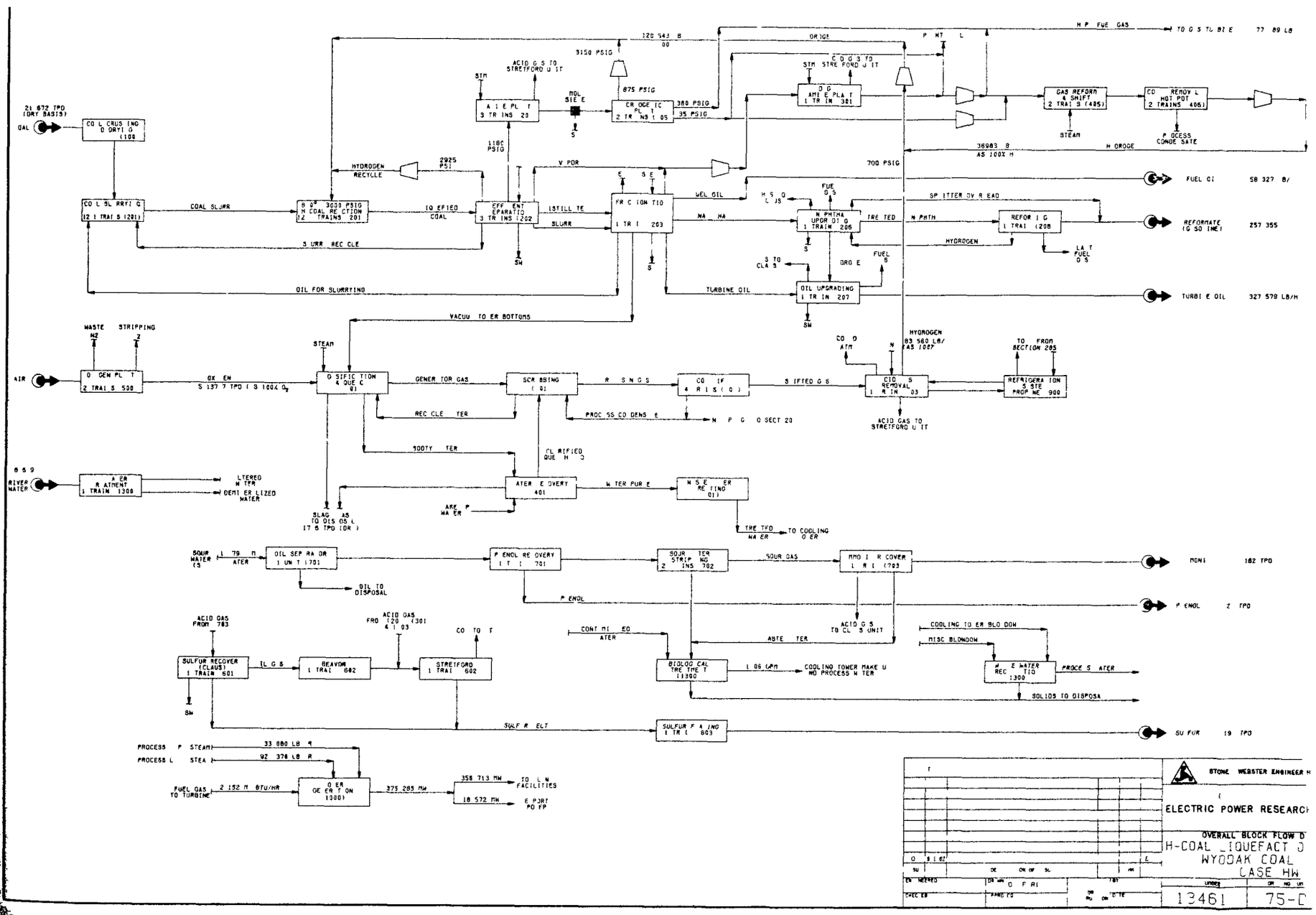
Table 6-1

LIST OF PROCESSING UNITS
CASE HW - WYODAK COAL

Unit	Section	Description	Number of Trains
100	100	Coal Preparation	
200	-	H-Coal Liquefaction	
	201	Coal Slurrying & H-Coal Reaction	12 + 1 Spare
	202	Effluent Separation	3
	203	Fractionation	1
	204	Amine Plant	3
	205	Cryogenic Plant	2
	206	Naphtha Hydrotreater	1
	207	Turbine Oil Hydrotreater	1
	208	Reformer	1
300	-	Light Ends Processing	
	301	DGA Amine Plant	1
400	-	Hydrogen Plant	
	401	Gasification (Texaco)	
	402	CO Shift	4
	403	Acid Gas Removal	1
	405	Gas Reform & Shift	2
	406	CO_2 Removal (K_2CO_3)	2
500	500	Oxygen Plant	2
600	-	Emission Control	
	601	Sulfur Recovery (Claus)	1
	602	Sulfur Recovery (Beavon-Stretford)	1
	603	Sulfur Flaking	1
700	-	Effluent Control	
	701	Phenol Recovery	1
	702	Sour Water Stripping	2
	703	Ammonia Recovery (PHOSAM)	1
800		Tank Storage	
900		Refrigeration	2
1000		Power Generation	
1100		Cooling Water System	
1200		Utility and Steam Summary	
1300		Water Management	
1400		Flare System	
1500		Buildings	
1600		Common Facilities	


21 872 TPD (DRY BASIS)
COAL
COAL CRUSHING & DRYING (108)
COAL SLURRYING (201)
COAL SLURRY
SLURRY RECYCLE
SLURRY PREPARATION & FEEDING (2 TRAINS 201)
IG EFIED COAL
EFFERVESCENT SEPARATION (3 TRAINS 202)
STILLBOTTOMS SLURRY
SW
FRACTIONATION (1 TRAIN 203)
HYDROGEN RECYCLE
2925 PSI
VAPOR
1180 PSIG
3150 PSIG
875 PSIG
380 PSIG
35 PSIG
ACID GAS TO STRETFORD UNIT
STM
AMINE PLANT (3 TRAINS 201)
MDEA SOLVENT
CRYOGENIC PLANT (2 TRAINS 205)
CO2 TO STRETFORD UNIT
GAS REFORMING & SHIFT (2 TRAINS 405)
STEAM
CO2 REMOVAL HOT POT (2 TRAINS 406)
PROCESS CONDENSATE
HYDROGEN
700 PSIG
FUEL OIL
58 327 B/
WELL OILS
H2S TO CLAUS
FUEL GAS
NAPHTHA UPGRADING (1 TRAIN 206)
SPLITTER OVERHEAD
NAPHTHA
REFORMATE (GASOLINE)
257 355
REFORMING (1 TRAIN 208)
HYDROGEN
LIGHT FUEL GAS
BROTH
FUEL GAS
OIL FOR SLURRYING
TURBINE OIL
OIL UPGRADING (1 TRAIN 207)
TURBINE OIL
327 578 LB/H
VACUUM TOWER BOTTOMS
WASTE N2
STRIPPING N2
STEAM
AIR
OXYGEN PLANT (2 TRAINS 530)
OXYGEN 5 137 7 TPD (95 1004 O2)
GASIFICATION & QUENCH (6)
GENERATOR GAS
SCRUBBING (101)
RAW GAS
CO SHIFT (4 RIGS (10))
SHIFTED GAS
CO2 REMOVAL (1 TRAIN 103)
CO2
HYDROGEN 83 560 LB/H PAS 1007
TO FROM SECTION 205
REFRIGERATION SYSTEM PROPANE 900
ACID GAS TO STRETFORD UNIT
RECYCLE WATER
PROCESS CONDENSATE
TO FROM SECTION 205
RIVER WATER
RAW WATER TREATMENT (1 TRAIN 1300)
FILTERED WATER
DEMINERALIZED WATER
WATER RECOVERY (401)
MAKEUP WATER
WATER PURGE
WASTE WATER TREATING (01)
SLAG TO DISPOSAL 17 6 TPD (DRY)
TREATED WATER
TO COOLING TOWER
SOUR WATER (S)
OIL SEPARATOR (1 UNIT (701)
OIL TO DISPOSAL
PHENOL RECOVERY (1 TRAIN 701)
SOUR WATER STRIPPING (2 TRAINS 702)
SOUR GAS
AMMONIA RECOVERY (1 TRAIN 703)
AMMONIA
162 TPD
PHENOL
2 TPD
ACID GAS FROM 703
ACID GAS FROM (20 1301)
CO TO STRETFORD
SULFUR RECOVERY (CLAUS) (1 TRAIN 601)
TAIL GAS
BEAVON (1 TRAIN 602)
STRETFORD (1 TRAIN 602)
SULFUR
SULFUR PACKING (1 TRAIN 603)
SULFUR
19 TPD
CONTAMINATED WATER
ACID GAS TO CLAUS UNIT
STRIPPER WATER
BIOLOGICAL TREATMENT (1300)
COOLING TOWER MAKEUP AND PROCESS WATER
COOLING TOWER BLOWDOWN
MISC BLOWDOWN
WATER RECYCLE (1300)
PROCESS WATER
SOLIDS TO DISPOSAL
PROCESS STEAM
33 880 LB/H
PROCESS STEAM
92 376 LB/H
FUEL GAS TO TURBINE
2 152 M BTU/HR
POWER GENERATION (1300)
375 285 MW
358 713 MW
TO FROM FACILITIES
16 572 MW
EXPORT POWER
STONE & WEBSTER ENGINEERING
ELECTRIC POWER RESEARCH
OVERALL BLOCK FLOW D
H-COAL LIQUEFACTION
WYODAK COAL
CASE HW
13461
75-C

UNIT 100 - COAL PREPARATION

Process Description - Case HW

The coal preparation unit for the Wyodak case is similar to the Illinois case except that coal is delivered from the mine by conveyor instead of by rail, and that pre-drying is necessary because of the high moisture content in the coal.

The coal is processed in the following flow quantities:

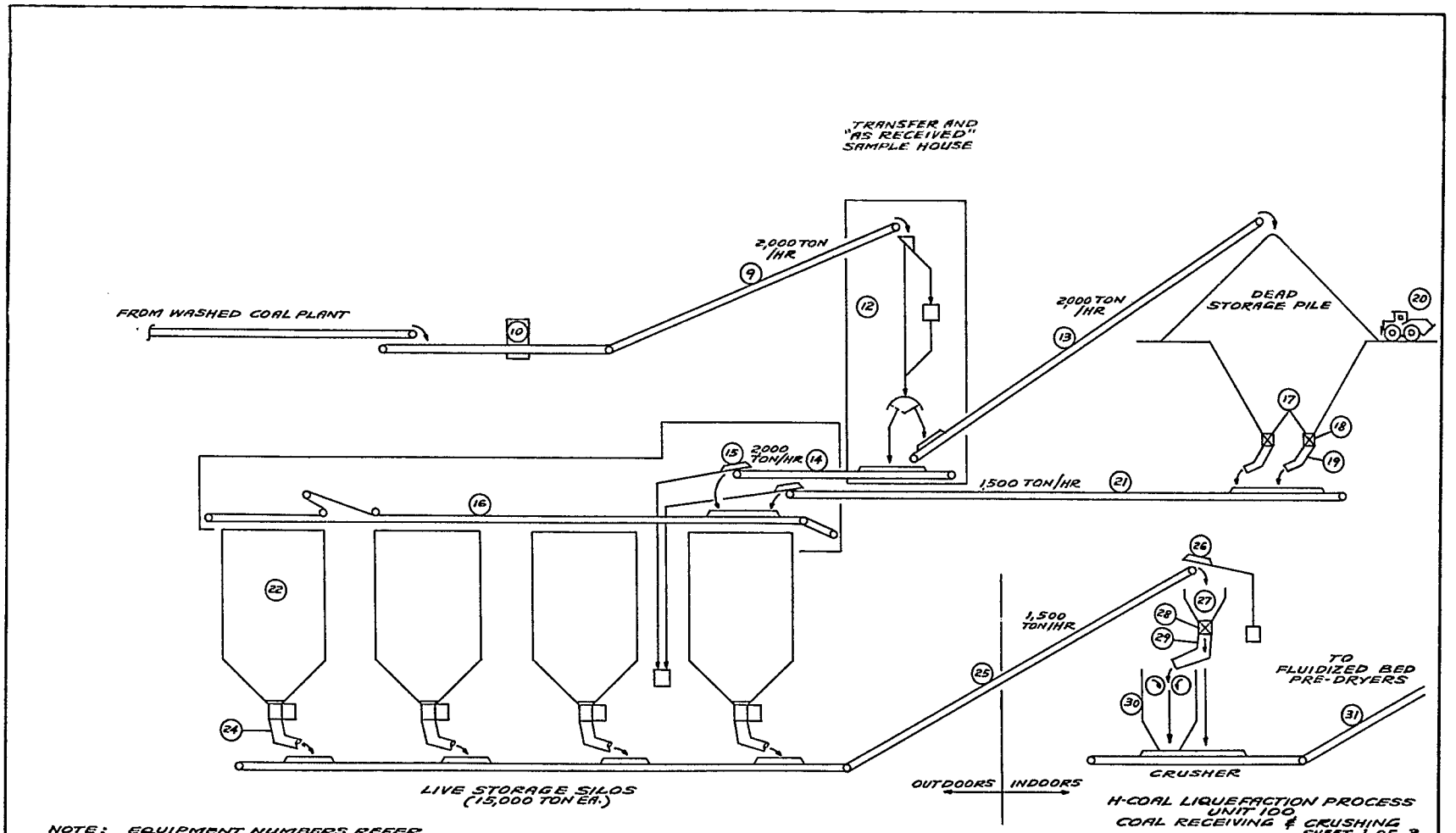
	Wyodak Coal st/sd
Coal as received (30% moisture)	30,960
Coal to reactor (approx. 2% moisture)	22,109
Coal, moisture free	21,672

An analysis of the Wyodak coal is shown in Section 3, Table 3-3. Process flow diagrams 75B-3, 75B-4, and 75B-5 show the schematic arrangements of the equipment. The equipment list is shown in Table 6-2 and the material summary is shown in Table 6-3.

After coal crushing and grinding, minus one-half inch coal particles, containing 30 percent moisture, are conveyed to five fluidized bed dryers where heated air at 900°F dries the coal to approximately 13 percent moisture. The coal pre-dryers use the process furnace flue gases and low pressure fuel gas from the cryogenic unit as the heat sources.

The pre-dried coal is conveyed and stored in five pairs of wet coal storage silos and then fed to the pulverizer-drying mills to reduce the particle size to minus 20 mesh and the moisture content to 2 percent. The heat for coal drying in the pulverizer-drying mills is supplied by the hot flue gas from the pre-dryers and supplemented by fuel gas burning, if required.

The additional pre-drying of the Wyodak coal adds approximately 40,000 kW of electricity and 660 x 10^6 Btu/hr of net heat to the energy requirements for coal preparation. This results in a significant reduction in thermal efficiency for the H-Coal process when using Wyodak coal.



NOTE: EQUIPMENT NUMBERS REFER TO EQUIPMENT LIST.

H-COAL LIQUEFACTION PROCESS
UNIT 100
COAL RECEIVING & CRUSHING
SHEET 1 OF 3

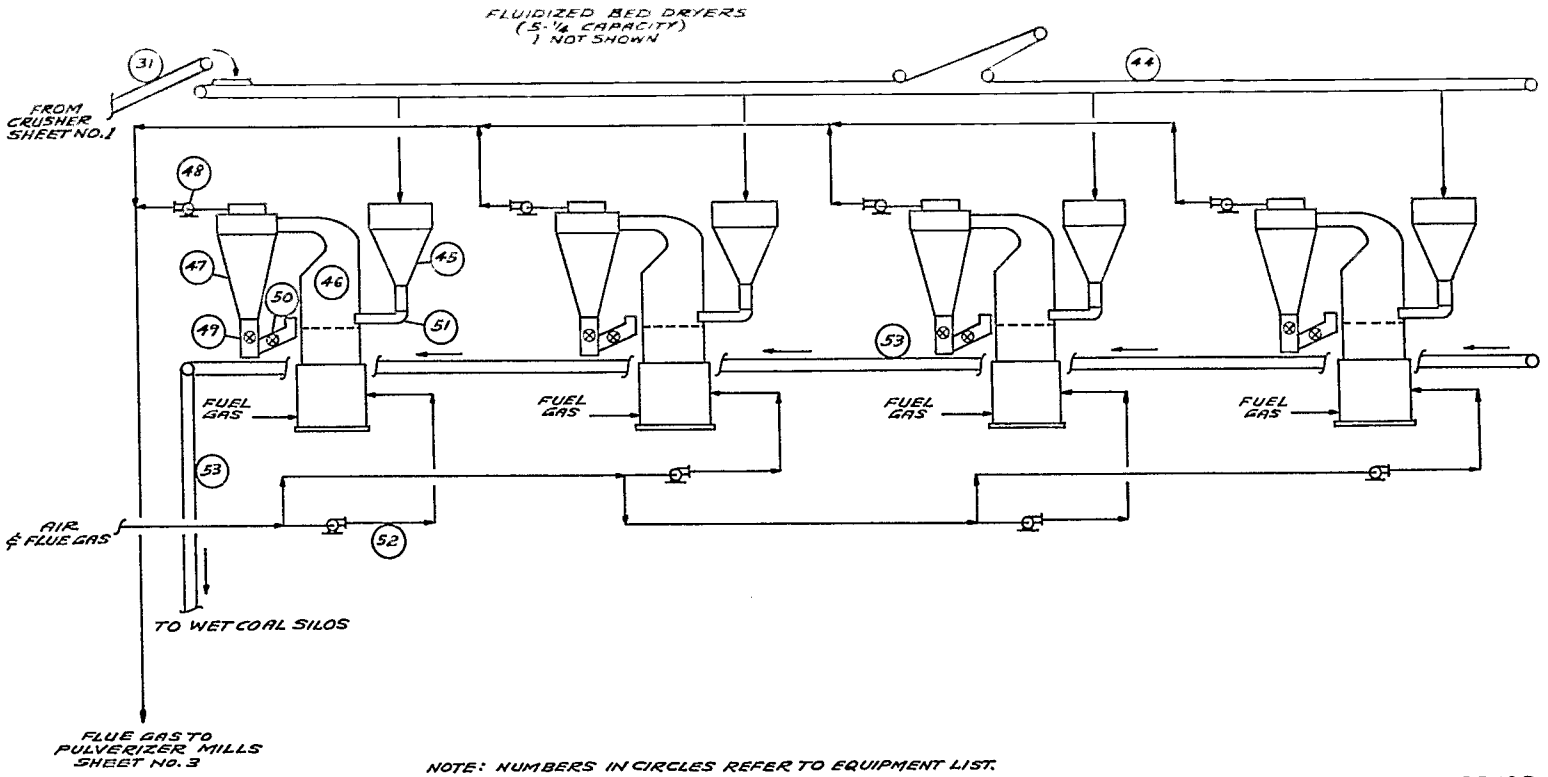
NO	REVISION DESCRIPTION	BY	DATE
B		E.V.P.	11-4-81
A		E.K.P.	1-13-81

CERT FOR FAB | CERT FOR CONST | APPROVED

ENGR: E.V.P.
DESIGN
DATE: 1-23-81
DRAWN F.M.
CHECKED

STONE & WEBSTER ENGINEERING CORPORATION
ELECTRIC POWER RESEARCH INSTITUTE
WYODAK COAL FEED

AREA	J.O. NO	DRAWING NO.	ISSUE
	13461	75-B3	B



NOTE: NUMBERS IN CIRCLES REFER TO EQUIPMENT LIST.

H-COAL LIQUEFACTION PROCESS
UNIT 100
COAL DRYING AND GRINDING
SHEET 2 OF 3

NO	REVISION DESCRIPTION	BY	DATE
A			
	CERT FOR FAB / CERT FOR CONST / APPROVED		

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DESIGN
DATE 3-19-81
DRAWN F.R.
CHECKED

STONE & WEBSTER ENGINEERING CORPORATION
ELECTRIC POWER RESEARCH INSTITUTE
WYODAK COAL FEED

AREA	J.O. NO.	DRAWING NO.	ISSUE
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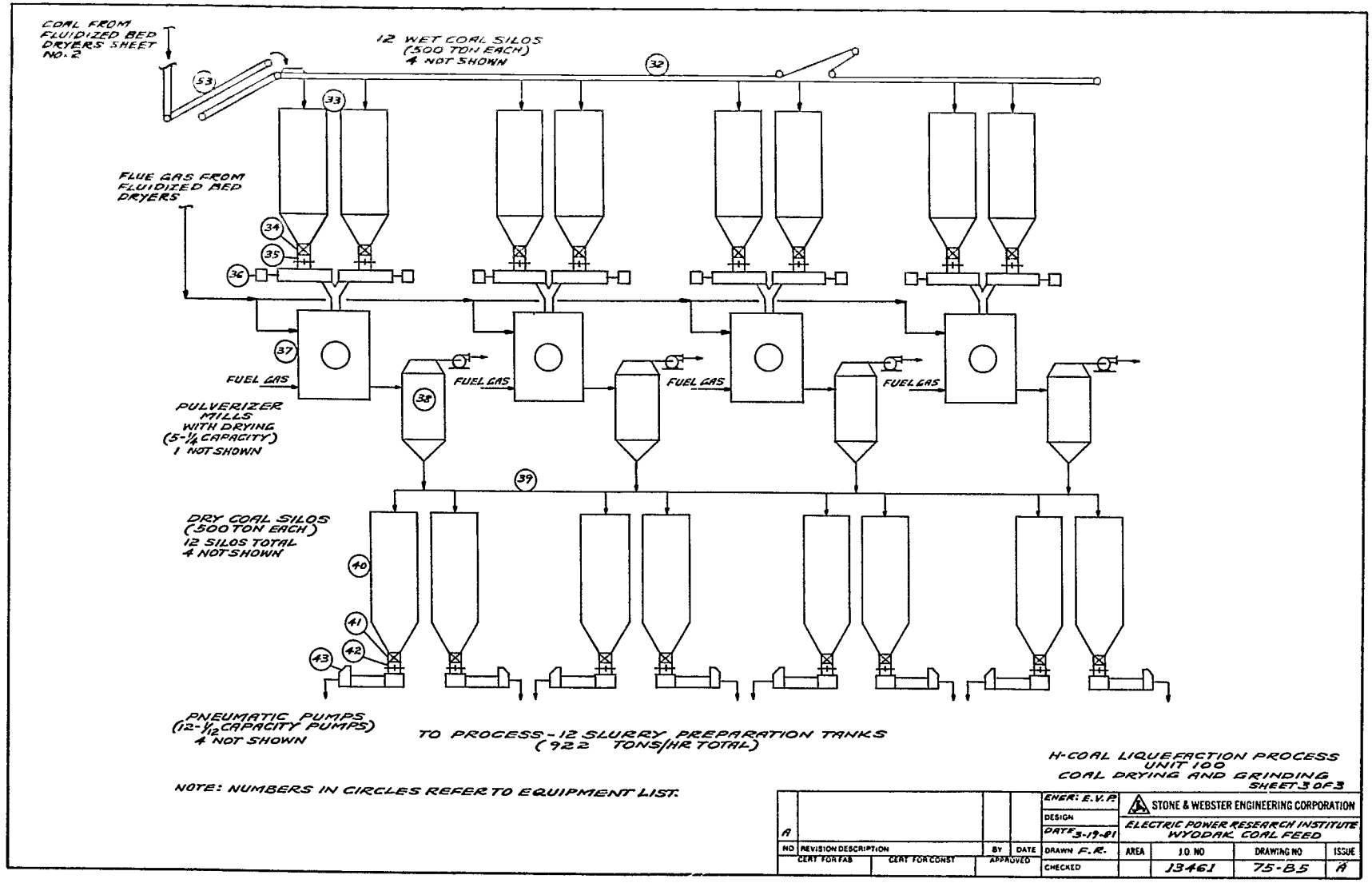

NOTE: NUMBERS IN CIRCLES REFER TO EQUIPMENT LIST.

H-COAL LIQUEFACTION PROCESS
UNIT 100
COAL DRYING AND GRINDING
SHEET 3 OF 3

NO	REVISION DESCRIPTION	BY	DATE
A	CERT FOR FAB / CERT FOR CONST	APPROVED	

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WYODAK COAL FEED

AREA	J.O. NO	DRAWING NO	ISSUE
	13461	75-B5	A

Table 6-2

EQUIPMENT LIST
UNIT 100 - COAL PREPARATION
CASE HW

Item No.	No. Req'd.	Description	Specification	Flowsheet Ref. No.
		Coal Delivery		
100W-109	1	Belt Conveyor with Gallery	48 inch width, 35° idlers, 700 ft/min, 2000 ton/hr capacity.	9
100W-110	1	Belt Scale	Mechanical or electronic.	10
100W-112	1	Transfer and Sample House	Includes sample system & flop gate.	12
100W-113	1	Stack Conveyor	48 inch width, 35° idlers, 700 ft/min to dead storage, 2000 ton/hr capacity.	13
100W-114	1	Belt Conveyor	48 inch width, 35° idlers, 700 ft/min to live storage, 2000 ton/hr capacity.	14
100W-115	2	Magnetic Separators	Self-cleaning.	15
100W-116	1 + 1	Tripper Conveyor	54 inch width, 600 ft/min, 35° idlers, 2000 tons/hr capacity. Includes gallery and transfer house	16
100W-117	1	Dead Storage Hopper	15 foot width x 30 foot length, two 15 foot cones each 50 ton capacity.	17
100W-118	2	Rack and Pinion Gates	48 inch, motor operated	18
100W-119	2	Vibrating Feeders	750 tons/hr capacity each.	19

Table 6-2 (cont'd)

Item No.	No. Req'd.	Description	Specification	Flowsheet Ref. No.
100W-120	1	Bulldozer		20
100W-121	1	Belt Conveyor with Gallery	48 inch width, 500 ft/min, 1500 ton/hr capacity 35° idlers, to live storage.	21
		Live Storage To Fluidized Bed Dryers		
100W-122	4	Concrete Storage Silos	15,000 tons each, 70 foot diameter by 200 feet tall, concrete construction.	22
100W-124	4	Rotary Plow Feeders	750 tons/hr	24
100W-125	1 + 1	Belt Conveyor with Gallery	48 inch width, 35° idlers, 500 ft/min, 1500 ton/hr capacity.	25
100W-126	1 + 1	Magnetic Separator	Self-cleaning.	26
100W-127	1 + 1	Crusher Surge Bin	5 ton capacity.	27
100W-128	1 + 1	Rack and Pinion Gate	24 inch, motor operated.	28
100W-129	2 + 1	Vibrating Feeder	With ½ inch hole grating, approximately 500 tons/hr.	29
100W-130	2 + 1	Coal Crusher	Approximately 500 tons/hr capacity, ½ inch end product, with chutes to belt conveyor.	30
100W-131	1 + 1	Belt Conveyor with Gallery	1500 tons/hr capacity, 35° idlers, 48 inch width, 500 ft/min.	31
100W-144	1 + 1	Tripper Conveyor with Housing	1500 tons/hr, 400 ft/min, 48 inch width, 35° idlers.	44

Table 6-2 (cont'd)

Item No.	No. Req'd.	Description	Specification	Flowsheet Ref. No.
		Fluidized Bed Dryers		
100W-145*	5	Dryer Surge Bin	300 ton capacity	45
100W-146*	5	Fluidized Bed Pre-Dryers	325 tons/hr capacity 10 feet x 10 feet x 22 feet, Dry from 30% to 13% wt. moisture	46
100W-147*	10	Cyclone Separators		47
100W-148*	10	Dryer Exhaust Fans	190,000 SCFM capacity	48
100W-149*	10	Rotary Valves	Motor operated	49
100W-150*	5	Rotary Valves	Motor operated	50
100W-151*	5	Coal Feeders	Vibrating feeder with feed regulator	51
100W-152*	10	Dryer Inlet Fans	170,000 SCFM capacity	52
100W-153	1 + 1	Belt Conveyor with Gallery	1500 tons/hr capacity, 48 inch width, 35° idlers, 500 ft/min.	53
		Wet Storage to Dry Storage		
100W-132	1 + 1	Tripper Conveyor with Transfer House	1500 tons/hr, 400+ ft/min, 35° idlers, 54 inch width.	32
100W-133	12	Wet Storage Silos	500 ton capacity, 24 foot diameter x 50 feet tall, located above mills, with cone bottom.	33

* Package of Fluidized Bed Dryer

Table 6-2 (cont'd)

Item No.	No. Req'd.	Description	Specification	Flowsheet Ref. No.
100W-134	12	Rack and Pinion Gates	48 inch, motor operated	34
100W-135	12	Flow Indicators	Flow/no flow indicators.	35
100W-136	12	Volumetric Feeders	150 tons/hr capacity	36
100W-137	5	Pulverizer Mills	350 tons/hr capacity, minus 20 mesh end product, with drying.	37
100W-138	5	Cyclone Separators	350 tons/hr capacity, with bag filters and exhaust fans, piping.	38
100W-139	3 + 1	Pneumatic Conveyor	To dry storage silos, approximately 350 tons/hr each, with compressors.	39
		Dry Storage		
100W-140	12	Dry Storage Silos	500 tons capacity, 24 foot diameter by 50 foot, double cone hopper.	40
100W-141	12	Rack and Pinion Gates	48 inch, motor operated	41
100W-142	12	Flow Indicators	Flow/no flow indicators.	42
100W-143	12	Pneumatic Pumps	Fuller Kinyon pumps with compressors, 200 ton/hr capacity max, with piping.	43

Note: Fifteen percent 304L, cladding of carbon steel (ASTM 264) is used as the material of construction for hoppers, feeders, silos, bins, gates, etc.

Table 6-3

MATERIAL SUMMARY - UNIT 100
COAL PREPARATION - CASE HW

Input		
Coal, Wyodak (as received) lb/hr		2,580,000
- Moisture content, weight percent		30
Output		
Coal to Reactor (2% moisture)	lb/hr	1,842,414
Water vapor discharge	lb/hr	737,586

UNIT 200 - COAL LIQUEFACTION

Process Description - Case HW

The H-Coal liquefaction plant for the Wyodak case is similar to the Illinois case and includes the same eight sections:

Reaction and Separation Sections

Section 201 - Coal Slurrying and H-Coal Reaction

Section 202 - Effluent Separation

Section 203 - Fractionation

Section 204 - Amine Plant

Section 205 - Cryogenic Plant

Product Hydrotreating and Reforming Sections

Section 206 - Naphtha Upgrading

Section 207 - Oil Upgrading

Section 208 - Reforming

The Reaction and Separation Sections for the Wyodak case are shown on the process flow diagrams, drawings 75-D7 and 75-D8. Equipment lists and process equipment specifications on major items of equipment are presented in Tables 6-4 and 6-5. A block flow diagram for Sections 201 through 205, drawing 75-B9, is followed by the material balance on Table 6-6.

Short descriptions of the Amine and Cryogenic Sections (204 and 205) and the Hydrotreating and Reforming Sections (206, 207, and 208) follow separately.

SECTIONS 201, 202, AND 203 - H-COAL LIQUEFACTION

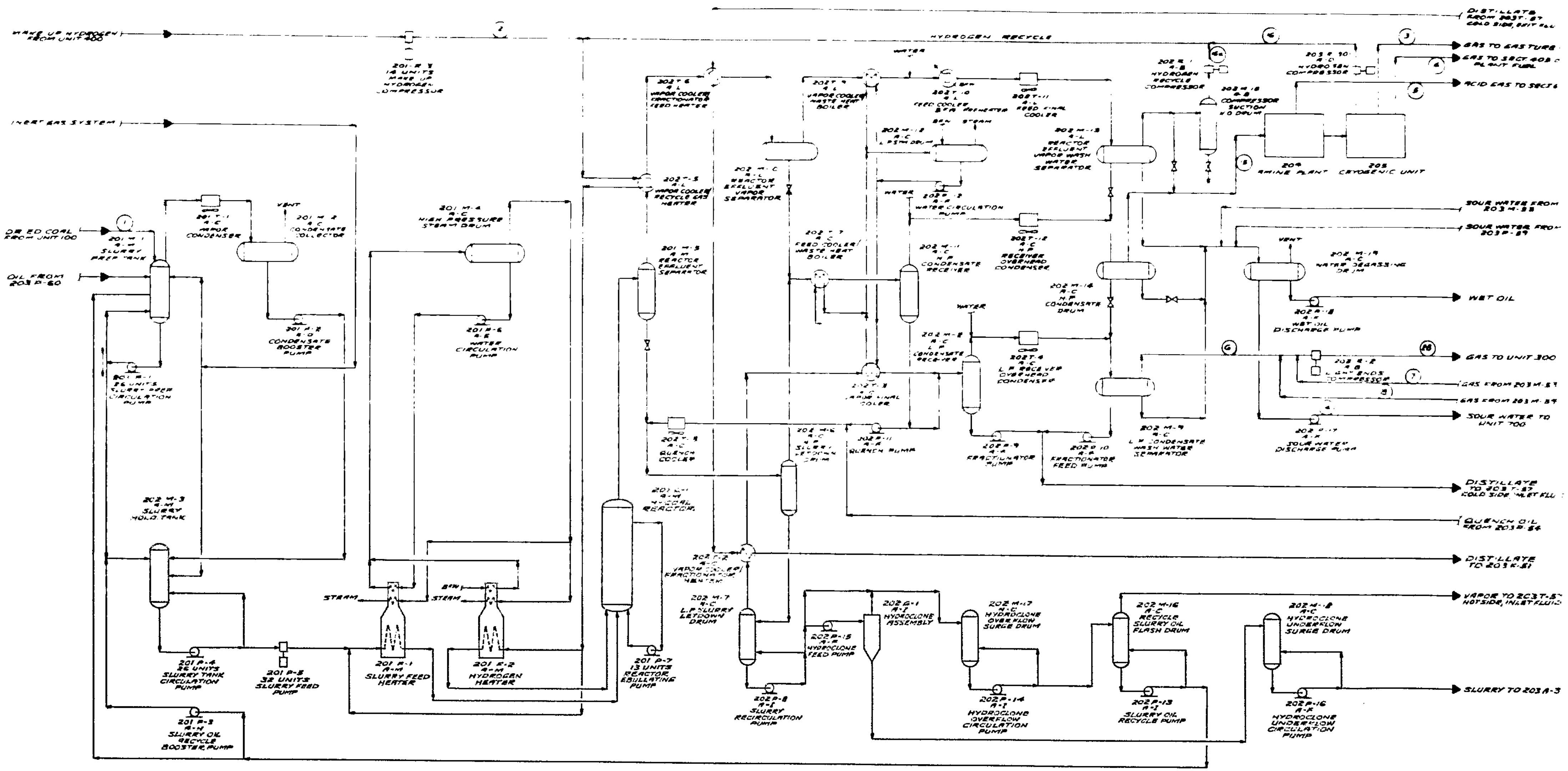
Process Description - Case HW

The design bases for the H-Coal liquefaction units were provided by HRI, the developer of the H-Coal process. Two separate design packages were furnished, one for Illinois coal feedstock and the other for Wyodak. Although the two cases represent somewhat different severities, they were selected as the most reliable at the time this study was initiated.

For a detailed description of process Sections 201, 202, 203, and the catalyst addition and withdrawal system, the reader is referred to Section 5 of the report for the H-Coal Illinois case.

Major process design differences between the Illinois and Wyodak cases are illustrated below:

	Case HW Wyodak	Case HE Illinois
Hydrogen consumed, lb/100 lb dry coal	6.27	4.89
No. of operating trains, Section 201	12	8
No. of operating trains, Section 202	3	2
Relative reactor throughput	2.62	1.0



NOTE: FIGURES IN CIRCLES REFER TO FLOW STREAMS IN MATERIAL BALANCE

SYSTEM					
0	9-1-82		E.V.F.		
ISSUE	DATE	DESCRIPTION OF ISSUE	BY	CHK	APPVD.

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STONE & WEBSTER ENGINEERING CORPORATION

CLIENT: ELECTRIC POWER RESEARCH INSTITUTE

TITLE: PROCESS FLOW DIAGRAM
H-COAL LIQUEFACTION PROCESS
UNIT 200
SECTION 201 COAL HYDROGENATION
SECTION 202 EFFLUENT SEPARATION
WYODAK COAL

JOB NUMBER	DRAWING NUMBER	ISSUE
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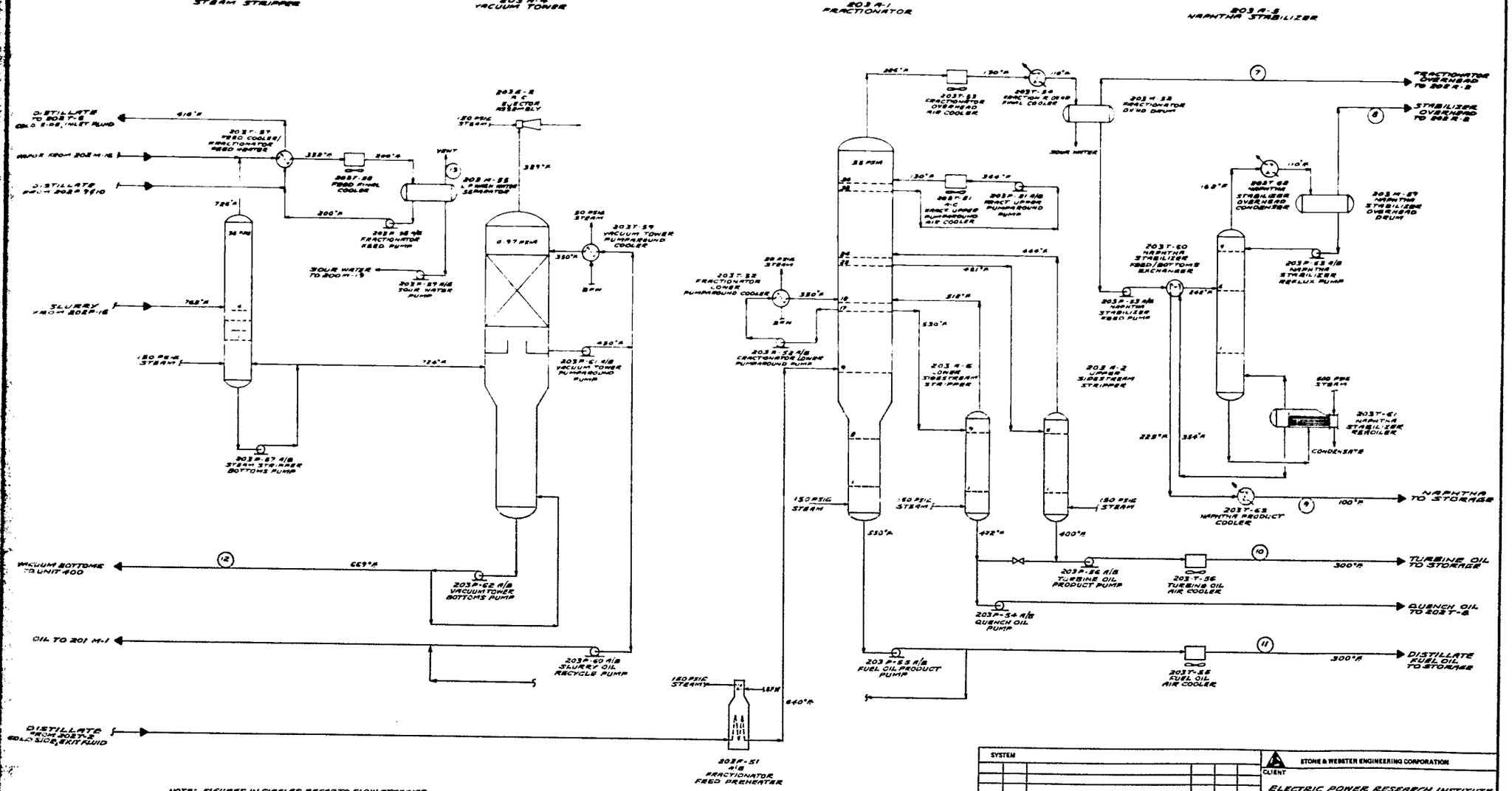

SYSTEM						
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CLIENT: ELECTRIC POWER RESEARCH INSTITUTE

TITLE: PROCESS FLOW DIAGRAM
H-COAL LIQUEFACTION PROCESS UNIT 200
SECTION 203 FRACTIONATION
WYODAK COAL

JOB NUMBER	DRAWING NUMBER	ISSUE
13461	75-D8	0

Chemetics Corporation

Table 6-4

EQUIPMENT LIST
UNIT 200 - SECTIONS 201, 202, AND 203
CASE HW

Section 201 - Coal Slurrying & H-Coal Reaction

Item No.	No. Req'd	Description
201 F-1	12 + 1	Slurry Feed Heater
201 F-2	12 + 1	Hydrogen Heater
201 L-1	12 + 1	H-Coal Reactor
201 M-1	12 + 1	Slurry Preparation Tank
201 M-2	3	Condensate Collector
201 M-3	12 + 1	Slurry Holding Tank
201 M-4	3	High Pressure Steam Drum
201 M-5	12 + 1	Reactor Effluent Separator
201 M-20	12 + 1	Catalyst Fill Hopper
201 M-21	12 + 1	Catalyst Addition Drum
201 M-22	12 + 1	Catalyst Dump Tank
201 M-23	12 + 1	Catalyst Withdrawal Drum
201 M-24	12 + 1	Catalyst Liquid Separator
201 P-1	12 + 14	Slurry Prep Circulation Pump
201 P-2	2 + 2	Condensate Booster Pump
201 P-3	6 + 3	Slurry Oil Recycle Booster Pump
201 P-4	12 + 14	Slurry Tank Circulation Pump
201 P-5	24 + 8	Slurry Feed Pump
201 P-6	3 + 2	Water Circulation Pump
201 P-7	12 + 1	Reactor Ebullating Pump

Table 6-4 (cont'd)

Section 201 - Coal Slurrying & H-Coal Reaction (cont'd)

Item No.	No. Req'd	Description
201 P-19	12 + 1	Catalyst Unloading Pump
201 P-20	12 + 1	High Pressure Heavy Flush Oil Pump
201 R-3	14	Make-up Hydrogen Compressor
201 T-1	3	Vapor Condenser

Table 6-4 (cont'd)

Section 202 - Effluent Separation

Item No.	No. Req'd	Description
202 G-1	9	Hydroclone Assembly
202 M-6	3	High Pressure Slurry Letdown Drum
202 M-7	3	Low Pressure Slurry Letdown Drum
202 M-8	3	Low Pressure Condensate Receiver
202 M-9	3	Low Pressure Condensate Wash Water Separator
202 M-10	12	Reactor Effluent Vapor Separator
202 M-11	3	High Pressure Condensate Receiver
202 M-12	2	Low Pressure Steam Drum
202 M-13	12	Reactor Effluent Vapor Wash Water Separator
202 M-14	3	High Pressure Condensate Drum
202 M-15	2	Compressor Suction Knockout Drum
202 M-16	3	Recycle Slurry Oil Flash Drum
202 M-17	3	Hydroclone Overflow Surge Drum
202 M-18	3	Hydroclone Underflow Surge Drum
202 M-19	3	Water Degassing Drum
202 P-8	6 + 3	Slurry Recirculation Pump
202 P-9	3 + 3	Fractionator Pump
202 P-10	3 + 3	Fractionator Feed Pump
202 P-11	3 + 3	Quench Pump
202 P-12	3 + 3	Water Circulation Pump
202 P-13	6 + 3	Slurry Oil Recycle Pump
202 P-14	6 + 3	Hydroclone Overflow Circulation Pump

Table 6-4 (cont'd)

Section 202 - Effluent Separation (cont'd)

Item No.	No. Req'd	Description
202 P-15	3 + 3	Hydroclone Feed Pump
202 P-16	3 + 3	Hydroclone Underflow Circulation Pump
202 P-17	3 + 3	Sour Water Discharge Pump
202 P-18	3 + 3	Wet Oil Discharge Pump
202 R-1	2	Hydrogen Recycle Compressor
202 R-2	2	Light Ends Compressor
202 T-2	3	Vapor Cooler/Fractionator Heater
202 T-3	3	Vapor Final Cooler
202 T-4	3	LP Receiver Overhead Condenser
202 T-5	12	Vapor Cooler/Recycle Gas Heater
202 T-6	12	Vapor Cooler/Fractionator Feed Heater
202 T-7	3	Feed Cooler/Waste Heat Boiler
202 T-8	3	Quench Cooler
202 T-9	12	Vapor Cooler/Waste Heat Boiler
202 T-10	12	Feed Cooler/Boiler Feedwater Preheater
202 T-11	12	Feed Final Cooler
202 T-12	3	HP Receiver Overhead Condenser

Table 6-4 (cont'd)

Section 203 - Fractionation

Item No.	No. Req'd	Description
203 A-1	1	Fractionator
203 A-2	1	Upper Sidestream Stripper
203 A-3	1	Steam Stripper
203 A-4	1	Vacuum Tower
203 A-5	1	Naphtha Stabilizer
203 A-6	1	Lower Sidestream Stripper
203 F-51	1 + 1	Fractionator Feed Preheater
203 G-2	2 + 1	Ejector Assembly
203 M-53	1	Fractionator Overhead Drum
203 M-55	1	Low Pressure Wash Water Separator
203 M-59	1	Naphtha Stabilizer Overhead Drum
203 P-51	1 + 1	Fractionator Upper Pumparound Pump
203 P-52	1 + 1	Fractionator Lower Pumparound Pump
203 P-53	1 + 1	Naphtha Stabilizer Feed Pump
203 P-54	1 + 1	Quench Oil Pump
203 P-55	1 + 1	Fuel Oil Product Pump
203 P-56	1 + 1	Turbine Oil Product Pump
203 P-57	1 + 1	Steam Stripper Bottoms Pump
203 P-58	1 + 1	Fractionator Feed Pump
203 P-59	1 + 1	Sour Water Pump
203 P-60	1 + 1	Slurry Oil Recycle Pump
203 P-61	1 + 1	Vacuum Tower Pumparound Pump

Table 6-4 (cont'd)

Section 203 - Fractionation (cont'd)

Item No.	No. Req'd	Description
203 P-62	1 + 1	Vacuum Tower Bottoms Pump
203 P-63	1 + 1	Naphtha Stabilizer Reflux Pump
203 T-51	3	Fractionator Upper Pumparound Air Cooler
203 T-52	1	Fractionator Lower Pumparound Cooler
203 T-53	1	Fractionator Overhead Air Cooler
203 T-54	1	Fractionator Overhead Final Cooler
203 T-55	1	Fuel Oil Air Cooler
203 T-56	1	Turbine Oil Air Cooler
203 T-57	1	Feed Cooler/Fractionator Feed Heater
203 T-58	1	Feed Final Cooler
203 T-59	1	Vacuum Tower Pumparound Cooler
203 T-60	1	Naphtha Stabilizer Feed/Bottoms Exchanger
203 T-61	1	Naphtha Stabilizer Reboiler
203 T-62	1	Naphtha Stabilizer Overhead Condenser
203 T-63	1	Naphtha Product Cooler

Table 6-5

EQUIPMENT SPECIFICATIONS
UNIT 200 - CASE HW

Equipment Item No.	Quantity Oper.	Quantity Spare	Service	Number of Trays	Horiz. or Vert.	Size Diam.	Size T-T	Design P/T psig/°F	Materials
TOWERS									
203 A-1	1	0	Fractionator	34	Vert.	22'0"	58'0"	75/650	SA516 with 12 Cr Cladding
203 A-2	1	0	Upper Side Stripper	6	Vert.	5'0"	21'0"	75/490	SA516
203 A-3	1	0	Steam Stripper	4	Vert.	7'0"	22'0"	50/775	SA516
203 A-4	1	0	Vacuum Tower		Vert.	15'0" and 10'0"	32'0" and 7'0"	50/725	CS with 410 SS Cladding
203 A-5	1	0	Naphtha Stabilizer	9	Vert.	7'6"	28'0"	115/400	A516
203 A-6	1	0	Lower Side Stripper	9	Vert.	12'0"	27'0"	75/570	SA516
REACTOR									
201 L-1	12	1	H-Coal Reactor		Vert.	12'6"	51'0"	3250/863	2¼ Cr - 1 Mo with 347 Weld Overlay and 6" Kastolite or Equal Refractory (Hot Wall Design)

Table 6-5 (cont'd)

EQUIPMENT SPECIFICATIONS
UNIT 200 - CASE HW

Equipment Item No.	Quantity Oper.	Quantity Spare	Service	Fired Duty 10^6 Btu/hr (Each)	Design Press. psig	Design Temp. °F	Materials
FIRED HEATERS							
201F-1	12	1	Slurry Feed Heater	58.4	3,250	750	347 SS
201F-2	12	1	Hydrogen Heater	22.0	3,250	1,100	347 SS
203F-51	1	1	Fractionator Feed Preheater	129.3	75	690	347 SS

Table 6-5 (cont'd)

EQUIPMENT SPECIFICATIONS
UNIT 200 - CASE HW

Equipment Item No.	Quantity Oper.	Quantity Spare	Service	Horiz. or Vert.	Size Diam.	Size T-T	Design P/T psig/°F	Materials
DRUMS								
201 M-1	12	1	Slurry Preparation Tank (15 HP Agitator)	Vert.	12'6"	26'0"	30/50	CS
201 M-2	3	0	Condensate Collector	Horiz.	4'0"	12'0"	30/280	CS
201 M-3	12	1	Slurry Holding Tank	Vert.	12'0"	23'0"	200/650	SA204 Gr C with 410 SS Cladding
201 M-4	3	0	High Pressure Steam	Horiz.	4'6"	12'0"		CS/1500 psig Steam
201 M-5	12	1	Reactor Effluent	Vert.	7'6"	19'6"	3250/863	SA367 Gr 22 Cl 2 with Separator 347 or 321 Cladding and 6" Kastolite or Equal Refractory
201 M-20	12	1	Catalyst Fill Hopper	Vert.	6'0"	7'6"	0/150	SA285 Gr C + 60° Cone
201 M-21	12	1	Catalyst Addition Drum	Vert.	3'0"	9'0"	3250/400	SA204 Cr C
201 M-22	12	1	Catalyst Dump Tank	Vert.	4'6"	9'0"	0/450	SA285 Gr C Hinged Cover Conical Bottom Section (90°)

Table 6-5 (cont'd)

EQUIPMENT SPECIFICATIONS
UNIT 200 - CASE HW

Equipment Item No.	Quantity Oper.	Quantity Spare	Service	Horiz. or Vert.	Size Diam.	Size T-T	Design P/T psig/°F	Materials
DRUMS (cont'd)								
201 M-23	12	1	Catalyst Withdrawal Drum	Vert.	2'6"	9'0"	3250/875	SA387 Gr 22 Cl 2 with 347 or 321 SS Cladding
201 M-24	12	1	Catalyst Liquid Separator	Vert.	3'0"	9'0"	3250/875	SA387 Gr 22 Cl 2 with 347 or 321 SS Cladding
202 M-6	3	0	High Pressure Slurry Letdown Drum	Vert.	11'0"	24'0"	1235/800	SA387 Gr 12 Cl 2 with 321 SS Cladding
202 M-7	3	0	Low Pressure Slurry Letdown Drum	Vert.	11'0"	22'0"	85/780	SA387 Gr 12 Cl 2 with 321 SS Cladding
202 M-8	3	0	Low Pressure Condensate Receiver	Horiz.	7'6"	18'0"	75/400	CS
202 M-9	3	0	Low Pressure Condensate Water Wash Separator	Horiz.	5'6"	18'0"	50/175	SA516 Gr 70
202 M-10	12	0	Reactor Effluent Vapor Separator	Horiz.	3'6"	8'0"	3250/550	1-¼ Cr - ½ Mo with 321 SS Cladding
202 M-11	3	0	High Pressure Condensate Receiver	Horiz.	4'0"	16'0"	1295/475	CS with 304L Cladding
202 M-12	3	0	Low Pressure Steam Drum	Horiz.	5'0"	46'0"	75/400	CS 50 psig Steam

Table 6-5 (cont'd)

EQUIPMENT SPECIFICATIONS
UNIT 200 - CASE HW

Equipment Item No.	Quantity Oper.	Quantity Spare	Service	Horiz. or Vert.	Size Diam.	Size T-T	Design P/T psig/°F	Materials
DRUMS (cont'd)								
202 M-13	12	0	Reactor Effluent Vapor Wash Water Separator	Horiz.	3'6"	10'0"	3230/180	SA516 Gr 70
202 M-14	3	0	High Pressure Condensate Drum	Horiz.	3'6"	12'0"	1285/175	SA516 Gr 70
202 M-15	3	0	Compressor Suction Knockout Drum	Vert.	3'6"	8'0"	2925/130	SA516 Gr 70
202 M-16	3	0	Recycle Slurry Oil Flash Drum	Vert.	8'6"	26'0"	30/775	SA515 Gr 70 with 410 SS Cladding
202 M-17	3	0	Hydroclone Overflow Surge Drum	Vert.	8'6"	24'0"	85/780	SA515 Gr 70 with 410 SS Cladding
202 M-18	3	0	Hydroclone Underflow Surge Drum	Vert.	4'0"	10'0"	85/780	SA515 Gr 70 with 410 SS Cladding
202 M-19	3	0	Water Degassing Drum	Horiz.	8'0"	20'0"	30/180	SA516 Gr 70
203 M-53	1	0	Fractionator Overhead Drum	Horiz.	11'0"	33'0"	50/250	SA516
203 M-55	1	0	LP Wash Water Separator	Horiz.	12'0"	42'0"	50/250	SA516
203 M-59	1	0	Naphtha Stabilizer Overhead Drum	Horiz.	5'6"	15'0"	125/250	Killed CS

Table 6-5 (cont'd)

EQUIPMENT SPECIFICATIONS
UNIT 200 - CASE HW

Equipment Item No.	No. Oper.	Required Spare	Service	Design gpm (Each)	Design Disch./Suct. psig	Oper. Temp. °F	Materials Casing	Materials Internals	Driver Type	Driver hp
PUMPS										
201 P-1	12	14	Slurry Prep Circulation	903	215/10	423	CA-6NM[a]	CA-6NM	Motor	200
201 P-2	2	2	Condensate Booster	66	215/5	230	CS	CS	Motor	30
201 P-3	6	3	Slurry Oil Recycle Booster	3,328	215/90	724	CA-6NM	CA-6NM	Motor	400
201 P-4	12	14	Slurry Tank Circulation	2,963	270/180	481	CA-6NM	CA-6NM	Motor	250
201 P-5	24	8	Slurry Feed[b]	1,078	3150/270	623	CA-6NM	CA-6NM	Motor	2500
201 P-6	3	2	Water Circulation (1500 psig)	3,300	1550/1500	590	12 Cr	12 Cr	Motor	150
201 P-7	12	1	Reactor Ebullating	8,310	[c]	[c]	316 SS	Trim: Tungsten Carbide	Motor	300
201 P-19	12	1	Catalyst Unloading	200	100/0	120-550	Steel Trim	12 Cr	Motor	30
201 P-20	12	1	High Pressure Heavy Flush Oil[b]	175	3250/0	550	CS	12 Cr	Motor	350

[a] Chrome steel
[b] Reciprocating pump
[c] HRI confidential information

Table 6-5 (cont'd)

EQUIPMENT SPECIFICATIONS
UNIT 200 - CASE HW

Equipment Item No.	No. Oper.	Required Spare	Service	Design gpm (Each)	Design Disch./Suct. psig	Oper. Temp. °F	Materials Casing	Materials Internals	Driver Type	Driver hp
PUMPS (cont'd)										
202 P-8	6	3	Slurry Recirculation	5,460	80/65	730	CA-6NM	CA-6NM	Motor	75
202 P-9	3	3	Fractionator	2,628	160/55	350	CS	12 Cr	Motor	250
202 P-10	3	3	Fractionator Feed	348	160/30	125	CS	12 Cr	Motor	50
202 P-11	3	3	Quench	887	1235/1170	425	12 Cr	12 Cr	Motor	60
202 P-12	3	3	Water Circulation (50 psig)	3,250	100/60	280	12 Cr	12 Cr	Motor	125
202 P-13	6	3	Slurry Oil Recycle	4,830	90/10	724	CA-6NM	CA-6NM	Motor	350
202 P-14	6	3	Hydroclone Overflow Circulation	5,110	90/65	730	CA-6NM	CA-6NM	Motor	125
202 P-15	3	3	Hydroclone Feed	612	160/80	730	CA-6NM	CA-6NM	Motor	50
202 P-16	3	3	Hydroclone Underflow Circulation	1,131	90/65	730	CA-6NM	CA-6NM	Motor	20
202 P-17	3	3	Sour Water Discharge	560	90/10	120	316 SS	316 SS	Motor	50
202 P-18	3	3	Wet Oil Discharge	10	90/10	130	CS	CS	Motor	5

Table 6-5 (cont'd)

EQUIPMENT SPECIFICATIONS
UNIT 200 - CASE HW

Equipment Item No.	No. Oper.	Required Spare	Service	Design gpm (Each)	Design Disch./Suct. psig	Oper. Temp. °F	Materials Casing	Materials Internals	Driver Type	Driver hp
PUMPS (cont'd)										
203 P-51	1	1	Fractionator Upper Pumparound	6,324	65/40	364	CS	CS	Motor	150
203 P-52	1	1	Fractionator Lower Pumparound	3,204	70/45	530	CS	CS	Motor	75
203 P-53	1	1	Naphtha Stabilizer Feed Pump	777	140/30	110	CS	CS	Motor	75
203 P-54	1	1	Quench Oil Pump	1,995	1235/40	443	CS	12 Cr	Motor	2,000
203 P-55	1	1	Fuel Oil Product	144	100/40	539	CS	12 Cr	Motor	25
203 P-56	1	1	Turbine Oil Product	1,000	100/40	447	CS	CS	Motor	50
203 P-57	1	1	Steam Stripper Btms	1,755	25/10	724	CA-6NM	CA-6NM	Motor	30
203 P-58	1	1	Fractionator Feed	1,245	160/5	200	CS	12 Cr	Motor	200
203 P-59	1	1	Sour Water	51	25/5	200	316 SS	316 SS	Motor	7½
203 P-60	1	1	Slurry Oil Recycle	3,081	90/40	520	5 Cr	5 Cr	Motor	150
203 P-61	1	1	Vacuum Tower Pumparound	2,370	40/-15	450	5 Cr	5 Cr	Motor	200
203 P-62	1	1	Vacuum Tower Btms	1,248	75/-15	661	CA-6NM	CA-6NM	Motor	125
203 P-63	1	1	Naphtha Stabilizer	168	130/100	110	CS	CS	Motor	7½

Table 6-5 (cont'd)

EQUIPMENT SPECIFICATIONS
UNIT 200 - CASE HW

Equipment Item No.	No. Required Oper.	Spare	Service	Rated Capacity ICFM (Each)	Pressure psig Suct.	Disch.	Gas Mol. Wt.	Description	Driver (Each) Type	hp
COMPRESSORS										
201 R-3	14	0	Make-up Hydrogen Compressor	761	700	3,150	2.83	Reciprocating	Motor	6,000
202 R-1	2	0	Hydrogen Recycle Compressor	760	2,925	3,150	8.44	Reciprocating	Motor	1,000
202 R-2	2	0	Light Ends	8,205	35	285	26.5	Centrifugal	Motor	5,000

Table 6-5 (cont'd)

EQUIPMENT SPECIFICATIONS
UNIT 200 - CASE HW

Equipment Item No.	Quantity Oper.	Quantity Spare	Service	Duty 10^6 Btu/hr (Each)	Area (Bare) (Each)	Design Press. psig	Design Temp. °F	Materials
AIR COOLERS								
201 T-1	3	0	Vapor Condenser	13.7	1,381	75	475	CS
202 T-4	3	0	LP Receiver Overhead Condenser	34.0	5,375	75	400	304 SS Tubes CS Headers
202 T-8	3	0	Quench Cooler	86.0	12,500	1,360	495	CS
202 T-11	12	0	Feed Final Cooler	20.4	3,469	3,235	550	304 SS Tubes CS Headers
202 T-12	3	0	HP Receiver Overhead Condenser	26.3	3,159	1,295	475	304 SS Tubes CS Headers
203 T-51	3	0	Fractionator Upper Pumparound Air Cooler	71.2	10,320	80	415	CS
203 T-53	1	0	Fractionator Overhead Air Cooler	137.7	10,560	75	340	CS
203 T-55	1	0	Fuel Oil Air Cooler	20.7	1,152	115	590	CS
203 T-56	1	0	Turbine Oil Air Cooler	22.2	1,275	115	520	CS
203 T-58	1	0	Feed Final Cooler	46.8	9,783	75	775	CS

Table 6-5 (cont'd)

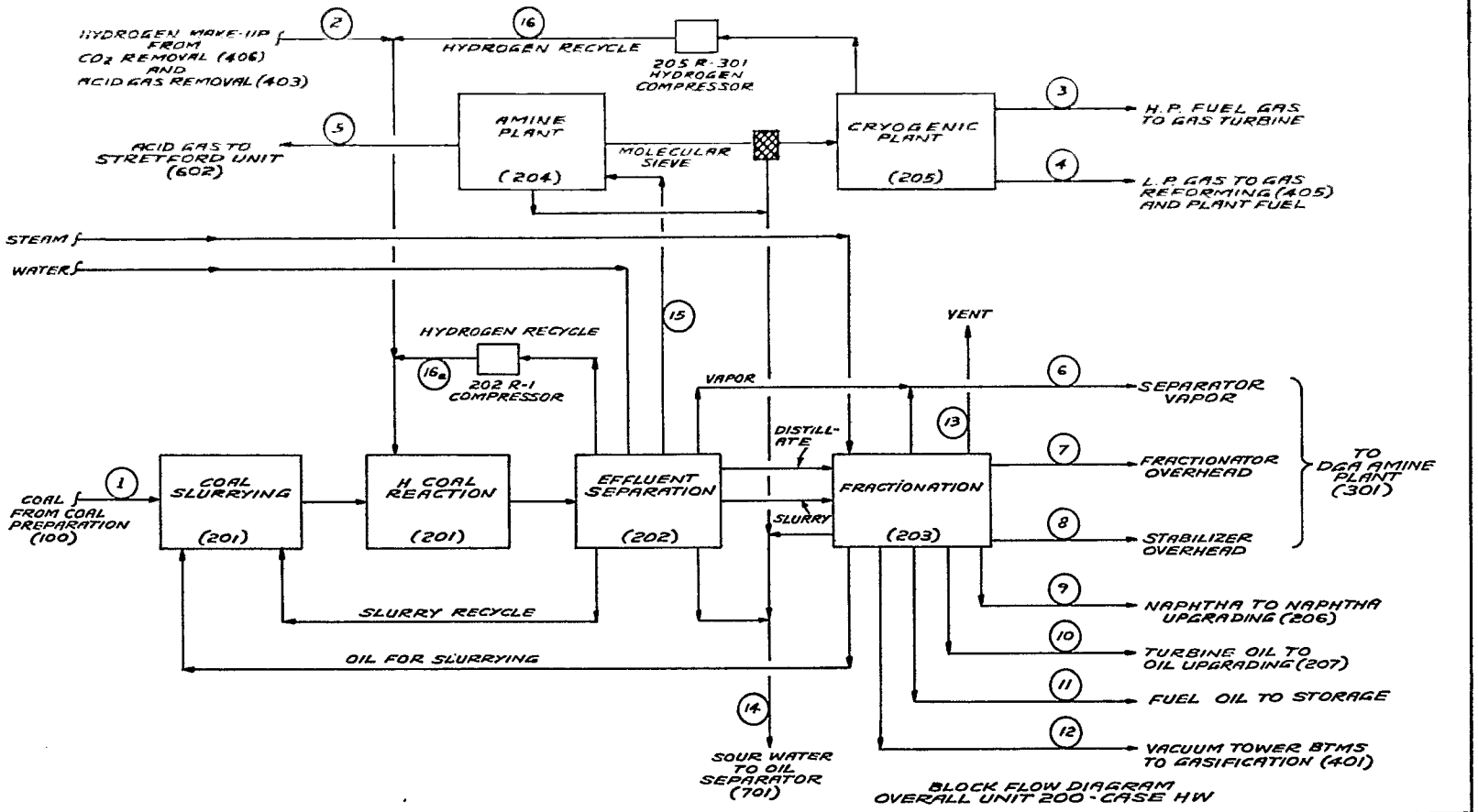
EQUIPMENT SPECIFICATIONS
UNIT 200 - CASE HW

Equipment Item No.	No. Required Oper.	Spare	Service	Duty 10^6 Btu/hr (Each)	Surface Area ft^2 (Each)	Design Press. psig/Temp.°F Shell	Tube	Materials Shell	Tube
SHELL AND TUBE EXCHANGERS									
202 T-2	3	0	Vapor Cooler/ Fractionator Feed Heater	88.7	13,190	85/780	90/650	KCS with 321 SS	304L SS
202 T-3	3	0	Vapor Final Cooler	83.5	6,950	80/780	75/360	CS	304 SS
202 T-5	12	0	Vapor Cooler/ Recycle Gas Heater	44.5	4,666	3290/890	3465/790	3 Cr - 1 Mo with 321 SS Clad	3 Cr - 1 Mo
202 T-6	12	0	Vapor Cooler/ Fractionator Feed Heater	7.4	1,018	3270/890	95/525	2-¼ Cr - 1 Mo with 321 SS Clad	304L SS
202 T-7	3	0	Feed Cooler/Waste Heat Boiler	39.7	2,165	1305/800	75/360	CS with 304L Clad	304 SS
202 T-9	12	0	Vapor Cooler/Waste Heat Boiler	23.5	2,044	3260/550	75/360	1-¼ Cr- ½ Mo with 321 SS Clad	321 SS
202 T-10	12	0	Feed Cooler/Boiler Feedwater Preheater	5.9	490	3245/550	75/290	CS with 304L Clad	304 SS
203 T-52	1	0	Fractionator Lower Pumparound Cooler	105.0	5,403	85/580	80/350	CS	CS

Table 6-5 (cont'd)

EQUIPMENT SPECIFICATIONS
UNIT 200 - CASE HW

Equipment Item No.	No. Required Oper.	Spare	Service	Duty 10^6 Btu/hr (Each)	Surface Area ft^2 (Each)	Design Press. psig/Temp.°F Shell	Tube	Materials Shell	Tube
SHELL AND TUBE EXCHANGERS (cont'd)									
203 T-54	1	0	Fractionator Overhead Final Cooler	4.2	2,298	75/250	100/125	CS	CS
203 T-57	1	0	Feed Cooler/ Fractionator Feed Heater	166.5	22,443	75/775	100/460	CS with 321 SS Clad	321 SS
203 T-59	1	0	Vacuum Tower Pumparound Cooler	32.4	12,078	75(vac)/500	80/350	CS	CS
203 T-60	1	0	Naphtha Stabilizer Feed/Bottoms Exchanger	19.5	1,872	125/300	110/405	CS	CS
203 T-61	1	0	Naphtha Stabilizer Reboiler	23.6	1,380	115/405	660/540	CS	CS
203 T-62	1	0	Naphtha Stabilizer Overhead Condenser	7.1	2,591	115/250	100/125	CS	CS
203 T-63	1	0	Naphtha Product Cooler	16.7	1,722	110/275	100/125	CS	CS



BLOCK FLOW DIAGRAM
OVERALL UNIT 200 - CASE HW

REF. TABLES 6-6 & 6-7

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

ENGR: E.V.P.
DESIGN
CHECKED
DRAWN F.R.
CHECKED
APPROVED

STONE & WEBSTER ENGINEERING CORPORATION
ELECTRIC POWER RESEARCH INSTITUTE
WYODAK COAL FEED

AREA	J.O. NO.	DRAWING NO.	ISSUE
	13461	75-B9	A

Table 6-6

OVERALL MATERIAL BALANCE
UNIT 200 - CASE HW

Stream Number	1		2/57			3	4/18&19	5/20
Description	Coal From (100)	H-Coal Reactor Yield	Hydrogen Make-up From (403) & (406)	Process Water & Steam	Total Input to Unit 200	H.P. Fuel Gas	L.P. Gas To (405) & Fuel	Acid Gas To (602)
Component Flowrate, lb/h								
H2		-115,229	120,543		5,314	124	1,355	
N2			9,106		9,106	110	5,458	
CO		-13,863	28,081		14,218	222	10,038	
H2S		15,713			15,713			661
NH3		13,545			13,545			
H2O	36,424	348,197		392,053	740,250			599
CO2		58,786	6,575		65,361			31,293
C1		101,875	10,955		112,830	1,866	86,642	
C2-		4,153			4,153	249	2,464	
C2		57,250			57,250	5,145	31,697	
C3		63,214			63,214	15,805	19,824	
C4		39,553			39,553	9,279	2,321	
IBP-100 F		42,225			42,225	6,552	229	
100-200 F		83,022			83,022	6,240	32	
200-300 F		126,384			126,384	1,722		
300-400 F		140,796			140,796	255		
400-500 F		153,663			153,663	94		
500-600 F		74,769			74,769	7		
600-700 F		43,812			43,812			
700-800 F		38,154			38,154			
800-900 F		46,545			46,545			
900-975 F		45,232			45,232			
Residuum		206,967			206,967			
Subtotal, lb/h	36,424	1,574,763	175,260	392,053	2,142,076	47,670	160,060	32,553
Coal	1,666,386	128,047			128,047			
Ash	139,604	139,604			139,604			
Total, lb/h	1,842,414	1,842,414	175,260	392,053	2,409,727	47,670	160,060	32,553
Temperature, F	200		220			99	116	110
Pressure, psig			3,150			380	35	15

Ref. Dwg. 75-B9

Table 6-6 (cont'd)

OVERALL MATERIAL BALANCE
UNIT 200 - CASE HW

Stream Number	6	7	8	9	10	11	12	13	14
Description	Separator Vapor To (301)	Fractionator Overhead To (301)	Stabilizer Overhead To (301)	Naphtha To (206)	Turbine Oil To (207)	Distillate Fuel Oil To Storage	Vacuum Tower Bottoms To (401)	Vent Gas From Wash Water Separator	Sour Water To (701)
Component Flowrate, lb/h									
H2	3,762	16	1					57	
N2	3,391	30	1					116	
CO	3,808	29	63					120	
H2S	1,467	151						94	13,277
NH3			95					46	13,499
H2O	4,018	216	354					1,550	733,772
CO2	31,359	2,349						6	
C1	23,508	453	30					331	
C2-	1,291	92	19					38	
C2	17,764	1,705	459					480	
C3	17,075	5,472	4,595					443	
C4	6,737	5,544	15,087	213				372	
IBP-100 F	2,036	3,182	17,972	12,008	20			246	
100-200 F	1,203	3,037	3,563	68,590	1,338			337	
200-300 F	126	782		122,247	76,306		68	169	
300-400 F	8	59		64,103	153,437	3,766	270	65	
400-500 F	1				70,717			63	
500-600 F					23,713	18,461	1,637	9	
600-700 F					4,002	22,853	11,299	1	
700-800 F						10,570	35,975		
800-900 F						2,677	42,555		
900-975 F							206,967		
Residuum									
Subtotal, lb/h	117,554	23,117	42,239	267,161	329,533	58,327	298,771	4,543	760,548
Coal							128,047		
Ash							139,604		
Total, lb/h	117,554	23,117	42,239	267,161	329,533	58,327	566,422	4,543	760,548
Temperature, F	125	110	110	100	300	300	669	200	120
Pressure, psig	35	35	85	150	150	100	115		

Ref. Dwg. 75-B9

SECTIONS 204 AND 205 - AMINE AND CRYOGENIC PLANTS

Process Description - Case HW

The vapor phase from the last condensation stage following the H-Coal reactor consists of hydrogen and low boiling hydrocarbons. These vapors are purified and separated in the amine and cryogenic plants as described for the Illinois case. A schematic block flow diagram of the process is shown in Figure 6-1. An equipment list and a material balance are shown in Tables 6-7 and 6-8, respectively.

SECTION 204 - AMINE PLANT

Process Description - Case HW

The vapor from the high pressure condensate vessel 202M-14 of the effluent separation section is joined by vapor from the wash water separator (202M-13) and is fed to a conventional amine plant for removal of H_2S and CO_2. The sour gas is stripped of H_2S and CO_2 by countercurrent contact with diethanolamine (DEA) in an absorber. The overhead gas stream from the absorber is cooled and then dried in a molecular sieve tower. The dried gas is sent to the cryogenic plant for separation of hydrogen from the light boiling components. The rich amine solution flows from the bottom of the absorber to a stripper in which acid gases are steam stripped from the amine solution. The acid gas stream exiting the top of the steam stripper is sent to the Stretford plant (Section 602) for separation of H_2S from CO_2. The lean amine solution exiting the bottom of the stripper is recycled to the absorber.

SECTION 205 - CRYOGENIC PLANT

Process Description - Case HW

The cryogenic plant recovers a relatively pure hydrogen stream and a light hydrocarbon gas stream from the treated gas produced in the amine plant. The hydrogen stream is compressed and recycled to the H-Coal reactor. The light hydrocarbon gas stream is used either as plant fuel or as feed to the gas reforming plant (Section 405) for additional hydrogen production. A more detailed description of the amine and cryogenic units is given for the Illinois case (Case HE) in Section 5.

FIGURE 6-1

BLOCK FLOW DIAGRAM
AMINE AND CRYOGENIC PLANTS

SECTIONS 204, 205 - CASE H W

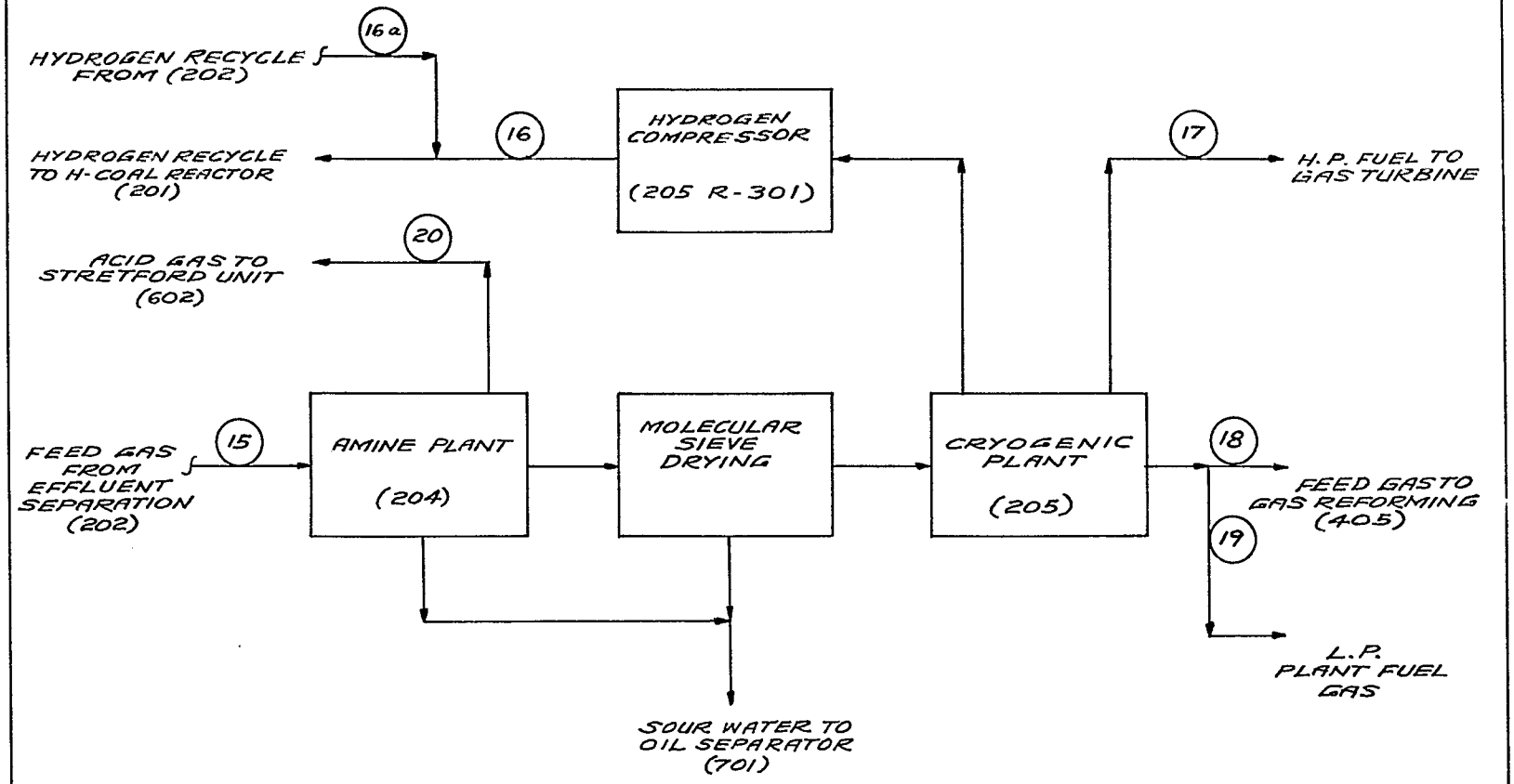


Table 6-7

MATERIAL BALANCE
AMINE AND CRYOGENIC PLANTS
SECTIONS 204, 205 - CASE HW

Stream Number	15	16	16a	17	18	19	20
Description	Feed Gas From (202)	Hydrogen Recycle To (201) From (205)	Hydrogen Recycle To (201) From (202)	H.P. Fuel To Gas Turbine	Feed Gas To (405)	L.P. Plant Fuel Gas	Acid Gas To (602)
Component Flowrate, lb/h							
H2	46,206	44,727	60,041	124	548	807	
N2	18,255	12,687	20,306	110	2,319	3,139	
CO	20,896	10,636	23,276	222	4,303	5,735	
H2S	661		749				661
H2O	599		578				599
CO2	31,293		24,262				31,293
C1-C4	184,583	9,291	203,956	32,344	61,376	81,572	
C5 +	15,131		16,450	14,870	84	177	
Total, lb/h	317,624	77,341	349,618	47,670	68,630	91,430	32,553
Temperature, F	126	258	145	99	120	116	110
Pressure, psig	1160	3150	3150	380	380	35	15

Ref. Fig. 6-1

Table 6-8

EQUIPMENT LIST
UNIT 200 - AMINE AND CRYOGENIC PLANTS
SECTIONS 204, 205 - CASE HW

Section 204 - Amine Plant

Item No.	No. Req'd	Description
204 A-200	1	Absorber
204 A-201	1	Stripper
204 A-202	1	Pre-Stripper
204 M-200	1	Hydrocarbon Flash Drum
204 M-201	1	Reflux Drum
204 M-202	1	DEA Surge Tank
204 P-200	1 + 1	Stripper Reflux Pump
204 P-201	1 + 1	Lean Amine Circulation Pump
204 P-202	1	Hydraulic Turbine Pump
204 Q-200	1	Amine Storage Tank
204 T-200	1	Stripper Reboiler
204 T-201	1	Stripper Condenser
204 T-202	1	Amine Preheater
204 T-203	1	Amine Cooler
204 V-200	1 + 1	Filter

Table 6-8 (cont'd)

Section 205 - Cryogenic Plant

Item No.	No. Req'd	Description
205 G-300	2	Cold Box
205 M-301	2	Separator Drum No. 1
205 M-302	2	Separator Drum No. 2
205 M-303	2	Separator Drum No. 3
205 M-304	2	Separator Drum No. 4
205 M-305	2	Expander Outlet Drum
205 R-300	2	Expander
205 R-301	4	Hydrogen Compressor
205 R-302	1	Cryogenic Tail Gas Compressor
205 T-300	2	Feed Water Cooler
205 T-301	2	Core Exchanger No. 1
205 T-302	2	Core Exchanger No. 2
205 T-303	2	Core Exchanger No. 3
205 T-304	2	Core Exchanger No. 4
205 T-305	2	Core Exchanger No. 5
205 T-306	2	Bypass Cooler

SECTIONS 206, 207, AND 208 - PRODUCTS HYDROTREATING AND REFORMING

Process Description - Case HW

The process sections for hydrotreating and reforming raw liquid products for the Wyodak case are shown schematically on block flow diagram Figure 6-2. An overall material balance for the upgrading scheme is given in Table 6-9. The process is the same as described for the Illinois cases in Section 5.

The process upgrades naphtha and turbine H-Coal distillate by hydrotreating to remove sulfur and nitrogen.

Illustrative properties of coal liquid distillates used in evaluating the naphtha and turbine fuel hydrotreating designs were furnished by EPRI and are shown below:

	H-Coal/Wyodak Liquids	
	Distillate	Hydrotreated
Naphtha: C_4/350°F		
S wt- ppm	200	1.0 max
N wt- ppm	1000	1.0 max
Turbine Fuel: 325/700°F		
S wt- ppm	1100	100
N wt- ppm	3800	1000

The hydrotreated naphtha is reformed to produce a gasoline blending stock and to furnish hydrogen to the hydrotreaters. The reformate has a calculated gravity of 37.3 °API and an estimated RON, clear, of 98. When blended with light naphtha from the naphtha splitter overhead, the gravity increases to 43.1 °API and the octane number drops to an estimated 94 RON, clear.

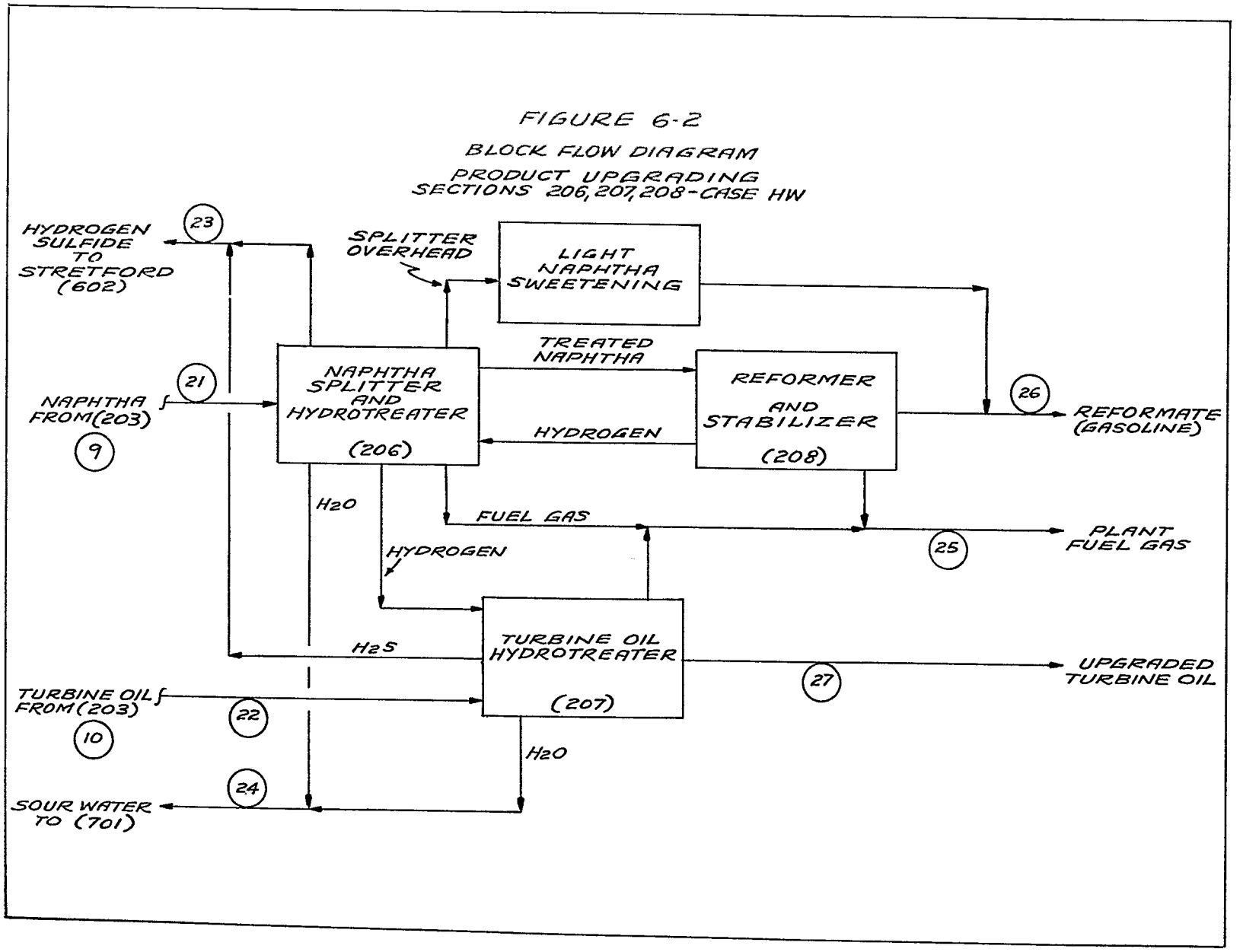


FIGURE 6-2

BLOCK FLOW DIAGRAM

PRODUCT UPGRADING

SECTIONS 206, 207, 208 - CASE HW

Table 6-9

MATERIAL BALANCE - PRODUCT UPGRADING
SECTIONS 206, 207, 208 - CASE HW

Stream Number	21	10/22	23	24	25	26	27
Description	Naphtha From (203)	Turbine Oil From (203)	H2S To Stretford (602)	Sour Water To (701)	Fuel Gas To Plant Header	Gasoline To Product Storage	Turbine Oil To Product Storage
Component Flowrate, lb/h							
H2			a		2,221		
H2S			413				
NH3			a	1,405			
H20			a	5,951			
C1			a		419		
C2					442		
C3					281		53
C4	213				628	487	332
C5+							327,194
C5-350 F	266,948	77,664				256,868	
350-650 F		251,869					
Total, lb/h	267,161	329,533	413	7,356	3,991	257,355	327,579
Temperature, °F	100	300	110	120	100	100	130
Pressure, psig	100	100	15	50	35	15	15

Ref. Fig. 6-2

a Quantities not determined.

UNIT 300 - LIGHT ENDS PROCESSING

Process Description - Case HW

The light ends treating system shown in Figure 6-3 consists only of an amine plant (Section 301). An LPG separation unit is not provided since the hydrocarbon fraction, which yields LPG product in the Illinois coal case, is required as fuel and as reformer feed for hydrogen production. The equipment list and material balance for this section are shown in Tables 6-10 and 6-11, respectively.

SECTION 301 - DIGLYCOLAMINE PLANT

The effluent separation and fractionation overhead gas streams from Unit 200 are mixed, compressed, and fed to the diglycolamine (DGA) plant for the removal of H_2S, CO_2, and COS. The DGA plant reduces the H_2S level to as low as 4 ppmv.

The DGA is regenerated in a high temperature reclaimer and sent back to the amine-gas contactor. The overhead acid gas from the regenerator column is sent to the Stretford sulfur recovery unit (Section 602). A part of the treated effluent gas from the amine plant is used as fuel in the plant. The remaining effluent gas is compressed and split into two streams, one being sent to the gas turbine and the other to steam reforming and shift for the production of hydrogen.

FIGURE 6-3

BLOCK FLOW DIAGRAM

DGA AMINE PLANT

SECTION 301 - CASE HW

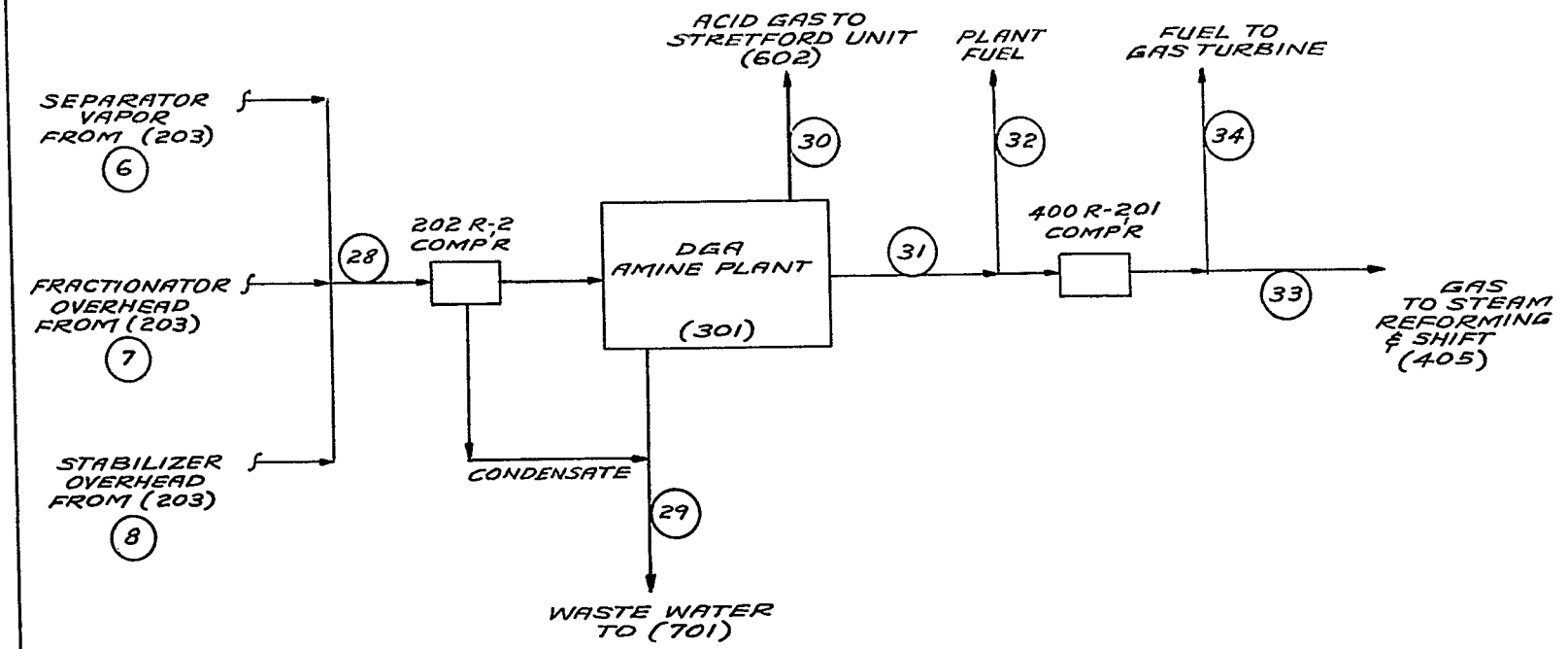


Table 6-10

MATERIAL BALANCE
DGA AMINE PLANT
SECTION 301 - CASE HW

Stream Number	28	29	30	31	32	33	34
Description	Feed To DGA Amine Plant (301)	Waste Water To (701)	Acid Gas To (602)	Gas From (301)	Plant Fuel	Gas to Stm. Reforming & Shift (405)	Fuel To Gas Turbine
Component Flowrate, lb/h							
H2	3,778			3,778	2,605	237	936
N2	3,422			3,422	2,503	216	703
CO	3,838			3,838	2,803	246	789
H2S	1,681		1,681				
H2O	4,329	2,385	1,077	867	634	55	178
CO2	34,062		34,042	20	16		4
C1_	23,991			23,991	17,516	1,536	4,939
C2_	1,402			1,402	1,099		303
C2	19,928			19,928	14,448	1,347	4,106
C3	27,142			27,142	19,807	1,734	5,601
C4	27,368			27,368	19,928	1,749	5,691
IBP-100 F	23,190			23,190	16,945	1,480	4,765
100-200 F	7,803			7,803	5,702	498	1,603
200-300 F	908			908	663	58	187
300-400 F	67			67	49	4	14
400-500 F	1			1	1		
Total, lb/h	182,910	2,385	36,800	143,725	104,719	9,187	29,819
Temperature, F	115	120	120	120	120	120	120
Pressure, psig	285	50	10	35	35	380	380

Ref. Fig. 6-3

Table 6-11

EQUIPMENT LIST
UNIT 300 - DGA AMINE PLANT
SECTION 301 - CASE HW

Item No.	No. Req'd	Description
301 A-1	1	Absorber
301 A-2	1	Stripper
301 A-3	1	Pre-Stripper
301 M-1	1	Hydrocarbon Flash Drum
301 M-2	1	Reflux Drum
301 M-3	1	DGA Surge Tank
301 P-1	1 + 1	Stripper Reflux Pump
301 P-2	1 + 1	Lean Amine Circulation Pump
301 Q-1	1	Diglycolamine Storage Tank
301 T-1	1	Stripper Reboiler
301 T-2	1	Stripper Condenser
301 T-3	1	Amine Preheater
301 T-4	1	Amine Cooler
301 T-5	1	Reclaimer
301 V-1	1 + 1	Filters

UNIT 400 - HYDROGEN PLANT

Process Description - Case HW

Direct liquefaction of Wyodak coal under the design conditions chosen requires more hydrogen than can be supplied by the gasification of available vacuum tower bottoms. Supplemental hydrogen is obtained by gas reforming the C1 through C5 hydrocarbons which were separated from the H-Coal light ends in the Cryogenic Plant (Section 205).

Hydrogen produced by the gasification of vacuum tower bottoms is represented by the block flow diagram in Figure 6-4. Hydrogen produced by gas reforming is shown in Figure 6-5.

The hydrogen plant consist of the following systems:

Section 401 - Gasification (Texaco)

Section 402 - CO Shift

Section 403 - Acid Gas Removal (Selexol)

Section 405 - Gas Reforming and CO Shift

Section 406 - Carbon Dioxide Removal (K_2CO_2)

The material balances for the hydrogen plant are shown in Tables 6-12 through 6-15 and equipment lists are shown in Table 6-16.

SECTIONS 401, 402, AND 403 - HYDROGEN PLANT
GASIFICATION, CO SHIFT, AND ACID GAS RECOVERY

Process Description - Case HW

Hydrogen production using the Texaco gasification process, CO shift, and acid gas recovery (Selexol) is similar to the processes used in the Illinois case, Section 5, Case HE. A comparison between the Illinois and the Wyodak cases for major process streams is shown below:

		Case HW Wyodak	Case HE Illinois
Vacuum Tower Bottoms	lb/hr	566,422	625,340
Oxygen input (100% O_2)	st/sd	5,137.7	4,917.8
Steam input	lb/hr	339,881	312,670
CO Shifted	lb/hr	687,154	645,670
CO_2 Removed	lb/hr	1,312,415	1,251,830
H_2S Removed	lb/hr	1,204	15,921
Hydrogen Produced (H_2)	lb/hr	89,614	82,561

The hydrogen stream from the gasification plant is joined by hydrogen from gas reforming to supply the total hydrogen make-up requirements to the H-Coal liquefaction plant.

SECTION 405 - REFORMING AND CO SHIFT

Process Description - Case HW

The feed to the gas reformer consists of C1 through C5 hydrocarbons separated from the light ends and acid gases in the Amine (Section 204), Cryogenic (Section 205), and DGA Amine (Section 301) plants. After passing over a hydrodesulfurization catalyst and a zinc oxide adsorbent for trace H_2S removal, the hydrocarbon feed is mixed with steam and enters a tubular catalytic reformer furnace fired by gaseous fuel.

The reformer produces a synthesis gas rich in hydrogen and in carbon monoxide which is converted to additional hydrogen in the CO shift catalytic converters. The waste heat from the reformer and CO shift reactors is recovered in boiler feedwater heating and in steam production.

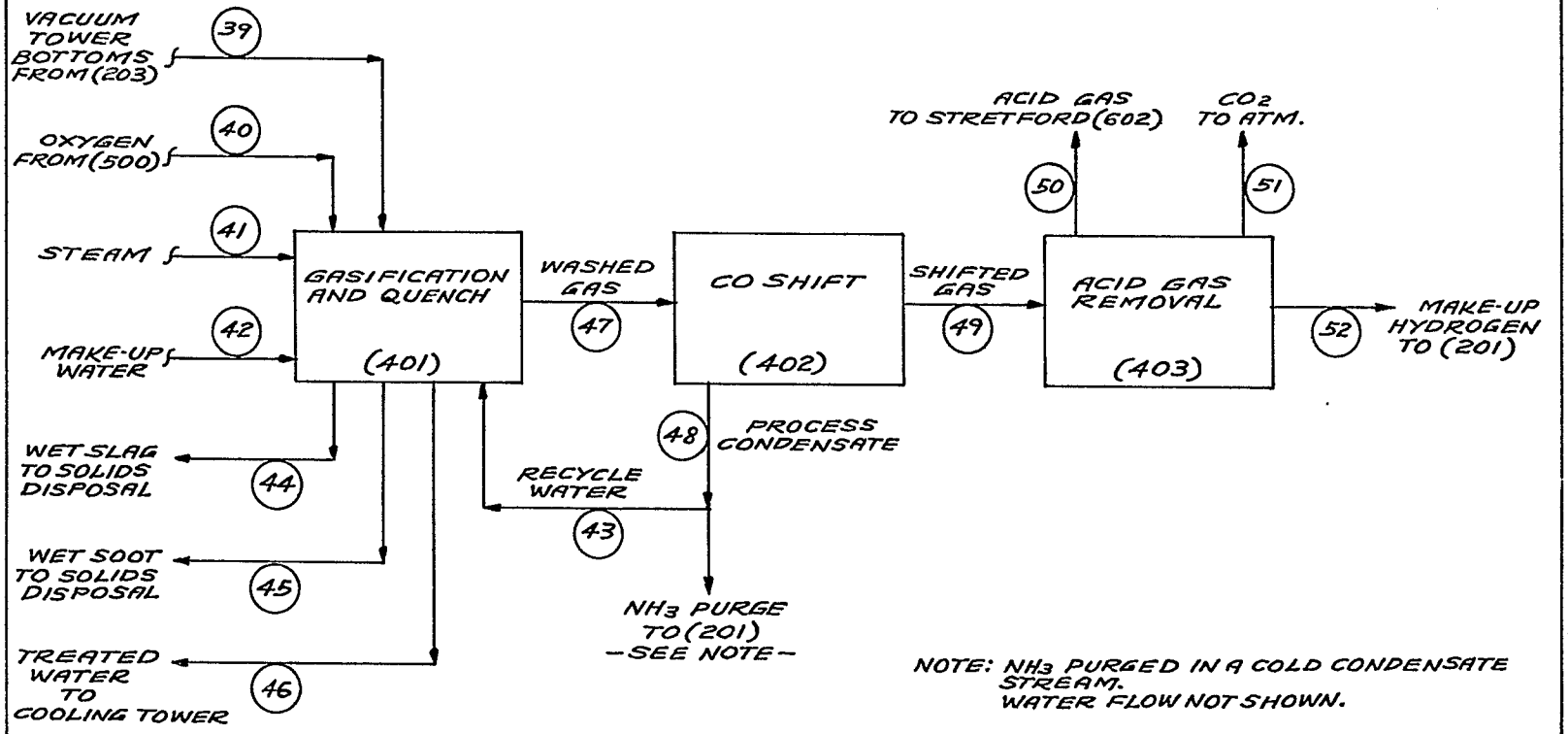
SECTION 406 - CARBON DIOXIDE REMOVAL (K_2CO_3)

Process Description - Case HW

The CO shift effluent from Section 405 enters an absorber tower where carbon dioxide is absorbed by a hot, lean potassium carbonate (K_2CO_3) solution in countercurrent flow to the gas stream. Hot process gas from CO shift is used in a reboiler of a regenerator tower to regenerate the K_2CO_3 solution which releases carbon dioxide to atmosphere. The overhead gas stream from the absorber, containing mostly hydrogen, is cooled to ambient temperature and compressed to 700 psig before joining the make-up hydrogen produced in the gasification section. The mixed gas stream flows to the make-up hydrogen compressor in Section 201 before entering the H-Coal reactor.

FIGURE 6-4

BLOCK FLOW DIAGRAM
HYDROGEN PLANT
SECTIONS 401, 402, 403-CASE HW



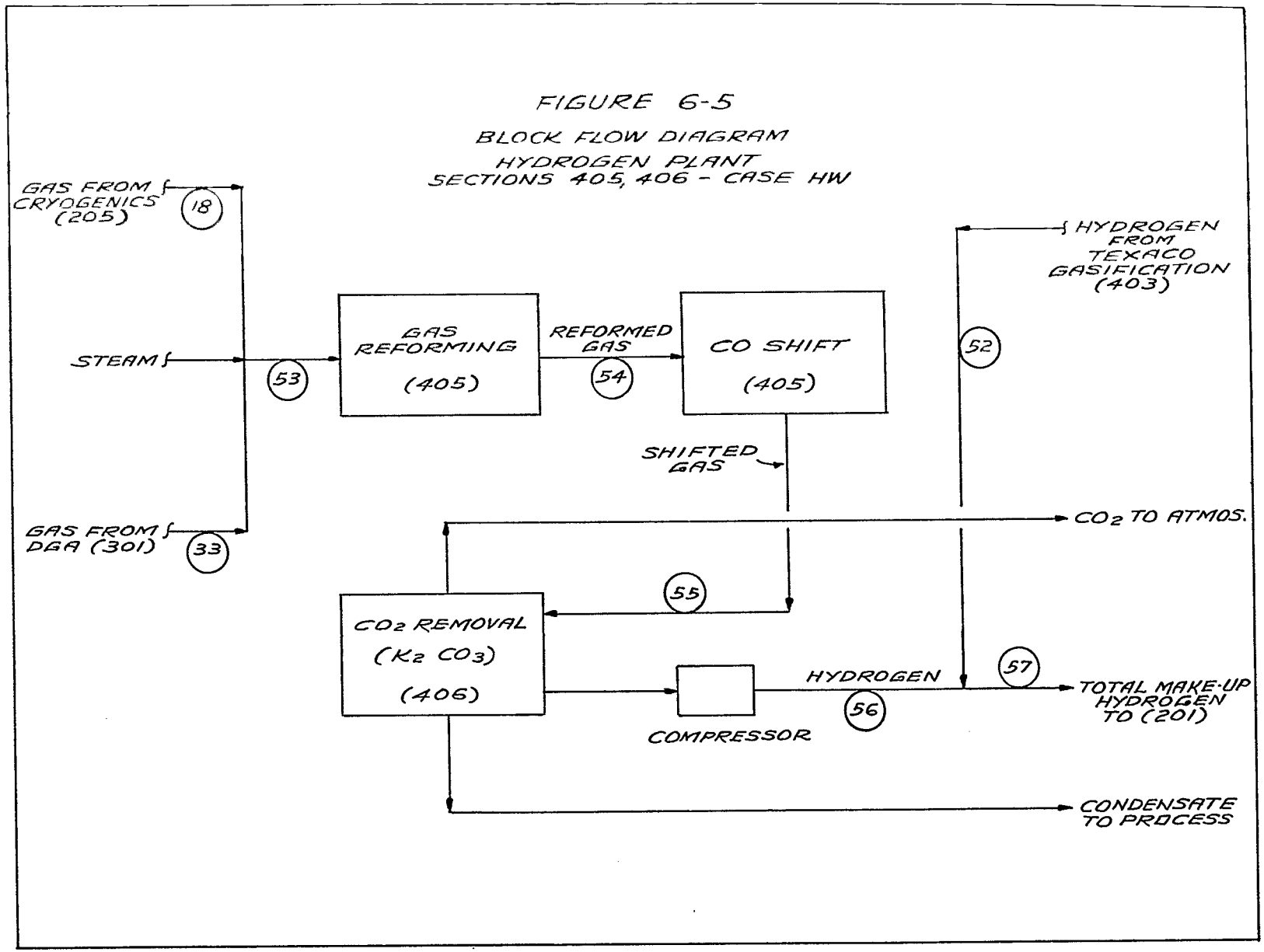


FIGURE 6-5
BLOCK FLOW DIAGRAM
HYDROGEN PLANT
SECTIONS 405, 406 - CASE HW
GAS FROM CRYOGENICS (205)
18
STEAM
53
GAS REFORMING (405)
REFORMED GAS
54
CO SHIFT (405)
HYDROGEN FROM TEXACO GASIFICATION (403)
52
SHIFTED GAS
GAS FROM DGA (301)
33
CO2 TO ATMOS.
55
CO2 REMOVAL (K2 CO3) (406)
COMPRESSOR
HYDROGEN
56
57
TOTAL MAKE-UP HYDROGEN TO (201)
CONDENSATE TO PROCESS

Table 6-12

FEED STREAM ANALYSES
HYDROGEN PLANT - SECTION 401
CASE HW

Vacuum Tower Bottoms

Cut	Wt %	Ultimate Analysis	Wt %
400-500°F	Trace	C	66.50
500-600°F	0.05	H	4.30
600-700°F	0.29	N	1.10
700-800°F	1.99	S	0.20
800-900°F	6.36	O	3.26
900-975°F	7.51	Ash	24.64
Residuum	36.54		100.00
Coal (ash free)	22.61		
Ash	24.65		
	100.00		

Oxygen

Ultimate Analysis	Wt %	Vol %
O2	99.73	99.69
N2 + Ar	0.27	0.31
	100.00	100.00

Table 6-13

MATERIAL BALANCE
GASIFICATION - SECTION 401
CASE HW

Stream No.	Input	Flowrate, lb/h
39	Vacuum Tower Bottoms	566,422
40	Oxygen	429,315
41	Steam	339,881
42	Make-up Water	438,428
43	Recycle Water	1,129,399
	Total	2,903,445

Stream No.	Output	Flowrate, lb/h
44	Wet Slag - Solids	105,205
	- Water	21,073
45	Wet Soot - Solids	37,820
	- Water	37,309
46	Treated Water	125,100
47	Washed Gas	2,576,938
	Total	2,903,445

Ref. Fig. 6-4

Table 6-14

MATERIAL BALANCE - HYDROGEN PLANT
CO SHIFT AND ACID GAS REMOVAL
SECTIONS 402 and 403 - CASE HW

Stream No.	47	48	49	50	51	52
Description	Washed Gas From (401)	Process Condensate	Shifted Gas From (402)	Acid Gas To Stretford (602)	CO2 To Atmos.	Make-up H2 To (201)
Component Flowrate, lb/h						
H2	40,242		89,700	13	73	89,614
N2	6,571		6,571		6,571	
CO	712,812		25,658	20	115	25,523
H2S	1,204		1,204	1,204		
NH3	1,013	1,013[b]				
H2O	1,573,197	1,129,399	1,820	1,215	605	
CO2	238,613		1,318,287	239,018	1,073,397	5,872
CH4	3,286		3,286	74	13	3,199
Total, lb/h	2,576,938	1,130,412	1,446,526	241,544	1,074,203	130,779
Temperature, °F	463	313/150[a]	103	120	120	58
Pressure, psig	770	700/0[a]	720	8	Atm.	700

Ref. Fig. 6-4

[a] Temperatures and pressures of hot and cold condensate streams.
[b] NH_3 purged to section 202 in a cold condensate stream.

Table 6-15

MATERIAL BALANCE-HYDROGEN PLANT
GAS REFORM AND SHIFT, CO2 REMOVAL
SECTIONS 405 and 406 - CASE HW

Stream No.	53	54	55	56	52	2/57
Description	Feed Gas From (205) & (301)	Reformer Effluent	Shift Effluent	Hydrogen From Booster Compressor	Hydrogen From Texaco Gasification	Total Make-up Hydrogen
Component Flowrate, lb/h						
H2	785	26,800	30,929	30,929	89,614	120,543
N2	2,535	2,535	2,535	2,535	6,571	9,106
CO	4,549	59,896	2,558	2,558	25,523	28,081
CO2		90,423	180,513	703	5,872	6,575
C1	38,703	7,756	7,756	7,756	3,199	10,955
C2	16,097					
C3	10,229					
C4	2,740					
C5+	2,124					
Dry Gas, lb/h	77,762	187,410	224,291	44,481	130,779	175,260
H2O	375,424	265,776	228,895			
Total lb/hr	453,186	453,186	453,186	44,481	130,779	175,260
Temperature, °F			230	110	58	71
Pressure, psig	390	320	290	700	700	700

Ref. Fig. 6-5

Note: CO2 to atmosphere 179,810 lb/hr
Condensate discharge 228,895 lb/hr

Table 6-16

EQUIPMENT LIST
UNIT 400 - HYDROGEN PLANT
SECTIONS 401, 402, 403, 405, 406 - CASE HW

Section 401 - Gasification - Texaco

Item No.	Description
401 G-1	Charge Section
401 G-2	Gasification and Quench Section
401 G-3	Gas Scrubbing Section
401 G-4	Water Recovery and Solids Handling Section
401 G-5	Waste Water Treating Section

Table 6-16 (cont'd)

Section 402 - CO Shift

Item No.	No. Req'd	Description
402 L-100	4	High-Temp. Shift Converter
402 L-101	4	Low-Temp. Shift Converter
402 M-100	4	H.P. Steam Drum
402 M-101	1	Condensate Separator No. 1
402 M-102	1	Condensate Separator No. 2
402 M-103	1	Condensate Separator No. 3
402 M-104	1	Condensate Separator No. 4
402 M-105	2	M.P. Steam Drum
402 M-106	1	Hot Condensate Drum
402 M-107	1	Cold Condensate Drum
402 P-100	1 + 1	Hot Condensate Pump
402 P-101	1 + 1	Cold Condensate Pump
402 T-100	4	Shift-Preheater
402 T-101	4	Syn Gas Cooler/H.P. Steam Generator
402 T-102	1	Syn Gas Cooler/BFW Heater
402 T-103	1	Phosam Regenerator Reboiler
402 T-104	4	Shift Startup Heater
402 T-105	1	Gray Water Heater
402 T-106	1	Syn Gas Cooler/Condensate Heater
402 T-107	2	Syn Gas Cooler/L.P. Steam Generator
402 T-108	1	Syn Gas Air Cooler
402 T-109	1	Syn Gas Final Cooler

Table 6-16 (cont'd)

Section 403 - Acid Gas Removal - Selexol

Item No.	No. Req'd	Description
403 A-50	2	CO_2 Absorber
403 A-51	2	CO_2 Stripper
403 A-52	1	H_2S Absorber
403 A-53	1	H_2S Stripper
403 M-50	2	Feed Gas Inlet Separator
403 M-51	2	CO_2 High Pressure Flash Drum
403 M-52	2	CO_2 Low Pressure Flash Drum
403 M-53	1	H_2S High Pressure Flash Drum
403 M-54	1	H_2S Low Pressure Flash Drum
403 M-55	1	H_2S Stripper Reflux Drum
403 P-50	2 + 1	CO_2 Semi-Lean Selexol Pump
403 P-51	2 + 1	CO_2 Stripper Feed Pump
403 P-52	2 + 1	CO_2 Lean Selexol Pump
403 P-53	2 + 1	H.P. Hydraulic Turbine
403 P-54	2 + 1	L.P. Hydraulic Turbine
403 P-55	1 + 1	H_2S Lean Selexol Pump
403 P-56	1 + 1	H_2S Stripper Feed Pump
403 P-57	1 + 1	CO_2 Presaturated Selexol Pump
403 P-58	1 + 1	H_2S Stripper Reflux Pump

Table 6-16 (cont'd)

Section 403 - Acid Gas Removal - Selexol (cont'd)

Item No.	No. Req'd	Description
403 Q-50	1	Selexol Storage Tank
403 R-50	2	CO_2 Recycle Gas Compressor
403 R-51	1	H_2S Recycle Gas Compressor
403 T-50	2	Selexol Cooler
403 T-51	2	Acid Gas Exchanger
403 T-52	2	Product Gas Exchanger
403 T-53	1	H_2S Stripper Reboiler
403 T-54	1	H_2S Stripper Condenser
403 T-55	1	H_2S Stripper Feed Exchanger
403 T-56	1	H_2S Selexol Cooler
403 T-57	1	Water Trim Cooler
403 V-50	1 + 1	Side Stream Filter

Table 6-16 (cont'd)

Section 405 - Gas Reform and Shift

Item No.	No. Req'd	Description
405 F-151	2	Reformer Furnace
405 F-151-R-1	2	Induced Draft Fan
405 F-151-R-2	2	Forced Draft Fan
405 F-151-T-1	2	Air Preheater Coil
405 F-151-T-2	2	Gas Preheat Coil
405 F-152-T-3	2	Steam Superheat Coil
405 F-153-T-4	2	Feed + Steam Preheat Coil
405 F-151-T-5	2	Convection Waste Heat Boiler Coil
405 F-151-V-1	2	Combustion Air Filter
405 L-151	2	Desulfurizing Reactor
405 L-152	2	High Temp. Shift Reactor
405 L-153	2	Low Temp. Shift Reactor
405 M-151	2	Feed Gas Separator
405 M-152	2	High Pressure Steam Drum
405 M-153	2	Low Temp. Shift Feed Separator
405 P-151	2 + 2	BFW Circulating Pump
405 T-151	2	Reformed Gas Waste Heat Boiler
405 T-152	2	Reformed Gas/BFW Exchanger
405 T-153	2	High Temperature Shift/ BFW Exchanger
405 T-154	2	Low Temp. Shift Startup Heater
405 T-155	2	Low Temp. Shift Effluent/BFW Exchanger

Table 6-16 (cont'd)

Section 406 - CO_2 Removal (Hot Potassium Carbonate)

Item No.	No. Req'd	Description
406 A-201	2	CO_2 Absorber
406 A-202	2	Regenerator
406 M-201	2	Regenerator Reflux Drum
406 M-202	2	Process Condensate Separator
406 M-203	2	Absorber Outlet Cooler Separator
406 P-201	2 + 2	Reflux Pump
406 P-202	2 + 2	Semi-Lean Solution Pump
406 P-203	2 + 2	Lean Solution Pump
406 P-204	2 + 2	Filter Pump
406 P-205	1	Sump Pump
406 Q-201	1	Solution Storage Tank
406 Q-202	1	Sump Pump Tank
406 R-201	2 + 1	Hydrogen Booster Compressor
406 T-201	2	Gas Cooler/Reboiler No. 1
406 T-202	2	Gas Cooler/Reboiler No. 2
406 T-203	2	Regenerator Condenser
406 T-204	2	Lean Solution Cooler
406 T-205	2	Lean Solution/BFW Makeup Exchanger

Table 6-16 (cont'd)

Section 406 - CO_2 Removal (cont'd)

Item No.	No. Req'd	Description
406 T-206	2	Absorber Outlet Cooler
406 T-207	2	Regenerator Condenser Trim Cooler
406 V-201	2	Side Stream Filter
406 V-202	2	Sump Filter

UNIT 500 - OXYGEN PLANT

Process Description - Case HW

The oxygen plant is a conventional commercial design which is available from air separation plant suppliers. The sequence of process steps is shown on the block flow diagram, Figure 6-6.

Two oxygen trains are provided with a nominal capacity of 2500 st/sd each. Liquid oxygen is stored in a 69 foot diameter sphere which provides two days' operation of one 2500 ton train. Gaseous nitrogen storage capacity is provided for 3,000,000 scf at 200 psig.

The equipment list and material balance for the oxygen plant are shown in Tables 6-17 and 6-18. The 5138 st/sd of oxygen needed for the Texaco gasifier, and 147 st/sd of stripping nitrogen for use in the acid gas removal system, are produced from a total air intake of 24,806 st/sd.

The main process steps shown in Figure 6-6 are described below:

- Atmospheric air is filtered and compressed to 90 psia by means of electric-motor-driven centrifugal compressors. Approximate power required for air compression is 57,595 kW.

- Carbon dioxide and water vapor are removed from the compressed air using a reversing heat exchanger system. Cold products are used to refrigerate the air to cryogenic temperatures in order to solidify carbon dioxide and water.

- Periodically, switching valves alternate the incoming air stream with the warm waste nitrogen stream. The solid deposits of carbon dioxide and water vaporize into the warm waste nitrogen stream and are carried out to the atmosphere.

- Distillation is used to separate nitrogen and oxygen from the purified air at cryogenic temperatures.

- Reciprocating compressors boost the pressure of the purified oxygen from 16 psia to 1015 psia which requires approximately 31,805 kW.

FIGURE 6-6

BLOCK FLOW DIAGRAM

OXYGEN PLANT - SECTION 500 - CASE HW

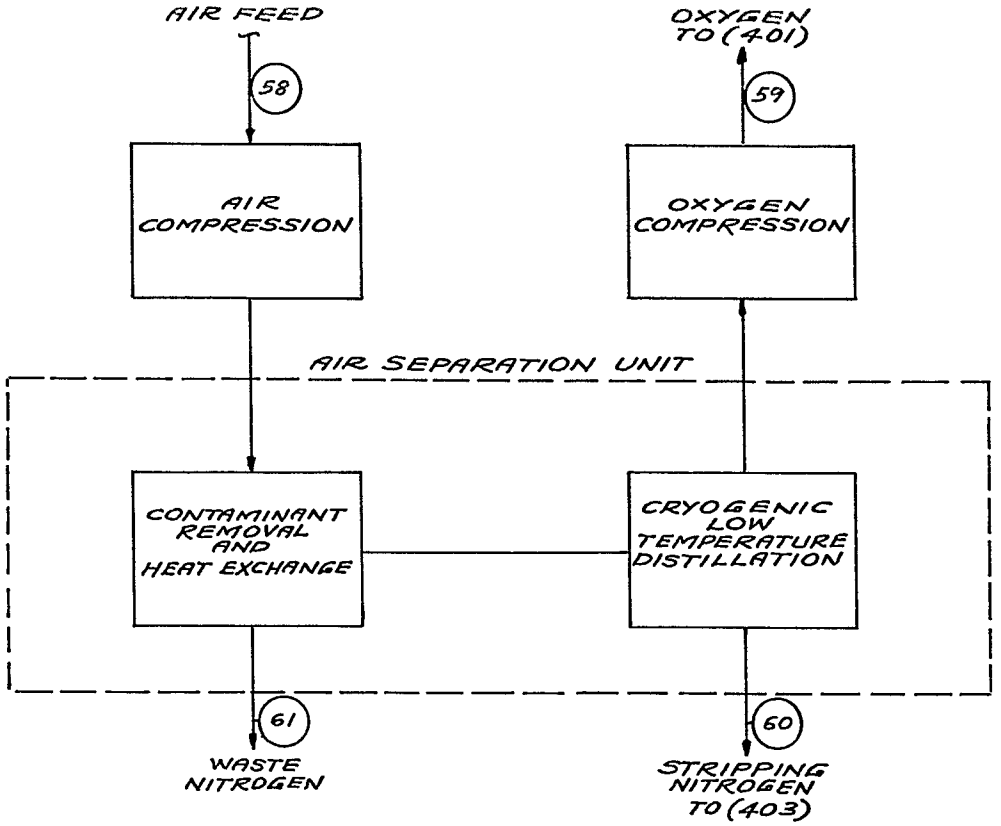


Table 6-17

EQUIPMENT LIST
UNIT 500 - OXYGEN PLANT
CASE HW

Item No.	No. Req'd	Description
500 G-1	2	Oxygen Plant
500 R-1	2	Air Compressor
500 R-2	2	Oxygen Compressor

Table 6-18

MATERIAL BALANCE
OXYGEN PLANT - SECTION 500
CASE HW

Stream No.	58	59	60	61
Description	Air Feed	Oxygen	Stripping Nitrogen	Waste Nitrogen
Component Flowrate, lb/h				
O_2	478,489	428,142	14	50,333
N_2[a]	1,588,686	1,173	122,222	1,465,291
Total, lb/h	2,067,175	429,315	122,236	1,515,624
Temperature, °F	88	200	95	95
Pressure, psig	0	1,000	70	0

Ref. Fig. 6-6

[a] As nitrogen plus argon.

UNIT 600 - EMISSION CONTROL

Process Description - Case HW

The treatment plants used in the emission control system are shown in Figure 6-7 and consist of the following:

Section 601 - Sulfur Recovery (Claus)

Section 602 - Beavon-Stretford Process

Section 603 - Sulfur Flaking

These plants are conventional types for converting H_2S into elemental sulfur and for purifying gaseous discharges to meet current emission standards. The material balance for Unit 600 is given in Table 6-19. The equipment list is shown in Table 6-20 including proprietary process design units.

In the Wyodak case, the sour gases produced in the Amine and Selexol units are much lower in H_2S concentration than in the Illinois case and are more economically processed to elemental sulfur in a Stretford plant. The Claus plant is provided to recover sulfur from the off-gases from Ammonia Recovery (Section 703), which have a high concentration of H_2S.

The acid gas from Ammonia Recovery (Section 703) is split and one-third is fed to a conventional two-stage Claus plant for converting H_2S to SO_2 in a waste heat boiler. The sulfur dioxide stream is reacted over bauxite catalyst with the remaining H_2S to form elemental sulfur. Variations from the 2:1 ratio of H_2S to SO_2 will affect the tail gas composition. The liquid elemental sulfur is converted to fine flakes on a cooled belt system in Section 603 and conveyed to an outdoor storage pile. The tail gas is sent to the Beavon treating system which replaces the SCOT tail gas treating system used in the Illinois case. There is no recycle gas to the Claus unit from the Beavon unit.

The Beavon sulfur removal process consists of a catalytic hydrogenation unit to convert all sulfur compounds to hydrogen sulfide. The Stretford unit oxidizes the hydrogen sulfide to elemental sulfur.

The hydrogen sulfide stream from the Beavon unit is mixed with acid gases from Units 200, 300, and 400 and fed to the Stretford unit. The Stretford unit uses a solution of sodium carbonate, anthraquinone disulfonic acid and vanadium salts to absorb the H_2S. The H_2S is then oxidized to elemental sulfur in an air blowing operation and is separated from the absorbing solution, filtered, and melted to obtain a product with low impurities. Exhaust gas from the process is discharged to the atmosphere.

FIGURE 6-7

BLOCK FLOW DIAGRAM
EMISSIONS CONTROL
SECTIONS 601, 602, 603 - CASE HW

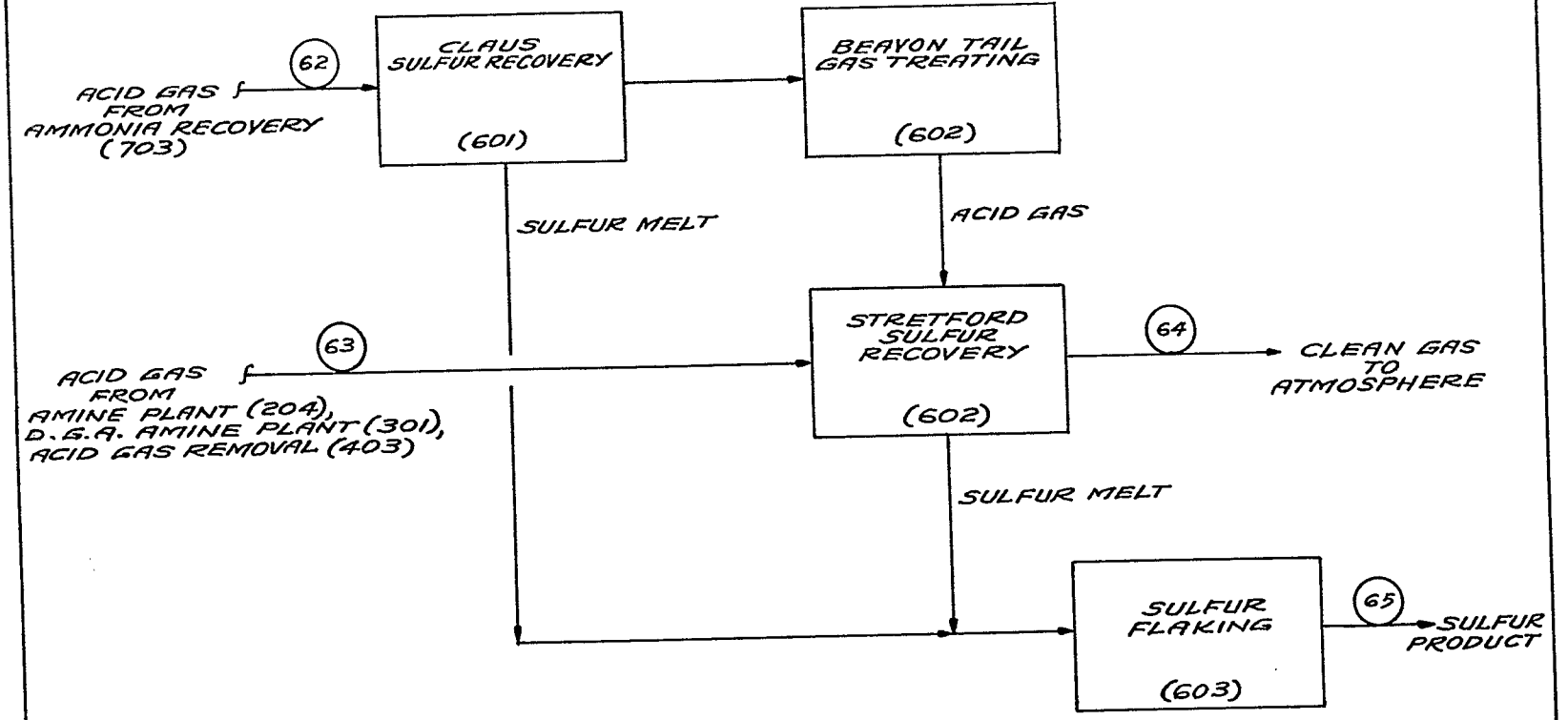


Table 6-19

MATERIAL BALANCE
EMISSION CONTROL
CLAUS, BEAVON-STRETFORD, AND SULFUR FLAKING
SECTIONS 601, 602, 603 - CASE HW

Stream No.	62	63	64	65
Description	Acid Gas To Claus (601)	Acid Gas to Stretford (602)	Clean Gas To Atmosphere [a]	Sulfur To Storage
Component Flowrate, lb/h				
H2		13		
CO		20		
H2S	13,270	3,959		
CO2	17,395	304,353	321,982	
H2O	14,518	2,891	26,800	
CH4		74		
S				16,161
SO2, ppmv[b]			(200)	
Total, lb/h	45,183	311,310	348,782	16,161

Ref. Fig 6-7

[a] Combustion fuel and air not included. Additional oxygen is required (8,487 lb/hr) to satisfy combustibles in feed streams.

[b] Maximum SO_2 on dry basis and zero percent oxygen.

Table 6-20

EQUIPMENT LIST
UNIT 600 - CLAUS, BEAVON-STRETFORD, AND SULFUR FLAKING
SECTIONS 601, 602, 603 - CASE HW

Section 601 - Sulfur Recovery
Section 602 - Tail Gas Treating
Section 603 - Sulfur Flaking

Item No.	No. Req'd	Description
Sulfur Recovery - Claus		
601 G-1	1	Sulfur Recovery Plant (Claus)
Tail Gas Treating		
602 G-50	1	Tail Gas Sulfur Recovery Plan (Beavon-Stretford)
Sulfur Flaking		
603 W-100	1	Sulfur Flaking Plant with Belt Cooler
603 W-101	1	Flaked Sulfur Recovery Belt
603 W-102	1	Sulfur Stacker
603 W-103	1	Loading Conveyor
603 W-104	1	Weigh Feeder System

UNIT 700 - EFFLUENT CONTROL

Process Description - Case HW

The effluent control system conditions the sour water, produced in the coal liquefaction plant, for biological treatment and reuse. This conditioning is accomplished by removing contaminants, such as phenol, H_2S, and ammonia, to their lowest levels by the best available technology.

The block flow diagram, shown in Figure 6-8, includes the following sections required for sour water treatment:

Section 701 - Phenol Recovery

Section 702 - Sour Water Stripping

Section 703 - Ammonia Recovery

A material balance for the Effluent Control System is given in Table 6-21. The equipment list for the effluent control system is shown in Table 6-22.

SECTION 701 - PHENOL RECOVERY

Process Description - Case HW

Sour process water enters a rectangular multichannel API oil-water separator. The water and oil are separated by their density differential and mutual insolubility. The effluent water flows to a single train phenol recovery plant and the oil is collected and recycled. The phenol recovery process uses a proprietary solvent in a packaged extraction-distillation system to remove the phenols from the water. The process was developed by Jones and Laughlin Steel Company and is licensed by Chem-Pro Equipment Corporation. The effluent water from the Phenol Recovery plant is fed to Sour Water Stripping (Section 702), and the mixture of phenols is sent to by-product storage.

SECTION 702 - SOUR WATER STRIPPING

Process Description - Case HW

Using steam stripping, this unit separates ammonia, carbon dioxide, and hydrogen sulfide from the sour water leaving the phenol recovery unit. The sour gases are delivered to ammonia recovery unit (Section 703) and the residual water, which contains small quantities of dissolved organics, is sent to a biological treatment plant before being returned to the process or used as cooling tower make-up.

SECTION 703 - AMMONIA RECOVERY

Process Description - Case HW

The ammonia is recovered in a Phosam-W process unit which is licensed by a division of the U.S. Steel Company, and is in commercial use on coke oven liquors. The unit employs an ammonium phosphate solution to achieve the separation between ammonia and H_2S. The acid gas stream generated, which contains the H_2S present in the feed, is sent to the Claus Plant (Section 601). The anhydrous ammonia stream, which is essentially free of H_2S, is sent to storage. Stripped water is sent to the biological treatment plant.

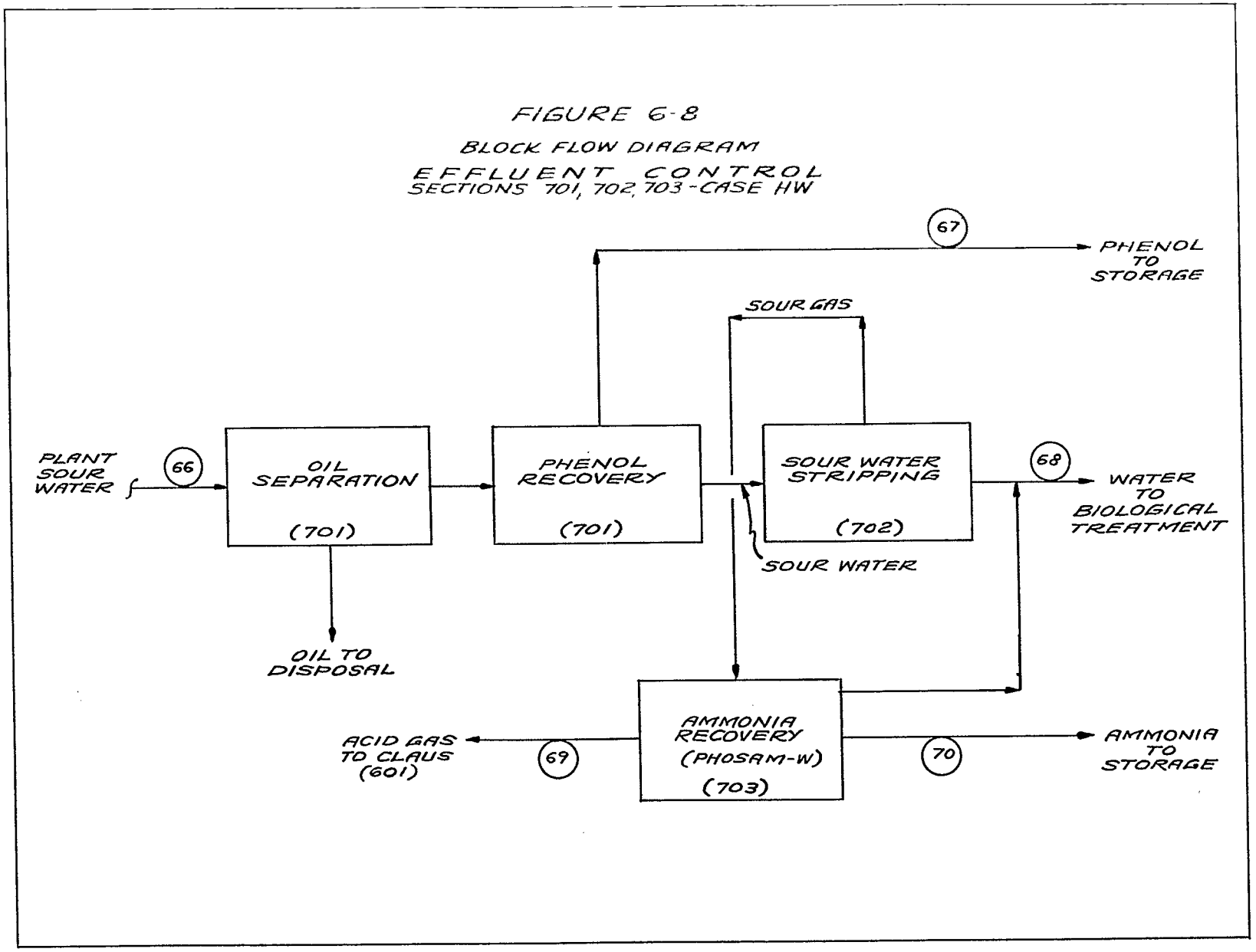


FIGURE 6-8
BLOCK FLOW DIAGRAM
EFFLUENT CONTROL
SECTIONS 701, 702, 703 - CASE HW
67
PHENOL TO STORAGE
SOUR GAS
PLANT SOUR WATER
66
OIL SEPARATION
(701)
PHENOL RECOVERY
(701)
SOUR WATER STRIPPING
(702)
68
WATER TO BIOLOGICAL TREATMENT
SOUR WATER
OIL TO DISPOSAL
AMMONIA RECOVERY
(PHOSAM-W)
(703)
ACID GAS TO CLAUS
(601)
69
70
AMMONIA TO STORAGE

Table 6-21

MATERIAL BALANCE
EFFLUENT CONTROL
SECTIONS 701, 702, 703 - CASE HW

Stream No.	66	67	68	69	70
Description	Plant Sour Water [a]	Phenol To Storage	Water to Biological Treatment	Acid Gas to Claus (601)	Ammonia to Storage
Component Flowrate, lb/h					
H2S	13,277		7	13,270	
NH3	14,904		13		14,891
CO2	17,395			17,395	
H2O	739,723		725,205	14,518	
Phenol	2,070	2,000	70		
Total, lb/h	787,369	2,000	725,295	45,183	14,891

Ref. Fig. 6-8

[a] Composition of sour water estimated.

Table 6-22

EQUIPMENT LIST
UNIT 700 - EFFLUENT CONTROL
SECTIONS 701, 702, 703 - CASE HW

Section 701 - Phenol Recovery
Section 702 - Sour Water Stripping
Section 703 - Ammonia Recovery

Item No.	No. Req'd	Description
Phenol Recovery		
701 G-1	1	API Oil Separator
701 G-2	1	Phenol Package
Sour Water Stripping		
702 A-1	2	Stripper
702 A-3	2	Condenser Drum
702 P-1	2 + 1	Stripper Feed Pump
702 P-2	2 + 1	Condenser Pump
702 P-3	2 + 1	Stripped Water Pump
702 Q-1	1	Feed Surge Tank
702 T-1	2	Stripper Reboiler
702 T-2	2	Stripper Feed Exchanger
702 T-3	2	Stripper Condenser
Ammonia Recovery		
703 G-50	1	Phosam Package

UNIT 800 - TANK STORAGE

Process Description - Case HW

Storage facilities for the H-Coal Wyodak case are listed in Table 6-23. Floating roof tanks are provided for naphtha storage. Refrigerated tanks are provided for ammonia and oxygen. Storage capacity equivalent to approximately three weeks' production is provided for the liquid products. The products storage volumes are indicated below:

	BBLS
Naphtha	360,000
Turbine Oil	612,000
Distillate Fuel Oil	82,000
Ammonia	26,000
Phenol	7,200

In addition, a storage capacity of 5,000 short tons of oxygen is provided, equivalent to a 2 days' supply in the event that only one of the two oxygen plants is operable.

Table 6-23

EQUIPMENT LIST
UNIT 800 - TANK STORAGE
CASE HW

Item No.	No. Req'd	Description
800 G-1	2	C_3 LPG Tank Refrigerant Unit
800 G-3	2	Ammonia Tank Refrigerant Unit
800 G-4	2	Light Oil Storage Tank Refrigerant Unit
800 P-1	1 + 1	C_3 LPG Storage Pump
800 P-5	2	Naphtha Storage Pump
800 P-6	3	Turbine Oil Storage Pump
800 P-7	1 + 1	Distillate Fuel Oil Storage Pump
800 P-8	1 + 1	Phenol Storage Pump
800 P-9	1 + 1	Ammonia Storage Pump
800 P-10	2	Sour Water Storage Pump
800 P-11	1 + 1	Phenol Treatment Pump
800 P-12	2	Light Emergency Storage Pump
800 P-13	1 + 1	Cold Rerun Storage Pump
800 P-14	1 + 1	Hot Rerun Storage Pump
800 P-15	1 + 1	Oxygen Storage Pump
800 P-16	1 + 1	Caustic Storage Pump
800 P-17	1 + 1	Flushing Oil Storage Pump

Table 6-23 (cont'd)

Unit 800 - Tank Storage (cont'd)

Item No.	No. Req'd	Description
800 Q-1	1	Atmospheric C_3 Storage Tank
800 Q-5	2	Naphtha Storage Tank
800 Q-6	3	Turbine Oil Storage Tank
800 Q-7	1	Distillate Fuel Oil Storage Tank
800 Q-8	1	Phenol Storage Tank
800 Q-9	1	Ammonia Storage Tank
800 Q-10	2	Sour Water Storage Tank
800 Q-11	1	Isopropyl Ether Storage Tank
800 Q-12	2	Light Emergency Oil Storage Tank
800 Q-13	1	Cold Rerun Storage Tank
800 Q-14	1	Hot Rerun Storage Tank
800 Q-15	1	Oxygen Storage Tank
800 Q-16	1	Caustic Storage Tank
800 Q-17	1	Flushing Oil Storage Tank
800 Q-18	1	Nitrogen Storage Tank

UNIT 900 - REFRIGERATION

Process Description - Case HW

Propane is used in a two-train refrigeration unit to provide 400 tons of refrigeration to the cryogenic plant (Section 205) and 3850 tons of refrigeration to the acid gas removal system (Section 403).

The electricity requirement is 4030 kW and the cooling water requirement is 12,969 gpm.

The equipment list is shown in Table 6-24.

Table 6-24

EQUIPMENT LIST
UNIT 900 - REFRIGERATION
CASE HW

Item No.	No. Req'd	Description
900 M-1	2	Propane 1st Stage Suction Drum
900 M-2	2	Propane 2nd Stage Suction Drum
900 M-3	2	Propane 3rd Stage Suction Drum
900 M-4	2	Propane 4th Stage Suction Drum
900 M-5	2	Propane Refrigerant Drum
900 R-1	2	Propane Refrigerant Compressor
900 T-1	2	Propane Aftercooler

UNIT 1000 - POWER GENERATION

Process Description - Case HW

The power generation system for the H-Coal Wyodak case, is shown on drawing 75-D16. The power is generated by one 180 MVA steam turbine and four 55 MVA gas turbines in a combined cycle power generation system, and is based upon the following:

- All plant rotating equipment shall be electric motor driven.
- Gas turbine fuel is provided by clean, light hydrocarbon gases separated in the H-Coal process units.
- Surplus steam, generated within the process, shall supplement steam generated from the hot turbine exhaust gases for use in the steam turbine generators.

Deaerator and cooling tower facilities for power generation are integrated with the process units and are shown on drawing 75-D16.

The combined cycle power generation system is designed to produce 400 MW of electricity. The normal output of electricity for the Wyodak case is 375.3 MW, of which 356.7 MW is for plant use and 18.6 is for export sale. The excess electricity results from a surplus of fuel gas and steam from the process.

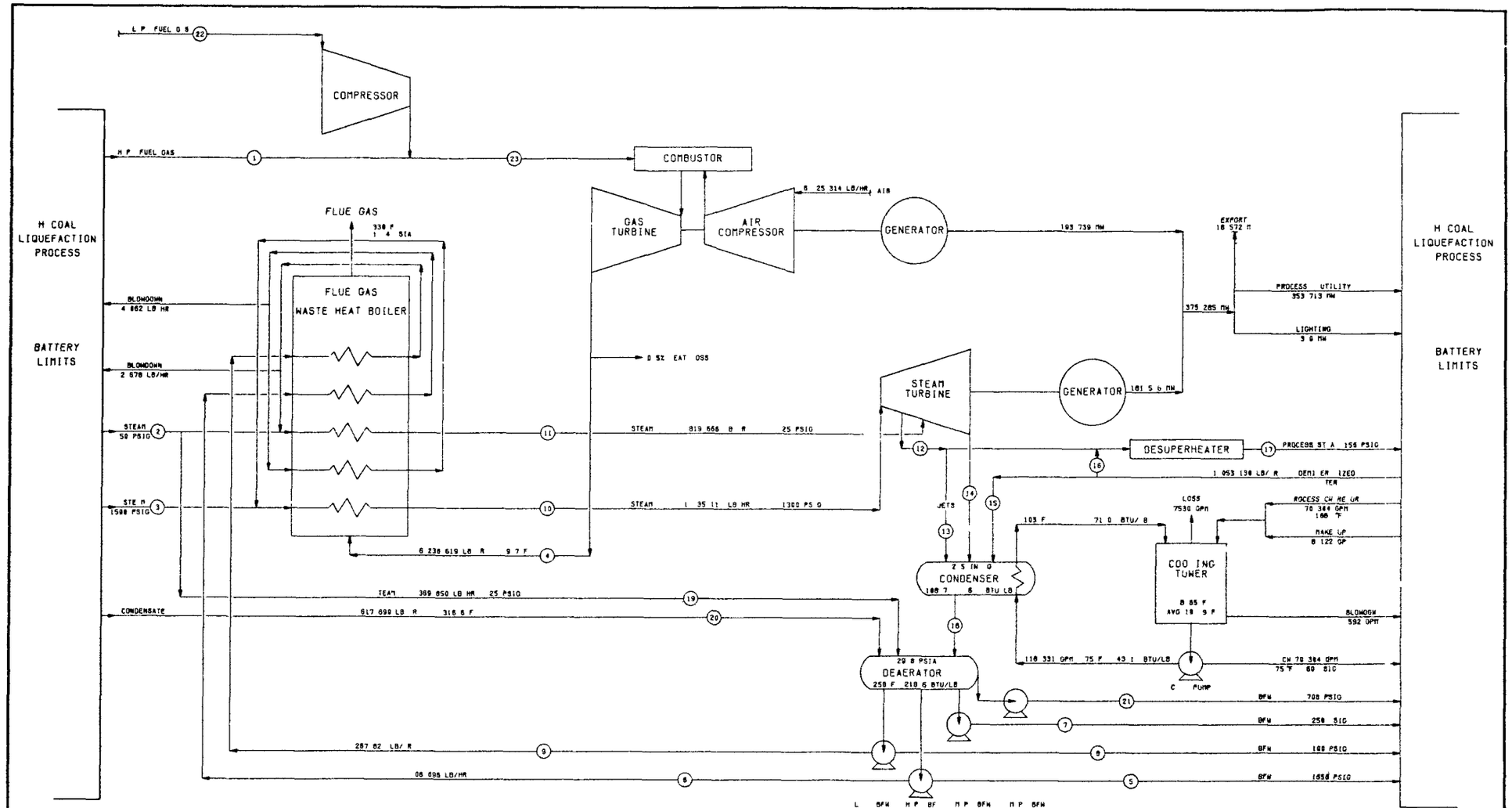
UNIT 1100 - COOLING WATER SYSTEM

Process Description - Case HW

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

The cooling water system is based on an overdesign of 10 percent. At a design wet bulb temperature of 65°F and a dry bulb temperature of 85°F, the water is cooled to 75°F. The cooling water circulation rate to the process is 70,304 gpm at a return temperature of 108°F. The circulation rate to the combined cycle power plant is 118,331 gpm at a return temperature of 103°F. The average temperature for this total circulation rate of 188,635 gpm is 104.9°F. To accommodate this heat load, an induced draft cross-flow cooling tower is employed.

Make-up to the cooling tower includes filtered and softened river water and biologically treated process water. Cooling tower blowdown is sent to a waste water reclamation unit (1300) for water recovery and return to the return to the process.



SERVICE	H P FUEL G S	PROCESS STEAM	PROCESS STE M	T RB NE ST EX G S	P BFW	H P BFW	P B W	L P BF	L BF	SUPER E TED STE M	SUPER HEA ED TE M	225 PSIG STEAM	STE JET RETUR	CONDE SI D STE	DEMI ER L ZED ER	DE L ERAL ZED AT R	50 PSIG STEAM	CONDE SATE	5 PSIG STE	CONDE S TE	M P BFW	P FUEL GAS	FUEL G TU BI E
T E G	1	2	3		5	6		8	9	10	11	1	13	L	15	16	7	8		20	21	2	3
FLO LB HR	77 89	92 3 0	733 068	6 238 6 9	467 820	406 896	23 170	1 455 370	287 82	135 14	832 298	229 822	2 800	1 72 958	8 8 352	12 778	239 800	2 768 10	69 650	61 690	135 370	27 8 6	145 385
TEMP*	220	298	598	9 7 1	50	258	250	250	50	900	578 9	50	120		70	70	366	108	66 6	316 6	250	100	219
PRESS RE PSIG	3 5	50	1500	0 8	850	1650	250	100	100	1300	25	225					150		25		700	15	3 5
E H LP BTU LB	19 765	1179	1169 3		224 6	224 8	213 6	218 6	218 6	1436 5	1323 3	1288 5	68 0	0 6 3	38 0	36 0	1195 8	8	169 6	285 0	218 8	22 267	20 438

NOTE STEAM ENTHALPY BASIS ASME 1967 STEAM TABLES

STONE & WEBSTER ENGINEERING CORPORATION

ELECTRIC POWER RESEARCH INSTITUTE

PROCESS FLOW DIAGRAM
POWER GENERATION
H-COAL WYODAK CASE HW
SECTION 1000

DRAWN	CHECKED	APPROVED	JOB NUMBER	DRAWING NUMBER	REV
D ANDERSON			13461	75-0 6	0

UNIT 1200 - UTILITY AND STEAM SUMMARY

Process Description - Case HW

The plant steam availability and user grid is shown on drawing 75-D12. The overall utility requirements for the individual units for Case HW are shown in Table 6-25.

The utility summary includes the steam, electrical power, water, and fuel gas requirements needed for the individual units.

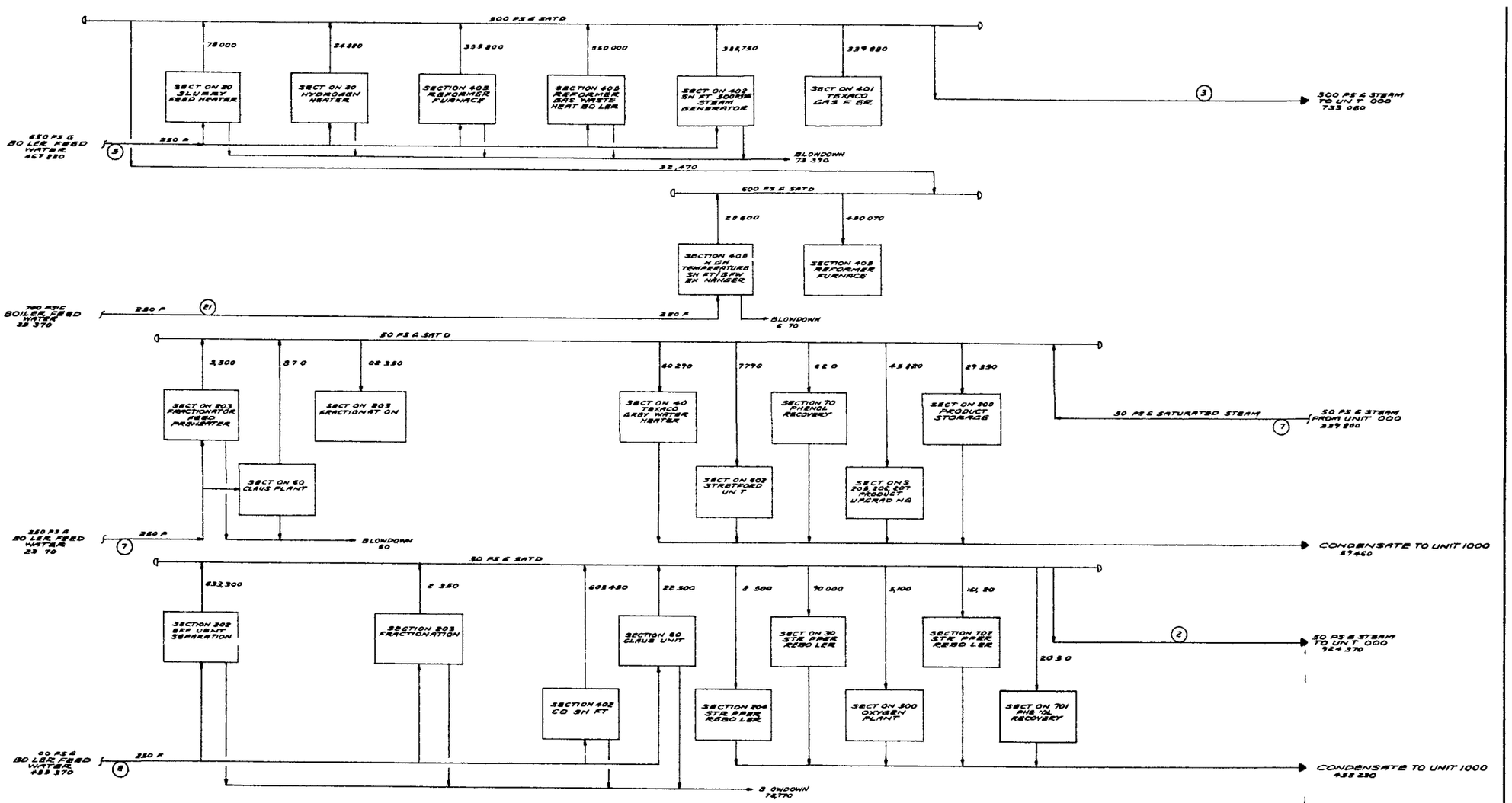
Steam is distributed throughout the plant at four levels: 1500, 600, 150, and 50 psig. Additional pressure control is provided by interconnecting bypass lines between the headers designed with automatic letdown valves and steam desuperheaters. The bypass lines also facilitate the transfer of steam as required from higher to lower steam headers. An excess-steam condenser is installed in order to avoid venting 50 psig steam during startup.

Chemical treating of boiler feedwater is provided for corrosion control and for the protection of the steam generation equipment against solid deposition and sludge formation.

Table 6-25

OVERALL UTILITY SUMMARY - CASE HW

Unit Description	Coal Preparation	H-Coal Plant	Light Ends Processing	Hydrogen Plant	Oxygen Plant	Emission Control	Effluent Control	Product Storage	Refrigeration	Power & Steam Generation	Utilities & Off-sites	Total
Unit Number	100	200	300	400	500	600	700	800	900	1,000	1,100 to 1,600	
Electrical Power, KW												
Produced										375,285		375,285
Consumed	52,943	145,218	659	35,765	89,810	422	1,688	1,558	4,030	17,720	6,900	356,713
Cooling Water, gpm												
Produced											188,635	188,635
Consumed		23,307	4,230	9,410	14,325	1,629	3,951	267	12,968	118,548		188,635
Fuel Gas, MM btu/hr												
Produced		2,867	2,689									5,556
Consumed	955	1,478		954		17				2,152		5,556
Raw Water, gpm												
Produced												
Consumed											8,693	8,693
Steam, 1500 psig, lb/hr												
Produced		102,880		1,291,550						402,034		1,796,464
Consumed				661,350						1,135,114		1,796,464
Steam, 600 psig, lb/hr												
Produced				450,070								450,070
Consumed				450,070								450,070
Steam, 150 psig, lb/hr												
Produced		13,300				8,710				239,800		261,810
Consumed		148,170		60,290		7,790	16,210	29,350				261,810
Steam, 50 psig, lb/hr												
Produced		754,650		605,450		22,500				265,146		1,647,746
Consumed		181,500	90,000		5,100		181,630			1,189,516		1,647,746
BFW, lb/hr												
Produced										3,755,650		3,755,650
Consumed		916,665		2,132,212		32,853				673,920		3,755,650
Condensate, lb/hr												
Produced		227,320	90,000	60,290	5,100	7,790	197,840	29,350		2,768,110		3,385,800
Consumed										3,385,800		3,385,800
Demin. Water, lb/hr												
Produced											1,053,130	1,053,130
Consumed										1,053,130		1,053,130



NOTE 1 NORMAL OPERATION 2 FLOWS N LB/HR 3 BLOWDOWN S/
4 STREAM NUMBERS FROM DWG 75 DA

SYSTEM							
0	9	1			EXP		
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TITLE BLOCK FLOW DIAGRAM

STEAM BALANCE
H COAL WYODAK CASE HW

JOB UMBR	RAWING NUMB	ISSUE
13461	75 D12	0

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UNIT 1300 - WATER MANAGEMENT

Process Description - Case HW

A block flow diagram of the water management system shown on drawing 75-D14 consists of the following divisions:

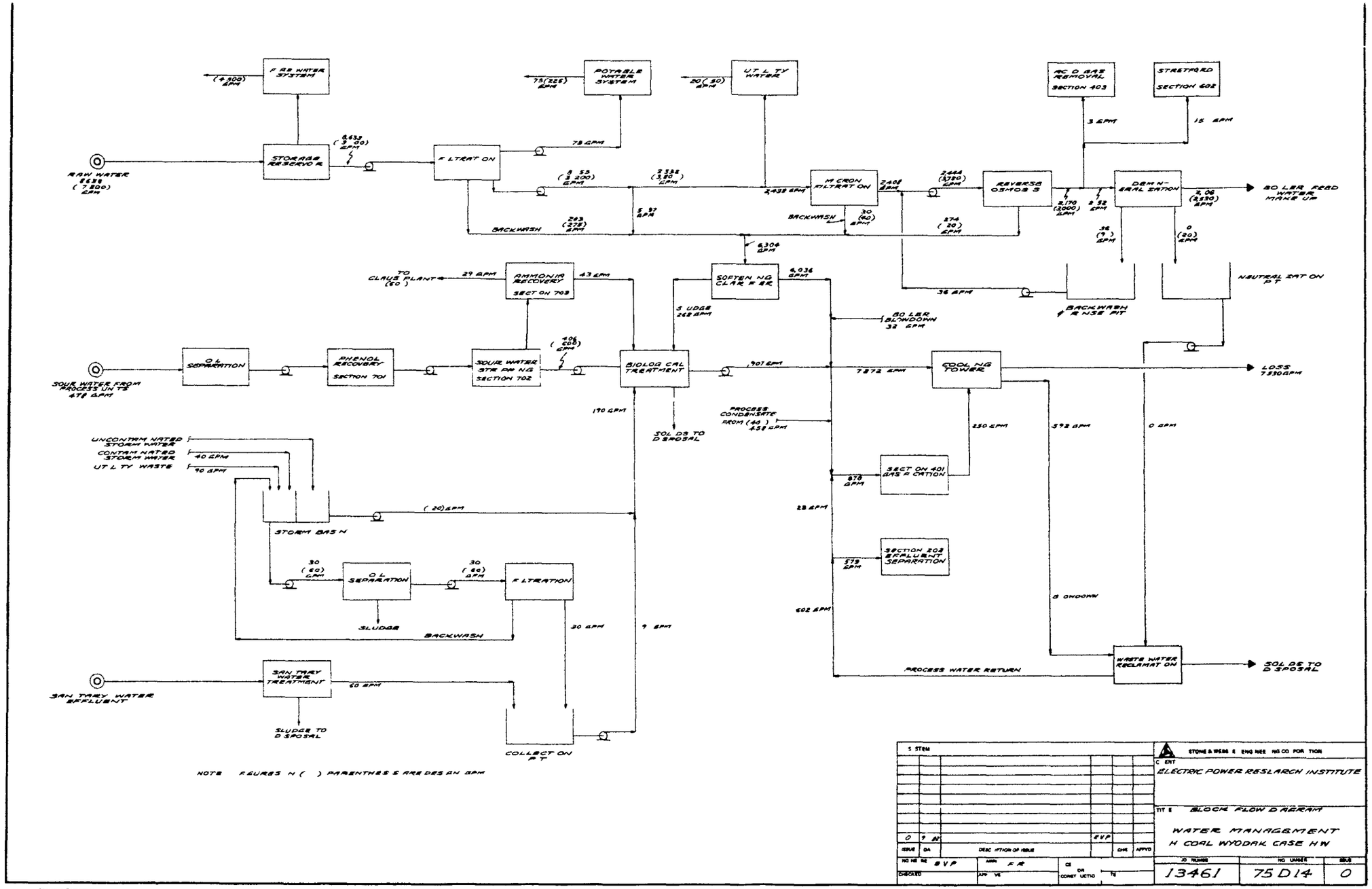
- Raw water storage and filtration.
- Fire, potable, and utility water distribution systems.
- Micron filtration, reverse osmosis, and demineralization for boiler feedwater make-up.
- Water softening, clarification, and biological treatment for cooling tower and process water make-up.
- Waste water reclamation for removal of solids and return of water to process.
- Storm water, utility waste, and sanitary water treatment.

Included in the block flow diagram are estimated normal and design flow quantities. The design flow quantities are in parentheses.

The following summarizes the normal plant water flow requirements:

	Water Make-Up GPM		Water Consumption GPM
Raw Water	8,633	Potable	75
Condensate	458	Utility	120
Sanitary	60	BFW	2,106
Storm	130	CT Losses	7,530
Boiler BD	326	Process	1,225
Sour Water	1,478	Claus Unit	29
Total	11,085	Total	11,085

Facilities are provided for the maximum reuse of water to accomplish zero discharge of liquid waste. These facilities include waste volume reduction by reverse osmosis followed by evaporation and condensation of the vapors for reuse. Using a cooling tower blowdown feed of 600 gpm, each pass through a reverse osmosis system produces about 400 gpm of good quality water suitable for cooling tower make-up or slurrying. The concentrate (reject), which contains 80 to 90 percent of the original dissolved solids, is processed by evaporation or, if feasible, processed through another reverse osmosis unit before evaporation. The solids are discarded to landfill.



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UNIT 1400 - FLARE SYSTEM

Process Description - Case HW

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

It is assumed that a dual relief system is required which includes one system for high pressure relief and one system for low pressure relief. One flare stack is provided for each system. In case of release, relief lines carry away process gases from the processing areas to the elevated flare stacks where ignition occurs. 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 into the relief system.

UNIT 1500 - BUILDINGS

Process Description - Case HW

The following buildings are provided:

Building	Approximate Size
Administration Building	2-story, 12,000 sq ft
Auxiliary Building	9,000 sq ft
Change House	Accommodation for 200 people, 9,000 sq ft
Chemical Storage Building	2,800 sq ft w/truck unloading facilities
Control Building	7,500 sq ft w/office space
Fire Station/First Aid Building	2,000 sq ft w/truck and ambulance bays
Guard House	480 sq ft
Laboratory	5,000 sq ft
Maintenance Shop	17,600 sq ft w/bridge crane
Maintenance Building	28,800 sq ft w/10 offices
Raw Water Treatment	15,000 sq ft
Utility Building	4,800 sq ft
Warehouse	13,200 sq ft w/truck unloading facilities

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

UNIT 1600 - COMMON FACILITIES

Process Description - Case HW

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.
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
Firewater distribution.