Section 7

COAL TO METHANOL
CASE CM - ILLINOIS COAL

GENERAL

This section describes a preliminary design for a grass roots indirect coal liquefaction plant to produce a nominal 15,000 st/sd of 98.29 weight percent fuel grade methanol. The design is based on several licensed processes including Texaco coal gasification, Lotepro Rectisol acid gas removal, and Lurgi methanol synthesis. The plant consumes 22,368 st/sd (MF basis) of Illinois No. 6 coal.

The plant facilities are divided into sixteen process areas as listed in Table 7-1. The number of trains of equipment is shown for major process areas except where this information is considered proprietary or does not apply.

The overall processing sequence is presented in Drawing No. 75-D20, Overall Block Flow Diagram. Table 7-2 is the material balance and Table 7-3 the overall utility balance for the Coal to Methanol Plant.

Process description, equipment lists, and flow diagrams are provided for the major non-proprietary areas of the plant.

Table 7-1

LIST OF PROCESS AREAS
COAL TO METHANOL
CASE CM

Area	Description	Number of Trains
100	Coal Preparation and Grinding	
200	Slurry Preparation	
300	Air Separation Plant	9
400	Gasification, Quench and Scrubbing	
500	Shift Conversion and Heat Recovery	8
600	Acid Gas Removal	4
700	Sulfur Recovery (CLAUS)	3
800	Tail Gas Treating (SCOT)	2
900	Methanol Synthesis	6
1000	Power Generation	
1100	Cooling Water System	
1200	Tank Storage	
1300	Water Management	
1400	Flare System	
1500	Buildings	
1600	Common Facilities	

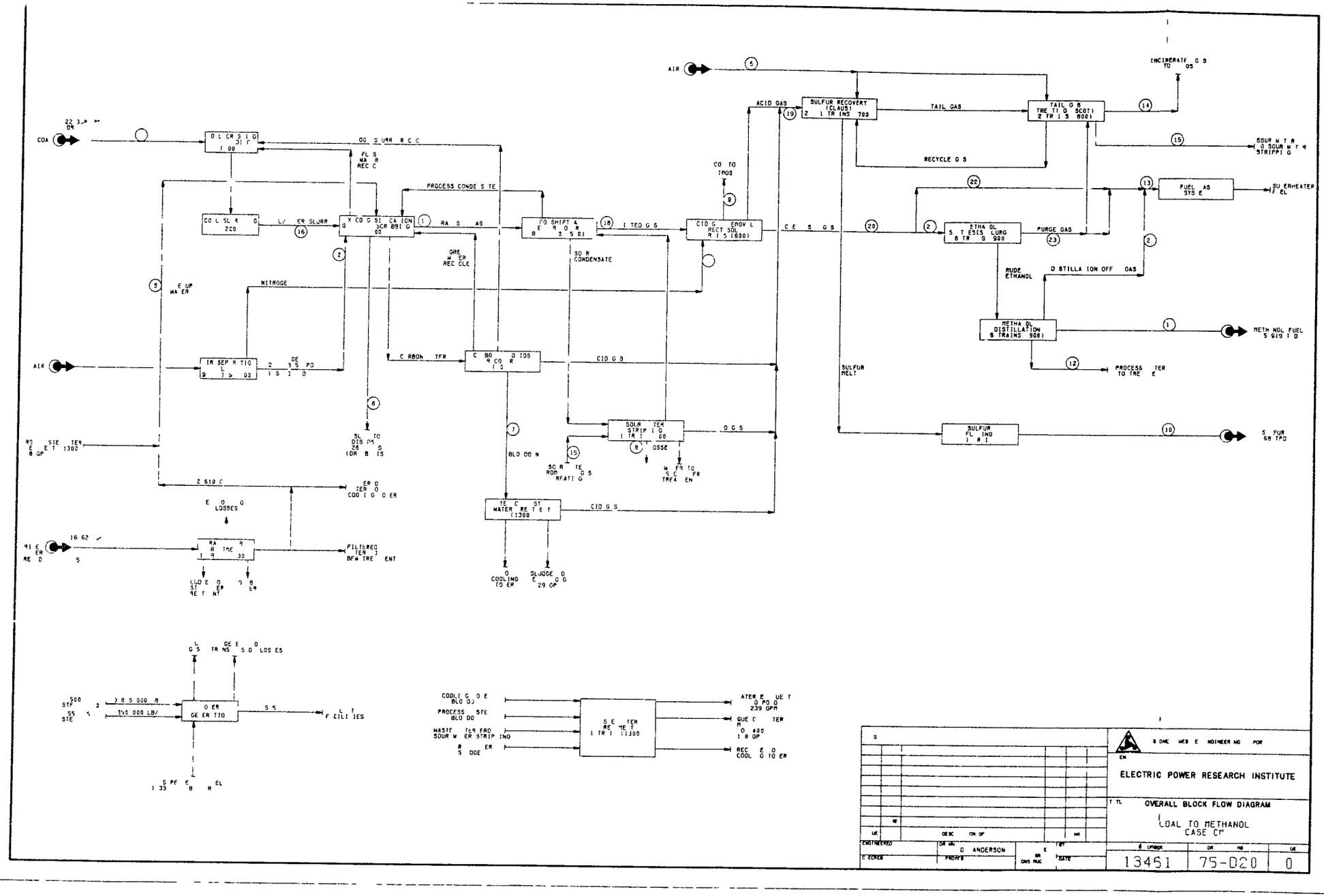

AIR
SULFUR RECOVERY (CLAUS) 2 TRAINS 700
TAIL GAS
TAIL GAS TREATING (SCOT) 2 TRAINS 800
INCINERATED GASES TO STACK
ACID GAS
RECYCLE GAS
SOUR WATER AND SOUR WATER STRIPPING
CO TO TMOS
FUEL GAS SYSTEM
SUPERHEATER FUEL
METHANOL SYNTHESIS LOOP 6 TRAINS 900
PURGE GAS
CRUDE ETHANOL
DISTILLATION OFF GAS
METHANOL DISTILLATION 6 TRAINS 900
METHANOL FUEL SHIPPING
PROCESS WATER TO TREATING
SULFUR MELTING
SULFUR SHIPPING
PROCESS CONDENSATE
SOUR CONDENSATE
CARBON TRANSFER
CO2 GAS
SOLVENT STRIPPING 1 TRAIN 600
SOLVENT REGENERATION GASES
WASTE WATER TO SOUR WATER STRIPPING
SLUDGE TO DISPOSAL
BLOWDOWN
MAKEUP WATER
NITROGEN
FILTERED WATER TO PLANT
SLUDGE TO LAGOON
COOLING TOWER BLOWDOWN
PROCESS STEAM BLOWDOWN
WASTE WATER TO SOUR WATER STRIPPING
SLUDGE TO DISPOSAL
WATER TO COOLING TOWER
SLUDGE TO LAGOON
ELECTRIC POWER RESEARCH INSTITUTE
OVERALL BLOCK FLOW DIAGRAM
COAL TO METHANOL
CASE C
13451
75-020
0
D. ANDERSON

Table 7-2

OVERALL MATERIAL BALANCE
COAL TO METHANOL - CASE CM
A. OVERALL FEED STREAMS

Stream Number	1	2	3	4	5
Description	Coal Feed	Oxygen Feed	Make-Up Water	Stripping Nitrogen	Air to Claus and SCOT
Component Flowrate, lb/h					
H2	91,522				
CO					
CO2					
CH4					
H2S					
COS					
SO2					
N2	27,401	4,925		392,588	133,673
O2	165,523	1,787,790			40,547
Ar		38,640			
CH3OH					
C	1,300,326				
S	64,681				
Ash	214,547				
H2O	254,182		1,379,070		2,613
Total, lb/h	2,118,182	1,831,355	1,379,070	392,588	176,833
Temperature, F		275		100	85
Pressure, psia		1100		65	14.7

Ref. Dwg. 75-D20.

Table 7-2 (cont'd)

OVERALL MATERIAL BALANCE
COAL TO METHANOL - CASE CM
B. OVERALL OUTLET STREAMS

Stream Number	6	7	8	9	10	11	12	13	14	15
Description	Wet Slag	Process Water Blowdown	Sour Water Stripping Losses	CO2 to Atmos.	Sulfur Product	Methanol Product	Process Water to Treat-ment	Total Fuel to Fuel System	Incine-rated Gas to Atmos.	Sour Water
Component Flowrate, lb/h										
H2				966				17,690		
CO				16,830				57,332		
CO2				2,686,289				32,062	93,482	
CH4				122				8,871		
H2S				Tr						Tr
COS				Tr						
SO2									961	
N2				390,298				30,702	137,587	
O2									374	
Ar				Tr				36,670	1,970	
CH3OH						1,303,932	955	8,827		
C	6,496									
S					64,000					
Ash	214,035	512 (a)								
H2O	26,000	647,000	2,000	2,414		22,662	42,573	Tr	14,420	29,996
Total, lb/h	246,531	647,512	2,000	3,096,919	64,000	1,326,594	43,528	192,154	248,794	29,996
Temperature, F				95	325	100			300	
Pressure, psia				16	14.7	100			14.7	

Ref. Dwg. 75-D20

(a) Soluble Ash

Table 7-2 (cont'd)

OVERALL MATERIAL BALANCE
COAL TO METHANOL - CASE CM
C. PRINCIPAL INTERMEDIATE STREAMS

Stream Number	16	17	18	19	20	21	22	23	24
Description	Coal Slurry Feed	Raw Syn Gas	Shifted Gas to AGR	Acid Gas To Claus	Clean Syn Gas	Syn Gas To Methanol Unit	Syn Gas To Fuel	Purge Gas	Distillation Off Gas
Component Flowrate, lb/h									
H2	91,522	116,027	191,926		190,960	184,554	6,406	11,913	
CO		2,176,832	1,122,746		1,105,916	1,068,814	37,102	21,357	
CO2		1,308,660	2,965,089	86,247	192,553	186,093	6,460	27,028	
CH4		9,256	9,256		9,134	8,828	306	9,042	
H2S		64,204	66,430	66,430					
COS		8,025	3,737	3,737					
SO2									
N2	27,401	32,326	32,326	2,264	32,352	31,267	1,085	31,267	
O2	165,523								
Ar		38,640	38,640		38,640	37,344	1,296	37,344	
CH3OH								Tr	8,827
C	1,371,846								
S	64,681								
Ash	268,039								
H2O	1,242,667	3,685,922	4,414						Tr
Total, lb/h	3,231,679	7,439,892	4,434,564	158,678	1,569,555	1,516,900	52,655	137,951	8,827
Temperature, F	140	463	100	105	95	95	95	100	
Pressure, psia	950	880	805	50	775	775	775	700	

Ref. Dwg. 75-D20.

Table 7-3

OVERALL UTILITY BALANCE
COAL TO METHANOL - CASE CM

	Produced	Consumed
1500 psig Sat'd Steam, lb/hr		
Area 400	3,840,000	
Area 1000		3,840,000
	3,840,000	3,840,000
550 psig Sat'd Steam, lb/hr		
Area 400		625,600
Area 900	1,585,000	
Area 1000		959,400
	1,585,000	1,585,000
65 psig Sat'd Steam, lb/hr		
Area 500	1,094,800	
Area 600		476,500
Area 700	184,100	6,300
Area 800	10,000	90,700
Area 900	622,500	1,293,000
Area 1000	259,000	71,400
Area 1300		120,000
Area 1500		112,500
	2,170,400	2,170,400
Cooling Water, gpm @ 85°F, T Return = 103.6°F		
Area 300		80,650
Area 400		4,300
Area 500		10,500
Area 600		64,600
Area 800		17,350
Area 900		127,800
Area 1000		505,800
Area 1100	831,300	
Miscellaneous		20,300
	831,300	831,300

Table 7-3 (cont'd)

	Produced	Consumed
Power, KW		
Area 100		11,400
Area 200		2,000
Area 300		401,200
Area 400		8,400
Area 500		1,000
Area 600		65,500
Area 700		3,600
Area 800		400
Area 900		19,800
Area 1000	575,000	13,300
Area 1100		37,900
Area 1200		600
Area 1300		6,100
Area 1500		3,800
	575,000	575,000
Fuel, 10^6 Btu/hr (LHV)		
Area 600	499.2	
Area 800		47.8
Area 900	982.2	
Area 1000		1,433.6
	1,481.4	1,481.4
		Heat Loss to Atmosphere
Air Cooling, 10^6 Btu/hr		
Area 400		220.8
Area 500		308.0
Area 900		521.1
Area 1300		108.1
		1,158.0

AREA 100 - COAL PREPARATION, CASE CM

The coal preparation unit provides facilities to unload, store, reclaim, weigh, crush and grind coal, and transfer ground coal to Unit 200, Slurry Preparation. The design is based on Illinois No. 6 coal, which is processed in the following flow quantities:

	Illinois No. 6 Coal st/sd
Coal as received, 12% moisture	25,418
Coal, moisture free (MF)	22,368

An analysis of Illinois No. 6 coal is shown is Section 3, Table 3-3. Process flow diagrams 75-B10 and 75-B11 show schematic arrangements of the equipment for both the coal preparation area (100) and the slurry preparation area (200). The equipment list is shown in Table 7-4.

Washed coal, having a nominal size of two inches by zero inches, is received in railroad cars. A thaw shed for three cars precedes a dumper house. In the dumper house, coal is unloaded into a receiving hopper at twice the process feed flow rate using a rotary car dumper, and is transferred to intermediate bins. An unloading conveyor transfers coal from the intermediate bins to a weigh scale, through an underground tunnel, and into a sample house. From the sample house, coal is conveyed either to a dead storage pile or to live storage silos. The dead storage coal pile is sized for 30 days' capacity. Coal may be transferred, when required, from the coal pile to the silos at a rate of 1 1/2 times the feed flow rate. The coal passes through a bifurcated hopper which distributes the coal to vibrating feeders and then on to a belt conveyor.

Four live coal storage silos are provided for 2 1/2 days' normal consumption. A magnetic separator upstream of the storage silos removes tramp iron from the incoming coal. At the outlet of each silo, rotary plow feeders discharge coal to a conveyor for transfer to crushing and grinding equipment. The entire silo fill system is enclosed, and dust suppression and collection systems are provided to control dust generated by the filling operation.

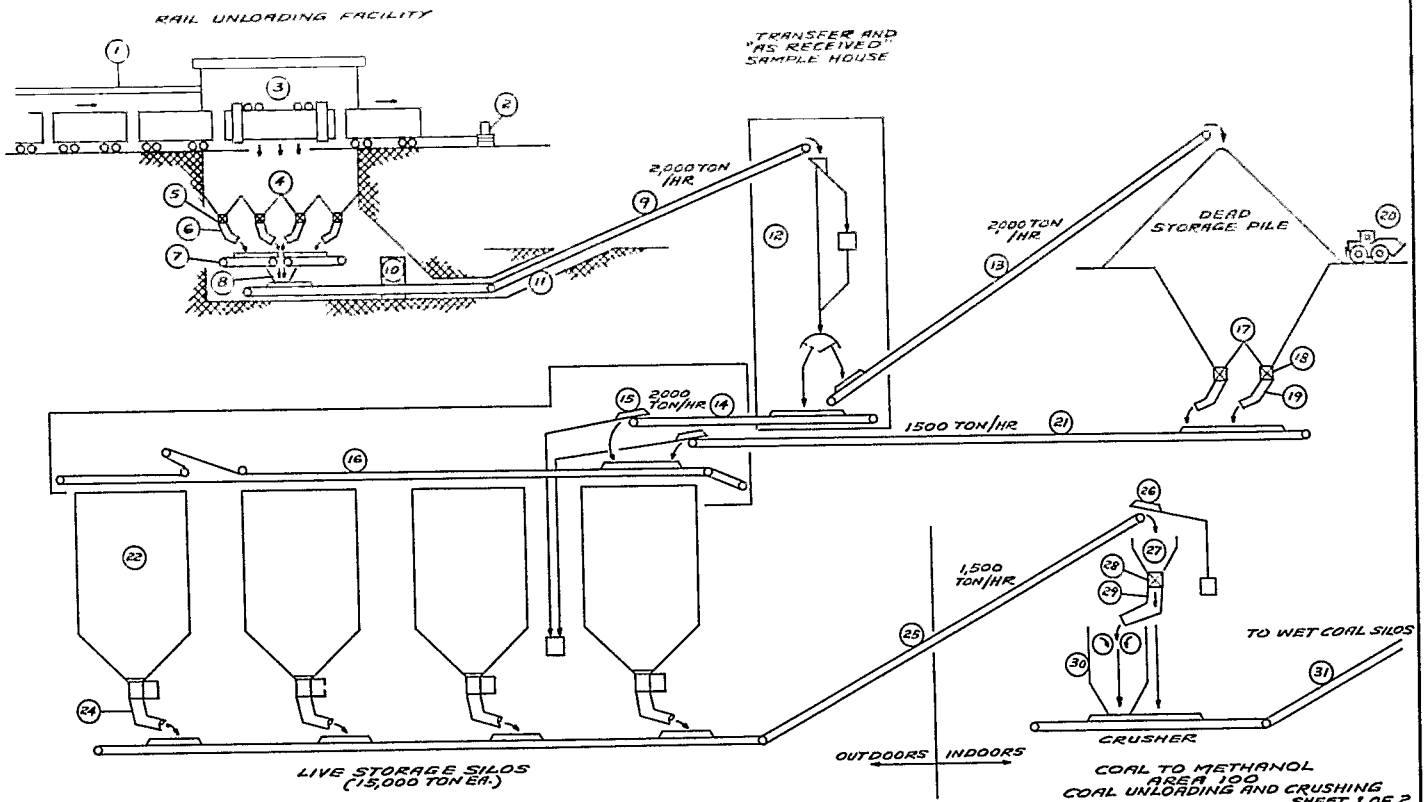
Crushing and grinding equipment is enclosed within a building. The coal from the live coal storage silos is screened to half-inch particle size, and the oversized coal is crushed to minus half-inch size. Coal from the crusher combines with raw coal separated ahead of the crusher and is conveyed from the building into four pairs of wet-coal silos at 1 1/2 times the process flow rate.

There are eight rotating mills of 150 st/hr capacity each, which are located below the wet storage silos. Each mill accepts feed from a single silo. The mill operation is a wet grinding process and the volume of water required is automatically controlled. The rotating mill product, containing about 60 percent solids, discharges to a sump where it is pumped to slurry mix tanks in Area 200.

AREA 200 - SLURRY PREPARATION, CASE CM

Mix tanks receive the slurry discharge from a single rotating mill. These tanks have pumps to circulate the slurry in order to maintain the mixture at a "well stirred" and pumpable viscosity. The tanks are continuously sampled and adjusted to maintain the proper flow of solids and water to the rotating mills.

The slurry is pumped from each mix tank at four times the inlet rate with the net discharge going to agitated belt line feed tanks. These tanks also have circulating pumps and are monitored for slurry concentration. The run tanks in the Texaco gasification area are fed from belt lines originating at the feed tanks.



NOTE: EQUIPMENT NUMBERS REFER TO EQUIPMENT LIST.

COAL TO METHANOL
AREA 100
COAL UNLOADING AND CRUSHING
SHEET 1 OF 2

NO	REVISION DESCRIPTION	BY	DATE	APPROVED
A	CERT FOR FAB / CERT FOR CONST	E.V.P.	11-5-81	

ENGR: E.V.P.
DESIGN
DATE 11-5-81
DRAWN A.R.
CHECKED

STONE & WEBSTER ENGINEERING CORPORATION
ELECTRIC POWER RESEARCH INSTITUTE
ILLINOIS NO. 6 COAL FEED

AREA	J.O. NO.	DRAWING NO.	ISSUE
	13461	75-B10	A

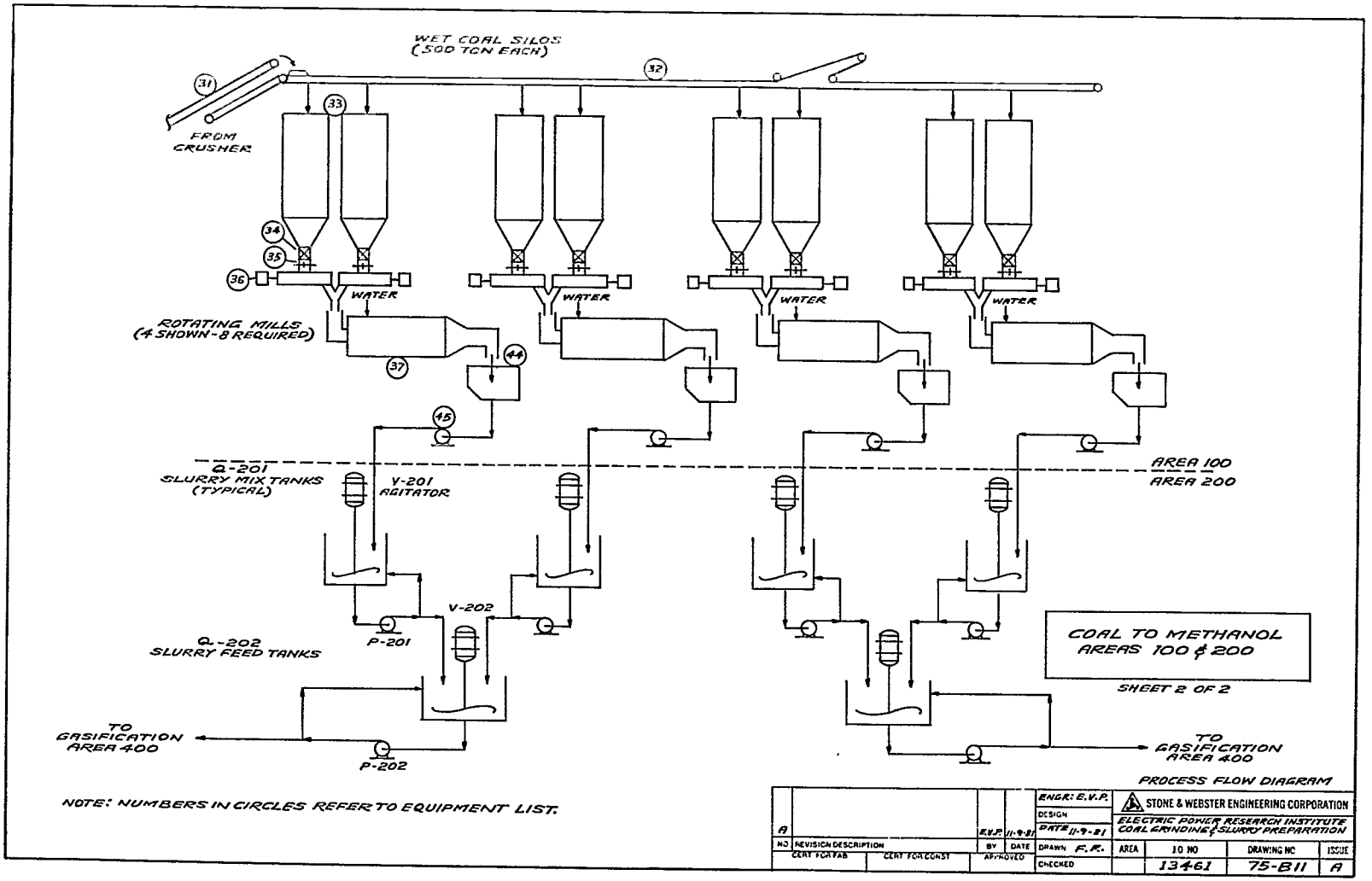

WET COAL SILOS
(500 TON EACH)
31
32
33
FROM
CRUSHER
34
35
36
WATER
WATER
WATER
WATER
ROTATING MILLS
(4 SHOWN - 8 REQUIRED)
37
44
45
Q-201
SLURRY MIX TANKS
(TYPICAL)
V-201
AGITATOR
AREA 100
AREA 200
V-202
P-201
Q-202
SLURRY FEED TANKS
TO
GASIFICATION
AREA 400
P-202
TO
GASIFICATION
AREA 400
NOTE: NUMBERS IN CIRCLES REFER TO EQUIPMENT LIST.
COAL TO METHANOL
AREAS 100 & 200
SHEET 2 OF 2
PROCESS FLOW DIAGRAM
A
E.V.P. 11-9-81
NO REVISION DESCRIPTION
BY
DATE
CERT FOR FAB
CERT FOR CONST
APPROVED
ENGR: E.V.P.
DESIGN
DATE 11-9-81
DRAWN F.A.
CHECKED
STONE & WEBSTER ENGINEERING CORPORATION
ELECTRIC POWER RESEARCH INSTITUTE
COAL GRINDING & SLURRY PREPARATION
AREA
J.O. NO
13461
DRAWING NO
75-811
ISSUE
A

Table 7-4

EQUIPMENT LIST
COAL AND SLURRY PREPARATION
AREAS 100, 200-CASE CM

Area 100 - Coal Preparation and Grinding

The equipment list for Area 100 is the same as presented for H-Coal, Illinois, Case HE, Table 5-2, with some exceptions as noted below:

Item No.	No. Req'd	Description
W-137	8	Pulverizer Mill is replaced by 150 st/hr Rotating Mill. There is no drying.
-	-	Delete Items W-138 through W-143
W-144	8	Add Rod Mill Sump.
W-145	16	Add Slurry Pump.

Area 200 - Slurry Preparation

Item No.	Description
P-201	Slurry Transfer Pump.
P-202	Slurry Belt Line Circulation Pump.
Q-201	Slurry Mix Tank.
Q-202	Slurry Belt Line Feed Tank.
V-201	Mix Tank Agitator.
V-202	Feed Tank Agitator.

AREA 300 - AIR SEPARATION PLANT, CASE CM

The Air Separation Plant has nine parallel 2400 st/sd oxygen trains to supply high purity oxygen for use in the gasification area, and nitrogen for use in the acid gas removal and product storage areas. The equipment list is shown in Table 7-5.

The technology involved is conventional. Atmospheric air is filtered and compressed to 90 psia by electric motor driven axial-centrifugal compressors. The design air intake rate is 100,272 st/sd and the power required for air compression is 257,000 kW. The compressed air is cooled in an aftercooler and delivered to a low temperature fractionation system.

After passing through a series of reversing heat exchangers, air is separated into nitrogen and oxygen in high and low pressure distillation columns. Pure nitrogen from the top of the high pressure column and waste nitrogen from the top of the low pressure column leave the cold box through the reversing heat exchangers.

Oxygen is compressed from 16 psia to 1100 psia by electric driven compressors which require approximately 133,500 kW of power. The design oxygen rate is 21,454 st/sd (as 100 percent oxygen) with a purity of 98 mol percent. The compressed oxygen is delivered to the gasifiers, Area 400. Liquid oxygen is stored in a 69 foot diameter sphere to provide a 5,000 ton emergency supply, which is equivalent to approximately two days' production of one 2400 st/sd oxygen plant.

Nitrogen, compressed and distributed at 60 psig, is used for solvent stripping in the acid gas removal area and for utility and purging requirements. Three nitrogen storage tanks are provided to store 9,000,000 scf at 200 psig for standby and emergency use.

Table 7-5

EQUIPMENT LIST
AREA 300 - AIR SEPARATION PLANT
CASE CM

Item No.	No. Req'd	Description
G-301	9	Air Separation Plant - Cold Box
M-301	9	Air Compressor Interstage K.O. Drum
M-302	9	Air Compressor Discharge K.O. Drum
R-301	9	Air Compressor
R-302	9	Oxygen Compressor
R-303	9	Nitrogen Compressor
T-301	9	Air Compressor Intercooler
T-302	9	Air Compressor Aftercooler
T-303	9	Oxygen Compressor 1st Stage Intercooler
T-304	9	Oxygen Compressor 2nd Stage Intercooler
T-305	9	Oxygen Compressor 3rd Stage Intercooler
T-306	9	Oxygen Compressor 4th Stage Intercooler
T-307	9	Nitrogen Compressor Intercooler
T-308	9	Nitrogen Compressor Aftercooler

AREA 400 - COAL GASIFICATION, CASE CM

In this area, Illinois No. 6 coal is gasified with oxygen by the Texaco coal gasification process. The process includes a gasifier reactor vessel, a radiant heat boiler, a quench and gas scrubbing unit, carbon recovery, and a blowdown water treatment system. A schematic block flow diagram of the process is shown in drawing 75-A3. The equipment list is shown in Table 7-6.

A 60 percent by weight coal-water slurry feed, consisting of fresh ground coal and recycled ash and carbon, is pumped to the gasifier from the slurry preparation section (Area 200), where a continuous, active recirculation is maintained to prevent solid-liquid separation.

The coal slurry and oxygen enter the gasifier through a specially designed burner. The burner is oriented downward from the top of the gasifier and is encased in a tempered water cooling coil. The gasifiers are refractory lined, vertical cylindrical vessels which can operate over a wide pressure range. At the burner tip, the coal undergoes partial combustion with oxygen at a pressure of 900 psig and a temperature in the range of 2300 to 2800°F. The gas consists mainly of carbon monoxide, hydrogen, carbon dioxide and steam with small amounts of methane, nitrogen, ammonia, argon, hydrogen sulfide, and carbonyl sulfide. The gas is essentially free of uncombined oxygen. Hydrogen sulfide and carbonyl sulfide constitute the principal gaseous impurities, and slag, ash, and char constitute the solid impurities.

The hot generator gas is cooled in a radiant heat boiler which produces saturated steam at 1500 psig. Molten slag and ash in the gas stream are solidified by the cooling action and quenched by settling through a water reservoir maintained at the bottom of the radiant heat boiler. The slag and quench water are collected in a lock hopper below the boiler and periodically discharged and externally separated. The slag reject stream is conveyed to the solids disposal area. The water, containing fine ash and unconverted carbon, is collected in a sump below the solids screen and pumped to the coal grinding unit (Area 100).

The generator gas from the radiant heat boiler enters a gas scrubber, where the gas is washed with water to remove unconverted carbon and ash fines. The solids-free gas leaves the gas scrubber saturated at a steam to gas ratio sufficient for the CO shift reaction.

The quench water from the gas scrubber, containing the unconverted carbon and ash fines, is cooled against cold recycle water and flashed to release dissolved acid gases. The flashed gas is cooled further and sent to the sulfur recovery unit (Area 700). The soot in the water is settled in a clarifier, concentrated, and recycled to the coal grinding section (Area 100). Clarified water is recycled for use in scrubbing and as lock hopper flush water. A portion of this water is withdrawn as blowdown to control the dissolved solids content in the circulating water system. This water is pumped to a waste water treatment unit designed by Texaco for this service.

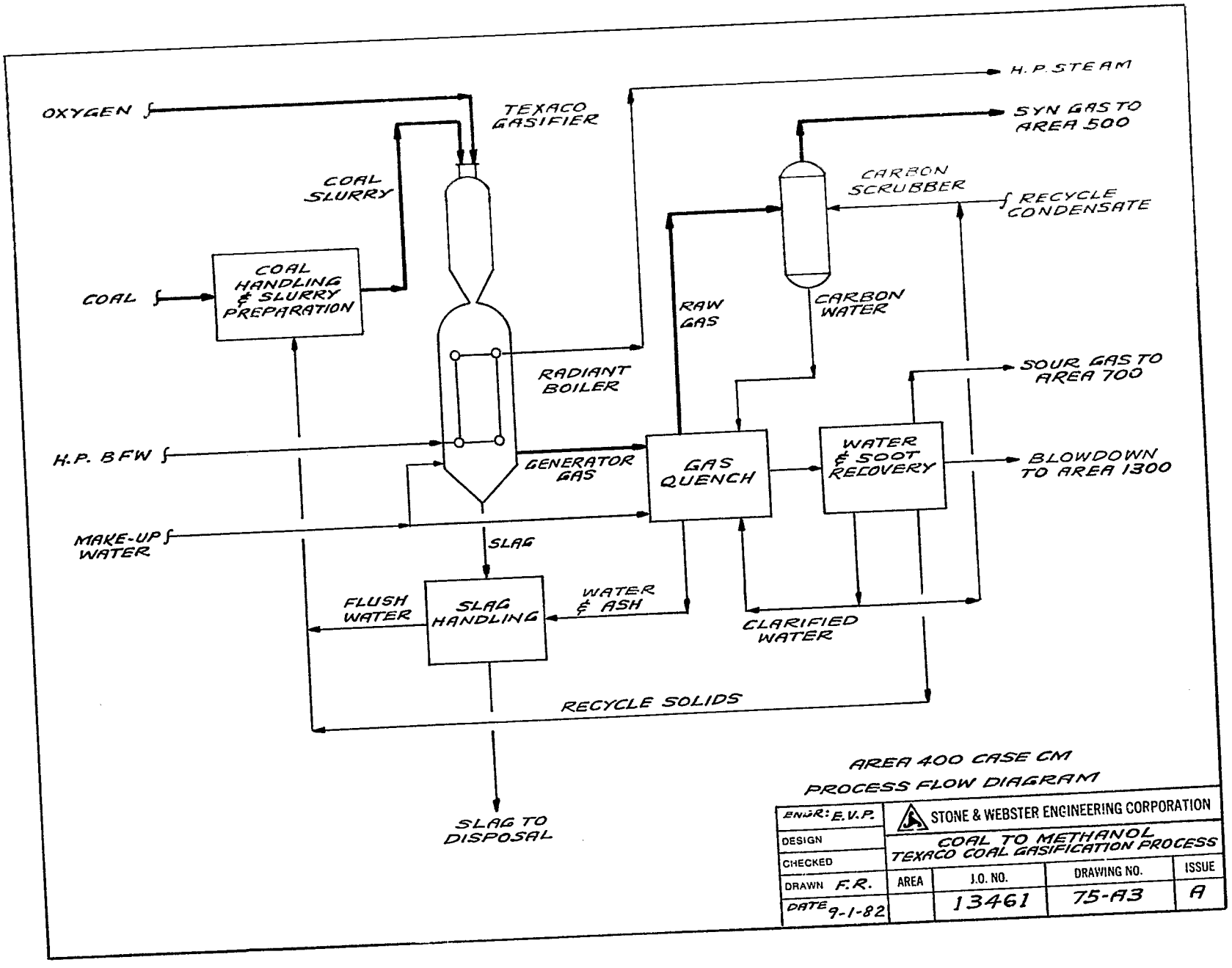

OXYGEN
TEXACO GASIFIER
H.P. STEAM
SYN GAS TO AREA 500
COAL SLURRY
CARBON SCRUBBER
RECYCLE CONDENSATE
COAL
COAL HANDLING & SLURRY PREPARATION
RAW GAS
CARBON WATER
RADIANT BOILER
SOUR GAS TO AREA 700
H.P. BFW
GENERATOR GAS
GAS QUENCH
WATER & SOOT RECOVERY
BLOWDOWN TO AREA 1300
MAKE-UP WATER
SLAG
FLUSH WATER
SLAG HANDLING
WATER & ASH
CLARIFIED WATER
RECYCLE SOLIDS
SLAG TO DISPOSAL
AREA 400 CASE CM
PROCESS FLOW DIAGRAM
ENGR: E.V.P.
DESIGN
CHECKED
DRAWN F.R.
DATE 9-1-82
STONE & WEBSTER ENGINEERING CORPORATION
COAL TO METHANOL
TEXACO COAL GASIFICATION PROCESS
AREA
J.O. NO. 13461
DRAWING NO. 75-A3
ISSUE A

Table 7-6

EQUIPMENT LIST
AREA 400 - GASIFICATION, QUENCH, AND SCRUBBING
CASE CM

Item No.	Description
G-401	Charge Section
G-402	Gasification and Heat Recovery
G-403	Gas Scrubbing Section
G-404	Water and Soot Recovery Section
G-405	Waste Water Treating Section

AREA 500 - CO SHIFT AND HEAT RECOVERY, CASE CM

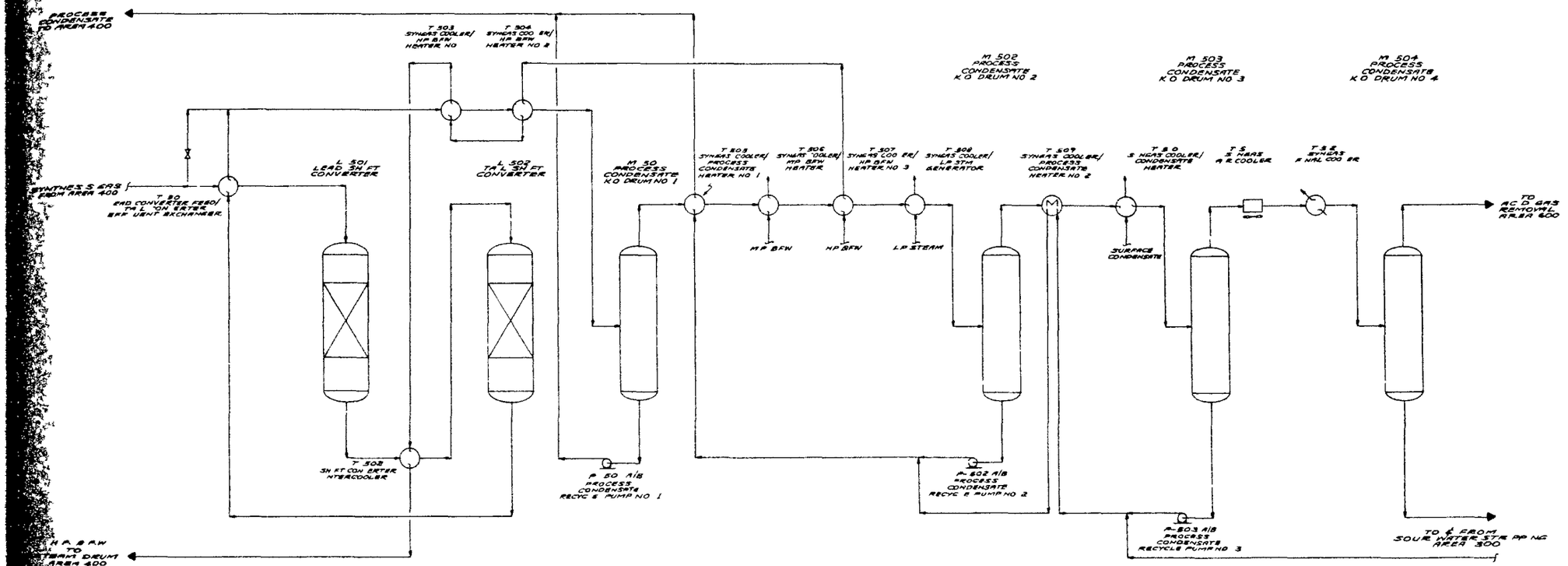
This area consists of the shift converters followed by a heat recovery train. The process flow diagram for this area is shown on drawing 75-D22. There are eight identical trains. The equipment list for CO Shift and Heat Recovery is shown in Table 7-7.

The washed gas from the Texaco gas scrubbers is fed to the shift converters at its dew point (463°F), which corresponds to a steam to dry gas mole ratio of 1.2:1. Approximately 60 percent of the feed gas stream is heated to 600°F in the feed/effluent exchanger and flows to the lead shift converter. The remaining feed gas bypasses the shift converters and combines with the shifted gas downstream in order to obtain the desired hydrogen to carbon monoxide ratio required for methanol synthesis.

In the shift reaction, carbon monoxide reacts with steam in the presence of a catalyst to form hydrogen and carbon dioxide. The converter is a conventional downflow type reactor using a sulfur tolerant cobalt-molybdenum catalyst. Due to the exothermic nature of the shift reaction, there is a temperature rise across the converter.

The effluent from the lead converter has a CO concentration of 16 mole percent. This stream is cooled from 829°F to 680°F against high pressure boiler feedwater before entering the tail shift converter. In the tail shift converter the CO concentration is reduced to 6 percent and the effluent gas temperature is raised to 786°F. The shifted gas is cooled against the feed gas and combined with the unshifted gas. The overall carbon monoxide conversion is controlled by the bypass process gas stream such that the hydrogen to carbon monoxide mole ratio is about 2.40:1 in the methanol synthesis gas. The total synthesis gas is cooled from a mix temperature of 550°F to 430°F by heat exchange with high pressure boiler feedwater and the condensate is recovered for recycle to the Texaco gasification section.

The gas is cooled further, in steps, to 350°F and then to 250°F. The heat recovered is used to reheat process condensate, preheat medium pressure boiler feed water, preheat high pressure boiler feedwater, generate 65 psig steam, and reheat high pressure condensate return water. The condensate recovered is reheated before recycle to the gasification section. The gas is finally cooled to 100°F by air and cooling water (T-512) before entering the acid gas removal section (Area 600). The condensate collected in the final knockout drum at 100°F is stripped with steam to remove ammonia from the system before it is recycled to Gasification, Quench and Scrubbing (Area 400).



NOTE ONE PROCESS TRA N SHOWN 4 ANT TRA NS REQU RED

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STONE & W EBSTER NG NEE RG CORPOR OR

L ENT ELECTRIC POWER RESEARCH INSTITUTE

TLE PROCESS FLOW D AGRAM
AREA 500
CO SH FT & SYNTHES S GAS COOL NG
COAL TO METHANOL
CASE CM

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CHECKED		APPROVE		CONST UCTION	
S J F		R R			

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13461	75 D22	0

Table 7-7

EQUIPMENT LIST
AREA 500 - CO SHIFT AND HEAT RECOVERY
CASE CM

Item No.	No. Req'd	Description
L-501	8	Lead Shift Converter
L-502	8	Tail Shift Converter
M-501	8	Process Condensate K.O. Drum No. 1
M-502	8	Process Condensate K.O. Drum No. 2
M-503	8	Process Condensate K.O. Drum No. 3
M-504	8	Process Condensate K.O. Drum No. 4
P-501	8 + 8	Process Condensate Recycle Pump No. 1
P-502	8 + 8	Process Condensate Recycle Pump No. 2
P-503	8 + 8	Process Condensate Recycle Pump No. 3
T-501	8	Lead Converter Feed/Tail Converter Effluent Exchanger
T-502	8	Shift Converter Intercooler
T-503	8	Syn Gas Cooler/HP BFW Heater No. 1
T-504	8	Syn Gas Cooler/HP BFW Heater No. 2
T-505	8	Syn Gas Cooler/Process Condensate Heater No. 1
T-506	8	Syn Gas Cooler/MP BFW Heater
T-507	8	Syn Gas Cooler/HP BFW Heater No. 3
T-508	8	Syn Gas Cooler/L.P. Steam Generator
T-509	8	Syn Gas Cooler/Process Condensate Heater No. 2
T-510	8	Syn Gas Cooler/Condensate Heater
T-511	8	Syn Gas Air Cooler
T-512	8	Syn Gas Final Cooler

AREA 600 - ACID GAS REMOVAL (RECTISOL), CASE CM

The Rectisol unit is a proprietary process offered by Lotepro Corporation.

Effluent gas from shift conversion enters the acid gas removal area and is cooled by heat exchange, with purified cold gas leaving the area, and by refrigeration. After separation and removal of condensed water, the cold feed gas enters the Rectisol unit, where H_2S, COS, and CO_2 impurities are removed by a multi-stage absorption process using methanol.

H_2S and COS are removed to a concentration of less than 1 ppm in a first-stage absorption step by contact with a cold, CO_2-rich methanol stream. CO_2 is subsequently removed to approximately 6 percent by contact with lean methanol in a second-stage absorption step.

The Rectisol process contains a two-stage solvent regeneration unit. The H_2S/COS-rich methanol solvent from the first stage of absorption is flashed to an intermediate pressure level to release co-absorbed hydrogen and carbon monoxide. These gases are recompressed and recycled to the feed and the flashed liquid is heated against lean methanol. The liquid is regenerated by reflashing to a first-stage stripper, where the acid gas components are stripped from the rich methanol solvent by reboiling with low pressure steam. The acid gas, rich in H_2S, is sent to the Claus unit (Area 700) for recovery of elemental sulfur. The lean methanol solvent is withdrawn, cooled, and pumped for use in the second-stage CO_2 absorption step. Water introduced into the solvent with the crude gas is bled from the system by withdrawing a water-rich solvent stream which is sent to the methanol distillation section in the methanol synthesis unit (Area 900).

Rich methanol solvent, leaving the second-stage absorber, is flashed to release absorbed hydrogen and carbon monoxide, which also are recycled to the feed. The solvent, after flashing again to low pressure to release part of the absorbed CO_2, enters a second-stage stripping operation, where the bulk of the CO_2 is removed by stripping with nitrogen. Vapors from stripping are combined with the low pressure flash vapors, cooled against the synthesis gas, and vented. The semi-lean methanol from stripping is pumped to the first stage absorption tower.

AREA 700 - SULFUR RECOVERY (CLAUS), CASE CM

The Claus unit is a proprietary design supplied by Amoco and others. This plant is designed to recover 768 st/sd of elemental sulfur from the sour gas streams. There are three identical 50 percent capacity trains (one spare). The feed gas consists of the sour gases from acid gas removal (Area 600), carbon and solids recovery (Area 400), sour water stripping (Area 400) and Texaco waste water treatment (Area 1300).

This sulfur recovery plant employs an improved version of the Claus process.

The process begins with the burning of one-third of the hydrogen sulfide to sulfur dioxide. Reaction of the sulfur dioxide in the combustion chamber with the remaining hydrogen sulfide produces elemental sulfur and water vapor. Heat is removed in a waste heat boiler and a sulfur condenser by generating useful steam; sulfur formed in the thermal reaction drains through a seal to the collection pit.

Gases from the condenser are then heated and pass to a catalytic converter, where sulfur-forming reactions continue. The catalytically produced sulfur is condensed and drained from the second condenser to the collection pit.

Gases from this second condenser are sufficiently reheated, usually in a line burner, to start the chemical reactions in a second catalytic converter. The reacted gases from this converter are also cooled to condense the additional sulfur produced for recovery.

Each condenser is fitted with a coalescer to collect fine droplets of liquid sulfur. Efficiency of the final coalescer is particularly critical. Exit gases from the coalescer are fed to Tail Gas Treating (Area 800) for a final clean-up before discharging to the atmosphere.

The molten sulfur product is kept warm in a molten sulfur pit and then converted to flakes for shipment.

AREA 800 - TAIL GAS TREATING (SCOT)

The Scot tail gas treating unit is a proprietary design offered by the Shell Oil Company.

Tail gas from the Claus plant, containing hydrogen sulfide, sulfur dioxide, carbonyl sulfide, carbon disulfide and free sulfur, is heated in an inline burner/mixer by burning fuel gas. A small amount of hydrogen- rich reducing gas is added to the mixer before the gas enters the reactor. In the reactor, almost all the sulfur compounds are catalytically converted to hydrogen sulfide. The hot gas from the reactor is cooled in a waste heat boiler, generating low pressure steam. The gases from the waste heat boiler are further cooled in a quench column by a recirculating water stream, which, in turn, is cooled by cooling water. Condensate from the gases is sent to the sour water stripper. The cooled gases flow to the amine absorber for removal of hydrogen sulfide and some of the carbon dioxide. This absorption system is specially designed for selective absorption of hydrogen sulfide to avoid overloading the Claus unit with carbon dioxide. The unabsorbed gases flow to the Claus incinerator for burning of the unabsorbed sulfides. The rich amine flows to a conventional stripper, where the hydrogen sulfide and carbon dioxide are stripped by steam generated in the reboiler. The stripped hydrogen sulfide and carbon dioxide are recycled to the Claus unit for recovery of the sulfur.

AREA 900 - METHANOL SYNTHESIS

The methanol synthesis area is based on designs licensed by Lurgi and includes methanol synthesis and distillation as shown on process flow diagram 75-D23. The equipment list is shown in Table 7-8.

Synthesis makeup gas from the acid gas removal unit (Area 600) is combined with recycled gas from the recycle gas compressor. The combined synthesis gas feed is split into two parallel streams and heated in the feed/effluent exchanger. The heated synthesis feed gas flows to the methanol synthesis reactor.

The methanol synthesis reactor system consists of two tubular type isothermal reactors with catalyst packed tubes and circulating shell side boiler feedwater for heat removal. The heat of reaction is removed by the generation of 550 psig steam in the reactor shell. The steam/boiler feedwater mixture leaving the reactor is separated in the medium pressure steam drum and flows to the 550 psig steam system. Boiler feedwater makeup is preheated in Area 500 against syn-gas cooling.

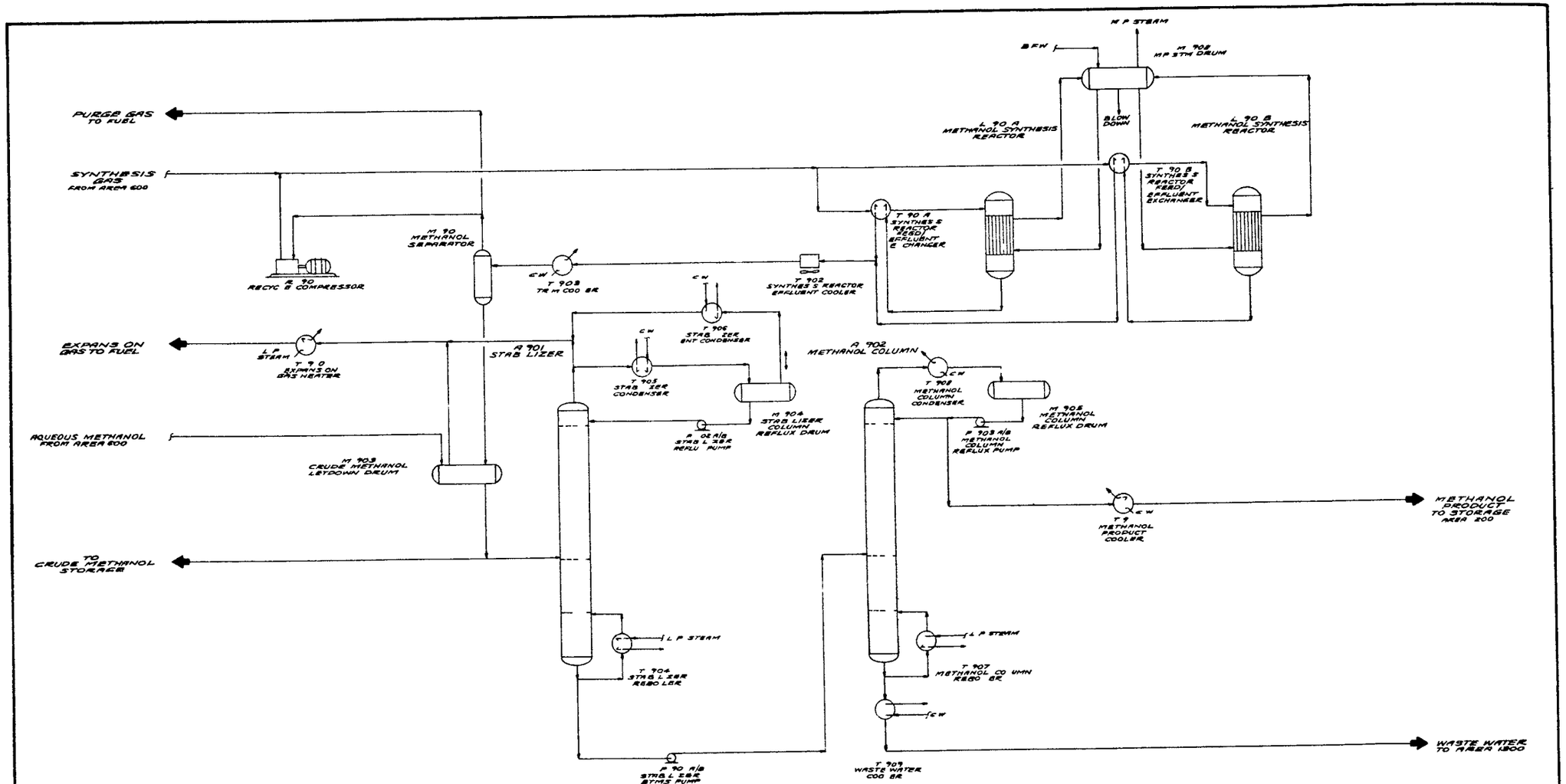
Reactor effluent heats the synthesis feed gas by exchange in the Synthesis Reactor Feed/Effluent Exchangers. A portion of the methanol is condensed in these exchangers. The reactor effluent streams then recombine and are cooled by air exchange in the Synthesis Reactor Effluent Cooler and by exchange with cooling water in the trim cooler.

The two-phase mixture from the trim cooler is separated and the gas from the separator splits into two streams. The bulk of the gas flows to the recycle gas compressor and the remaining gas is purged from the system to prevent the buildup of inerts within the synthesis loop. This purge gas is used for superheater fuel in Area 1000.

The crude methanol from the separator, containing water and dissolved inerts, flashes in a drum at relatively low pressure. The crude methanol from the drum flows to the stabilizer column.

In the stabilizer the low boiling compounds and any remaining dissolved gases are stripped from the crude methanol. The overhead vapors from the column are combined with the flash drum vapor and used for fuel. The bottoms from the stabilizer is pumped to the methanol column.

In the methanol column, water is removed by distillation to the required purity (97 mol percent). The methanol product is cooled and sent to storage (Area 1200). The waste water from the bottom of the column is sent to the reclaimed water system (Area 1300).



NOTE ONE PROCESS TRAIN SHOWN
3 X TRAINS REQUIRED

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TITLE PROCESS FLOW DIAGRAM
METHANOL UNIT
AREA 900
COAL TO METHANOL
CASE CM

JOB NUMBER	DRAWING NUMBER	ISSUE
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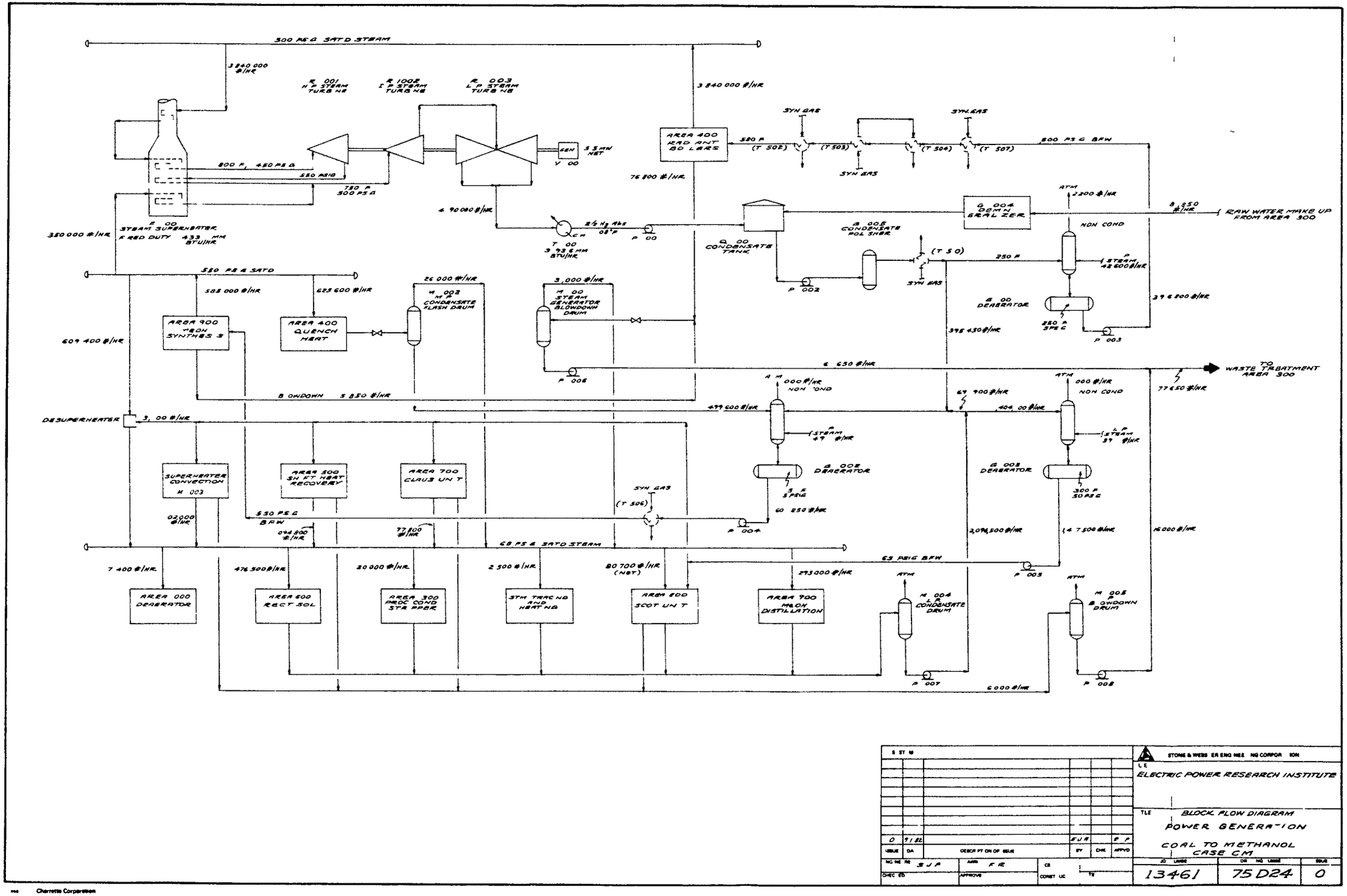
Table 7-8

EQUIPMENT LIST
AREA 900 - METHANOL SYNTHESIS
CASE CM

Item No.	No. Req'd	Description
A-901	12	Stabilizer
A-902	6	Methanol Column
L-901	12	Methanol Synthesis Reactor
M-901	6	Methanol Separator
M-902	6	M.P. Steam Drum
M-903	6	Crude Methanol Letdown Drum
M-904	6	Stabilizer Reflux Drum
M-905	6	Methanol Column Reflux Drum
P-901	6 + 6	Stabilizer Bottoms Pump
P-902	6 + 6	Stabilizer Reflux Pump
P-903	6 + 6	Methanol Column Reflux Pump
R-901	6	Recycle Compressor
T-901	6	Synthesis Reactor Feed/Effluent Exchanger
T-902	6	Synthesis Reactor Effluent Cooler
T-903	6	Trim Cooler
T-904	6	Stabilizer Reboiler
T-905	6	Stabilizer Condenser
T-906	6	Stabilizer Vent Condenser
T-907	6	Methanol Column Reboiler
T-908	6	Methanol Column Condenser
T-909	6	Waste Water Cooler
T-910	6	Expansion Gas Heater
T-911	6	Methanol Product Cooler



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TLE BLOCK FLOW DIAGRAM
POWER GENERATION
COAL TO METHANOL
CASE CM

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13461	75 D24	0

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Table 7-9

EQUIPMENT LIST
AREA 1000 - POWER GENERATION
CASE CM

Item No.	No. Req'd	Description
B-1001	1	Start-up High Pressure Steam Boiler
F-1001	8	Steam Superheater Furnace and Auxiliaries Package
		F-1001-F-1 Steam Superheater Furnace
		F-1001-R-1 Flue Gas Fan
G-1001	2	High Pressure Condensate Deaerator
G-1002	1	Medium Pressure Condensate Deaerator
G-1003	1	Low Pressure Condensate Deaerator
G-1004	1	Makeup BFW Demineralizer
G-1005	2	Condensate Polisher
M-1001	1	Steam Generator Blowdown Drum
M-1002	1	Medium Pressure Condensate Flash Drum
M-1003	4	Low Pressure Steam Drum
M-1004	4	Low Pressure Condensate Flash Drum
M-1005	1	Low Pressure Steam Generator Blowdown Drum
P-1001	6	Power Generation Turbine Surface Condensate Pump
P-1002	4	Condensate Return Pump

Table 7-9 (cont'd)

Area 1000 - Power Generation (cont'd)

Item No.	No. Req'd	Description
P-1003	4	High Pressure BFW Pump
P-1004	2	Medium Pressure BFW Pump
P-1005	2	Low Pressure BFW Pump
P-1006	2	Steam Generator Blowdown Pump
P-1007	4	Low Pressure Condensate Return Pump
P-1008	2	Low Pressure Steam Generator Blowdown Pump
Q-1001	2	Condensate Collection Tank
R-1001	4	High Pressure Steam Power Generation Turbine
R-1002	4	Medium Pressure Steam Power Generation Turbine
R-1003	4	Low Pressure Steam Power Generation Turbine
T-1001	4	Power Generation Turbine Surface Condenser
V-1001	2	Power Generator

AREA 1100 - COOLING WATER SYSTEM

The cooling water system provides cooling water for process heat rejection, condensation of steam from turbines and cooling of mechanical equipment.

The system is based on an overdesign factor of 10 percent, a wet bulb temperature of 75°F and a dry bulb temperature of 88°F. The cooling water circulation rate to the process is 325,500 GPM at 85°F. The circulation rate to the power plant is 505,800 GPM at 85°F. The average return temperature of this total circulation of 831,300 GPM is 103.6°F. An induced draft, cross-flow cooling tower is employed.

Makeup water to the cooling tower includes clarified and filtered river water, reclaimed waste water and treated water from the Texaco waste water treatment system. Cooling tower blowdown is sent to the reclaimed waste water treatment system.

AREA 1200 - TANK STORAGE

Complete storage facilities are tabulated in the equipment list, Table 7-10. Floating roof tanks are provided for product methanol storage. The capacities of the larger storage tanks and their corresponding operating periods are indicated below:

	BBLS	Operation Period, Days
Methanol Product	2,400,000	20
Raw Methanol	120,000	1
Caustic (concentrated)	15,000	100
Process Water Blowdown	15,000	3

Emergency storage for liquid oxygen and gaseous nitrogen is provided. Liquid oxygen is stored in a sphere which holds 5000 tons of oxygen, which is equivalent to two days' production of one 2400 st/sd oxygen plant. Three 3,000,000 SCF storage tanks hold a supply of gaseous nitrogen at 200 psig.

Table 7-10

EQUIPMENT LIST
AREA 1200 - TANK STORAGE
CASE CM

Item No.	No. Req'd	Description
G-1201	2	Refrigeration Equipment
P-1201	9	Methanol Product Transfer Pump
P-1202	2	Raw Methanol Recycle Pump
P-1203	2	Process Water Pump
P-1204	2	Caustic Transfer Pump
P-1205	2	DIPA Makeup Pump
Q-1201	6	Methanol Product Tank
Q-1202	2	Raw Methanol Storage Tank
Q-1203	1	Process Water Blowdown Storage Tank
Q-1204	1	DIPA Storage Tank
Q-1205	2	Refrigerant Storage Bullets
Q-1207	1	Oxygen Storage Sphere
Q-1208	1	Caustic Storage Tank
Q-1209	3	Nitrogen Storage Tank

AREA 1300 - WATER MANAGEMENT

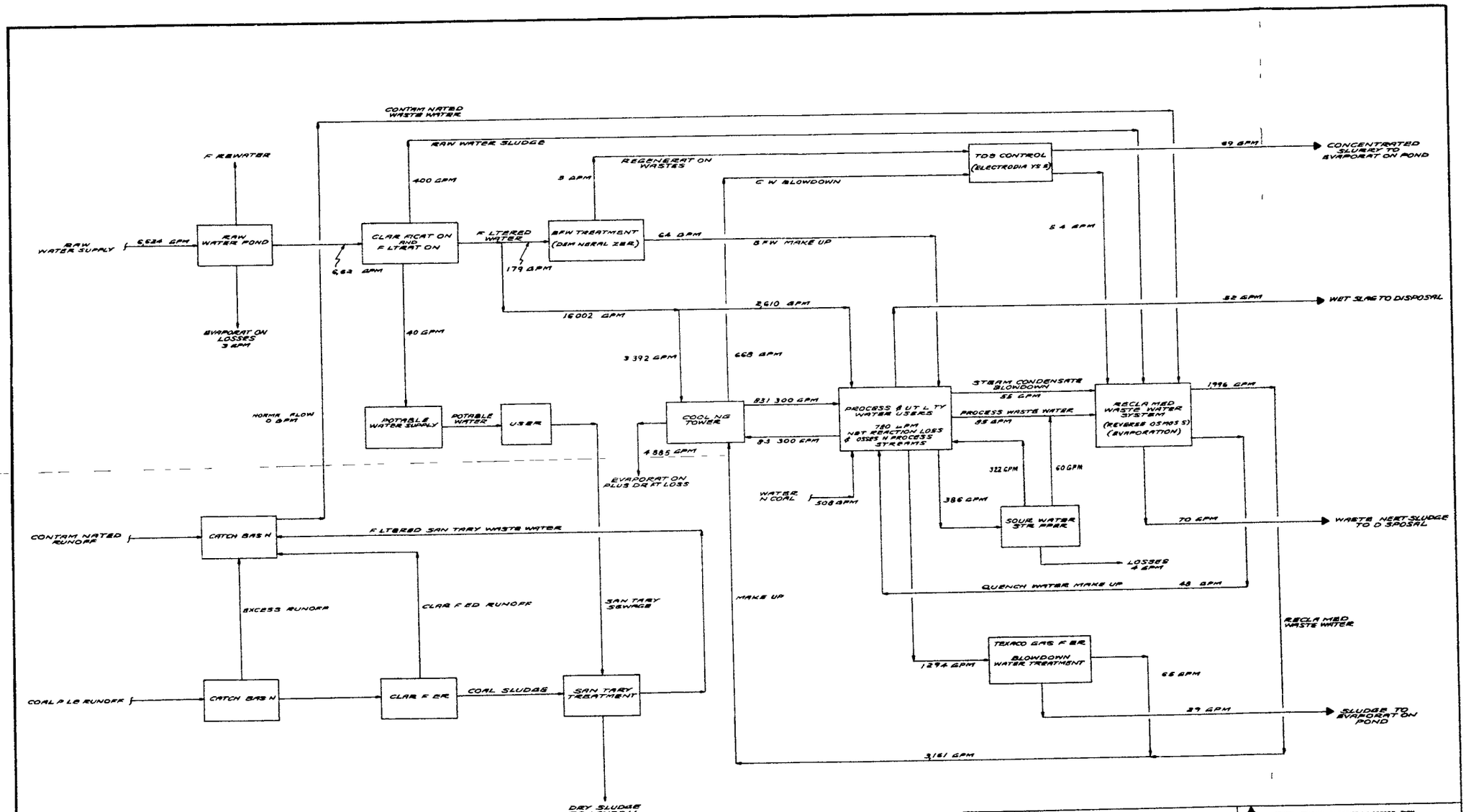
The plant water management and waste water treatment systems are shown in Drawing 75-D25. These systems include the following components:

- Raw water holding pond, clarification and filtration.
- Potable water distribution system.
- Boiler feedwater treatment and electrodialysis for total dissolved solids control.
- Reclaimed waste water treatment system for cooling tower makeup water and return of water to process.
- Texaco (proprietary) gasifier blowdown water treatment.
- Runoff collection and sanitary water treatment.

Waste water reclamations facilities are provided for maximum reuse of water. These facilities include waste volume reduction by reverse osmosis followed by evaporation and condensation of the water vapor for reuse. The concentrate (reject) is discharged to landfill.

The overall water balance is summarized as follows:

Input	GPM
Raw water makeup	16,624
Water in coal	508
Total	17,132
Output	
Cooling tower losses	14,885
Process water consumption and process and utility losses	1,780
Water losses in solids disposal and in evaporation from sludge	420
Potable water	40
Miscellaneous losses	7
Total	17,132



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TITLE BLOCK FLOW DIAGRAM

WATER SYSTEM COAL TO METHANOL

CASE CM

JOB NUMBER	DRAWING NUMBER	ISSUE
13461	75 D25	0

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AREA 1400 - FLARE SYSTEM

The Flare System includes the flare header system and disposal facilities for flammable and noxious gases vented during normal and emergency plant operations. The system is designed to protect the process equipment from overpressure in conformance with accepted practice.

It is assumed that a dual relief system is provided which includes one system for high pressure and one system for low pressure relief. Relief lines carry process gases from the processing areas to the elevated flare stacks, where ignition occurs in case of release. Separator drums are provided at the base of each stack to separate liquids, which are pumped to slops storage. Molecular seals are provided in each stack to prevent air intrusion in the relief system.

AREA 1500 - BUILDINGS

The list of buildings is similar to that provided for H-Coal and includes administration, change house and cafeteria, clock house, fire station with first aid, guard house, laboratory, maintenance and fabrication shops with cranes, warehouse, and miscellaneous auxiliary buildings for chemical storage, switchgear, garage, etc.

Buildings are equipped with facilities consistent with the services rendered, including offices, reception and conference rooms, library, lavatory, heating and air conditioning, stock rooms and storage areas.

AREA 1600 - COMMON FACILITIES

A list of common facilities included in this study is given below:

Facility	Description
Interconnecting Piping	All major process and utility lines carried on overhead pipeways.
Electrical Systems Distribution	138 kV switchyard with lines to transformers, sub-stations and motor control centers. Motors are rated for 13,200 V, 4,000 V, 460 V and 120 V.
Site Preparation	Clear and graded site, 8,000 ft by 5,500 ft (1000 acres).
Roads and Parking Areas	Constructed with 3" asphaltic concrete and 6" cement treated base.
Curb, Ditch and Gutters	100,000 lineal ft allowed.
Culverts	2,000 lineal ft, average 36" diameter.
Railroad Siding	40,000 lineal ft including ballast, wood ties, turnouts and switches.

Facility	Description
Site Fence	27,000 lineal ft, 8 ft high.
Fire Protection Equipment	Fire equipment vehicles, fire truck, ancillary facilities.

In addition to the above, a cost allowance is included for other facilities common to the plant, which include:

Mobile equipment (other than fire trucks)
Spare parts
Landfill
Steam and condensate system
Instrument and plant air distribution
Inert gas distribution
Fire water distribution