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PNL-3695 App C
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Investigations on Catalyzed Steam Gasification of Biomass

Appendix C: Feasibility Study of Methane Production via Catalytic Gasification of 200 Tons of Wood Per Day

January 1981

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
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INVESTIGATIONS ON CATALYZED STEAM GASIFICATION OF BIOMASS

APPENDIX C: FEASIBILITY STUDY OF METHANE PRODUCTION VIA CATALYTIC GASIFICATION OF 200 TONS OF WOOD PER DAY

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January 1981

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Richland, Washington 99352

PACIFIC NORTHWEST LABORATORY
WOOD TO METHANE STUDY

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Major contributors to this report from Davy McKee were T. J. Kendron, O. A. Kuby, J. H. Rooker, and M. L. McClintock.

I. EXECUTIVE SUMMARY

This report is a result of an additional study made of the economic feasibility of producing substitute natural gas (SNG) from wood via catalytic gasification with steam. The report has as its basis the original 2000 tons of wood per day study generated from process development unit testing performed by the Pacific Northwest Laboratory. The goal of this additional work was to determine the feasibility of a smaller scale plant one-tenth the size of the original or 200 tons of dry wood feed per day.

Plant production based on this wood feed is 2.16 MM Scfd of SNG with a HHV of 956 Btu per Scf. All process and support facilities necessary to convert wood to SNG are included in this study. The plant location is Newport, Oregon.

The capital cost for the plant is $26,680,000 - September, 1980 basis. Gas production costs which allow for return on capital have been calculated for various wood prices for both utility and private investor financing. These wood prices represent the cost of unchipped wood delivered to the plant site. For utility financing, the gas production costs are respectively $14.34, $14.83, $15.86, and $17.84 per MM Btu for wood costs of $5, $10, $20, and $40 per dry ton. For private investor financing, the corresponding product costs are $18.76, $19.26, $20.28, and $22.31 per MM Btu for the corresponding wood costs. The costs calculated by the utility financing method includes a return on equity of 15% and an interest rate of 10% on the debt. The private investor financing method, which is 100% equity financing, incorporates a discounted cash flow (DCF) return on equity of 12%.

The thermal efficiency without taking an energy credit for char is 57.4%.

II. INTRODUCTION AND CONCLUSIONS

A. INTRODUCTION

The purpose of this study is to determine the feasibility of producing synthetic natural gas (SNG) in a small-scale commercial plant, utilizing the catalytic gasification of wood and forest residue with steam. The plant is designed to process 200 tons per day of dry feedstock. The study is an extension of an earlier study based on a larger plant to process 2000 tons per day of dry feedstock. All necessary process and support facilities needed to convert forest residue to SNG are included in this work. The plant location is Newport, Oregon.

This report contains both the technical and economic results of this study. The technical information includes: (1) a process summary, (2) layout drawings of the wood preparation, (3) a flow schematic for wood storage and drying, (4) a single line equipment list, (5) a four line equipment list for the areas of wood preparation, wood drying, gasification, and catalyst regeneration, (6) a detailed drawing of the gasifier, and (7) a summary of process materials and utilities. The economic information includes: (1) a capital cost estimate, and (2) product cost estimates using both utility and private investor financing.

B. BASIS OF DESIGN

The original 2000 ton per day study, which serves as the foundation for this additional work, was based on data from the Pacific Northwest Laboratory process development unit, operated by Battelle. The data provided included gasifier operating conditions such as temperature, pressure, char and gas yield, size and throughput, and feedstock conditions. From this information an overall processing scheme was developed.

The design basis and basic assumptions for this study are essentially the same as in the original. The only significant deviation in the process scheme is that wood being delivered to the plant is now assumed to be unchipped, whereas the original study assumed wood would be delivered in a chipped form. New detailed designs and estimates were made for the areas of wood handling, wood drying, gasification, and catalyst regeneration. The costs of the remaining areas were obtained by selectively factoring the costs from the larger plant.

C. SUMMARY

Production costs for SNG from wood were calculated according to both utility financing and private investor financing methods. These costs were calculated for a base case of $20 per dry ton, with costs also calculated for prices of $5, $10, and $40 per dry ton. This price is for wood delivered to the plant unchipped and with a moisture content of 49.5 wt.%. For utility financing the production costs are $14.34, $14.83, $15.86, and $17.84 per MM Btu for wood prices $5, $10, $20, and $40 per dry ton respectively. For private investor financing and the same wood prices, the corresponding production costs are $18.76, $19.26, $20.28, and $22.31 per MM Btu. Both financial

SUMMARY - (Continued)

calculation methods included a return on equity -- a rate of 15% for the utility method and a DCF rate of 12% for the private investor method. The capital cost of the plant is $26,680,000 - September, 1980 basis.

The thermal efficiency of the plant, as defined by the following equation, is 57.4%. When the heating value of the excess char is included in the output, the thermal efficiency is 63.8%.

$$\text{Efficiency, \%} = \frac{\text{SNG, HHV}}{\text{Wood, HHV + Electricity + Diesel Fuel}} \quad (100)$$

The plant production is 6.81×10^{11} Btu per year. The yield is 10,790 Scf per ton of dry wood feed.

III PLANT LAYOUT AND DESCRIPTION

A. PROCESS AND OFF-SITES DESCRIPTION

B. FLOWSHEET FOR WOOD PREPARATION AREA

C. LAYOUT DRAWING FOR WOOD PREPARATION AREA

D. DETAILED DRAWING FOR GASIFIER

E. SINGLE LINE EQUIPMENT LIST

F. DETAILED EQUIPMENT LIST

A. PROCESS AND OFFSITE DESCRIPTIONS

General

The process plant complex described in the following sections is capable of producing 2.1 million cubic feet per day (MMSCFD) of substitute natural gas from 200 tons per day of dry wood. The feedstock to the plant will consist primarily of forest residues of various species from logging operations within a 100 mile radius of Newport, Oregon. The wood is reacted with steam in the presence of a Ni catalyst in a fluid bed gasifier. The raw gas produced is methanated to produce a substitute natural gas. The following are the major process and offsite units of this plant.

Plant Areas

401 Wood Storage
402 Wood Drying
403 Gasification
404 Compression
405 Shift Conversion
406 Primary Methanation
407 Acid Gas Removal
408 Final Methanation and Product Gas Drying
409 Catalyst Regeneration
410 Wastewater Treating
411 Raw Water Treating and Cooling Water
412 Boilers and Boiler Feedwater System
413 Miscellaneous Utility Systems

Summary

Forest residue which has been delivered to the plant by truck is chipped and stored in open piles. The chips are reclaimed automat-

ically and dried to 10% moisture content in rotary drum dryers. From drying, the chips are transferred to fluid bed gasifiers and partially gasified with steam in the presence of a Ni catalyst. In the reacting bed are tubes through which flow hot combustion gases which supply heat to the reactants. Products of gasification are a raw gas containing methane, carbon dioxide, hydrogen, carbon monoxide, and steam and a char residue. The char is used as fuel to supply heat to the gasifier, to dry the wood, and to generate steam in a boiler.

The gas is compressed and then shifted to adjust the ratio of hydrogen, carbon monoxide, and carbon dioxide. The gas is then reacted in the primary methanator to reduce substantially the concentration of hydrogen and carbon monoxide. The gas is cooled and a portion is recycled to the inlet of the methanator to be combined with gas from the shift area. The remainder of the gas goes to a Benfield system for carbon dioxide removal. After removal of the carbon dioxide, the gases flow to the final methanator in which the carbon monoxide content is reduced to less than 0.1%. The product gas is then compressed to 1015 psia, dried in an ethylene glycol system, and delivered to battery limits.

Cooling tower water is used for process cooling. Steam is generated from waste heat sources and by combustion of char. Excess char will be stored for shipment from the plant. Raw water is available at plant battery limits and requires clarification before use in the cooling tower and demineralization before use as boiler feedwater. All wastewater streams will be treated before discharge, the treatment to consist of neutralization followed by biological treatment.

Detailed Description of Wood Handling Areas

The forest residue is delivered to the plant site by self unloading trucks. Trucks entering and leaving the unloading area are weighed on the truck scale. The 200 ft. long by 50 ft. wide unloading area permits a maximum unloading rate of 120 TPH, which represents 15 to 20 trucks per hour depending on the bulk density of each load. Two of four grapples each mounted on an overhead 50 ft. span crane transfer the forest residue within the unloading area on two of the three chain feeders each serving one 60 TPH capacity stationary chipper. Two chippers will be normally operating, reducing the forest residue as it arrives to the 1/2" chips. The installation of the third chipper will permit changing of the knifes and so ensure continuous operation of the two chippers.

Each chipper, when operating, will blow the chips into a common collecting hopper which will feed the chips onto a tripper/stacker belt conveyor. The tripper/stacker conveyor delivers the chips to one of the two (2) storage piles via a double wing stacker. Each pile is limited to approximately 40 ft. high, as some bark and fines are supplied along with the 1/2" chips. The stacker builds 25 days capacity storage and any enlargement of the storage will be done by one (1) bulldozer spreading the piles.

Each of the two (2) storage piles is 1,000 ft. long and 80 ft. wide for 25 days capacity, with possible enlargement to 160 ft. width and 75 days capacity.

The reclaiming of chips from the storage is carried out by 10 chain reclaimers (8 ft. wide), five for each pile. Each reclaimer has a capacity of 20 TPH which represents the total required reclaiming rate based on 24 hrs/day, 7 days/ week. The bulldozer is used to push chips toward reclaimers when needed. Two reclaiming belt conveyors, one for each pile, collect chips from the respective chain reclaimers and deliver them to the screening station.

The screening station consists of equipment for rock and tramp iron removal and for rechipping of oversize chips.

Detailed Description of Wood Handling Areas - (Continued)

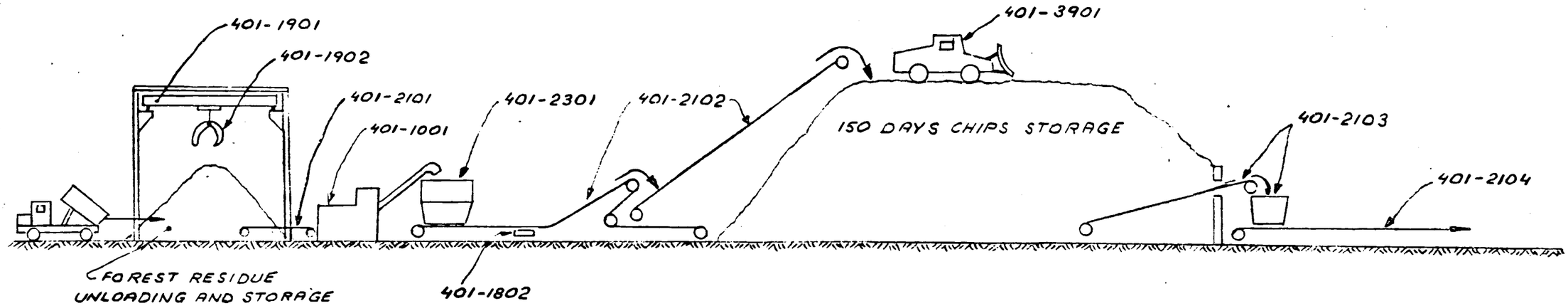
The chips from the screening station are conveyed by conveyor to the surge bin for the dryer.

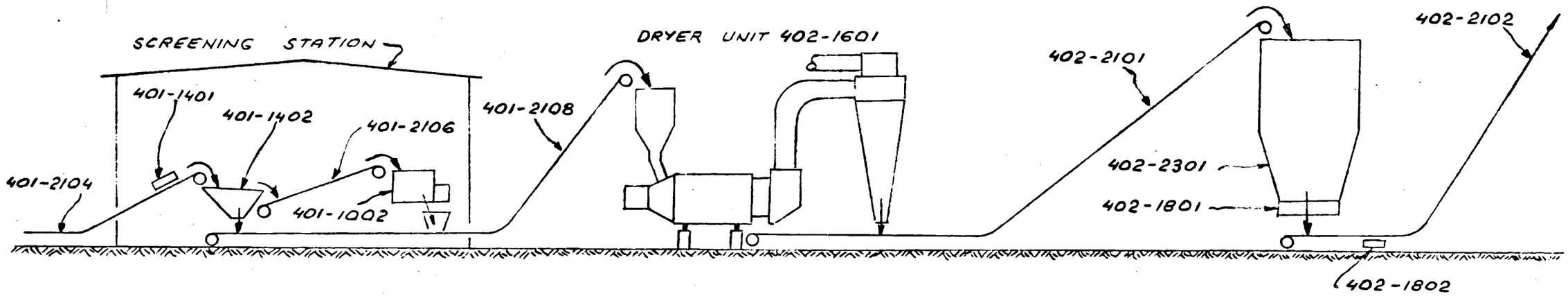
One (1) rotary drum dryer complete with a burner, ash removal cyclone, exhaust dust cyclone, ducting, and all necessary appurtenances is installed to reduce the moisture content of green chips from 50 wt.% of total feed to 10%. The by-product char from the gasifier is used to fuel the burners for the dryers.

Dried chips are conveyed from the dryer to a collecting hopper of ten hours capacity. The chip inventory of this hopper allows necessary maintenance of the dryer. The chips from this hopper are conveyed to the gasifier lock hopper systems.

B. FLOWSHEET FOR WOOD PREPARATION AREA

A flowsheet showing the major equipment in the wood preparation area has been prepared and is shown on drawing number 5471-F-0401 which follows.





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TITLE: WOOD TO METHANE
WOOD PREPARATION AREA
FLOWSHEET

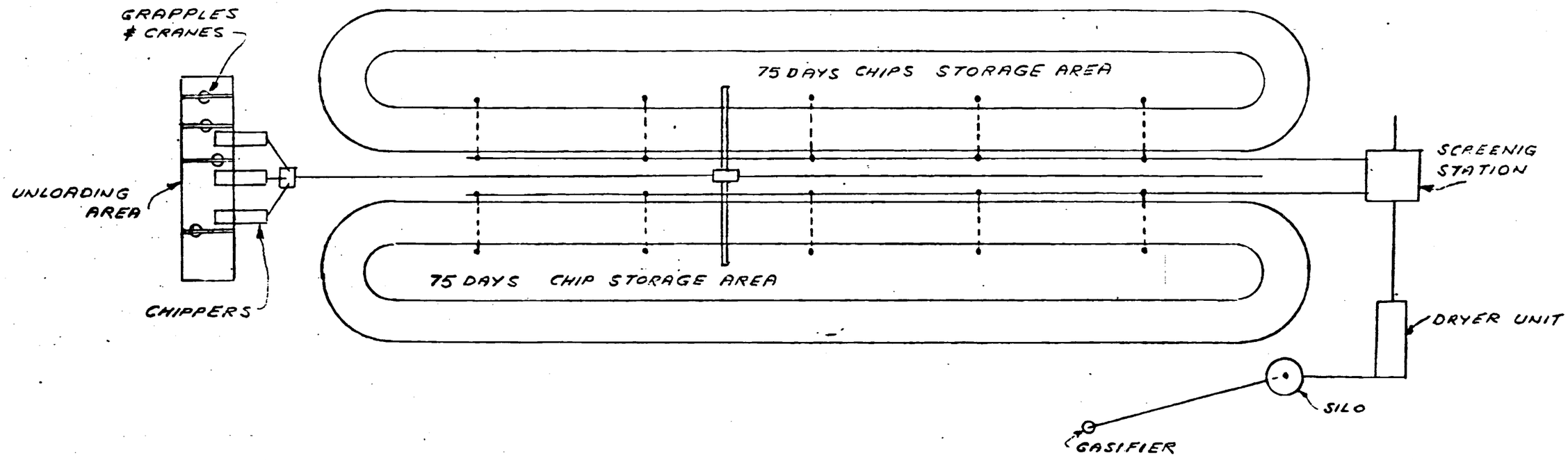
SCALE —

DRAWING NO. 5471-F-0401

REV. 0

C. LAYOUT DRAWING FOR WOOD PREPARATION AREA

The following drawing, number 5471-A-0401, is a proposed layout of the wood preparation area and shows the relative arrangement of all the major pieces of equipment.



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DAVY-1320-1 REV. 4/80

TITLE
WOOD TO METHANE
WOOD PREPARATION AREA
PLOT PLAN

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SCALE 1"=100'

DRAWING NO.
5471-A-0401

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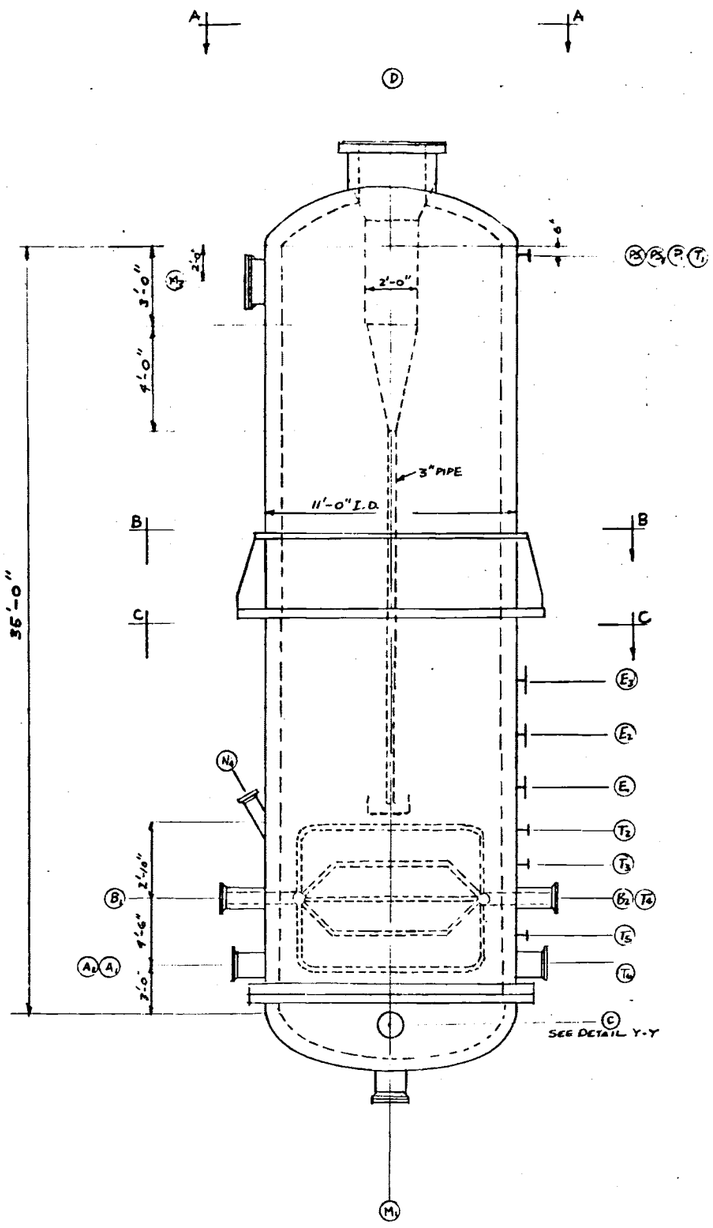
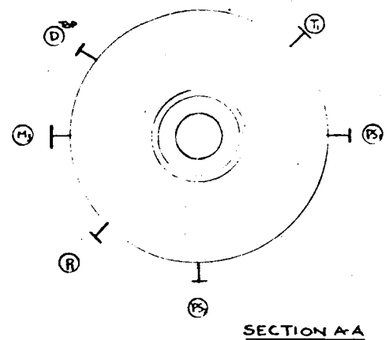
D. DETAILED DRAWING FOR GASIFIER

A detailed drawing of the gasifier, equipment item number 303-2201, follows this page and is labeled drawing number 5471-V-0401.

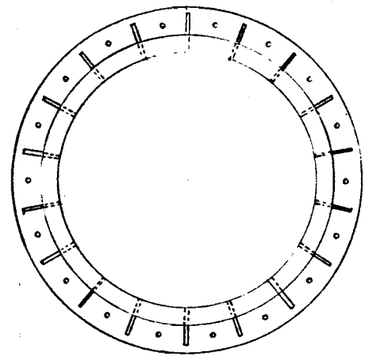
SCALING RULES 1/8" 1/4" 3/8" 1/2"

MARK	NUMBER	SIZE	RATING	SERVICE	REMARKS
A_{1-2}	2	24"	150#	WOOD FEED	4" REFRACTORY LINING
B1	1	12"		HOT GAS FEED	
B_2	1	12"		HOT GAS OUTLET	
C	1	10"		STEAM FEED	
D	1	3'-6"	CLASS 175	GAS OUTLET	8" REFRACTORY LINING
E_1	1	18"	150#	CHAR OVERFLOW	4" REFRACTORY LINING
E_{2-3}	2	18"		FUTURE OUTLET	
F	1	1"		AERATION GAS	W/ INTERNAL PIPE
M_{1-3}	3	30"		MANWAY	4" REFRACTORY LINING
P	2	8"		PRESSURE GAGE	
PS_1	1	8"		RELIEF VALVE	
PS_2	1	8"		RUPTURE DISC	
T_{1-6}	6	1½"		THERMO WELLS	
N_4	1	8"		CATALYST FEED	

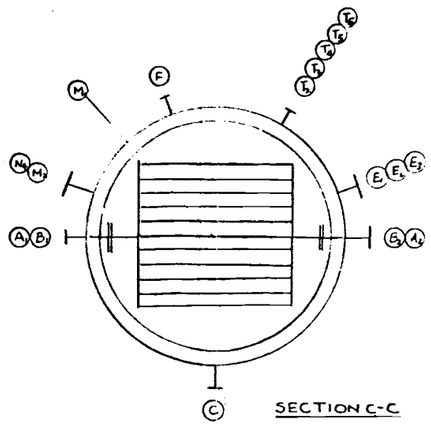




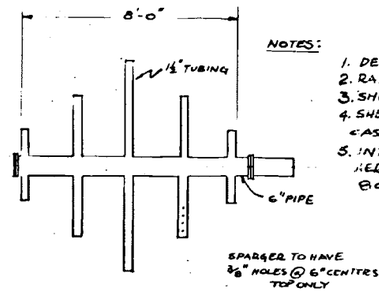
SECTION A-A



SECTION B-B



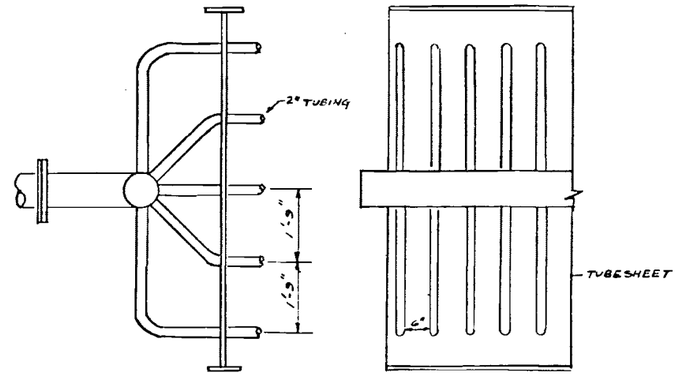
SECTION C-C



DETAIL Y-Y

NOTES:

1. DESIGN: 160 PSIG @ 500°F
2. RADIOGRAPHY: PARTIAL
3. SHELL & HEAD MAT'L: SA-516-70
4. SHELL & HEADS TO BE REFRACTORY LINED WITH 8" INSULATING CASTABLE AND 4½" REFRACTORY BRICK
5. INTERNALS INCLUDE CYCLONE, HEAT EXCHANGER, STEAM FEED, AERATION GAS AND SUPPORTS, MATERIAL TO BE RA-333 OR INCOLOY 800H.



SIDE VIEW END VIEW

DETAIL X-X

5 ROWS TUBES WITH 11 TUBES EACH ROW

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DATE TO: CLIENT / FIELD

TITLE: WOOD GASIFIER - METHANE
TAG 403-2201

SCALE: NTS ERNO:

5471-V-0401

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E. SINGLE LINE EQUIPMENT LIST

The following pages list each major piece of equipment by area. The equipment number is shown along with the quantity required.

WOOD STORAGE - AREA 401

ITEM NO.	NUMBER REQUIRED	DESCRIPTION
401-1001	2 + 1	Chippers
401-1002	1	Rechipper
401-1003	2	Hand Saws
401-1401	1	Tramp Iron Separator
401-1402	2	Screens
401-1801	1	Truck Weigh Scale
401-1802	1	Belt Weigh Scale
401-1901	4	Cranes
401-1902	4	Grapples
401-2101	3	Feeders to Chippers
401-2102	1	Storage Stacker Conveyor
401-2103	10	Chip Reclaimer
401-2104	2	Reclaim Conveyor
401-2105	1	Collecting Conveyor
401-2106	1	Oversize Conveyor
401-2107	1	Trash Conveyor
401-2108	1	Screen Delivery Conveyor
401-2301	1	Collecting Hopper
401-3901	1	Bulldozer

WOOD DRYING - AREA 402

ITEM NO.	NUMBER REQUIRED	DESCRIPTION
402-1601	1	Wood Dryer Unit
402-1801	1	Dried Chip Feeder
402-1802	1	Belt Weigh Scale
402-2101	1	Dried Wood to Storage Conveyor
402-2102	1	Storage to Gasifier Conveyor
402-2301	1	Dry Chips Silo

GASIFICATION - AREA 403

ITEM NO.	NUMBER REQUIRED	DESCRIPTION
403-1101	1 + 1	Ash Slurry Pump
403-1301	1	Combustion Air Blower
403-1401	1	Char-Catalyst Screen
403-1402	1	Magnetic Separator
403-1501	1	Gasifier Heater
403-1601	1	HT Steam Superheater
403-1602	1	Steam Superheater
403-1603	1	Gasifier WH Boiler
403-1604	1	Gasifier Heater WH Boiler
403-1605	1	BFW Heater
403-1606	1	Combustion Air Preheater
403-1701	1	Cyclone
403-1702	1	Raw Gas Bag Filter
403-1703	1	Ventilation Bag Filter
403-1704	1	Heater Dust Collector
403-2101	1	Char Overflow Feeder
403-2102	1	Waste Heat Boiler Discharge Feeder
403-2103	1	Cyclone Discharge Feeder
403-2104	1	Bag Filter Discharge Feeder
403-2105	1	Ventilation Collector Discharge Feeder

ITEM NO.	NUMBER REQUIRED	DESCRIPTION
403-2106	1	Heater Collector Discharge Feeder
403-2201	1	Gasifier
403-2202	1	Steam Drum
403-2203	1	BD Flash Drum
403-2301	1	Char Surge Hopper
403-2302	1	Catalyst Hopper
403-2303	1	Char Storage Bin
403-2304	1	Wood Storage Bin
403-2305	1	Ash Slurry Tank
403-2501	1	Char-Catalyst Lock Hopper Assembly
403-2502	2	Wood Feed Lock Hopper Assembly
403-2503	1	Catalyst Feed Lock Hopper Assembly
403-2504	1	Char Catalyst Screen Feed Conveyor
403-2505	1	Spent Catalyst to Storage Conveyor

COMPRESSION - AREA 404

EQUIPMENT NUMBER	NUMBER REQUIRED	DESCRIPTION
404-1301	1	Booster Compressor
404-1602	1	Booster Compressor Bypass Cooler
404-2201	1	Booster Compressor Feed K.O. Drum

SATURATION AND SHIFT CONVERSION - AREA 405

EQUIPMENT NUMBER	NUMBER REQUIRED	DESCRIPTION
405-1101	1 + 1	Saturator Circulating Pump
405-1102	1 + 1	Process Gas Condensate Pump
405-1501	1	Start-up Shift Gas Heater
405-1601	1	Gas-Gas Exchanger
405-1602	1	Saturator Water/Gas Exchanger
405-1603	1	Methanator Feed Gas Reheater
405-1604	1	Demineralized Water Heater
405-1605	1	Trim Gas Cooler
405-1606	1	Process Gas Condensate Cooler
405-2201	1	Saturator
405-2202	1	Process Gas K.O. Drum No. 1
405-2203	1	Process Gas K.O. Drum No. 2
405-2204	1	Process Gas K.O. Drum No. 3
405-2205	1	High Temperature Shift Reactor

PRIMARY METHANATION - AREA 406

EQUIPMENT NUMBER	NUMBER REQUIRED	DESCRIPTION
406-1301	1	Circulator
406-1601	1	Methanator Feed Gas Heater
406-1602	1	Saturator Water/Methanator Gas Exchanger
406-2201	1	Primary Methanation Reactor

ACID GAS REMOVAL - AREA 407

EQUIPMENT NUMBER	NUMBER REQUIRED	DESCRIPTION
407-2501	1	Benfield Acid Gas Removal System Includes the following major equipment: Absorber Regenerator Flash Tank Feed Gas Separator Acid Gas Separator Solution Pump Reflux Pump K_2CO_3 Reboiler Acid Gas Condenser

FINAL METHANATION AND DRYING - AREA 408

EQUIPMENT NUMBER	NUMBER REQUIRED	DESCRIPTION
408-1301	1	Product Gas Compressor
408-1601	1	Final Methanator Preheater
408-1602	1	Product Gas Cooler
408-1603	1	Interstage Cooler
408-1604	1	Compressor Discharge Cooler
408-2201	1	Final Methanator
408-2202	1	Pdt. Gas Condensate K.O. Drum
408-2203	1	Compressor Intercooler K.O. Drum
408-2204	1	Compressor Discharge K.O. Drum
408-2501	1	Product Gas Drying Package

CATALYST REGENERATION - AREA 409

EQUIPMENT NUMBER	NUMBER REQUIRED	DESCRIPTION
409-1301	2	Inert Gas Compressor
409-1601	1	Compressor Suction Inert Gas Cooler
409-1602	1	Compressor Discharge Inert Gas Cooler
409-1603	1	Inert Gas Heater
409-1604	1	Inert Gas Exhaust Cooler
409-1701	1	Inert Gas Vent Baghouse
409-2201	1	Regenerator #1
409-2202	1	Regenerator #2
409-2203	1	Compressor Suction Knock-out Drum
409-2204	1	Aftercooler Knock-out Drum
409-2301	1	Spent Catalyst Storage
409-2302	1	Regenerated Catalyst Storage
409-2501	1	Spent Catalyst Conveyor
409-2502	1	Stored Catalyst Conveyor (to Regenerator)
409-2503	1	Regenerator Catalyst Conveyor (to Storage)

WASTEWATER TREATMENT - AREA 410

EQUIPMENT NUMBER	NUMBER REQUIRED	DESCRIPTION
410-1101	1 + 1	Neutralizing Basin Circulation Pump
410-1102	1 + 1	Boiler Ash Wash Pump
410-1103	1 + 1	Lime Solution Pump
410-1104	1 + 1	Boiler Ash Sludge Pump
410-1105	1 + 1	Biological Sludge Pump
410-1201	1	Lime Solution Tank Agitator
410-1301	1	Lime Conveying Blower
410-1701	1	Lime Storage Hopper Bag Filter
410-2101	1	Lime Rotary Feeder
410-2301	1	Neutralizing Basin
410-2302	3	Sludge Lagoons
410-2303	1	Boiler Ash Slurry Settling Basin
410-2304	1	Lime Storage Hopper
410-2305	1	Lime Solution Tank
410-2501	1	Biological Treating Package

RAW WATER TREATING AND COOLING WATER - AREA 411

EQUIPMENT NUMBER	NUMBER REQUIRED	DESCRIPTION
411-1101	1 + 1	Firewater Pump
411-1102	1 + 1	Firewater Jockey Pump
411-1103	1 + 1	Raw Water Feed Pump
411-1104	1 + 1	Sand Filter Pressure Pump
411-1105	1 + 1	HP Demin. Water Pump
411-1106	1 + 1	Potable Water Pump
411-1107	1 + 1	Cooling Tower Circulation Pumps
411-1108	1 + 1	Demin. Water Pump
411-1401	1	Sand Filter
411-1402	1	Cooling Tower Sidestream Filter
411-1403	1	Activated Carbon Filter
411-1404	1	Raw Water Clarifier
411-1601	1	Cooling Tower
411-2301	1	Demin. Water Storage Tank
411-2302	1	Potable Water Storage Tank
411-2303	1	Raw Water Settling Basin
411-2304	1	BFW Clearwell
411-2501	1	Water Treatment Chemical Feed Package
411-2502	1	Demin. Water Package
411-2503	1	Cooling Tower Chemical Injection Package

BOILER AND BOILER FEEDWATER SYSTEM - AREA 412

EQUIPMENT NUMBER	NUMBER REQUIRED	DESCRIPTION
412-1101	1 + 1	BFW Pump
412-1701	1	Boiler Char Collector
412-2201	1	Boiler Blowdown Flash Drum
412-2202	1	Deaerator
412-2301	1	Char Bunker
412-2302	1	Ash Slurry Tank
412-2303	1	Char Storage Bins
412-2304	1	Dryer Char Storage Bins
412-2501	1	Char/Gas Fired Boiler
412-2502	1	BFW Chemical Injection Package
412-2503	1	Char Conveying to Storage
412-2504	1	Char Conveying to Boiler
412-2505	1	Char Loadout Conveying
412-2506	1	Char Conveying to Dryer

MISCELLANEOUS UTILITIES - AREA 413

EQUIPMENT NUMBER	NUMBER REQUIRED	DESCRIPTION
413-1101	1	Carbonate Charging Pump
413-1301	1	CO_2 Compressor
413-1501	1	Flare Stack
413-1601	1	CO_2 Aftercooler
413-2201	1	CO_2 Surge Drum
413-2202	1	CO_2 Aftercooler K.O. Drum
413-2301	1	Diesel Fuel Tank
413-2302	1	Carbonate Storage Tank
413-2501	1	Instrument Air Package
413-2502	1	CO_2 Drying System

F. Detailed Equipment List

A four line equipment list by plant area is given for the areas of wood receiving and storage, wood drying, catalyst regeneration, and gasification with the following legend applying.

T	-	Type
C	-	Capacity
S	-	Size
M	-	Material
D	-	Driver
A	-	Area
Des P/T	-	Design Pressure/Temperature

1. Wood Storage - Area 401

Equipment Number	Number Required	Description
401-1001	3	Chippers T - Drum chipper C - 60 TPH D - 500 hp
401-1002	1	Rechipper T - Drum chipper C - 4 tons/hr
401-1003	2	Hand Saws T - Chain Saw S - Bar 19" to 43" D - Gasoline Engine

Equipment Number	Number Required	Description
401-1401	1	Tramp Iron Separator T - Magnetic
401-1402	2	Screens T - Vibrating S - 3' x 8'
401-1801	1	Weigh Scale T - Truck C - 50 tons
401-1802	1	Weigh Scale T - 30" Belt C - 150 TPH Max.
401-1901	4	Cranes T - Overhead C - 10 Tons D - 15 hp, 5 hp, 30 hp
401-1902	4	Grapples T - 5 Tine C - 3/4 Cord @ 4' LG.
401-2101	3	Feeders to Chippers T - Chain S - 40" W x 18' LG C - 60 TPH M - CS Drive - Direct Mechanical From Chipper

Equipment Number	Number Required	Description
401-2102	1	Storage Stacker Conveyor T - Belt w/tripper S - 30" w x 1,000' w/125' stacker boom C - 12,000 ft^3/hr M - CS D - 20 hp, 20 hp, 2 - 5 hp
401-2103	10	Chip Reclaimers T - Chain S - 8' x 60' ctrs. x 10' lift C - 2,000 ft^3/hr M - CS D - 30 hp
401-2104	2	Reclaim Conveyors T - Belt S - 24" w. x 900' C - 2,000 ft^3/hr M - CS D - 15 hp
401-2105	1	Collecting Conveyor T - Belt S - 24" w x 40' C - 2,000 ft^3/hr M - CS D - 3 hp
401-2106	1	Oversize Conveyor T - Belt C - 400 ft^3/hr

Equipment Number	Number Required	Description
401-2107	1	Trash Conveyor T - Belt
401-2108	1	Screen Delivery Conveyor T - Belt S - 24" w x 400' ctrs. x 20' lift C - 2,000 ft^3/hr M - CS D - 2 hp
401-2301	1	Collecting Hopper T - Belt Feed S - 8' - 8' plan M - CS
401-3901	1	Bulldozer T - Caterpillar D7G
2. Wood Drying - Area 402		
402-1601	1	Wood Dryer Unit T - Rotary Drum S - 10' ø x 30' C - 480 ton/day of wood from 50% to 10% H_2O M - CS
402-1801	1	Dried Chip Feeder T - Rotary table S - 17' ø C - 1,700 ft^3/hr M - CS D - 5 hp

Equipment Number	Number Required	Description
402-1802	1	Weigh Scale T - 24" Belt C - 25 tph Max.
402-2101	1	Dried Wood To Storage Conveyor T - Belt S - 24" w x 400' C - 2,000 ft^3/hr M - CS D - 50 hp
402-2102	1	Storage to Gasifier Conveyor T - Belt S - 24" w x 1,000' x 125' lift C - 1,700 ft^3/hr M - CS D - 100 hp
402-2301	1	Silo T - Concrete C - 20,000 ft^3

3. Gasification - Area 403

Equipment Number	Number Required	Description
403-1101	1	Ash Slurry Pump T - Vertical Centrifugal C - 10 gpm @ 50 psi Δ P M - 304 SS D - 1 hp Electric Motor
403-1301	1	Combustion Air Blower T - Centrifugal C - 5500 Scfm @ 60^{o}F and 5 psi Δ P M - C.S. D - 150 hp
403-1402	1	Magnetic Separator T - Induced Magnetic Roll Separator C - 2 ton/hr of Char-Catalyst S - 10" wide roll
403-1501	1	Gasifier Heater T - Forced, Draft Combustion Chamber C - 10 MM Btu/hr Heat Release w/Char Combustion
403-1601	1	HT Steam Superheater T - Shell & Tube A - 190 ft^{2} (0.6 MM Btu/hr) M - Shell - C.S., Refractory-Lined; Tubes, 310 SS Des P/T - Shell-15 psig/650^{o}F Tubes-675 psig/1100^{o}F
403-1602	1	Steam Superheater T - Shell & Tube A - 60 ft^{2} (1.0 MM Btu/hr) M - Shell - C.S., Refractory-Lined; Tubes - C.S. Des P/T - Shell-160 psig/650^{o}F Tubes-675 psig/825^{o}F
403-1603	1	Gasifier WH Boiler T - Shell & Tube A - 230 ft^{2} (2.6 MM Btu/hr) M - Shell, C.S., Refractory-Lined; Tubes, C.S. Des P/T - Shell, 180 psig/650^{o}F Tubes, 675 psig/550^{o}F

Equipment Number	Number Required	Description
403-1604	1	Gasifier Heater WH Boiler T - Shell & Tube A - 150 ft^2 (2.9 MM Btu/hr) M - Shell, C.S., Refractory-Lined; Tubes, C.S. Des P/T - Shell, 15 psig/650°F Tubes, 675 psig/550°F
403-1605	1	BFW Heater T - Shell & Tube A - 300 ft^2 (2.1 MM Btu/hr) M - C.S. Des P/T - Shell, 160 psig/650°F Tubes, 675 psig/550°F
403-1606	1	Combustion Air Preheater T - Shell & Tube A - 2600 ft^2 M - Shell, C.S., Refractory-Lined; Tubes, C.S. Des P/T - Shell, 15 psig/650°F Tubes, 15 psig/550°F
403-1701	1	Cyclone T - Centrifugal C - 800 Acfm @ 150 psia, 350°F S - 2' Ø M - C.S. Des P/T - 160 psig/650°F
403-1702	1	Raw Gas Bag Filter T - Bag Filter C - 800 Acfm @ 150 psig, 350°F M - C.S. Des P/T - 160 psig/400°F

Equipment Number	Number Required	Description
403-1703	1	Ventilation Bag Filter T - Bag Filter C - 500 Acfm M - C.S. w/Nomex Bags Des P/T - ATM/350°F
403-1704	1	Heater Dust Collector T - Bag Filter C - 7,500 Acfm M - C.S. w/Nomex Bags Des P/T - ATM/350°F
403-2101	1	Char Overflow Feeder T - Rotary Valve C - 2 T/hr M - C.S. D - 1 hp Electric Motor
403-2102	1	Waste Heat Boiler Discharge Feeder T - Rotary Valve C - 2 T/hr M - C.S. D - 1 hp Electric Motor
403-2103	1	Cyclone Discharge Feeder T - Rotary Valve C - 2 T/hr M - C.S. D - 1 hp Electric Motor
403-2104	1	Bag Filter Discharge Feeder T - Rotary Valve C - 2 T/hr M - C.S. D - 1 hp Electric Motor
403-2105	1	Ventilation Collector Discharge Feeder T - Rotary C - 1 ton/hr M - C.S. D - 1 hp

Equipment Number	Number Required	Description
403-2106	1	Heater Collector Discharge Feeder T - Rotary C - 1 ton/hr M - C.S. D - 1 hp
403-2201	1	Gasifier T - Cylindrical Vessel S - 9' I. Ø x 35' T-T M - C.S., Refractory-Lined Des P/T - 175 psia/650^{o}F
403-2202	1	Steam Drum T - Horizontal S - 3' x 6' T-T M - C.S. Des P/T - 675 psia/550^{o}F
403-2203	1	BD Flash Drum T - Vertical S - 6" Ø x 3' T-T M - C.S. Des P/T - 75 psig/350^{o}F
403-2301	1	Char Surge Hopper T - Cylindrical Bin w/60^{o} Conical Bottom S - 6' Ø x 14' total M - C.S. Des P/T - ATM/400^{o}F
403-2302	1	Catalyst Hopper T - Cylindrical Bin w/60^{o} Conical Bottom S - 1'6" Ø x 4' Straight Sides M - C.S. Des P/T - 15 psig/400^{o}F
403-2303	1	Char Storage Bin T - Cylindrical Bin w/60^{o}F Conical Bottom S - 14' Ø x 24' Straight Sides M - C.S. Des/PT - ATM/400^{o}F

Equipment Number	Number Required	Description
403-2304	1	Wood Storage Bin T - Cylindrical Bin w/Conical Bottom S - 10' Ø x 10' Straight Sides M - C.S. Des P/T - ATM/150^{o}F
403-2305	1	Ash Slurry Tank T - Open-Top S - 3' Ø x 3' M - C.S. Des P/T - ATM/200^{o}F
403-2501	1	Char Catalyst Lock Hopper Assembly T - Double-Chamber Lock Hopper Assembly C - 450 ft^{3}/hr of Char-Catalyst from 150 psig to ATM
403-2502	2	Wood Feed Lock Hopper Assembly T - Double-Chamber Lock Hopper Assembly C - 2000 ft^{3}/hr of Wood from ATM to 150 psia
403-2503	1	Catalyst Feed Lock Hopper Assembly T - Double-Chamber Lock Hopper Assembly C - 6 ft^{3}/hr of Catalyst from ATM to 150 psia
403-2504	1	Char Catalyst Screen Feed Conveyor T - Pneumatic C - 500 ft^{3}/hr S - 20' x 100' Lift
403-2505	1	Spent Catalyst to Storage Conveyor T - Pneumatic C - 2 ft^{3}/hr S - 60' x 30' Lift

4. Catalyst Regeneration - Area 409

Equipment Number	Number Required	Description
409-1301	2	Inert Gas Compressor T - Centrifugal C - 250 Scfm @ 20 psi Δ P M - C.S. w/304 SS Inlet Wheel D - 25 hp
409-1601	1	Compressor Suction Inert Gas Cooler T - Shell & Tube A - 290 ft^2 M - Shell, C.S.; Tubes,304 SS Des P/T - Shell, 75 psig/150°F Tubes, 50 psig/250°F
409-1602	1	Compressor Discharge Inert Gas Cooler T - Shell & Tube A - 15 ft^2 M - Shell, C.S.; Tubes, 304 SS Des P/T - Shell, 75 psig/150°F Tubes, 50 psig/400°F
409-1603	1	Inert Gas Heater T - Shell & Tube A - 5 ft^2 M - C.S. Des P/T - Shell, 50 psig/550°F Tubes, 650 psig/550°F
409-1604	1	Inert Exhaust Cooler T - Shell & Tube A - 5 ft^2 M - C.S. Des P/T - Shell 50 psig/550°F Tubes 75 psig/150°F
409-1701	1	Inert Gas Vent Baghouse T - Bag Filter C - 150 Acfm M - C.S. w/Nomex Bags Des P/T - ATM/350°F
409-2201	1	Regenerator No. 1 T - Cylindrical, Conical btm S - 4' Ø x 8' Straight Sides M - C.S., Refractory Lined Des P/T - 200 psia/1200°F

Equipment Number	Number Required	Description
409-2202	1	Regenerator No. 2 T - Cylindrical, Conical btm S - 4' Ø x 8' Straight Sides M - C.S. Refractory Lined Des P/T - 200 psia/1200°F
409-2203	1	Compressor Suction Knock-Out Drum T - Vertical S - 1' Ø x 3' T-T M - 304 SS Des P/T - 20 psig/250°F
409-2204	1	After Cooler Knock-Out Drum T - Vertical S - 1' Ø x 3' T-T M - 304 SS Des P/T - 50 psig/400°F
409-2301	1	Spent Catalyst Storage T - Rectangular Hopper w/double discharge S - 4' x 8' x 15' OAH M - C.S. Des P/T - ATM/150°F
409-2302	1	Regenerated Catalyst Storage T - Rectangular Hopper w/double discharge S - 4' x 8' x 15' OAH M - C.S. Des P/T - ATM/150°F
409-2501	1	Spent Catalyst to Regenerators Conveyor T - Pneumatic C - 60 ft^3/hr
409-2502	1	Spent Catalyst to Regenerators Conveyor T - Pneumatic C - 60 ft^3/hr
409-2503	1	Regenerated Catalyst to Gasifier Conveyor T - Pneumatic C - 5 ft^3/hr

IV. SUMMARY OF PROCESS MATERIALS AND UTILITIES

In the following sections are given the expected raw materials and utilities consumption and production for the plant complex.

A. Summary of Raw Materials and Utilities Imported

1. Wood

Quantity, dry tons per day	200
Moisture content, wt. %	49.5

2. Raw Water

Flow, gpm	70

3. Gasifier Catalyst

Usage, lb/hr.	5

4. Electricity

Normal operating draw, kw	980

5. Diesel Fuel

Average usage, gallons/day	33

B. Products and Byproducts Exported

1. Product Substitute Natural Gas

Production, scfh	89,950
HHV, Btu/scf	956

2. Wood Char

Quantity, tons/day		8.5
Composition:	wt.% combustibles	80.2
	wt. % ash	19.8

3. Wood Ash to Pond

Quantity, tons/day	9.6

4. Treated Wastewater

Flow, gpm	34

5. Sludge from Wastewater Treating

Quantity, tons/day	7.2

C. Summary of Catalyst and Chemicals

1. Catalysts

	INITIAL CHARGE, $ft.^3$	MINIMUM LIFE, YEARS
Shift Conversion	150	1
Primary Methanation	62	1
Secondary Methanation	40	1

2. Process Chemicals

	lbs/Day
K_2CO_3 for Acid Gas Removal	19
V_2O_5 for Acid Gas Removal	0.4
DEA for Acid Gas Removal	1.5
Lime for Wastewater Treating	6,450

Boiler Chemicals

Scale Inhibitor	1.5
Oxygen Scavenger	0.1
Corrosion Inhibitor	0.8

Cooling Tower

H_2SO_4 for pH Control	13
Corrosion Control	4
Dispersant	1.6
Algae Control	0.5
Chlorine	7

D. Summary of Operating Labor

Areas	Personnel Required
Wood Storage and Drying	8
Gasification, Cleanup, Shift, Methanation, Compression, Acid Gas Removal, Gas Drying	18
Offsites including Boilers, Char Distribution, Cooling Tower, Wastewater Treatment, Catalyst Regeneration	18
TOTAL	44

V. CAPITAL COST ESTIMATE

This section includes the Capital Cost Estimate for the Wood to Methane plant. Total plant costs are indicated as well as costs by plant area. The capital cost is $26,680,000 - September 1980 basis for the plant to process 200 tons per day of dry wood. The detailed estimate summary is included on the following pages.

NC-5471
11/17/80

EXECUTIVE SUMMARY

200 TPD WOOD TO METHANE

	COST	% OF T.I.C.
Equipment & S/C Equipment	$ 9,110M	31.5
Direct Purchase Material	2,800	9.7
Subcontract: Material	180	0.6
Labor (99M MHRS)	2,650	9.2
Direct Hire Labor (177M MHRS)	2,280	7.9
SUBTOTAL DIRECT COSTS	$17,020M	58.9
Field Indirects	3,840	13.3
Pro-Services	5,350	18.5
Other	470	1.6
9/12/80 T.I.C.*	$26,680M	92.3
ESCALATION	2,220	7.7
ESCALATED T.I.C.	$28,900M	100.0

EXCLUSIONS:

- Property
- Start-up Costs
- Plant Roadways
- Demolition of Underground Obstructions
- Premium Time
- Operating and Maintenance Costs
- Contingency

*9/12/80 basis was used for consistency with the 2000 TPD Plant estimate.

Davy McKee

NC-5471
11/17/80

CLIENT: Battelle Pacific Northwest Laboratories

LOCATION: Newport, Oregon

PROJECT: 200 TPD of Wood to Methane

TYPE OF ESTIMATE: Class VII Total Installed Cost Estimate

DOCUMENTS: The following documents prepared for this project were used to prepare the estimate:

- NC-5471 T.I.C. Estimate for Battelle PNL, 2000 TPD Wood to Methane dated September 12, 1980 (Value = $103MM ± 25%).
- Four line equipment list developed by Process Engineering for Areas 401,402,403 and 409.
- Preliminary layout drawing of the Wood Sizing and Wood Storage areas.

SCOPE OF WORK: Davy McKee is to determine the economic feasibility of producing methane by catalytic gasification of wood. The Estimating Department is to evaluate the cost of Engineering, Procurement, and Construction for the plant based on the following areas:

401 - Wood Storage and Sizing
402 - Wood Drying
403 - Gasification
404 - Compression
405 - Shift Conversion
406 - Primary Methanation
407 - Acid Gas Removal
408 - Final Methanation and Product Gas Drying
409 - Catalyst Regeneration
410 - Waste Water Treating
411 - Raw Water Treating and Cooling Water
412 - Boilers and Boiler Feedwater System
413 - Miscellaneous Utility System

DM-2207

SCHEDULE:

The following schedule was assumed based on historical information:

Engineering:	Start	10/01/80	
	Completion	2/01/82	
	Duration		16 Months
Procurement:	Start	4/01/81	
	Completion	8/01/82	
	Duration		16 Months
Construction:	Start	4/01/81	
	Completion	2/01/83	
	Duration		22 Months

TOTAL PROJECT DURATION: 28 Months

ESTIMATE APPROACH:

This estimate is a scale down of the earlier estimate for Battelle PNL, 2000 TPD of Wood to Methane dated 9/12/80 (under the same contract: NC-5471). The following paragraphs outline the techniques used for the entire project.

MAJOR EQUIPMENT ($2,730M Direct Purchase, 9.4% of TIC)
($6,381M S/C Equip. Mat'l. Portion, 22.1% of TIC)

The major equipment for Areas 401, 402, 403, and 409 was defined on four line equipment lists developed by Davy McKee's Process Department. Equipment pricing for Areas 401 and 402 was based on installed cost budget quotations solicited from vendors by Davy McKee specifically for the 200 TPD Wood to Methane project. Each piece of equipment in Areas 403 and 409 was priced in one of three ways:

- Vendor quotations for similar equipment (similarity determined by 4-line equipment list) on recent estimates.
- In-house historical cost information correlating cost to equipment characteristics (e.g., pricing exchangers on a dollar per square foot of exchanging area basis).
- Factoring to other recent estimates using the six-tenths method.

Equipment pricing for all other areas was obtained by using scale down factors applied to the original (2000 TPD) estimate. The scale down factors were developed by the Estimating Department based on the type of equipment in each area (Reference: Table 1).

ESTIMATE APPROACH: (continued)

MAJOR EQUIPMENT (continued)

An allowance for freight, where applicable, was made and included in the equipment price.

DIRECT PURCHASE MATERIAL ($2,800M, 9.7% of TIC)

Direct Purchase Materials except those in Areas 401, 402, and 407 were factored to equipment using the same material dollar to equipment dollar ratios developed for the original (2000TPD) estimate. Materials except Civil for Areas 401 and 402 were included with the vendor quote. The Civil work was estimated utilizing preliminary site layouts for these areas. Area 407 was factored from a previous quotation on a Total Installed Cost basis, therefore required no specific calculation to develop the cost of direct purchase materials.

The material purchase strategy (i.e., direct purchase vs. subcontractor purchase) is identical to the strategy in the original estimate.

SUBCONTRACTS (Material $175M, 0.6% of TIC)
(Labor $2,652M, 9.2% of TIC)
(Excludes S/C Equip. Mat'l. Portion)

The subcontractor purchase material was factored to equipment using the same material dollar to equipment dollar ratios developed for the 2.000 TPD 9/12/80 estimate.

Subcontract labor man-hours for material and equipment were factored using man-hour to material dollar relationships based on the original (2000 TPD) estimate. Labor man-hours were priced using a S/C labor rate of $26.96/MHR in accordance with the 2000 TPD 9/12/80 estimate.

DIRECT HIRE LABOR ($2,280M, 7.9% of TIC)

Equipment erection/installation direct hire man-hours for Areas 403 and 409 were developed using Davy McKee Base 1.0 man-hours. All other direct hire man-hours were factored using man-hour per material dollar ratios based on the original estimate. Labor man-hours were priced at the composite wage rate of $12.84/MHR in accordance with the original estimate.

ESTIMATE APPROACH:
(continued)

FIELD INDIRECTS ($3,838M, 13.3% of TIC)

The field indirects estimate includes construction supervision, field office labor, auxiliary labor, temporary construction, construction equipment, small tools, consumables, field office costs, and direct and indirect labor payroll burdens. Costs for these items except for payroll burdens were developed on a percent to direct hire direct labor wages basis using historical data on completed projects. (Ref.: TABLE 2)

Payroll burdens were calculated using in-house data on craft labor fringe benefits and existing governmental rates for payroll taxes and insurances.

PROFESSIONAL SERVICES ($5,350M, 18.5% of TIC)

Professional Services include Engineering, Clerical, Engineering Services, Estimating, Cost Engineering, Schedule Control, Procurement, Home Office Construction, and Accounting. Home Office (H.O.) salaries were determined by factoring to total direct costs based on a similar sized estimate. Out-of-pocket costs (reproduction, computer utilization, telephone, etc.) were factored using a percentage of Home Office Salaries based on the same recent estimate. Fringe Benefits and Overhead were established at 118.9% of H.O. Salaries; Professional Services Fee was established at 7.5% of Professional Services costs. These terms are in accordance with government guidelines. (Ref.: TABLE 3)

TERMS

Salaries		12% x Direct Cost
Fringe Benefits Overhead	)	118.9% x Salaries
Fee: Pro-Services		7.5% x Pro-Service Cost
Construction		2.0% x TIC

INSURANCE ($420M, 1.5% of TIC)

Insurance coverages include general liability, automobile liability, installation all risk, and bare rental coverage. The cost of insurance was established at 1.5% of the Total Installed Cost based on recent gasification estimates.

TAXES

There are no applicable sales or use taxes in Oregon.

ESTIMATE APPROACH:
(continued)

ROYALTIES & COMMISSIONS

A one-time, paid-up license fee of $50M for the Benfield process is included. This fee was developed by the Estimating Department based on in-house information.

ESCALATION ($2,224M, 7.7% of TIC)

Escalation percentages for the 200 TPD plant are the same as in the original estimate. The following table summarizes the results of the escalation analysis:

	BASE COST ($-M)	PROJECTED ESC. (%)	TOTAL ESC. ($-M)
Equipment	2,730	10.4	280
Direct Material	2,800	10.1	280
Subcontract (E, M, & L)	9,208	9.8	902
D/H Labor	2,280	8.7	200
S/T DIRECTS	17,018	9.8	1,662
Field Indirects	3,238	9.5	312
Professional Services	4,975	5.1	250
Items Not Subject to Escalation*	1,445	--	--
TOTAL	26,676	8.3	2,224

*NOTE: Items not subject to escalation include license fees, Pro-Service fee, construction fee, and insurance because these items were based on escalated values.

EXCLUSIONS:

- Property
- Start-up Costs
- Plant Roadways
- Demolition of Underground Obstructions
- Premium Time
- Operating and Maintenance Costs
- Contingency

TABLE 1

SCALE DOWN FACTORS USED
FOR PRICING EQUIPMENT

AREA	TITLE	SCALE DOWN EXPONENT FACTOR		MULTIPLIER	REFERENCE AREA FROM BASE ESTIMATE
404	Compression	$(x)^{.7}$	=	.200	204
405	Shift Conversion	$(x)^{.65}$	=	.224	205
406	Primary Methanation	$(x)^{.65}$	=	.224	206
407	Acid Gas Removal	$(x)^{.5}$	=	.316	207
408	Final Methanation	$(x)^{.65}$	=	.224	208
410	Waste Water Treating	$(x)^{.6}$	=	.251	210
411	Raw Water & Cooling Water	$(x)^{.6}$	=	.251	211
412	Boilers & BFW System	$(x)^{.6}$	=	.251	212
413	Misc. Utility System	$(x)^{.65}$	=	.224	213

NOTE: $x = \frac{200\ TPD}{2000\ TPD} = 0.1$

TABLE 2
FIELD INDIRECTS DEVELOPMENT

	PC-4511(1)		PC-4707(1)		PC-4228(1)		COMPOSITE		RECOMMENDED FOR NC-5471	
D/H Labor: Man-hours	383.1M		330.5M		1,087.6M		1,801.2M		177.2M	
Wage Rate ($/MHR)	12.84		12.84		12.84		12.84		$12.84	
Wages 9/12/80	$4,919M		$4,244M		$13,965M		$23,127M		$2,280M	
	COST ($-M)	% OF D/H WAGES	COST ($-M)	% OF D/H WAGES	COST ($-M)	% OF D/H WAGES	COST ($-M)	% OF D/H WAGES	COST ($-M)	% OF D/H WAGES
Construction Mgmt. - Salaries	749	15.2	776	18.3	2,006	14.4	3,531	15.3	349	15.3
- Other Costs	170	3.5	179	4.2	--	--	349(2)	3.8	87	3.8
Field Office Labor	138	2.8	117	2.8	998	7.1	1,253	5.4	123	5.4
Auxiliary Field Labor	337	6.9	438	10.3	--	--	775(2)	8.5	194	8.5
Temporary Construction	553	11.2	659	15.5	1,733	12.4	2,945	12.7	290	12.7
Construction Equipment	881	17.9	1,077	25.4	2,824	20.2	4,782	20.7	472	20.7
Small Tools & Consumables	373	7.6	475	11.2	31	0.2	848(2)	9.3	212	9.3
Field Office Expenses	86	1.7	145	3.4	--	--	231(2)	2.5	57	2.5
Subtotal	3,287	66.8	3,866	91.1	7,592	54.3	N/A	--	1,784	78.2
PAYROLL BURDENS										
Constr. Supv. @ 38% x Sal.	N/A	--	N/A	--	N/A	--	N/A	--	133	5.8
F. O. Labor @ 38% x Sal.	N/A	--	N/A	--	N/A	--	N/A	--	47	2.1
Aux. Labor @ 51.5% x Sal. (3)	N/A	--	N/A	--	N/A	--	N/A	--	100	4.4
D.H. Labor @ 51.5% x Sal. (3)	N/A	--	N/A	--	N/A	--	N/A	--	1,174	51.5
Subtotal	N/A	--	N/A	--	N/A	--	N/A	--	1,454	63.8
TOTAL									3,238	142.0
							CONSTRUCTION FEE: 2.0% x T.I.C.		600	26.0
									3,838	168.0

NOTES:
(1) Escalated to 9/1/80
(2) Composite based on PC-4707 and PC-4511
(3) F/B Component = $2.34/HR ÷ $12.84/HR = 18.2%
Balance = F.I.C.A. (6.13%), F.U.I. (0.7%), S.U.I. (4.3%), W.C. (22.21%) = 33.3%
51.5%

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NC-5471
11/17/80

TABLE 3

PROFESSIONAL SERVICES DEVELOPMENT

	$-M
H.O. Salaries @ 12% x D.C.	$2,040M
Other Costs @ 25% x H.O. Salaries	510
F/B & O/H @ 118.9% x H.O. Salaries	2,425
SUBTOTAL	$4,975M
Fee @ 7.5% x Professional Services	375
TOTAL PROFESSIONAL SERVICES (9/12/80 Basis)	$5,350M
Escalation @ 5.1% x Professional Services	250
ESCALATED PROFESSIONAL SERVICES	$5,600M

PROJECT SUMMARY SHEET

McKee

M-292 Rev. 5/79

ESTIMATE NO. NC-5471

SCHEDULE: AWARD DATE 10/1/80

MECH. COMPL: 2/1/83 28 MO.

CONSTR. START: 4/1/81 22 MO.

CLIENT: BATTELLE PNL

PLANT: 200 TPD WOOD TO METHANE

LOCATION: NEWPORT, ORE. DATE: 11/17/80

ITEM	PROJECT SUMMARY SHEET (ALL AMOUNTS IN 1000'S)	MH DATA	
1	EQUIPMENT		2730
2	MATERIAL		2800
3	SUBCONTRACT: EQUIP & MAT'L. 6556 LABOR 2652	99	9208
4	LABOR	177	2280
5	PREMIUM TIME S/C D.L.		
6	ESCALATION: EQUIP. 280 ; MAT'L. 280 ; S/C 902 ; LABOR 200		1662
7	SUB TOTAL DIRECT COST	276	18680
8	CONSTR. SUPERVISION: W: O.C.		
9	FIELD OFFICE LABOR		
10	AUXILIARY LABOR		
11	TEMPORARY CONSTRUCTION: MAT'L. ; S/C ; LABOR		
12	CONSTRUCTION EQUIPMENT: EQUIP. LABOR		
13	SMALL TOOLS CONSUMABLES		
14	FIELD OFFICE COST		
15	PAYROLL BURDEN		
16	ESCALATION		312
17	SUB TOTAL FIELD INDIRECT COST		3550
	ESCALATION (@ 5.1 % x P.S.)		250
18	ENGINEERING W: O.C.		
19	PROCUREMENT W: O.C.		
20	H.O. CONSTRUCT. SUPPORT W: O.C.		
21	COMPANY FRINGES ON P.S. COST @ % OF $		
22	SUB TOTAL PROFESSIONAL SERVICES		5225
23	SUB TOTAL ESTIMATED COST ITEMS 7, 17 & 22		27455
24	CONTINGENCY: D.C. F.I.C. P.S. O.C.		
25	ROYALTIES & COMMISSIONS		50
26	TAXES		
27	INSURANCE (@ 1.5% x T.I.C)		420
28	SUB TOTAL OTHER COST		470
29	OVERHEAD: % OF P.S. ; % OF CONSTR. SUPERV.		INCLUDED
30	FEE: PROFESSIONAL SERVICES @ 7.5% x P.S.		375
31	FEE: CONSTRUCTION @ 2.0% x T.I.C.		600
32	TOTAL PROJECT COST		28900

APPROVED:

PAGE OF

DIRECT COST SUMMARY SHEET
Davy McKee
DM 1359A Rev. 10/79

ALL MANHOURS & DOLLARS IN, 1000'S

PROJECT	PLANT AREA	PROJECT NO.
200 TPD WOOD TO METHANE	TOTAL PLANT - DIRECT COST SUMMARY	NC-5471
LOCATION	**OWNER**	**BY** / **DATE**
NEWPORT, ORE	BATTELLE PNL	CJH

CODE NO.	DESCRIPTION	MILESTONE QTY	MILESTONE UNIT	DIRECT P/O MATERIAL TOTAL $	SUBCONTRACT MATERIAL $	SUBCONTRACT LABOR MAN HRS.	SUBCONTRACT LABOR RATE	SUBCONTRACT LABOR TOTAL $	SUBCONTRACT GRAND TOTAL	DIRECT HIRE LABOR MAN HRS.	DIRECT HIRE LABOR RATE	DIRECT HIRE LABOR TOTAL $	GRAND TOTAL $	PERCENTAGES ITEM TO CAT	PERCENTAGES ITEM TO TOTAL
401	WOOD STORAGE			739	3451	42.7		1151	4602	71.8	12.84	922	6263		
402	WOOD DRYING				1329	16.5		444	1773				1773		
403	GASIFICATION			1527	119	6.3		171	290	29.6		380	2197		
404	COMPRESSION			320	6	0.6		15	21	4.2		54	395		
405	SHIFT CONVERSION			516	13	1.2		31	44	9.3		120	680		
406	PRIMARY METHANATION			397	8	0.7		18	26	6.7		86	509		
407	ACID GAS REMOVAL				430	10.0		270	700				700		
408	FINAL METHANATION & PRODUCT GAS DRYING			497	28	1.1		29	57	8.6		111	665		
409	CATALYST REGENERATION			378	6	0.5		13	19	6.3		82	479		
410	WASTE WATER TREATING			119	167	4.6		124	291	4.6		60	470		
411	RAW WATER & COOLING WATER			249	184	4.1		110	294	8.2		105	648		
412	BOILERS & BFW SYSTEM			514	801	10.5		262	1063	17.2		223	1800		
413	MISC. UTILITY SYSTEM			274	14	0.5		14	28	10.7		137	439		
	TOTAL			5530	6556	99.3		2652	9208	177.2		2280	17018		

Page ____ Sheet ___ of ___

DIRECT COST SUMMARY SHEET
Davy McKee
DM 1359A Rev. 10/79

ALL MANHOURS & DOLLARS IN, 1000'S

PROJECT	PLANT AREA	PROJECT NO.
200 TPD WOOD TO METHANE	401 - WOOD STORAGE	NC-5471
LOCATION	**OWNER**	**BY** / **DATE**
NEWPORT, ORE	BATTELLE PNL	CJH

CODE NO.	DESCRIPTION	MILESTONE QTY	MILESTONE UNIT	DIRECT P/O MATERIAL TOTAL $	SUBCONTRACT MATERIAL $	SUBCONTRACT LABOR MAN HRS.	SUBCONTRACT LABOR RATE	SUBCONTRACT LABOR TOTAL $	SUBCONTRACT GRAND TOTAL	DIRECT HIRE LABOR MAN HRS.	DIRECT HIRE LABOR RATE	DIRECT HIRE LABOR TOTAL $	GRAND TOTAL $	PERCENTAGES ITEM TO CAT	PERCENTAGES ITEM TO TOTAL
	EQUIPMENT & BULKS (EXCL. CIVIL)				3405	40.1	26.96	1082	4487				4487		
	CIVIL			739	46	2.6		69	115	71.8	12.84	922	1776		
	TOTAL			739	3451	42.7		1151	4602	71.8	12.84	922	6263		

DIRECT COST SUMMARY SHEET
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DM 1359A Rev. 10/79

ALL MANHOURS & DOLLARS IN, 1000'S

PROJECT	PLANT AREA	PROJECT NO.
200 TPD WOOD TO METHANE	402 - WOOD DRYING	NC-5471
LOCATION	**OWNER**	**BY** / **DATE**
NEWPORT, ORE.	BATTELLE PNL	CJH

CODE NO.	DESCRIPTION	MILESTONE QTY	MILESTONE UNIT	DIRECT P/O MATERIAL TOTAL $	SUBCONTRACT MATERIAL $	SUBCONTRACT LABOR MAN HRS.	SUBCONTRACT LABOR RATE	SUBCONTRACT LABOR TOTAL $	SUBCONTRACT GRAND TOTAL	DIRECT HIRE LABOR MAN HRS.	DIRECT HIRE LABOR RATE	DIRECT HIRE LABOR TOTAL $	GRAND TOTAL $	PERCENTAGES ITEM TO CAT	PERCENTAGES ITEM TO TOTAL
	EQUIPMENT & BULKS (EXCL. CIVIL)				1329	16.5		444	1773				1773		
	CIVIL				INCLUDED IN AREA 401										
	TOTAL				1329	16.5		444	1773				1773		

Page ____ Sheet ___ of ___

DIRECT COST SUMMARY SHEET

Davy McKee

DM 1359A Rev. 10/79

ALL MANHOURS & DOLLARS IN, 1000'S

PROJECT	PLANT AREA	PROJECT NO.
200 TPD WOOD TO METHANE	403 - GASIFICATION	NC-5471
LOCATION	**OWNER**	**BY** / **DATE**
NEWPORT, ORE.	BATTELLE PNL	CJH

CODE NO.	DESCRIPTION	MILESTONE QTY	MILESTONE UNIT	DIRECT P/O MATERIAL TOTAL $	SUBCONTRACT MATERIAL $	SUBCONTRACT LABOR MAN HRS.	SUBCONTRACT LABOR RATE	SUBCONTRACT LABOR TOTAL $	SUBCONTRACT GRAND TOTAL	DIRECT HIRE LABOR MAN HRS.	DIRECT HIRE LABOR RATE	DIRECT HIRE LABOR TOTAL $	GRAND TOTAL $	PERCENTAGES ITEM TO CAT	PERCENTAGES ITEM TO TOTAL
	EQUIPMENT			877	72	2.5	26.96	68	140	4.6	12.84	59	1076		
	PIPING			275						12.4		159	434		
	CIVIL			42						3.7		48	90		
	STRUCTURAL STEEL			210						2.9		37	247		
	ELECTRICAL			16	25	1.2		32	57				73		
	INSTRUMENTS			92						4.1		53	145		
	INSULATION				10	0.8		22	32				32		
	PAINTING				8	1.0		27	35				35		
	FIREPROOFING				4	0.8		22	26				26		
	MISCELLANEOUS @(1%M+7%L)			15						1.9		24	39		
	TOTAL			1527	119	6.3		171	290	29.6		380	2197		

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DIRECT COST SUMMARY SHEET

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ALL MANHOURS & DOLLARS IN, 1000'S

PROJECT	PLANT AREA	PROJECT NO.
200 TPD WOOD TO METHANE	409 - CATALYST REGENERATION	NC-5471
LOCATION	**OWNER**	**BY** / **DATE**
NEWPORT, ORE.	BATTELLE PNL	CJH

CODE NO.	DESCRIPTION	MILESTONE QTY	MILESTONE UNIT	DIRECT P/O MATERIAL TOTAL $	SUBCONTRACT MATERIAL $	SUBCONTRACT LABOR MAN HRS.	SUBCONTRACT LABOR RATE	SUBCONTRACT LABOR TOTAL $	SUBCONTRACT GRAND TOTAL	DIRECT HIRE LABOR MAN HRS.	DIRECT HIRE LABOR RATE	DIRECT HIRE LABOR TOTAL $	GRAND TOTAL $	PERCENTAGES ITEM TO CAT	PERCENTAGES ITEM TO TOTAL
	EQUIPMENT			288						1.9	12.84	24	312		
	PIPING			50						2.3		30	80		
	CIVIL			10						0.9		12	22		
	STRUCTURAL STEEL			10						0.2		3	13		
	ELECTRICAL				3	0.2	26.96	5	8				8		
	INSTRUMENTS			16						0.6		8	24		
	INSULATION				2	0.2		5	7				7		
	PAINTING				1	0.1		3	4				4		
	FIREPROOFING				-				-				-		
	MISCELLANEOUS @(1%M+7%L)			4						0.4		5	9		
	TOTAL			378	6	0.5		13	19	6.3		82	479		

VI OPERATING COST ESTIMATE

The production cost of SNG from wood has been calculated based upon the capital costs and operating costs as generated by this study. The methods of calculating these costs are those presented in "Coal Gasification Commercial Concepts Gas Cost Guidelines," a paper prepared for the United States Energy Research and Development Administration and the American Gas Association by C. F. Braun & Co. (NTIS 8463). There are two potential methods of financing a plant of this type, (1) utility financing, and (2) private investor financing. Production costs have been calculated using both procedures.

The total plant investment has been estimated to be $ 26,680,000 September, 1980 basis. To obtain the total capital requirement for the plant, additional costs must be added to the estimated plant investment. These costs are an allowance for funds during construction, start-up costs, and working capital. These costs and the basis for their calculation is show in Table I. The total capital requirement for this plant is $31,805,000

The annual direct operating costs have been calculated and are shown in Table II. These costs include raw materials, utilities, catalysts and chemicals, labor, administration and general overhead, supplies, and taxes and insurance, with a credit for by-product char. Total maintenance costs were calculated as percentage of plant investment as suggested by the guidelines. These annual costs are $ 6,833,600 . The most significant costs are wood, gasifier catalyst, labor, and taxes and insurance. Labor costs would not be very easy to reduce significantly, while taxes will depend upon local conditions and incentives. The major variable costs are wood and catalyst usage in the gasifier. At $20/dry ton for wood, which is the value used for the base case shown in Table II , wood costs are almost 20% of the total direct costs and almost 15% of the total production costs using utility financing. Thus, either lowering the wood cost or improving yields from the wood would

have more impact on costs than any other single variable. The production costs have also been calculated for wood costs of $5, $10, and $40 per dry ton delivered to the plant.

In Tables III and IV the methods for calculating production costs are given based upon utility financing and private investor financing, respectively. The calculations for the base case of a wood cost of $20/dry ton are shown. For utility financing, the SNG production costs are $14.34, $14.83, $15.86 , and $17.84 per MM Btu for wood prices of $5, $10, $20, and $40 per dry ton. For private investor financing, the SNG production costs are $18.76, $19.26, $20.28, and $22.31 per MM Btu for the corresponding wood costs.

TABLE I

TOTAL CAPITAL REQUIREMENT

Total Plant Investment	$ 26,680 M	
Allowance for funds During Construction (Total Plant Investment x 1.25 years x 0.09)	$ 3,002 M	
Start-up Costs (20% of Total Annual Gross Operating Costs)	$ 1,375 M	
Working Capital (Sum of (1) raw material inventory of 14 days at full rate, (2) materials and supplies at 0.9% of total plant investment, and (3) net receivables at 1/24 annual gas and by-products revenue at calculated sales price)	$ 56 M $ 240 M $ 452 M	(1) (2) (3)
Total Capital Requirement	$ 31,805 M	

TABLE II

ANNUAL DIRECT OPERATING COSTS

Operating Factor: 330 days/year

COST COMPONENT	ANNUAL USE	COST $/UNIT	COST $1000/YR.
Raw Material			
Wood	66,000 dry tons	20/dry ton	1,320.0
Utilities			
Water	33,264 Mgal	0.50/Mgal	16.6
Electricity	7.76×10^6 KWh	0.03/KWh	232.8
Diesel Fuel	10,890 gal	1.00/gal	10.9
Catalysts and Chemicals			
Chemicals			51.0
Shift Catalyst	150 ft^3	107/ft^3	16.0
Methanation Catalyst	100 ft^3	435/ft^3	43.5
Gasifier Catalyst	38,016 lb	8.51/lb	323.5
Labor			
Process Operating	44 men @ 2080 hr. ea.	10.70/hr	979.3
Maintenance @	60% of total maintenance		760.8
Supervision @	20% of process operating and maintenance labor		348.0
Administration and General Overhead			
@	60% of total labor		1252.9
Supplies			
Operating @	30% of process operating labor		293.8
Maintenance @	40% of total maintenance		507.2

Taxes and Insurance			
@	2.7% of total investment		720.4
Total Gross Operating Cost per Year			6876.7
By-Product Credits			
Char	2805 tons	$15.35/ton	(43.1)
Total Net Operating Cost per Year			6833.6

TABLE III

GAS COST - UTILITY FINANCING METHOD

BASIS:

20-year project life

5%/year straight line depreciation on total capital requirement excluding working capital

48% federal income tax rate

75/25 debt/equity ratio

10% interest on debt

15% return on equity

DEFINITION OF TERMS:

C = Total Capital Requirement, 10^6 $

W = Working Capital, 10^6 $

N = Total Net Operating Cost, 10^6 $/year

G = Annual Gas Production, 10^{12} Btu/year

d = Fraction debt

i = Interest on debt, %/year

r = Return on equity, %/year

p = Return on rate basis, %/year

EQUATION FOR RETURN ON RATE BASE

$$p = (d)\ i + (1-d)\ r$$

GENERAL GAS COST EQUATION

Average Gas Cost, $/MM Btu =

$$\frac{N + 0.05\ (C-W) + 0.005\ (p + 48/52\ (1-d)\ r)\ (C + W)}{G}$$

$C = 31.805 \times 10^6$ $/yr

$W = .748 \times 10^6$ $/yr

$N = 6.834 \times 10^6$ $/yr

$G = .681 \times 10^{12}$ Btu/yr

CALCULATION

$P = (0.75)\ (10) + 1\text{-}0.75)\ (15) = 11.25$

Average gas cost, \$/MM Btu =

$$\frac{6.834 + (.05)\ (31.805\text{-}.748) + (.005)\ (14.70)\ (31.805 + .748)}{.681}$$

= \$15.83/MM Btu

TABLE IV

GAS COST - EQUITY FINANCING METHOD

BASIS:

20 - year project life

16 - year sum-of-the-years' - digits depreciation on total plant investment

100% equity capital

12% DCF return rate

48% federal income tax rate

DEFINITION OF TERMS:

I = Total plant investment, 10^6 $

S = Start-up costs, 10^6 $

W = Working Capital, 10^6 $

N = Total net operating cost, 10^6 $/year

G = Annual gas production, 10^{12} Btu/year

GAS COST EQUATION AT 12% DCF RETURN

Gas cost, $/$10^6$ Btu =

$$\frac{N = 0.247I + 0.1337S + 0.2305W}{G}$$

$I = 26.680 \times 10^6$ $

$S = 1.375 \times 10^6$ $

$W = .873 \times 10^6$ $

$N = 6.834 \times 10^6$ $/yr.

$G = .681 \times 10^{12}$ Btu/yr

CALCULATION

Gas cost, $/$10^6$ Btu =

$$= \frac{6.834 + (0.247)\ (26.680) + (0.1337)\ (1.375) + (0.2305)\ (.873)}{.681}$$

= $20.28

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