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

Appendix D: Feasibility Study of Methanol 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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PNL-3695 App D

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INVESTIGATIONS ON CATALYZED STEAM GASIFICATION OF BIOMASS

APPENDIX D: FEASIBILITY STUDY OF METHANOL PRODUCTION VIA CATALYTIC GASIFICATION OF 200 TONS OF WOOD PER DAY

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WOOD TO METHANOL 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 fuel grade methanol 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 (PNL). 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 100 tons per day of methanol with a HHV of 9784 Btu per pound. All process and support facilities necessary to convert wood to methanol are included in this study. The plant location is Newport, Oregon.

The capital cost for the plant is $34,830,000 - September, 1980 basis. Methanol production costs which allow for return on capital have been calculated for various wood prices for both utility and private investor financing. These wood costs include delivery to the plant. For utility financing, the methanol production costs are respectively $1.20, $1.23, $1.30, and $1.44 per gallon for wood costs of $5, $10, $20, and $40 per dry ton. For private investor financing, the corresponding product costs are $1.60, $1.63, $1.70, and $1.84 per gallon for the corresponding wood costs.

The costs calculated by the utility financing method include 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 of the plant is 52.0%.

II. INTRODUCTION AND CONCLUSIONS

A. INTRODUCTION

The purpose of this study is to determine the feasibility of producing methanol 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. This 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 methanol 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, and gasification, (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) production 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 yields, 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 the 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 methanol synthesis and distillation. The costs of the remaining areas were obtained by selectivity factoring the costs from the larger plant.

C. SUMMARY

Production costs for methanol 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 $1.20, $1.23, $1.30, and $1.44 per gallon for wood prices of $5, $10, $20, and $40 per dry ton respectively.

SUMMARY - (Continued)

For private investor financing and the same wood prices, the corresponding production costs are $1.60, $1.63, $1.70, and $1.84 per gallon. Both financial calculation methods include 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 $34,830,000 - September, 1980 basis.

The thermal efficiency of the plant, as defined by the following equation, is 52.0%.

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

The plant production is 6.46×10^{11} Btu per year. The yield is 150 gallons 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 OFF-SITES DESCRIPTION

Summary

The process plant complex detailed in the following description is capable of producing 100 tons per day of fuel grade methanol. These flows are based on a dry wood feed to the plant of 200 tons per day. The wood feed is a mixture of forest residue, twigs, and alder, and is gasified with steam to produce a synthesis gas suitable for methanol production by means of the ICI low pressure methanol process. Following is a list of the major process and offsite units of the plant:

Process Areas -

301 - Wood Storage and Sizing
302 - Wood Drying
303 - Gasification
304 - Shift Conversion
305 - Acid Gas Removal
306 - Compression
307 - Methanol Synthesis and Distillation
308 - Purge Gas Reforming
309 - Waste Water Treating
310 - Raw Water Treating and Cooling Water
311 - Boilers and BFW System
312 - Miscellaneous Utility Systems
313 - Storage and Loading - Product and Utilities

The mixture of forest residue is delivered by truck to the plant site. The wood is chipped and then stored. Withdrawal from storage is done by chain reclaimers assisted by bulldozers as necessary. Belt conveyors then deliver wood to drying and subsequently to the gasifier. The catalytic reaction of wood and steam in the gasifier

produces a gas consisting mainly of hydrogen, carbon monoxide, carbon dioxide and water vapor along with various hydrocarbons and nitrogen. This gas is cooled primarily by the generation of steam before it passes through a baghouse to remove any entrained particulates. The gas is then heated to a temperature suitable for reaction in a high temperature shift reactor, which adjusts the hydrogen to carbon monoxide ratio to the proper level for methanol synthesis. Prior to the synthesis stage, the gas must go through a Benfield CO_2 removal system and a compression step. When the gas has been processed in the synthesis unit, crude liquid methanol product is made and sent to the distillation unit for purification and then to product storage.

A purge gas rich in combustibles is a by-product of the methanol synthesis. This gas is combined with steam and reacts in a steam reforming furnace to produce a second gas rich in hydrogen, carbon monoxide, and carbon dioxide. This effluent gas is combined with the synthesis gas prior to CO_2 removal.

The remaining light ends, flash gases, and light oils from the distillation process are combined and used as a fuel supplement to the package boiler.

A portion of the wood delivered to the plant is used both as fuel for the package boiler and as fuel to supply heat for the gasifier.

The char generated in the gasifier is removed, separated from any accompanying catalyst, and used as fuel in both the wood dryers and the package boiler. Catalyst is recovered from the char by magnetic separation and returned to the gasifier.

All waste water streams will be treated before discharging. The treatment will 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)

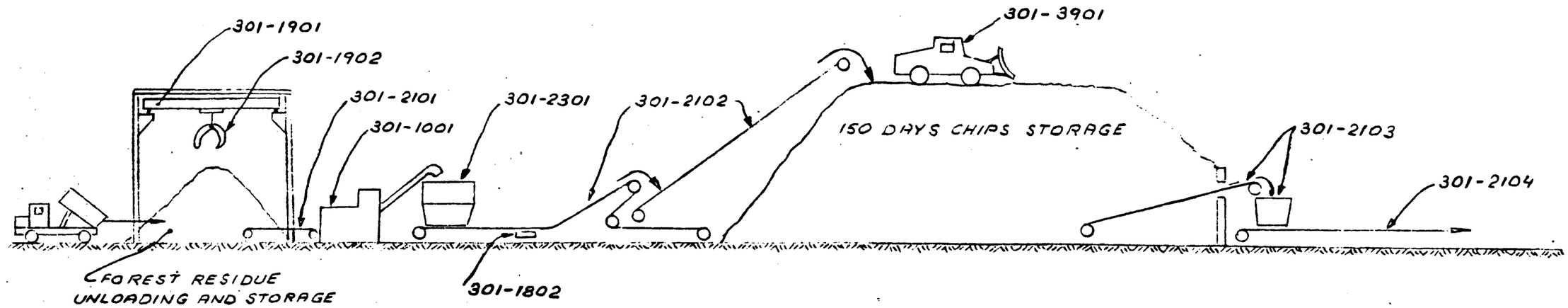
The chips from the screening station are conveyed by conveyor to the surge bin for the dryer.

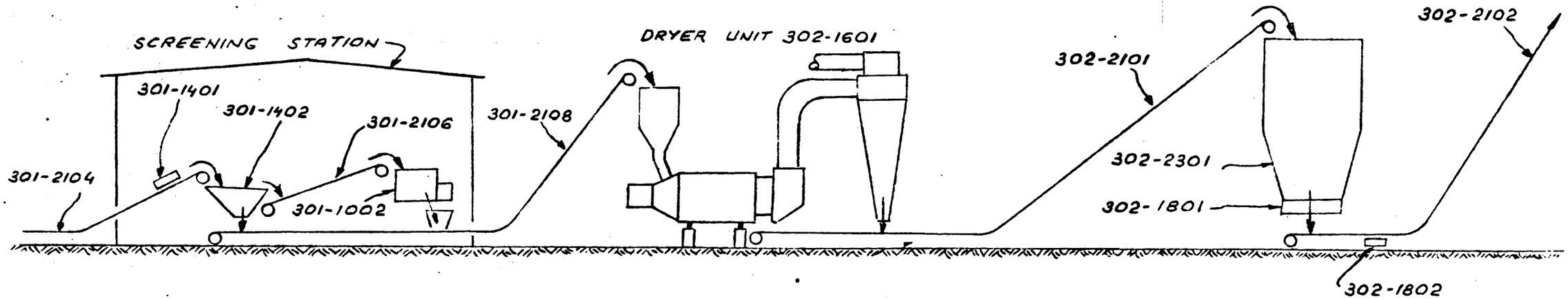
One (1) rotary drum dryer complete with a burner, ash removal cyclone, exhaust dust cyclone, ducting, and all necessary appurtenances is installed to reduce the moisture content of green chips from 50 wt.% of total feed to 10%. The by-product char from the gasifier is used to fuel the burners for the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

A flowsheet showing the major equipment in the wood preparation area has been prepared and is shown on drawing number 5471-F-0301 which follows.





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CK'D	JJL	
APP		
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TITLE: WOOD TO METHANOL
WOOD PREPARATION AREA
FLOWSHEET

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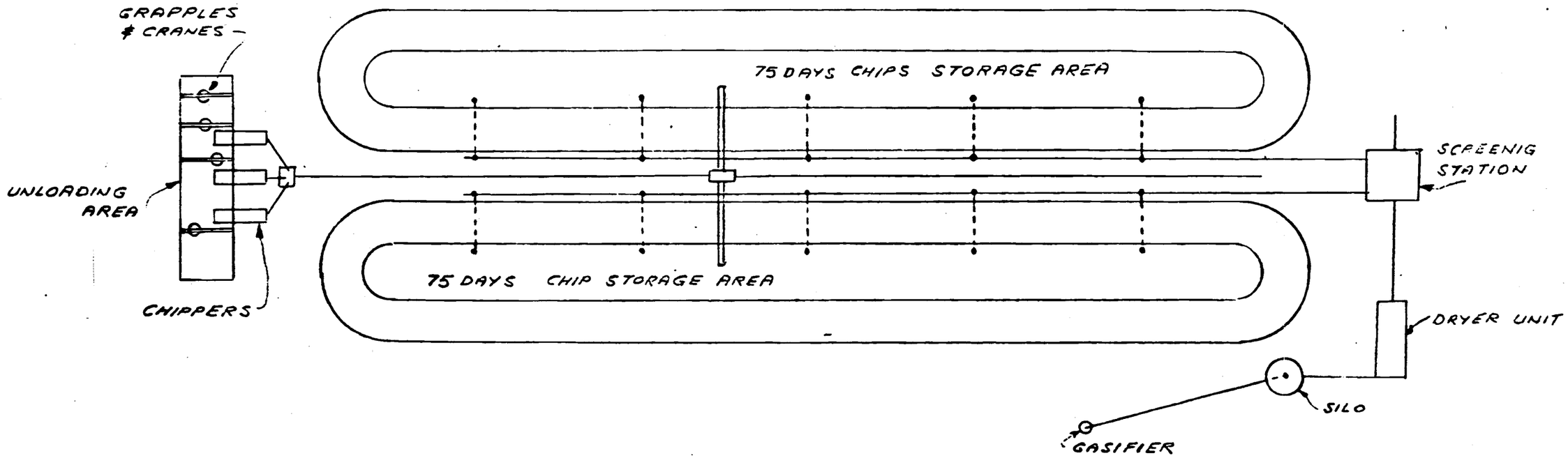
SCALE —— | REV. 0

DRAWING NO. 5471-F-0301

TTT 7

C. LAYOUT DRAWING FOR WOOD PREPARATION AREA

The following drawing, number 5471-A-0301, 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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TITLE
WOOD TO METHANOL
WOOD PREPARATION AREA
PLOT PLAN

SCALE 1" = 100'

DRAWING NO.
5471-A-0301

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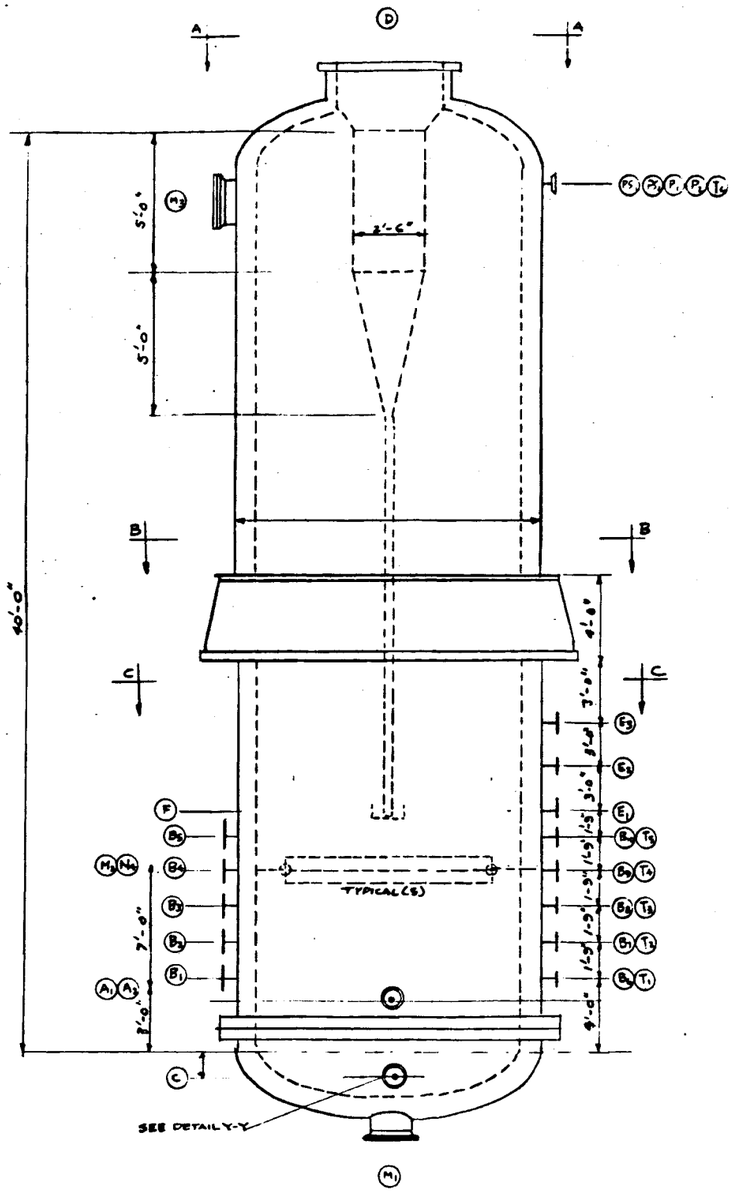
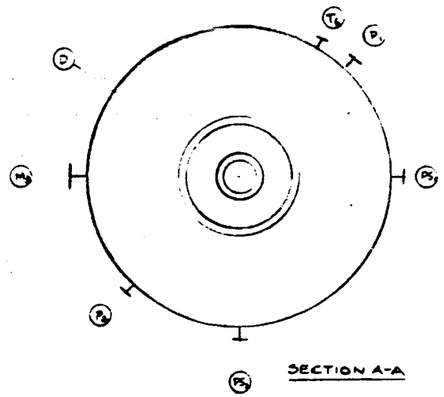
D. DETAILED DRAWING FOR GASIFIER

A detailed drawing of the gasifier, equipment item number 303-2201, follows this page and is labeled drawing number 5471-V-0301.

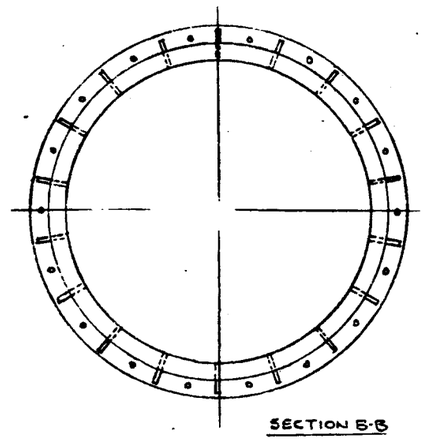
SCALING RULES 1/8" 1/4" 3/8" 1/2"

MARK	NO REQ	SIZE	RATING	SERVICE	REMARKS
A1-2	2	24"	150#	WOOD FEED	6" REFRACTORY LINED
B1-5	5	12"		HOT GAS FEED	
B6-10	5	12"		HOT GAS DISCHARGE	
C	1	10"		STEAM FEED	
D	1	4'-0"	CLASS 175	GAS OUTLET	REFRACTORY LINED
E1	1	18"	150#	CHAR OVERFLOW	
E2-3	2	18"		FUTURE OUTLET	
F	1	1"		AERATION GAS	
M1-3	3	30"		MANWAY	
P1-2	2	8"		PRESSURE TAP	
PS1	1	8"		RELIEF VALVE	
PS2	1	8"		RUPTURE DISC	
T1-6	6	1½"		THERMOWELLS	
N4	1	8"		CATALYST FEED	





SECTION A-A



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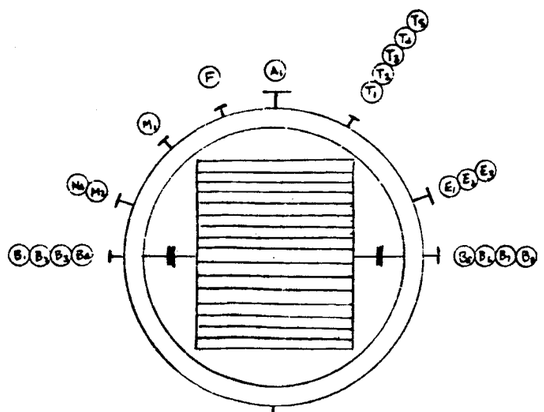
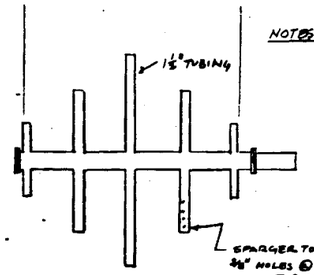


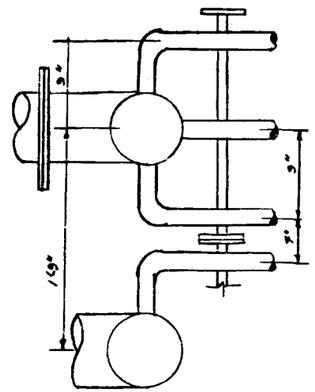
SECTION C-C



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 ALL SUPPORTS. MAT'L TO BE AA-333 OR INCOLOY 800H.



DETAIL X-X
17 ROWS W/15 TUBES EACH ROW

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TITLE: WOOD GASIFIER - METHANOL
TAG 303-2201

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5471-V-0301

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III-15

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 301

Item No.	Number Required	Description
301-1001	2 + 1	Chippers
301-1002	1	Rechippers
301-1003	2	Hand Saws
301-1401	1	Tramp Iron Separator
301-1402	2	Screens
301-1801	1	Truck Weigh Scale
301-1802	1	Belt Weigh Scale
301-1901	4	Cranes
301-1902	4	Grapples
301-2101	3	Feeders to Chippers
301-2102	1	Storage Stacker Conveyor
301-2103	10	Chip Reclaimer
301-2104	2	Reclaim Conveyor
301-2105	1	Collecting Conveyor
301-2106	1	Oversize Conveyor
301-2107	1	Trash Conveyor
301-2108	1	Screen Delivery Conveyor
301-2301	1	Collecting Hopper
301-3901	1	Bulldozer

WOOD DRYING - AREA 302

Item No.	Number Required	Description
302-1601	1	Wood Dryer Unit
302-1801	1	Dried Chip Feeder
302-1802	1	Belt Weigh Scale
302-2101	1	Dried Wood to Storage Conveyor
302-2102	1	Storage to Gasifier Conveyor
302-2301	1	Dry Chips Silo

GASIFICATION - AREA 303

Item No.	Number Required	Description
303-1101	1	Ash Slurry Pump
303-1301	1	Combustion Air Blower
303-1401	1	Char/Catalyst Screen
303-1402	1	Magnetic Separator
303-1501	1	Gasifier Heater
303-1601	1	HP Steam Superheater
303-1602	1	CO Shift Feed Preheater
303-1603	1	Gasifier Waste Heat Boiler
303-1604	1	Gasifier BFW Preheater
303-1605	1	HP Steam Preheater
303-1606	1	Combustion Air Preheater
303-1701	1	Cyclone
303-1702	1	Raw Gas Bag Filter
303-1703	1	Ventilation Bag Filter
303-1704	1	Gasifier Heater Collector
303-2101	3	Double Screw Feeder
303-2102	3	Gasifier Feed Screw
303-2103	1	Waste Heat Boiler Discharge Feeder
303-2104	1	Cyclone Discharge Feeder
303-2105	1	Bag Filter Discharge Feeder
303-2106	1	Screw Conveyor to Heater Feed Bin
303-2107	1	Screw Feeder to Heater
303-2108	1	Char Overflow Feeder
303-2109	1	Combustion Gas Dust Collector Feeder
303-2110	1	Ventilation Collector Discharge Feeder
303-2201	1	Gasifier
303-2202	1	Steam Drum
303-2203	1	Blowdown Flash Drum

Item No.	Number Required	Description
303-2301	1	Wood Surge Bin
303-2302	1	Heater Feed Bin
303-2303	1	Char Surge Hopper
303-2305	1	Catalyst Hopper
303-2501	2	Wood Feed Lock Hopper
303-2502	1	Char/Catalyst Lock Hopper
303-2503	1	Catalyst Feed Lock Hopper

SHIFT CONVERSION - AREA 304

Item No.	Number Required	Description
304-1601	1	Reformer Effluent Waste Heat Boiler
304-1602	1	Demineralized Water Heater
304-1603	1	Trim Gas Cooler
304-2201	1	Synthesis Gas K-O Drum #1
304-2202	1	Synthesis Gas K-O Drum #2
304-2204	1	High Temperature Shift Reactor
304-2205	1	Steam Drum

ACID GAS REMOVAL - AREA 305

Item No.	Number Required	Description
305-1101	1	Condensate Solution Pump
305-1102	1	Reflux Pump
305-1301	4	Steam Ejectors
305-1601	1	Acid Gas Cooler
305-1602	1	Lean Solution Cooler
305-1603	1	Reboiler
305-2201	1	Absorber
305-2202	1	Regenerator
305-2203	1	Condensate Separator
305-2204	1	Flash Tank

GAS COMPRESSION - AREA 306

Item No.	Number Required	Description
306-1301	1	4-Stage Booster Compressor
306-1601	1	Precompressor Gas Cooler
306-1602	1	First Stage BC Intercooler
306-1603	1	Second Stage BC Intercooler
306-1604	1	Third Stage BC Intercooler
306-1605	1	Post Compressor Gas Cooler
306-2201	1	Precompressor K-O Drum
306-2202	1	Post Compressor K-O Drum
306-2203	1	Chloride Guard Bed
306-2204	1	Sulfur Guard Bed

METHANOL SYNTHESIS AND DISTILLATION - AREA 307

Item No.	Number Required	Description
307-1101A,B	1 + 1	Crude Methanol Pump
307-1102A,B	1 + 1	Bottoms Pump
307-1103A,B	1 + 1	Reflux Pump
307-1104A,B	1 + 1	Steam Condensate Pump
307-1301	1	Circulator
307-1401A,B	1 + 1	HP Methanol Filter
307-1402A,B	1 + 1	LP Methanol Filter
307-1601	1	Cold Shell Loop Interchanger
307-1602	1	Warm Shell Loop Interchanger
307-1603	1	Loop Start-up Heater
307-1604	1	Loop Saturator Water Heater
307-1605	1	Crude Methanol Condenser
307-1606	1	Feed/Overheads Exchanger
307-1607	1	Primary Condenser
307-1608	1	Secondary Condenser
307-1609	1	Feed/Bottoms Exchanger
307-1610	1	Bottoms Cooler
307-1611	1	Reboiler
307-1612	1	Methanol Cooler
307-1613	1	Fusel Oil Cooler
307-2201	1	Methanol Converter
307-2202	1	Methanol Separator
307-2203	1	Letdown Vessel
307-2204	1	Distillation Column
307-2205	1	Reflux Drum
307-2206	1	Steam Condensate Drum
307-2301	1	Crude Methanol Storage Tank
307-2501	1	Caustic Dosing Set

PURGE GAS REFORMING - AREA 308

Item No.	Number Required	Description
308-1501	1	Reforming Furnace
308-1601	1	Feed Effluent Gas Exchanger

WASTEWATER TREATING - AREA 309

Item No.	Number Required	Description
309-1101	1 + 1	Neutralizing Basin Circulation Pump
309-1102	1 + 1	Lime Solution Pump
309-1103	1 + 1	Sludge Pump
309-1201	1	Lime Solution Tank Agitator
309-1301	1	Lime Conveying Blower
309-1701	1	Lime Storage Hopper Bag Filter
309-2101	1	Lime Rotary Feeder
309-2301	1	Neutralizing Basin
309-2302	3	Sludge Lagoons
309-2303	1	Lime Storage Hopper
309-2304	1	Lime Solution Tank
309-2501	1	Biological Treating Package

RAW WATER TREATING AND COOLING WATER - AREA 310

Item No.	Number Required	Description
310-1101	1 + 1	LP Softened Water Pump
310-1102	1 + 1	Cooling Tower Circulation Pump
310-1103	1 + 1	Raw Water Feed Pump
310-1104	1 + 1	Potable Water Pump
310-1401	1	Sand Filter
310-1402	1	Cooling Tower Sidestream Filter
310-1403	1	Activated Carbon Filters
310-1601	1	Cooling Tower
310-2301	1	Softened Water Storage Tank
310-2302	1	Raw Water Storage Tank
310-2303	1	Potable Water Storage Tank
310-2501	1	Water Softening Package
310-2502	1	Cooling Tower Chemical Injection Package

BOILER AND BOILER FEED WATER SYSTEM - AREA 311

Item No.	Number Required	Description
311-1101	1 + 1	LP Boiler Feed Water Pump
311-1102	1 + 1	HP Boiler Feed Water Pump
311-2201	1	HP Boiler Blowdown Flash Drum
311-2202	1	Deaerator
311-2203	1	Fuel Gas Drum
311-2501	1	Package Boiler

MISCELLANEOUS UTILITY SYSTEM - AREA 312

Item No.	Number Required	Description
312-1301	1	CO_2 Compressor
312-1501	1	Methanol Flash Flare
312-1502	1	Gasifier Start-up Flare
312-2201	1	CO_2 Receiver
312-2501	1	Instrument Air Package

STORAGE AND LOADING - PRODUCT & UTILITIES - AREA 313

Item No.	Number Required	Description
313-1101	2	Methanol Loading Pumps
313-1102	1	Carbonate Charging Pump
313-2301	2	Methanol Product Storage Tank
313-2302	1	Diesel Fuel Storage Tank
313-2303	1	Carbonate Storage Tank

F. Detailed Equipment List

A four line equipment list by plant area is given for the areas of wood receiving and storage, wood drying 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 301

Equipment Number	Number Required	Description
301-1001	2 + 1	Chippers T - Drum chipper C - 60 TPH D - 500 hp
301-1002	1	Rechipper T - Drum chipper C - 4 tons/hr
301-1003	2	Hand Saws T - Chain Saw S - Bar 19" to 43" D - Gasoline Engine

Equipment Number	Number Required	Description
301-1401	1	Tramp Iron Separator T - Magnetic
301-1402	2	Screens T - Vibrating S - 3' x 8'
301-1801	1	Weigh Scale T - Truck C - 50 tons
301-1802	1	Weigh Scale T - 30" Belt C - 150 TPH Max.
301-1901	4	Cranes T - Overhead C - 10 Tons D - 15 hp, 5 hp, 30 hp
301-1902	4	Grapples T - 5 Tine C - 3/4 Cord @ 4' LG.
301-2101	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
301-2102	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
301-2103	10	Chip Reclaimers T - Chain S - 8' x 60' ctrs. x 10' lift C - 2,000 ft^3/hr M - CS D - 30 hp
301-2104	2	Reclaim Conveyors T - Belt S - 24" w. x 900' C - 2,000 ft^3/hr M - CS D - 15 hp
301-2105	1	Collecting Conveyor T - Belt S - 24" w x 40' C - 2,000 ft^3/hr M - CS D - 3 hp
301-2106	1	Oversize Conveyor T - Belt C - 400 ft^3/hr

Equipment Number	Number Required	Description
301-2107	1	Trash Conveyor T - Belt
301-2108	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
301-2301	1	Collecting Hopper T - Belt Feed S - 8' - 8' plan M - CS
301-3901	1	Bulldozer T - Caterpillar D7G
2. Wood Drying - Area 302		
302-1601	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
302-1801	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
302-1802	1	Weigh Scale T - 24" Belt C - 25 tph Max.
302-2101	1	Dried Wood To Storage Conveyor T - Belt S - 24" w x 400' C - 2,000 ft^3/hr M - CS D - 50 hp
302-2102	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
302-2301	1	Silo T - Concrete C - 20,000 ft^3

3. Gasification - Area 303

Equipment Number	Number Required	Description
303-1101	1	Ash Slurry Pump T - Vertical Centrifugal C - 10 gpm @ 50 psiΔP M - 304 SS D - 1 hp Electric Motor
303-1301	1	Combustion Air Blower T - Centrifugal C - 15,000 Scfm @ 60°F & 5 psi ΔP M - C.S. D - 100 hp Electric Motor
303-1401	1	Char/Catalyst Screen T - Vibrating Screen C - 2 T/hr M - C.S. - 100 Mesh Screen
303-1402	1	Magnetic Separator T - Induced Magnetic Roll Separator C - 2 T/hr of Char/Catalyst S - 10' Wide Roll
303-1501	1	Gasifier Heater T - Forced Draft Combustion Chamber C - 21 MM Btu/hr Heat Release w/Wood Combustion

Equipment Number	Number Required	Description
303-1601	1	H.P. Steam Superheater T - Shell and Tube - Shell Refactory Lined C - 1.35 MM Btu/hr S - 40 ft^2 M - Shell and Tube - C.S. Des P/T - Shell - 160 psig/1520°F Tubes - 660 psig/825°F
303-1602	1	CO Shift Feed Preheater T - Shell and Tube - Shell Refactory Lined C - 2.03 MM Btu/hr S - 60 ft^2 M - Shell and Tubes - C.S. Des P/T - Shell-160 psig/1520°F Tubes-160 psig/400°F
303-1603	1	Gasifier Waste Heat Boiler T - Water Tube - Shell Refactory Lined C - 5.61 MM Btu/hr S - 460 ft^2 M - Shell and Tubes - C.S. Des P/T - Shell-160 psig/1520°F Tubes-660 psig/540°F
303-1604	1	Gasifier BFW Heater T - Water Tube - Shell Refactory Lined C - 2.21 MM Btu/hr S - 65 ft^2 M - Shell and Tubes - C.S. Des P/T - Shell-160 psig/1520°F Tubes-675 psig/540°F

Equipment Number	Number Required	Description
303-1605	1	H.P. Steam Preheater T - Shell and Tube C - 14.84 MM Btu/hr S - 400 ft^2 M - Shell - C.S., Tubes - 310 SS Des P/T Shell-15 psig/1760°F Tubes-675 psig/1600°F
303-1606	1	Combustion Air Preheater T - Shell and Tube C - 10.92 MM Btu/hr S - 350 ft^2 M - Shell and Tubes - C.S. Des P/T - Shell-15 psig/770°F Tubes-15 psig/880°F
303-1701	1	Cyclone T - Centrifugal C - 1500 Acfm @ 150 psia, 350°F S - 2' 6" Ø M - C.S. Des P/T - 160 psig/650°F
303-1702	1	Raw Gas Bag Filter T - Bag Filter C - 1500 Acfm @ 150 psia/350°F M - C.S. Glass Bags Des P/T - 160 psig/400°F
303-1703	1	Ventilation Bag Filter T - Bag Filter C - 1000 Acfm M - C.S. Glass Bags Des P/T - Atmospheric/400°F

Equipment Number	Number Required	Description
303-1704	1	Gasifier Heater Collector T - Bag Filter C - 20,000 acfm M - C.S. w/Nomex Bags Des P/T - Atm/350°F
303-2101	1	Double Screw Feeder T - Screw Conveyor C - 11,100 ft^3/hr S - 18" Ø x 20' M - C.S. D - 5 hp
303-2102	1	Gasifier Feed Screw T - Screw Conveyor C - 2200 ft^3/hr S - 14" x 14' M - Heat Resistant Alloy D - 5 hp Variable Des P/T - 175 psi/1500°F
303-2103	1	Waste Heat Boiler Discharge Feeder T - Rotary C - 1 T/hr M - C.S. D - 1 hp Electric Motor, Direct
303-2104	1	Cyclone Discharge Feeder T - Rotary C - 1 T/hr M - C.S. D - 1 hp Electric, Direct

Equipment Number	Number Required	Description
303-2105	1	Bag Filter Discharge Feeder T - Rotary C - 1 T/hr M - C.S. D - 1 hp Electric Motor, Direct
303-2106	1	Screw Conveyor to Heater Feed Bin T - Screw C - 1.5 T/hr M - C.S. D - 1.5 hp Electric Motor, Direct
303-2107	1	Screw Feeder to Heater T - Screw C - 1.5 T/hr M - C.S. D - 1.5 hp Electric Motor, Direct
303-2108	1	Char Overflow Feeder T - Rotary C - 1 T/hr M - C.S. D - 1 hp Electric Motor, Direct
303-2109	1	Combustion Gas Dust Collector Feeder T - Rotary C - 300 lb/hr M - C.S. D - 1/2 hp

Equipment Number	Number Required	Description
303-2110	1	Ventilation Collector Discharge Feeder T - Rotary C - 300 lb/hr M - C.S. D - 1/2 hp
303-2201	1	Gasifier T - Fluid Bed, Vertical, Refactory Lined S - 9' I.D. x 40' T/T M - C.S. Des P/T - 160 psig/500°F
303-2202	1	Steam Drum T - Horizontal C - 7700 lb/hr S - 3' Ø x 6' T/T M - C.S. Des P/T - 660 psig/825°F
303-2203	1	Blowdown Flash Drum T - Vertical S - 1' Ø x 3' T/T M - C.S. Des P/T - 75 psig/350°F
303-2301	1	Wood Surge Bin T - Cylindrical w/Conical Bottom C - 2000 ft^3 M - C.S. Des P/T - Atmospheric/125°F

Equipment Number	Number Required	Description
303-2302	1	Heater Feed Bin T - Rectangular w/Screw Conveying Line Bottom S - 4' x 6' x 10' T/T M - C.S. Des P/T - Atmospheric/125°F
303-2303	1	Char Surge Hopper T - Cylindrical Bin w/60° Conical Bottom S - 6'6" Ø x 6' T/T M - C.S. Des P/T - Atmospheric/400°F
303-2305	1	Catalyst Hopper T - Cylindrical Bin w/60° Conical Bottom S - 1' 6" Ø x 3' T/T M - C.S. Des P/T - 15 psig/400°F
303-2501	2	Wood Feed Lock Hopper T - Double Chamber Lock Hopper Assembly to Include - Lower Lock Hopper - Surge Hopper - Gas Valves (2/System) - Rotary Feeder C - 2000 ft^3/hr from Atmospheric to 150 psia

Equipment Number	Number Required	Description
303-2502	1	Char/Catalyst Lock Hopper T - Double Chamber Lock Hopper Assembly C - 300 ft^3/hr of Char and Catalyst from 150 psia to Atmospheric
303-2503	1	Catalyst Feed Lock Hopper T - Double Chamber Lock Hopper Assembly C - 5 ft^3/hr of Catalyst from Atmospheric to 150 psia

IV SUMMARY OF PROCESS MATERIALS AND UTILITIES

A. Raw Material and Utilities Imported

1.	Wood	
	Quantity, tons per day wet	397
2.	Raw Water	
	Flow, gpm	111
3.	Electricity	
	Normal operating usage, kw	2845
4.	Diesel Fuel gallons per day	33

B. Products and Utilities Exported

1.	Fuel Grade Methanol	
	Production, tons per day	100
2.	Treated Wastewater	
	Flow, gpm	59
3.	Wood Ash	
	Quantity, tons per day	11
4.	Sludge from Wastewater Treating	
	Quantity, tons per day	10

C. Catalysts and Chemicals

1. Catalyst Initial Charge	Requirements	Life
Gasifier Charge	*	
Shift Converter Charge	15 ft^3	3-5 yrs.
Chloride Guard Bed Charge	330 ft^3	2-5 yrs.
Sulfur Guard Bed Charge	250 ft^3	2-5 yrs.
Methanol Catalyst	Confidential	2-5 yrs.
Reformer Charge	15 ft^3	2-5 yrs.

*.05 tons/day
1.4 lb/hr of catalyst is continually fed to the gasifier as a make-up stream.

2. Process Chemicals	lb/day
K_2CO_3 for Acid Gas Removal	91
V_2O_5 for Acid Gas Removal	2
DEA for Acid Gas Removal	7
Caustic for Methanol Distillation	17
Lime for Wastewater Treating	8,400
3. Boiler Chemicals	
Scale Inhibitor	6
Oxygen Scavenger	1
Corrosion Inhibitor	3
4. Cooling Tower	
H_2SO_4 for pH control	24
Corrosion control	8
Dispersant	3
Algae control	1
Chlorine	14

D. Summary of Operating Labor

Area	Total Operating Personnel Required
Wood storage and drying	8
Gasification, cleanup, shift, acid gas removal, compression, methanol synthesis and distillation, and purge gas reforming	22
Offsites including boilers, char distribution, cooling tower, wastewater treatment, and raw water treatment	18
TOTAL	48

V. CAPITAL COST ESTIMATE

This section includes the Capital Cost Estimate for the Wood to Methanol plant. Total plant costs are indicated as well as costs by plant area. The capital cost is $34,830,000 - September 1980 basis for the plants to process 200 tons per day of dry wood. The detailed estimate summary is included on the following pages.

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EXECUTIVE SUMMARY

200 TPD WOOD TO METHANOL

	COST	% OF T.I.C.
Equipment & S/C Equipment	$ 9,000M	23.7
Direct Purchase Material	2,530	6.6
Subcontract: Material	180	0.5
Labor (103M MHRS)	2,780	7.3
Direct Hire Labor (162M MHRS)	2,080	5.5
SUBTOTAL DIRECT COSTS	$16,570M	43.6
Field Indirects	3,550	9.3
Pro-Services	5,220	13.7
Other	490	1.3
METHANOL PLANT (By Lakeland T.I.C.)	9,000	23.7
9/12/80 T.I.C.*	$34,830M	91.6
ESCALATION	3,220	8.4
ESCALATED T.I.C.	$38,050M	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.

NC-5471
11/17/80

CLIENT: Battelle Pacific Northwest Laboratories

LOCATION: Newport, Oregon

PROJECT: 200 TPD of Wood to Methanol

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 Methanol, dated September 12, 1980 (Value = $132MM ± 25%).
- Four line equipment list developed by Process Engineering for Areas 301,302, and 303.
- Davy McKee interoffice communication - Estimate of the Methanol Plant from A. J. Frost of the Lakeland Office to T. Kendron of the Cleveland Office, dated November 11, 1980.
- Preliminary layout drawing of the Wood Sizing and Wood Storage areas.

SCOPE OF WORK: Davy McKee is to determine the economic feasibility of producing methanol 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:

301 - Wood Storage and Sizing
302 - Wood Drying
303 - Gasification
304 - Shift Conversion
305 - Acid Gas Removal
306 - Compression
307 - Methanol Synthesis and Distillation
308 - Purge Gas Reforming
309 - Waste Water Treating
310 - Raw Water Treating and Cooling Water
311 - Boilers and Boiler Feedwater System
312 - Miscellaneous Utility System
313 - Storage and Loading - Product and Utilities

SCHEDULE:

The following schedule was assumed based on historical information:

Engineering:	Start	10/01/80	
	Completion	4/01/82	
	Duration		18 Months
Procurement:	Start	4/01/81	
	Completion	10/01/82	
	Duration		18 Months
Construction:	Start	4/01/81	
	Completion	4/01/83	
	Duration		24 Months

TOTAL PROJECT DURATION: 30 Months

ESTIMATE APPROACH:

This estimate is a scale down of the earlier estimate for Battelle PNL, 2,000 TPD of Wood to Methanol dated 9/12/80 (under the same contract: NC-5471). The following paragraphs outline the techniques used to estimate the cost of the entire project exclusive of the Methanol Plant (Area 307) which was estimated by Davy Powergas Inc., Lakeland at a current Installed Cost of $9,000M.

MAJOR EQUIPMENT ($2,172M Direct Purchase, 5.7% of TIC)
($6,824M S/C Equip. Mat'l Portion, 18.0% of TIC)

The major equipment for Area 301, 302, and 303 was defined on four line equipment lists developed by Davy McKee's Process Department. Equipment pricing for Areas 301 and 302 was based on installed cost budget quotations solicited from vendors by Davy McKee specifically for the 200 TPD Wood to Methanol project. Each piece of equipment in Area 303 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.

ESTIMATE APPROACH: (continued)

MAJOR EQUIPMENT (continued)

Equipment pricing for all other areas was obtained by using scale-down factors applied to the original (2,000 TPD) estimate. The scale-down factors were developed by the Estimating Department based on the type of equipment in each area (Reference: Table 1).

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

DIRECT PURCHASE MATERIALS ($2,533M, 6.6% of TIC)

Direct purchase material except those in Areas 301, 302, and 305 were factored to equipment using the same material dollar to equipment dollar ratios developed for the original (2,000 TPD) estimate. Materials except Civil for Areas 301 and 302 were included with the vendor quote. The Civil work was estimated utilizing preliminary site layouts for those areas. Area 305 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 $177M, 0.5% of TIC)
(Labor $2,786M, 7.3% 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 (2,000 TPD) estimate. Labor man-hours were priced using a subcontract labor rate of $26.96/MHR in accordance with the 2000 TPD 9/12/80 estimate.

DIRECT HIRE LABOR ($2,079M, 5.5% of TIC)

Equipment erection/installation direct hire man-hours for Area 303 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)

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 ($3,218M, 8.4% 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	2,172	11.0	238
Direct Material	2,533	11.3	287
Subcontract (E,M,&L)	9,787	10.5	1,023
D/H Labor	2,079	9.3	191
S/T DIRECTS	16,571	10.5	1,739
Field Indirects	2,951	10.1	299
Professional Services	4,860	5.7	280
Items Not Subject to Escalation*	1,450	--	--
TOTAL (excl. AREA 307-Methanol Plant)	25,832	9.0	2,318
AREA 307-Methanol Plant	9,000	10.0	900
TOTAL INSTALLED COST	34,832	9.2	3,218

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

EXCLUSIONS:

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

ESTIMATE APPROACH: (continued)

FIELD INDIRECTS ($3,551M, 9.3% 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 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 insurance.

PROFESSIONAL SERVICES ($5,220M, 13.7% 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 recent similar sized estimate. Out-of-pocket costs (reproductions, 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 and 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-Services Cost
Construction		2.0% x TIC (Cleveland Scope)

INSURANCE ($440M, 1.3% 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 (Cleveland Scope) based on recent gasification estimates.

TAXES

There are no applicable sales or use taxes in Oregon.

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TABLE 1

SCALE DOWN FACTORS USED
FOR PRICING EQUIPMENT

AREA	TITLE	SCALE DOWN EXPONENT FACTOR		MULTIPLIER	REFERENCE AREA FROM BASE ESTIMATE
304	Shift Conversion	$(x)^{.65}$	=	.224	104
305	Acid Gas Removal	$(x)^{.6}$	=	.251	105
306	Compression	$(x)^{.7}$	=	.200	106
308	Purge Gas Reforming	$(x)^{.6}$	=	.251	108
309	Waste Water Treating	$(x)^{.6}$	=	.251	109
310	Raw Water & Cooling Water	$(x)^{.6}$	=	.251	110
311	Boilers & BFW System	$(x)^{.6}$	=	.251	111
312	Misc. Utility System	$(x)^{.65}$	=	.224	112
313	Product Storage & Loading	$(x)^{.6}$	=	.251	113

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		162.0M	
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		$2,079M	
	COST ($-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	318	15.3
- Other Costs	170	3.5	179	4.2	--	--	349(2)	3.8	79	3.8
Field Office Labor	138	2.8	117	2.8	998	7.1	1,253	5.4	112	5.4
Auxiliary Field Labor	337	6.9	438	10.3	--	--	775(2)	8.5	177	8.5
Temporary Construction	553	11.2	659	15.5	1,733	12.4	2,945	12.7	264	12.7
Construction Equipment	881	17.9	1,077	25.4	2,824	20.2	4,782	20.7	430	20.7
Small Tools & Consumables	373	7.6	475	11.2	31	0.2	848(2)	9.3	193	9.3
Field Office Expenses	86	1.7	145	3.4	--	--	231(2)	2.5	52	2.5
Subtotal	3,287	66.8	3,866	91.1	7,592	54.3	N/A	--	1,625	78.2
PAYROLL BURDENS										
Constr. Supv. @ 38% x Sal.	N/A	--	N/A	--	N/A	--	N/A	--	121	5.8
F. O. Labor @ 38% x Sal.	N/A	--	N/A	--	N/A	--	N/A	--	43	2.1
Aux. Labor @ 51.5% x Sal. (3)	N/A	--	N/A	--	N/A	--	N/A	--	92	4.4
D.H. Labor @ 51.5% x Sal. (3)	N/A	--	N/A	--	N/A	--	N/A	--	1,070	51.5
Subtotal	N/A	--	N/A	--	N/A	--	N/A	--	1,326	63.8
TOTAL									2,951	142.0
									CONSTRUCTION FEE:	
									2.0% x T.I.C.	600	29.0
										3,551	171.0

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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TABLE 3

PROFESSIONAL SERVICES DEVELOPMENT

	$-M
H.O. Salaries @ 12% x D.C.	$1,990M
Other Costs @ 25% x H.O. Salaries	500
F/B & O/H @ 118.9% x H.O. Salaries	2,370
SUBTOTAL	$4,860M
Fee @ 7.5% x Professional Services	360
TOTAL PROFESSIONAL SERVICES (9/12/80 Basis)	$5,220M
Escalation @ 5.7% x Professional Services	280
ESCALATED PROFESSIONAL SERVICES	$5,500M

PROJECT SUMMARY SHEET

McKee

M-292 Rev. 5/79

ESTIMATE NO. NC-5471

SCHEDULE: (ASSUMED) AWARD DATE 10/1/80

MECH. COMPL: 4/1/83 30 MO.

CONSTR. START: 4/1/81 24 MO.

CLIENT: BATTELLE PNL

PLANT: 200 TPD WOOD TO METHANOL

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

ITEM	PROJECT SUMMARY SHEET (ALL AMOUNTS IN 1000'S)	MH DATA	CLEV.	LKLD	TOTAL
1	EQUIPMENT		2172		
2	MATERIAL		2533		
3	SUBCONTRACT: EQUIP. & MAT'L. 7001 LABOR 2786	103	9787	9000	
4	LABOR	162	2079		
5	PREMIUM TIME S/C D.L.				
6	ESCALATION: EQUIP. 238 ; MAT'L. 287 ; S/C 1023 ; LABOR 191		1739	900	
7	SUB TOTAL DIRECT COST	265	18310	9900	28210
8	CONSTR. SUPERVISION: W: 318 O.C. 79		397		
9	FIELD OFFICE LABOR		112		
10	AUXILIARY LABOR		177		
11	TEMPORARY CONSTRUCTION: MAT'L. ; S/C ; LABOR		264		
12	CONSTRUCTION EQUIPMENT: EQUIP. LABOR		430		
13	SMALL TOOLS CONSUMABLES		193		
14	FIELD OFFICE COST		52		
15	PAYROLL BURDEN		1326		
16	ESCALATION		299		
17	SUB TOTAL FIELD INDIRECT COST		3250	INCLUDED	3250
	ESCALATION (@ 5.7% x P.S)		280		
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		5140	INCLUDED	5140
23	SUB TOTAL ESTIMATED COST ITEMS 7, 17 & 22		26700	9900	
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. (CLEV. SCOPE)		440		
28	SUB TOTAL OTHER COST		490	INCLUDED	490
29	OVERHEAD: % OF P.S. ; % OF CONSTR. SUPERV.		INCLUDED		
30	FEE: PROFESSIONAL SERVICES @ 7.5% x P.S.		360		360
31	FEE: CONSTRUCTION @ 2.0% x T.I.C. (CLEV. SCOPE)		600		600
32	TOTAL PROJECT COST		28150	9900	38050

APPROVED: BMD

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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 METHANOL	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
301	WOOD STORAGE			739	3451	42.7		1151	4602	71.8		922	6263		
302	WOOD DRYING				1329	16.5		444	1773				1773		
303	GASIFICATION			1706	166	7.7		208	374	33.3		428	2508		
304	SHIFT CONVERSION			147	5	0.5		14	19	2.7		36	202		
305	ACID GAS REMOVAL				740	15.2		410	1150				1150		
306	COMPRESSION			892	12	0.8		21	33	12.3		159	1084		
307	METHANOL SYNTHESIS & DISTILLATION			BY DAVY POWER GAS - LAKELAND											
308	PURGE GAS REFORMING			184	8	0.7		19	27	2.4		30	241		
309	WASTE WATER TREATING			160	320	4.7		126	446	7.4		94	706		
310	RAW WATER & COOLING WATER			335	155	3.4		90	245	10.2		131	711		
311	BOILERS & BFW SYSTEM			291	572	7.7		208	780	11.4		146	1217		
312	MISC. UTILITY SYSTEMS			201	7	0.3		8	15	8.0		102	318		
313	PRODUCT STORAGE & LOADING			44	236	3.2		87	323	2.5		31	398		
	TOTAL			4705	7001	103.4		2786	9787	162.0		2079	16571		

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 METHANOL	301 - 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		922	6263		

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 METHANOL	303 - 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			968	112	3.4	26.96	91	203	4.9	12.84	63	1234		
	PIPING			310						14.0		180	490		
	CIVIL			48						4.2		54	102		
	STRUCTURAL STEEL			240						3.4		44	284		
	ELECTRICAL			18	29	1.4		38	67				85		
	INSTRUMENTS			105						4.6		59	164		
	INSULATION				12	1.0		27	39				39		
	PAINTING				9	1.1		30	39				39		
	FIREPROOFING				4	0.8		22	26				26		
	MISCELLANEOUS @(1%M+7%L)			17						2.2		28	45		
	TOTAL			1706	166	7.7		208	374	33.3		428	2508		

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 METHANOL	302 - 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 301											
	TOTAL				1329	16.5		444	1773				1773		

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VI OPERATING COST ESTIMATE

The production cost of fuel-grade methanol 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 $ 34,830,000 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 are shown in Table I. The total capital requirement for this plant is $ 41,221,000 .

The annual direct operating costs have been calculated and are shown in Table II. These costs include raw materials, utilities, catalyst and chemicals, labor, administration and general overhead, supplies, and taxes and insurance. Maintenance costs are calculated as a percentage of capital investment, as suggested by the cited guidelines. These annual costs are $ 7,794,800 . 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 about 17% of the total direct costs and are 10% of the total production costs. Thus, either lowering the wood cost or improving yields from the wood 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 day ton. These prices for wood include delivery to the plant.

In Tables III and IV are given the methods for calculating production costs 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 methanol production costs are $1.20, $1.23, $1.30 and $1.44 per gallon for wood prices of $5, $10, $20, and $40 per dry ton. For private investor financing, the methanol production costs are $1.60, $1.63. $1.70 and $1.84 per gallon for the corresponding wood costs.

TABLE I. TOTAL CAPITAL REQUIREMENT

Total Plant Investment	$34,830 M	
Allowance for Funds During Construction (Total Plant Investment x 1.25 years x 0.09)	3,918 M	
Start-Up Costs (20% of Total Annual Gross Operating Costs)	1,559 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 Methanol and by-products revenue at calculated sales price)	56 M 313 M 545 M	(1) (2) (3)
Total Capital Requirement	$41,221 M	

TABLE II. ANNUAL DIRECT OPERATING COSTS

Operating Factor: 330 days/year

Cost Component	Annual Use	$/Unit	$1000/Yr.
Raw Material			
Wood	66,000 Dry Ton	20/Dry Ton	1,320.0
Utilities			
Water	52,652 M Gal.	0.50/M Gal.	26.3
Electricity	2.43×10^7 kwh	.03/kwh	729.6
Diesel Fuel	10,890 Gal.	1.00/Gal.	10.9
Catalysts and Chemicals			
Gasifier Catalyst	33,066 lbs.	8.51/lb.	281.4
Shift Catalyst	15 $ft.^3$	107/$ft.^3$	1.6
Chloride Guard Catalyst	330 $ft.^3$	151/$ft.^3$	50.0
Sulfur Guard Catalyst	250 $ft.^3$	75/$ft.^3$	18.8
Methanol Catalyst	Confidential	------	36.0
Reformer Catalyst	15 $ft.^3$	235/$ft.^3$	3.5
Labor			
Process Operating	48 Men @ 2080 hrs/ea.	10.70/hr.	1068.3
Maintenance	@ 60% of Total Maintenance		873.6
Supervision	@ 20% of process operating and maintenance labor		213.7

ADMINISTRATIVE AND GENERAL OVERHEAD

@ 60% of Total Labor	1293.4

SUPPLIES

Operating @ 30% of Process Operating Labor	320.5
Maintenance @ 40% of Total Maintenance Cost	582.4

TAXES AND INSURANCE

@ 2.77% of Total Plant Investment	964.8
Total Gross* Operating Costs Per Year	7794.8

* No credits were taken for any by-products so that Total Net Operating Costs are the same as the Total Gross.

TABLE III. METHANOL COST - UTILITY FINANCING METHOD

BASIS:

20 - years 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 Fuel Production, 10^6 Gallon/Yr.
d = Fraction Dept.
i = Interest on Debt, %/Year
r = Return on Equity Base, %/Year
P = Return on Rate Base, %/Year

EQUATION FOR RETURN ON RATE BASE

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

TABLE III. METHANOL COST - UTILITY FINANCING METHOD (Cont'd)

Average Methanol Cost, $/Gallon =

$$\frac{N + .05\,(C-W) + .005\left[P + \frac{48}{52}\,(1-d)r\right](C + W)}{G}$$

CALCULATION

$P = (0.75)\,(10) + (1 - 0.75)\,(15) = 11.25$

$G = 9.911 \times 10^6$ Gallon/yr

$C = 41.221 \times 10^6$ $/yr

$W = .914 \times 10^6$ $/yr

$N = 7.795 \times 10^6$ $/yr

Average Methanol Cost

$$= \frac{7.795 + (.05)\,(40.307) + (.005)\,(14.70)\,(42.135)}{9.911}$$

= $ 1.30/gal.

TABLE IV. METHANOL 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 $/yr.
G = Annual Methanol Production, 10^6 gallon/year

METHANOL COST EQUATION AT 12% DCF RETURN

Methanol Cost, $/$10^6$ Btu =

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

N = 7.795 10^6/yr
G = 9.911 10^6 gal/yr
I = 34.830 10^6 $/yr
S = 1.559 10^6 $/yr
W = 1.071 10^6 $/yr

Average Methanol Cost

$$= \frac{7.795 + (.247)\ (34.830) + (.1337)\ (1.559) + (.2305)\ (1.071)}{9.911}$$

= $ 1.70/gal.

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