (Flux)	10,472	-
Fuel Gas	2,536	57.54
Chemicals	2,832	-
Electrical Power	-	204.72*
Total Inputs	656,274	1,405.80
Output Streams		
Pipeline Gas (SNG)	33,416	758.16
Oil	2,696	43.46
Naphtha	1,852	31.86
Phenols	360	4.61
Ammonia	717	6.90
Sulfur	4,850	19.64
Slag	32,912	0.42
Vent Gases	396,053	-
Solid Wastes	624	-
Water Losses & Consumed	182,794	-
Heat Losses	-	540.75
	656,274	1,405.80

* 20,995 KW at 35 percent generation efficiency.

1.5 Products and By-Products

The Demonstration Plant is designed to produce 19.08 million standard cubic feet per day of pipeline quality gas (SNG). Of this 17.52 million standard cubic feet per day will be available for sale to customers. The balance is consumed in the plant as shown below:

Plant Use	Plant Section	Million SCFD
Gasifier	300	0.062
Beavon Unit	900	0.044
Steam Boilers	2000	1.438
Flare Pilots	3000	0.012
Total		1.556

The design composition and heating value of the product gas are:

Component	Volume Percent
Methane	94.02
Hydrogen	3.18
Carbon Monoxide	0.03
Carbon Dioxide	0.76
Nitrogen	1.99
Water	0.02
	100.00

Gross Heating Value, Btu/SCF 960

The plant is designed to produce the following by-products for sale to customers:

By-product	Plant Section	Pounds per Day
Naphtha	400	44,448
Sulfur	900	116,400
Oil	1100	64,704
Crude Phenols	1200	8,640
Ammonia	1300	17,208

1.6 Plant Waste Streams

The Demonstration Plant is designed to produce the following gaseous and solid waste streams. No liquid waste streams are produced. The plant is designed to meet all Federal and state environmental regulations.

Waste Stream	Plant Section	Disposition	Pounds per Hour
Particulates	100	Atmosphere	9
Nitrogen Vent	200	Atmosphere	155,806
Lock Vent Gases	300	Atmosphere	8,454
Carbon Dioxide	600	Atmosphere	115,631
Water Vapor	800	Atmosphere	55
Oxidizer Vent	900	Atmosphere	16,000
Incinerator Vent	900	Atmosphere	41,804
Spray Dryer Vent	900	Atmosphere	6,900
Water Vapor	900	Atmosphere	34,095
Evaporated Salts	900	Landfill*	384
Slag	1000	Landfill	32,912
Treatment Sludge	2000	Landfill	86
Boiler Stack Gas	2000	Atmosphere	46,916
Deaerator Vent	2000	Atmosphere	937
Water Vapor	2400	Atmosphere	137,526
Waste Water Sludge	2700	Landfill*	130

*Secure landfill for hazardous solid wastes.

The nitrogen vent from Plant Section 200 consists of 97.6 volume percent nitrogen, the balance being oxygen and water. The drying vent from Plant Section 800, the cooling tower vents from Plant Sections 900 and 2400, and the deaerator vent from Plant Section 2000 are 100 percent water vapor.

Compositions of the other vent gases are given below in weight percent:

Plant Section	300	600	900*	2000**
Component				
Nitrogen	0.40	-	64.20	71.92
Oxygen	0.30	-	11.51	3.62
Carbon Dioxide	98.31	92.94	16.10	17.40
Carbon Monoxide	0.01	-	-	-
Hydrogen	0.32	-	-	-
Methane	-	0.04	-	-
Sulfur Dioxide	-	-	0.01	0.05
Nitrogen Oxides	-	-	-	0.03
Water	1.02	7.02	8.18	6.97
Particulates	-	-	-	0.01
	100.00	100.00	100.00	100.00

* Combined oxidizer, incinerator, and spray dryer vents.
** Stack gas from burning fuel oil; no SO_2 is in stack gas if SNG is the fuel.

The vent gas from the incinerator in Plant Section 900 contains 130 ppmv of sulfur dioxide; that from the spray dryer contains 60 ppmv of sulfur dioxide.

Two on site landfills for solid waste disposal are to be constructed. One is a conventional landfill for disposal of slag and water treatment sludge. Neither are classified as hazardous wastes. The other is a secure landfill for disposal of the evaporated salts from Plant Sections 900 and 2700 waste streams and the waste water sludge from Plant Section 2700. Both of these contain soluble metallic salts which are classified as hazardous wastes. The secure landfill is designed to prevent soluble salts from entering the ground water. It is designed to meet Ohio EPA requirements.

1.7 Definitive Cost Estimate

Foster Wheeler Energy Corporation made a definitive estimate of the erected plant cost. The accuracy of this estimate is between minus 5 and plus 15 percent. Conoco Inc. added other cost items to arrive at a total plant investment cost of 410 million dollars (first quarter 1981, no escalation for inflation).

The definitive cost estimate is summarized below:

Item	Million Dollars
Erected Plant Cost	267.01
A&E Engineering & Construction Management	59.92
Conoco Inc. Adminstrative & Engineering	22.67
Paid-up Royalties	9.95
Initial Charge of Catalyst & Chemicals	1.71
Contingency	49.04
Total Plant Investment	410.30

1.8 Plant Personnel

The operating and maintenance personnel required for the Demonstration Plant are summarized below:

Function	Number Required
Managerial	7
Technical Support	59
Operations Staff	17
Maintenance Staff	38
Health and Safety	21
Administrative Services	20
Process Operators	90
Maintenance Mechanics	106
Total Plant Personnel	358

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